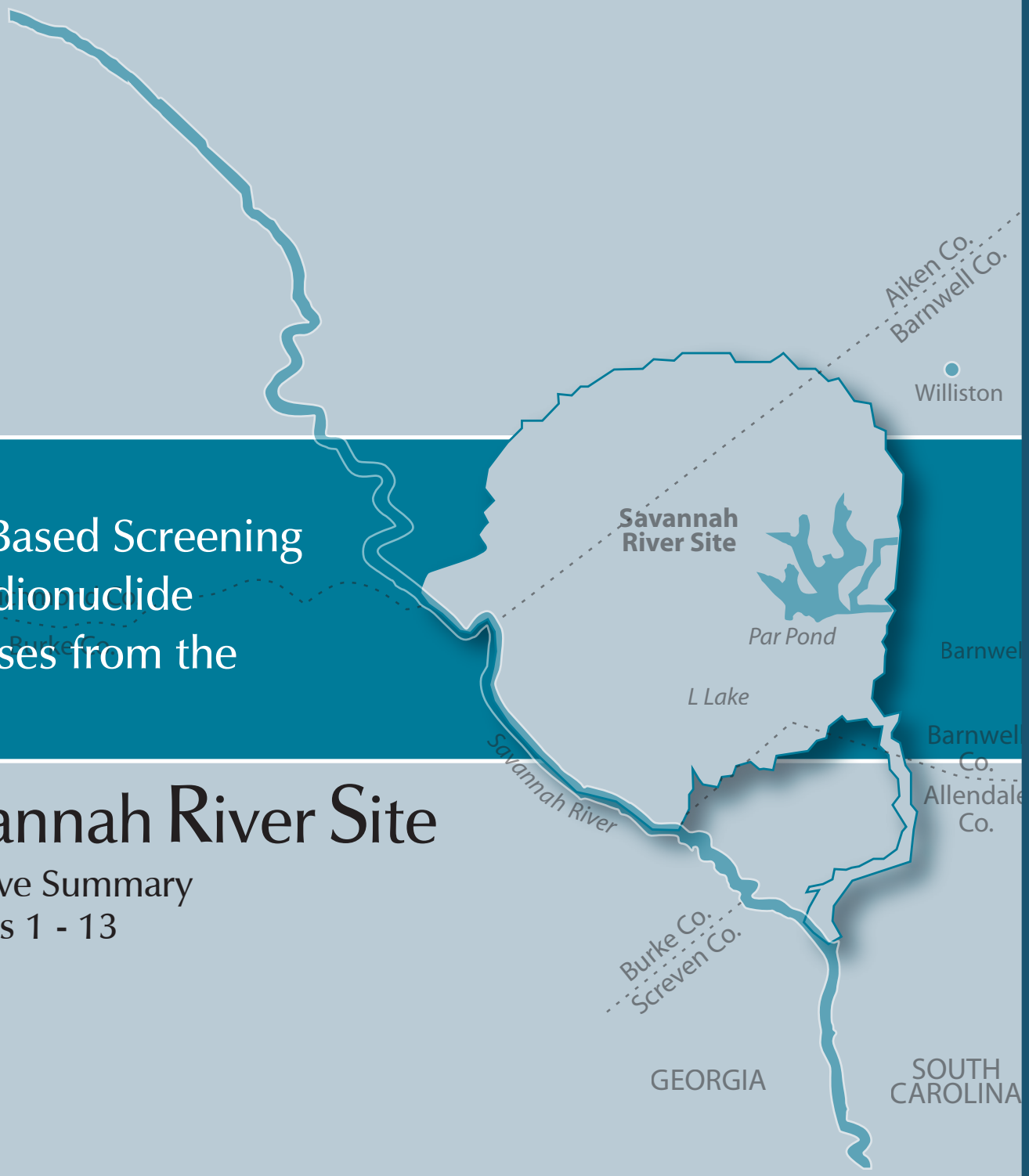
Risk-Based Screening of Radionuclide Releases from the Savannah River Site

Executive Summary
Sections 1 - 13



CDC

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EXECUTIVE SUMMARY

1 Introduction

This report is the product of Phase III of the Savannah River Site (SRS) Dose Reconstruction Project. It estimates the radiation doses and associated cancer risks for hypothetical persons living near SRS and performing representative activities. SRS is a U.S. Department of Energy (DOE) facility that produced nuclear materials such as tritium and Pu-239 for national defense and other programs.

The SRS Dose Reconstruction Project examines the releases from the SRS for the 39-year period from its inception in 1954 to the end of 1992, when main production activities ceased. The Project is sponsored by the Radiation Studies Branch, National Center for Environmental Health, Centers for Disease Control and Prevention (CDC) of the U.S. Department of Health and Human Services. The Project is a study of the potential health risks to people exposed to chemicals and radioactive materials released to the environment resulting from historical SRS operations. However, this report only addresses radiation doses and risks.

1.1 Purpose

The original purpose of Phase III was to do screening calculations; after the study was underway the CDC and the HES jointly decided to go ahead and estimate doses for hypothetical individuals. This phase of the Savannah River Site (SRS) Dose Reconstruction Project estimates the radiation doses and associated cancer risks for hypothetical persons living near SRS and performing representative activities. The purpose of this phase was (1) to determine if there was sufficient information available to make a preliminary dose assessment, (2) to perform a screening analysis to identify the significant pathways and radionuclides contributing to dose, and (3) provide preliminary estimates of radiation doses and risks to members of seven hypothetical exposure scenarios.

1.2 Brief Summary of SRS Operations

SRS is located about 19 miles (32 km) south of Aiken, South Carolina, and about 22 miles (36 km) southeast of Augusta, Georgia. It borders the Savannah River for about 17 miles and comprises parts of Aiken, Barnwell, and Allendale Counties in southwestern South Carolina. Figure 1 shows the general location of SRS.

The SRS, a 300 square-mile site, was operated from 1954 to 1992, first by E.I. duPont de Nemours and Company (Dupont) for the U.S. Atomic Energy Commission (AEC), and later by Westinghouse Savannah River Company for DOE (1). SRS operated five reactors and two chemical separations operations and numerous laboratories and support facilities to produce and purify plutonium, tritium, and other radioactive isotopes. The primary mission was production of ^{239}Pu and tritium. During the time of operation, radionuclides and chemicals were disposed of into the ground or released into surface waters and into the air. These releases potentially resulted in radioactive and chemical exposures to persons living near the site. By 1992, the production reactors had all ceased operation. Some separation processing and support facilities, waste management facilities, and environmental remediation facilities still operate.

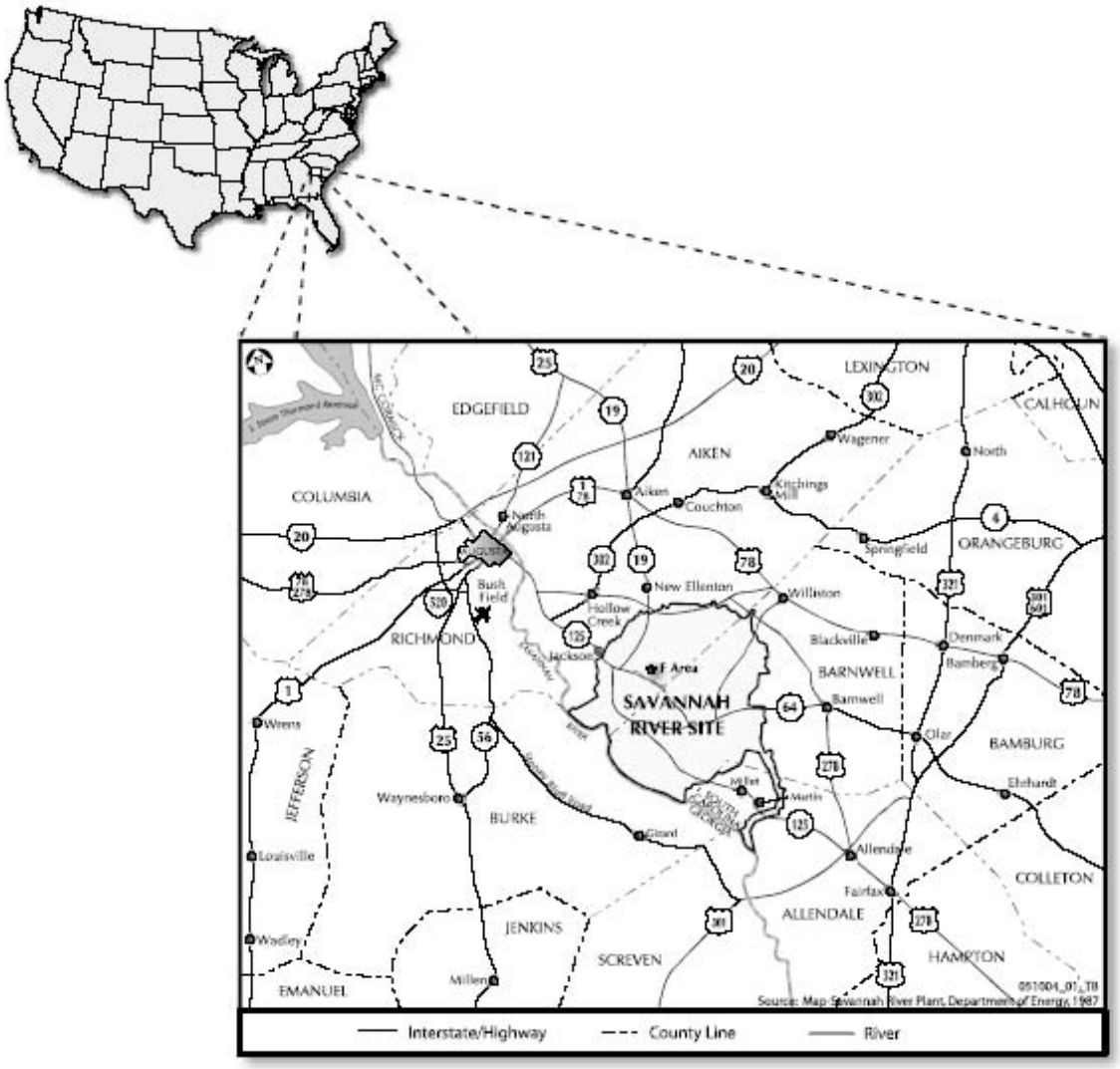

Figure 1 General Location of the SRS

1.3 CDC Phased Approach and Scope of Phase III

At the initiation of the SRS Dose Reconstruction Project in 1992, CDC designed the project to consist of five phases as summarized in Table 1 (2.).

The design of the project ensured open public participation. Among other citizen outreach activities, the SRS Health Effects Subcommittee (SRSHES) was established to advise CDC on the health research and public health activities associated with SRS. An Advisory Committee to CDC constituted under the Federal Advisory Committee Act, the SRSHES is comprised of citizens selected to reflect the diversity of the communities impacted by SRS (3).

Phase I of the study was a search of SRS to find and copy documents and other records of potential value to the project. This effort was completed in 1995. An electronic document database was created to store information about the records.

Table 1 Phases of SRS Dose Reconstruction Project

Phases	Description
Phase I	A systematic review of available documents at SRS and the development of a document database.
Phases II	Initial source-term development and pathway analysis. This work consisted of estimating the amount of radioactive materials and toxic chemicals released to the environment from the SRS from 1954 to 1992.
Phase III	Screening dose and exposure calculations.
Phase IV	Developing methods for assessing environmental pathways and environmental doses.
Phase V	Calculation of environmental exposure and doses.

Phase II of the study began in October 1995 to develop an estimate of the releases of the most significant radionuclides and chemicals from various facilities at SRS from 1954 to 1992. This estimation included a list of radioactive materials and chemicals that were used or produced at the site as well as descriptions of key processes at SRS. In addition, the results of past SRS environmental monitoring programs were reviewed. In September 1998, CDC provided the results of the Phase II study to outside reviewers, including the National Academy of Science and the SRSHES. After considering and addressing comments, the final Phase II report was produced in April 2001 (4).

CDC's original plan for the Phase III effort was to use "scenarios provided by CDC and a screening protocol approved by CDC" and to "perform screening calculations to determine which radionuclide releases from the Savannah River Site may have biological significance." The implication was that those radionuclides not screened out as unimportant would warrant further analysis (in Phases IV and V) primarily to estimate doses. The screening analysis would have used conservative modeling assumptions, and the main focus of the analysis would have been the determination of radionuclides and exposure pathways for further study in Phases III and IV.

However, CDC recognized that the process set forth in Table 1 would take considerable time, perhaps several years, to complete through Phase V. During this time, questions would remain unanswered about the possible public health consequences from past SRS operations. In addition, there was concern about the availability of the funding required to complete the remaining phases given other competing priorities. Consequently, in late 2002 and early 2003, CDC expanded the scope of the Phase III effort to include a more detailed estimation of representative doses and risks using the CDC scenarios. In effect, the expanded scope went beyond the previously defined Phase III scope, but stopped short of the detailed modeling of environmental pathways contemplated for a Phase IV study. The CDC scenarios included several hypothetical sets of individuals performing realistic, but in some cases extreme, activities on and near the site. Each hypothetical scenario represented a family that lived, worked, and engaged in recreational activities in the vicinity of SRS, and raised children born during years of large SRS releases of radioactive material to the environment. In addition, the scope of Phase III was expanded to include evaluation of uncertainty in the calculated doses, in order to establish confidence intervals for the dose estimates.

1.4 Phase II Release Estimates

Estimates of release into the atmosphere and surface water, as developed in the Phase II study, were to be used as the basic source term for Phase III. Phase III uses from Phase II both the identification of important radionuclides and the detailed source terms for radionuclides determined to be especially important. This determination was accomplished by a two-step screening analysis (2). For completeness, the radionuclides meeting the less stringent Level 1 screening criterion were retained for study in Phase III. For radionuclides meeting the more stringent Level 2, Phase II developed detailed source terms.

Because the scenarios specified for study in Phase III had important space and time characteristics, the source terms used in Phase III needed to represent variations in space and time. Because some of the source term data in Phase II tended to be aggregated in space, or time, or both the detailed source terms were not used directly. Instead the adjustments made to develop detailed source terms in Phase II were applied to the detailed historical data on which Phase II was based.

1.5 Scenario Descriptions

In addition to the six exposure scenarios originally proposed by CDC (6), a seventh was added to provide more complete geographical representation around the SRS, with the concurrence of the CDC and the SRSHES. In each scenario, exposure locations were identified to represent where family members lived, worked, attended school, engaged in recreational activities, where their food was grown, and other activities. For this study a total of 12 exposure locations were used to model doses. Exposures to radionuclides were modeled at ten locations for radionuclides released to the air and two locations for radionuclides released to water. Depending upon the scenario specifications, a given receptor might be exposed at 1 to 6 exposure locations.

The exposure locations assumed for the seven exposure scenarios are shown in Figure 2. Table 2 summarizes the exposure locations for contamination released into the air; Table 3 summarizes the exposure locations for contamination released to surface water. The Lower Three Runs Creek exposure location is in the vicinity of Martin, South Carolina. The downstream Savannah River exposure location is representative of multiple possible locations downstream from the site.

It was assumed that each of the seven hypothetical families had the same composition:

- A male who was an adult (over age 18) in 1954.
- A female who was an adult (over age 18) in 1954.
- A male child born in 1955.
- A male child born in 1964.

This family composition facilitated comparisons based on birth year and gender; the child born in 1955 was exposed to relatively large releases of radionuclides to the environment during the early years of SRS operation, while the child born in 1964 was not. Male children were modeled because males receive slightly larger radiation exposures for some pathways than females (e.g., males eat more than females) and therefore provide more conservative estimates of doses and risks. It was desirable to make both children the same gender in order to allow direct comparison of the effect of being born at different times.

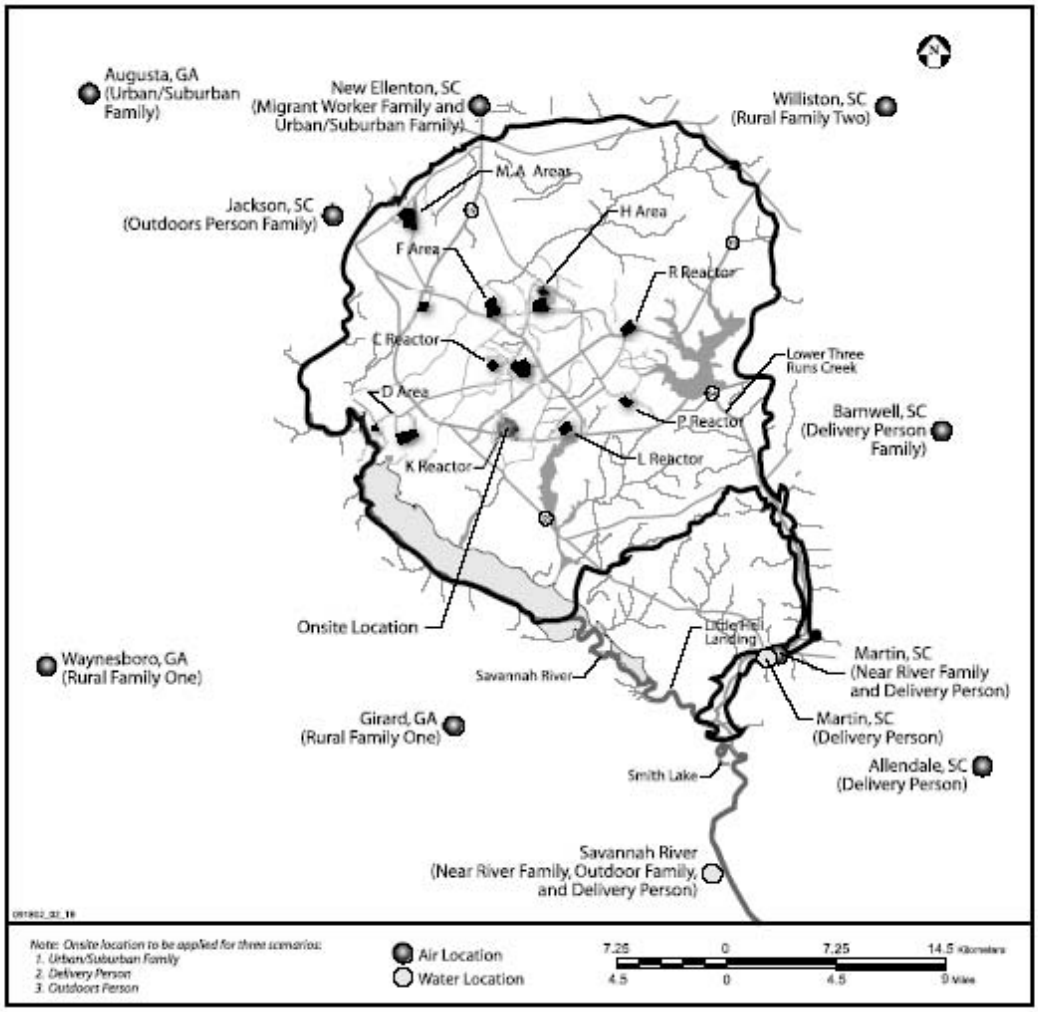

Figure 2 Exposure Locations for Exposure Scenarios

Table 2 Summary of Exposure Locations for SRS Releases to Air

Exposure Scenario	Activity*	Exposure Location									
		Girard, GA	Waynesboro, GA	Martin, SC	Augusta, GA	Williston, SC	SRS Onsite Location	Barnwell, SC	Allendale, SC	Jackson, SC	New Ellenton, SC
Rural Family One	All except high school†	X									
	High school		X								
Rural Family Two	All activities					X					
Urban/Suburban Family	All except employment				X						
	Employment						X				
Migrant Worker Family	All activities										X
Delivery Person Family	All except those below:							X			
	Employment								X		
	Employment						X				
	Church, grocery (partial), swimming, boating, hunting, fishing			X							
Outdoors Person Family	All except employment									X	
	Employment						X				
Near River Family	All activities			X							

* Activities included school, work, recreation, church, production of foodstuffs, and indoor and outdoor activities around the home.

† For all receptors, excluding the children of Rural Family One, the same exposure location was used for their high school as for their residence. Children of all scenarios attended grade school at the same exposure location that was used for their residence.

Table 3 Summary of Exposure Locations for SRS Releases to Surface Water

Scenario	Activities / Pathways	Downstream Savannah River	Lower Three Runs Creek	No Exposure to Water Affected By Liquid Releases*
Rural Family One	All activities†			X
Rural Family Two	All activities†			X
Urban/Suburban Family	All activities†			X
Migrant Worker Family	All activities†			X
Delivery Person Family	Fishing, swimming, shoreline		X	
	Fishing, shoreline, boating	X		
Outdoors Person Family	Fishing, shoreline, boating	X‡		
	Swimming			X§
Near River Family	All activities†	X		

*Exposure occurred in water not affected by releases from the SRS to water.
†"All activities" included fishing, boating, swimming, and shoreline.
‡Shoreline exposures were only received at work by the Adult Male and the children when they each reached age 18. Recreational shoreline activities by all family members were in unaffected water.
§For the entire family while recreating on the Savannah River.

Brief descriptions of the hypothetical scenarios follow:

- **Rural Family One.** This family lived on a farm near Girard, Georgia. The Girard exposure location was where the family hunted, fished, and grew or produced much of their food. Although the adults always stayed near the farm, the children attended high school in Waynesboro, Georgia.
- **Rural Family Two.** This family lived on a farm near Williston, South Carolina. The Williston exposure location was where the family hunted, fished, and grew or produced much of their food. All family members lived at the Williston exposure location for all 39 years, including grade and high school for the children.
- **Urban/Suburban Family.** This family lived near the intersection of E. Boundary and East Telfair Street in Augusta, Georgia. The Augusta exposure location was assumed for most family activities including swimming, boating, and fishing. It was the exposure location where much of the family's food was grown or produced, including half of their milk. The other half of their milk came from cows located in New Ellenton, South Carolina. The father worked onsite at SRS. The children also worked onsite at SRS when they grew up. A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location.
- **Migrant Worker Family.** This family lived in New Ellenton, South Carolina, for half of any year. The New Ellenton exposure location was assumed for all exposures and activities (home, schools, church, work, recreation, and the source for locally grown vegetables, milk, and meat).

- **Delivery Person Family.** This family lived in Barnwell, South Carolina, and attended church in Martin, South Carolina. Some of the food eaten by this family was obtained from Barnwell and some from Martin. The father worked in Allendale, South Carolina, and onsite at SRS. (So did the children when they grew up.) A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location. The father hunted deer and wild fowl near Martin. The family engaged in recreation on the shore of Lower Three Runs Creek (at Martin) and on the shore of the Savannah River below its confluence with Lower Three Runs Creek. The family boated on, and ate fish from, the Savannah River at this same exposure location. The family also ate fish that were caught in Lower Three Runs Creek.
- **Outdoors Person Family.** This family lived in Jackson, South Carolina, where the family also attended church and the children went to grade and high school. Much of the food eaten by the family was grown in Jackson. The father worked and hunted on the SRS site (as did the children when they grew up). The same location on the SRS site, near the K-Reactor, was assumed for the work exposure location and the hunting exposure location. The father boated on the Savannah River while working and with his family for recreation. The family swam and spent time along the shoreline at the Jackson Boat Ramp, which is upstream of the SRS discharge to the Savannah River. All family members ate fish that were caught in the Savannah River below its confluence with Lower Three Runs Creek.
- **Near River Family.** This family lived in Martin, South Carolina. The Martin exposure location was assumed for all activities (home, schools, church, work, recreation, source of milk, and the source of locally grown vegetables). In addition, the family boated in, and ate fish from, the Savannah River below its confluence with Lower Three Runs Creek.

2 Conclusions

Primary conclusions address the main objective of the study – estimates of doses and risks. Secondary conclusions relate to how the doses arose, including the important radionuclides, pathways, and years of release.

2.1 Primary Conclusions

Calculated doses and risks to the hypothetical receptors summed over the 39-year period studied appear to be small. The largest point estimate dose was 9.4 mSv (0.94 rem) for the Outdoor Family Child Born in 1955 ; the corresponding risk of cancer incidence is 0.10% and the corresponding risk of cancer fatality is 0.024%. By way of comparison, the annual average radiation exposure for a member of the U.S. population is about 3.6 mSv (5), mainly from naturally occurring sources of radiation and medical sources (e.g., x rays). An annual background dose of 3.6 mSv over a period of 39 years would produce a dose of 140 mSv (14 rem). Although estimated doses (and the risks of cancer incidence) could be higher or lower when uncertainties in variables were considered, these differences are not sufficient to change this conclusion. For example, when uncertainties were considered, the Outdoor Family Child Born in 1955 received the largest mean dose of 13 mSv (1.3 rem) and the largest median dose of 11 mSv (1.1 rem). Observation of extreme values of dose, in this case representing the highest and lowest 2.5% of doses, illustrates the variation in estimated doses; for the same receptor the maximum dose was 60.3 mSv (6 rem) and the minimum dose was 2.53 mSv (0.25 rem). Table 4 summarizes point estimate doses for all 28 hypothetical receptors modeled. Note that the first four scenarios listed were exposed only to air releases of radionuclides, while the last three scenarios were exposed to both air and water releases. Table 5 summarizes the uncertainty analysis results, which includes the mean, median, minimum, and maximum doses estimated. Note that the means and medians of the dose are generally larger than the corresponding point estimate dose. The confidence intervals calculated around the mean values of doses were relatively

small; although these intervals are not displayed, the relative small size of the standard deviations shown in Table 5 indicates that the confidence intervals are narrow.

Table 4 39-Year Point Estimate Effective Dose (mSv) for Each Member of Each Scenario

Scenario	Pathways	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Rural Family One	Air	0.30	0.42	1.6	0.072
Rural Family Two	Air	0.70	0.97	3.8	0.14
Urban/Suburban Family	Air	0.33	0.73	2.7	0.11
Migrant Worker Family	Air	0.45	0.62	2.2	0.083
Delivery Person Family	Air	0.40	0.57	2.1	0.12
	Water	5.7	5.7	3.1	2.0
	All	6.1	6.3	5.2	2.1
Outdoors Person Family	Air	1.6	2.5	8.3	0.36
	Water	1.5	1.7	1.2	1.5
	All	3.0	4.2	9.4	1.8
Near Water Family	Air	0.31	0.42	1.7	0.088
	Water	1.8	1.8	1.4	1.7
	All	2.1	2.2	3.1	1.8

Table 5 Statistics on Total Effective Dose Equivalent for Different Receptors* -

Family	Family Member	Mean (mSv)‡	Median (mSv)‡	Minimum† (mSv)‡	Maximum† (mSv)‡	Standard Deviation (mSv)
Delivery Family	Adult Female	12.812	9.072	1.813	60.911	0.01223
Delivery Family	Adult Male	13.001	9.281	1.737	61.183	0.01226
Delivery Family	Child Born 1955	10.164	7.993	1.767	35.010	0.00776
Delivery Family	Child Born 1964	4.498	3.159	0.712	15.146	0.00373
Migrant Family	Adult Female	0.793	0.562	0.138	4.615	0.00090
Migrant Family	Adult Male	1.117	0.756	0.184	6.770	0.00129
Migrant Family	Child Born 1955	3.676	2.489	0.417	24.269	0.00445
Migrant Family	Child Born 1964	0.127	0.093	0.043	0.732	0.00013
Near Water Family	Adult Female	3.431	2.738	1.138	9.896	0.00204
Near Water Family	Adult Male	3.574	2.929	1.183	10.084	0.00206
Near Water Family	Child Born 1955	4.815	4.311	1.293	18.333	0.00303
Near Water Family	Child Born 1964	2.850	2.290	0.867	14.090	0.00231
Outdoor Family	Adult Female	4.687	4.263	1.272	11.751	0.00246

Family	Family Member	Mean (mSv)‡	Median (mSv)‡	Minimum† (mSv)‡	Maximum† (mSv)‡	Standard Deviation (mSv)
Outdoor Family	Adult Male	6.055	5.546	2.026	14.246	0.00295
Outdoor Family	Child Born 1955	13.331	10.988	2.529	60.270	0.01021
Outdoor Family	Child Born 1964	2.951	2.309	0.893	14.158	0.00231
Rural Family One	Adult Female	0.502	0.387	0.090	3.005	0.00053
Rural Family One	Adult Male	0.712	0.538	0.120	4.406	0.00076
Rural Family One	Child Born 1955	2.681	1.697	0.281	17.410	0.00334
Rural Family One	Child Born 1964	0.093	0.077	0.037	0.340	0.00006
Rural Family Two	Adult Female	1.174	0.890	0.199	7.162	0.00128
Rural Family Two	Adult Male	1.655	1.198	0.267	10.502	0.00185
Rural Family Two	Child Born 1955	6.362	4.006	0.642	41.579	0.00798
Rural Family Two	Child Born 1964	0.190	0.153	0.072	0.796	0.00014
Urban Family	Adult Female	0.447	0.284	0.083	2.204	0.00039
Urban Family	Adult Male	0.895	0.698	0.263	3.276	0.00055
Urban Family	Child Born 1955	4.314	2.551	0.345	30.820	0.00557
Urban Family	Child Born 1964	0.115	0.107	0.054	0.215	0.00003

* The number of decimal places for values in the table is to allow easy display; the values should be considered to have a precision no greater than two significant digits.
† These minimum and maximum values are for this sample; another set of realizations will likely have different values. However, any sample minimum value is greater than or equal to the population minimum value, while any sample maximum value is less than or equal to the population maximum value.
‡ mSv = millisieverts.

2.2 Secondary Conclusions

1. For people who ate fish from the Savannah River or Lower Three Runs Creek, downstream of the SRS, fish ingestion was the most significant pathway and the most important radionuclides were generally ^{137}Cs, ^{32}P, and ^{90}Sr. As an example for the Delivery Person Family, Figure 3 shows the relative importance of pathways and Figure 4 shows the relative importance of radionuclides.
2. For people who did not eat fish from bodies of water contaminated by releases of radionuclides to water, milk and beef were the most significant pathways and ^{131}I and ^{3}H were the most important radionuclides. As an example for Rural Family One, Figure 5 shows the relative importance of pathways and Figure 6 shows the relative importance of radionuclides.
3. Immersion in ^{41}Ar was a generally small, but constant contributor to dose.
4. Larger doses occurred in years corresponding to larger releases from the SRS, especially releases of ^{131}I; for the Adult Male, Adult Female, and Child Born in 1955 a large fraction of the total dose was received during the years 1955-1961. As an example for Rural Family One, Figure 7 shows the relative importance of year of release.
5. There were significant differences in doses, pathway significance, and radionuclide significance between children born in 1955 and those born in 1964, because the children born in 1955 experienced the large iodine releases early in the site history while those born in 1964 did not.

6. Doses caused by ingesting fish from Lower Three Runs Creek were significantly higher than doses caused by ingesting fish from the Savannah River.
7. For air releases, the variations in air dispersion of radionuclides from the site generally produced a significant, but not overriding, variation in estimated doses; other factors in the analysis caused bigger dose impacts.
8. Consideration of uncertainty in the variables used to estimate doses could cause an estimated dose to be higher or lower than the corresponding point estimate result. The mean of the distribution of total dose for any receptor ranged between 2.15 to 1.07 times the corresponding point estimate dose; thus, the means of the uncertain doses were close to the corresponding point estimate values.
9. The use of hypothetical scenarios to demonstrate the interactions of a range of receptor behaviors with the site and release characteristics was an effective analytical tool.

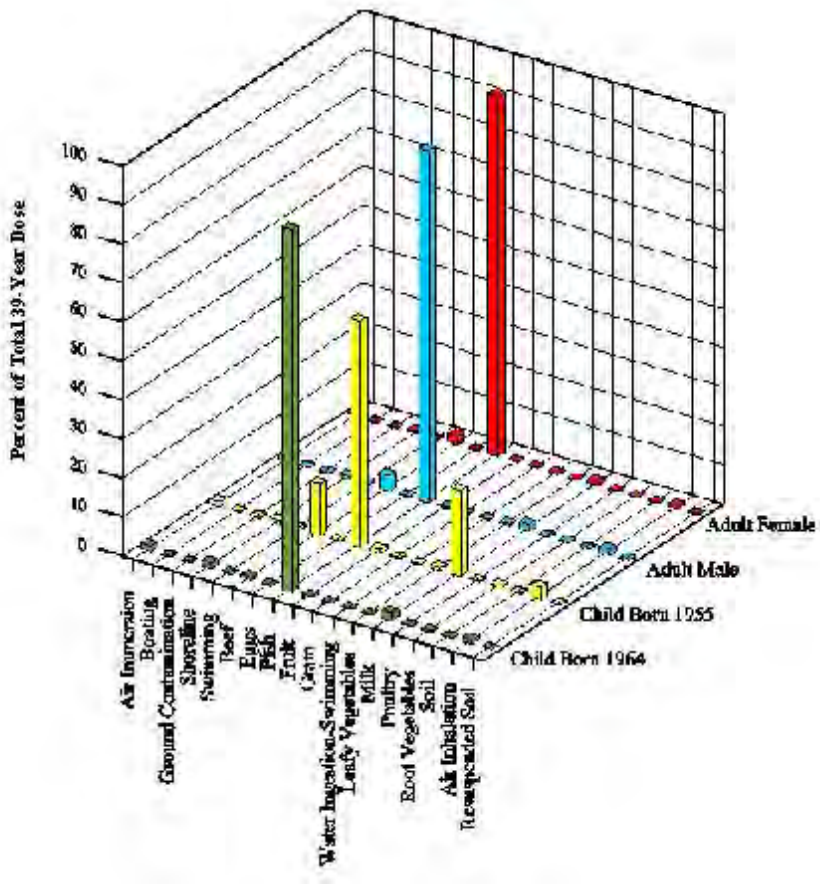

Figure 3 Percent of 39-Year Effective Dose by Exposure Pathway for Delivery Person Family

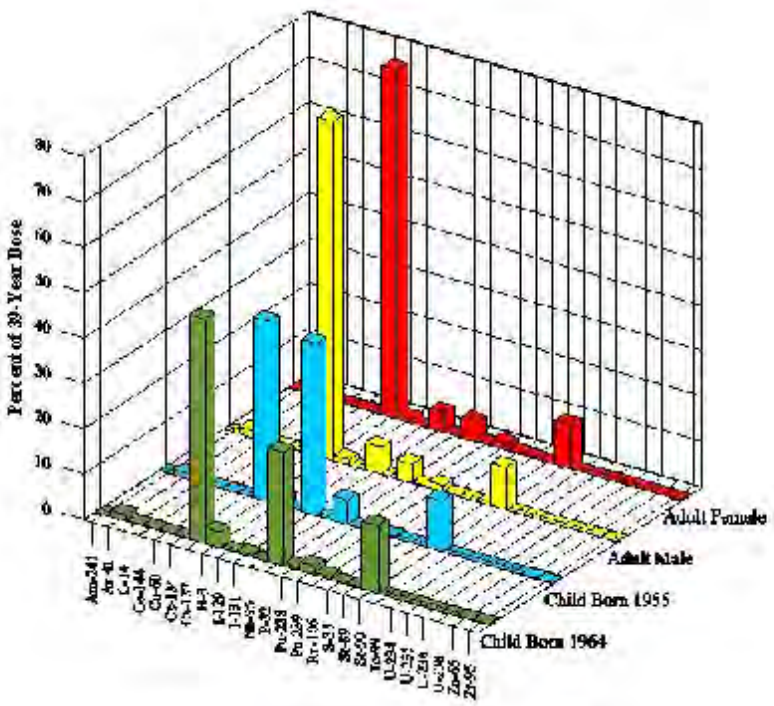

Figure 4 Percent of 39-Year Effective Dose by Dominant Isotopes for Delivery Person Family

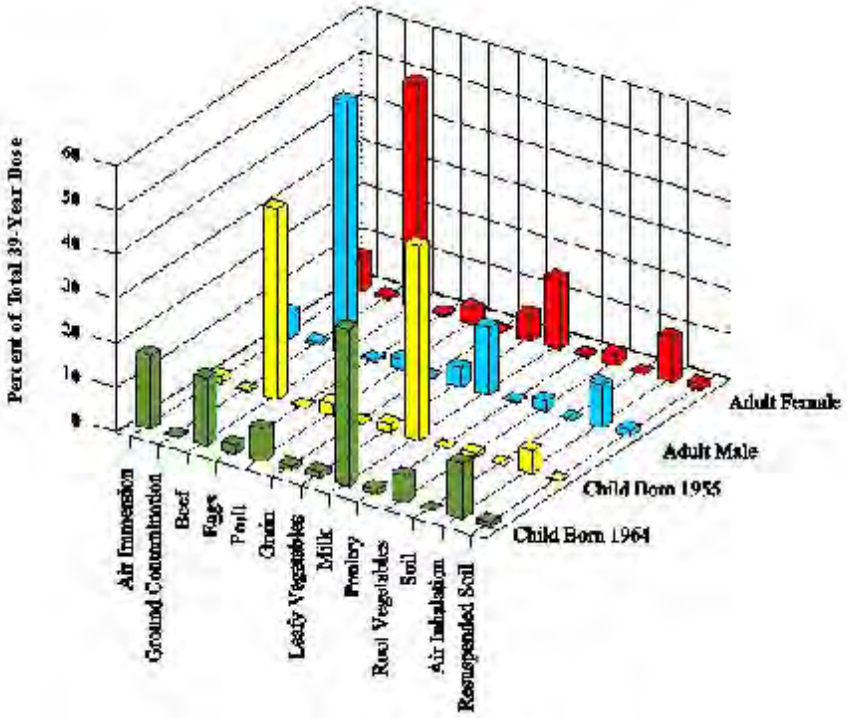

Figure 5 Percent of 39-Year Effective Dose by Exposure Pathway for Rural Family One

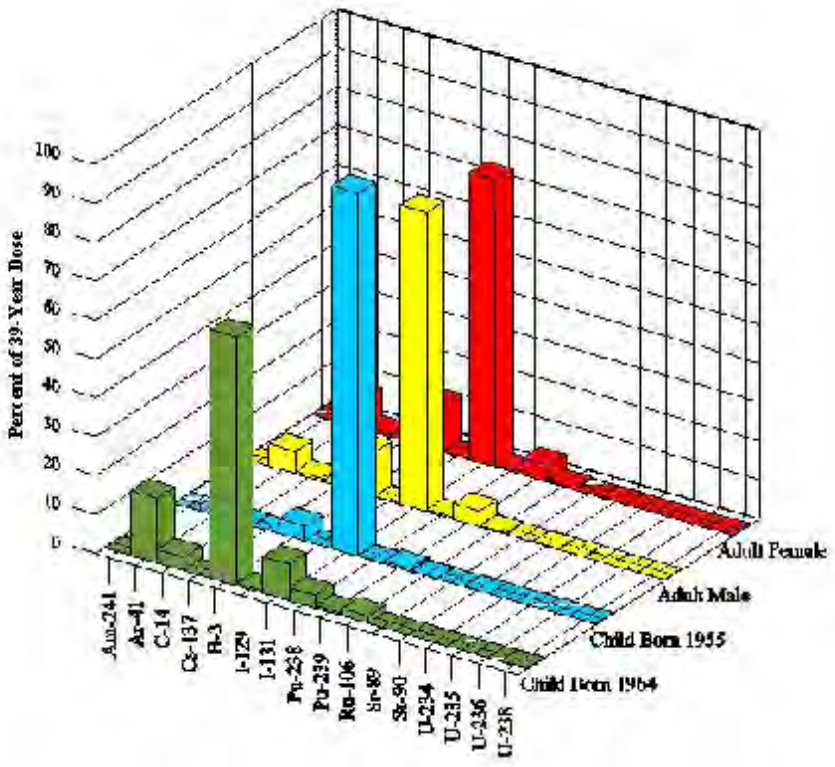

Figure 6 Percent of 39-Year Effective Dose by Dominant Isotopes for Rural Family One

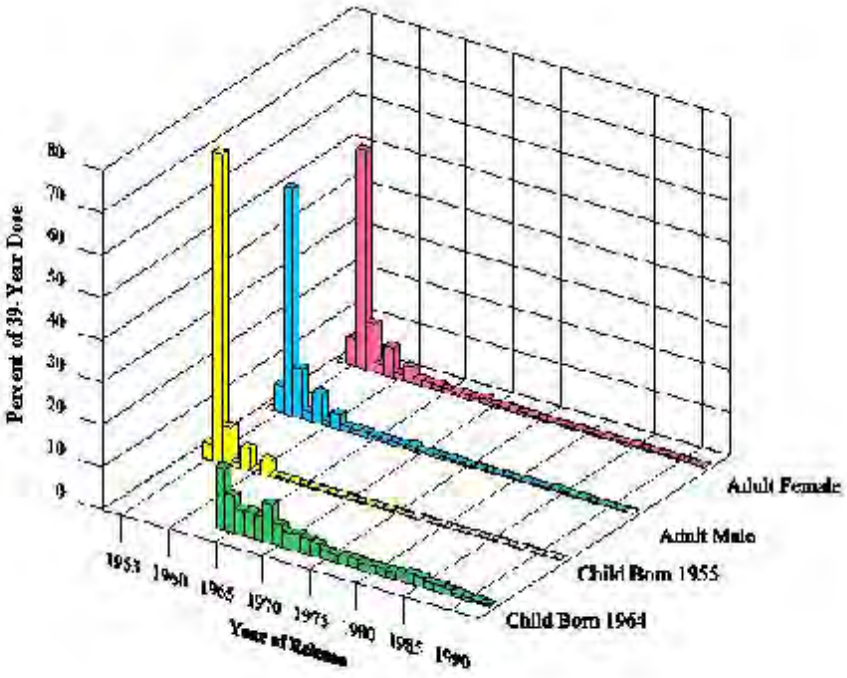

Figure 7 Percent of 39-Year Effective Dose by Year for Rural Family One

3 Overall Analytical Approach –

This dose reconstruction, a special type of retrospective dose assessment, starts with the release of radionuclides from SRS; continues with the transport by air, water, and the food chain; models the exposure of the hypothetical receptors to contaminated media (air, water, soil, and food); and results in an estimation of doses and risks.

The complex nature of this dose reconstruction, with 28 receptors, 12 exposure locations, 18 exposure pathways, and over 30 radionuclides (some radionuclides were counted twice, once for release in air and once for release in water) required that the dose computations be automated. This automation was achieved by developing software specifically for this dose reconstruction and by employing a generic dose assessment computer code, the GENII version 2 computer code (7), developed at Pacific Northwest National Laboratory (PNNL) to support radiological exposure and risk assessment for EPA's Office of Indoor Air and Radiation. A dose assessment program was created having three components: a preprocessor, a dose calculation module, and a postprocessor (Figure 8). The preprocessor compiled input data such as the quantities of radionuclides released annually into the air and water, and prepared the data for use by the dose calculation module. Using standard dose assessment models, the dose calculation module performed the transport and exposure pathway computations that estimated the movement, dilution, and concentration of radionuclides in the environment and the human intake of and exposure to the radionuclides. The postprocessor extracted results from output files and compiled them in a readily useable format.

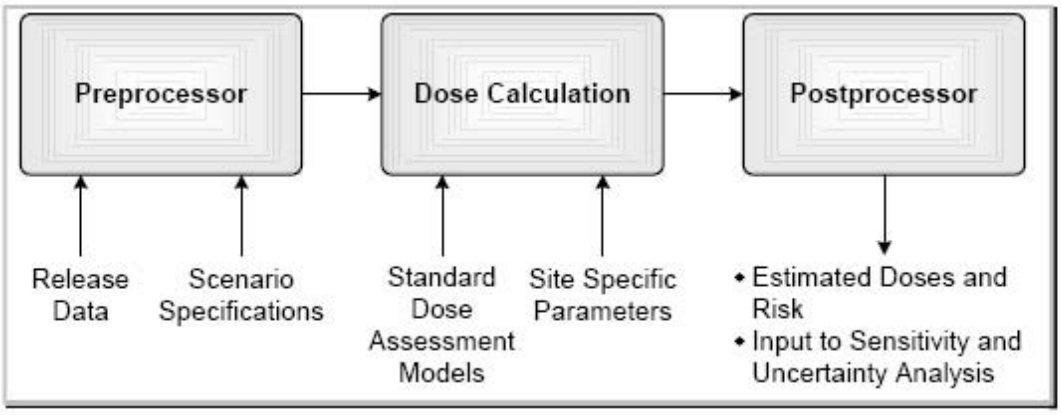

Figure 8. Conceptual Configuration of SRS Dose Assessment

Although the GENII code has already encoded a large variety of mathematical models, a major and crucial task of this project was to configure the GENII code to represent the scenarios and the site. This configuration was achieved in two main ways:

1. The GENII code is comprised of many modules, and each module represents a particular process in the overall approach (e.g., the uptake of radionuclides by a plant from the soil in which it grows). Incremental doses to a receptor are estimated by linking together a sequence of these modules. For example, a particular sequence might include: 1) transport of some of the release by air dispersion to a specified location, 2) deposition onto the soil, 3) incorporation into the soil, 4) uptake by a plant, 5) ingestion of the edible portion by the receptor, 6) dose to the receptor, and 7) resulting risk to the receptor. A fundamental decision was determining which modules to use and how they should be interconnected. Figure 8 and Figure 9 show how modules were interconnected for the SRS dose reconstruction. Some modules, although available in GENII, were deliberately omitted (e.g.,

contamination of soil by irrigation with contaminated water was not used because agricultural practices in the SRS vicinity did not include irrigation by river water). Each complete set of modules leading to a receptor dose has been termed "an exposure pathway". A total of 18 different exposure pathways, shown in Table 6, were used in this study: 13 for air releases and 5 for water releases.

2. Providing the number and location of places where radionuclides were released and receptors were exposed was essential in representing the site.

For this study it was necessary to consider: 1) the complex geometrical configuration of sources and receptors, 2) the time-varying characteristics of the releases and receptors, 3) the complex processes governing transport of radionuclides in air and water, and 4) the uncertainties in release data and other information. For this dose reconstruction, determination of the conceptual model required careful research and in some cases extensive analyses. These enabling analyses are incorporated in this report; several were supplied to the CDC and SRHES as independent white papers for review and comment as the work was in progress.

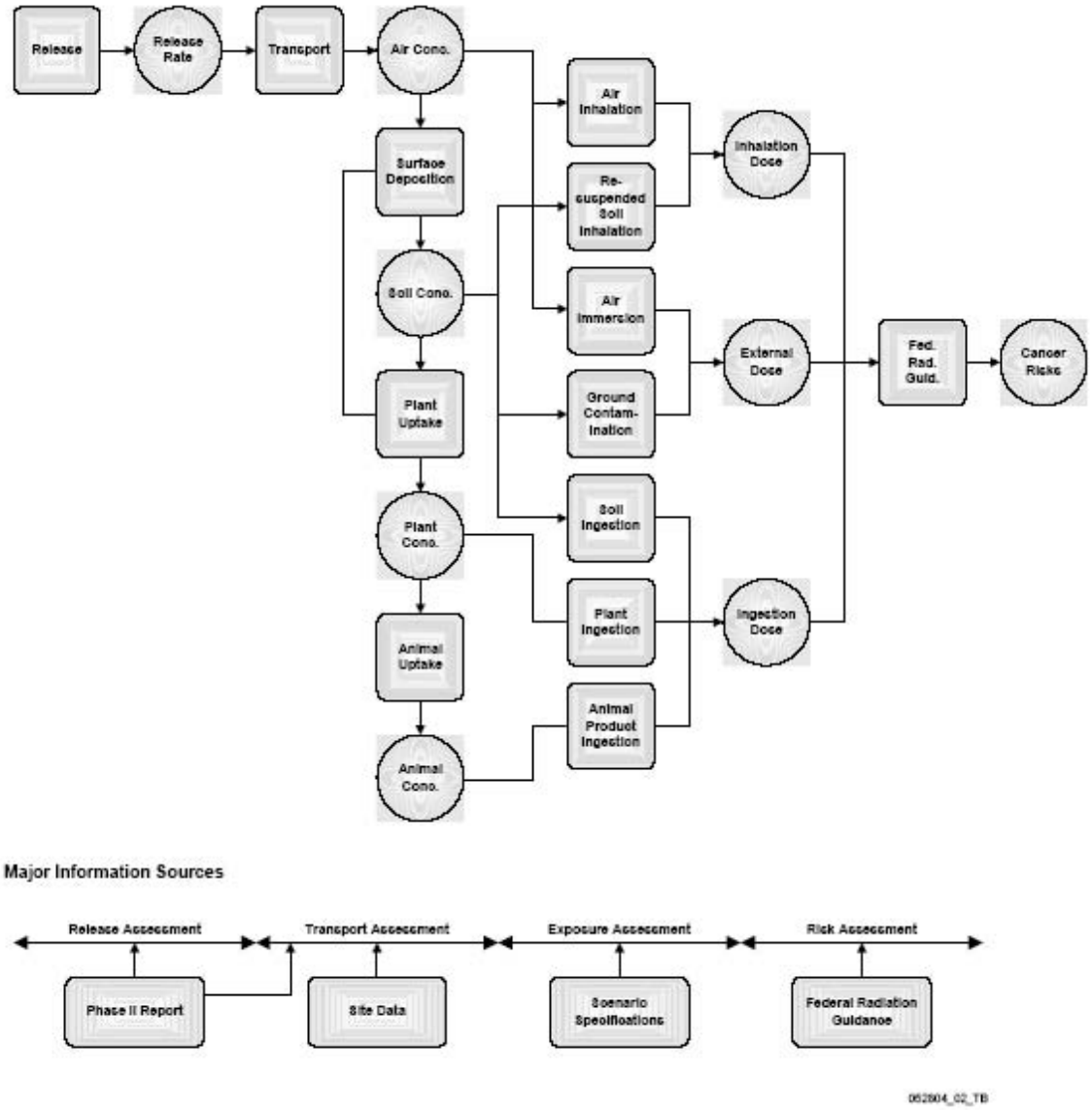

Figure 9 Overall Modeling Approach for Air Releases

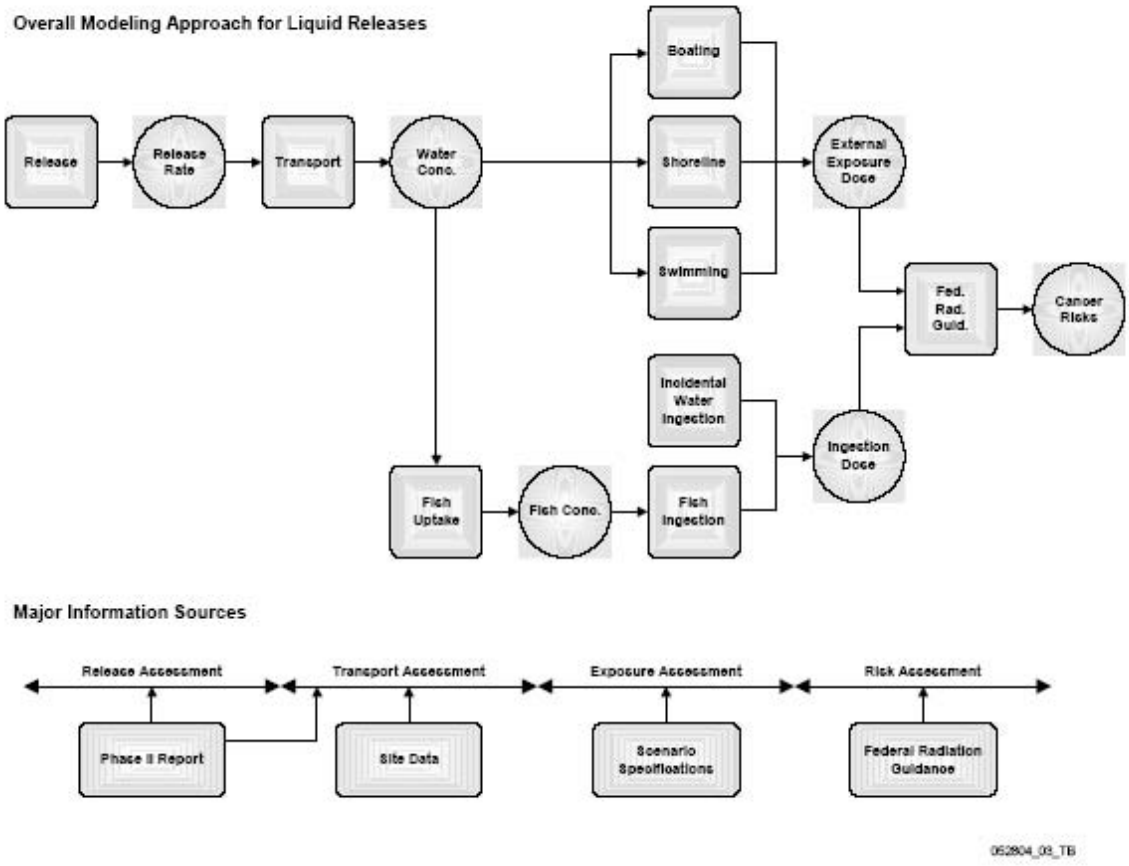

Figure 10 Overall Modeling Approach for Liquid Releases

Some of the topics requiring extensive analysis included:

1. **Releases to Air**. Air releases for each radionuclide of interest were carefully compiled by year and facility. Releases from 15 individual facilities were merged into 4 virtual sources, after a careful analysis showed that this simpler geographical representation of the sources would provide an appropriate degree of precision. In order to better represent health effects and/or environmental transport, some releases, compiled as a group, were partitioned into individual isotopes and/or chemical forms. This partitioning was based on analyses of the processes conducted at the different facilities.

2. **Releases to Water.** Because of the complex transport conditions between the radionuclides' point of release of to water at various SRS facilities and their arrival at exposure locations, the GENII code was not used to estimate the concentrations. Analyses performed outside the GENII code generated annual concentrations of radionuclides in the Savannah River and Lower Three Runs Creek. A model developed in Phase II was extrapolated based on the geochemical characteristics of the radionuclides to estimate their annual concentrations in the Savannah River. A simple model for Lower Three Runs Creek, based on annual flow rates and quantities of radionuclides released, did not match measured concentrations. Therefore, actual measured concentrations for three critical radionuclides, ^{137}Cs, ^{90}Sr, and tritium were used.

3. **Input Variables.** The large variety of situations modeled, representing radionuclide transport in the environment and exposure of humans, required specification of a large number (over 300) input variables to obtain a point estimate of dose for each receptor. Data sources were extensively reviewed and values of input variables were selected according the following preference hierarchy: (1) values specific to the SRS; (2) generic values recommended by an international body (8); (3) default values built into the GENII code.

Table 6 Exposure Pathways Associated with Exposure Routes and Release Medium

Exposure Route & Pathway	Shorthand Description	Air Releases	Water Releases
External Radiation			
• Immersion in a Plume of Contaminated Air	Air Immersion	X	
• Exposure to Soil Contaminated with Radionuclides Deposited from the Air	Ground Contamination	X	
• Exposure to a Shoreline Contaminated with Radionuclides Deposited from Water	Shoreline		X
• Exposure to Contaminated Water while Swimming	Swimming		X
• Exposure to Contaminated Water while Boating	Boating		X
•			
Ingestion			
• Leafy Vegetable Consumption	Leafy Vegetables	X	
• Root Vegetable Consumption	Root Vegetables	X	
• Fruit Consumption	Fruit	X	
• Grain Consumption	Grain	X	
• Beef Consumption*	Beef	X	
• Poultry Consumption*	Poultry	X	
• Milk Consumption	Milk	X	
• Egg Consumption	Eggs	X	
• Inadvertent Soil Consumption	Soil	X	
• Fish Consumption	Fish		X
• Inadvertent Ingestion of Water While Swimming	Inadvertent Swimming Ingestion		X
Inhalation			
• Inhalation of Contamination in a Plume of Air	Air Inhalation	X	
• Inhalation of Contamination Resuspended from Soil after Deposition from the Air	Resuspended Soil	X	

*Beef consumption is a surrogate for consumption of all types of beef, including venison acquired through deer hunting on or near SRS. See Chapter 8 for a discussion of this assumption. Poultry consumption is a surrogate for consumptions of chicken and other fowl, including that acquired through bird hunting on or near SRS.

The analysis was conducted in two steps: 1) a deterministic step resulting in a point-estimate of dose for each receptor and 2) an uncertainty step resulting in many estimates of dose (a dose distribution) for each receptor. Table 7 summarizes some important differences between the two analysis steps.

Table 7 Comparison of Steps 1 and 2

Attribute	Step 1	Step 2
Analysis Type	Deterministic.	Uncertainty (Probabilistic).
Variables	All have a fixed value.	Most have a fixed value; 14 uncertain.
End Point	Dose and risks.	Dose.
Subcategories of Dose and Risk	All (organs, radionuclides, exposure pathways, release mode).	Only total dose.
Radionuclides	All (result of Level 1 screening in Phase II).	Minor contributors to dose screened out.
Exposure Pathways	All (all potential contributors).	Minor contributors to dose screened out.
Primary Goal	Understand how doses arise; screening for Step 2.	Establish confidence intervals around mean estimated dose.
Result	Single estimate of dose for each receptor.	Multiple estimates of dose for each receptor.

Step 1 established a point-estimate value of dose and risks for each receptor by assigning a single representative value for each variable used in the dose assessment; for this study these representative values were chosen to be realistic (i.e., not intentionally overestimating or underestimating the doses). These point-estimates of dose for each receptor were used to understand the relative importance of radionuclides, transport pathways, exposure pathways, and other factors.

Step 2 of the analysis evaluated the effect of input variable uncertainty on dose estimates. This uncertainty analysis was simplified to focus the analysis and eliminate some extensive computations likely to yield little benefit. Variables associated with receptor behavior specified by the scenarios and those associated with health effects (dose and risk coefficients) were considered to be certain and not evaluated in the uncertainty analysis. Then a systematic approach selected, from the remaining large set of variables, 14 variables evaluated to have a dominant effect on uncertainty in the dose estimates. Probability distributions established for these 14 variables were then used to generate 40 random sets of input variables, which generated 40 corresponding estimates of dose for each scenario member. This distribution of doses was the basis for generating the statistics (mean, median, maximum, minimum, confidence interval about the mean) that describe the uncertainty in dose. Although the probability distributions describing the input variables were anchored by the point estimate values for those variables, the mean and median doses calculated in Step 2 were generally higher than the point-estimates of dose calculated in Step 1.

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1 INTRODUCTION

The purpose of the Dose Reconstruction Project is to determine the total cumulative effective radiation dose to the populations surrounding the Savannah River Site[1] (SRS) for a 39 year (1954 – 1992) period. SRS is a U.S. Department of Energy (DOE) facility that produced nuclear materials such as tritium and Pu-239 for national defense and other programs. The SRS Dose Reconstruction Project examines the operations of SRS for the 39-year period from its inception in 1954 to the end of 1992, when main production activities ceased. The Project is sponsored by the Radiation Studies Branch, National Center for Environmental Health, Centers for Disease Control and Prevention (CDC) of the U.S. Department of Health and Human Services. The Project is a study of the potential health risks to people exposed to chemicals and radioactive materials released to the environment resulting from historical SRS operations.

This report is the product of Phase III of the Savannah River Site[1] (SRS) Dose Reconstruction Project. It estimates the cumulative effective radiation doses and associated cancer risks for each of 28 hypothetical persons living near SRS and performing representative activities.

Phase III assessed radiation doses and risks to members of seven hypothetical families (exposure scenarios) that were assumed to live in the SRS vicinity during the 39-year period. Assumptions about the activities of these hypothetical families were developed through collaboration between CDC and the SRS Health Effects Subcommittee (SRSHES).

1.1 Purpose and Scope of the Phase III Report

SRS was operated from 1954 to 1992, first by E.I. duPont de Nemours and Company (Dupont) for the U.S. Atomic Energy Commission (AEC), and later by Westinghouse Savannah River Company for DOE. SRS operated five reactors and two chemical separations operations to produce and purify plutonium, tritium, and other radioactive isotopes. During this time, radionuclides and chemicals were disposed of into the ground or released into surface waters and into the air. These releases potentially resulted in radioactive and chemical exposures to persons living near the site. By 1992, the production reactors had all ceased operation. The separation and some processing and support facilities, waste management, and environmental remediation facilities still operate. These operations may continue to release small quantities of radioactive and chemical materials to the environment.

The SRS Dose Reconstruction Project was begun in 1992 and is being conducted to determine if the health of people who lived near the site was affected by past releases of chemicals and radioactive materials from the site (CDC, 1999). Such a determination is not straightforward, and an analysis of the public health consequences of SRS operations must confront the following technical challenges:

- The site is large with many points of release at different locations.
- The site operations were complex, varied, and changed over time; a large variety of radionuclides and chemicals were released at various rates over time.
- The quantities and physicochemical nature of the released materials are uncertain; this is especially true for early site operations for which records are incomplete;

[1] The SRS was known as the Savannah River Plant (SRP) until 1989.

- Air and water transported some of the released material offsite within a geographically large and complex physical and ecological system.

- Some human exposures involved contaminant transport through the food chain, which is both complex and uncertain.

- The exposed population was potentially large, geographically dispersed, and engaged in a variety of behaviors that could affect the potential doses received from site releases.

- The doses received by the population in the vicinity of SRS were generally low and could not be measured directly by conventional dosimetry instruments; consequently, these doses must be inferred from models of releases, transport in the environment, and exposure.

- Concentrations in environmental media (air, water, biota), which are precursors to exposure, were low and often difficult to quantify using standard monitoring techniques.[2]

Therefore, radiological health risks from past SRS operations may best be estimated using a dose reconstruction process. This process consists of quantitative modeling of estimated doses and scientific and technical evaluations that support and enable the quantitative modeling. The quantitative modeling entails:

- Modeling releases using historical information to estimate the annual quantities of radioactive materials released from all significant SRS sources.

- Modeling the migration of radionuclides in air, water, and the food chain to estimate the concentrations of radionuclides in environmental media that may be contacted by a human receptor over time.

- Performing exposure assessments to estimate radiation doses.

- Estimating risks that may be caused to the receptor from exposure to these radionuclides.

A variety of strategies was used to overcome these technical challenges. These strategies included:

- Appropriate simplifications of highly complex processes (e.g., the use of standard models for internal and external dose and cancer risks)

- Use of hypothetical scenarios to bracket the behavior of persons living near SRS.

- Quantitative estimation of dose uncertainty due to uncertainties in model input variables.

1.2 CDC Phased Approach to Dose Reconstruction

At the initiation of the SRS Dose Reconstruction Project in 1992, CDC designed the project to consist of five phases as summarized in Table 1-1 (1).

The design of the project ensured open public participation. Among other citizen outreach activities, the SRS Health Effects Subcommittee (SRSHES) was established to advise CDC on

[2] The ability to detect and quantify radionuclides and chemicals in media has improved since SRS began operations.

the adequacy of their health research and public health activities associated with SRS. An Advisory Committee to CDC constituted under the Federal Advisory Committee Act, the SRSHES is comprised of citizens selected to reflect the diversity of the communities impacted by SRS (2).

Table 1-1 Phases of SRS Dose Reconstruction Project

Phases	Description
Phase I	A systematic review of available documents at SRS and the development of a document database.
Phases II	Initial source-term development and pathway analysis. This work consisted of estimating the amount of radioactive materials and toxic chemicals released to the environment from the SRS from 1954 to 1992.
Phase III	Screening dose and exposure calculations.
Phase IV	Developing methods for assessing environmental pathways and environmental doses.
Phase V	Calculation of environmental exposure and doses.

Source: (1).

Phase I of the study was a search of SRS to find and copy documents and other records of potential value to the project. This effort was completed in 1995. About 50,000 boxes of SRS records were examined, and numerous SRS workers were interviewed. Many of the records were formerly secret reports that were declassified. An electronic document database was created to store information about the records. An additional product was a description of SRS areas and processes organized by location (3).

Phase II of the study began in October 1995 to develop an estimate of the releases of the most significant radionuclides and chemicals from various facilities at SRS from 1954 to 1992. This estimation included a list of radioactive materials and chemicals that were used or produced at the site as well as descriptions of key processes at SRS. In addition, the results of past SRS environmental monitoring programs were reviewed.

In September 1998, CDC provided the results of the Phase II study to outside reviewers, including the National Academy of Science and the SRSHES. After considering and addressing comments, the final Phase II report was produced in April 2001. This 1,400-page report, titled "Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released from the Savannah River Site (Phase II)," is available on the Internet at http://www.cdc.gov/nceh/radiation/savannah.

1.3 Modifications to the Original CDC Approach

CDC's original plan for the Phase III effort was to use "scenarios provided by CDC and a screening protocol approved by CDC" and to "perform screening calculations to determine which radionuclide releases from the Savannah River Site may have biological significance." The implication was that those radionuclides not screened out as unimportant would warrant further analysis (in Phases IV and V) primarily to estimate doses. In a presentation to the SRSHES in June 2002, CDC stated that they intended to use Safety Series Report No. 19 issued by the International Atomic Energy Agency (IAEA) as the model to perform the screening analysis(4).

The screening analysis would have used conservative modeling assumptions, and the main focus of the analysis would have been the determination of radionuclides for further study in Phases III and IV. Two similar screening analyses, based on the total amount of radionuclides released from SRS, were incorporated in the Phase II report. The Level 1 screening analysis considered doses from all pathways, while the Level 2 screening analysis was a more refined analysis in which the role of a radionuclide in the doses for each individual pathway was considered.

However, CDC recognized that the process set forth in Table 1-1 would take considerable time, perhaps several years, to complete through Phase II. During this time, questions would remain about the possible public health consequences from past SRS operations. In addition, there was concern about the availability of the funding required to complete the remaining phases given other competing priorities.

Consequently, in late 2002 and early 2003, CDC expanded the scope of the Phase III effort to include a more detailed estimation of representative doses and risks using the CDC scenarios. In effect, the expanded scope went beyond the previously defined Phase III scope, but stopped short of the detailed modeling of environmental pathways contemplated for a Phase IV study. The CDC scenarios included several hypothetical sets of individuals performing realistic, but in some cases extreme, activities on and near the site. Each hypothetical scenario represented a family that lived, worked, and engaged in recreational activities in the vicinity of SRS, and raised children born during years of large SRS releases of radioactive material to the environment. As the basic source term for environmental assessment, CDC used the estimates of release into the atmosphere and surface water as provided in the Phase II study. In addition, the uncertainty of the calculated doses was to be addressed.

CDC initially developed the scenarios for Phase III that were then further refined by CDC, the SRSHES, and the preparers of this report. Originally, CDC proposed the following six scenarios:

1. A rural family just downwind of the site boundary.
2. An urban/suburban family just downwind of the site boundary.
3. A delivery person scenario.
4. An outdoors person (hunting, fishing, camping, etc.
5. A family living near the river.
6. A migrant worker family living mostly outdoors.

CDC presented proposed assumptions about these six scenarios at a meeting of the SRSHES held in January 2002 in Charleston, South Carolina. The SRSHES considered CDC's proposed scenarios and presented comments to CDC on the proposed scenarios at a meeting held on September 6, 2002. These comments included suggestions about modifying the scenarios (5).

The preparers of this report had several additional suggestions including the addition of a second rural family scenario (6). The seven scenarios considered in Phase III are described in detail in Chapter 3.

The revised approach adopted by CDC allowed the levels of dose and risk, and their main contributors, to be identified and addressed in a more focused manner than the screening analysis that was originally intended.

Technical Challenges In addition to the technical challenges delineated in Section 1.1, other significant challenges had to be addressed.

1.3.1 Scenario Implementation

Although CDC and the SRSHES provided the descriptions and scopes of the exposure scenarios considered for the study, many of the details of the scenarios were either unspecified or had to be adjusted to enable mathematical modeling. Chapter 3 summarizes the detailed scenario specifications and Appendix E discusses these scenario specifications in detail.

1.3.2 Merging of Air Release Sources

The Phase II report identified 15 principal SRS locations for release of radionuclides into the air plus several other smaller sources (Phase II). Given the large computational requirements needed to model the transport of radionuclides from each of these sources to each of the exposure locations considered in the study, all of these release locations were merged into four virtual locations. Chapter 6 summarizes the procedures used in creating these four virtual sources, and Appendix A discusses the procedures in detail.

1.3.3 Doses and Risks from Radionuclides Discharged to Surface Water

The evaluation of doses and risks from radionuclides released to onsite surface water bodies had to be performed in a somewhat different way than the evaluation for radionuclides released to air. Doses and risks were calculated for exposure to radionuclides discharged to the Savannah River and for exposure to radionuclides in Lower Three Runs Creek. To determine the concentrations of radionuclides released annually to the Savannah River, a procedure was developed that considered delay in surface water sediments, biota, etc. To determine radiation exposures from radionuclides in Lower Three Runs Creek, environmental monitoring data were used directly in the analysis (See Chapter 7).

1.3.4 Radionuclide Retention in the Streams and Swamp

Many radionuclides discharged into onsite streams were not immediately transferred off the SRS site but were sorbed or taken up by minerals, sediments, plants and biota. These processes reduced the quantities of radionuclides that were annually released from SRS to the Savannah River. A procedure was developed in Phase II to mathematically account for these processes and their influence on the transport of radionuclides to the Savanna River. This procedure was applied to three radionuclides. For Phase III, the procedure was expanded to all the radionuclides in the Phase III source term that were released to surface water. A description of this procedure is found in Chapter 7, Release of Radionuclides to Water and Transport to an Exposure Location.

1.3.5 Completion and Qualification of the Contaminant Release Database

To complete this phase of the SRS dose reconstruction study, quantified estimates were needed for all the major radionuclides released into air and surface water during each year of SRS operation. Although the Phase II report was the basis for these estimates, it did not provide all the information that was needed. For example, the Phase II report lacked annual estimates of release to air for some radionuclides for the years 1954 through 1989 and for most radionuclides for the years 1990 through 1992. The information provided in the Phase II report was expanded using data from the SRS monitoring program and other sources (see Chapters 5 and 7).

1.3.6 Input Data Determination

To model the migration of radionuclides in air, water, and the food chain, and subsequent human radiation exposures through various exposure pathways, values had to be determined for more than 250 parameters used in the analysis. Some parameters pertained to physical conditions in the SRS vicinity such as the densities of soils and sediments. For these parameters, values were selected that considered several references such as SRS-specific environmental assessments (see Appendix F).

Many parameters pertained to transport of radionuclides through the food chain (i.e., into plants and animal products eaten by humans). A three-step process was used to determine transfer factors used as measures of the partitioning between soil and plants, animals and humans consuming animal products, and fresh water and fish (see Appendix F).

1. Site-specific data were used when available (7).

2. If no site-specific data were suitable, data were considered from a detailed handbook of parameter values addressing a variety of environmental settings (8).

3. If no data were available and suitable from these sources, default values used in Version 2 of the GENII code (9) were used.

A document providing much site-specific information (10) and other references were used to determine values for additional parameters used in the analysis such as crop-growing periods and feed-consumption rates by animals.

Finally, some parameters pertained to activities conducted by the human receptors, including activities such as breathing rates and the amounts of nine different foods eaten each year by each receptor (Appendix E). Each parameter value had to be specified consistent with the age and gender of the receptor. Age-specific data for these parameter values were obtained mainly from standard references such as EPA's *Exposure Factor Handbook* (11).

1.3.7 Determination of Probability Distributions

A sensitivity and uncertainty analysis was performed on the doses that were calculated in this study. This analysis included a process called a stochastic assessment that quantitatively analyzed the uncertainties associated with the values used in the computer model. The stochastic assessment required the development of probability distributions (which are graphs, tables or formulas that give the probability of occurrence for each value of the variable) for the parameter values, and numerous computations were performed where parameter values were randomly selected according to their probability distributions. Assessments were then made concerning the influence of these parameters on the calculated doses.

The computational requirements for this effort were reduced by the following process. First, a detailed analysis was performed of the doses calculated for all the exposure scenarios. Second, those exposure pathways and radionuclides that contributed the least to the doses received by the receptors were eliminated from the stochastic assessment. Third, parameters were eliminated from the uncertainty assessment if they either had values that were considered fixed or were shown to be small contributors to variance. From this process, a reduced list of parameters and radionuclides was produced for the stochastic assessment (see below and Chapters 4 and 12).

Probability distributions were determined for 14 parameters selected from the process described above. All but one of the probability distributions were lognormal distributions. Distributions for this analysis were selected after considering a handbook of parameter values (8) and other references, and applied site-specific values when available (see Chapter 12).

1.3.8 Deer and Game Dose

One of the principal concerns raised by the SRSHES early in Phase III was the possibility for significant radiation exposures from eating contaminated game animals such as deer. For a variety of reasons, it was difficult to model radiation exposures and doses through this pathway (see Appendix D.1.1.2.2).[3] Radiation exposures from eating venison and wild fowl were modeled as exposures from eating additional contaminated quantities of beef and poultry (see Chapter 3 and Appendix D).

1.3.9 Calculational Needs

The most daunting challenge was the sheer size of the computation effort required. The doses and risks that were calculated for Phase III were performed by each receptor (i.e., each scenario family member) by summing the incremental doses and risks received each year by each receptor from each radionuclide and through all exposure pathways. This analysis included the following factors:

- Sixteen radionuclides released to the air and 22 radionuclides released to surface water.
- Thirteen exposure pathways for radionuclides released to air and five exposure pathways for release to surface water.
- Thirty-nine years of radionuclide release to air and water.
- For each receptor and year, calculation of effective dose and doses to 23 bodily organs or tissues.
- For each receptor and year, calculation of total cancer risk and risk to 16 cancer sites in the body.
- Assessments of calculational uncertainty including stochastic analysis of important variables and dominant radionuclides.

Data storage and handling requirements for the analysis were large and led to the development of custom software to perform the detailed computations for the study.

A dose assessment program was created having three components: a preprocessor, a dose calculation module, and a postprocessor (Figure 1-1). The preprocessor compiled input data such as the quantities of radionuclides released annually into the air and water, and prepared the data for use by the dose calculation module. Using standard dose assessment models, the dose calculation module performed the transport and exposure pathway computations that estimated the movement, dilution, and concentration of radionuclides in the environment and the human

[3]The concentrations of radionuclides measured in deer in the SRS vicinity are similar to (and sometimes smaller than) concentrations of radionuclides measured in deer well away from the SRS vicinity. It was difficult to model radiation exposures and doses through this pathway (see Appendix D).

intake of and exposure to the radionuclides. The postprocessor extracted results from output files and compiled them in a readily useable format.

An existing environmental assessment code was adapted for use as the dose calculation module. After a rigorous code selection process (summarized in Appendix G), Version 2 of the GENII family of computer codes was selected. The original version of GENII was developed in the late 1980's for use at DOE's Hanford Reservation although the codes were designed with the flexibility to accommodate input parameters for a wide variety of generic sites. GENII has been included in the VAMP project, an international effort to compare environmental radionuclide transport models with measured environmental data.[4] GENII Version 2 incorporates improved transport models, exposure options, dose and risk estimates, and user interfaces. It implements dosimetry models recommended by the International Commission on Radiological Protection (ICRP) and is designed to function within the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES). FRAMES allows GENII to execute with, and provide inputs to, other related programs (9,12,13).

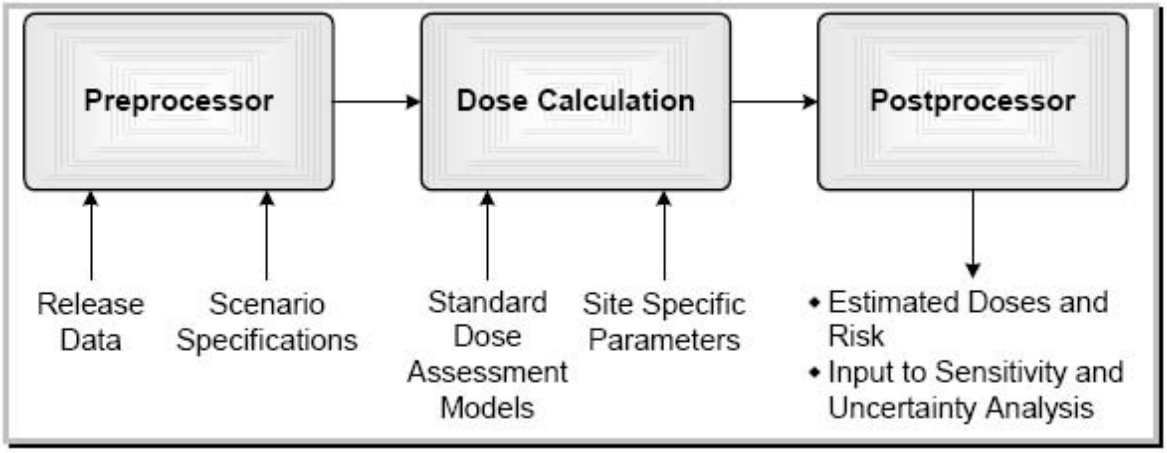

Figure 1-1 Conceptual Configuration of SRS Dose Assessment

However, using the GENII Version II code in accordance with the revised objectives of the study dictated the need to investigate, justify, and document more than 250 parameter values for use in GENII [5]. Therefore, it became desirable to make some simplifying assumptions to make the model more tractable although still representative. In particular, it became desirable to combine the air release points into a smaller number of virtual release points and to merge some of the possible exposure locations.

A strong effort was initiated to document all decisions made in the design and execution of this study. Some decisions could be explained in a few sentences, while others required detailed analyses. A variety of assessments and "white papers" were developed to document and justify decisions. Most were submitted to CDC for review and, through CDC, to the SRSHES for

[4] VAMP stands for Validation of Model Predictions, an acronym for the Coordinated Research Program on Validation of Models for the Transfer of Radionuclides in Terrestrial, Urban and Aquatic Environments, an international effort to compare environmental radionuclide transport models with measured environmental data. Results for test scenario CB, based on environmental measurements following the Chernobyl accident, indicated that dose estimates from GENII were comparable to, although slightly higher than, those of other participating models (12).

[5] Unless otherwise noted, all references to "GENII" in this study mean Version 2 of GENII.

information and comment. The following decision documents are either incorporated into the text of this report or referenced:

- **"Combining Sources of Air Releases for the SRS Dose Reconstruction."** This document contains the methodology and decision process for combining 15 major sources of air releases and several minor sources into 4 virtual sources while maintaining the ability of the data to accurately represent the contaminant exposure conditions over the period of the study.

- **"Soil-to-Water Distribution Coefficients for Radionuclides Considered in the Dose Reconstruction of Savannah River Site."** This document describes the distribution coefficients selected for evaluating potential doses and health risks to individuals residing in the vicinity of SRS during the period of concern (1954-1992). The principal application of these distribution coefficients is to model leaching of radionuclides from soil.

- **Treatment of Radionuclide Concentrations in Wild Game in Dose Reconstruction Modeling."** This document describes the decisions made concerning the use of beef consumption data to model venison consumption in the GENII computer model.

- **"Base Case Values for Exposure Activity and Usage Factors for the CDC SRS Dose Reconstruction Project."** This document describes in detail the characteristics of the hypothetical receptor groups modeled in the SRS Dose Reconstruction. The specific characteristics of the receptor families (i.e., exposure pathways and exposure locations) are used in the model to calculate the nature of radioactive exposure to each individual in the families for each of the potential exposure pathways being modeled.

- **"Comparison of Phase II and Phase III Source Terms for Water Releases."** The purpose of this document was to record the similarities and differences between the Phase II source-term values for water releases and the Phase III values used for the dose reconstruction.

- **"Basis for Determining Isotopic Fractions from SRS Environmental Reports for Performing Radiological Dose Assessments."** This document provides the technical basis and assumptions for identifying a release quantity for individual isotopes that have not been specifically identified in SRS environmental reports. Such isotopes include Sr-89, Sr-90, Zr-95, Nb-95, Cs-134, Cs-137, uranium, plutonium; and identified alpha, beta, and gamma.

- **"Documentation for GENII Model Parameters Used in SRS Base Case Calculation."** This document identifies the source, transport, and exposure variables used in the SRS Base Case GENII model runs, indicates the GENII module and the section and subsection of FRAMES where the variable is used, states the units and input value(s) of each variable, and describes how each value was determined.

- **"Position Paper for Use of the Savannah River as an Irrigation Source."** The purpose of this document was to determine if the use of the Savannah River as a source of irrigation water for farming is an appropriate assumption. One of the exposure scenarios involves a family living in Girard, Georgia downstream from SRS and using the river as an irrigation source for growing crops.

- **"Adjustment of Dose Conversion Factors and Risk Factors."** This document describes the appropriate factors to correct the doses and risks contained in the GENII-V2 output files. The GENII-V2 output files are generated assuming an adult. Therefore the calculated doses and risk results have to be corrected for the receptor's current age.

- **"Base Case Values for Receptor Activity and Usage Factors for the CDC SRS Dose Reconstruction Project."** This document describes in detail the characteristics of the hypothetical receptor families modeled in the SRS Dose Reconstruction. The specific characteristics of the receptor families are used in the model to calculate the radioactive exposure to each individual in each family for each of the potential exposure pathways being modeled. Some pathways occur for airborne releases of contaminants, and others occur for waterborne releases.

- **"Proposed Values of Transfer, Bioconcentration, and Bioaccumulation Factors Used for Modeling Dose Reconstruction for Historical Releases from the U.S. Department of Energy Savannah River Site."** This document describes how values were determined for a set of modeling variables known informally as transfer factors. The transfer factors are used in GENII-V.2 modeling software for modeling food chain transport of radionuclides. Many of these variables describe the ratio (at equilibrium) between contamination levels in two media types (e.g., the ratio of contamination levels in soil and in a plant that grows in soil). Other variables describe the steady-state ratio between contamination levels in plant matter and contamination levels in animal products (meat, eggs, or milk) that are produced from animals that consume the plant matter at a unit intake rate.

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2 BACKGROUND

2.1 Overview of Site Operations

In 1946, Congress created the U.S. Atomic Energy Commission (AEC) to administer the nuclear programs created for the World War II Manhattan Project. AEC needed new production capacity for nuclear weapons materials used in national defense and, in November 1950, AEC selected a location in South Carolina for the Savannah River Plant. Covering about 300 square miles (780 km^2), the site was chosen because of its low population density, large supply of water, freedom from major floods and storms, and other factors (1).

SRS is located about 19 miles (32 km) south of Aiken, South Carolina, and about 22 miles (36 km) southeast of Augusta, Georgia. It borders the Savannah River for about 17 miles and comprises parts of Aiken, Barnwell, and Allendale Counties in southwestern South Carolina. Figure 2-1 shows the general location of SRS.

The Savannah River Plant was designed, constructed, and operated for the AEC by E.I. duPont de Nemours and Company (DuPont). Construction began in 1951 (2). The basic plant was completed within five years and included five nuclear reactors, two chemical separations plants, and numerous laboratories and support facilities. The primary mission was production of ^{239}Pu and tritium. SRS bombarded fuel and targets containing ^{238}U and ^{6}Li with neutrons in the nuclear reactors, and recovered the ^{239}Pu and tritium from the fuel and targets at the separations facilities. DuPont continued operation of the plant until 1989 when operation was taken over by the Westinghouse Savannah River Company. At that time, the site was renamed the Savannah River Site (Phase II).

As production continued, the need for specific materials waned. As a result, site facilities gradually ceased operation until the primary defense-related mission ended in 1992. Since that time, certain activities continue to manage waste, conduct environmental restoration activities, and perform new missions (2).

Table 2-1 summarizes the SRS facilities of main importance for this study, and shows the principal SRS areas and facilities. Most are located in a rough circle in the approximate center of the site.[1] SRS contains two large ponds, Par Pond and L-Lake, and is drained by five major streams feeding into the Savannah River: Upper Three Runs Creek, Four Mile Branch, Pen Branch, Steel Creek, and Lower Three Runs Creek. With the exception of Lower Three Runs Creek, all of these streams empty into the Savannah River Swamp bordering the east side of the Savannah River.

[1] SRS facilities are identified by a system, using numbers and letters that reference them to a particular onsite area containing a complex of related or supporting operations. For example, each of the two chemical separations areas is identified by a letter of the alphabet (F and H Areas), and each building or structure within an area is numbered in accordance with a century nomenclature (i.e., the reactor areas are the 100-Areas, the separations areas are the 200-Areas, and so forth). A structure in one of the 100-Areas (reactor areas) is identified by a number in the 100's, a structure in one of the 200-Areas is identified by a number in the 200's, etc.

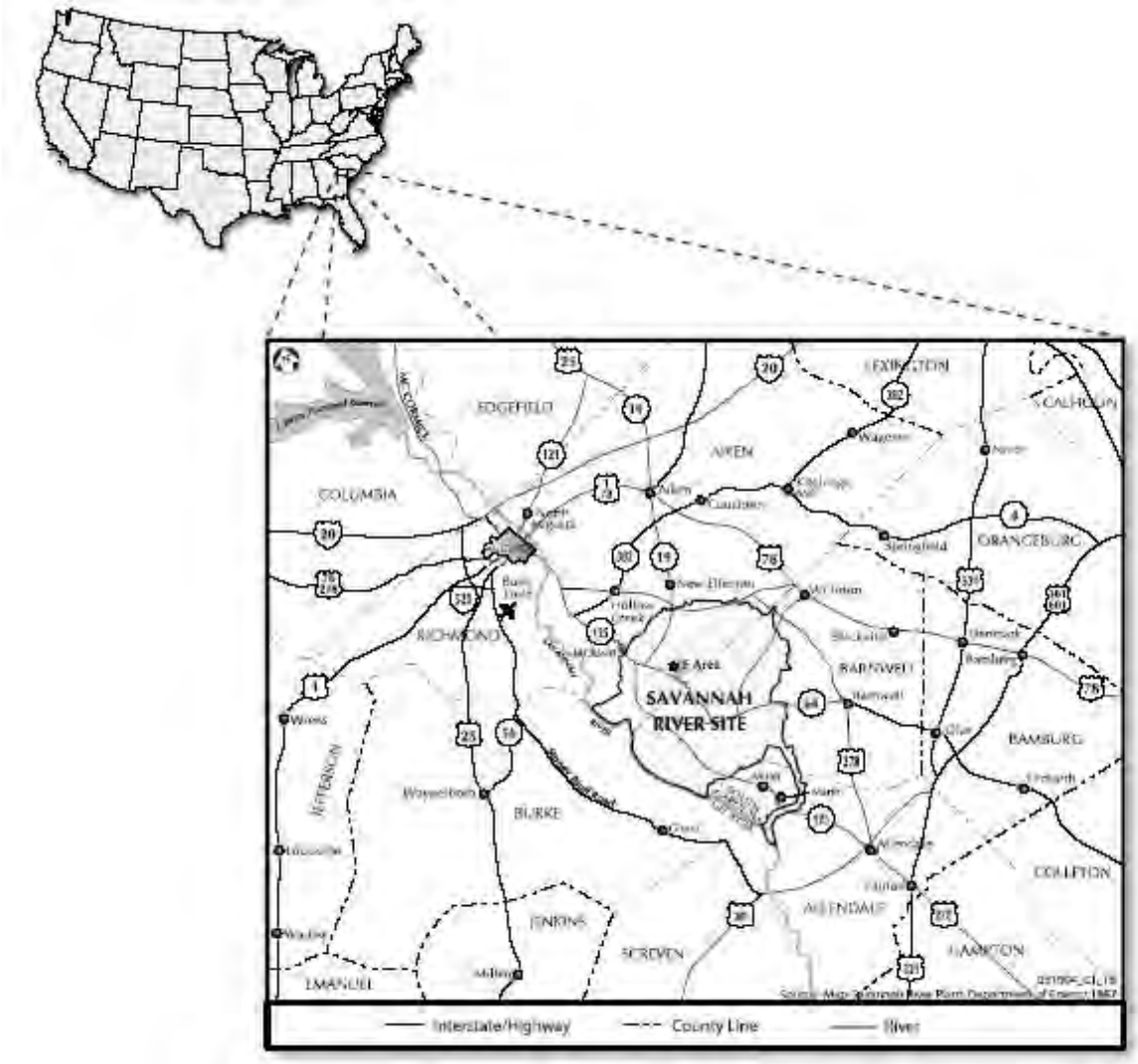

Figure 2-1 General Location of SRS

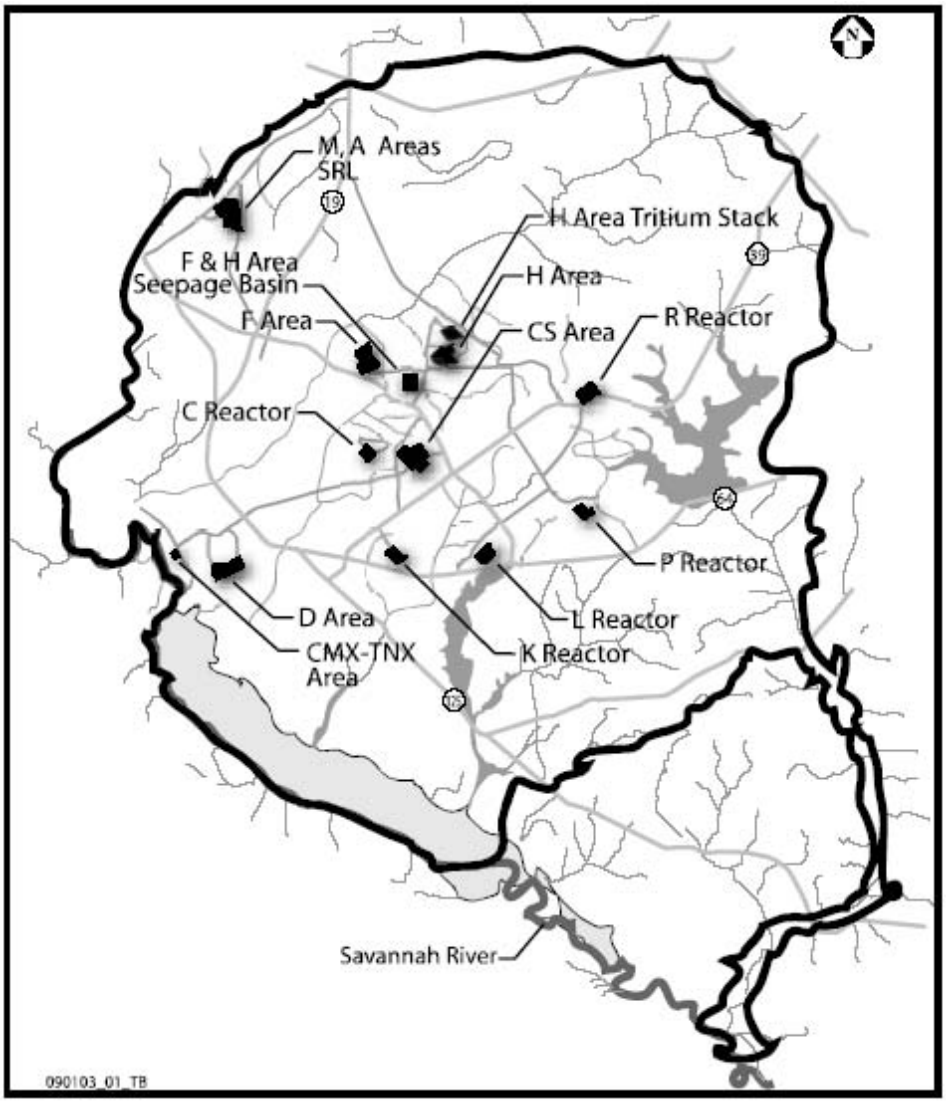

Figure 2-2 Principal SRS Areas and Facilities

Table 2-1 Principal Areas and Facilities

Areas	Facilities	Dates	Notes
100	R-Reactor P-Reactor C-Reactor K-Reactor L-Reactor	1953-1964 1954-1988 1955-1985 1954-1988 1954-1968 1985-1988	Reactors used heavy water as a neutron moderator and primary coolant. L-Reactor operated from 1954 to 1968, and from 1985 to 1988. K-Reactor was the last operating reactor.
200	H-Area Chemical Separations	Completed November 1954	Facilities for chemical separation and purification of plutonium (Pu), tritium (^{3}H), and other products from irradiated targets and fuel. Also used for recovery of tritium from weapons reservoirs.
	F-Area Chemical Separations	Completed July 1955	
300	M-Area Fuel and Target Production	Completed January 1953	Produced reactor fuel and target assemblies for irradiation in reactors.
400	D-Area Heavy Water Plant	First operating by October 1952; full capacity by May 1953	Concentrated heavy water from Savannah River. Reconcentrated heavy water after contamination with light water in reactors.
600	E-Area Waste Management	First disposals in 1953	Burial grounds located in E-Area between F-and H-Areas. Still in use.
	CMX and TNX Facilities	Completed 1953	Technical support, pilot plant development and training. Located near D-Area Heavy Water Plant.
700	A-Area Administration	Opened with site	Administrative offices. Includes Savannah River Technology Center.

Source: (3).

2.1.1 D-Area: Heavy Water Production and Processing

Some of the first facilities to be constructed were those producing heavy water for use in the reactors. The Extraction Plant, which operated until 1981, concentrated heavy water[2] from a natural level in river water (about 0.015 percent) to a concentration sufficient for reactor operations. The Rework Unit and the Distillation Plant removed light water that, over time, would contaminate the heavy water in the production reactors. Additional facilities included a laboratory, a facility to clean drums used for heavy water storage and transportation, and a coal-fired powerplant (3).

[2] Each molecule of water consists of two hydrogen atoms and one oxygen atom. One or both of the hydrogen atoms in heavy water contains a neutron in the nucleus in addition to a proton. A hydrogen atom containing a neutron and a proton in the nucleus is a deuterium (D).

Because tritium[3] is created from deuterium by neutron bombardment, concentrations of tritium in the reactor moderator built up over time. Consequently, the processes used to reclaim reactor moderator discharged tritium into the air and surface water.

The largest source of tritium released to air from D-Area was the Rework Unit, where releases to air occurred from leaks from the Rework Unit pump room and from the exhausts from the area used for storage of recovered heavy water. Releases also occurred from the drum-cleaning facility and the laboratory (1).

The Rework Unit was also responsible for the largest source of tritium released to surface water from D-Area. Typically, waste distillate was collected in tanks before sampling and discharge to cooling water effluent that drained to Beaver Dam Creek (1).[4] The tritium in the waste distillate was normally in concentrations that were too low for practical recovery (1).

2.1.2 M-Area: Reactor Materials

Fuel and target elements for irradiation in the SRS reactors were fabricated in the M-Area. Major facilities located in the M-Area were the Alloy Extrusion Unit, the Uranium Metal Element Fabrication Unit, the Target Extrusion Unit, and the Metallurgical Laboratory. All uranium for fuel and targets was received from offsite sources (1).

Activities generated airborne and liquid effluents containing uranium isotopes. Air treatment procedures differed depending on the operational processes within each M-Area building. Initially, liquids containing uranium were discharged to Tims Branch and pond beds adjacent to M-Area (1).[5] As of 1977, about 50 percent of the discharged uranium had settled in the stream and beds and had "not reached the main stream leading to the river" (1). After late 1976, most liquids were discharged to the M-Area settling basin (1).

<u>Reactor Areas</u>

Table 2-2 summarizes the dates of operation of the five SRS production reactors. All reactors used heavy water as a neutron moderator and primary coolant. All were housed in buildings constructed of heavy concrete to provide radiation shielding to personnel. Reactor systems and auxiliaries included the primary and secondary coolant systems, the component-handling systems, and the disassembly basins (1).

<u>Coolant Systems</u>

The primary coolant system consisted of heavy water circulating through the reactor core. In each system, coolant entered a plenum and then flowed through the reactor core. Heated coolant then passed through heat-exchangers where heat from the fission process was transferred to a secondary coolant system (1).

At each reactor, water bled from the primary coolant system was circulated through a water-treatment system to maintain ionic purity of the coolant and to reduce radiation exposures to personnel.[6] Typical water treatment equipment included filters, deionizers, and evaporators. An offshoot from the deionizer

[3] A tritium (T) atom is a radioactive atom of hydrogen containing two neutrons and a proton in the nucleus.
[4] This creek flows to the Savannah River Swamp and then follows a meandering route through the swamp to the river, mixing with a portion of the flow from Four Mile Branch.
[5] Tim's Branch empties into Steeds Pond about 1-1/2 miles from the 300-Area. Overflow from Steeds Pond drains into Upper Three Runs Creek, which empties into the Savannah River.
[6] Operation of the reactor resulted in contamination of the coolant with radionuclides due to neutron activation of coolant, cladding, and reactor components; corrosion of cladding and components; and leakage of fission products from fuel.

effluent passed through a distillation unit that removed light-water impurities from the heavy-water coolant (1).[7]

Table 2-2 Summary of Reactor Operations

Reactor	Dates of Operation	Comments
C	1955-1985	Shut down in 1985.
K	1954-1988	Shut down in 1988, but operated briefly in 1992. In 1993, it was put in cold standby as the Nation's tritium source. Shut down permanently in 1996.
L	1954-1968 1985-1988	Shut down for upgrades in 1968. Restarted in 1985. Shut down in 1988.
P	1954-1988	Shut down in 1988.
R	1953-1964	Shut down in 1964.

Source: (2).

The secondary coolant system consisted of water from the Savannah River. River water was pumped to reservoirs located in the reactor areas, and from the reservoirs passed through the reactor heat exchangers. As reactor thermal power gradually increased from 1954 to 1962,[8] additional secondary cooling capacity was achieved by measures such as doubling the number of heat exchangers used in the secondary coolant system, by increasing river-pump capacity, and by the construction of Par Pond in 1958 (3).

Par Pond is a 2,700-acre reservoir formed by damming Lower Three Runs Creek. Pond water pumped to the P- and R-Reactors was returned to Par Pond,[9] allowing increased delivery of river water to the L-, P-, and C-Reactor secondary cooling systems. Until 1985 and 1988, respectively, effluent cooling water from C- and K-Reactor heat exchangers flowed back to the river via onsite streams. Until 1988, cooling water from P-Reactor continued to flow to Par Pond. In 1985, SRS formed L-Lake by damming Steel Creek. SRS used L-Lake as a heat sink for L-Reactor when it operated from 1985 through 1988 (3).

Component-Handling System

The component-assembly area of a reactor building was used to receive fresh fuel from the 300-M Area and to discharge irradiated fuel from the reactor[10] to a reactor disassembly basin (1).[11]

Disassembly Basin

A disassembly basin is a deep pool of water used to temporarily store fuel and miscellaneous reactor components removed from the reactor. During the 1950's and 1960's, irradiated material stayed in the disassembly basins for less than nine months. In later years, the storage period was longer (3).

[7] Buildup of light water in the primary coolant system primarily resulted from exposure of the coolant to humid air within the system.
[8] The reactor thermal power, or heat output, is proportional to the rate of fission and the creation of fission products in the fuel. With higher rates of fission, higher reactor core densities of neutrons were achieved resulting in larger rates of production of tritium and other products.
[9] Before construction of Par Pond, cooling water from the heat exchangers was discharged directly into onsite streams.
[10] Control rods and other components were similarly charged into the reactor and discharged as needed.
[11] Also called a fuel and target storage basin or a fuel pool.

2.1.2.1 Air and Water Treatment and Effluent

Releases of radionuclides to air and water varied over time depending on modifications to reactor operations, reactor equipment, and air- and water-treatment systems. Releases to air and water also resulted from occasional problems with equipment.

Air

Principal sources of airborne release at reactor areas included the reactor building, disassembly basins, and seepage basins (3).

Exhaust from each of the process areas in a nuclear reactor was routed through an air treatment system consisting of moisture separators, filters, and charcoal beds to remove elemental iodine vapor and gaseous iodine compounds.[12] Exhaust was discharged from a 200-foot stack (1). Radionuclides released from the reactor building included tritium and fission and activation products, including iodine isotopes and ^{41}Ar. Tritium was released mainly from evaporation of the moderator (3).[13]

Exhaust from the disassembly basin area was discharged to the air from a roof vent. Releases mainly consisted of tritium in water evaporating from the pool surface. Ground-level release of tritium occurred from evaporation of seepage basin water (3).

Water

Table 2-3 summarizes liquid effluent procedures for each reactor. During operation, some of the radionuclides contaminating the reactor coolant were transferred to secondary coolant water from leakage of the heat exchangers. Thus, coolant water discharged to surface waters contained tritium and other radionuclides.

The disassembly basins were additional sources of contaminated liquid effluent. To ensure visual clarity and maintain personnel exposure levels at acceptable levels, the basins were purged with river water. Until the mid 1960's, basin purge water was continuously discharged to site streams along with secondary cooling water. Sand filters were added to the disassembly basins in the early 1970's, and continuous purging to site streams ceased although periodic purging continued from 1970 to 1977. In 1978, SRS began to discharge water from periodic purges to reactor seepage basins. These seepage basins were constructed at all reactor basins during the second half of 1957 primarily for disposal of water generated from vacuum-cleaning the disassembly basins (3).

2.1.3 F- and H-Separations Areas

Chemical separations facilities at SRS consist of two main complexes: F- Area and H-Area. Each complex contains a shielded separations building divided into two parallel "canyons" as well as auxiliary facilities that include a waste concentration and storage system, seepage basins, powerhouses, and service facilities. F-Area contains a laboratory, the plutonium metallurgical building, and the Plutonium Fuel Form Facility (PuFF). H-Area contains the tritium process buildings, the Receiving Basin for Offsite Fuels (RBOF), and the Resin Regeneration Facility (RRF).

[12] This equipment was typical by the end of 1963 when all reactor ventilation systems had been fitted with charcoal beds and high-efficiency particulate filters. This air-treatment system was installed in R-, P-, and K-Reactors in 1962, and in the remaining two reactors the following year.

[13] Tritium built up due to neutron capture by deuterium and primarily released as either T_2O or DTO.

Table 2-3 Summary of Liquid Discharge Procedures at SRS Reactors

Reactor	Operation	Liquid Effluents
R	1953-1964	To Lower Three Runs Creek, Par Pond, and one seepage basin
P	1954-1988	To Steel Creek, Par Pond, and three seepage basins
C	1955-1985	To Four Mile Creek and three seepage basins
K	1954-1988	To Pen Branch and two seepage basins
L	1954-1968 1985-1988	To Steel Creek, L Lake (built in early 1980's by damming Steel Creek), and a seepage basin

Source: (3).

Separations

Operations at either of the two separations facilities typically began with dissolution of the cladding from the irradiated fuel or targets, followed by dissolution of the declad materials, generally in nitric acid. This process evolved volatile fission products such as iodine isotopes. The solution was then sent through a series of solvent extraction cycles. The first solvent extraction cycle stripped the product (e.g., plutonium and uranium) from the fission products. The product was then purified in subsequent chemical processes. Fission products (and some residual plutonium and uranium) from the first solvent extraction cycle were routed to the high-level waste tanks (3).

Tritium Recovery

The tritium facilities in the H-Area consist of three buildings (i.e., 232-H, 234-H, and 238-H) where tritium was separated from irradiated lithium-aluminum targets, further purified, and packaged (1).

Receiving Basin for Offsite Fuels

This H-Area building houses fuels from offsite reactors. Fuels are received and either stored or cut and packaged for reprocessing. In addition, the RBOF received special nuclear fuels from SRS and offsite research reactors. It is now shut down (1,3).

Resin Regeneration Facility

This H-Area facility received ion-exchange resin beds and filters from reactor areas for regeneration (1).

Metallurgical Building

This F-Area facility was used to fabricate components for uranium, neptunium, and plutonium reactor elements (1).

Plutonium Fuel Form Facility

This F-Area facility manufactured Pu-238 heat source fuel forms (3).

Analytical Laboratory

This F-Area facility supplied radioanalytical services to the entire plant except for the Savannah River Laboratory (1).

Waste Concentration and Storage

High-activity waste liquids from separations operations were concentrated and stored in tanks. Most notably, high-level liquid wastes from the solvent extraction process were pumped to large underground tanks located in "farms" in each separations area. As of 2002, 37 million gallons of waste remained stored in 49 tanks in 2 tank farms (4).

2.1.3.1 Air and Water Treatment and Effluents

Air

Both separations buildings were ventilated by systems that directed air from clean areas to areas that were contaminated. Ventilation air was passed through filters before discharge to stacks. The main stacks for both separations areas were 200 feet tall. The F-Area Canyon was also equipped with an auxiliary stack for dissolver off-gas as well as a 160-foot stack for air ducted from the plutonium processing areas (1).

Air from the three tritium facilities (232-H, 234-H, and 238H) was discharged through tall stacks (1)

Off-gas from the RBOF building was filtered and discharged to air through 53-foot stacks. In addition, gases collected from fuel-cask opening or fuel-cutting operations were passed through charcoal and HEPA filters before discharge (1).

Water

Radioactive contamination released to surface water mainly came from two sources: coolant water for the separations process vessels and seepage basins. One coolant-water system, used for areas that were unlikely to become contaminated, recirculated coolant water through a cooling tower. A second system was a once-through system: water was normally discharged to Four Mile Creek if measured levels of contamination were sufficiently low. If water from either system contained contamination above prescribed limits, the water was diverted to seepage basins constructed in each of the two separations areas. If seepage basin limits were exceeded, the water was sent to retention basins for storage pending treatment (1).

Three seepage basins were used at each separations area. Liquid discharged into the seepage basins seeped through the ground until it discharged to a seepline draining to Four Mile Creek. After 1988, when the Effluent Treatment Facility for the separations areas became operational, the F- and H-Area seepage basins were not used (3).

2.1.4 Waste Management Areas

Activities at SRS have generated large quantities of radioactive wastes, most of which were either disposed or stored onsite. Disposal of radioactive wastes has occurred at 20 locations within SRS. The high-level waste is stored in several underground tanks located in the F- and H-Areas (3). These wastes are not of particular interest to this study due to the low levels of radionuclide release from waste storage and disposal operations to air and surface water. However, liquid effluents that have been released to seepage basins are of interest. Seepage basins have been discussed above.

2.1.5 Additional SRS Facilities

Several additional facilities and support areas exist on the SRS and provide small to negligible discharge of radionuclides to water or air.

2.1.5.1 A-Area: Administrative Area

The Administrative Area contains organizations and facilities that support SRS operations. The only facility that historically contributed radionuclides to air and water was the Savannah River Technology Center (SRTC), which was established in 1951 as the Savannah River Laboratory. For its first few decades of operation, the SRTC fabricated fuel-element prototypes, targets containing radioactive oxides, and sealed radioactive sources. It also performed research and development of separations processes. Airflow through contaminated areas was filtered and vented through either a 100-foot or a 160-foot stack. If within prescribed concentration limits, low-activity contaminated liquids were transferred to laboratory seepage basins; otherwise, they were transported to F-Area for treatment. High-activity-level liquids were transferred to F-Area for storage (1,3).

Other facilities in the A-Area include the U.S. Department of Energy site office and the Savannah River Ecology Laboratory.

2.1.5.2 TNX and CMX Semiworks

Although considered part of the SRTC, the TNX and CMX Semiworks are located near the Savannah River next to the 400-D Area. The TNX facilities were used to study chemical-processing problems and test production-scale equipment. Tests were conducted using natural uranium or other surrogates. In later years, the facility researched and developed waste treatment processes. The CMX facility conducted non-nuclear tests of the hydraulic systems of the SRS reactors until it shut down in 1984 (3).

2.2 Principal Radionuclides Released During SRS Operations

During 39 years of operation, SRS released a variety of radionuclides into air and surface water. For the SRS dose reconstruction effort, the Phase II report provides estimates of the release of those radionuclides determined to be most significant for public health concerns (3).

Challenges faced in the Phase II study included incomplete records of radionuclide release, gaps in monitoring data, and questions about early radiation detection and analysis equipment. Releases of radionuclides from times when data were available were scaled in Phase II to times when data were not available based on knowledge of the processes that resulted in the release. SRS procedures for monitoring releases from plant operations were reviewed as was the SRS environmental monitoring program. Estimates of release for some radionuclides were adjusted from those reported by SRS (3).

To focus the effort, a two-step screening analysis was performed using a screening process set forth by the National Council on Radiation Protection and Measurements (6). From the first step of the screening process, the Phase II study identified a list of key radionuclides that had been released into the air and water from SRS operations. The key radionuclides released to air were ^{241}Am, ^{41}Ar, ^{14}C, ^{137}Cs, ^{3}H, ^{129}I, ^{131}I, ^{238}Pu, ^{239,240}Pu, ^{103,106}Ru, ^{89,90}Sr, and uranium. The key radionuclides released to surface water were ^{137}Cs, ^{60}Co, ^{3}H, ^{129}I, ^{131}I, ^{32}P, ^{238}Pu, ^{239,240}Pu, ^{89,90}Sr, ^{35}S, ^{99}Tc, uranium, ^{91}Y, ^{65}Zn, and ^{95}Zr/Nb. From the second step of the screening process, which considered possible exposure pathways in more detail, the Phase II study identified two smaller sets of radionuclides released to the air and water for further detailed analysis. These radionuclides consisted of ^{131}I, ^{3}H, ^{41}Ar, ^{129}I, ^{239,240}Pu, and uranium released to air, and ^{137}Cs, ^{3}H, ^{89,90}Sr, ^{60}Co, ^{32}P, ^{131}I, and uranium released to water (3).

For the Phase III effort, the source term provided in the Phase II report was closely reviewed and refined. Chapters 5 and 7 discuss these adjustments in detail. The radionuclide release data presented in the Phase II report could not be used directly in the Phase III effort due to the following three major concerns:

1. The Phase II report did not provide annual release estimates for all key radionuclides. For some radionuclides, the report provided a 36-year total source term.

2. The Phase II report did not provide release estimates for many radionuclides for the years 1990 through 1992.

3. The Phase II report included estimates for some radionuclides as aggregated quantities (e.g., ^{89,90}Sr, uranium). However, this format was incompatible with the requirements of the GENII code.

The estimates provided in the Phase II report were refined to determine annual release estimates of each of the key radionuclides for all 39 years of the study[14]. To do so, data in SRS reports (7) was examined. For key radionuclides cited in the Phase II report as aggregated isotopes (e.g., ^{89,90}Sr, uranium), the radionuclides were separated into their isotopic constituents based on an understanding of the processes that generated the isotopes.[15] In addition, some of the data in SRS reports were presented in terms of undifferentiated activity (i.e., unidentified [gross] alpha and unidentified [gross] beta-gamma activity). For these data, ^{239}Pu was assumed for reported unidentified alpha activity and ^{90}Sr was assumed for reported unidentified beta-gamma activity. Finally, information was reviewed about the likely chemical forms of the released radionuclides, a consideration needed for certain portions of the analysis. See Chapters 5 and 7, and Appendix B, for additional information about partitioning assumptions and procedures.

2.2.1 F- and H-Separations Areas

Chemical separations facilities at SRS consist of two main complexes: F- Area and H-Area. Each complex contains a shielded separations building divided into two parallel “canyons” as well as auxiliary facilities that include a waste concentration and storage system, seepage basins, powerhouses, and service facilities. F-Area contains a laboratory, the plutonium metallurgical building, and the Plutonium Fuel Form Facility (PuFF). H-Area contains the tritium process buildings, the Receiving Basin for Offsite Fuels (RBOF), and the Resin Regeneration Facility (RRF).

Table 2-4 lists the radionuclides and whether they were released via the air or surface water pathway. Appendix B provides lists of the quantities released of each radionuclide through air and water pathways as a function of year.

[14] ^{106}Ru, ^{144}Ce, and ^{134}Cs were added to the list of isotopes considered in Phase III for release to surface water. ^{91}Y was deleted for release to surface water. Although ^{91}Y was listed as a key radionuclide in the Phase II report, it actually did not pass the screening criteria used for either step of the Phase II screening analysis.

[15] In this report, ^{89,90}Sr was partitioned into ^{89}Sr and ^{90}Sr, ^{95}Zr/Nb was partitioned into ^{95}Zr and ^{95}Nb, and uranium was partitioned into ^{234}U, ^{235}U, ^{236}U, and ^{238}U. It was assumed that activity identified as ^{239,240}Pu was all ^{239}Pu, activity identified as ^{103,106}Ru was all ^{106}Ru, and activity identified as ^{141,144}Ce was all ^{144}Ce.

Table 2-4 Radionuclide Release Pathways

Radionuclide	Released to Air	Released to Surface Water
^{3}H (tritium)	X	X
^{14}C	X	
^{32}P		X
^{35}S		X
^{41}Ar	X	
^{60}Co		X
^{65}Zn		X
^{89}Sr	X	X
^{90}Sr	X	X
^{95}Zr		X
^{95}Nb		X
^{99}Tc		X
^{106}Ru	X	X
^{129}I	X	X
^{131}I	X	X
^{134}Cs		X
^{137}Cs	X	X
^{144}Ce		X
^{234}U	X	X
^{235}U	X	X
^{236}U	X	X
^{238}U	X	X
^{238}Pu	X	X
^{239}Pu	X	X
^{241}Am	X	

*Source: (8).
†y = years; d = days; h = hours.

2.2.1.1 Iodine and other Beta-Gamma-Emitting Particles

Radioactive iodine and other beta-emitting-radionuclides were released mainly from the separations areas. In particular, iodine and other volatile isotopes evolved from dissolution of reactor fuels and targets.

Iodine releases included elemental iodine (I_2) and organic iodides (e.g., CH_3I). The Phase II report observed that releases if iodine for the early years of operation (through about 1961) contained significant uncertainties. The Phase II estimates of ^{131}I release included a significant correction to release estimates provided by SRS[16] (3).

Release of other beta-gamma-emitting isotopes also occurred, mainly from the F- and H-Areas. These isotopes included $^{89,90}Sr$, $^{95}Zr/Nb$, $^{103,106}Ru$, ^{137}Cs, and $^{141,144}Ce$ (3).

2.2.1.2 Activation Products

Activation products are generated when neutrons produced during fission interact with reactor materials such as control rods and structural members, with fuel and target cladding, with air within the reactor, and with impurities and anti-corrosion chemicals in the moderator. Table 2-5 lists the principal activation products generated in SRS reactors (3). The principal activation product of concern for release into the air is ^{41}Ar. Because argon is a noble gas, it was released from SRS facilities (primarily reactors) without capture by the air treatment and filtration systems.

Table 2-5 Characteristics of Activation Products

Radionuclide	Primarily Produced From	Half-Life
^{32}P	^{31}P	14.3 days
^{35}S	^{35}Cl	87.3 days
^{41}Ar	^{40}Ar	1.83 hours
^{51}Cr	^{50}Cr	27.7 days
^{60}Co	^{59}Co	5.27 years
^{65}Zn	^{64}Zn	244 days

Source: (3).

2.2.1.3 Alpha-Emitting Radionuclides

Alpha-emitting radionuclides—principally isotopes of uranium and plutonium—were released to air at SRS primarily from the M-Area, the reactors, and the separations facilities. Measured releases were small from M- Area and the reactors, and larger from the separations facilities. Most plutonium emissions occurred from 1955 to 1969 from F- and H-Area stacks. Uranium releases were largest during 1955, 1968, and 1969 from H-Area stacks; and during 1955, 1956 and throughout the 1960s from F-Area stacks (3).

2.2.2 Release of Radionuclides to Surface Water

2.2.2.1 Tritium

The major sources of tritium released to surface water were reactor and separations area effluents discharged to streams and seepage basins. Lesser quantities of tritium were released to surface water from the D-Area (3).

2.2.2.2 Iodine and other Beta-Gamma-Emitting Particles

The major sources of iodine, ^{137}Cs, and other beta-gamma-emitting particles released to surface water were reactor and separations area effluents discharged to streams and seepage basins (3).

2.2.2.3 Activation Products

The major sources of activation products released to surface water were reactor and separations area effluents discharged to streams and seepage basins (3).

2.2.2.4 Alpha-Emitting Radionuclides

Alpha-emitting radionuclides released to surface water included isotopes of uranium and plutonium. Uranium isotopes were released from M-Area and the separations areas. Plutonium releases to surface water came mainly from the separations areas (3).

2.3 SRS Environmental Setting

This section provides a background discussion of human and environmental factors within the vicinity of SRS that are of interest to this study. Primary references are (1), (3), (4), and (10).

2.3.1 Population and Land Use

The area was sparsely populated when SRS was created. Although the only towns on the plant site were Ellenton (population 600) and Dunbarton (population 251), the communities of Leigh, Hawthorn, Robbins, and Meyers contained isolated groups of families (1). About 6,000 persons comprising 1,500 families (10) were relocated. Some moved to New Ellenton, which was established north of the SRS boundary to replace Ellenton (4).

Construction of SRS employed a peak force of 38,500 workers (4). The operating work force initially numbered 5,000 workers (1), climbed to 7,500 by 1980, and totaled nearly 26,000 by 1992 (4). As of 2000, it numbered 14,000 (4).

When SRS was sited, about 67 percent of the land was forested and about 33 percent was pasture and cropland. The main crops were cotton and corn (1). Abandoned fields gradually became pine forests. Current land use on SRS is about 56 percent pine forest, 35 percent hardwood, 7 percent in SRS facilities and open fields, and 2 percent water (10). Except for three roads and a rail line near the edge of the site, public access to SRS is restricted to environmental studies, guided tours, and controlled deer hunts (10). Adjacent to SRS, about 21 percent of the land is devoted to agriculture and about 70 percent comprises forests, wetlands, water bodies, and unclassified, predominately rural lands. Less than 8 percent is urban or built-up (10).

2.3.2 Environmental Characteristics

2.3.2.1 Meteorology and Climatology

The climate in the region of SRS is subtropical, characterized by long, warm, and humid summers and short, mild winters. The average annual temperature at SRS is 64.7^{o}F and the average precipitation is 49.5 inches. The driest season is fall, with an average monthly rainfall of 3.3 inches; the wettest season is summer, with an average monthly rainfall of 5.2 inches. The average annual relative humidity is 70 percent. The average daily maximum relative humidity is 91 percent, and the average daily minimum is 45 percent. Winds currently blow most frequently from the northeast and southwest. Current SRS atmospheric conditions have been classified as unstable about 56 percent of the time (10).[17]

[17] More detailed historical information about wind speeds, directions, and stability classes are more difficult to obtain. Of interest to this report would be detailed meteorological data from the mid 1950's to the 1990's. SRS lacked a formal meteorological program until the early 1970's, leaving a gap of about 20 years in SRS-specific meteorological data.

2.3.2.2 Geology and Hydrology

Regional Geology

SRS is located on the Upper Atlantic Coastal Plain. Most soils at SRS are sandy over loamy or clayey subsoil. Annual erosion rates for regional soils, including cropland, range from 1.5 to 2.0 kg/m^2/yr. Two soil profile horizons are commonly noticed. The upper horizon (A Horizon) typically consists of structureless fine- to medium-grain quartz sand up to 3 meters thick. The lower horizon (B Horizon) contains iron and aluminum compounds and may range in thickness from 0.6 to 3 meters (10).

Ground Water Hydrology

The shallow ground water on the site is contained within the Floridian Aquifer System, comprising the lowermost Gordon aquifer unit, the Gordon confining unit, and the uppermost Upper Three Runs aquifer unit that contains the water table (4,9). The water table varies from ground surface to a depth of about 100 feet. In F- and H-Areas, the ground-water velocity ranges from a few hundredths of a foot per day to one foot per day near streams (1).

The shallow aquifers beneath the industrial areas that make up about to 10 percent of the SRS have been contaminated with industrial solvents, metals, tritium, and other constituents used or generated at SRS. In general, DOE does not use these aquifers for SRS process operations although there are a few low-yield wells in the Gordon Aquifer and the lower zone of the Upper Three Runs Aquifer. The shallow aquifer units of the Floridian System discharge to SRS streams and eventually the Savannah River (4).

Despite the contamination in some of the shallow aquifers on the site, "there is no data available to suggest that groundwater containing radionuclides has migrated off the SRS to the surrounding communities" (12). Rather, as stated above, localized contaminated ground water on the SRS discharges into onsite streams that ultimately discharge to the Savannah River (12).[18]

Surface Water Hydrology

Operations at SRS caused large withdrawals of cooling water from the Savannah River as well as discharge of heated water to onsite streams. Thermal discharges were reduced after construction of a cooling tower to support K-Reactor operation and L-Lake to support L-Reactor operation (3).

Five major tributaries to the Savannah River drain SRS: Upper Three Runs Creek, Four Mile Branch, Beaver Dam Creek, Steel Creek, and Lower Three Runs Creek. Figure 2-3 shows the major river and stream system at SRS. These streams meander for several miles through SRS and—except for Lower Three Runs Creek— through the Savannah River Swamp before emptying into the river. A sixth stream, Pen Branch, joins Steel Creek in the Savannah River Swamp. One stream in the northeast area of SRS drains to the Salkehatchie River. The natural flow of SRS streams ranges from about 10 cubic feet per second (cfs) in smaller streams to 245 cfs in Upper Three Runs Creek (4). For several years, coolant and effluent discharges greatly increased flow in these streams above their natural rates. Savannah River flow in 1995 averaged about 10,000 cubic feet per second at SRS (4).

F- and H-Areas are situated on a divide that separates drainage into Upper Three Runs Creek and Four Mile Branch. About half of each area drains into each stream. The F- and H-Areas are drained by Upper Three Runs Creek to the north and west and by Four Mile Branch to the west. The surface aquifer for

[18]The Phase II report concludes, in Appendix J, that "although groundwater contamination from SRS releases may be a potential exposure pathway for the future, the evidence suggests that it did not impact offsite residents before 1992" (3).

both F- and H-Areas discharges at seeplines along both Four Mile Branch and Upper Three Runs Creek (3,4).

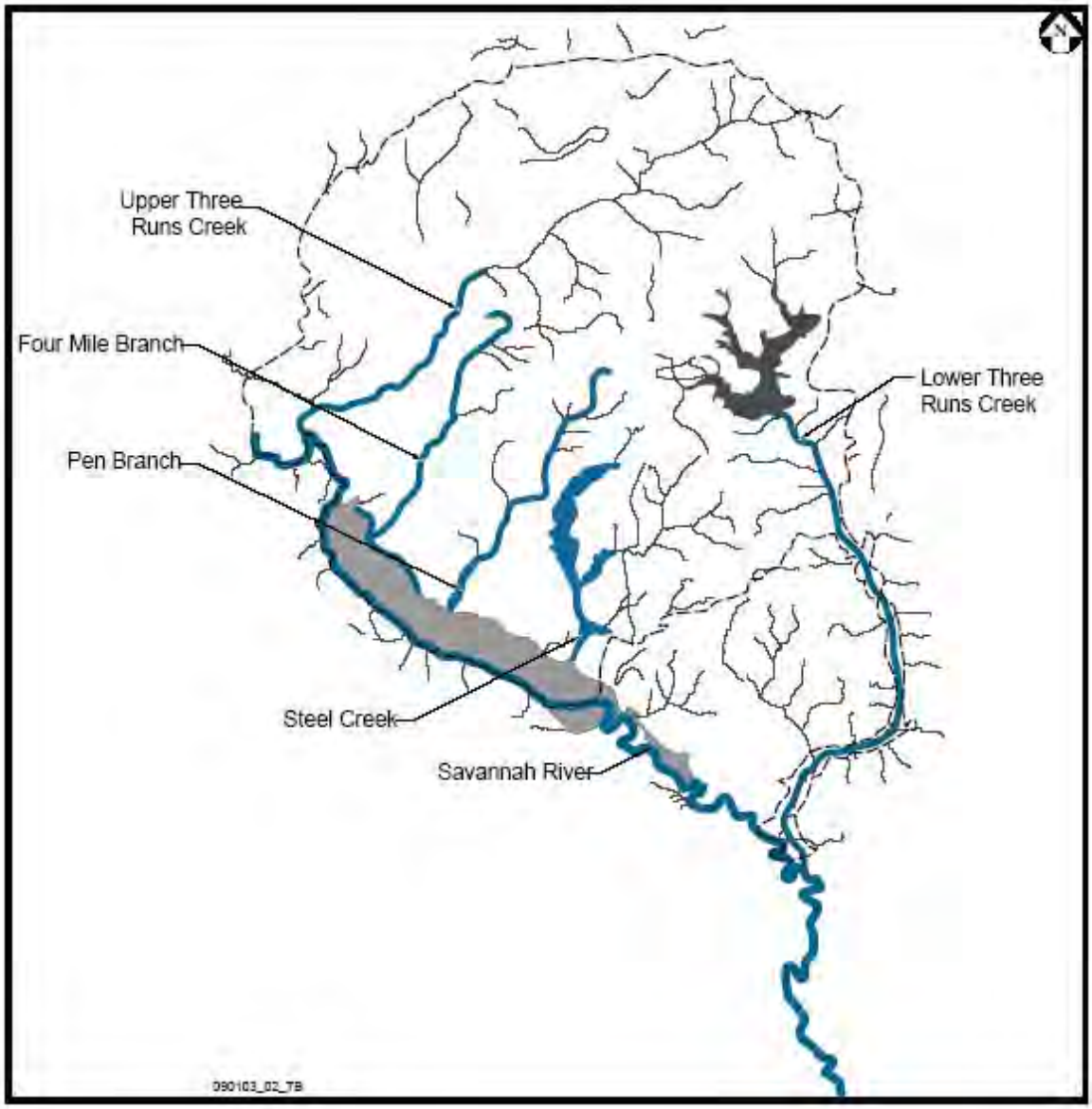

Figure 2-3 Major River and Stream Systems at SRS

Upper Three Runs Creek is the only major tributary on SRS that has not received thermal discharges (4). One of Upper Three Run Creek's tributaries—Tim's Branch—received (at Road C) effluents from A-Area and M-Area. Steed's Pond, located on Tim's Branch just north of Road 2, was a mixing and settling pond for A-Area and M-Area wastes (3,4).

Four Mile Branch originates near the center of SRS and flows southwest before emptying into the Savannah River (4). It drains much of the F-, H-, and C-Areas and received C-Reactor cooling water about 0.5 miles south of Road 3. It flows parallel to the Savannah River behind natural levees and enters

the river through a breach downriver from Beaver Dam Creek. In its lower reaches, Four Mile Branch broadens and flows via braided channels through a delta formed by the deposition of sediments. Downstream from the delta, the channels rejoin into one main channel (3,4).

Steel Creek and Lower Three Runs Creek both received significant quantities of reactor effluents. Steel Creek received discharges from the L- and P-Reactor Areas before Par Pond was built in 1958. K-Reactor effluent from Pen Branch was discharged to Steel Creek via the swamp through one major and one or more minor streams about a half mile above Steel Creek's mouth (3). Lower Three Runs Creek received some discharge from the R-Reactor area before 1958. Overflow from Par Pond carried runoff from the northeast portion of the plant and any contaminants leaking to the reactor secondary cooling water system (3).

The mouths of Steel Creek, Pen Branch, and Four Mile Branch have built sedimentation deltas from erosion of stream banks caused by stream channels carrying many times their natural flows. In the late 1950's and early 1960's, L- and P-Reactor effluents increased the flow in Steel Creek from its natural level of 35 cfs to 250-400 cfs (3).

The Savannah River Swamp borders the river for about 10 miles (16 km) and has an average width of about 2.4 km (1.5 miles). From 1958 to 1967, the swamp flooded about 74 days per year. The river historically overflowed its channels when flows were equal to or exceeded 438 cubic meters per second. The highest levels in the Savannah River typically occur in winter and spring, and the lowest levels occur in fall and winter (3).

2.3.3 Ecology

Because public use of the Savannah River Site was restricted, and because the production and support facilities occupy only a fraction of the total site area, SRS is a natural preserve for biota typical of the southeastern Coastal Plain.

2.3.3.1 Vegetation

The site is about evenly divided between the Aiken Plateau and three Coastal terraces: Brandywine, Sunderland, and Wicomico. The Aiken Plateau is hilly and deeply dissected by streams and contains extensive growths of scrub oak and longleaf pine. Soils are sandy in the Aiken Plateau and sandy loam in the terraces (1).

Little timber management occurred before Federal acquisition of the site. Generations of logging had depleted stands of timber except for floodplain hardwoods, which were not generally exploited. Much of the site consists of managed pine forests. Dry, sandy areas of the site are typically covered with scrub oak and contain longleaf pine, turkey oak, blue jack oak, black jack oak, dwarf post oak, and huckleberry. Trees available in moister soils along streams and on old floodplains include tulip poplar, beech, sweetgum, willow oak, swamp chestnut oak, water oak, loblolly pine, and ash. Bald cypress and tupelo gum are dominant trees in the Savannah River Swamp (1).

2.3.3.2 Mammals

Mammal populations—particularly deer—increased rapidly after closure of the site to the public on December 14, 1952. By the mid 1970's the deer population grew to more than 20 deer per square mile or about 5,000 to 8,000 deer on the plant site. Controlled hunts open to the public were begun in 1965. Thousands of deer have been taken in public hunts. In addition, feral hogs are present. These were

domestic animals that reverted to a semiwild state after abandonment in 1952. Similar to deer, the hogs grew sufficient in number to warrant hunts. About 125 were taken between 1969 and the mid 1970's (1).

Additional wild mammals common to the site include mice, rats, shrews, gray and red foxes, raccoons, wildcats, striped skunks, opossums, fox squirrels, and beavers (1).

2.3.3.3 Birds

Biologists have identified more than 200 species of birds on the plant site. Of note is the wild turkey population, which was small at the time the site opened. However, wild turkey populations have increased as the result of a program initiated in 1972 that used the site as a breeding ground for stocking other parts of the States. In addition, large numbers of coots and ducks spend winters on and near the site (1).

2.3.3.4 Aquatic Animals

Diverse populations of reptiles and amphibians exist onsite, including numerous species of turtles, lizards, snakes, salamanders, frogs, and toads. Alligators have been seen in ponds and streams. Onsite fish species include largemouth bass, black crappie, bluegill, redbreasted sunfish, flat bullhead, and blueback herring (1).

Hundreds of species of aquatic insects have been identified on SRS (e.g., a study conducted from 1976 to 1977 identified 551 species in the Upper Three Runs Creek system including species and genera that were new to science). Otherwise, populations of fish and aquatic insects in some of the onsite streams were adversely affected during SRS's nuclear production period due to thermal loadings, principally from reactor discharge of heated cooling water. But as operational changes (e.g., reactor shutdown) reduced the volumes of heated water discharged to onsite streams, the fish and aquatic insects have returned (4). For example, since C-Reactor was shut down in 1985, macroinvertebrate communities have recovered in Four Mile Branch and, in some parts of the stream; have resembled those in other nonimpacted SRS streams. Macroinvertebrate communities of Four Mile Branch currently tend to show more diversity in downstream than in upstream reaches (4).

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3 SCENARIO DESCRIPTIONS

This chapter presents the seven exposure scenarios used in Phase III of the Savannah River Site (SRS) Dose Reconstruction Project, including the behavior of the four receptors comprising each scenario (28 receptors total). The behavior of each receptor, which was based on the scenario descriptions provided by CDC, was used to develop values for many of the parameters in the radiological assessment. Appendix E, Receptor Activities and Usage Rates, presents the derivation of point-estimate values for those parameters that depend on the receptors' behavior (e.g., times spent in various exposure locations). Appendix F, Parameter Values for Base Case Evaluation, presents model parameter values that are not clearly receptor-specific (e.g., food crop production rates).

The exposure scenarios considered for this report evolved over time. The six exposure scenarios that were originally proposed in 2002 by the Centers for Disease Control and Prevention (CDC) were modified and refined by the Savannah River Site Health Effects Subcommittee (SRSHES) and by preparers of this report.

3.1 Scenarios Proposed by CDC and Considered by the SRSHES

CDC originally proposed the following six scenarios (1):

1. A rural family just downwind of the site boundary.
2. An urban/suburban family just downwind of the site boundary.
3. A delivery person.
4. An outdoors person (e.g., hunter, fisherman, camper, etc.).
5. A family living near the river.
6. A migrant worker family living mostly outdoors.

These scenarios, which describe hypothetical families that might have lived in the SRS vicinity, were meant to represent a range of activities that were typical, and in some sense bounding, for the area. The activities postulated for these scenarios were intended to represent a broad range of lifestyles.

In January 2002, CDC presented proposed assumptions about these six scenarios at a meeting of the SRSHES in Charleston, South Carolina. The SRSHES formed a work group to consider the proposed scenarios. The SRSHES Work Group presented its comments and recommendations about the proposed scenarios at a September 2002 SRSHES meeting (1). Table 3-1 summarizes the CDC's proposed scenarios (as modified) and the SRSHES Work Group's comments and recommendations (1).

The SRS Dose Reconstruction Team discussed the proposed scenarios with CDC staff in early 2003 (2, 3). These discussions principally addressed overall decisions about the number of exposure scenarios to be considered, and where the hypothetical families comprising these exposure scenarios would live, work, attend church and school, obtain food, and recreate.

Table 3-1 CDC Proposed Scenarios and SRSHES Comments and Recommendations

CDC Proposed Scenarios and Descriptions	Summary of SRSHES Work Group Comments and Recommendations
Rural	
▪ Use the closest downwind location where there could have been farms in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume lots of time outdoors working in soil. ▪ Assume they drank milk from a backyard cow. ▪ Assume the crops were irrigated from Savannah River. ▪ Assumption of "working in soil" to include resuspension of soil contaminants in the breathing zone. ▪ In addition to two infants, consider the mother nursing at least one of the infants.	▪ Farm in rural Burke County, GA (Girard, GA, 3 miles W of the Savannah River, SW of SRS. Population about 200 in 1950s.) ▪ 1950s: 2 parents, 5 children. 1960s: 2 parents, 3 children. ▪ Schools: Girard Elementary, Waynesboro High School. ▪ Cash crops: peanuts, corn, cotton. Vegetables grown for family consumption. ▪ Religion: Methodist. ▪ In 1950s, 50% of meat & vegetables grown on farm. In 1960s, 25% grown on farm; most milk from one of two Girard dairies. Family had dairy cows. ▪ Family had dogs for pets and chickens. ▪ Some swimming, but minimal camping. No boating. ▪ Fishing from Briar Creek, 2 miles east of Girard. Hunting for deer, quail and dove. Limited trapping.
Urban/Suburban	
▪ Use closest downwind location where urban or suburban families could have lived in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume the adult worked at the nearest industrial location downwind in 1955. ▪ Assume milk from the nearest dairy or rural neighbor. ▪ Assume the adult worked on-site at SRS in lieu of the "nearest industrial location." ▪ Assume the onsite work location was associated with higher radiological exposures -- e.g., SRS Canyons.	▪ Family lived in Augusta, GA near Broad and Greene Streets. ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents, 3 children. ▪ Schools: Augusta neighborhood schools ▪ Father worked in the SRS F-Area Canyon Building from 1955 to 1992. The mother worked on site until well into her first pregnancy, but stayed home after birth of first child to raise the children. ▪ Attended local church in Augusta, GA. ▪ Food and milk were from local grocery stores in Augusta, GA. Milk was supplied to local stores from dairies in the Aiken and Augusta area. Include backyard cow. ▪ Include a family pet. ▪ Swimming & boating in Clark's Hill Lake. ▪ No hunting. Fished Clark's Hill Lake, 2 weekends/month.
Migrant	
▪ Use the closest downwind location. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values ▪ Assume always outdoors contacting the soil. ▪ Assume that crops were irrigated by the Savannah River. ▪ Assume they obtained their food from the nearest local farm or grocery store.	▪ Scenario Location: TBD ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents 3 children. ▪ Schools: TBD ▪ Work: TBD ▪ Religion: TBD ▪ Food Sources: TBD ▪ Swimming, Boating, Camping, Hunting, & Fishing: TBD.

Table 3-1 CDC Proposed Scenarios and SRSHES Comments and Recommendations

CDC Proposed Scenarios and Descriptions	Summary of SRSHES Work Group Comments and Recommendations
Delivery	
▪ Same as Urban/Suburban Family. ▪ Use closest downwind location where urban or suburban families could have lived in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume the adult worked at the nearest industrial location downwind in 1955. ▪ Assume they drank milk from the nearest dairy or rural neighbor. ▪ Assume that the person spent 8 hours per week on site.	▪ Family lived in Barnwell, SC. Father provided weekly beverage deliveries to SRS. ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents, 3 children. ▪ Schools: Barnwell, SC school system. ▪ The delivery person worked at the Allendale Coca Cola Bottling Plant in Allendale, SC, and made routine deliveries to SRS, spending 8 hours/week on-site. No dosimetery. ▪ Consider backyard chickens and/or rabbits at home. ▪ Attended Mount Hope Baptist Church, Martin, SC. ▪ Food Sources: Barnwell, SC grocery stores, and Furses' Grocery Store, Martin, SC ▪ Swimming in Lower Three Runs Creek outside Martin, SC. Boating and camping at Little Hell Landing on Savannah River. ▪ Hunting at Lower Three Runs Creek area (known for poaching). Fishing at Lower Three Runs Creek, and Savannah River's Smith Lake. ▪ Family drank carbonated drinks, including beer.
Outdoor	
▪ Assume camping at the nearest downwind location making sense with the season (hunting, fishing, etc.) ▪ Assume that the person was always outdoors. ▪ Use default consumption values. ▪ Assume the person spent 8 hours per day on the Savannah River in the summer. ▪ Assume the person spent 8 hours per week on site hunting or fishing (in season). ▪ Assume the person obtained fish and meat (deer, game birds, turtles) from hunting and fishing onsite (some authorized, some not — a "poacher" assumption.)	▪ Family lived in Jackson, SC ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents, 3 children. ▪ Schools: (1950) Jackson Elementary. (1986) Redcliff Elementary. Jackson High School. ▪ Worked as a hunter/trapper subcontractor to the primary SRS Contractor or the US Forest Service. Some potential exposure from trapping activities, streams, ponds, etc. ▪ Scenario includes the hypothetical poacher. ▪ Hunting dogs were family pets. ▪ Religion: First Baptist Church, Jackson, SC ▪ 50% of vegetables locally grown and irrigated from a surface creek. 75% of meat obtained from SRS. Fish from the Savannah River. Water from a well on home property. ▪ Boating in Savannah River from Jackson, SC, boat ramp. ▪ Took deer, hogs from work at SRS. Fished in Savannah River.
Near River	
▪ Use the nearest docking location downwind where people could have lived on houseboats in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume always outdoors contacting the Savannah River.	▪ Scenario Location: Consider Martin-Millet area ▪ Family: TBD ▪ Schools: TBD ▪ Work: TBD ▪ Religion: TBD ▪ Food Sources: Shell fishing, shrimping, crabbing ▪ Swimming, Boating, Camping, Hunting, & Fishing: TBD.

Table 3-1 CDC Proposed Scenarios and SRSHES Comments and Recommendations

CDC Proposed Scenarios and Descriptions	Summary of SRSHES Work Group Comments and Recommendations
▪ Assume they obtained their food from the nearest local farm or grocery store. ▪ Validate with the Citizens Advisory Board that the boat scenario is plausible; if so, define a location. ▪ If not plausible, replace with a new scenario: a site construction worker living in a trailer.	

Source: (1).

3.1.1 Exposure Scenarios and Locations

As discussed in Chapter 6, releases to the air from any SRS source were modeled as being transported in each of sixteen sectors defined by the sixteen major compass directions. In any sector, at a given distance from a source, concentrations were modeled as being the same along all points of an arc defined by the radial distance from the source. This is shown in Figure 3-1. It shows the relative radionuclide concentration from a unit source at a distance of ten miles from the source. In each sector, the relative concentration is constant across the sector width.

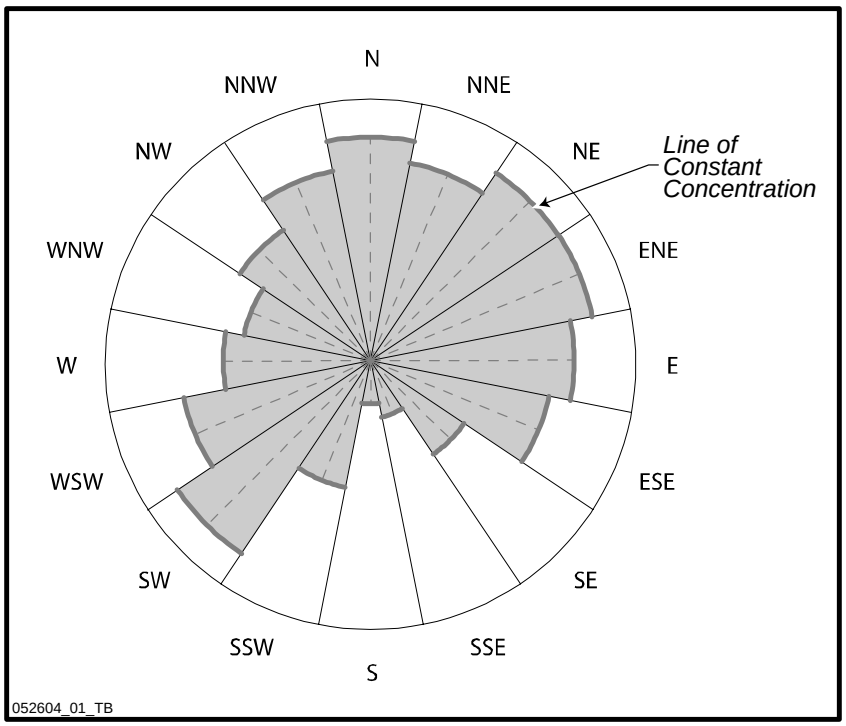

Figure 3-1 Example of Modeled Radionuclide Concentration at Ten Miles from a Unit SRS Source

The meaning of this modeling simplification is that at a given distance from a source, the same concentrations will be determined anywhere the concentration in a given sector is modeled as constant.

Thus, two hypothetical exposure locations that are fairly close together will generally not differ significantly in modeled concentrations.

Exposure scenarios and locations considered for Phase III. In addition to the six exposure scenarios originally proposed by CDC, a seventh was added. When the scenario locations were plotted on a map of the area surrounding the SRS, it was noted that approximately 90° out of 360° -- generally towards the northeast – was without an exposure scenario. Therefore a seventh – identified as Rural Family #2 – was added with concurrence from CDC and the SRSHES.

In each scenario, exposure locations were identified to represent where family members lived, worked, attended school, engaged in recreational activities, where their food was grown, and other activities. For all seven scenarios, exposures to radionuclides were modeled at ten locations for radionuclides released to the air and two locations for radionuclides released to water.

The exposure locations assumed for the seven exposure scenarios are shown in Figure 3-2. Table 3-2 summarizes the exposure locations for contamination released into the air, while Table 3-3 summarizes the exposure locations for contamination released to surface water. The Lower Three Runs Creek exposure location is in the vicinity of Martin, South Carolina. The downstream Savannah River exposure location is representative of multiple possible locations downstream from the site.

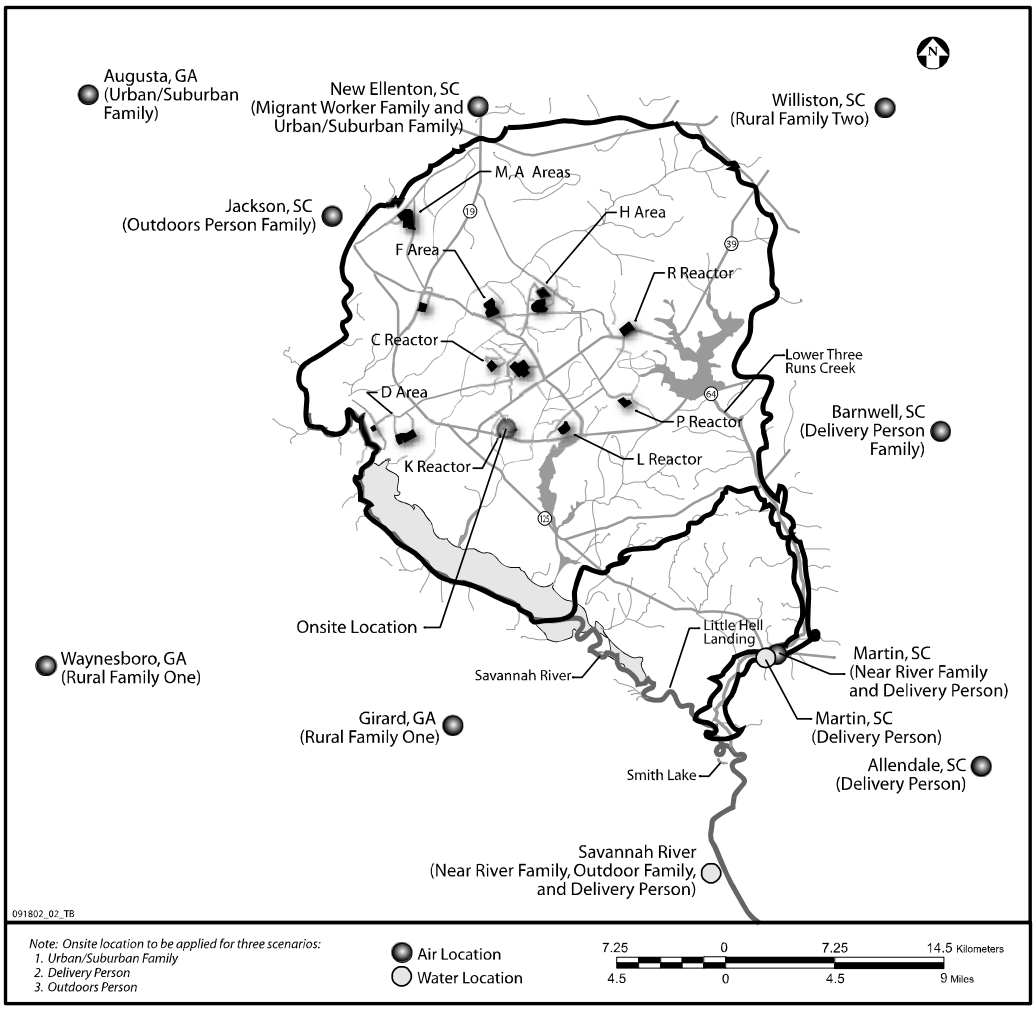

Figure 3-2 Exposure Locations for Exposure Scenarios

Table 3-2 Summary of Exposure Locations for SRS Releases to Air

Exposure Scenario	Activity*	Exposure Location									
		Girard, GA	Waynesboro, GA	Martin, SC	Augusta, GA	Williston, SC	SRS Onsite Location	Barnwell, SC	Allendale, SC	Jackson, SC	New Ellenton, SC
Rural Family One	All except high school†	X									
	High school		X								
Rural Family Two	All activities					X					
Urban/Suburban Family	All except employment				X						
	Employment						X				
Migrant Worker Family	All activities										X
Delivery Person Family	All except those below:							X			
	Employment								X		
	Employment						X				
	Church, grocery (partial), swimming, boating, hunting, fishing			X							
Outdoors Person Family	All except employment									X	
	Employment						X				
Near River Family	All activities			X							

* Activities included school, work, recreation, church, production of foodstuffs, and indoor and outdoor activities around the home.

† For all receptors, excluding the children of Rural Family One, the same exposure location was used for their high school as for their residence. Children of all scenarios attended grade school at the same exposure location that was used for their residence.

Table 3-3 Summary of Exposure Locations for SRS Releases to Surface Water

Scenario	Activities / Pathways	Downstream Savannah River	Lower Three Runs Creek	No Exposure to Water Affected By Liquid Releases*
Rural Family One	All activities†			X
Rural Family Two	All activities†			X
Urban/Suburban Family	All activities†			X
Migrant Worker Family	All activities†			X
Delivery Person Family	Fishing, swimming, shoreline		X	
	Fishing, shoreline, boating	X		
Outdoors Person Family	Fishing, shoreline, boating	X‡		X§
	Swimming			
Near River Family	All activities†	X		

*Exposure occurred in water not affected by releases from the SRS to water.
†"All activities" included fishing, boating, swimming, and shoreline.
‡Shoreline exposures were only received at work by the Adult Male and the children when they each reached age 18. Recreational shoreline activities by all family members were in unaffected water.
§For the entire family while recreating on the Savannah River.

The scenarios and exposure locations are:

- Rural Family One. This family lived on a farm near Girard, Georgia. The Girard exposure location was where the family hunted, fished, and grew or produced much of their food. Although the adults always stayed near the farm, the children attended high school in Waynesboro, Georgia.

- Rural Family Two. This family lived on a farm near Williston, South Carolina. The Williston exposure location was where the family hunted, fished, and grew or produced much of their food. All family members lived at the Williston exposure location for all 39 years, including grade and high school for the children.

- Urban/Suburban Family. This family lived near the intersection of East Boundary and East Telfair Street in Augusta, Georgia. The Augusta exposure location was assumed for most family activities including swimming, boating, and fishing. It was the exposure location where much of the family's food was grown or produced, including half of their milk. The other half of their milk came from cows located in New Ellenton, South Carolina. The father worked onsite at SRS. The children also worked onsite at SRS when they grew up. A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location.

- Migrant Worker Family. This family lived in New Ellenton, South Carolina, for half of any year. The New Ellenton exposure location was assumed for all exposures and activities (home, schools, church, work, recreation, and the source for locally grown vegetables, milk, and meat).

- Delivery Person Family. This family lived in Barnwell, South Carolina, and attended church in Martin, South Carolina. Some of the food eaten by this family was obtained from Barnwell and some from Martin. The father worked in Allendale, South Carolina, and onsite at SRS. (So did the children when they grew up.) A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location. The father hunted deer and wild fowl near Martin. The family engaged in recreation on the shore of Lower Three Runs Creek (at Martin) and on the shore of the Savannah River below its confluence with Lower Three Runs Creek.[1] The family boated on, and ate fish from, the Savannah River at this same exposure location. The family also ate fish that were caught in Lower Three Runs Creek.

- Outdoors Person Family. This family lived in Jackson, South Carolina, where the family also attended church and the children went to grade and high school. Much of the food eaten by the family was grown in Jackson. The father worked and hunted on the SRS site (as did the children when they grew up). The same location on the SRS site, near the K-Reactor, was assumed for the work exposure location and the hunting exposure location. The father boated on the Savannah River while working and with his family for recreation.[2] The family swam and spent time along the shoreline at the Jackson Boat Ramp, which is upstream of the SRS discharge to the Savannah River. All family members ate fish that were caught in the Savannah River below its confluence with Lower Three Runs Creek.

- Near River Family. This family lived in Martin, South Carolina.[3] The Martin exposure location was assumed for all activities (home, schools, church, work, recreation, source of milk, and the source of locally grown vegetables). In addition, the family boated in, and ate fish from, the Savannah River below its confluence with Lower Three Runs Creek.

Discussion of assumptions about exposure scenarios and locations. The following discussion provides additional information about the selection of exposure scenarios and the locations:

- Two rural farming families – Rural Family One and Rural Family Two -- were assumed rather than one. Rural Family Two was added to the area near Williston, South Carolina. CDC staff had suggested adding an exposure scenario to the northeast of SRS to assure that possible radiation exposures in that direction would be considered (3). It was decided that this exposure scenario would be a rural family similar to the farming family located near Girard, Georgia (Rural Family One).

- New Ellenton, South Carolina, was chosen as the exposure location for the Migrant Worker Family. Although a migrant worker scenario had been proposed by CDC, the location where the scenario would be sited was undetermined. (The SRSHES Work Group did not recommend a location (1).) The Migrant Worker Scenario was located in New Ellenton to assure that exposures from radionuclides released to the north from SRS would be considered, and because migrant farm families were probably present in the New Ellenton area during much of the period of interest (2). In addition, the New Ellenton area was chosen as the location of a dairy patronized by the Urban/Suburban Family (2).

- The Urban/Suburban Family was assumed to fish, swim, and boat at the Augusta exposure location. The SRSHES Scenarios Work Group had proposed using Clark's Hill Lake (now called the Strom

[1] Exposures from air immersion and deposition that were received while conducting water-related activities were modeled assuming the Martin exposure location.
[2] All boating occurred below the confluence of the Savannah River with Lower Three Runs Creek.
[3] Note that Martin, South Carolina, is not directly on the river.

Thurmond Reservoir) for these activities (1). The Augusta location was chosen as an alternative, in order to help limit the number of exposure locations that had to be modeled. Because both Clark's Hill Lake and Augusta are well above any point of surface water discharge from SRS, at neither location would receptors have experienced radiological exposures from radionuclides released by SRS to surface water. The only exposures would have been from radionuclides that had been released into the air. But Augusta is closer to SRS than Clark's Hill Lake, and both locations are northeast of SRS. For this reason, Augusta was a more conservative choice than Clark's Hill Lake.

- Any person exposed on the SRS site was assumed not to have been a radiological worker whose radiation exposures would have been routinely measured. This person would have had access to the site but not to areas controlled for purposes of radiation protection. Two candidate locations were identified: (1) near K-Reactor, and (2) the F- and H-Areas. Although hunting was probably more likely near K-Reactor, more people were employed in the F- and H-Areas. The K-Reactor vicinity was chosen to represent the exposure location for all onsite receptors, whether working or hunting.

- For all scenarios, all hypothetical family members stayed in the SRS area over the entire 39-year period. Children born and raised in the area always remained at home except for participating in specified activities such as school and recreation. After finishing high school, the children lived in their home communities. Each child adopted the same occupation and recreational activities as the adult male in their family from age 18 on.

- All radiation exposures associated with the Savannah River (boating, swimming, shoreline, fishing) were assumed to occur at a location below the confluence of the Savannah River with Lower Three Runs Creek. Below the confluence, the Savannah River contained radionuclides that were discharged into the river through the Savannah River Swamp as well as radionuclides that were discharged into the river from Lower Three Runs Creek. The flow rate was not significantly larger than further upstream. For purposes of calculating air exposures while recreating on the Savannah River (e.g., immersion and inhalation doses), the Martin location was assumed as representative. Martin, Smith Lake, and Little Hell Landing are all within a few miles of one another.

3.1.1.1 Additional Refinements to Proposed Exposure Scenarios

In addition to the overall decisions described above, several refinements were made to the specifics of the exposure scenarios proposed by the CDC and addressed by the SRSHES:

Consumption of locally acquired milk. It was assumed for all scenarios that family members drank milk from cows located in the SRS vicinity, meaning that all milk contained radionuclides that had been released into the air from SRS. This assumption met the intent of the SRSHES Work Group's suggestion that the urban/suburban and rural families should drink milk from family cows (1).

Consumption of poultry. It was assumed that much of the poultry eaten by all members of all scenarios was produced in the SRS vicinity. This assumption largely met the intent of the SRSHES Work Group's suggestion to include family chickens in some scenarios (1).

Hunting and trapping. It was assumed for several scenarios that the adult male spent time outdoors while hunting and trapping. Radiation exposures received through consumption of game animals was modeled for the two rural families, the Delivery Person Family, and the Outdoors Person Family by assuming that meat from game animals could be represented as either a form of beef or poultry (see Section 3.2.2).

Consumption of crustaceans. All radiation exposures from eating aquatic animals were assumed to come from eating fish. The SRSHES Work Group had suggested that shell fishing, shrimping, and crabbing should be considered as food sources for the Near River Family scenario (1). However, the potential for the crustaceans cited by the SRSHES to be present at the scenario locations was considered very remote. The habitat for the crustaceans cited is located a significant distance downriver in brackish water, far enough away from SRS so that the levels of radiation in the crustaceans would be quite small.

Irrigation. Irrigation with water contaminated with radionuclides from SRS was not modeled as an exposure pathway. Although the proposed CDC scenario had envisioned that the rural family and migrant families would irrigate crops with water taken from the Savannah River (1), it was determined that such a pathway would be unrealistic for the SRS area.

Houseboating. The Near River Family was assumed to live in Martin, South Carolina, an exposure location that was consistent with the recommendations of the SRSHES Work Group (1). CDC had proposed that the family living near the river should live on a houseboat (1). Yet there was no evidence that persons lived on houseboats in the SRS area.

Family Composition. Each exposure scenario consists of two adults and two children. The SRSHES Work Group had suggested that five children be assumed for the rural family and three for the delivery person family (1). Modeling additional children would not provide significantly different information from that already obtained from the two children already studied. Each scenario proposed by CDC included two children who were born during years that SRS released large quantities of radionuclides into the air (1).

Religion. It was assumed that all family members attended religious services for a few hours each week. This assumption was consistent with the SRSHES Work Group's suggestions (1). For most scenarios, it was assumed that the place of worship was near the family residence. The scope of the study did not support making distinctions between the specific locations of the structures within a small geographical area.

Pets. Pets were not modeled as a separate exposure pathway. The SRSHES Work Group suggested that persons living in the SRS vicinity would probably have had pets such as hunting dogs (1). These pets may have brought radionuclides into a house from dust or dirt caught in their fur. However, the Phase III radiological assessment made no distinction between radionuclide concentrations indoors or outdoors, in the air. Given that a generally accepted model for exposure to radionuclides from contaminated pets is not available, that many modeling assumptions were conservative, and that doses from this pathway were not expected to be large, dose estimates for this pathway were not included in this Phase of the dose reconstruction.

Nursing mothers. The rural family scenario as proposed by CDC called for a mother nursing at least one of the children (1). Separate exposures through this pathway were not modeled because a standard approach to simulate this pathway was not readily available. However, the Phase III radiological assessment did consider the consumption of contaminated foodstuffs by infants, including contaminated cow's milk, which should have simulated these exposures.

***In Utero* Exposures**. It was assumed that the Adult Female for the Urban/Suburban Family scenario always worked at home. The SRSHES Work Group had suggested that the mother of the urban/suburban family be assumed to work onsite until well into her pregnancy (1). It was recognized that the Work Group's proposed assumption was directed at assessing *in utero* exposure to an unborn child. However,

neither the modeling approach used nor the dose and risk coefficients that were used as principal components of the analysis address such exposures.[4]

3.2 Additional Assumptions About Scenarios

To perform the Phase III radiological assessments, it was necessary to add several additional assumptions to those provided by the CDC and the SRSHES to address specific features of the exposure scenarios. These assumptions are addressed in detail in Appendix E and summarized here:

3.2.1 Composition of Exposure Scenario Families

It was assumed that each of the seven hypothetical families had the same composition:

- A male who was an adult (over age 18) in 1954.
- A female who was an adult (over age 18) in 1954.
- A male child born in 1955.
- A male child born in 1964.

This family composition was chosen to model infant exposures during 1955 and 1964, when releases of radionuclides to the environment were relatively large. Male children were modeled because males receive slightly larger radiation exposures for some pathways than females (e.g., males eat more than females) and therefore provide more conservative estimates of doses and risks. It was desirable to make both children the same sex in order to allow direct comparison of the effect of being born at different times.

Figure 3-4 presents the age and gender of each receptor for each year of exposure. A 39-year period was modeled starting at the beginning of 1954 and finishing at the end of 1992. Information about the age and gender of each member of the scenario families was used to determine the ingestion rates of certain foods (Section 3.2.2), the times spent performing different activities (Section 3.2.3), and breathing rates (Section 3.2.4). In addition, information about each individual's age and gender was used to convert exposure levels to lifetime radiation dose and cancer risk as discussed in Chapter 10 and Appendix D.

As the children grew from infants to adults, assumptions about parameter values were made that were appropriate for their age. Each child was assumed to grow from a male infant (his first year), to a preschooler (three years from age 2-4), to a grade-school aged child (seven years from age 5-11), to a teenager (six years from age 12-17) years), to an adult age (all remaining years from age 18 on). After each child reached age 18, parameter values appropriate for an adult were maintained for the rest of the study period. The Child Born in 1955 became an adult in 1973; the Child Born in 1964 became an adult in 1982.

3.2.2 Food Products

To address radiation exposures through consumption of food and animal products, quantities of each food product eaten by each receptor were estimated as well as the fraction of each food product that had been contaminated with radionuclides released by SRS. (See Appendix E for details.)

[4]The dose and risk coefficients that were used are up-to-date coefficients issued by the Environmental Protection Agency in their 1992 update to Federal Guidance Report 13, Cancer Risk Coefficients for Environmental Exposure to Radionuclides (4).

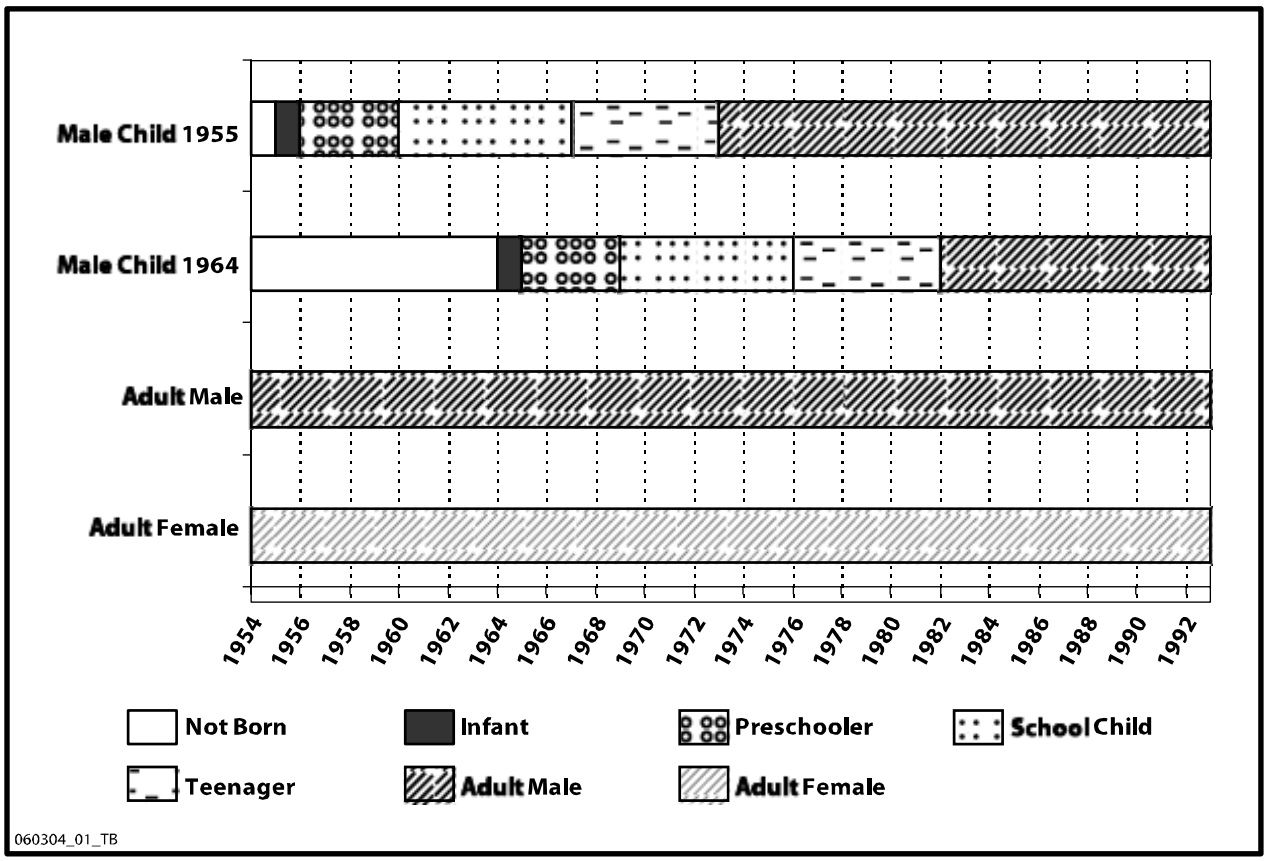

Figure 3-4 Age and Gender Categories of Modeled Receptors by Year

Assumptions were made for each family member about the consumption rates of the food products listed below. The primary data source for these assumptions was EPA's Exposure Factors Handbook (5):

- Leafy vegetables
- Root vegetables
- Fruit
- Grain
- Beef.
- Poultry
- Milk
- Eggs
- Fish

The quantity of each food product consumed annually depended on the age and gender of the receptor. Adults living in the SRS vicinity at the start of SRS operations in 1954 ate a constant annual quantity of each food product over the 39 years of the study. Adult females generally ate less food than did the adult males. The children ate different quantities of each food product depending on their age. When each child reached age 18, they thereafter ate each food product in annual quantities appropriate for an adult male.

Assumptions about food product contamination depended on the food product and scenario. If the food product was grown or produced locally (e.g., from local farms or dairies), then it was assumed that all was contaminated. If the food product was from a local store, then it was assumed that some (generally half) was obtained locally (and therefore contaminated) and the remainder was obtained from sources external to the SRS vicinity.

For beef, poultry, fruit, and vegetables, a time-dependent, locally-produced fraction was assumed for Rural Families One and Two consistent with the SRSHES Work Group recommendations for meat and vegetables (see Table 3-1). The fraction that was eaten that originated from the farm was reduced after the end of 1959. For other scenarios it was assumed that half of the beef, poultry, fruit, and vegetables from stores was produced locally.

Radiation exposure from eating game animals taken near the SRS site was modeled by assuming that meat from all game animals could be represented as forms of beef (e.g., venison) or poultry (e.g. wild fowl). Members of Rural Family One and Two, the Delivery Person Family, and the Outdoors Person Family were assumed to eat game animal meat. The total quantities of beef and poultry that these members ate were the same as that eaten by comparable members of the other three scenarios. However, larger fractions of this meat were assumed to be locally produced for these four scenarios compared to the other three scenarios.

3.2.3 Times Spent Per Activity

Each member of each scenario was assigned a home area, a work area for the Adult Male (and for the children after they became adults), food procurement areas, and areas for activities including church, school, work, hunting, fishing, swimming, and boating. Times spent in each area not derived from the suggestions of the SRSHES Work Group (1) were mainly determined using EPA's Exposure Factors Handbook (5) and an SRS report on land and water use characteristics in the vicinity of the Savannah River (6). Times spent performing each activity were used in assessing radiation exposures through several exposure pathways (e.g., the radiation dose received at an exposure location from immersion in a plume of contaminated air depended on the time spent at that exposure location). Assessments of radiation exposure from contaminated soil depended on the time spent either indoors or outdoors.

Home. The time spent at home depended on assumptions for each member of each scenario about work, church, school, and recreation. The times spent by each family member either indoors or outdoors were assumed based on data from EPA's Exposure Factors Handbook (5). Different times indoors and outdoors were assumed based on whether the family member was an adult male, an adult female, or a child within a particular age group.

Food Procurement. It was generally assumed that food for family members was obtained locally to their residences. As noted above, some food was obtained from stores and some was locally grown. However, half the milk for the Urban/Suburban Family scenario was obtained from an exposure location away from their residence, and half of all food products (other than fish) for the Delivery Person Family scenario was obtained from an exposure location away from their residence. For these situations, the difference in external or inhalation exposures that may have occurred during the limited time spent in these locations obtaining food was not assessed. However, the assessment did consider the location where the food was grown.

Church. All members of each scenario spent 104 hours per year (52 weeks/year x 2 hours/week) at church. All church hours were assumed to be part of the time all receptors spent indoors.

School. Children and teenagers attending school each spent 1,260 hours per year in school. Of these 1,260 hours, 900 hours were spent indoors and 360 hours were spent outdoors (5 hours indoors/day, 2 hours outdoors/day x 180 days/year). It was assumed that no food was obtained or was grown in the school locations.

Hunting/Fishing. For most scenarios, it was assumed that when the Adult Male was hunting (Rural Families One and Two, and Delivery Person Family), the amount of time spent hunting was included in

the residential outside hours. The Outdoors Person hunted as part of work, and all hunting hours were spent outside.

Swimming, Shoreline, and Boating. Most members of most scenarios were assumed to swim for 21 hours each year and spend 85 hours each year along a river or creek shoreline based on data from the SRS report on land and water use characteristics in the vicinity of the Savannah River (6). But members of the Near River Family spent 91 hours per year swimming (an hour per day during the summer for each member) as well as 365 hours per year along the Savannah River shoreline. These assumptions were based on the statement by the SRSHES Work Group to "assume they were always in contact with the Savannah River" (1). All hours were spent outdoors. The Adult Male of the Outdoors Person Family annually spent 260 additional hours on the Savannah River shoreline as part of work.

Consistent with the recommendations of the SRSHES Work Group (1), members of Rural Families One and Two and the Migrant Family did not go boating. Members of the Urban/Suburban, Delivery Person, and Outdoors Person Families boated in the Savannah River for 96 hours per year based on data from the SRS report (6). Members of the Near River Family boated in the Savannah River vicinity for 192 hours per year – i.e., twice the value in the SRS report (6). These assumptions were based on the statement by the SRSHES Work Group to "assume they were always in contact with the Savannah River" (1).

3.3 Overview of Final Exposure Scenarios

The seven scenarios and the assumed home locations for each of the hypothetical families making up these scenarios are described in detail in the following sections:

Section 3.3.1: Rural Family One in Girard, Georgia.

Section 3.3.2: Rural Family Two in Williston, South Carolina.

Section 3.3.3: Urban/Suburban Family in Augusta, Georgia.

Section 3.3.4: Migrant Worker Family in New Ellenton, South Carolina.

Section 3.3.5: Delivery Person Family in Barnwell, South Carolina.

Section 3.3.6: Outdoors Person Family in Jackson, South Carolina.

Section 3.3.7: Near River Family in Martin, South Carolina.

3.3.1 Rural Family One

This hypothetical family lived in Girard, Georgia. All family members spent much of their work, home activities, and recreation time outdoors. The Adult Male was a farmer, and the Adult Female worked at home. The family hunted, fished, and swam in the Girard area and in the nearby area of Briar Creek. The family did no boating. The children stayed at home until they reached school age; then they attended grade schools in Girard and high school in Waynesboro, Georgia. When not attending school, the children remained in the Girard area. When the children grew to adulthood, they became farmers and fished, hunted, and engaged in recreational activities in the Girard area. All family members remained permanently in the Girard area. Figure 3-5 shows the exposure locations of Rural Family One.

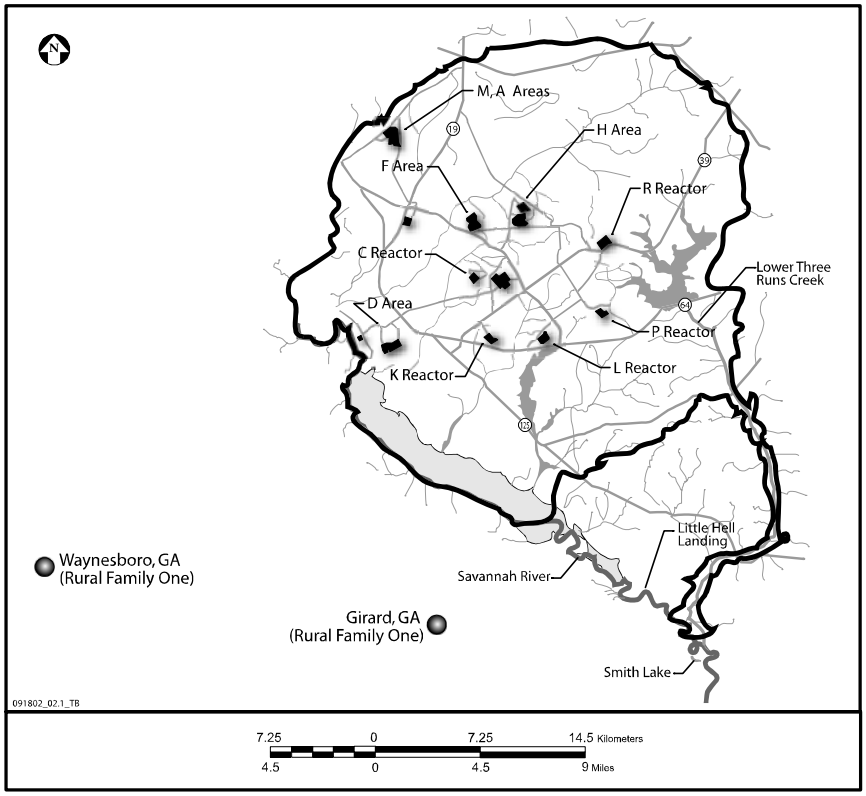

Figure 3-5 Exposure Locations of Rural Family One

All the family's milk and eggs came from cows and hens located in Girard. The fish eaten by the family was caught in Briar Creek or other nearby locations. Because Briar Creek is not located hydrologically downstream from SRS, none of the fish consumed by the family was affected by SRS release of radionuclides to surface water. During the 1950s, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remainder came from other sources such as stores in Girard. Half of this remaining food was locally grown or produced. Beginning in 1960, only 25% of their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75% came from sources such as stores. Half of this remaining food was grown or produced in Girard, and half came from sources outside the SRS. It was assumed that all of the locally-grown grain eaten by the family was corn.[5] Drinking water and water used to irrigate the food grown and eaten by the family came from local ground water or surface water sources that were assumed to be unaffected by SRS releases.

[5] This assumption was made for all receptors and scenarios. As discussed in Appendix E, individuals in the SRS vicinity would have consumed grain products such as breads, pasta, or flours; however, most of these grain products were likely grown or produced out of the SRS vicinity and therefore were not contaminated by SRS operations. But it is plausible to assume that individuals in the SRS vicinity consume locally grown corn. Such consumption could occur for those persons living in a suburban as well as a rural environment. Although corn may have been consumed as a vegetable, uptake of radionuclides by corn is appropriately modeled as grain uptake.

3.3.2 Rural Family Two

Rural Family Two was a hypothetical family substantially similar to Rural Family One, except that the family lived and spent all their time in Williston, South Carolina. Figure 3-6 shows the exposure location of Rural Family Two.

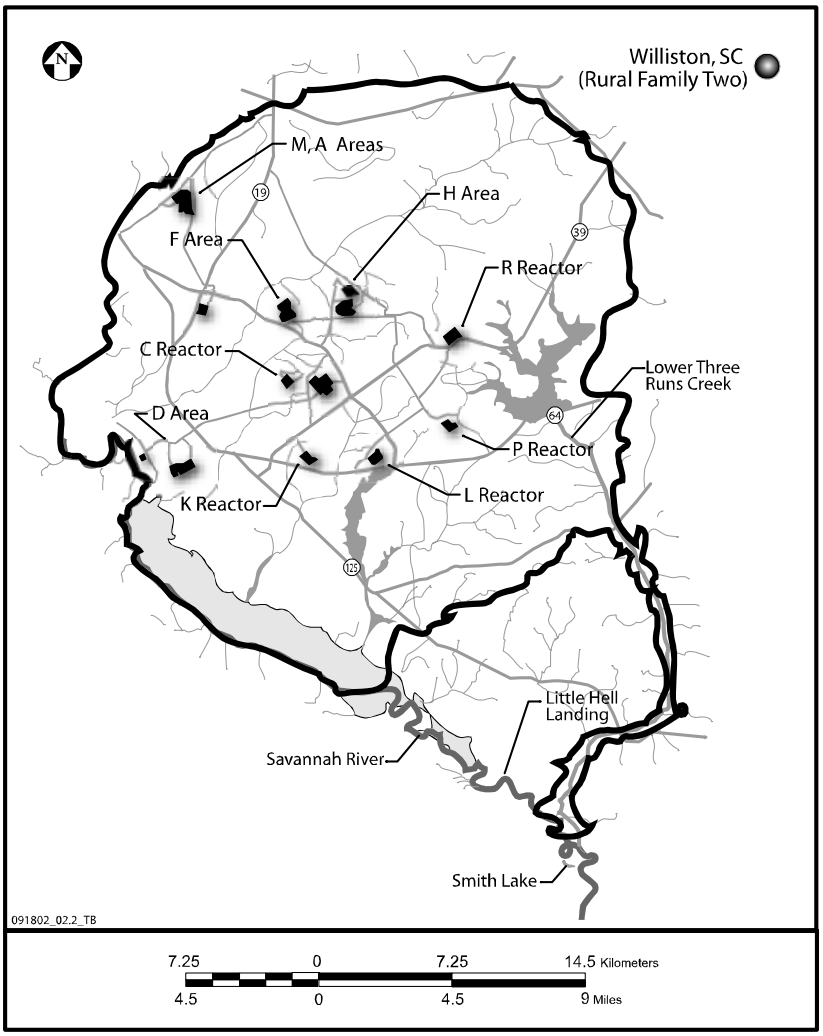

Figure 3-6 Exposure Location of Rural Family Two

All family members spent much of their work, home activities, and recreation time outdoors. The adult male was a farmer, and the adult female worked at home. The family hunted, fished, and swam in the Williston area. Like Rural Family One, this family did no boating. The children stayed at home until they reached school age, and then they attended schools in Williston. When not attending school, the children remained in the Williston area. When the children grew to adulthood, they became farmers. The family always lived, engaged in recreational activities, and worked in and around the Williston area.

All of the family's milk and eggs came from cows and hens located in Williston (on the family farm or nearby). All of the fish eaten by the family was caught in streams or ponds in or near Williston. Because these streams and ponds are not hydrologically downstream from SRS, none of the fish eaten by the family was affected by SRS releases of radioactive material to surface water.

During the 1950s, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remaining half came from other sources such as stores in Williston. Half of this remaining food (i.e., food not grown or raised on the family farm) was grown or produced in Williston and the other half came from outside the SRS area. Beginning in 1960, only 25% of their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75% was obtained from other sources such as stores in Williston. Half of this remaining food was locally-grown or produced, and half came from outside the SRS area.

All locally-grown grain eaten by the family was corn. Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases

3.3.3 Urban/Suburban Family

This hypothetical family lived in Augusta, Georgia, and all family members were present there for most activities including school and church. The Adult Male worked onsite at SRS for the duration of the study period (39 years). The children worked onsite at SRS beginning in 1973 for the Child Born in 1955 and 1982 for the Child Born in 1964. All family members swam, boated, and fished in the Savannah River flowing through the Augusta area, a location well upstream of any point of radionuclide discharge to surface water from SRS. Figure 3-7 shows the exposure locations of the Urban/Suburban Family.

Half the family's milk came from cows in the Augusta area and half from cows in the New Ellenton area. All eggs came from hens located in the Augusta area. Half of their beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in the Augusta area, and half came from unaffected non-local sources. All locally-grown grain eaten by the family was corn. Fish came from sources unaffected by liquid releases from SRS (e.g., from the nearby Savannah River). Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases

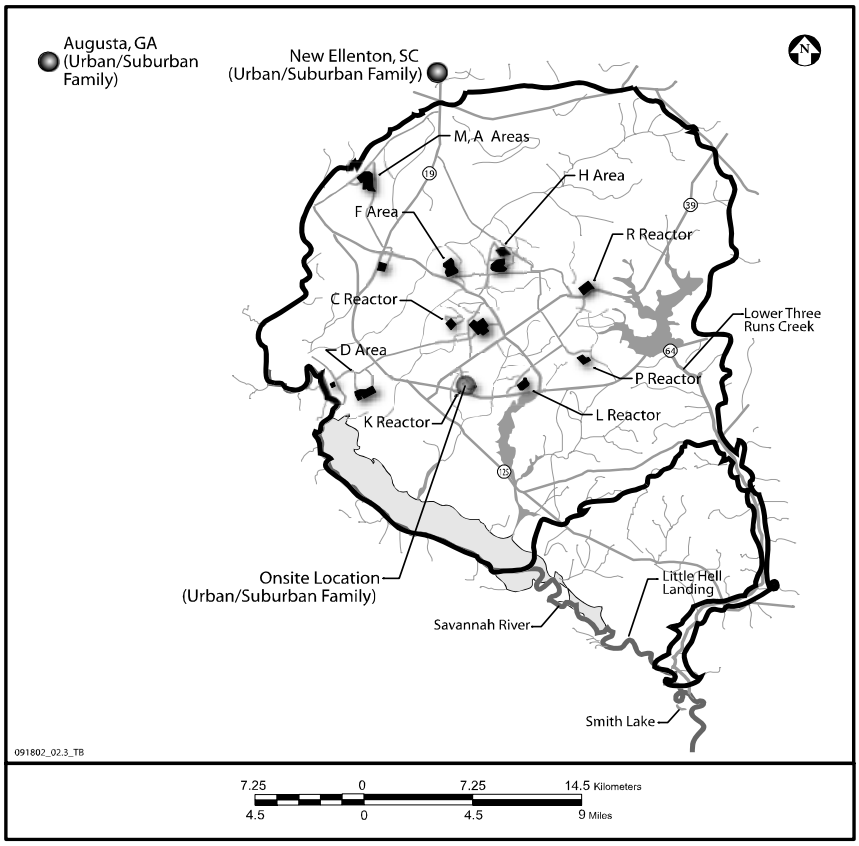

Figure 3-7 Exposure Locations of Urban/Suburban Family

3.3.4 Migrant Worker Family

All family members spent much of their work, home activities, and recreation time outdoors in New Ellenton, S.C. Figure 3-8 shows the exposure location of the Migrant Worker Family. Because the Adult Male and Adult Female worked as migrant farm workers, the family lived in New Ellenton for only half of any year. While living in New Ellenton, the family participated in hunting, trapping, and other outdoor activities. The family did no boating but did participate in other water sports such as fishing and swimming in local pools, ponds, and creeks. The children stayed at home until they reached school age and attended schools in New Ellenton. When the children grew to adulthood, they became migrant farmers spending half the year in New Ellenton and half the year away from the SRS vicinity.

During the six months of each year that the family lived in New Ellenton, all of their milk and eggs were produced or collected in or near New Ellenton. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in the New Ellenton area and half came from sources outside the SRS vicinity. All of their corn was grown in the New Ellenton area. Because ponds and creeks in the vicinity of New Ellenton are not hydrologically downstream from SRS, none of the fish eaten by the family was affected by SRS liquid releases. Drinking water and water used to irrigate foods eaten by the family came from ground water or surface water sources unaffected by SRS liquid releases.

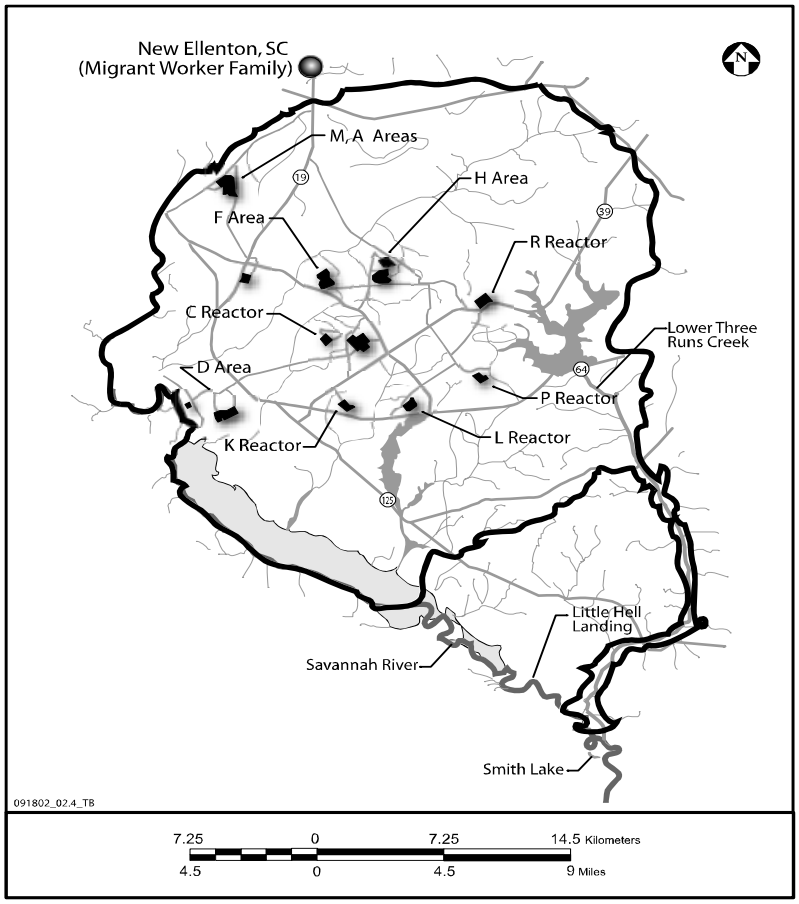

Figure 3-8 Exposure Location of Migrant Worker Family

3.3.5 Delivery Person Family

This hypothetical family lived in Barnwell, South Carolina, where the children attended grade and high school. Because the Adult Male worked as a delivery driver for a bottling plant located in Allendale, South Carolina, he spent portions of his time in Allendale and portions onsite at SRS, where he made periodic deliveries. (When the children reached 18, they lived in Barnwell and became delivery drivers like the Adult Male.) All family members attended religious services in Martin, South Carolina, for two hours each week. All family members swam, fished, and spent time along the shoreline at Lower Three Runs Creek near Martin. The adult male hunted for deer and fowl in the Martin vicinity. Figure 3-9 shows the exposure locations of the Delivery Person Family.

The family boated on the Savannah River using the boat ramp at Little Hell Landing, which is upstream of the confluence of the Savannah River with Lower Three Runs Creek. The family then moved the boat to the Smith Lake area for fishing and activities along the Savannah River shoreline. Smith Lake is located just below the confluence of the Savannah River with Lower Three Runs Creek. The family did not swim in the Savannah River.

Half of the family's milk and eggs came from cows and hens in the Barnwell area and half came from cows and hens in the Martin area. In addition, half the family's beef and poultry came from Barnwell and half from Martin. Half of the beef and poultry from Barnwell was actually produced in the Barnwell area, and half was acquired from sources away from the SRS area. Of the beef and poultry from Martin, 25% consisted of meat from hunting deer and wild fowl. That is, 25% of the beef from Martin consisted of locally-hunted venison while 25% of the poultry from Martin consisted of locally-hunted wild fowl. Of the remaining 75% of the beef and poultry from Martin, half was produced in the Martin area and half was acquired (e.g., by stores) from sources well away from the SRS[6]

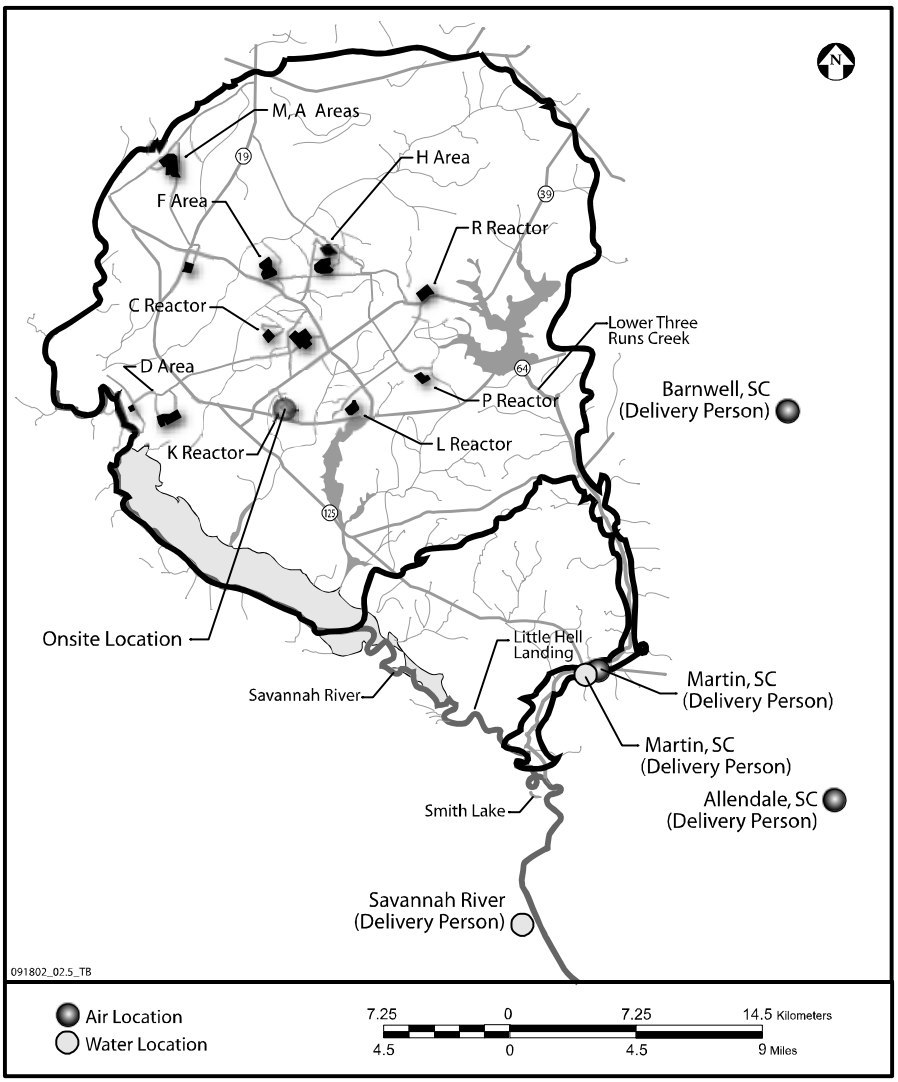

Figure 3-9 Exposure Locations of Delivery Person Family

Half the leafy vegetables, root vegetables, and fruit came from Barnwell, and half came from Martin. Half of the produce obtained in the Barnwell area was grown in areas away from the SRS vicinity and half of the produce obtained in the Martin area was grown in areas away from the SRS vicinity. Half of the corn eaten by the family was grown in Barnwell and half in Martin.

Half of the fish eaten by the family was caught in Lower Three Runs Creek at Martin and half was caught in the Savannah River.

[6] Combining the venison and wild fowl obtained from hunting with other beef and poultry obtained in Martin, it was assumed that 62.5% of all beef (including venison) obtained from Martin potentially contained radionuclides from the SRS, as did 62.5% of all poultry (including wild fowl) eaten by the family.

3.3.6 Outdoors Person Family

This hypothetical family lived in Jackson, South Carolina, and all family members were present there for most activities including school and religious services. When the children grew to adulthood, they continued to live in Jackson. Family members were not present in Jackson during employment activities for the Adult Male nor during employment activities for the children after they each reached age 18. The Adult Male worked onsite at SRS as a hunter, as did the children when they grew up. During the time the Adult Male spent onsite at SRS annually, he took game animals in the form of deer and birds, and caught fish from the Savannah River. His job required him to spend 260 hours per year along on the Savannah River shoreline as well as 260 hours per the year boating on the Savannah River. Figure 3-10 shows the exposure locations of the Outdoors Person Family.

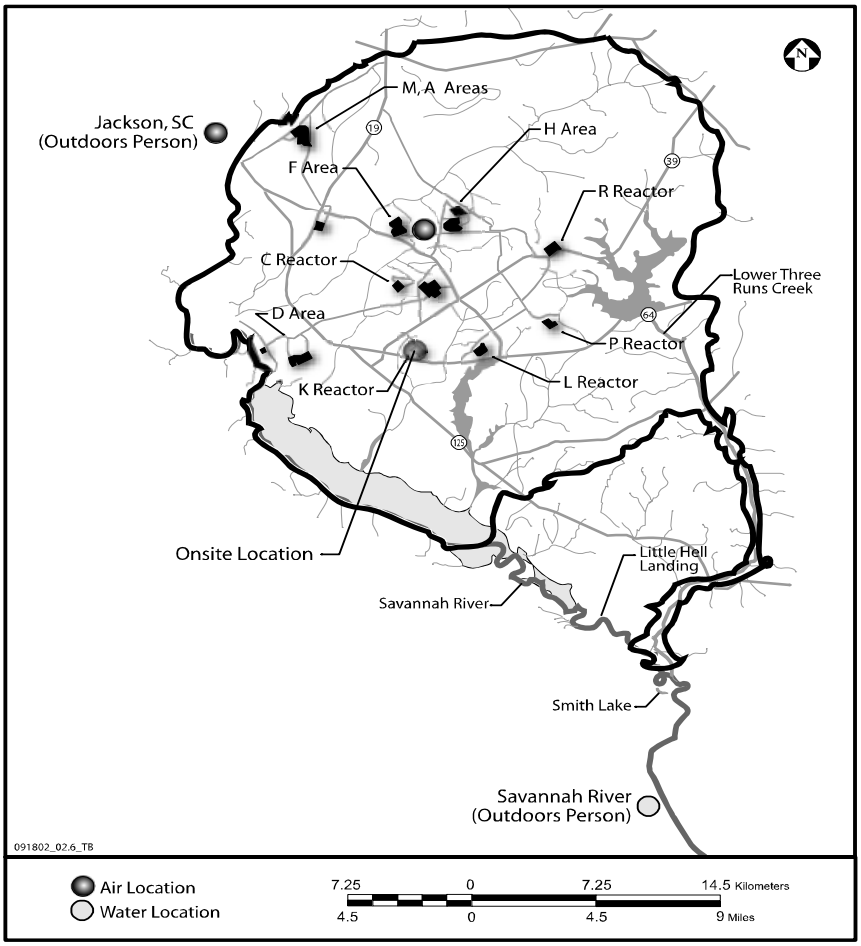

Figure 3-10 Exposure Locations of Outdoors Person Family

All family members (including the Adult Male) engaged in recreational swimming in the Savannah River and spent time along the Savannah River shoreline near the Jackson boat ramp (upstream of sources of SRS radionuclide release to the Savannah River). All family members boated in the Savannah River downstream of SRS.[7]

All milk and eggs came from cows and hens located in Jackson. Half the leafy and root vegetables and fruit were grown in Jackson, and half came from sources away from the SRA area. All of the family corn was grown in Jackson.

Three-quarters of the family's beef and poultry consisted of venison and wild fowl that was hunted by the Adult Male on the SRS site. Their remaining beef and poultry came from other sources such as stores. Of

[7] After putting the boat in the water at the Jackson boat ramp, the family moved the boat to an area downstream of the confluence of the Savannah River with Lower Three Runs Creek. Therefore, the Adult Male received radiation exposures while recreationally boating as well as while working at the SRS.

this, half was produced in Jackson and half came from sources away from the SRS area. All fish taken from the Savannah River contained radionuclides from SRS operations.

3.3.7 Near River Family

This hypothetical family lived in Martin, SC. All members spent much of their work, home activities, and recreation time outdoors. The family lived, worked, and went to school and church in Martin, and participated in outdoor activities such as hunting, fishing, and boating. Figure 3-11 shows the exposure location of the Near River Family.

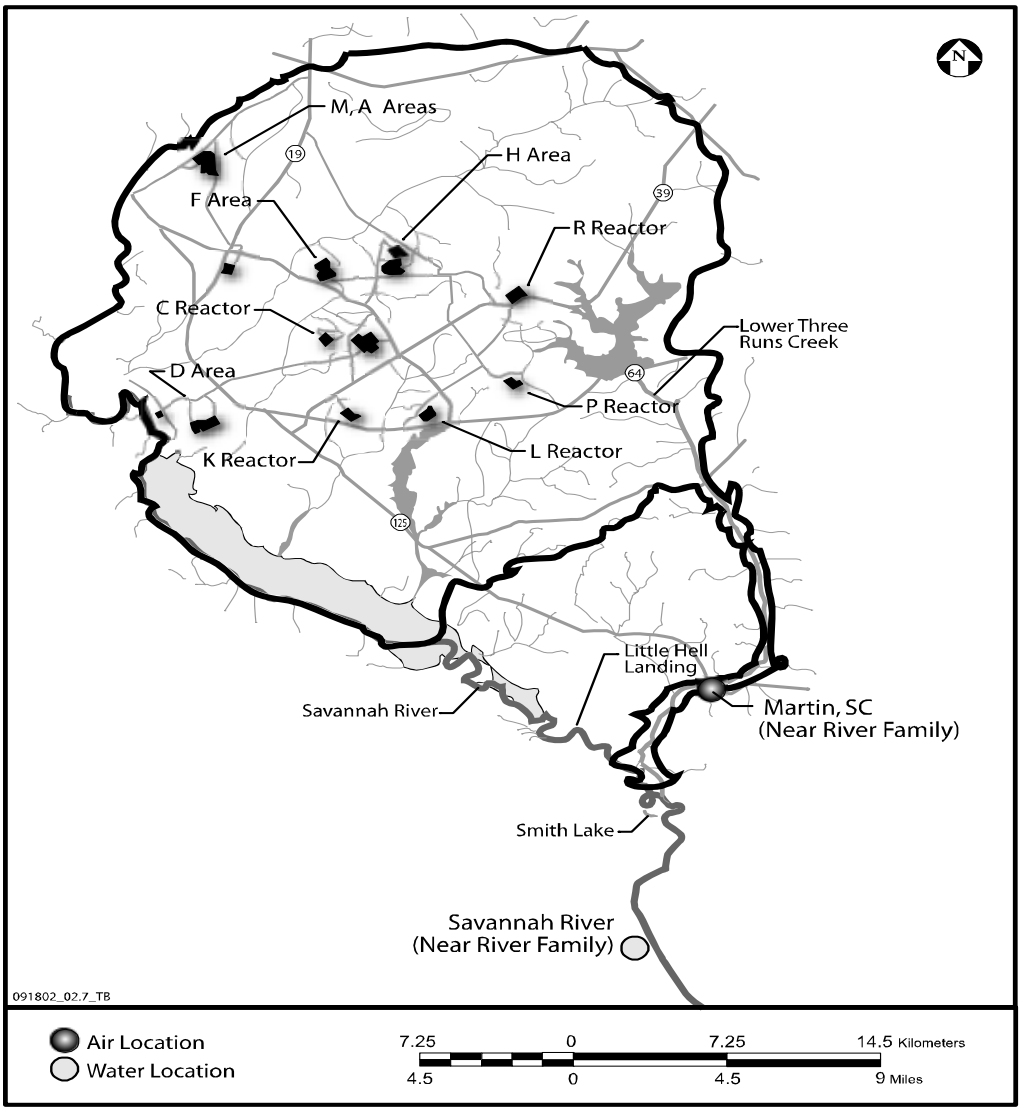

Figure 3-11 Exposure Locations for Near River Family

This family spent twice as much time boating (in the Savannah River) as did other families. Each family member spent an average of an hour per day of each year on the Savannah River shoreline, and an average of an hour a day swimming during the summer in the Savannah River. When the children grew up, they continued to live in Martin. The family's milk and eggs all came from cows and hens located in Martin. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in Martin and half came from sources outside the SRS vicinity. All of the corn eaten by the

family was grown in Martin. All of the fish eaten by the family was caught in the Savannah River below its confluence with Lower Three Runs Creek. Drinking water and any irrigation used to produce the food eaten by the family came from sources assumed to be unaffected by SRS releases.

3.4 References

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4 OVERVIEW OF APPROACH

4.1 Statement of Goals and Constraints

The goal of this phase of the Savannah River Site (SRS) Dose Reconstruction Project is to estimate the doses and cancer risks to hypothetical receptors from SRS releases of radioactive materials to the air and water over 39 years of operation. The behaviors of the hypothetical receptors were designed to represent a range of plausible activities for the population living near SRS, but these projections were in some sense bounding without being unrealistic. This is an intermediate phase dose reconstruction that provides more detail and precision than a screening analysis, but it lacks the detail and precision of a full dose reconstruction that is based on the behavior of real people.

Although the overall goal for this dose reconstruction is simply stated, it was necessary for the analysis to address the particular characteristics of the area surrounding the SRS and the level of detail sought for this phase of the dose reconstruction. The following considerations shaped the choice of approach:

- Radionuclide releases:
  - -- Vary substantially with time.
  - -- Several radionuclides.
  - -- Releases to air and water.
  - -- Multiple locations for releases.
  - -- Base release estimates and their uncertainties on Phase II.
- Working group scenarios:
  - -- Seven scenarios with four receptors each.
  - -- Age of receptors is an important factor to explore.
  - -- Scenarios incomplete as work commenced.
  - -- Many different types of activities for each receptor.
  - -- One home location for each scenario; additional locations for several receptors.
- End points of analysis:
  - -- Dose.
  - -- Risk.
  - -- Organ doses as needed.
  - -- Evaluate uncertainty in dose.
  - -- Use generic environmental models.
  - -- Estimate dose and risk by radionuclide, year, receptor, pathway, etc.
- Comprehensive approach:
  - -- Use site-specific data or, if unavailable, appropriate generic data.
  - -- Model dose-significant aspects of the scenarios.
  - -- Model all important transport and exposure processes.
  - -- Use representative variable values not intended to overestimate or underestimate dose.

The approach described in this chapter responds to these particular aspects as well as to the overall goal of the study. These aspects were addressed by the choice of: an overall approach, the models used, and the implementation of the models, the data input to the calculation, the data obtained from the calculation, and the software used to automate the calculations.

4.2 Analytical Framework

The analytical framework may be described in terms of the assessment process, the modeling process, and the analysis steps. Although these aspects are related, they address different facets of the overall analytical framework.

4.2.1 Assessment Process

A dose reconstruction is a special type of retrospective dose assessment or radiological assessment based on past releases of radioactive material to the environment. The essence of a radiological assessment has been succinctly summarized (1) as:

> "The ultimate goal of radiological assessment is to show the relationship between the 'source term,' or quantity and types of released radionuclides, and the potential effect on human health. The assessment process must proceed in a logical fashion, following the radioactive pollutant of interest from its point of origin along various exit pathways to the environment, then considering its transport in air, water, soil, or food sources to man. Once transport and intake are determined, the dose from radiation and resulting risk to health can be calculated."

In other words, the dose reconstruction starts with the release of radionuclides from SRS; continues with the transport by air, water, and the food chain; models the exposure of the hypothetical receptors to contaminated media (air, water, soil, and food); and results in an estimation of doses and risks.

Figure 4-1 shows the risk assessment approach (2), and Section 4-3 discusses the approach in more detail. The INPUT is the set of site information including the releases compiled in Phase II (3) and the specification of the hypothetical scenarios. The OUTPUT is the health risk to each individual receptor estimated by the radiological assessment. Note that the output of any step of the overall assessment is the input to the next step of the assessment.

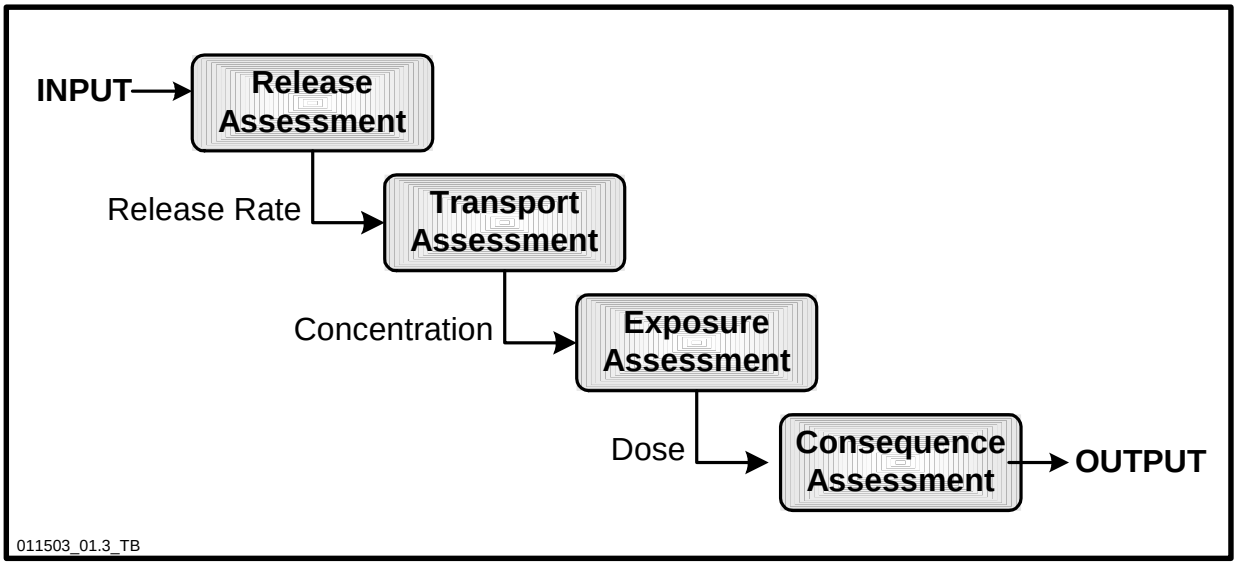

Figure 4-1 Risk Assessment Approach (2)

This dose reconstruction process can be viewed as four linked assessments (2). In the case of a radiological assessment, these linked assessments provide the following data:

- The Release Assessment provides the rate of release of radionuclides as a function of time and location of the source.
- The Transport Assessment provides the concentration of radionuclides in the environment (i.e., concentrations in air, water, soil, and foodstuffs as a function of time and location around the SRS).
- The Exposure Assessment provides the dose to a particular receptor based on their contact with contaminated media (air, water, soil, or foodstuffs).
- The Consequence Assessment provides the risk of cancer incidence and mortality.

The assessment process is described in a greater level of detail in Figure 4-2 for air releases and Figure 4-3 for liquid releases. Figure 4-2 for air releases shows how the transport assessment links concentrations in different media: air, soil, plants, and animals. These contaminated media lead to exposure of receptors by different pathways (4 of the 13 pathways for air releases are shown explicitly; “plant ingestion” represents 5 distinct pathways; “animal ingestion” represents 4 distinct pathways). Receptors are exposed through three exposure routes: inhalation and ingestion of radionuclides and exposure to direct radiation (external dose). Doses and risks are estimated using standard dose conversion factors. Figure 4-3 for liquid releases shows how the transport assessment links concentration in the water to concentration in fish. These contaminated media lead to exposure of receptors by different pathways (all of the 5 pathways for water releases are shown). Each of the four major parts of the assessment is primarily supported by different sources of information, as shown at the bottom of the figures. The Release Assessment is based primarily on the Phase II Report; the Transport Assessment is based primarily on the Phase II Report and Site Data; the Exposure Assessment is largely based on the scenarios specified by the CDC; and the Risk Assessment is based on Federal Radiation Guidance 11, 12, and 13.

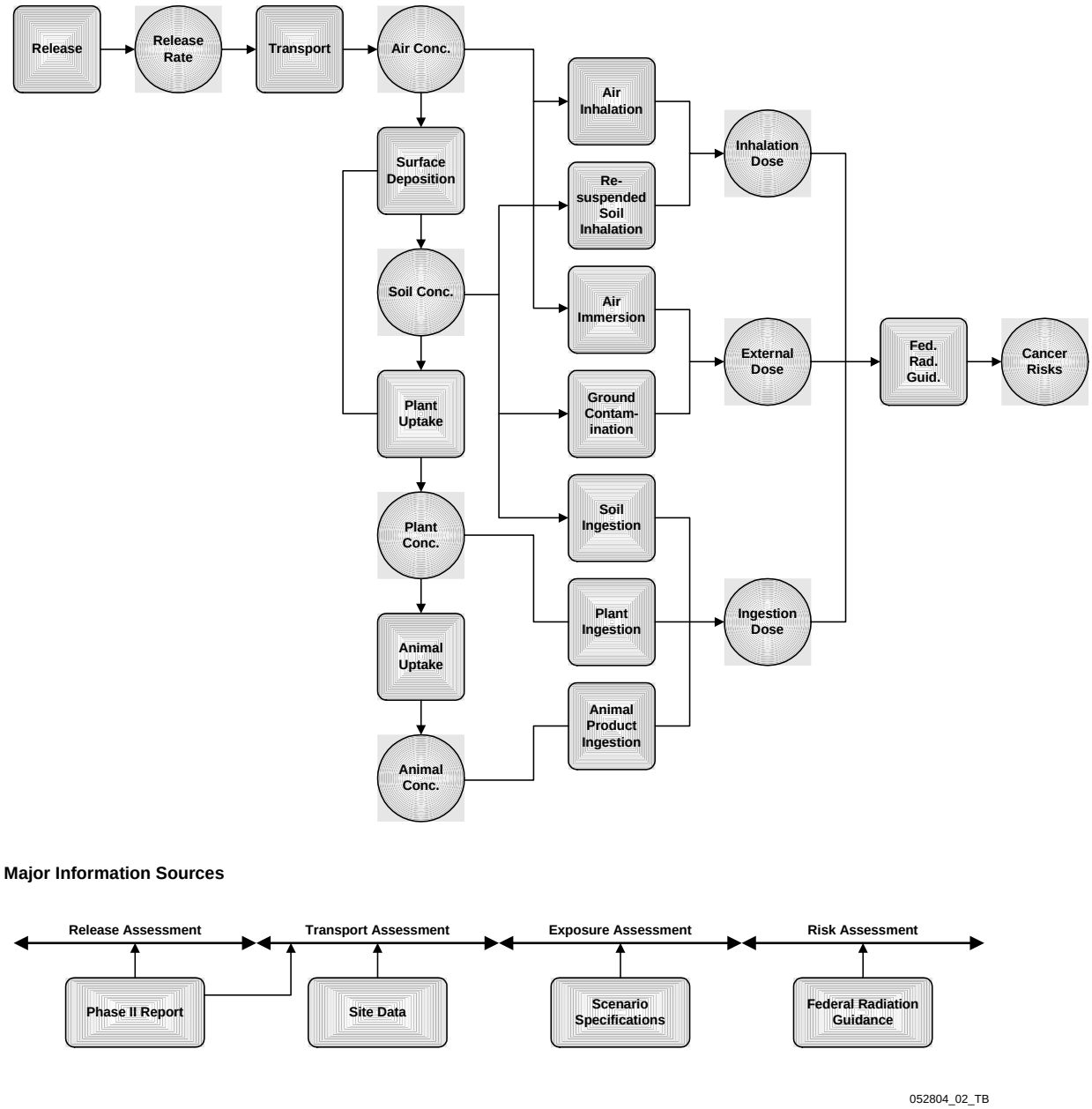

Figure 4-2 Overall Modeling Approach for Air Releases

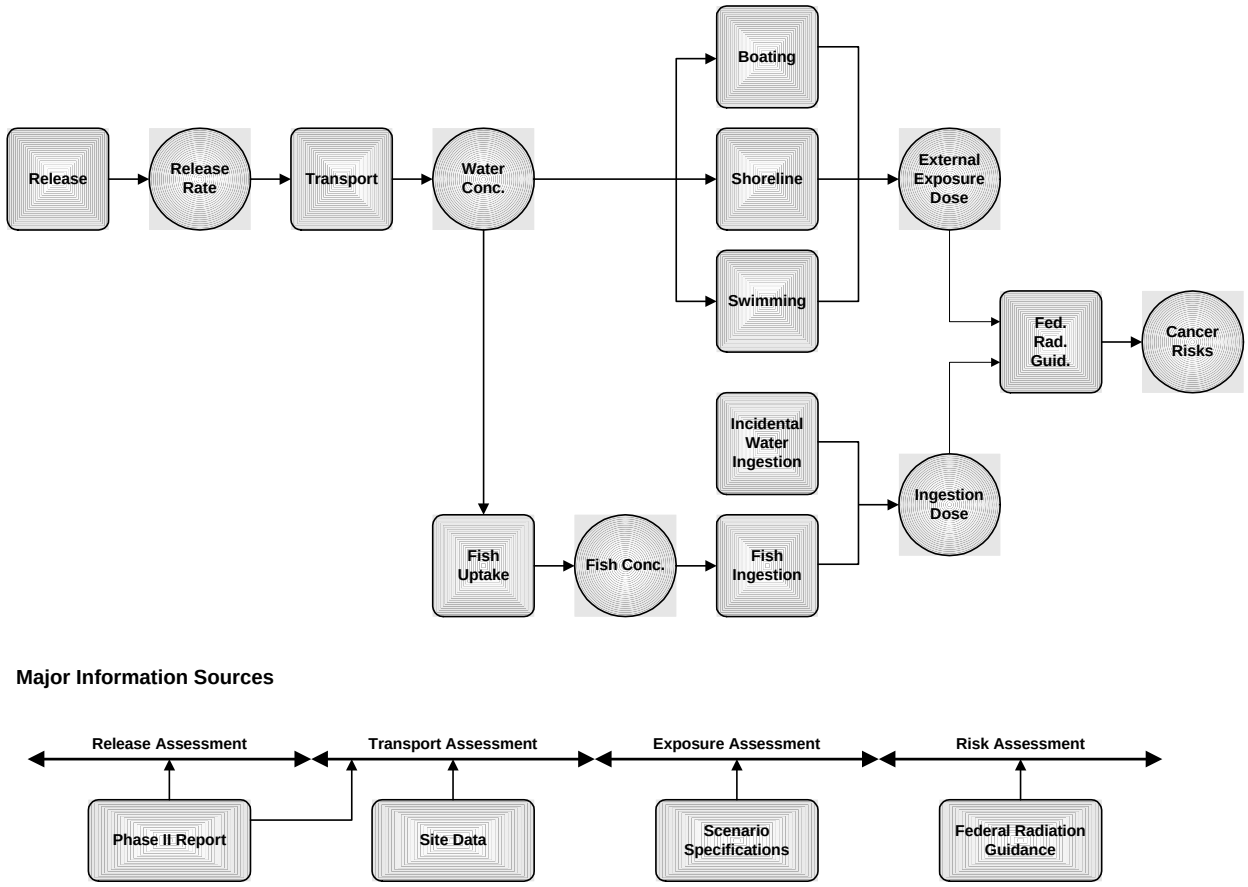

Figure 4-3 Overall Modeling Approach for Liquid Releases

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4.2.2 Modeling Process

These steps, described above in the text and Figure 4-1, provide a general procedure used to conduct this dose reconstruction; however, there are several other dimensions to the study. One important dimension is the modeling sequence followed in this and most environmental studies. The modeling sequence, shown schematically in Figure 4-4, consists of three components: 1) conceptual model, 2) mathematical model, and 3) numerical model.

The conceptual model is developed first and is a qualitative or semi-quantitative representation of the processes, conditions, features, and behaviors involved in the release and transport of radionuclides, the exposure of receptors to contaminated media, and the risks incurred in each receptor from these exposures. Section 4.3 presents many of the aspects of the conceptual model. For example, this dose reconstruction requires consideration of a time-varying release of radionuclides, the release of multiple radionuclides together, releases of radionuclides into air and water, releases of radionuclides from multiple locations, and receptors engaged in varied activities at several locations. If any of these aspects were different, the entire modeling approach would be different. For example, if we were studying pollution from the morning rush hour in a large urban area, the pollution would be released over a relatively short time (not years) and it would be released relatively uniformly over a large area (not released at a point).

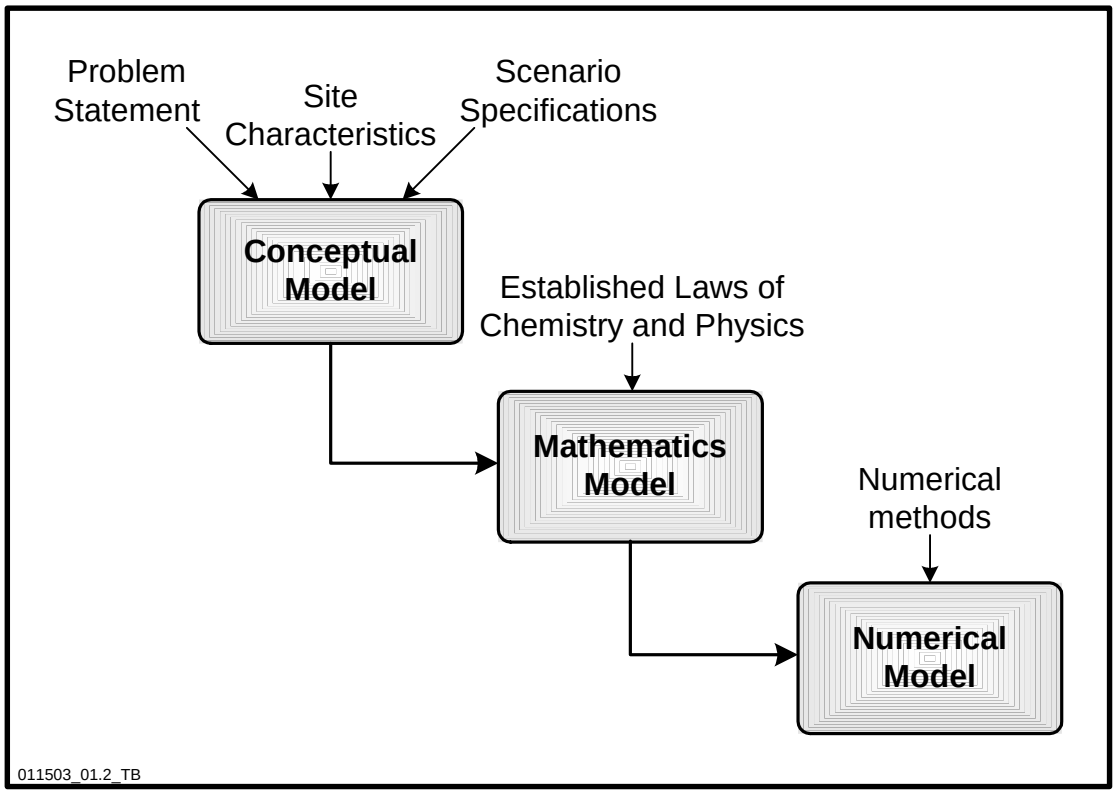

Figure 4-4 Schematic of Modeling Process

The mathematical model is derived from the conceptual model. It represents all the aspects of the conceptual model as a set of mathematical equations that usually involve a number of variables (quantities that may change with location, time, events, releases, receptors, or particular activities). These equations use well-established laws of physics, chemistry, and biology to represent the four dose reconstruction assessments

In turn, the numerical model is derived from the mathematical model. The numerical model is essential because it provides the quantitative estimate of dose to each receptor that is the study end goal. The numerical model may be little more than a bookkeeping method or a very complex numerical procedure; for this study, the numerical model included both ends of this spectrum. To obtain the quantitative estimate, values for all the variables employed in the mathematical model must be supplied. For this study, a very large number of variables needed to be carefully specified because the variable specification must represent the characteristics of the site and the surrounding area and the behavior of the receptors.

As described in more detail in Section 4.4, the numerical model used for this dose reconstruction is encoded in the GENII computer code. Although this generic dose assessment computer code has already encoded a large variety of mathematical models, a major and crucial task of this project was to configure the GENII code to represent the conceptual model for this dose reconstruction. This configuration was achieved in two main ways:

1. The GENII code is comprised of many modules, and each module represents a particular process in the overall approach presented in Figure 4-1 (e.g., the uptake of radionuclides by a plant from the soil in which it grows). Incremental doses to a receptor are estimated by linking together a sequence of these modules. For example, a particular sequence might include: 1) transport of some of the release by air dispersion to a specified location, 2) deposition onto the soil, 3) incorporation into the soil, 4)

uptake by a plant, 5) ingestion of the edible portion by the receptor, 6) dose to the receptor, and 7) resulting risk to the receptor. A fundamental decision was determining which modules to use and how they should be interconnected. Some modules, although available in GENII, were deliberately omitted (e.g., contamination of soil by irrigation with contaminated water was not used because agricultural practices in the SRS vicinity did not include irrigation by river water.) Each complete set of modules leading to a receptor dose has been termed "an exposure pathway" as described in Chapters 9 and 11. A total of 18 different exposure pathways were used in this study: 13 for air releases and 5 for water releases.

2. Providing the number and location of places where radionuclides were released and receptors were exposed was essential in representing the site. Chapter 3 describes the choice of the exposure locations based on the CDC/SRS Health Effects Subcommittee (SRSHES) scenarios. Chapter 6 describes the choice of locations for the release of radionuclides to air; four virtual sources were used to represent time-varying releases from multiple facilities. Chapter 7 describes how concentrations of radionuclides in water were estimated at two locations based on releases from multiple facilities.

An essential aspect of the analytical framework is the central importance of the conceptual model. Very simple environmental and radiological analyses may be performed by choosing a computer code, supplying a set of input data, and directly obtaining the answer. However, all but the simplest environmental analyses require careful development of the conceptual model. For this study it was necessary to consider: 1) the complex geometrical configuration of sources and receptors, 2) the time-varying characteristics of the releases and receptors, 3) the complex processes governing transport of radionuclides in air and water, and 4) the uncertainties in release data and other information. For this dose reconstruction, determination of the conceptual model required careful research and in some cases extensive analyses. These enabling analyses are incorporated in this report; several were supplied to the CDC and SRSHES as independent white papers for review and comment as the work was in progress.

4.2.3 Analysis Steps

The analysis was conducted in two steps: 1) a deterministic step resulting in a point-estimate of dose for each receptor and 2) a probabilistic step resulting in many estimates of dose (a dose distribution) for each receptor. Although the two steps had different scopes, goals, and results, they yield complementary information that provides a more comprehensive understanding of how the SRS releases induced doses in the hypothetical receptors. Table 4-1 summarizes some important differences between the two analysis steps.

Step 1 established a point-estimate value of dose and risks for each receptor. This was accomplished by assigning a single representative value for each variable used in the dose assessment; for this study hundreds of variables were specified after research and evaluation. These representative values were chosen to be realistic (i.e., not intentionally overestimating or underestimating the doses). Perhaps more important than establishing a point-estimate of dose, these modeling results were used to understand the relative importance of radionuclides, transport pathways, exposure pathways, and other factors. This information, presented in Chapter 11, was used as input for conducting the second step.

Although a single representative value was used for each input variable in Step 1, every variable is uncertain to one degree or another. Two major types of uncertainty are variability and lack of knowledge. Variability comes from parameter values that change in time or over the geographical region modeled. For example, consumption rates by receptors for various foodstuffs changed with nutritional habits over time, but were assumed constant, because these data were not available on a site-specific basis. Because there is not a single value, there is uncertainty as to which one to choose. An example of lack of knowledge is a parameter value not measured for the SRS, but measured elsewhere. There may be a value, but it cannot be applied without uncertainty. Both types of uncertainty were encountered in this

study. This uncertainty in input variables is usually represented by a probability distribution that describes the likelihood that a variable will have a particular value.

Table 4-1 Comparison of Steps 1 and 2

Attribute	Step 1	Step 2
Analysis Type	Deterministic.	Probabilistic.
Variables	All have a fixed value.	Most have a fixed value; 14 uncertain.
End Point	Dose and risks.	Dose.
Subcategories of Dose and Risk	All (organs, radionuclides, exposure pathways, release mode).	Only total dose.
Radionuclides	All (result of Level 1 screening in Phase II).	Minor contributors to dose screened out.
Exposure Pathways	All (all potential contributors).	Minor contributors to dose screened out.
Primary Goal	Understand how doses arise; screening for Step 2.	Establish confidence intervals around mean estimated dose.
Result	Single estimate of dose for each receptor.	Multiple estimates of dose for each receptor.

Step 2 of the analysis evaluated the effect of input variable uncertainty on dose estimates. This probabilistic analysis was simplified by 1) eliminating radionuclides and exposure pathways that were clearly minor contributors to dose and 2) eliminating from the set of uncertain input variables those variables estimated to be minor contributors to the uncertainty in dose. These simplifications helped to focus the analysis and eliminated some extensive computations likely to yield little benefit. By considering input variables with a strong influence on the uncertainty in dose as uncertain, Step 2 provided average values (mean and median) of the dose for each receptor as well as confidence intervals around those values. Although the probability distributions describing the input variables were anchored by the point estimate values for those variables, the mean and median doses calculated in Step 2 were generally higher than the point-estimates of dose calculated in Step 1. In addition, Step 2 included some sensitivity and uncertainty analyses. These analyses developed quantitative measures that indicated which input variables had the largest effect on dose and which variables contributed most to the uncertainty in dose.

4.3 Assessment of Radionuclide Release, Transport, Exposure, and Consequence

The modeling process for this study has four major components:

1. Release of radionuclides into the air and to surface water.
2. Transport of radionuclides through the air, surface water, and food chain (soil, plants, and animals) to exposure locations.
3. Exposure of receptors to contaminated media (air, water, soil, foodstuffs).
4. Dose and risk assessment.

Each of these components is described more fully below. Note that, because calculation of dose is performed in the fourth, rather than the third component, this is a slightly different breakdown than is shown in Figure 4-1. This change, which is explained more fully in Section 4.3.3, is made for convenience and has no substantive effect.

4.3.1 Release of Radionuclides

Chapters 5, 6, and 7 discuss the release and transport of radionuclides into the air and surface water. Because it was difficult to cleanly separate the analysis of release and transport, Chapters 6 and 7, although nominally treating transport, also treat certain aspects of the release. The goal of the release assessment was to develop a time history of radionuclide release on a yearly basis. Although information was available for some facilities and some radionuclides on a much shorter time interval, annual average releases were considered suitable for this intermediate-phase dose reconstruction.

Using information from the Phase II study and from other sources, a compilation of data was created that listed the quantities of radionuclides released for each year into the air and water by each major SRS facility. Data were compiled for 15 individual facilities, including 5 reactors, 2 separations facilities, 1 tritium recovery and purification facility, 2 waste treatment facilities, 2 seepage basins, and 3 other areas were radioactive materials were handled and stored. These data were used as input to the transport assessments performed for this study. For example, facility-specific atmospheric releases were coalesced into four groups that were then represented in the transport calculation by four virtual sources.

In compiling these data, careful checking and evaluation was performed to ensure that the detailed source terms compiled for this phase were consistent with the summary releases stated in the Phase II report. Because the summary releases incorporated certain correction factors that could depend on a particular radionuclide, facility, and year, ensuring consistency required significant care and effort. For the probabilistic analysis, the same single factor was applied to all radionuclides, from all facilities, for all years; this factor raised or lowered all releases to account for the uncertainty in knowing precisely the quantities that were released.

4.3.2 Air, Water, and Food Chain Transport Assessment

Radionuclides migrate from the point of release through the environment and end up in one of five environmental compartments or media: air, water, soil, plants, or animals. The transport assessments estimate the concentrations of radionuclides in these various media. As described in Section 4.3.3, a receptor may come into contact with these contaminated media in a variety of ways that can result in a dose to the receptor. For convenience, this report has partitioned the discussion of transport into three parts: 1) Chapter 6, Transport of Radionuclides through the Air to an Exposure Location; 2) Chapter 7, Release of Radionuclides to Water and Transport to an Exposure Location; and 3) Chapter 8, Food Chain Transport.

As discussed in Chapter 6 and Appendix D, the transport of radionuclides released to the air from onsite facilities to exposure locations is estimated by an extension of the Gaussian plume model. This extended model, the sector-averaged model, sums up contributions over a range of wind speeds and stability classes characteristic of the site. The result of this calculation is an annual concentration of each radionuclide in air at the specified exposure location, which depends only on the release for that year.

In the absence of detailed information about meteorological conditions during the early days of the SRS operation, data averaged over 20 years of SRS operation (the Joint Frequency Distribution data) was applied to each of the entire 39 years considered in the study. Modeling the changes in annual average meteorology did not seem appropriate at this phase because other, more significant uncertainties would

not have been addressed. For example, acute releases occurring over a few hours or days contributed substantially to the release quantities in early years. These releases, if modeled more precisely as acute events with weather conditions specific to the release time, may have produced substantially different dose estimates. Considering weather conditions on an annual basis would not address these uncertainties. During transport of radionuclides from the release point to the exposure location, the model considered loss of radioactive material resulting from radioactive decay and deposition. Release and exposure locations were modeled as points. Transport of radionuclides from 4 virtual sources to 10 exposure locations was analyzed. For the uncertainty analysis, the Joint Frequency Distribution data obtained for the SRS were considered to be fixed. However, parameter variable distributions for certain other parameters related to air transport, such as the radii of radioactive particles, were considered uncertain.

The water transport was addressed by estimating the concentration of radionuclides in water at two exposure locations: 1) a point near the town of Martin on Lower Three Runs Creek and 2) a point on the Savannah River just below its confluence with Lower Three Runs Creek. The exposure location on the Savannah River was used to represent potential exposure locations elsewhere on the river because there was no strong basis for the estimation elsewhere and, at this point, all the liquid releases from the site were diluted by the smallest quantity of river water containing the entire release.

The simplest approach to modeling water concentrations is to divide the annual quantity of radionuclides released by the annual flow. This simple model was unsuccessful because 1) the concentrations estimated this way did not match the measured concentrations for key radionuclides and 2) significant processes for storage and release of radionuclides by sediment and biota on the SRS were not addressed. Tables 7-3 and 7-4 present the estimated versus actual concentrations for key radionuclides.

Two different modeling approaches were used to calculate concentrations in the Savannah River and Lower Three Runs Creek. For concentrations in the Savannah River, a model used in Chapter 5 of the Phase II report for three radionuclides was adapted and extended to additional radionuclides included in this study. This model had taken into account the storage and release of radionuclides in bodies of water on the SRS site. For Lower Three Runs Creek, actual measured concentrations at Martin were used whenever possible; however, only data for ^{137}Cs, ^{90}Sr, and tritium concentrations were available. For early years, when concentrations were likely high, direct measurements were not available; however, concentrations were estimated based on annual releases and flowrates by extrapolating from years with concentration data. Chapter 7 describes more fully these models and extrapolation methods. For the uncertainty analysis, liquid transport variables were considered to be fixed; however, the radionuclide concentrations were varied by the adjustment factor described for releases.

Soil concentration was determined by considering deposition from the air, mixing in the soil layer, and removal by radioactive decay, leaching, and weathering. Many of the variables in this model (e.g., particle diameter and weathering rates) were considered candidates for treatment in the probabilistic analysis. The process of deposition at exposure locations was the same as those used to assess depletion of the plume during transport of radionuclides from the release point to the exposure location. Similar models are used to estimate deposition on plant surfaces. A simpler model was used to estimate deposition of radionuclides from water into sediments on the side of streams. Chapter 8 describes these models and variables in more detail.

A standard but complex model was used to estimate the concentration of radionuclides in plants. The model considers uptake from deposition on leaves, uptake by roots from contaminated soil, migration to edible parts by the plant, and removal by weathering and other processes. Numerous plant-specific and radionuclide-specific uptake factors were researched for inclusion in this study (e.g., the growing period and standing biomass for forage was researched). Many of these food-chain input variables were

considered as candidates for treatment in the probabilistic analysis. Chapter 8 describes these plant food-chain models and variables in more detail.

A relatively simple, standard model was used to estimate the concentration of radionuclides in animals. This model considers the daily ingestion rate of the radionuclide and the fraction of the amount ingested that is retained in a particular tissue such as meat (muscle), milk, or eggs. These variables (i.e., the consumption rates for particular animals and uptake rates for particular radionuclides and animals) were researched. Many of these variables were considered candidates for treatment in the probabilistic analysis. Chapter 8 describes these animal food-chain models and variables in more detail.

4.3.3 Exposure Assessment

To produce a dose estimate, an exposure assessment usually combines information about radionuclide concentrations in contaminated media with information about how receptors come in contact with the contamination. However, as explained in Section 4.3.4, it is more convenient to combine the dose and risk considerations together. The exposure assessment then calculates intake for radionuclides inhaled or ingested, or calculates exposure for external radiation. These outputs of the exposure assessment are readily converted to dose (and risks) by multiplying an appropriate dose conversion factor that is age dependent.

Dose to a receptor is produced when contaminated media contact the body through one of three exposure routes: external exposure, ingestion, or inhalation. A fourth exposure route, dermal contact, is not considered important in this study. Eighteen different exposure pathways were selected as appropriate to characterize the doses produced at the SRS through these three exposure routes. The following exposure pathways are associated with each exposure route:

- External radiation:
  - Immersion in a plume of air.
  - Exposure to contaminated soil.
  - Exposure to a contaminated shoreline.
  - Exposure to contaminated water while swimming.
  - Exposure to contaminated water while boating.

- Ingestion:
  - Leafy vegetable consumption.
  - Root vegetable consumption.
  - Fruit consumption.
  - Grain consumption.
  - Beef consumption.
  - Poultry consumption.
  - Milk consumption.
  - Egg consumption.
  - Inadvertent soil consumption.
  - Fish consumption.
  - Inadvertent ingestion of water while swimming.

- Inhalation:
  - Inhalation of contamination in the air.
  - Inhalation of contamination resuspended from soil.

The models used for each of these exposure pathways are similar and involve multiplication of the following factors:

- Medium concentration.
- Intake/contact rate.
- Exposure duration.
- Daily activity factor.
- Annual activity factor.

An example of an intake rate is the quantity of beef consumed per year. A contact rate could be the amount of air breathed per day. Exposure duration measures the amount of time a subject is in contact with contaminated media. The daily exposure factor could be the number of hours spent swimming or boating for each occurrence of such a recreational event. The annual activity factor could be how many days a year was spent swimming or boating. The result of these 18 exposure models are either the amount of radionuclide taken into the body (intake) or the amount of exposure to external radiation.
Although the form of each model is the same, the variable values used in each are selected to represent the characteristics of the receptor as delineated in the scenarios. Appendix E presents the rationales for variable values associated with receptor behavior such as food consumption rates and breathing rates. Generally, U.S. average values (e.g., from U.S. Environmental Protection Agency [EPA] or U.S. Nuclear Regulatory Commission [NRC] guidance) were used. Variable values associated with receptor behavior were not treated as uncertain variables because they described hypothetical scenarios. In addition, overlaying an additional treatment of uncertainty seemed redundant because the specification of these hypothetical scenarios was intended to bracket a wide range of behaviors. Furthermore, other variables associated with the scenarios, such as the location and the age of family members, were fixed by the scenario specifications.

Appendix F addresses variables that are independent of receptor actions but depend on site-specific environmental conditions. Where information was available, values specific to the SRS or the surrounding region were used. Some variables depended on local practices that varied over time. However, SRS-specific data frequently were not available. In those cases, generic data were obtained from other sources, such as the International Atomic Energy Agency's handbook of parameter values (4), if the variable values were available and were appropriate. As a last resort, default variable values associated with the GENII code were used (5).

4.3.4 Dose and Risk Assessment

This assessment calculates dose, cancer incidence, and cancer risk for each receptor. These doses and risks are calculated from the intakes and exposures that are the output of the exposure assessment. The calculation is accomplished by multiplying the intake or exposure by a dose conversion factor or a risk conversion factor. These conversion factors have been developed through over 50 years of scientific research and modeling and are approved by international and national radiation protection organizations. The U.S. Environmental Protection Agency (EPA) issued tables of these coefficients in its April 2002 update to Federal Guidance Report (FGR) No. 13 (6). External exposure doses for all pathways except water immersion were calculated using adult dose coefficients issued by EPA in FGR No.13 (7). Dose coefficients for external exposure from water immersion were those issued by EPA in its FGR No. 12 (8). Similarly, cancer risks (both incidence and fatality) were calculated by using risk coefficients issued by EPA in its April 2002 update to FGR No. 13 (6). External exposure risks for all pathways except water immersion were calculated using adult dose coefficients issued by EPA in FGR No.13 (7). Risk coefficients for external exposure from water were assumed to be 0.05 per Seivert for cancer fatality and 0.06 per Seivert for cancer incidence.

For this study, all risk and dose coefficients (conversion constant from radiation exposure to probability of cancer and radiation dose from exposure) were applied to the analysis as point-estimates. Uncertainty in the dose and risk coefficients in the uncertainty analysis was not analyzed. Appendix D of FGR No.13 (7) outlines an approach to derive uncertainty intervals for these dose and risk coefficients. This approach, however, is complex and lengthy and requires multiple expert elicitations. This was judged to be beyond the scope of this phase, which focused on variables with far more uncertainty which focused on the characteristics of the site and the surrounding population.

4.4 Computational Framework – Computer Analysis

To automate the computational process, a combination of existing and custom-designed software was used. The assessments of radionuclide transport, human exposure, dose, and risk were performed using state-of-the-art environmental analysis and risk assessment software (i.e., Version 2 of GENII). The GENII code was linked to a pre-processor and post-processor. The pre-processor was developed to efficiently compile and prepare input data for use by the GENII code. The post-processor was developed to efficiently determine doses and cancer risks for both the point-estimate and probabilistic analyses. For the latter, a generally available computer program, Latin Hypercube Sampling (LHS), was used to provide multiple samples of the input variable values (realizations) to the core computer code (9).

4.4.1 Selection of Environmental Analysis and Risk Assessment Software

At the early stages of the project, it was recognized that the assessments to be performed were computationally demanding. There were three main reasons for this:

1. As explained in Section 4.2, the dose assessment requires the linking of several sub-assessments or calculation modules. Given the 18 different exposure pathways considered and the number of times each chain of modules is activated, the calculation must be automated for the calculation to be feasible. Furthermore, each module requires input variable values, which it may share with other modules. The consistent and accurate transfer of these variable values between modules also must be automated.
2. The dose was calculated by adding up incremental doses from each year, radionuclide, exposure pathway, medium of release, etc. This calculation was done for each of the 28 receptors. Doses and risks were also disaggregated by organ (i.e., a huge amount of data needed to be stored, transferred, and processed).
3. Some variables changed as a function of time. The quantities released of each radionuclide changed annually. The sensitivity of the receptors to radiation dose was modeled as changing with the age of the children in each scenario. Some behavioral characteristics (e.g., the amount of beef consumed) also changed in time. These temporal changes were required to be synchronized.

Three approaches were considered to automate the dose reconstruction calculations: 1) use an existing code, 2) custom-develop a code, and 3) use an existing code but augment it with additional custom software to facilitate the analysis. Approaches 1) or 3) were preferred, assuming an existing computer code could be found that met the analytical requirements of the study.

As addressed in Appendix H, the analytical requirements were compared to the capabilities of existing computer codes. Among these requirements were the ability to simulate the models in each of the four linked assessments described in Section 4.2, the ability to allow desired inputs and provide desired outputs, and the flexibility to adapt to conditions near the SRS. Sixty-six codes were identified based on their general classification as tools for environmental transport, exposure, dose, and risk modeling. After screening these codes, 17 candidate codes were evaluated for their suitability. This evaluation eliminated codes that only addressed a limited number of pathways and exposure scenarios. From this evaluation,

two suitable codes emerged: Hanford Environmental Dosimetry System, Generation II, Version 2 (GENII); and Multimedia Environmental Pollutant Assessment System (MEPAS). Additional relevant information about the two codes was collected by obtaining and reviewing available literature and copies of these codes, and discussing various code characteristics with representatives who were responsible for developing and validating the codes. These codes were then critically compared for each analytical requirement. This evaluation chose Version 2 of GENII.

The GENII computer code was developed at Pacific Northwest National Laboratory (PNNL) to support radiological exposure and risk assessment for EPA's Office of Indoor Air and Radiation. The GENII code was developed to provide a state-of-the-art, technically peer-reviewed, documented set of programs for calculating radiation doses from radionuclides released to the environment. Radionuclide transport via air, water, or biological activity may be considered. Details of the GENII code may be found in its software design document (5).

4.4.2 Linkage of GENII Code with Pre- and Post-Processors

To efficiently address the large amount of data that was used for the analysis and the voluminous nature of the calculated results, a pre-processor and post-processor were linked schematically to the GENII code. Figure 4-5 shows the schematic of information flow. Appendix G presents a detailed discussion of the computational process.

The pre-processor warehouses input data (e.g., the quantities of radionuclides annually released into the air and water and the specifications of the seven hypothetical family exposure scenarios) and prepares this data for use by the dose program. After receiving this input data, GENII performs the transport and exposure pathway computations that estimate the dose and risk. These calculations are based on unit values (1 Becquerel (Bq) released, 1 kilogram of beef ingested per year, 1 hour spent at an exposure location). The post-processor then accepts the output from GENII and performs additional calculations to adjust the output from GENII to reflect receptor behaviors and characteristics representative of the assumed age of the receptor (e.g., the annual quantities of a specified food consumed by a teenager). Adjustments are also made for the age-sensitivity of the receptor. The result is radiation doses and cancer risks for each receptor that are appropriate for the age and assumed lifestyle of that receptor. The post-processor is also used to create files for input to the sensitivity and uncertainty analysis.

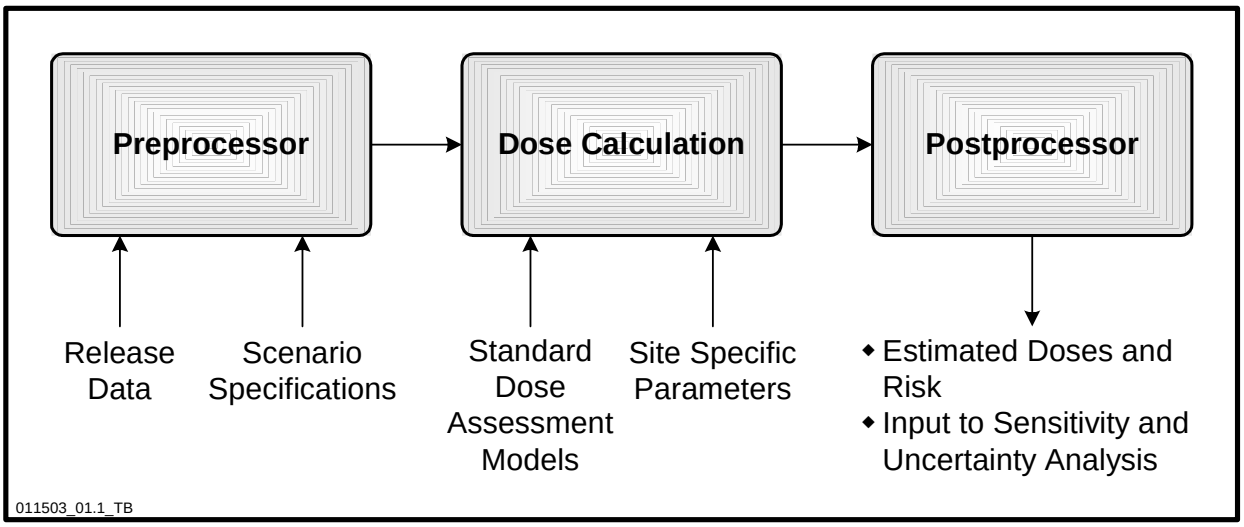

Figure 4-5 Schematic of Information Flow for the Dose Reconstruction Effort

4.4.3 Probabilistic Calculations

The same basic computational approach was used to perform the probabilistic analysis. However, multiple sets of input variable values (realizations) were generated by the generally available LHS computer code (9). The LHS code takes as input the probability distributions describing the uncertainty in selected input variables and provides a set of realizations of those variables. The statistical method encoded in LHS permits efficient estimation of statistics for the dose. Thus, the dose calculation was performed for each realization. The pre-processor was used to sequence through the 40 realizations of uncertain input variables.

4.5 Quality Assurance and Quality Control Procedures

The Quality Assurance Program for this study was designed to provide oversight of all activities and actions performed in support of the development of the point-estimates and the uncertainty analysis. In the initial stages of this study, it was determined that errors could be introduced through calculations and adjustments to existing information and data, through inputting data into electronic spreadsheets and files, through programming of modeling software, and through the interpretation of the modeling results. To address these potential sources of error, Standard Operating Procedures (SOPs) were developed which delineate the protocols for reviewing data management activities, data input, software development, and technical and editorial review of the study report.

The SOPs developed for use on this study include:

- Work Process Controls for the Savannah River Dose Assessment.
- Quality Assurance Training.
- Technical Review and Approval of Task Products for the Savannah River Dose Assessment.
- Records Management for the Savannah River Dose Assessment.
- Quality Assurance Review of Scanned Documents.
- Production of Electronic Records from Hardcopy Documents.
- Computer Software Design for the Savannah River Dose Assessment.
- Quality Assurance of Computer Codes Used for the Savannah River Dose Assessment.
- Quality Assurance (QA) for Testing and Accessing Computer Codes Used for the Savannah River Dose Assessment.
- Information Control.

These SOPS were prepared by the Project Quality Assurance Manager, approved by the Project Director, and the project staff was trained to the requirements of the SOPs.

The basic requirements of the Quality Assurance program for this study as delineated in the SOPs include:

- All project staff must be knowledgeable of the requirements of the applicable SOPs.
- All work products developed in support of this study must be technically or editorially reviewed by a qualified independent reviewer for calculational or input errors and approved for use on the study by the Project Director. A qualified independent reviewer is someone who has the appropriate background through education or experience and was not responsible for the development of the work product.

- All calculations or modifications to data must be reviewed to determine 1) if the calculation was appropriate, i.e. was the right mathematical formula used for the calculation, and 2) was the calculation executed correctly.
- All software developed for this study must be supported by an approved design document and the software must be verified and validated as correct. The software verification and validation process is described in Appendix P – Quality Assurance/Quality Control.
- All documentation relating to the development and review of work products, such as technical review forms, drafts of report sections, decision documents, project staff communications, and original data sources, are considered Quality Assurance Records and must be maintained in accordance with the Records Management and Information Control SOPs.

4.6 References

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5 RELEASE OF RADIONUCLIDES TO AIR

This chapter summarizes the Phase III effort to derive a detailed source term for radionuclides released into the air from Savannah River Site (SRS) facilities. These radionuclides and the annual quantities released are listed in Appendix B.

CDC previously sponsored Phase I and II of the SRS Dose Reconstruction Project. During Phase I, records necessary for the project were assembled, including facility release records, monthly and weekly reports, laboratory notes, research papers, and personnel interviews. During Phase II, radionuclide and chemical releases were estimated using the records obtained during Phase I. The Phase II study considered uncertainties in the SRS reports of historical radionuclide release. For some isotopes of concern, particularly ^{131}I, the Phase II study provided estimates of release that are notably larger than those historically reported by SRS (Phase II).

The Phase II study was used as the primary basis for the Phase III source term. The Phase II estimates were refined for use in Phase III to achieve greater source term resolution in time and space: i.e., releases by year and location. This greater resolution was mandated by geographically distributed scenarios and the concern with temporal changes expressed in the scenario specifications. Other refinements related to isotopic composition and chemical form provided for more precise modeling of health effects.

5.1 Development of Study Source Term

5.1.1 Approach to Development of Study Source Term

As discussed in Chapter 1, the scope of this Phase III dose reconstruction study was intended to move beyond a screening analysis to identify biologically significant radionuclides and dose pathways. In order to produce a dose assessment with the desired level of detail and confidence, a more refined source term than was available from Phase II was sought. This refined source term for air releases addressed specific requirements of the analysis, which included the following broad themes.

To use the results of Phase II, including the identification of significant radionuclides by a screening analysis and modification of historical release data to account for instrumentation deficiencies;

To provide enough spatial definition to the source term so that the geographical characteristics of the various scenarios (and their proximity to particular sources on site) would be adequately represented;

To provide enough temporal definition to the source term so that the age-related characteristics of scenario members (as they interacted with the time-varying releases from the SRS) would be adequately represented;

To provide enough detail about the chemical and isotopic characteristics of the releases so that the dose and risk modeling (treatment of health effects) would be more precise.

To enhance the completeness and/or accuracy of the source term.

Starting with the Phase II results, a sequence of steps was followed to obtain as source term for Phase III with the desired qualities. Figure 5-1 outlines this sequence and briefly describes for each step the requirement or need addressed, the additional input information used, and the status of the data set representing the source term after each modification. Each step is described in more detail in the following sections.

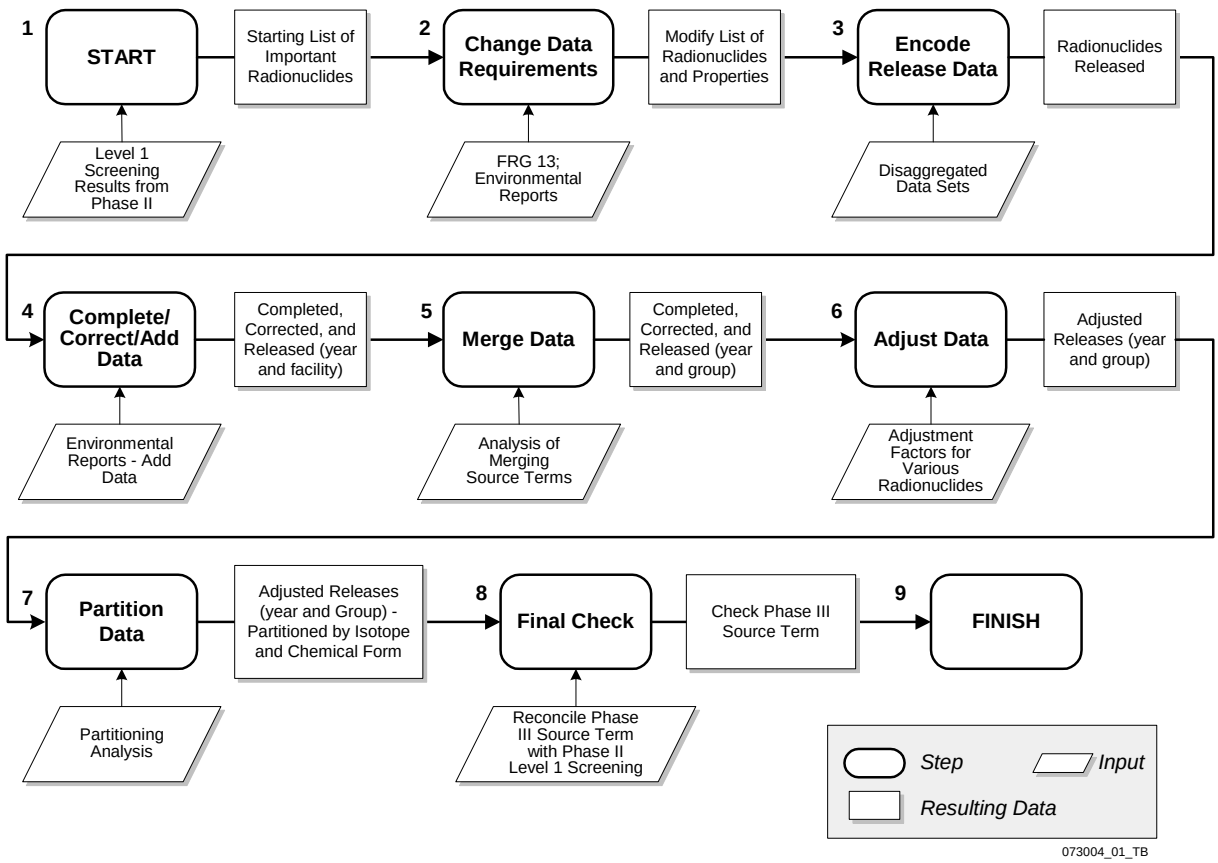

Figure 5-1 Development of Study Source Term

5.1.2 Identify Important Radionuclides based on Phase II

Phase II provided a number of results that became starting points for Phase III, including: (1) Two screening analyses that established a reduced set of radionuclides to consider in the dose reconstruction; and (2) Detailed source terms for these radionuclides, with varying degrees of spatial definition. These two aspects are summarized in the following sections.

5.1.2.1 Use Phase II Results (Step 1)

Phase II, Screening Level 1, identified twelve groups of key radionuclides released to air; Screening Level 2 further refined the list to include only six radionuclides. To avoid possibly overlooking an important contributor to the Phase III radiological assessment, all twelve groups of key radionuclides identified in the Level 1 screening were modeled in Phase III.

The Phase II screening assessment started with a master list of radionuclides that had been released into the air from SRS facilities. Preliminary estimates of their annual average release rates were also made. But because this list was too large for efficient analysis, a screening assessment was performed to identify a smaller list of key radionuclides that were the dominant contributors to radiation dose and risk (Phase II). This screening assessment was performed using a two-step method recommended by the National Council on Radiation Protection and Measurements (NCRP) for prospective evaluation of a new facility. The method featured (1) a screening considering the summation of six possible exposure pathways, and (2) a screening considering each of the exposure pathways plus the sum total of all six pathways (1), (2).

In both screening steps significant simplifications included:

- releases were averaged over 36 years (from 1954 to 1989)
- concentrations at the point of release were used, rather than concentrations plausibly at the locations of individuals
- standard human behavior patterns -- e.g., consumption rates of foods -- were assumed; and
- adult rather than age-dependent dose conversion factors were used (Phase II).

For these and other reasons, the screening values thus calculated were not plausible representations of doses to actual humans. Rather, the screening values were highly conservative estimates meant only to identify those radionuclides that should be considered in further analyses.[1]

For Level 1, a total screening value was calculated representing the sum of all screening values calculated for each radionuclide. Then those radionuclides were identified that had screening values contributing at least 0.1% of the total screening value. Using a cut-off of 0.1% of the total estimated dose, the initial list of radionuclides was reduced to twelve. These twelve key radionuclides together accounted for more than 99% of the total screening value (Phase II). The radionuclides thus identified in the Level 1 of the screening assessments for air release are listed in Table 5-2. Many of the radionuclides are actually groups of aggregated isotopes such as combined ^{239}Pu and ^{240}Pu.

Table 5-2 Radionuclide Rank from Phase II Level 1 Screening

Radionuclide	Percent of Total Screening Value (%)
^{131}I	50.6
^{3}H	33.7
^{41}Ar	7.0
$^{239, 240}$Pu	2.6
^{129}I	2.3
^{103,106}Ru	1.1
^{238}Pu	0.7
^{14}C	0.6
^{137}Cs	0.6
Uranium*	0.3
^{89,90}Sr	0.2
^{241}Am	0.1
Total	99.8
*Screened in Phase II as combined ^{235}U and ^{238}U.	

[1]A report describing the NCRP screening method notes, on page 4: "The assumptions and methods incorporated into all of the screening procedures presented in this Report are such that actual doses should not be underestimated by more than one order of magnitude. In most situations, the actual dose will be significantly less than the values calculated for screening" (2).

This is the starting list of important radionuclides for Phase III.

5.1.2.2 Phase II Estimates of Radionuclide Release

Phase II provided estimates as annual averages over 36 years of site operation for all twelve groups of key radionuclides identified in Level 1 of the screening analysis (see Table 5-3). These averages spanned a period from 1954 through 1989. Annual release estimates were provided for all twelve radionuclide groups except ^{14}C and ^{241}Am for which 36-year averages were provided. More detailed estimates were provided on an annual basis for tritium; $^{89,90}Sr$; ^{129}I; ^{131}I; ^{137}Cs; uranium; ^{238}Pu; and $^{239,240}Pu$. The level of detail varied depending on the isotope. In some cases, for example, releases from specific SRS facilities (such as specific nuclear reactors) were identified, and in other cases, releases from SRS Areas or groups of facilities (such as groups of seepage basins) were identified.

Table 5-3 Radionuclides Reported in Phase II Study by Facility and Year

Radionuclide Group	Annual Estimates Provided for a Specific Facility or a Group of Facilities?	Estimates Provided as a 36-Year Average Yearly Release from the Entire Site?
^{3}H	Annual	Yes
^{14}C	Not available	Yes
^{41}Ar	Annual	Yes
$^{89,90}Sr$	Annual	Yes
$^{103,106}Ru$	Annual	Yes
^{129}I	Annual	Yes
^{131}I	Annual	Yes
^{137}Cs	Annual	Yes
Uranium	Annual	Yes (reported as $^{235,238}U$)
^{238}Pu	Annual	Yes
^{239}Pu	Annual	Yes (reported as $^{239,240}Pu$)
^{241}Am	Not available	Yes

5.1.3 Change Data Requirements to Better Model Health Effects (Step 2)

The initial list of important radionuclides resulting from the Phase II Level 1 screening analysis was modified in several ways for use in Phase III:

1. Some groups of radionuclides were partitioned into separate isotopes. This was done to provide a more refined treatment of dose modeling. By treating isotopes individually, health effects coefficients specific to those isotopes could be used in the dose modeling; if isotopes were aggregated by element, as in the Phase II screening analyses, a single coefficient (related to the isotope with the greatest health effects) would characterize all the isotopes of the element, possibly greatly overestimating doses and risks. Table 5-4 shows 16 isotopes modeled.
2. Because the releases of Ruthenium were relatively small, all releases were modeled as ^{106}Ru.

3. Uranium isotope ^{234}U and ^{236}U were added to account for production of these isotopes in the nuclear reactors.
4. One radionuclide, ^{240}Pu was dropped from consideration. The data upon which the Phase II estimates of releases were based did not list ^{240}Pu releases separately, but always combined with other isotopes. Furthermore, the health effects coefficients for ^{239}Pu and ^{240}Pu are very close, so modeling ^{240}Pu as ^{239}Pu will have little effect on the dose estimates. Since there appeared to be no basis and no motivation for differentiating these two isotopes, separate consideration of ^{240}Pu was dropped.
5. It was considered appropriate to include as releases radioactivity measured as unidentified alpha or unidentified beta-gamma activity. Although the SRS had recorded releases of such material over the years of site operation, an explicit treatment in Phase II was not apparent. Therefore two additional categories were added for these types of releases. However, to provide bounding estimates of their health effects, the unidentified alpha activity was added to the releases for ^{239}Pu and the unidentified beta-gamma activity was added to the releases for ^{90}Sr. These two classes are added to Table 5-4 to indicate that these activities were compiled and tracked separately.
6. At this point the need to refine the treatment of certain radionuclides by defining their chemical form was established. Two radionuclides: tritium and ^{131}I can have substantially different behavior in the environment depending on their chemical form. The methods used to partition these radionuclides into different chemical forms are described in Section 5.1.8.2. Methods used to partition some elements into different isotopes are described in Section 5.1.8.1

Table 5-4 Modified List of Radionuclides Considered for Phase III*

^{241}Americium	^{238,239}Plutonium†
^{41}Argon	^{89,90}Strontium‡
^{14}Carbon	^{234,235,236,238}Uranium
^{137}Cesium	^{106}Ruthenium
Tritium (^{3}H)	
^{129,131}Iodine	

*Underlined radionuclides were added.
†Unidentified alpha-emitters were modeled as ^{239}Pu
‡Unidentified beta-gamma emitters were modeled as ^{90}Sr

5.1.4 Encode Release Data from Cummins Report (Step 3)

The Phase III source term needed definition in space and time so the assessment of radiation doses and cancer risks would be able to reflect differences associated with the seven hypothetical exposure scenarios considered in Phase III. Enhanced spatial definition of the source term allowed the radiological assessment to model and to evaluate the importance of several facets of the Phase SRS dose reconstruction, including:

1. Different mixtures of radionuclides dominated the releases from the major SRS discharge locations, and these locations are often separated by several miles.
2. Radiation doses at different exposure locations specified by the scenarios depended on: (1) the quantities of particular radionuclides released into the air at the various SRS location and (2) direction-related meteorological conditions, such as the frequency that the wind blew in the direction of a particular exposure location. Several exposure locations are close to the release points, relative to the distances between some release points.

A more refined definition of the spatial distribution of releases allows for a more precise estimate of doses compared to a source term with a single assumed release point to represent all SRS release points.

Enhanced temporal definition of the source term -- that is, specifying the amount of release for each radionuclide for each year -- allowed the radiological assessment to model and to evaluate the importance of several facets of the Phase III SRS dose reconstruction:

- The behavior of the children in each hypothetical scenario changed significantly during their childhood; this included breathing rates, food ingestion rates, time spent indoors and outdoor;
- The dose and risk factors for children were adjusted until they became adults;
- The annual release rates of many key radionuclides changed considerably over 39 years; of special note were the early years of large releases (e.g., 1956).

The source term, the behaviors of the hypothetical receptors, and their dose and risk characteristics all varied in time; by considering the annual variation of the source term, the interaction of all these time variations was considered. A source term that was expressed in terms of an average over 39 years would not have allowed these important variations to be adequately considered.

To provide the desired level of spatial and temporal definition in the source term, historical release data (3), (4) was keyed into an electronic data base. This data base described radionuclide releases by isotope, facility, and year. All the data were fully cross-checked and was subject to a thorough quality assurance program.

5.1.5 Complete and Correct Data Set (Step 4)

In the initial stages of the Phase III source term data compilation, it was observed that data were not available in the Phase II report for annual release estimates for some radionuclides for the years 1954 through 1989 and for most radionuclides for the years 1990 through 1992. For Phase III, refinements to the Phase II release estimates were made to obtain a source term for all radionuclides: (1) on an annual basis; (2) for all 39 years of the study; and (3) on the basis of major SRS facilities.

For the years 1954 through 1989, when annual release estimates were given in the Phase II report in sufficient detail, Phase II was used to determine annual facility-group release rates. Otherwise, data gathered from SRS references was used. For example, for ^{14}C and ^{241}Am, the Phase II report only provided estimates for the entire site as averaged over 36 years. For $^{103,106}Ru$, the electronic version of Phase II provided a supplemental Excel file that listed annual release estimates for the F- and H-Separations Areas, but not for reactors. Phase II provided annual release data for ^{41}Ar, but the data was not proportioned among the five reactors that released this isotope.

To apportion release data among the different SRS facilities releasing radionuclides into the air, the primary reference was (3). In some cases, information in (3) and other references were given as combined values for a group of facilities (e.g., reactors). For these cases, SRS site release history was reviewed and the combined values were apportioned among facilities in accordance with the processes in the facilities that resulted in the airborne releases. See Section 5.1.8.1 and Appendix R for further information on how the release data was partitioned.

For the years 1990 through 1992, release estimates were not provided in Phase II for most radionuclides Therefore, SRS environmental reports and other environmental data (3), (4), (5), (6), (7), (8) were reviewed for these three years, and the missing source terms were added when information was available.

5.1.6 Merge Data from Fifteen Facilities into One of Four Groups (Step 5)

Section 5.1.4 describes the motivation for refining the spatial definition of the source term. At this point in the analysis, the source term was defined in a data base by each radionuclide, year, and facility. Fifteen separate facilities were considered to be independent sources of air releases. The types of radionuclide releases from each of these fifteen facilities are shown in Table 5-5.

Table 5-5 Main Sources of Air Releases of Radionuclides at SRS

Facility Type	Designation	Principal Radionuclides Released			
		Tritium	β-emitters	α-emitters	Activation Products
Reactors	C	X	X		X
	K	X	X		X
	L	X	X		X
	P	X	X		X
	R	X			X
Separations Facilities	F Canyon	X*	X	X	X
	H Canyon	X*	X	X	X
	H Tritium Stack	X*			
Waste Facilities	All Reactors Seepage Basin Evaporation†	X			
	CMX-TNX	X			
	D Area	X			
	F & H Seepage Basin Evaporation‡	X			
Other Facilities	A Area	X	X	X	X
	M Area	X		X	
	SRL	X§	X§	X§	

*Releases for these three facilities are combined in available literature for security purposes.
†The "All Reactors Seepage Basin Evaporation" is already a virtual source. Each reactor had its own seepage basin. The location of this virtual source was chosen to be close to the centroid of the locations of the reactors.
‡The "F & H Seepage Basin Evaporation" is already a virtual source, but the seepage basins for F- and H-Areas are only about one mile apart.
§Releases from the SRL may have been included in the A-Area releases for at least some years.

Although greater spatial definition was desired, these 15 major sources, as well as several minor sources were too numerous for efficient analysis considering the number of radionuclides, exposure scenarios, and exposure pathways to be addressed and the sensitivity and uncertainty analyses to be performed.

Although spatial simplification of the source term was desirable, any such simplification needed to preserve the inherent geographical variation of the air source term and a suitable level of precision in the dose calculations. Therefore, a two part analysis was performed:

1. Different combinations of individual sources into groups (virtual sources) were evaluated to determine a representative set of "virtual" sources. Different numbers of virtual sources were evaluated, ultimately settling on four groups of sources (as shown in Table 5-6).
2. A careful evaluation was performed to assure that representation of a group of sources by a single virtual source preserved a suitable precision in estimating concentrations; as discussed in more detail

below, the representation of a group of sources by these virtual sources was deemed to be sufficiently precise.

Consider a single real source on the SRS, e.g., Reactor L. Since a static, 20-year average meteorology was assumed, a given release from this single source will produce a certain concentration at each of the nine offsite exposure locations of interest, e.g., Girard, GA. First, a unit release rate (e.g., one Ci/y) was assumed for each of the 15 real sources in turn; the concentrations that the GENII code estimated were produced by these unit releases were considered to be the "correct" value. Second, a unit release rate was assumed for each of the 4 virtual sources in turn; the concentrations that the GENII code estimated were produced by these releases were considered to be the "approximate" value for the sources in each group. Third, the "correct" and "approximate" releases were compared; the result was an agreement within 18% between the "correct" and "approximate" values for all sources except one, which was within 27%. This is considered to be excellent agreement for a very stringent comparison, given that for most groups the individual sources do not operate alone. Also recall that the "correct" value is based on modeling that incorporates many assumptions and uncertainties. For example, release rates were assumed to be constant over any given year, when in actuality acute releases caused substantial deviations from this assumption. When the concentrations induced by the virtual sources were compared to the concentration induced by a group of sources of equal strength (e.g., for Group 1 each of the three real sources was assumed to have a release rate of 1/3 Ci/y, while the virtual source had a release rate of 1 Ci/y), the comparisons were even closer; the results agreed within 11%.

This simplification of sources is summarized in Chapter 6 and addressed in detail in Appendix A. The source groupings developed as a result of this analysis are shown in Table 5-6 and Figure 5-2..

Table 5-6 Groupings for Four Virtual Sources

Groups	Facilities in Group
Group 1	A-Area, M-Area, SRL
Group 2	F-Canyon, H-Canyon, H Tritium Stack, F&H Seepage Basins
Group 3	C-Reactor K-Reactor, L-Reactor, Reactor Seepage Basin release attributable to C-, K-, and L-Reactors, D-Area, CMX-TNX
Group 4	P-Reactor. R-Reactor, Reactor Seepage Basin release attributable to P- and R-Reactors

The Phase III source term for releases to air, compiled up to this point for each facility by year and radionuclide, was aggregated based on these four virtual release points.

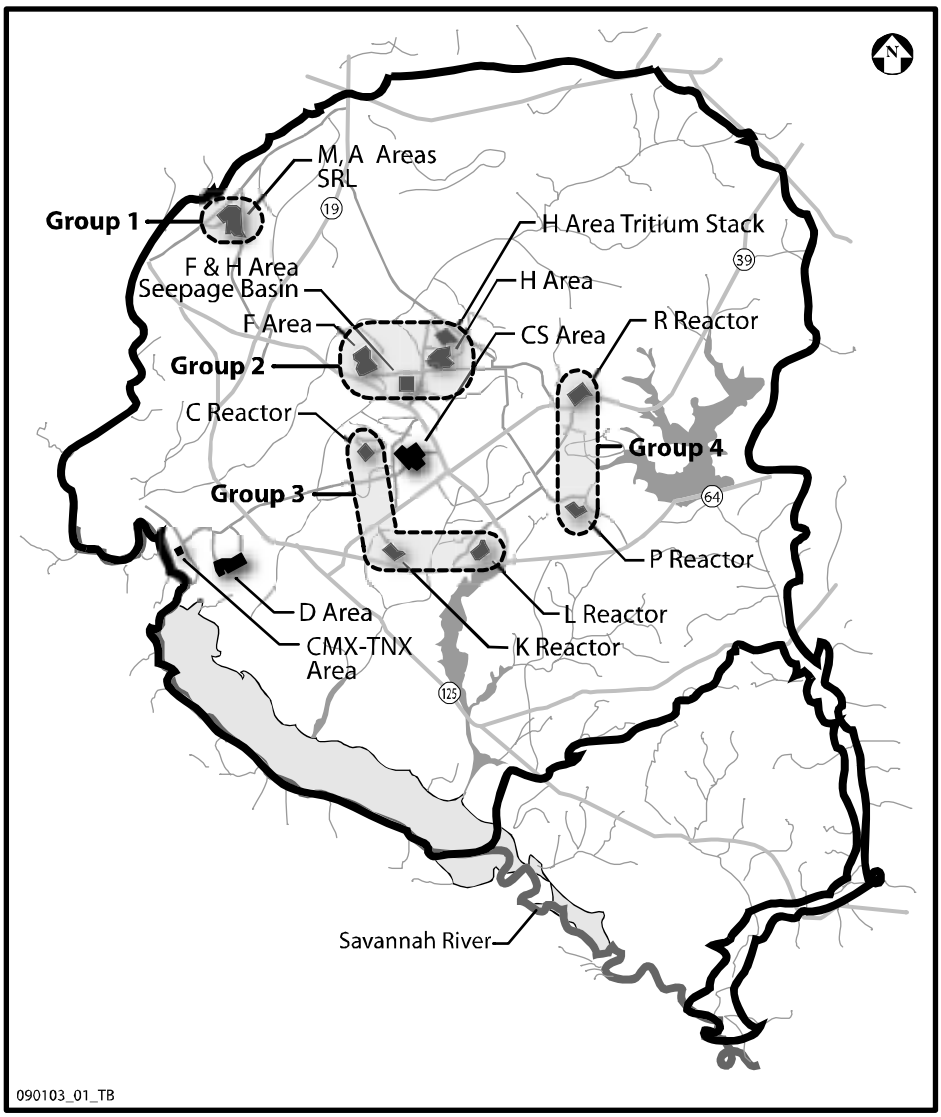

Figure 5-2 Virtual Source Locations

5.1.7 Adjust Data in Accordance With Modifications Made Phase II (Step 6)

Particularly for ^{131}I, uranium, plutonium, and tritium the Phase II estimates of radionuclide release were larger than those historically reported by SRS (3), (4). Phase II increased the released quantities to account for deficiencies in instrumentation and recording releases. Since historical data was used to provide a greater degree of spatial and temporal definition to the source term, these historical data needed to be modified for use in Phase III to account for these adjustments introduced in the Phase II report.

In Phase II, additional detailed analyses of historical estimates of release were performed for iodine, plutonium, uranium and tritium. These Phase II analyses compensated for several factors that may have caused the reported site releases to be smaller than the releases that actually occurred, including the use of different samplers over time, sampler collection efficiencies, errors associated with counting equipment, and the chemical forms of the released radionuclides. Based on a model of the transmission of effluents in sampling lines and Monte Carlo analyses, Phase II provided revised estimates for iodine, uranium, and plutonium that were generally larger from those reported over the years by SRS (Phase II). Of particular

note was ^{131}I: The Phase II estimates were significantly larger than releases historically reported by SRS.2 Phase II also observed that releases for the early years of operation (through about 1961) were more uncertain than later releases. Phase II developed probability distributions describing the releases for key radionuclides for each year modeled in Phase II. These probability distributions showed more spread (larger ratios of standard deviations to the mean value) in earlier years than in later years.

In order to incorporate the release values adjusted for uncertainties that were developed in Phase II, the adjusted values of release by year and by facility were imported from spreadsheets attached to the Phase II report (Phase 2, Directory titled Supporting_Files). Adjusted data were used for plutonium, uranium, and iodine releases. Adjusted data were not used for tritium releases in Phase III.

5.1.8 Partition Data to Account for the Mix of Isotope and Chemical Form (Step 7)

In some cases, the radionuclide releases studied in Phase II were compiled on a combined basis, e.g. all isotopes of uranium, all chemical forms of tritium. In order to enhance modeling of the health effects of air releases from the SRS in Phase III, some of these combined releases were partitioned further into specific isotopes or chemical forms. The following sections describe how certain combined releases were separated further into specific isotopes or specific chemical forms.

5.1.8.1 Isotopic Partitioning

Several radioactive constituents that were reported in the Phase II study and in SRS environmental reports were apportioned from the combined activities stated by these sources into release estimates for individual isotopes. For example, the release estimates provided in the Phase II study for ^{89}Sr and ^{90}Sr combined, were partitioned into release estimates for each of these isotopes by considering the nuclear processes occurring at the facilities that generated these isotopes. These constituents included:

- ^{89}Sr, ^{90}Sr
- ^{134}Cs, ^{137}Cs
- Uranium
- Plutonium
- Unidentified alpha
- Unidentified beta + gamma

Table 5-7 summarizes the sixteen radionuclides that were determined from this partitioning process for release to air. Source terms for Phase III were developed for each of these sixteen radionuclides. Table 5-8 summarizes how the total activity of each constituent was partitioned into constituent isotopes for each SRS site area. Additional technical information and general assumptions for the partitioning process are in Appendix C.

[2] SRS revised its iodine monitoring and sampling systems and procedures over time. According to the Phase II report, about 99% of the ^{131}I released into the air came from the separations areas. Until September 1961, only elemental ^{131}I was measured at the separations areas. SRS estimated organic iodide activity from elemental ^{131}I release, assuming that organic forms represented 70-90% of all iodine released from separations. The Phase II report addressed measurement uncertainties such as sample collection efficiency, and measurement biases resulting from deposition of elemental iodine in sampling lines, and concluded that SRS underestimated the release of ^{131}I to air during early years (1950s and early 1960s). For example, for each year from 1955 through 1960, the Phase II report estimated that the annual total iodine released to the air was at least 20 times larger than was reported in Cummins (3). For the year 1961 the total iodine released to air was 12 times larger. SRS staff (9) have criticized these Phase II estimates. After 1961, however, the Phase II estimates of ^{131}I release more closely correspond to those reported by SRS (with few exceptions). Annual ^{131}I releases after 1961 were much smaller than in earlier years (Phase II).

Table 5-7 Radionuclides Considered in Phase III Compared to Those Cited in Phase II

Radionuclides Identified in Step 1 of Phase II Screening	Radionuclides Considered in Phase III Air Release Assessments
^{3}H	^{3}H
^{14}C	^{14}C
^{41}Ar	^{41}Ar
$^{89,90}Sr$	^{89}Sr & ^{90}Sr
$^{103,106}Ru$	^{106}Ru
^{129}I	^{129}I
^{131}I	^{131}I
$^{134,137}Cs$	^{137}Cs
Uranium	^{234}U, ^{235}U, ^{236}U, & ^{238}U
^{238}Pu	^{238}Pu
$^{239,240}Pu$	^{239}Pu
^{241}Am	^{241}Am

Table 5-8 Summary of Assumed Isotopic Distributions for Air Release

Constituent	SRS Area	Isotopic Distribution by Activity
$^{89,90}Sr$	F&H Areas	75% ^{89}Sr; 25% ^{90}Sr
	A Area	100% ^{90}Sr
	D Area	100% ^{90}Sr
	Central Shops	100% ^{90}Sr
$^{134,137}Cs$	D Area	100% ^{137}Cs
Uranium	Reactor Areas	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	F Area	1.27% ^{235}U; 98.73% ^{238}U
	H Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	M Area	49.49% ^{234}U; 2.25% ^{235}U; 48.26% ^{238}U
	A Area (SRL)	91.44% ^{234}U; 1.8% ^{235}U; 6.4% ^{236}U; 0.36% ^{238}U
	CMX/TNX	49.49% ^{234}U; 2.25% ^{235}U; 48.26% ^{238}U
	D Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
Total Plutonium	All Areas	100% ^{239}Pu
Unidentified Alpha	All Areas	100% ^{239}Pu
Unidentified Beta-gamma	All Areas	100% ^{90}Sr

Radionuclides identified as $^{89,90}Sr$ in the Phase II report were apportioned into ^{89}Sr and ^{90}Sr. For most facilities, the activity was assumed to be ^{90}Sr. For the separations area, the activity was apportioned into 75% ^{89}Sr and 25% ^{90}Sr based on Cummins et al (3).

Radionuclides identified as ^{134,137}Cs in the Phase II report were assumed to all be ^{137}Cs because the fission-yield of ^{134}Cs in nuclear reactors was determined to be very small in comparison with ^{137}Cs (see Appendix C).

Radionuclides identified as ^{103,106}Ru in the Phase II report were assumed to all be ^{106}Ru. This assumption was consistent with the screening analysis used in the Phase II report to identify key radionuclides.[3] This assumption will conservatively estimate doses from ingestion and inhalation.

Radionuclides identified as uranium in Phase II were apportioned into four uranium isotopes: ^{234}U, ^{235}U, ^{236}U, and ^{238}U. The Phase II report only considered the uranium isotopes ^{235}U and ^{238}U when it performed its screening analysis. For Phase III, however, ^{234}U and ^{236}U were included. ^{234}U contributes much of the activity of natural or slightly enriched uranium. ^{236}U is produced from neutron bombardment in nuclear reactors, and would have been present in uranium released from the separations areas, among other areas at SRS.

Radionuclides identified as ^{239,240}Pu in the Phase II report were assumed to all be ^{239}Pu. The fractional activity of ^{240}Pu for weapons grade plutonium was determined to be small compared to that for ^{239}Pu (see Appendix C). Radioactive releases at SRS were often reported as unidentified alpha activity, unidentified beta-gamma activity, or undifferentiated plutonium activity. In most cases, the unidentified constituents would have been a combination of several isotopes. The fractions of total activity that individual isotopes represented probably varied from one release event to another. For simplicity, unidentified alpha activity was conservatively assumed to be ^{239}Pu because it was one of the more prevalent isotopes created at SRS, and because it is more radiotoxic than uranium isotopes for many of the exposure pathways. Other transuranic isotopes that have been produced and used at the SRS (such as ^{237}Neptunium, ^{244}Curium and ^{252}Californium) may have contributed to unidentified alpha activity, but these isotopes were produced primarily during brief periods.

Unidentified beta-gamma activity was modeled as ^{90}Sr, which was commonly reported in environmental release reports at SRS. ^{90}Strontium has a half-life that is sufficiently long (28 years) that it may persist in the environment for many years after release. On the other hand, the health effects of ^{90}Sr will exceed those of other radionuclides for important dose pathways (e.g., doses per unit of activity from inhalation and ingestion will be greater for ^{90}Sr than for ^{60}Co).

Undifferentiated plutonium (occasionally found in SRS reports) was assumed to be ^{239}Pu as this was the main plutonium isotope produced at the site.

5.1.8.2 Chemical Forms of Radionuclides

For the Phase III study two types of releases were partitioned according to their chemical form: tritium and iodine. Section 5.1.8.2.1 discusses Phase III assumptions about the chemical forms of tritium released to air. Section 5.1.8.2.2 discusses Phase III assumptions about chemical forms of iodine isotopes released to air.[4]

[3] In the supplemental files provided as part of Chapter 3 of Phase II, the following notation was made: "We combined all estimates of reported releases of ^{103}Ru (0.2 Ci), ^{106}Ru (0.5 Ci), and ^{103,106}Ru (~1 Ci), and then used the screening factor for ^{106}Ru to ensure a conservative approach" (Phase II).

[4] Other radionuclides were not partitioned by chemical form. Although health effects may depend upon "the lung clearance class" for other radionuclides, only a single class was considered for each of these other radionuclides. In addition, the model for uptake of tritium by biota depends on the chemical form.

Table 5-7 Radionuclides Considered in Phase III Compared to Those Cited in Phase II

Radionuclides Identified in Step 1 of Phase II Screening	Radionuclides Considered in Phase III Air Release Assessments
^{3}H	^{3}H
^{14}C	^{14}C
^{41}Ar	^{41}Ar
$^{89, 90}Sr$	^{89}Sr & ^{90}Sr
$^{103,106}Ru$	^{106}Ru
^{129}I	^{129}I
^{131}I	^{131}I
$^{134,137}Cs$	^{137}Cs
Uranium	^{234}U, ^{235}U, ^{236}U, & ^{238}U
^{238}Pu	^{238}Pu
$^{239,240}Pu$	^{239}Pu
^{241}Am	^{241}Am

Table 5-8 Summary of Assumed Isotopic Distributions for Air Release

Constituent	SRS Area	Isotopic Distribution by Activity
$^{89, 90}Sr$	F&H Areas	75% ^{89}Sr; 25% ^{90}Sr
	A Area	100% ^{90}Sr
	D Area	100% ^{90}Sr
	Central Shops	100% ^{90}Sr
$^{134, 137}Cs$	D Area	100% ^{137}Cs
Uranium	Reactor Areas	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	F Area	1.27% ^{235}U; 98.73% ^{238}U
	H Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	M Area	49.49% ^{234}U; 2.25% ^{235}U; 48.26% ^{238}U
	A Area (SRL)	91.44% ^{234}U; 1.8% ^{235}U; 6.4% ^{236}U; 0.36% ^{238}U
	CMX/TNX	49.49% ^{234}U; 2.25% ^{235}U; 48.26% ^{238}U
	D Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
Total Plutonium	All Areas	100% ^{239}Pu
Unidentified Alpha	All Areas	100% ^{239}Pu
Unidentified Beta-gamma	All Areas	100% ^{90}Sr

Radionuclides identified as $^{89,90}Sr$ in the Phase II report were apportioned into ^{89}Sr and ^{90}Sr. For most facilities, the activity was assumed to be ^{90}Sr. For the separations area, the activity was apportioned into 75% ^{89}Sr and 25% ^{90}Sr based on Cummins et al (3).

iodine is elemental iodine (I_2). This form of iodine has a relatively high deposition rate. It is important for assessing exposures to the thyroid through the food chain. Under favorable situations (e.g. the existence of other reactive elements, and the presence of catalysts), elemental iodine can combine with other elements and form less reactive gases such as HI, HOI and IO_3, or react with organic compounds forming even less reactive organic iodides like methyl iodide (CH_3I). Iodine existing as an organic molecule contributes to exposure by inhalation but is relatively unimportant for food chain pathways. Radioiodine can also associate with particles that can lower its reactivity. The gaseous radioiodine compound can be absorbed by non-radioactive particulate matter as well.

Two isotopes of iodine were considered in Phase III: ^{131}I and ^{129}I. Annual ^{131}I releases were monitored for the H- and F-Area separations facilities, reactors, and other facilities, mainly SRL. Annual ^{129}I releases were monitored for only the separations areas.

The Phase II report addressed the chemical form of the released iodine. Phase II release estimates for ^{131}I from the F- and H-Separations areas were apportioned between elemental iodine (I_2) and organic iodine (Phase II). Phase II did not similarly partition release estimates for ^{129}I from the separations areas, although one might expect a similar distribution. For reactors, Phase II cited measurements of iodine released at commercial pressurized water nuclear reactors by Pelletier et al (15). From this reference, Phase II estimated that "about 30% of the total would be elemental iodine and that the remainder would be divided between less reactive inorganic forms (~40% of total) and organic iodides (~30% of total)."[7] For ^{131}I releases from SRL, it was suggested in Phase II (p. 4.2-27) that "most of the radioiodine released from the shielded cells was probably in an elemental form" (Phase II).

For Phase III, the released quantities of iodine into the air were split between elemental and organic iodine in a manner consistent with the information in Phase II and summarized in Appendix B. However, data indicate that the chemical forms of released iodine change as the iodine is transported through the air (16). Therefore, the computations in Phase III for transport, dispersion, and deposition of iodine were performed assuming that the iodine was a mixture of chemical forms – i.e., 40% particulate, 30% reactive gas (elemental), and 30% nonreactive gas (organic).[8] These fractions were built into the GENII code by its creators based on their experience with modeling iodine releases (17). The manual for the RATCHET[9] computer code, which was used for the thyroid dose reconstruction work for the Hanford Reservation, observes the following regarding the transport and mid-air partitioning of elemental iodine (16):

> *In the time that it took the iodine to travel 3200 meters (2 miles), about two-thirds of the iodine had changed form. Approximately one-third of the iodine was in organic species and the remaining third was associated with particulate material. The partitioning of iodine at 3200 in Ludwick's experiments is consistent with the results of the measurement of iodine in plumes from the stacks at the Hanford Site…with the partitioning of iodine in the plume following the Chernobyl reactor accident.*

5.1.9 Compare Final Source Term to Phase II Level 1 (Step 8)

To assure consistency between the Phase II release estimates and the Phase III source term, the total release of each radionuclide over 39 years, as determined in Phase III, was compared with the 36-year

[7] Essentially, the Pelletier data indicated that iodine was released in a highly reactive form, a moderately reactive form, and a less reactive form. For the sake of conservatism, the moderately reactive and highly reactive forms could be grouped rather than the moderately reactive and the less reactive forms, leading to a split of about 70% elemental and 30% organic.

[8] Data files containing annual releases of elemental and organic forms of 131I were input into the pre-processor and added. The total 131I was then split between chemical forms in the ratios of 40% particulate, 30% elemental, and 30% organic. The revised files from the preprocessor were then input to GENII for the air transport, deposition, and radiation exposure computations. See Appendix G for details.

[9] RATCHET: Regional Atmospheric Transport Code for Hanford Emission Tracking (16).

total release estimate used in Phase II for the screening assessment. This comparison is shown in Table 5-9. The information herein cited for Phase II was obtained from the Excel spreadsheets included with the Phase II report. As discussed in greater detail in Appendix C.4, the source term used for Phase III is generally consistent with Phase II. Some groups of isotopes, however, deserve comment:

Table 5-9 Comparison of 39-Year Phase III Total Releases (Ci) to 36-Year Phase II Releases Used for Phase II Screening Assessment (Ci)

Radio-nuclide	Phase III Total from All virtual Sources	Phase II Total	Difference (Phase III – Phase II)	Percent Difference (Phase III –Phase II) x 100/Phase III	Note
^{241}Am	5.88×10^{-3}	0	5.88×10^{-3}	+ 100	X
^{41}Ar	$6.36 \times 10^{+6}$	$6.36 \times 10^{+6}$	$- 1.00 \times 10^{+3}$	- 0.02	
^{14}C	$2.97 \times 10^{+3}$	$3.00 \times 10^{+3}$	- 30.0	- 1.01	
^{137}Cs	3.51	3.51	3.72×10^{-3}	0.11	
^{3}H	$2.51 \times 10^{+7}$	$2.69 \times 10^{+7}$	$-1.80 \times 10^{+6}$	- 7.17	
^{129}I	5.67	5.65	2.20×10^{-2}	0.39	
^{131}I	$4.91 \times 10^{+4}$	$4.90 \times 10^{+4}$	$5.42 \times 10^{+1}$	0.11	
^{238}Pu	2.08	2.08	4.8×10^{-3}	0.23	X
^{239}Pu	13.2	13.14	6.03×10^{-2}	0.46	X
^{103,106}Ru*	$1.58 \times 10^{+2}$	$1.58 \times 10^{+2}$	-0.31	- 0.20	
^{89,90}Sr*	47.0	1.54	45.5	96.73	X
Uranium*	3.51	1.00	3.29×10^{-2}	0.94	X

*In the Phase II study, Ru-103,106 was screened assuming that all activity was Ru-106, Sr-89,90 activity was screened assuming that all activity was Sr-90, and uranium activity was screened assuming that all activity was U-235. For Phase III, activity reported as uranium was apportioned among the uranium isotopes U-234, U-235, U-236, and U-238.

^{241}Am: The citation of zero for Phase II in Table 5-9 reflects the fact that a 36-year screening total was not provided in the Phase II Excel spreadsheets for ^{241}Am. However, other entries in this table suggest that the value used in Phase II may well have been 5.60×10^{-03} Ci over 36 years, which is only slightly smaller than the 39-year total for Phase III of 5.88×10^{-03} Ci.

Plutonium isotopes: The Phase III source term is slightly larger than the Phase II release estimates because unidentified alpha activity was assumed to be ^{239}Pu. Because the unidentified alpha activity only summed to 0.08 curies, this adjustment to ^{239}Pu was not a significant change to the Phase II release estimate.

^{89,90}Sr: The Phase III source term for ^{89,90}Sr increased by 45 curies over the Phase II estimates because unidentified beta-gamma activity was assumed to be ^{90}Sr.

Uranium: The 39-year total uranium value used for Phase III is larger than the 36-year Phase II screening value. After performing the screening assessment, the Phase II study increased the estimated

releases of uranium from SRS over that reported by SRS to account for sampling and measurement inefficiencies (see Chapter 4.4 of the Phase II report). The Phase III source term reflects these increased Phase II estimates as well as releases during the years 1990 through 1992.

5.2 Phase III Source Term by Groups of Radionuclides

This section contains summaries of the assumptions and procedures used to develop the source term for each radionuclide released into the air and listed in Table 5-9.

Tables of the annual quantities of these radionuclides released from each of the four virtual sources identified in Section 5.1.6 are provided in Appendix B. Uncertainties associated with these release estimates are addressed in Chapter 12.

5.2.1 Tritium

The main sources of tritium release to the air from SRS were the reactors and the separations areas. Phase II provided tritium release estimates for reactors and the separations areas for almost the entire period of interest. There is good agreement between the Phase II release estimates and SRS data for the reactor and the separations areas (Phase II.). For Phase III, however, sources were added that were not addressed in detail in Phase II. These sources included tritium that evaporated annually from the reactor and separations areas seepage basins, as well as annual releases from the A-, M- and D-Areas, SRL, CMX-TNX. The information on annual release of tritium from these additional areas, facilities, and seepage basins was obtained from Cummins et al (3).

Seepage basin evaporation data in Cummins et al were presented as totals for all reactor and separations areas seepage basins (3). Annual quantities of tritium evaporated from the reactor seepage basins had to be apportioned into two virtual groups of reactor facilities consistent with Table 5-6. It was assumed for Phase III that evaporation from the seepage basins was linked to the tritium inventories that were discharged to the reactor seepage basins in liquid form. Since tritium losses by evaporation are expected to be proportional to the concentration of tritium in the seepage basin, assuming that these releases to air are proportional to the tritium inventory discharged to the basin, conservatively neglects changes in concentration from seepage of tritium into the ground; nevertheless, this seepage of tritium is then accounted for in the liquid source term. For each year, the total tritium inventory that was released into all reactor seepage basins was determined. The fractions of this total tritium inventory that were released into each of two groups of reactor seepage basins was also determined (C-, K-, and L-seepage basins in one group and P- and R-seepage basins in another). Then these fractions were assumed for the annual release of evaporated tritium into the air from each group of reactor seepage basins. These two fractions were multiplied by the total annual amount of tritium evaporated from reactor seepage basins to arrive at annual releases from both virtual groups of reactor facilities.

In addition, for Phase III, environmental report data for 1990 through 1992 was used rather than the reactor estimates for these years from Phase II. The combined totals from these environmental reports are somewhat larger than those listed in Phase II. This may be due to limited data in early studies. For these years, tritium release data were reported in the SRS environmental reports as combined releases from all reactors (4), (5), (6). Information from Phase II was used to group the tritium released from all reactors into two virtual groups of reactor facilities.

5.2.2 ^{131}I

As noted in Section 5.1.8.2.2 annual ^{131}I releases were determined in this Phase III study for the H- and F-Area separations facilities, reactors, and for SRL, and were grouped into the four virtual sources

summarized in Table 5-6. Annual release information for the years 1954 through 1989 was obtained for these facilities from Phase II. For the separations areas and reactors, the median values from the Excel spreadsheets published with the electronic version of Phase II were used. Annual release information for the years 1990 through 1992 was obtained from environmental reports (4), (5), (6). Information from (3) was used to partition the ^{131}I estimates from Phase II, which are given for all reactors, into two virtual sources consistent with the reactor groupings in Table 5-6.

5.2.3 ^{41}Ar

^{41}Argon is an activation product that was created in large quantities during reactor operations. It is a noble gas having a short (1.83 hours) half life.

For Phase III, as in Phase II, all ^{41}Ar released into the air was assumed to come from the SRS reactors. Information from Phase II, from Cummins et al (3), and from Savannah River environmental reports (4), (5), (6) for the years 1990 through 1992 was used to partition ^{41}Ar release from the five reactors into the two reactor virtual source groupings listed in Table 5-6.

5.2.4 ^{241}Americium

For Phase III, annual ^{241}Am release data was obtained for the years 1977 through 1989 from Cummins et al (3). This reference identified ^{241}Am only for the F- and H-Separations Areas. For the years 1999 through 1992, additional data were available from SRS environmental reports (4), (5), (6) and from (18).

5.2.5 ^{14}C

For Phase III, estimates of ^{14}C released into the air were made for the separations areas and for the reactors. For the separations areas, data was available from Cummins et al. for the years 1955 to 1989 (3). Data from SRS environmental reports were used for 1990 through 1992 (4), (5), (7).

For the reactors, data was available from Cummins et al for the following time frames (3):[10]

- C-Reactor: 1955 through 1985.
- K-Reactor: 1955 through 1988.
- L-Reactor: 1955 through 1968, 1987, and 1988.
- P-Reactor: 1955 through 1988.
- R-Reactor: 1955 through 1964.

After 1988, information on ^{14}C release from nuclear reactors was available in the SRS Environmental Report for 1992 as summed over all reactors (6). For 1992, the ^{14}carbon released from the reactors was apportioned the C-, K-, L-, and P-Reactors in equal fractions.[11]

[10] Recall that R-Reactor shut down in 1964, C-Reactor shut down in 1985, P-Reactors shut down in 1988, and that L-Reactor was shut down in 1968, but was restarted in 1985 and shut down again in 1988. K-Reactor was shut down in 1988 but briefly operated in 1992 (Phase II).

[11] Release from R-Reactor was assumed to have been much smaller for the years 1990-1992, compared with other reactors, because it had permanently shut down much earlier (at least 21 years) than did the other reactors. Because of uncertainty about the fraction of the total release that should have been allotted to each of the other four reactors, the 1992 ^{14}C release (0.183 Ci) was apportioned equally among the four reactors. Hence, 75% of the ^{14}C was released from the C-, K-, and L-Reactor group, and 25% was released from the P- and R-Reactor group.

5.2.6 ^{137}Cs

For Phase III, annual releases of ^{137}Cs were estimated for all years from the separations areas and for a few years from the reactors.

Most of the SRS atmospheric release of ^{137}Cs occurred from the F- and H-separations Areas (Phase II, 3). To develop source terms for ^{137}Cs release from the separations areas, information from these references was used for the years 1954 through 1989, and data from SRS environmental reports was used for the years 1990 through 1992 (4), (5), (6).

For reactors, ^{137}Cs release was not reported for the years 1954 through 1989 (3). ^{137}Cs releases from reactors were reported, however, in SRS environmental reports for the years 1990 and 1992 (4), (6). These releases were small (on the order of 0.00002 Ci in 1990 and 0.00003 Ci in 1992), but were added to the source term for completeness. For 1990, the released activity was apportioned equally among C-, K-, L-, and P-Reactors. For 1992, the activity was all released from L- and K-Reactors. This was done because for 1992, data was available that apportioned the total released ^{137}Cs activity (3.05×10^{-5} Ci) between these two reactors (7).

5.2.7 ^{129}I

For Phase III, consistent with the information in the Phase II study and in Cummins et al., it was assumed that all release of ^{129}I to the air came from the separations areas (Phase II, 3). For Phase III, the annual ^{129}I release estimates from the Phase II study were compared with the smaller annual release estimates provided in Cummins et al. (3). For the Phase III study, the Phase II estimates were used rather than the Cummins et al estimates. As discussed in Chapter 4 of the Phase II report, the historical SRS reports may have underestimated the true release because of sampling line loss, sampler collection efficiency, and counting errors (Phase II).

For 1990 through 1992, annual release estimates from SRS environmental reports were used for the separations areas (4), (5), (6).

5.2.8 $^{103, 106}$Ruthenium

For Phase III, annual release estimates for ^{106}Ru were made for the F- and H-Separations Areas. For the years 1955 through 1989, release data were obtained from an Excel worksheet linked to the electronic version of Phase II (Phase II). For the years 1955 through 1968, data were provided as combined ^{103,106}Ru for both the F- and H-Areas. For the years 1969 through 1989, data was separately provided for ^{103}Ru and ^{106}Ru (Phase II).

For Phase III, releases documented in Phase II for the years 1955 through 1989 of ^{103}Ru, ^{106}Ru, and combined ^{103,106}Ru were assumed to be entirely ^{106}Ru. This assumption was consistent with that used in the Phase II screening analysis (Phase II) and provides conservative estimates of dose by inhalation and ingestion. Releases of ^{106}Ru for the years 1990 through 1992 from the separations areas were obtained from SRS environmental reports (4), (5), (6).

The Phase III source term also includes ^{106}Ru release from the reactor areas for the year 1990. This release was documented in the SRS Environmental Report for 1990 (4). Although the release was small (about 0.00003 Ci), it was included for completeness. This release was apportioned among the reactors.

5.2.9 ^{89}Strontium and ^{90}Strontium with Unidentified Beta-Gamma

For the Phase III study, ^{89}Sr and ^{90}Sr were anticipated to have been released into the air from the separations areas. ^{90}Sr was anticipated to have been released into the air from the reactors and from the A-Area.

Separations areas. Annual release data for combined ^{89,90}Sr from the F- and H-Separations Areas were provided in the Phase II report for 1954 – 1989 (Phase II). In Phase III, the combined ^{89,90}Sr activity was apportioned into 75% ^{89}Sr and 25% ^{90}Sr (see Section 5.1.8.1). To this activity was added the activity that was reported through 1989 in Cummins et al as unidentified beta-gamma activity (3). All this unidentified activity was assumed to be ^{90}Sr (see Section 5.1.8.1).

^{89}Sr and ^{90}Sr activity was assigned to the years 1990 and 1991 using information from SRS environmental reports (3), (5). For these two years, data were reported in these two references as combined ^{89,90}Sr, including unidentified beta-gamma. This combined activity was assumed to be all ^{90}Sr. For 1992, Arnett et al reported 1.62×10^{-3} Ci of combined ^{89,90}Sr with unidentified beta-gamma activity (6). A second reference reported 2.75×10^{-4} Ci of combined ^{89,90}Sr activity without referencing unidentified beta-gamma activity (6). The difference was 1.35×10^{-3} Ci. The activity (1.62×10^{-3} Ci) reported by (6) was partitioned between ^{89}Sr and ^{90}Sr in a 75%-25% ratio. The difference (1.35×10^{-3} Ci) was assumed to be ^{90}Sr.

Reactors. For reactors, ^{90}Sr release data were not provided in the Phase II report (Phase II). However, for the years 1954 through 1989, annual unidentified beta-gamma activity was released from reactors and reported in Cummins et al (3). This activity was assumed for Phase III to be ^{90}Sr. Reactor-specific annual ^{90}Sr estimates were apportioned using Cummins (3) data into two virtual source groups consistent with Table 5-6. For the years 1990 through 1992, the release data obtained from environmental reports for the reactor areas were equally apportioned into C-, K-, L- and P-Reactors.

A-Area. For the years 1954 through 1989, annual releases from A-Area that were identified in Cummins et al as unidentified beta-gamma activity (3) were assumed to be ^{90}Sr. For the years 1990 through 1992, SRS environmental reports were used to develop ^{90}Sr release estimates from A-Area (4), (5), (6).

5.2.10 Uranium and Plutonium with Unidentified Alpha

For Phase III, annual estimates of uranium released into the air were made for the F- and H-Separations Areas and for M-Area. Annual estimates of plutonium released into the air were made for the separations areas, the reactors, and for A-Area.

Separations Areas. The Phase II release estimates were based on information from Cummins et al (3). However, the Phase II estimates were increased in earlier years, compared with that reported by Cummins et al (3), because of concerns about sampling uncertainties. For Phase III, the Phase II estimates of release of uranium and plutonium from the separations areas were enhanced using additional data from environmental reports.

For Phase III, uranium activity was apportioned into four uranium isotopes based on the isotopic partition assumptions summarized in Section 5.1.8.1 and Table 5-8. Note that uranium isotopic composition varied in the F- and H- Separations Areas, because the processes conducted in each area differed. Uranium data for Phase III were available for 36 years from Phase II (Phase II) and for three years from SRS environmental reports (4), (5), (6).

For the years 1954 through 1989, uranium released from the F-Separations Area was reported separately in Phase II from uranium released from the H-Separations Area. This information was sufficient to

partition the uranium released from both the separations areas. But for 1990 through 1992, information about uranium released from the separations areas was provided in SRS environmental reports (4), (5), (6) only as combined releases from both areas. Isotopic partitioning of uranium was performed for these years using an SRS report for the year 1992 that provided uranium release data separately for F- and H-Areas (6). This reference indicated that 95% of the uranium in 1992 was released from the F-Area and 5% from the H-Area (6). It was assumed that this 95%-5% uranium split between F- and H-Areas was also applicable to 1990 and 1991. The total uranium released from each separations area for these years was apportioned into isotopic distributions consistent with Table 5-8. Then the total release of each uranium isotope from both separations areas was determined for purposes of the virtual source grouping. Finally, release data for each uranium isotope in F- and H-Area were increased for Phase III using the same method described in Chapter 4 of Phase II to compensate for sampling line loss.

For plutonium, Phase II increased its estimates of plutonium released into the air, relative to that reported by SRS, to compensate for sampling line loss. The source term adjustment in Phase II for plutonium air release was done for ^{238}Pu and for ^{239,240}Pu together. Because sampling line loss should have been the same for any plutonium isotope, for Phase III the procedure cited in Phase II to compensate for sampling loss was applied to both ^{238}Pu and ^{239}Pu. The total plutonium activity reported in Phase II before adjustment matched the calculated plutonium term in Cummins et al (3). Using the isotopic information provided in (3), plutonium reported as total plutonium in Phase II was apportioned for Phase III into ^{238}Pu and ^{239}Pu.

Cummins et al reported unidentified alpha activity released from the F- and H-Separations Areas (3). For Phase III, this unidentified activity was included as ^{239}Pu. The activity was increased in Phase III, relative to that reported in Cummins (3), to compensate for sampling line loss. As discussed earlier, the inclusion of this unidentified activity as ^{239}Pu did not significantly change the plutonium source term.

Reactors. Annual estimates of ^{239}Pu released from the nuclear reactors were made for Phase III using information from Cummins et al for the years 1973 through 1989 (3). In this case, starting in 1973, Cummins (3) provided air release data for unidentified alpha activity for the reactor areas. For Phase III it was assumed that this alpha activity was ^{239}Pu consistent with Section 3.5.4. For 1990 through 1992, information from SRS environmental reports was used (4), (5), (6). No estimates were made for uranium release from reactors, because such releases were not identified in Phase II, Cummins (3), or other documents.

M-Area. Annual estimates of uranium isotope releases from M-Area were made in Phase III using information from (3). This reference listed annual uranium releases (as U-Nat – i.e., natural uranium) from 1975 through 1989, except that no releases were listed for 1981 and 1984. This activity was apportioned among the isotopes ^{234}U, ^{235}U, and ^{238}U. Releases for the years 1990 through 1992 were estimated using information from SRS environmental reports (4), (5), (6).

A-Area. Cummins et al reported annual release of unidentified alpha activity from A-Area for most of the years from 1961 through 1992 (3). No release information was provided for 1964-1967, 1972, 1979, 1981, 1982, 1984, and 1985. This unidentified alpha activity was assumed to be ^{239}Pu for Phase III. Information from environmental reports was used to complete the estimates for 1990 through 1992 (4), (5), (6).

5.3 Annual Release of Tritium, ^{131}Iodine, and ^{41}Argon

As will be seen in Chapter 11, radiation doses calculated from the air pathway are dominated by tritium, ^{131}I, and ^{41}Ar. To help shed light on these calculated doses, the source term assumed in Phase III for these radionuclides is graphically depicted in the Figures below. The annual release of tritium to air from the

four virtual sources used in Phase III is shown in Figure 5-3. The bulk of the tritium released over the 39 years of nuclear materials production came from the F-and H-Separations Areas (Virtual Source 2) rather than from the reactor areas. Annual releases of ^{131}iodine from all four virtual sources are shown in Figure 5-4. Note that the bulk of the ^{131}I was released from the separations areas (Virtual Source 2), and that the largest ^{131}I release from this virtual source occurred in 1956. (Also note that the y-axis of this graph (Curies of ^{131}I released) is in a logarithmic scale.) Annual releases of ^{41}Ar from the four virtual sources are shown in Figure 5-5. Although ^{41}Ar releases rise and fall over the years, one can see a succession of peaks that gradually diminish in height. The largest peak occurred over roughly a five-year period between 1958 and 1963. Successively smaller peaks occurred in the years 1967 and 1968, in 1973, and in 1986.

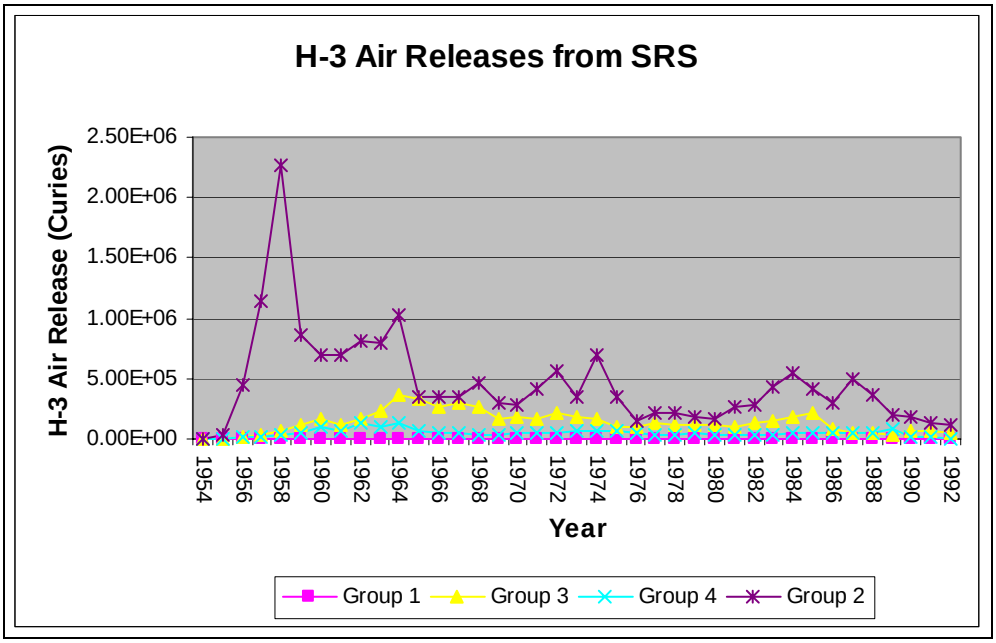

Figure 5-3 Tritium Release to Air from SRS

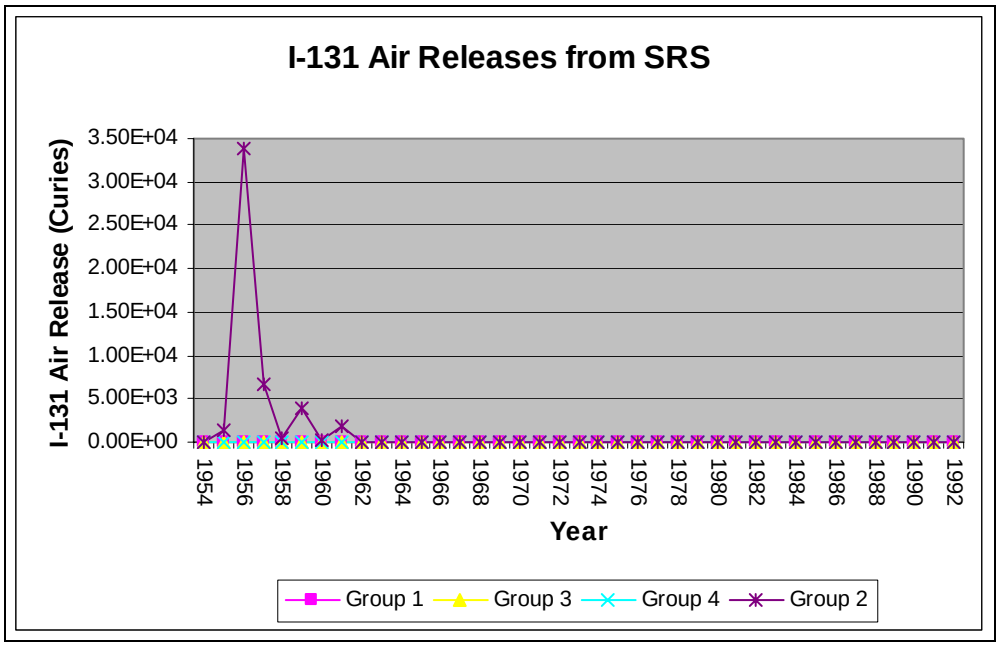

Figure 5-4 Release of ^{131}I to Air from SRS

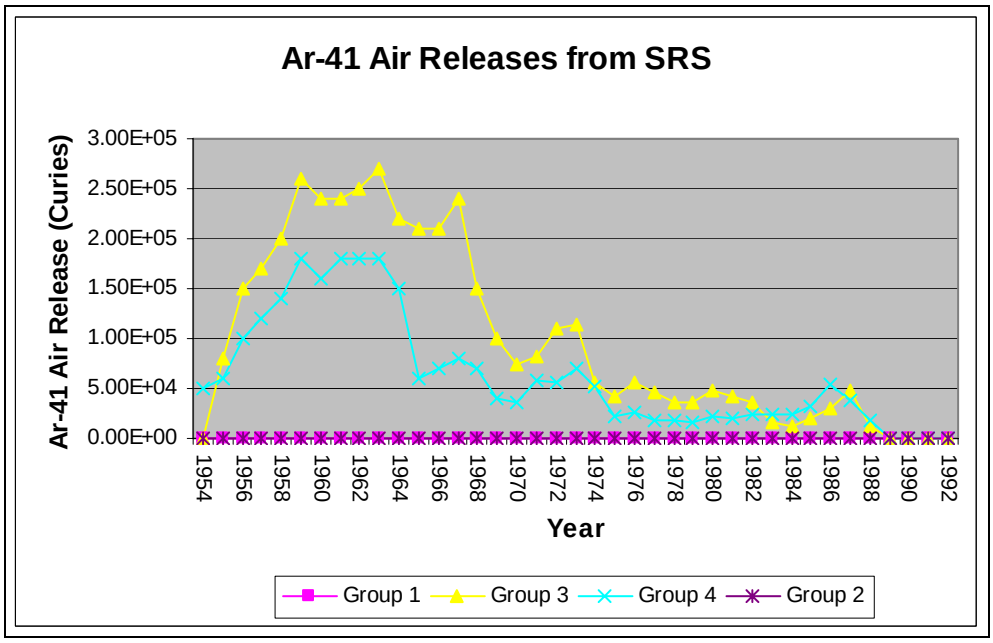

Figure 5-5 Release of ^{41}Ar to Air from SRS Reactors

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6 TRANSPORT OF RADIONUCLIDES THROUGH THE AIR TO AN EXPOSURE LOCATION

Radioactive materials in the form of gases and particulates may be released into the air and transported by the wind to an exposure location. The radionuclide concentrations in air and deposited on ground surfaces at this exposure location depend on atmospheric transport, diffusion, and deposition processes that affect the transport of radionuclides from the point of release to the exposure location (Figure 6-1).

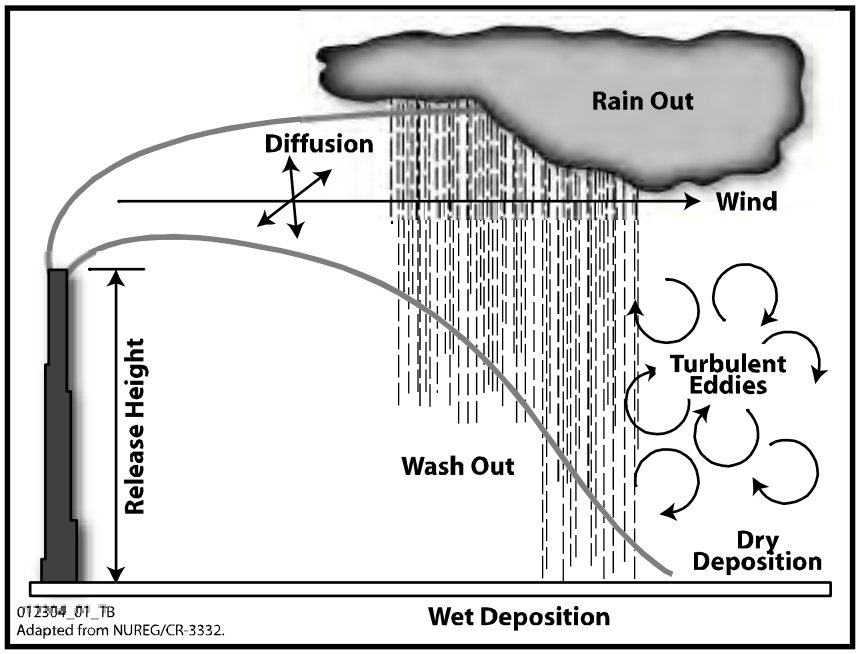

Figure 6-1 Atmospheric Dispersion and Removal Processes

Adapted from NUREG/CR-3332 (1)

6.1 Description of Atmospheric Processes

Some of the atmospheric processes that are important for Phase III of the SRS Dose Reconstruction Project include: dispersion, depletion, and release height.

Dispersion. As the effluent plume is transported from the source, turbulent eddies within the plume diffuse the effluent. The combined influences of diffusion and transport are generally called dispersion (1). A concentration gradient exists in the effluent, so that the effluent concentrations in the center of the plume are larger than those toward the plume edges.

As the plume moves with the wind, diffusion continues in the upward vertical direction to the mixing height, generally ranging from about 200 to 2,000 meters above the surface of the earth (1). Within this atmospheric mixing layer,[1] turbulence is generated that mixes the effluent. But the top of the mixing layer is marked by a decrease in turbulence. Above this "boundary," further vertical diffusion can be significantly reduced (1).

[1] Another name for the mixing layer is the planetary boundary layer (1).

There are two main types of turbulence within the mixing layer: mechanical turbulence caused by ground surface effects, and thermal turbulence caused by heating and cooling of the earth's surface.

Mechanical turbulence results from the frictional drag of the earth's surface. Turbulence increases in proportion to the wind speed and the roughness of the underlying surface. Within the mixing layer, wind speed tends to increase with height because of reduced friction between the air and the earth's surface. In heavily built up areas, such as urban areas, wind speed increases with height at a slower rate than in areas where the terrain is less rough, such as the suburbs, or in level country.

Thermal turbulence depends on the stability of the atmosphere within the mixing layer. Atmospheric conditions within the mixing layer are unstable, stable, or neutral depending on conditions that promote, retard, or have no effect the movement of air particles from one location to another. Assuming that a parcel of air (and the particles within it) is set in motion so that it either rises or falls, further movement depends on the temperature of the parcel of air relative to that of the surrounding atmosphere into which it moves (1):

- *Unstable conditions.* If an initially rising parcel of air is warmer than the surrounding atmosphere, it is more buoyant than the surrounding atmosphere and continues to rise. But if an initially falling parcel of air is cooler than the surrounding atmosphere, it becomes denser than the surrounding atmosphere, and therefore less buoyant. It continues to sink. In either case, air particle movement is promoted.
- *Stable conditions.* If an initially rising parcel of air is cooler than the surrounding atmosphere, it becomes denser than the surrounding atmosphere, and sinks. But if an initially falling parcel of air is warmer than the surrounding atmosphere, it becomes more buoyant than the surrounding atmosphere, and rises. In either case, air particle movement is retarded.
- *Neutral conditions.* If a rising or falling parcel of air is at the same temperature as the surrounding atmosphere, then movement of air particles is neither promoted nor retarded by buoyancy forces.

Different atmospheric stability conditions can strongly affect the dispersion of effluents. For example, under stable conditions and when winds are strong and in a constant direction, a plume of effluent from a stack can retain a narrow shape in the vertical direction for a long distance downwind. On the other hand unstable conditions can result in a looping plume, and the effluent released from a stack can contact the ground relatively close to the release point (2).

Depletion. Removal mechanisms that reduce effluent concentrations within the plume include wet and dry deposition, radioactive decay, and chemical change.

Wet deposition processes include rainout and washout. Rainout is a process that occurs within clouds. Effluents interact with precipitation formation processes and are removed from the clouds by rain. Washout occurs below the cloud layer. Falling rain contacts the effluent, carrying it to earth. Dry deposition processes include removal of effluent due to gravitational settling, or from contact with the ground, vegetation, or buildings.

Radioactive isotopes decay during transport to a downwind receptor. The significance of this removal process depends on the radionuclide half-life and the transport time.

The chemical forms of the radioactive isotopes affect their deposition rates and therefore their depletion from the plume. Factors to be considered include whether a radioactive isotope is being transported as a gas or a particle, and if the latter, its diameter and density.

Release Height. Almost all the radionuclide activity that was released into the air from SRS was released from stacks rather than from ground level. Concentrations are essentially zero near the base of the stack, but rise quickly to a peak value at some distance downwind, and then decrease regularly thereafter. Concentrations are larger along the centerline of the plume than on the ground on either side (3). The higher the effluent release point, the farther the effluent usually travels before significant concentrations of effluent reach ground level.

6.2 Gaussian Plume Model

One of the most widely used models for numerically describing the movement and dispersion of effluent from a release point is the Gaussian plume model (1). Figure 6-2 shows a simplified depiction of a Gaussian plume model, depicting contaminants released from a stack. The model accounts for the downward movement as well as the vertical and horizontal dispersion of the released contaminants, and predicts contaminant concentrations on the ground and in the air. The figure depicts Gaussian (normal) distributions in the vertical and crosswind directions. Near the point of release, the concentration is high near the centerline and falls off rapidly toward the edges. But further downstream, the distribution of concentration spreads from the centerline (4).

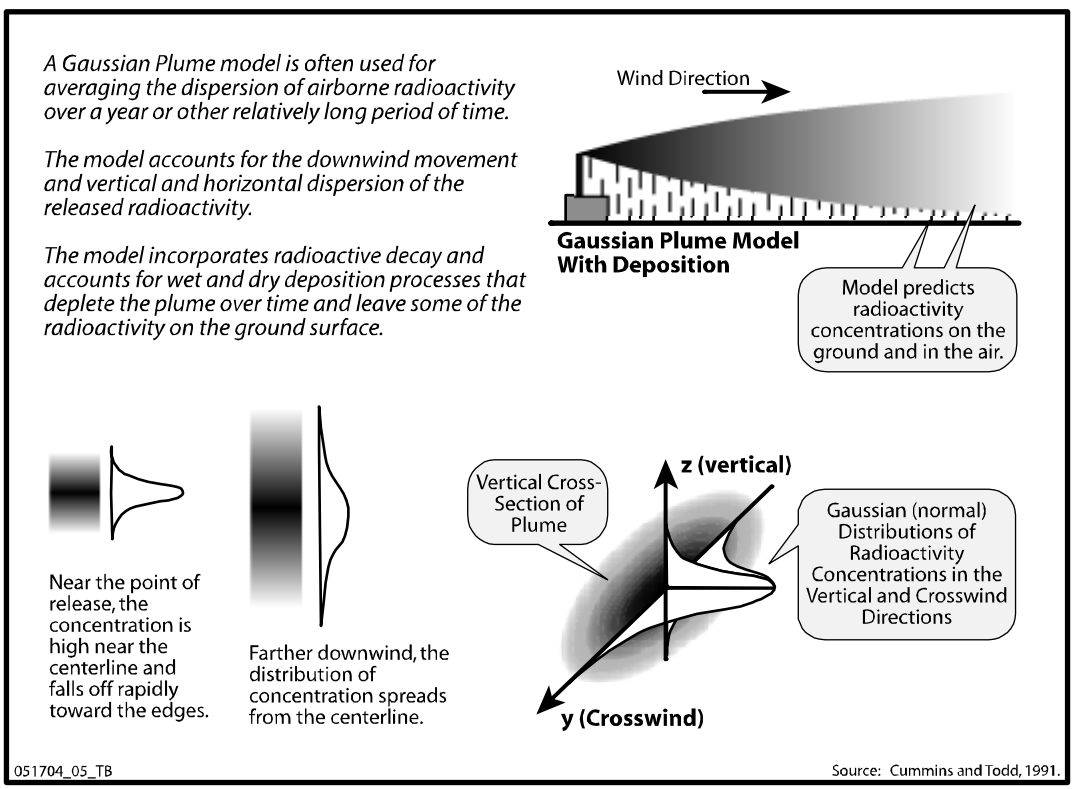

Figure 6-2 Illustration of Straight-Line Gaussian Plume Model
Source: (4)

The shapes of the concentration distributions are described in the Gaussian plume model by parameters known as diffusion coefficients.[2] Assuming that diffusion along the direction of the wind is small compared to transport by wind, the Gaussian plume model incorporates two diffusion coefficients, σ_y and

[2] Some references refer to σ_y and σ_z as diffusion coefficients; others as dispersion coefficients.

σ_z, that are the standard deviations of the Gaussian distributions in the crosswind (horizontal) (σ_y) and vertical (σ_z) directions.[3]

Many systems have been used to estimate diffusion coefficients. Most of the systems have been based on atmospheric stability classes and the distance from the source. These atmospheric classes are linked to the three atmospheric stability conditions (neutral, stable, and unstable) described in Section 6.1. A commonly used system is the Pasquill-Gifford system (1). It uses a set of equations that approximate a corresponding set of empirically-determined curves. The curves provide σ_y and σ_z values as a function of the distance from a source for six stability classes.[4] This system was used for the Phase III study because it is well established and compatible with the data that was obtained for the SRS.

6.3 Sector Average Modification to Gaussian Plume Model

Wind normally does not blow from the same direction for prolonged periods. For chronic or long-duration releases, the basic Gaussian plume model is modified using a sector-average approximation:

- An imaginary circle is drawn around the effluent release point, and the circle is divided into a series of pie-shaped wedges, called sectors.
- The quantity of effluent discharged into each sector is determined by considering the frequency that the wind blows in the direction of the sector.
- In each sector, the average effluent concentrations are determined as a function of distance from the release point by considering the wind speed and stability class, weighted by the frequency that these conditions occur in each sector.

Historically, the circumference around the release point has been divided into sixteen sectors corresponding to the sixteen major compass directions: N, NE, NNE, E, and so forth. Each sector is a pie-shaped wedge describing a 22.5^o arc (360° /16 sectors). Radionuclide concentrations and deposition rates were calculated in each sector. At a given distance from the release point, the model considers the concentration to be constant across the sector. The actual concentration, in fact, would not be discontinuous, as this suggests, but because the model considers only sixteen directions, the numerical result is coarser. If smaller and smaller sectors were chosen for the analysis (i.e., one degree), then the magnitude of any discontinuities would become extremely small.

Appendix A has a more detailed description of the sector average modification and how it was employed on this study.

6.4 Use of Joint Frequency Distribution Data

6.4.1 Definition

The joint frequency distribution (JFD) is a set of data for a specific location that represents a summary of meteorological conditions over a specified period of time such as a year. The joint frequency distribution is computed by compiling meteorological data, usually determined and recorded for each hour, over an appropriate time interval and computing the frequency of occurrence of each joint frequency category. Each joint frequency category represents a band (range) of wind speeds, directions, and stability conditions.

[3] By convention, the coordinate system used in Gaussian plume models defines the x-axis as the direction downwind of the source, the y-axis as the cross wind direction (lateral to the source), and the z-axis as the vertical direction.
[4] The six stability classes are: (A) extremely unstable, (B) moderately unstable, (C) slightly unstable, (D) neutral, (E) slightly stable, and (F) moderately stable (2).

6.4.2 Data Available from SRS

To estimate airborne radionuclide transport from release points to exposure locations, a set of meteorological data was needed that reflected the conditions that existed between 1954 and 1992. The data was needed to establish the joint frequency distributions for input to the computer model.

The preference was to use SRS-specific meteorological data that spanned all 39 years of nuclear material production. Unfortunately, the onsite SRS meteorological program was established in the early 1970's, leaving a data gap of about 20 years. To approximate meteorological data for all 39 years, consideration was given to using data from the National Weather Stations (NWSs) located near Columbia, South Carolina, and near Augusta, Georgia. Even though these two NWSs were only about 90 km apart and reasonably close to SRS,[5] there were differences in topography and weather patterns, as well as limitations in the available meteorological data (5). A comparison of wind roses for the years 1992 -1996 between these NWSs and the SRS meteorological station showed clear differences in wind patterns (5). The data from these NWSs was considered not sufficiently representative of SRS meteorological conditions to warrant using these data for Phase III.

Therefore, the limited available data from the SRS meteorological station was used to represent all 39 years of nuclear material production. Because joint frequency distribution data from the SRS meteorological station was available for Phase III as five-year averages, four five-year JFD averages were combined to arrive at a twenty-year average. This assumption appeared to be reasonable in light of the general practice used by the SRS for estimating environmental consequences. For example, the SRS Environmental Report for 1991 states that SRS used the meteorological measurements made over a five year period (1982-1986) and that other time periods "show very little change in dispersion conditions" (6).

6.5 Source and Exposure Locations

Figure 6-3 shows the locations of the four virtual sources considered for Phase III for release of radionuclides into the air. Also shown are the ten exposure locations where members of the hypothetical exposure scenarios were exposed to radionuclides that had been transported from the four virtual sources.

Exposure locations and the exposure scenarios are listed in Table 6-1. Members of some exposure scenarios (e.g., Migrant Worker Family) were exposed to radionuclides in air and deposited on the ground at only one exposure location, while members of other exposure scenarios (e.g., Delivery Person Family) were exposed to radionuclides in air and deposited on the ground at more than one exposure location.

[5] The Augusta NWS station is about 30 km west-northwest of the SRS meteorological station, while the Columbia NWS station is about 80 km northeast of the SRS meteorological station (5).

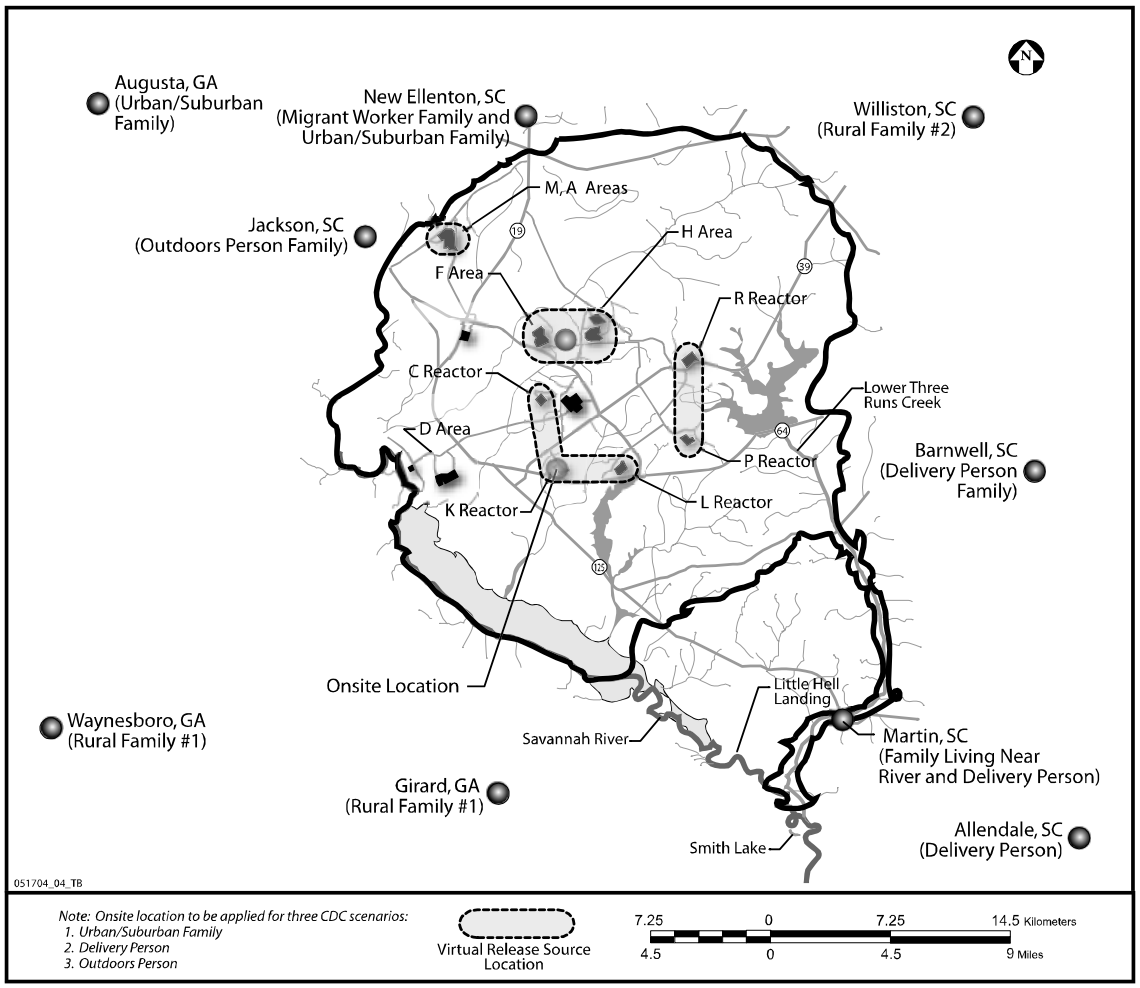

Figure 6-3 Virtual sources and Air Pathways Exposure Locations

Table 6-1 Exposure Locations and Exposure Scenarios

This Exposure Location	Is Considered for These Exposure Scenarios
1. Girard, GA	Rural Family One
2. Waynesboro, GA	Rural Family One
3. Augusta, GA	Urban/Suburban Family
4. Jackson, SC	Outdoors Person Family
5. New Ellenton, SC	Urban/Suburban Family, Migrant Worker Family
6. Barnwell, SC	Delivery Person Family
7. Martin, SC	Delivery Person Family, Near River Family
8. Allendale, SC	Delivery Person Family
9. Williston, SC	Rural Family Two
10. SRS near K-Reactor	Urban/Suburban Family, Delivery Person Family, Outdoors Person Family

The distances from each virtual source to each of the ten exposure locations are presented in Table 6-2 in order of increasing distances from each source.

Table 6-2 Distances (m) from Virtual Sources to Exposure Locations

A-Area, M-Area, SRL		F- and H-Area*		C-, K-, & L-Reactors, D-Area, CMX-TNX*		P- & R-Reactors*	
Distance	Exposure Location	Distance	Exposure Location	Distance	Exposure Location	Distance	Exposure Location
4,824	Jackson	8,666	On site	1,889	On site	8,881	On site
9,266	New Ellenton	12,392	Jackson	16,582	Jackson	20,648	Barnwell
16,226	On site	14,205	New Ellenton	21,092	New Ellenton	20,666	New Ellenton
24,196	Augusta	25,657	Williston	23,149	Girard	20,961	Jackson
30,065	Williston	28,585	Barnwell	23,629	Martin	21,880	Martin
36,789	Barnwell	29,293	Martin	27,743	Barnwell	22,354	Williston
37,477	Girard	30,033	Girard	29,256	Williston	25,800	Girard
38,309	Martin	33,397	Augusta	36,775	Waynesboro	36,775	Allendale
38,710	Waynesboro	39,858	Waynesboro	38,318	Augusta	41,940	Augusta
54,256	Allendale	45,038	Allendale	40,178	Allendale	44,286	Waynesboro

*Includes tritium evaporation from seepage basins.

6.6 Additional Parameters Used for Transport Analysis

In addition to basic meteorological data, values for several additional model parameters were specified. All four virtual sources are modeled as point sources having elevated release heights as listed in Table 6-3.

Table 6-3 Heights of Virtual Sources

Virtual Source Group	Height (m)	Actual Sources Represented
1	10	A-Area, M-Area, SRL
2	61	F-Canyon, H-Canyon, H-Area Tritium Stack (includes stacks and basin evaporation)
3	61	C-, K- and L-Reactors (includes stacks and basin evaporation), D-Area, CMX-TNX.
4	61	P- and R-Reactors (includes stacks and basin evaporation)

Values for other parameters used for the air transport assessment are provided in Appendix F.

6.7 References

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7 RELEASE OF RADIONUCLIDES TO WATER AND TRANSPORT TO AN EXPOSURE LOCATION

This chapter summarizes the Phase III work to estimate the release of radionuclides from the Savannah River Site (SRS) facilities to surface water and their transport by water to locations where hypothetical receptors could be exposed. This work resulted in estimates of the annual concentrations of twenty-two radionuclides at two exposure locations: one in the Savannah River and one in Lower Three Runs Creek. Appendix B lists these annual estimated radionuclide concentrations. This analysis provides the starting point for estimating dose resulting from liquid releases of radionuclides from the SRS. The concentrations of radionuclides in water developed by the methods discussed here are used as input to aquatic food chain transport modeling described in Chapter 8, and external and internal exposure models discussed in Chapter 9.[1]

7.1 Overview of the Problem and Solution

The required end points for considering water releases of radionuclides from SRS facilities are the annual concentrations produced by those releases at locations where receptors might be exposed. These annual concentrations depended on three factors: (1) the exposure locations; (2) the annual radionuclide releases to water from the SRS facilities; and (3) the physical and chemical processes affecting the migration of the radionuclides from the points of release to the exposure locations.

In order to estimate doses from radionuclide releases to water, the GENII[2] code allows the user the flexibility to: (1) specify radionuclide releases to water and the water flow rate for the receiving body of water or (2) specify the radionuclide concentrations. The second option was selected for this study because, as discussed in the following, the estimation of radionuclide concentrations is too complex to perform except external to the GENII code.

7.1.1 Exposure Locations

The scenarios (Chapter 3) outline exposure to radionuclides through various activities, including fishing, hunting, and boating in the SRS vicinity. In order to assess dose from these exposures, it is essential to know the concentrations of radionuclides at the exposure locations. The two locations chosen to represent exposure to water releases from the SRS are:

- The Savannah River below the point of confluence with Lower Three Runs Creek and
- Lower Three Runs Creek at Martin, S.C.

These locations are shown in Figure 7-1.

For this study, the radionuclide concentrations in surface waters are considered to be dependent on liquid releases of radionuclides from SRS facilities to on-site streams and seepage basins. In fact, some radionuclide concentrations in surface waters may have resulted from the deposition of air borne radionuclides onto the surface waters or the land surfaces they drained. These concentrations (and the doses that result from them) are expected to be small compared to the concentrations induced by water releases from SRS facilities. Consequently, exposures of receptors to bodies of water not hydrologically

[1] For Phase III the exposure pathways dependent on water releases of radionuclides include: consumption of fish taken from contaminated river or creek water, external exposure while occupying the shoreline of the contaminated river or creek, external exposure from swimming in the river, inadvertent ingestion of water while swimming in the river, and external exposure from boating on the river

[2] All references to GENII in this chapter refer to version 2 of GENII.

downstream of the SRS were assumed to have negligible radionuclide concentrations and were not modeled.

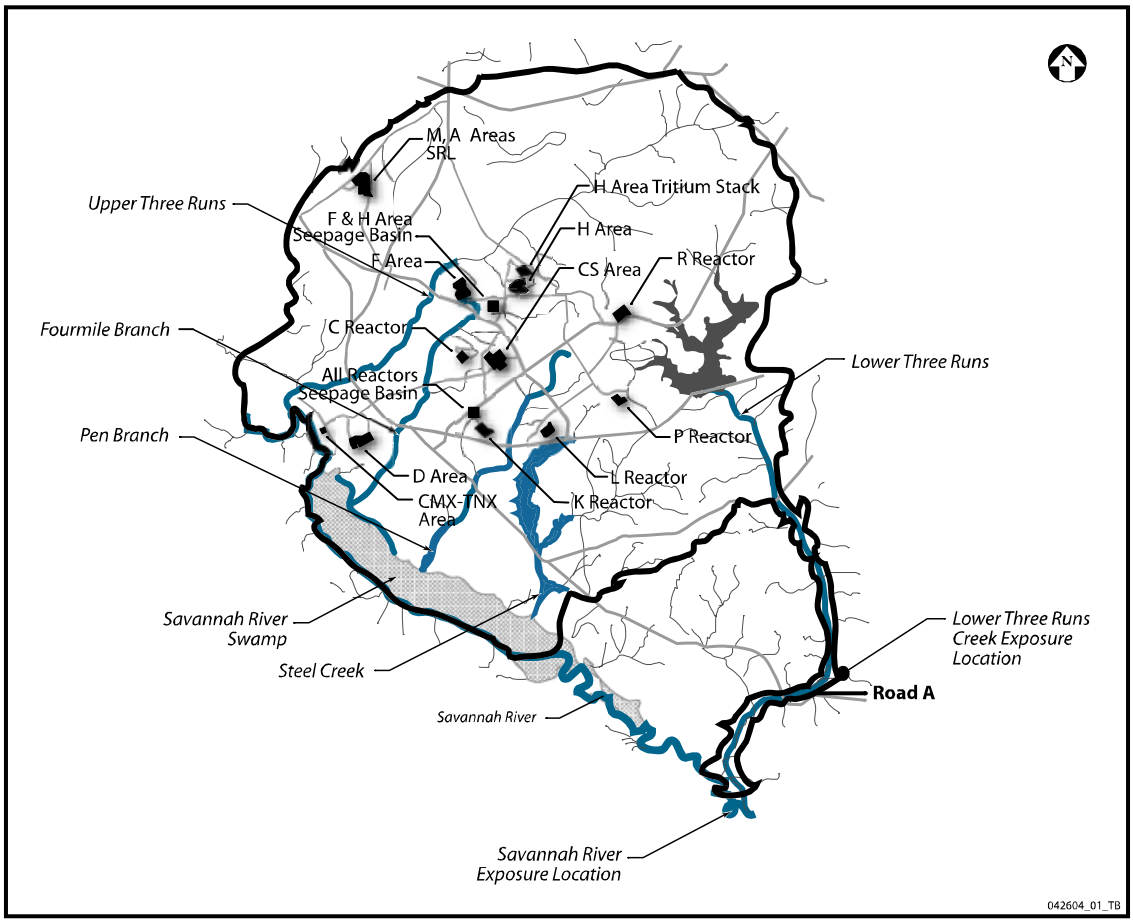

Figure 7-1 Major SRS Sources of Release to Surface Water

7.1.2 Sources of Release to SRS Surface Waters

Figure 7-1 depicts the major facilities releasing radionuclides to surface water bodies on the SRS site:

- The C-, P-, K-, L-, and R-Reactor areas
- The H- and F-Separations areas
- The A-Area
- The M-Area
- The D-Area and CMS-TNX
- The Central Shops (CS) Area

The reactor areas were the sources of most radionuclides released to surface water. Releases from the reactor and separations areas included radionuclides discharged directly to onsite streams as well as radionuclides discharged into seepage basins located in reactor and separations areas. Radionuclides released into seepage basins could leak to underlying sediments and then be carried by groundwater to onsite streams. Surface water releases of radionuclides were highest in the early to middle 1960s and decreased into the 1980s.

7.1.3 Migration of Radionuclides in SRS Surface Waters

As shown in Figure 7-1, there are five major onsite streams that received radionuclides from SRS facilities. Waters from Upper Three Runs Creek, Fourmile Branch, Pen Branch, and Steel Creek pass through a low-lying wetland area adjacent to the Savannah River and the SRS, the Savannah River Swamp, before they discharge into the Savannah River. Water from Lower Three Runs Creek does not pass through the swamp. Figure 7-1 also shows Road A which passes through the SRS from the southeast to the northwest. Road A is significant because environmental monitoring stations are located where Road A crosses these five SRS streams. These Road A monitoring stations are the final points on the SRS site of routine stream monitoring before discharge of the stream water to the Savannah River.

Figure 7-1 illustrates some of the geographic features of the SRS that require consideration while deriving radionuclide concentrations for human contact from surface water. For example:

- Releases to surface water were channeled by way of drainage to one or more of the streams that flowed into the Savannah River. Because of this, radiation exposures could only occur in well-defined geographic locations – i.e., at accessible locations below site discharge points in the Savannah River or along Lower Three Runs Creek.
- Each stream flowing offsite contained the contribution of more than one SRS facility or Area.
- Much liquid effluent was discharged over the years to seepage basins rather than directly to onsite streams. A portion of the radionuclides was eliminated by radioactive decay, which was a major purpose of the seepage basins. Some portion of the volatile and gaseous radionuclides discharged into seepage basins entered the atmosphere, essentially becoming part of the air source term. A portion of the radionuclides in the seepage basins seeped into the soil and entered the groundwater system. Some of this material then seeped into surface streams, where their transportation characteristics were affected by other processes, such as sorption on sediments or migration.
- Some of the radionuclides discharged to onsite streams were not immediately transported to locations where the radionuclides could have been contacted by members of the public. (Except for Lower Three Runs Creek, it was assumed that contamination in SRS streams was not accessible by members of the public.) Streams containing radionuclides had to flow for several miles before being discharged to the Savannah River. Through this process many radionuclides may have been sorbed onto stream and swamp sediments, reducing the inventory eventually released offsite.
- All but one of the major onsite streams discharging radionuclides to the Savannah River passed through the Savannah River Swamp. Because of sedimentation processes characteristic of wetlands, radionuclides were likely deposited into swamp sediments. The swamp, however, historically flooded about 20% of the time. Flooding would tend to re-suspend contaminated sediments and re-dissolve sorbed radionuclides; in this way radionuclides released at earlier times could increase radionuclide content in the Savannah River above that attributed to the site radionuclide releases during a given year.

7.1.4 Summary of Approaches to Estimating Concentrations

Because of these considerations, annual radionuclide concentrations in water at the two exposure locations specified by the Phase III scenarios were estimated by modeling performed outside the GENII computer code. These concentration estimates needed to reflect the complex processes governing radionuclide migration from the release facility to the exposure location; these processes include radioactive decay, surface water transport, sorption on sediments, groundwater transport, sorption on soil, and uptake by biota

Different approaches were used in developing concentration estimates for the Savannah River exposure location and the Lower Three Runs Creek exposure location, because the physical situations for release and transport to these exposure locations were different and the information available to make estimates was different.

As shown in Figure 7-2, the procedure for developing concentration estimates began with the initial, common starting point: those radionuclides identified in Phase II as important for estimating doses. However, as described in the following, different modeling approaches were used for concentration estimates in the Savannah River and those in Lower Three Runs Creek at Martin.

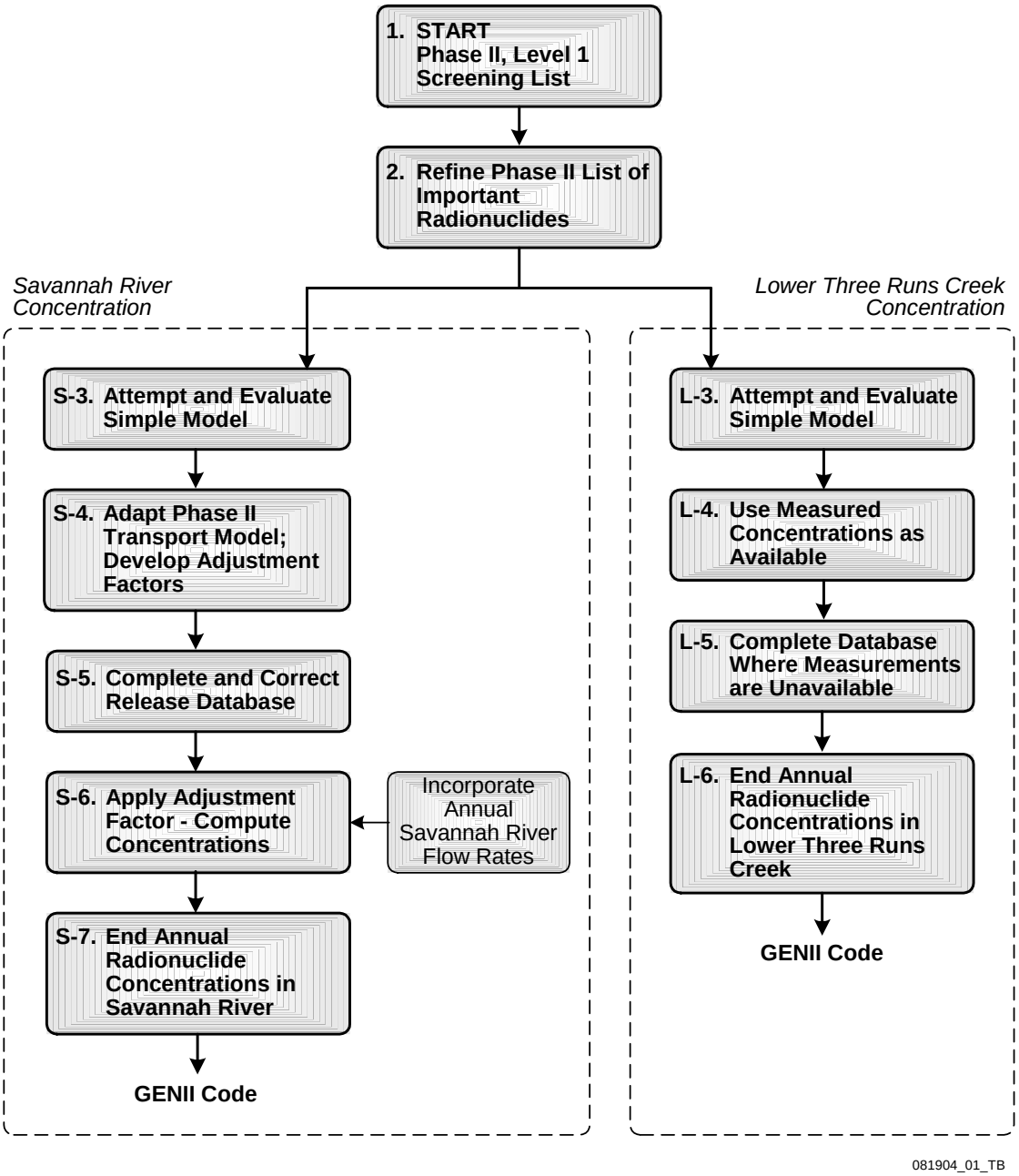

Figure 7-2 Approaches to Estimating Radionuclide Concentrations in Water at Exposure Locations

These procedural steps for developing the source term are briefly described in the following list. Then each subsection that follows discusses these steps in more detail.

Common Steps:

1. START: List of important radionuclides from Phase II, Level 1 screening analysis;
2. Refine list of radionuclides. Two isotopes of uranium were added to refine the treatment of health effects. ^{91}Y was deleted because it fell below the requirement for inclusion.

Savannah River Steps:

S-3. Attempt a simple model: estimate annual concentrations in the Savannah River by dividing annual release rate by the annual flow rate. This did not provide acceptable results when compared to measured concentrations in the river.

S-4. .Phase the II model; develop scaling factors for all radionuclides based on K_D. Phase II modeled radionuclide releases to the Savannah River for three important radionuclides based on several factors influencing transport from the point of release to the river. Adjustment factors were derived based on these modeled releases and tabulations of annual amounts of radionuclides released at the point-of-release. These adjustment factors were to be applied to each remaining radionuclide not modeled in Phase II, depending on its geochemical K_D.

S-5. Complete and correct the release data base; release data for some years not compiled in the Phase II report and files were supplied from other sources. Corrections for unidentified alpha emitters and unidentified beta-gamma emitters were added. Other minor anomalies were corrected.

S-6. Apply adjustment factors; the adjustment factors based on the Phase II modeling were used to estimate annual concentrations from the tabulated values of annual releases. In order to calculate concentrations, incorporate data on annual flow rates in the Savannah River.

S-7. END: Concentrations by year and radionuclide in the Savannah River.

Lower Three Runs Creek Steps:

L-3. START: Attempt a simple model; estimate annual concentrations in Lower Three Runs Creek by dividing annual release rate by the annual flow rate. This did not provide acceptable results when compared to measured concentrations in the river.

L-4. Use measured concentrations for three radionuclides, ^{137}Cs, ^{90}Sr, ^{3}H; there were in adequate or no measurements for the remaining nuclides of interest;

L-5. Complete the concentration data base for ^{137}Cs, ^{90}Sr, and ^{3}H, for instances where measured concentration data was unavailable.

L-6. END: Concentrations for ^{137}Cs, ^{90}Sr, and ^{3}H by year and radionuclide in Lower Three Runs Creek.

7.2 Identify Important Radionuclides Based on Phase II

Phase II of the SRS Dose Reconstruction Project identified the radionuclides that were released to the surface water from SRS, performed a screening assessment to identify a smaller group of radionuclides to be addressed in more detail, and estimated radionuclide quantities released into water over much of the time period of nuclear material production. This information was used as the starting point for estimating the water concentrations of radionuclides at the exposure locations of interest.

7.2.1 Phase II Screening Assessment

The Phase II screening assessment started with a master list of radionuclides that had been reported as released into surface water from SRS facilities. Preliminary estimates of their yearly average release rates were made for a 36-year period. A screening assessment was performed to identify a smaller list of key radionuclides that were the dominant contributors to radiation dose and cancer risk (Phase II). This screening assessment was performed using a two-step method recommended by the National Council on Radiation Protection and Measurements (NCRP).

The initial screening analysis conservatively assumed that all radionuclides were discharged into a single body of surface water with a fixed flow rate. Using the NCRP methodology referenced above, estimated 36-year average releases (representing 1954-1989), and an average dilution flow rate of 7.7 x 109 m^3/y of water, the total effective doses were estimated for each radionuclide. A total dose was estimated by summing the incremental doses from each radionuclide. A screening factor was computed for each radionuclide equal to the ratio of the incremental dose from each radionuclide to the total dose. Those radionuclides that contributed at least 0.1% to the screening factor were given further consideration in estimation of the source term. The radionuclides that Phase II identified as meeting this criterion were ^{137}Cs, ^{60}Co, ^{3}H, ^{131}I, ^{32}P, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{89}Sr, ^{90}Sr, ^{35}S, ^{99}Tc, uranium, ^{91}Y, ^{65}Zn, ^{95}Zr, and ^{95}Nb. A summary of the Level 1, Phase II screening results is presented in Table 7-1. A second, Level -2 screening, which ranked radionuclides according to their relative importance by exposure pathway, was also performed. Seven radionuclides identified in this fashion were: ^{3}H, ^{137}Cs, ^{90}Sr, ^{60}Co, ^{32}P, ^{131}I, and uranium.

Table 7-1 Radionuclides Identified as Significant in the Level 1 Screening Analysis in Phase II

Radionuclide	Percent of Total Screening Value
^{141}Ce, ^{144}Ce*	0.91
^{134}Cs	0.52
^{137}Cs	75.23
^{60}Co	1.80
^{3}H	0.74
^{131}I	0.91
^{32}P	5.64
^{239}Pu, ^{240}Pu*	0.48
^{238}Pu	0.21
^{103}Ru, ^{106}Ru*	1.39
^{89}Sr, ^{90}Sr*	9.35
^{35}S	0.68
^{99}Tc	0.13
Uranium*	0.57
^{65}Zn	0.68
^{95}Zr, ^{95}Nb*	0.38
Total	**99.6**

*^{140}Ba, ^{140}La were screened as ^{140}Ba; ^{141}Ce, ^{144}Ce as ^{144}Ce; ^{239}Pu, ^{240}Pu as ^{239}Pu; ^{103}Ru, ^{106}Ru as ^{106}Ru; ^{124}Sb, ^{125}Sb as ^{125}Sb; ^{89}Sr, ^{90}Sr as ^{90}Sr; uranium as ^{235}U and ^{238}U; and ^{95}Zr, ^{95}Nb as ^{95}Zr.
Source: Phase II Rad-Screening.xls Excel spreadsheet (Phase II).

Note that although ^{91}Y was included as significant based on the Level 1 Phase II screening analysis, the numerical analysis in Phase II does not appear to support its inclusion based either on the Level 1 or Level 2 screening criteria; its screening value was only 0.0345% of the total screening value, which is below the 0.1% screening value criterion for Level 1 screening. Neither did it rank among the top three radionuclides for any exposure scenario considered in the Level 2 screening analysis.

7.2.2 Modify List of Radionuclides and Properties

As shown in Figure 7-2, the second generic step in defining the source term for liquid releases was to modify the list of radionuclides identified as important in Phase II. The initial list of important radionuclides resulting from the Phase II Level 1 screening analysis was modified in several ways:

1. Some groups of radionuclides were partitioned into separate isotopes. This was done to provide a more refined treatment of dose modeling. By treating isotopes individually, health effects coefficients specific to those isotopes could be used in the dose modeling. If isotopes were aggregated by element, as in the Phase II screening analyses, a single coefficient (related to the isotope with the greatest health effects) would characterize all the isotopes of the element, possibly greatly overestimating doses and risks. Table 7-2 shows the 22 isotopes modeled for liquid releases in Phase III.
   a. Each member of the mother-daughter pair, ^{95}Nb and ^{95}Zr, was modeled as a separate isotope to account for the slight differences in health effects.
   b. ^{134}Cs and ^{137}Cs were modeled as separate isotopes; furthermore the Level 1 screening value for ^{134}Cs, 0.52%, exceeded the criterion for retention.
   c. ^{89}Sr and ^{90}Sr were modeled separately.
2. Because the releases of Ruthenium were relatively small, all releases were modeled as ^{106}Ru.
3. ^{129}I was included for Phase III even though, like ^{91}Y, its screening value did not meet the 0.1% criterion (its screening value was 0.06%). ^{129}I was included for three reasons: (a) it has similar chemical and physical properties as ^{131}I, which was identified as a key radionuclide; (b) there were concerns about possible health effect after it concentrates in the thyroid; and (c) although the liquid release of ^{129}I is not as well monitored as ^{131}I (Kantelo 1993), its long half-life (~1.7x10+07 years) is orders of magnitude longer than that of ^{131}I (~8.04 days), thus making it much longer lasting in the environment. This long half-life could be a differential factor for some scenarios and exposure pathways.
4. One radionuclide, ^{240}Pu was dropped from consideration. The data upon which the Phase II estimates of releases were based did not list ^{240}Pu releases separately, but always combined with other isotopes. Furthermore, the health effects coefficients for ^{239}Pu and ^{240}Pu are very close, so modeling ^{240}Pu as ^{239}Pu will have little effect on the dose estimates. Since there appeared to be no basis and no motivation for differentiating these two isotopes, separate consideration of ^{240}Pu was dropped.
5. It was considered appropriate to include as releases radioactivity measured as unidentified alpha or unidentified beta-gamma activity. Although the SRS had recorded releases of such material over the years of site operation, an explicit treatment in Phase II was not apparent. Therefore two additional categories were added for these types of releases. However, to provide bounding estimates of their health effects, the unidentified alpha activity was added to the releases for ^{239}Pu and the unidentified beta-gamma activity was added to the releases for ^{90}Sr. These two classes are indicated in Table 7-2 to indicate that these activities were compiled and tracked separately.

Table 7-2 Modified List of Radionuclides Considered for Water Concentrations in Phase III

^{144}Ce	^{106}Ru
^{134}Cs	^{89}Sr‡
^{137}Cs	^{90}Sr‡**
^{60}Co	^{35}S
^{3}H	^{99}Tc
^{129}I*	^{234}U*
^{131}I	^{235}U§
^{95}Nb†	^{236}U*
^{32}P	^{238}U§
^{238}Pu	^{65}Zn
^{239}Pu¶	^{95}Zr†

*These radionuclides were added.
$^{†, ‡, §}$ These radionuclides were paired in the Phase II, Level 1 screening analysis.
¶Unidentified alpha-emitters were modeled as ^{239}Pu
**Unidentified beta-gamma emitters were modeled as ^{90}Sr

The general approach for partitioning aggregate quantities of radionuclides is summarized in Table 7-3. (See Appendix C for details.) Unlike the analysis of releases to air, there was no need to refine the treatment of certain radionuclides by defining their chemical form; this is because all radionuclides were either dissolved or suspended in water, which dominated the chemistry. For example, tritium would be present as tritiated water.

Table 7-3 Partitioning Assumptions for Radionuclides Released to Surface Water

Constituent	SRS Area	Isotopic Distribution by Activity
^{89}Sr, ^{90}Sr	F&H Areas	75% ^{89}Sr; 25% ^{90}Sr
	A Area	100% ^{90}Sr
	D Area	100% ^{90}Sr
	Central Shops	100% ^{90}Sr
^{95}Nb, ^{95}Zr	All areas	65% ^{95}Nb; 35% ^{95}Zr
^{134}Cs, ^{137}Cs	D Area	100% ^{137}Cs
Uranium	Reactor Areas	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	F Area	1.27% ^{235}U; 98.73% ^{238}U
	H Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	M Area	1.27% ^{235}U; 98.73% ^{238}U
	A Area (SRL)	91.44% ^{234}U; 1.8% ^{235}U; 6.4% ^{236}U; 0.36% ^{238}U
	CMX/TNX	49.49% ^{234}U; 2.25% ^{235}U; 48.26% ^{238}U
	D Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
Total plutonium	All Areas	100% ^{239}Pu
Unidentified alpha	All Areas	100% ^{239}Pu
Unidentified beta-gamma	All Areas	100% ^{90}Sr

7.3 Modeling Releases and Concentrations for the Savannah River

7.3.1 A Simple Model (Step S-3)

As a first step in estimating radionuclide concentrations in the Savannah River, a simple model based on conservation of mass was evaluated (Step 3 in Figure 7-2). Recall that the point of interest on the Savannah River was located below the confluence with Lower Three Runs Creek; actually, the point of interest is very close to the USGS flow monitoring station at river mile 120 (RM-118.8 in later years) at highway 301 (also designated in various SRS reports as station 10A or R-10). Because the location of interest is downriver from the points where site streams drain into the Savannah River, one can reasonably assume that all liquid releases exiting the site boundary must pass through this point. Since the river flow is measured very close to this point, one can construct a simple mathematical model based on conservation of mass for the average radionuclide concentration at this location:

$$C_{ij} = R_{ij}/Q_j \qquad (7\text{-}1)$$

Where,

C_{ij} is the concentration of radionuclide i in year j (Bq/m^3);
R_{ij} is the quantity of radionuclide i released from the SRS to water in year j (Bq/y);
Q_j is the flow rate of water past the location for year j (m^3/y)

However, as described in Section 7.1.3, the migration of radionuclides from their point of release on the SRS to this location of interest in the Savannah River is not direct or simple. Nevertheless, to test a simple approximation, the quantities of radionuclides released from the facility were assumed to be equal to the quantities ending up in the river, for any given year. Figure 7-3 and Figure 7-4 compare radionuclide concentrations computed according to this simple model to measured concentrations at this location. Comparisons are shown for tritium in Figure 7-3 and ^{137}cesium in Figure 7-4. Measured concentrations at this location were not apparent for years prior to 1960. Two different estimates of flow rate were used to compute the calculated concentrations. In one case the "USGS Actual Flow Rate" was used for each year of the calculation, in full accord with equation (7-1). In the other case, the "39-year Average Flow Rate" was used; i.e., the flow rate was a fixed value (9.49 billion cubic meters) for all years. Note that the measured and calculated concentrations do not agree very well. For tritium, measured values in early years are higher than calculated values; in later years, the peaks and dips do not correspond in time very well. For cesium, early measured values are higher than calculated concentrations, but in middle years calculated values are higher than measured values.

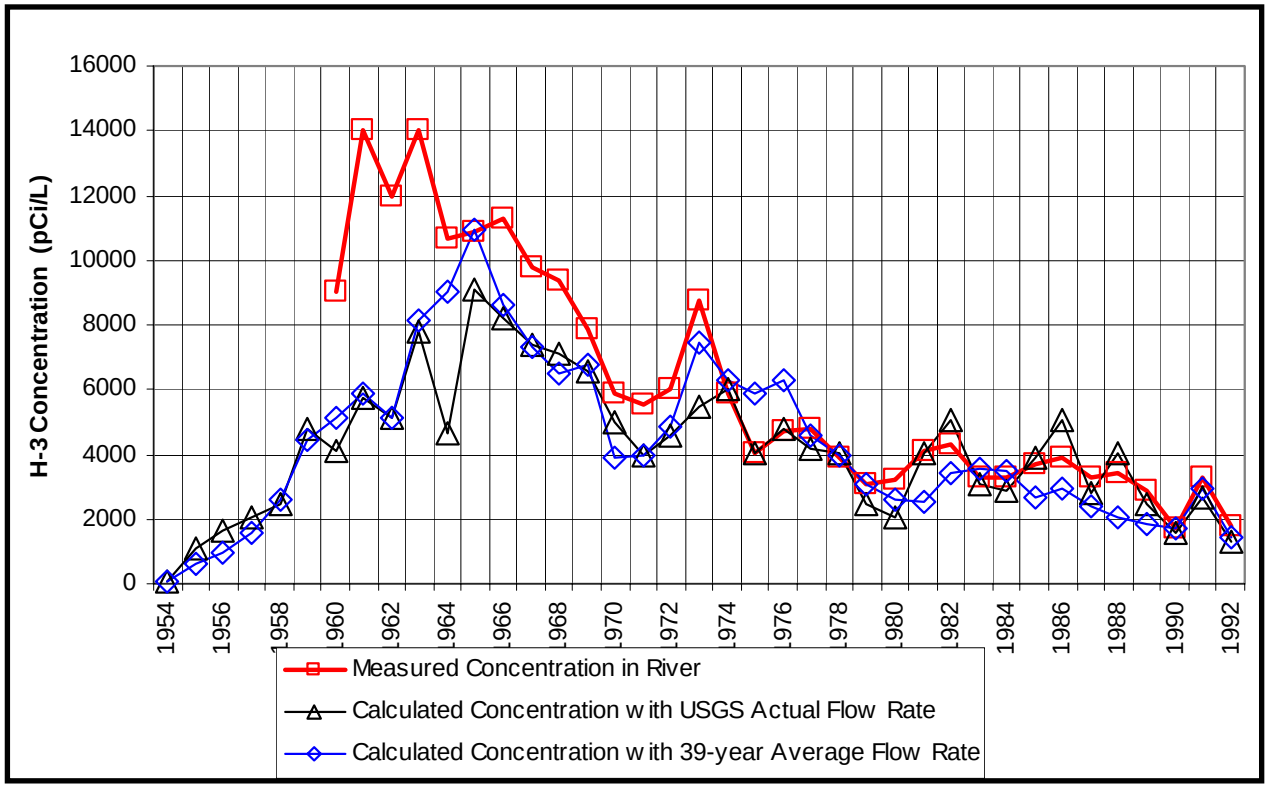

Figure 7-3 ^{3}H Concentration in Savannah River (pCi/L)

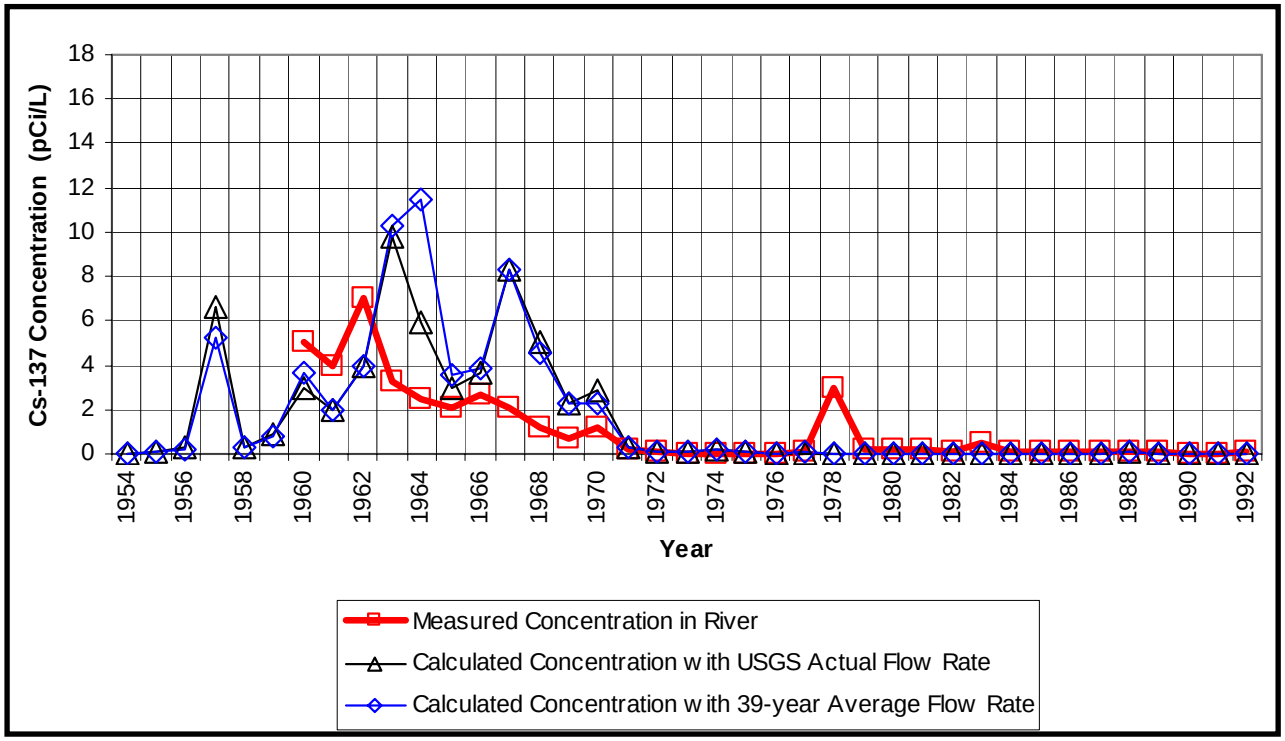

Figure 7-4 ^{137}Cs Concentration in Savannah River Water (pCi/L)

Because of this lack of agreement with measured concentrations, use of this simple modeling approach was abandoned. However, this presented the problem of exactly how this necessary input for the dose reconstruction (i.e., radionuclide concentrations in the Savannah River) would be obtained. Although there were measured concentrations for a few radionuclides (^{3}H, ^{137}Cs, ^{131}I, ^{90}Sr, and others), this was not a suitable solution because:

- The goal of the dose reconstruction was to represent doses from the set of 22 radionuclides selected (Table 7-2) and there were no measured values for most of these;
- The measured concentrations were frequently near detection limits for the instruments used, so the accuracy of the measurements was questionable; in some cases, the detection limit (or half the detection limit) was listed as the measured value;
- Consistent measurements of concentrations were not available during some of the important early years of site operation, when releases were known to be large;
- The estimates of average annual measured concentrations were based on periodic samples that were subject to substantial uncertainties:
  - the possibility that major releases were not effectively or consistently sampled and
  - the possibility that the turbulent, unsteady flow in the river steered contaminated water toward or away from the sampling locations.

7.3.2 Adapt the Phase II Water Transport Model for Savannah River Concentrations (Step S-4)

In order to overcome the difficulties encountered with a simple model of radionuclide concentrations in the Savannah River, the model developed in Phase II for a few radionuclides was adapted and extended for Phase III. This is shown as Step 4 in Figure 7-2.

7.3.2.1 Phase II Water Transport Model

Section 7.1.3 of this report and Chapter 5 of Phase II discuss why the accounting of releases to the surface water pathway ***at the point of release*** is not an accurate estimate of the actual releases from the SRS site to the Savannah River. Chapter 5 of the Phase II report describes how a relatively simple model was used to estimate the release to the Savannah River of ^{3}H, ^{90}Sr, and ^{137}Cs, based on concentrations of these constituents measured at the sampling stations along Road A, the sampling point closest to the river (Phase II). These three radionuclides were identified in Phase II as important possible contributors to either offsite release or dose and had been monitored extensively during the years of nuclear material production.

The Phase II model explicitly considers the following factors:

1. Transport of radionuclides through surface water as dissolved and suspended constituents.
2. Release of previously retained radionuclides by periodic flooding of the Savannah River Swamp.
3. Measurement uncertainty.

The effects of the various physical and chemical interactions of released radionuclides with the soil, biota, and other features of the SRS generally decreased the modeled radionuclide quantities reaching the Savannah River. On the other hand, many of the radionuclide measurement uncertainties, when incorporated into the Phase II model, increased the modeled quantities discharged to the Savannah River.

The SRS Swamp was observed to flood about 20% of the time (74 days per year on the average) from 1958 to 1967. It was assumed that additional releases to the Savannah River from the swamp occurred when there was flooding. This uncertainty was considered a source of bias that increased releases of radionuclides such as cesium and strontium that were retained in the swamp. For most years, releases were increased for cesium and strontium by 20% (with a range of 10%-30%). For years with very high rainfall amounts like 1964 and 1971, a value of 40% (with a range of 25%- 60%) was assumed. For years with low rainfall, it was assumed that the swamp flooded only about 10% of the time (with a range of 5%-15%) (Phase II). (Detailed records existed for annual rainfall). Uncertainties associated with the release estimates were considered to originate from analytical errors in measurement of flow and in sampling and analysis of radionuclide concentrations in the water. Because tritium was not impacted heavily by flow through the SRS swamp, sampling and analytical uncertainties were the major sources of uncertainty in the release estimates for tritium. The effluent volume to the site streams was monitored reasonably well by both the Site and the USGS (Phase II). Estimates of error for the routine concentration measurements varied with the radionuclide, the sample preparation and with the counting procedure (Phase II).

Measurements of effluent releases and concentrations for ^{137}Cs and ^{90}Sr at the Road A monitoring locations specific were not made in early years. Prior to 1960, only nonvolatile beta activity was measured. To estimate annual ^{137}Cs releases for times when ^{137}Cs specific measurements were not made, a ratio was calculated of ^{137}Cs to nonvolatile beta activity when both measurements were made at the same time and location. This ratio was used along with the nonvolatile beta activity measurements to estimate levels of ^{137}Cs activity in the site streams at the Road A monitoring locations for years when ^{137}Cs -specific measurements were not made. A similar procedure was used for ^{90}Sr.

7.3.2.2 Adaptation of Phase II Model for Savannah River Concentrations

A mathematical model of the transport of individual radionuclides to the Savannah River, similar to that used in Phase II, would require significant resources to develop and validate. The complex nature of radionuclide transport by surface water at the SRS requires consideration of the loss mechanisms, time delays, and uncertainties that influence radionuclide concentrations reaching the Savannah River. Because

each chemical species has unique aqueous transport properties, developing a model that would accommodate the variations in chemical-physical transport was beyond the scope of Phase III.

However, Phase II had modeled the quantities of three specific radionuclides (^{3}H, ^{90}Sr, ^{137}Cs) released into the Savannah River, taking into account the complex phenomena and issues governing their migration. The release quantities estimated by the Phase II model are different from the facility releases (point of release quantities) compiled in Phase II and in the SRS historical data. These differences represent the effect of the phenomena causing radionuclide decay, storage, and release, during migration in site streams, from seepage basins, and through the Savannah River swamp and measurement uncertainty. A quantitative measure representing these phenomena is just the ratio of the modeled release activity to the facility release activity:

$$F_{jk} = R_{Mjk}/R_{Fjk} \qquad (7\text{-}2)$$

Where,

F_{jk} is the factor representing the effects of radionuclide migration for year j and modeled radionuclide k;
R_{Mjk} is the modeled release of radionuclide k for year j;
R_{Fjk} is the facility release of radionuclide k for year j tabulated from site data.

Note that the index "k" is used to denote the radionuclide here, rather than the index "i" used in equation (7-1), because "k" refers only to one of the three radionuclides (^{3}H, ^{90}Sr, ^{137}Cs) modeled in Phase II, while "i" refers to any radionuclide.

The fundamental assumption made to extend these results of Phase II modeling to the analysis in Phase III is that the distribution coefficient (K_D – a measure of the degree to which a particular radionuclide is sorbed to soil, sediment, and some biota) of a radionuclide would be the primary factor affecting the influence of the site, as represented by the factor, F_{jk}. Using this assumption, one could extend the modeling of the three radionuclides performed in Phase II to the entire suite of radionuclides modeled in Phase III. As will be described in more detail, this extension was based on three categories of K_D into which the Phase III radionuclides were binned. A more precise rendering was not considered warranted given the extent of other uncertainties.

As stated in Section 7.3.2.1, other factors incorporated into the Phase II model were periodic flooding of the Savannah River swamp and uncertainties in measuring the quantities of released radionuclides. Clearly, K_D does not encompass these factors. However, the factors representing river flooding were tied to precipitation records and were adjusted from year to year; similarly, the factors representing measurement uncertainty were adjusted annually, with larger uncertainties in earlier years. Thus, the annual variations in the factor defined by equation (7-2) should incorporate these other facets of the Phase II model. However, some of the uncertainties related to measuring tritium in environmental samples are unique to tritium. This may mean that factors developed for tritium, if applied to other radionuclides, may overestimate the degree of measurement uncertainty.

A complication in applying equation (7-2) is that R_{mjk}, the modeled release of radionuclide k for year j, is a random variable, not a single value, because the model used in Phase II was probabilistic. However, the median value of the distribution was chosen as a measure of the central tendency of these quantities.

The remaining steps needed to estimate releases of any radionuclide of interest to the Savannah River, based on the factors defined by equation (7-2) are:

1. Determine the annual radionuclide water releases for each radionuclide from SRS facilities, for the three modeled radionuclides, R_{Fjk}, and for all other radionuclides, R_{Fij};

2. Compute the ratios, F_{jk}, indicated by equation (7-2);
3. Bin the radionuclides by K_D group;
4. Apply the ratios for each group of radionuclides to annual releases from facilities, thereby obtaining adjusted annual releases by radionuclide. However, the release data base needed to be completed and corrected before applying the adjustment factors (discussed in Section 7.3.3), so this aspect is discussed in Section 7.3.4.

7.3.2.2.1 Annual Radionuclide Release at Points of Release

The principal reference used to develop the annual radionuclide point-of-release data files, (i.e. files containing R_{Fjk}, the facility release of radionuclide k for year j tabulated from site data) was Cummins et al (Cummins 1991a). To develop the data files, a guiding decision had to be made about the specific releases to be included.

Liquid releases from the site can be placed into three categories:

1. Category 1 - Direct releases to onsite streams
2. Category 2 - Migration from seepage basins into onsite streams
3. Category 3 - Direct releases to seepage and containment basins.

Although the total release to site streams could be the sum of Categories 1 and 2, the Phase II report generally used the sum of Categories 1 and 3 to represent the liquid source terms in the screening assessment. There appear to be at least two reasons for this choice:

> (A) because migration from the seepage basins is distributed in time and space, measurements of concentrations immediately downstream of the seepage basins may under-represent the total flux from the seepage basins to the streams; and
>
> (B) the sum of Categories 1 and 3 should be a conservative estimate of liquid releases to site streams.

Exceptions are ^{3}H and ^{131}I, where only direct releases to streams (Category 1) were considered for the screening assessment.

For these reasons, the annual sums of releases from Categories 1 and 3 were chosen as representative of SRS releases to site streams. This meant that tritium evaporated from seepage and containment basins was excluded from the point-of-release data file created for tritium. Evaporated tritium was included in the Phase III atmospheric releases (Chapter 5). It also meant that the estimated ^{137}Cs desorption from the Four Mile Creek bed that was reported by Cummins et al (Cummins 1991a) was not included in the data files. The activity reported in this desorption was already included in the Category 1 and 3 releases as described above. Including these desorption estimates would have caused double counting.

7.3.2.2.2 Adjustment Factor Development

Adjustment factors were calculated according to equation (7-2) by dividing the median values of radionuclide release computed by the Phase II release model for each of three modeled radionuclides by the radionuclide releases for these radionuclides from all facilities. These modeled and tabulated releases are listed in Table 7-4. The resultant adjustment factors are listed in Table 7-5.

Table 7-4 Tabulated Releases from Facilities and Median Value of Modeled Releases Used for Adjustment Factors (Ci)

	Tabulated Releases from Facilities			Median Value of Modeled Releases		
Year	^{3}H	^{137}Cs	^{90}Sr	^{3}H	^{137}Cs	^{90}Sr
1954	$3.66x10^{+02}$	$1.80x10^{-01}$	$3.90x10^{-02}$	$7.64x10^{+03}$	$1.41x10^{-01}$	$4.13x10^{-02}$
1955	$5.87x10^{+03}$	$1.37x10^{0}$	$8.16x10^{-01}$	$1.32x10^{+04}$	$2.65x10^{-01}$	$1.45x10^{-01}$
1956	$9.39x10^{+03}$	$3.43\ x10^{0}$	$1.04x10^{+01}$	$1.50x10^{+04}$	$1.11\ x10^{0}$	$3.60x10^{-01}$
1957	$2.24x10^{+04}$	$8.40x10^{+02}$	$1.96x10^{+02}$	$2.16x10^{+04}$	$1.16\ x10^{0}$	$1.54\ x10^{0}$
1958	$2.88x10^{+04}$	$1.04x10^{+02}$	$1.58x10^{+01}$	$2.88x10^{+04}$	$9.51\ x10^{0}$	$8.30x10^{-01}$
1959	$5.17x10^{+04}$	$4.14x10^{+01}$	$2.18x10^{+01}$	$6.29x10^{+04}$	$3.59\ x10^{0}$	$1.80\ x10^{0}$
1960	$6.09x10^{+04}$	$4.36x10^{+01}$	$2.36x10^{+01}$	$6.98x10^{+04}$	$7.60\ x10^{0}$	$1.76x10^{+01}$
1961	$8.11x10^{+04}$	$4.06x10^{+01}$	$9.85\ x10^{0}$	$8.28x10^{+04}$	$1.03x10^{+01}$	$4.22\ x10^{0}$
1962	$7.23x10^{+04}$	$1.03x10^{+02}$	$1.04x10^{+01}$	$6.47x10^{+04}$	$1.92x10^{+01}$	$6.78\ x10^{0}$
1963	$9.66x10^{+04}$	$1.23x10^{+02}$	$2.10x10^{+01}$	$9.69x10^{+04}$	$1.68x10^{+01}$	$1.07x10^{+01}$
1964	$1.17x10^{+05}$	$1.30x10^{+02}$	$1.41x10^{+01}$	$1.21x10^{+05}$	$5.15x10^{+01}$	$1.13x10^{+01}$
1965	$1.28x10^{+05}$	$5.56x10^{+01}$	$1.17x10^{+01}$	$1.06x10^{+05}$	$2.35x10^{+01}$	$5.22\ x10^{0}$
1966	$1.33x10^{+05}$	$5.36x10^{+01}$	$6.12\ x10^{0}$	$9.56x10^{+04}$	$2.72x10^{+01}$	$4.46\ x10^{0}$
1967	$1.04x10^{+05}$	$6.87x10^{+01}$	$6.72\ x10^{0}$	$8.75x10^{+04}$	$3.80x10^{+01}$	$4.82\ x10^{0}$
1968	$1.07x10^{+05}$	$7.08x10^{+01}$	$9.19\ x10^{0}$	$8.39x10^{+04}$	$2.08x10^{+01}$	$5.46\ x10^{0}$
1969	$7.88x10^{+04}$	$5.14x10^{+01}$	$1.02x10^{+01}$	$7.64x10^{+04}$	$1.04x10^{+01}$	$3.58\ x10^{0}$
1970	$6.61x10^{+04}$	$4.43x10^{+01}$	$7.26\ x10^{0}$	$4.25x10^{+04}$	$1.02x10^{+01}$	$3.89\ x10^{0}$
1971	$4.47x10^{+04}$	$1.05x10^{+01}$	$3.14\ x10^{0}$	$4.44x10^{+04}$	$1.69\ x10^{0}$	$3.81\ x10^{0}$
1972	$6.09x10^{+04}$	$9.14\ x10^{0}$	$1.25\ x10^{0}$	$4.68x10^{+04}$	$6.28x10^{-01}$	$1.92\ x10^{0}$
1973	$8.69x10^{+04}$	$7.48\ x10^{0}$	$9.01x10^{-01}$	$6.10x10^{+04}$	$4.44x10^{-01}$	$2.07\ x10^{0}$
1974	$5.61x10^{+04}$	$8.09\ x10^{0}$	$4.27x10^{-01}$	$5.41x10^{+04}$	$7.01x10^{-01}$	$1.72\ x10^{0}$
1975	$5.15x10^{+04}$	$7.75\ x10^{0}$	$9.12x10^{-01}$	$4.93x10^{+04}$	$3.61x10^{-01}$	$1.46\ x10^{0}$
1976	$7.32x10^{+04}$	$8.94\ x10^{0}$	$4.76x10^{-01}$	$4.64x10^{+04}$	$1.46x10^{-01}$	$1.18\ x10^{0}$
1977	$4.59x10^{+04}$	$6.58\ x10^{0}$	$5.55x10^{-01}$	$4.03x10^{+04}$	$2.45x10^{-01}$	$9.04x10^{-01}$
1978	$3.76x10^{+04}$	$1.04x10^{+01}$	$2.06\ x10^{0}$	$3.55x10^{+04}$	$1.04x10^{-01}$	$6.20x10^{-01}$
1979	$4.52x10^{+04}$	$6.27\ x10^{0}$	$2.68\ x10^{0}$	$2.84x10^{+04}$	$1.04x10^{-01}$	$6.24x10^{-01}$
1980	$3.54x10^{+04}$	$1.83\ x10^{0}$	$1.55x10^{-01}$	$3.00x10^{+04}$	$7.72x10^{-02}$	$5.05x10^{-01}$
1981	$3.94x10^{+04}$	$2.81\ x10^{0}$	$1.04\ x10^{0}$	$2.51x10^{+04}$	$1.16x10^{-01}$	$4.61x10^{-01}$
1982	$3.15x10^{+04}$	$2.85\ x10^{0}$	$6.98x10^{-01}$	$3.08x10^{+04}$	$8.36x10^{-02}$	$3.95x10^{-01}$
1983	$4.06x10^{+04}$	$3.43\ x10^{0}$	$2.35x10^{-01}$	$3.24x10^{+04}$	$7.74x10^{-02}$	$3.84x10^{-01}$
1984	$3.58x10^{+04}$	$6.13\ x10^{0}$	$9.44x10^{-02}$	$3.23x10^{+04}$	$1.22x10^{-01}$	$4.25x10^{-01}$
1985	$3.40x10^{+04}$	$6.23\ x10^{0}$	$1.70x10^{-01}$	$2.21x10^{+04}$	$5.14x10^{-02}$	$2.25x10^{-01}$
1986	$4.52x10^{+04}$	$1.13x10^{+01}$	$1.28x10^{-01}$	$2.21x10^{+04}$	$5.51x10^{-02}$	$3.26x10^{-01}$
1987	$2.75x10^{+04}$	$1.54x10^{+01}$	$5.69x10^{-02}$	$2.04x10^{+04}$	$1.98x10^{-01}$	$3.63x10^{-01}$
1988	$1.44x10^{+04}$	$6.39\ x10^{0}$	$4.40x10^{-02}$	$1.82x10^{+04}$	$2.92x10^{-01}$	$2.63x10^{-01}$
1989	$3.97x10^{+03}$	$2.10x10^{-01}$	$1.68x10^{-02}$	$1.76x10^{+04}$	$1.82x10^{-01}$	$2.56x10^{-01}$
1990	$2.62x10^{+03}$	$4.83x10^{-02}$	$4.28x10^{-01}$	$1.53x10^{+04}$	$4.29x10^{-02}$	$5.41x10^{-01}$
1991	$1.06x10^{+04}$	$2.64x10^{-02}$	$8.91x10^{-02}$	$2.64x10^{+04}$	$2.57x10^{-02}$	$1.14x10^{-01}$
1992	$2.00x10^{+03}$	$1.02x10^{-01}$	$7.86x10^{-01}$	$1.30x10^{+04}$	$8.46x10^{-02}$	$8.84x10^{-01}$

Table 7-5 Adjustment Factors by Radionuclide Group and Year

Year	Group 1 ^{3}H	Group 2 ^{90}Sr	Group 3 ^{137}Cs	Year	Group 1 ^{3}H	Group 2 ^{90}Sr	Group 3 ^{137}Cs
1954	1.0000*	1.0582	0.7813	1976	0.6346	2.4755	0.0163
1955	2.2482	0.1773	0.1927	1977	0.8775	1.6271	0.0372
1956	1.6024	0.0345	0.3224	1978	0.9418	0.3006	0.0101
1957	0.9645	0.0079	0.0014	1979	0.6284	0.2326	0.0165
1958	1.0004	0.0527	0.0918	1980	0.8490	3.2573	0.0423
1959	1.2175	0.0824	0.0867	1981	0.6378	0.4416	0.0412
1960	1.1465	0.7467	0.1744	1982	0.9787	0.5655	0.0294
1961	1.0203	0.4284	0.2528	1983	0.7962	1.6370	0.0226
1962	0.8954	0.6499	0.1871	1984	0.9031	4.5042	0.0200
1963	1.0024	0.5079	0.1362	1985	0.6496	1.3263	0.0083
1964	1.0340	0.8037	0.3964	1986	0.4893	2.5464	0.0049
1965	0.8273	0.4443	0.4223	1987	0.7426	6.3833	0.0128
1966	0.7190	0.7290	0.5078	1988	1.2619	5.9846	0.0456
1967	0.8421	0.7171	0.5530	1989	4.4292	15.1968	0.8696
1968	0.7872	0.5945	0.2933	1990	5.8478	1.2652	0.8899
1969	0.9703	0.3495	0.2026	1991	2.5013	1.2751	0.9724
1970	0.6430	0.5361	0.2313	1992	6.4926	1.1252	0.8279
1971	0.9923	1.2122	0.1611				
1972	0.7686	1.5321	0.0687	**Mean**	1.3325	1.7623	0.2339
1973	0.7021	2.3023	0.0593	**Median**	0.9589	0.8037	0.0918
1974	0.9644	4.0233	0.0866	**Max**	6.4926	15.1968	0.9724
1975	0.9589	1.5961	0.0467	**Min**	0.4893	0.0079	0.0014

*Originally this value was calculated as 20.8814.

Note that the adjustment factor initially calculated for tritium in year 1954 was 20.8814, which is three times larger than the next highest tritium adjustment factor and about 20 times larger than the median value of all adjustment factors over 39 years. This large factor was calculated because of the inclusion of estimated releases from D-Area in the Phase II modeling of tritium release to the Savannah River. In Phase II, 17,530 curies of tritium from D-Area was assumed to be released surface waters in 1954 (Phase II). This D-Area release, however, is not documented in Cummins et al (Cummins 1991a). For Phase III, it was reasoned that if tritium release from D-Area were the only reason for such a large adjustment factor in 1954, the other radionuclides in this group (i.e. ^{129}I, I^{131}, ^{99}Tc, and ^{35}S) should not be similarly adjusted lest the true releases of these radionuclides be significantly overestimated. Another reason for not using such a large adjustment factor for the tritium group in 1954 was that the functionality of D-Area was heavy water rework, and site effluent release data (Cummins 1991a) does not show iodine, technetium, and sulfur being released from that facility in 1954. The factor 1.0 was thus used for the tritium group in 1954 to avoid overestimation of other radionuclide releases.

7.3.2.2.3 Binning Radionuclides by Distribution Coefficient, K_D

As stated above, the adjustment factors developed in the previous section are to be applied according to the geochemical characteristics of the released radionuclides as indicated by the distribution coefficient. The soil-to-water distribution coefficient K_D is a measure of the partitioning between solid and liquid phases that a radionuclide experiences as it passes through environmental media. As radioactive contaminants move through the soils, sediments, and the swamp at the SRS site, they will be attracted to various surfaces. This attraction results in a delay (retardation) of the transport of the contaminant through the system relative to the flow of water. The amount of a particular radionuclide that will reach the Savannah River is expected to depend on this retardation phenomenon and the radiological half-life of the radionuclide.

The K_D values of the radionuclides considered in this analysis span many orders of magnitude. However, to simplify the analysis, the radionuclides have been divided into only three groups:

(1) $K_D \leq 10$
(2) $10 \leq K_D \leq 1000$
(3) $K_D > 1000$

These groups correspond to the nominal K_D values used in the Phase II modeling of water releases: 0, 100, and 10,000, respectively for ^{3}H, ^{90}Sr, and ^{137}Cs. All radionuclides analyzed in Phase III were assigned to a particular group and were assigned the same annual adjustment factor calculated for that group. The group assigned to each radionuclide is stated in Table 7-6. Table 7-6 also provides the K_D value(s) used to determine the group assigned to each radionuclide. Note that the "Adjustment Factor Group" in the last column in Table 7-6 corresponds to the index "k" in equation (7-2).

Table 7-6 Grouping of Radionuclides According to K_D Values

Radionuclide	Soil-to-Water Distribution Coefficient, K_D			Adjustment Factor Group
	Phase II Value	Soil Value*	Swamp Value†	
^{3}H	**0**	0		^{3}H
^{129}I, ^{131}I		1.55		^{3}H
^{99}Tc		2.49		^{3}H
^{35}S		7.5		^{3}H
^{103}Ru, ^{106}Ru		55		^{90}Sr
^{60}Co		60		^{90}Sr
^{89}Sr, ^{90}Sr	**100**	3040	1676	^{90}Sr
^{95}Nb		160		^{90}Sr
^{32}P		173		^{90}Sr
^{65}Zn		200		^{90}Sr
^{141}Ce, ^{144}Ce		490	255	^{90}Sr
^{95}Zr		600		^{90}Sr
U		1000	170	^{90}Sr
Pu		4100		^{137}Cs
^{134}Cs, ^{137}Cs	**10,000**	59		^{137}Cs

*Source: Kaplan et al., 2003.
†Source: Kaplan and Serkiz, 2000.

It should be noted that the K_D's used in Phase II are orders of magnitude different from those reported in recent SRS literature (Kaplan, 2003). In the Phase II modeling, a range of K_D's having a median value of 10,000 were used for cesium, whereas the range of values used for strontium had a median value of 100. Median K_D's reported by Kaplan et al for agricultural soils are 59 for cesium and 3041 for strontium (Kaplan 2003). Another report by Kaplan gives a K_D value of 1676 for ^{90}Sr in the swampy soils (Kaplan and Serkiz, 2000).

7.3.3 Completion and Correction of the Release Data Base (Step S-5)

The data base describing liquid releases from various SRS facilities was compiled in electronic format largely from SRS tabulations (Cummins, 1991a). This initial set of data was completed and corrected as follows:

1. Data for releases in the years 1990-1992 were added by examining the appropriate Site Environmental Reports (Cummins, 1990; Cummins, 1991b; Arnett, 1992; Arnett, 1993).
2. Releases categorized as unidentified beta-gamma activity were added to the ^{90}Sr releases on an annual basis.
3. Releases categorized as unidentified alpha activity were added to the ^{239}Pu releases on an annual basis.
4. Releases of ^{131}I (half-life of 8.04 days) into seepage basins were not included because it was assumed the activity would substantially decay before the iodine could migrate from the seepage basins to the surface streams; i.e., for ^{131}I only category 1 releases were included.
5. The Phase II report and SRS reports indicate a total release of 3 Ci of ^{129}I for the period from 1955-89. This 3 Ci release was apportioned evenly over these years, since no more defined information was available. As with other radionuclides, releases for 1990-1992 were obtained from SRS Environmental Reports.
6. Conflicting values for releases of ^{90}Sr from the L-reactor were obtained from the Cummins report for 1989, depending upon whether radionuclides were summed by facility or radionuclide indexes. What appear to be two spurious entries for ^{90}Sr releases from the L-reactor in 1989 were not included.

7.3.4 Apply Adjustment Factors and Compute Concentrations for Savannah River (Step S-6)

The completion and correction of facility release data described in the preceding section resulted in a tabulation of the quantity of contaminants released by year and radionuclide for the 22 radionuclides listed in Table 7-2. These corrected facility release quantities are used to derive the estimated releases by year and radionuclide to the Savannah River, as follows:

$$R^R_{ij} = R^{CF}_{ij} \cdot F_{jk} \qquad (7\text{-}3)$$

Where,

R^R_{ij} is the release to the Savannah River of radionuclide i and year j;
R^{CF}_{ij} is the Corrected Facility releases of radionuclide i and year j estimated according to the procedure in Section 7.3.3
F_{jk} is the adjustment factor computed according to equation (7-2).

Note that the correction factor, F_{jk}, depends upon the both the year j and the radionuclide group k; for each radionuclide i the correction factor group is indicated in Table 7-6. When the radionuclide release being adjusted in equation (7-3) was one of those modeled in Phase II (i.e., ^{137}Cs, ^{90}Sr, or ^{3}H), the computed release to the river, R^R_{ij}, is just the modeled release from Phase II for each year. However, this

is not entirely the case for ^{90}Sr. Because the corrected facility release for ^{90}Sr included unidentified beta-gamma activity, the computed releases to the river, R^R_{ij}, is higher than the releases modeled in Phase II.

Figure 7-5 shows the yearly activity estimated by the procedure described above for release of tritium to the Savannah River from the SRS. This graph is consistent with the median (50th percentile) of the Phase II model discussed in Section 7.2.3 Releases rise to a peak in 1964 and then decrease. Figure 7-5 shows the yearly activity estimated in Phase III for release of ^{137}Cs and ^{90}Sr to surface water on the SRS site. Somewhat like tritium, releases of ^{137}Cs rise to a rough peak in 1964, and then decrease, although a second, smaller peak is seen in 1967. The large peak for ^{90}Sr in 1967 reflects the release into the K-Area containment basin of over 100 curies of unidentified beta-gamma activity during that year.

Once the radionuclide releases to the Savannah River have been obtained by the procedure described above, the concentrations of the radionuclides in the river can be easily computed by a variant of equation (7-1):

$$C_{ij} = R^R_{ij}/Q_j \qquad (7\text{-}4)$$

These concentrations were computed in this fashion, tabulated in a spreadsheet, and input to the GENII code. Concentrations in the Savannah River for various radionuclides computed in the manner described above are shown in Figure 7-5. Note the peaks in activity seen for ^{32}P, ^{137}Cs, and ^{90}Sr in the years 1966 and 1967. Chapter 11 discusses how the peaks caused high doses in receptors exposed to the contaminants released to the water through fish ingestion.

In order to compute the concentrations indicated in equation (7-4) the annual flow rates, Q_j, for the Savannah River were required. Annual flow rates for the Savannah River were derived in two ways:

1. For the years 1954 through 1969 and for the years 1983 through 1992, flow rates for the Savannah River as measured at Burtons Ferry Bridge (Highway 301) near Millhaven, Georgia, were obtained from the USGS [USGS 2003c]. This monitoring station is located about 500 feet downstream of the bridge on U.S. Highway 301 linking Screven County, GA, with Allendale County, SC. Hence, it is downstream of all surface water discharge points into the Savannah River from SRS.
2. No information was available from USGS for this monitoring station for the years 1970 through 1982. For these years, flow rates were projected from flow rates measured at Augusta, GA. The projected flow rates were derived using a relationship from [Hayes & Marter]. This reference reports a strong linear relationship (r = 0.98) between the flows at the Burtons Ferry Bridge and Augusta monitoring stations: $Flow_{BFB} = 1.15\ Flow_{AUG} + 202$.

The flow rates derived for this report are listed in Table 7-7 in units of cubic feet per second (cfs). Table 7-7 also presents the Savannah River volumes (liters) calculated for Phase III assuming 365 days per year (except for 366 days per year every leap year).

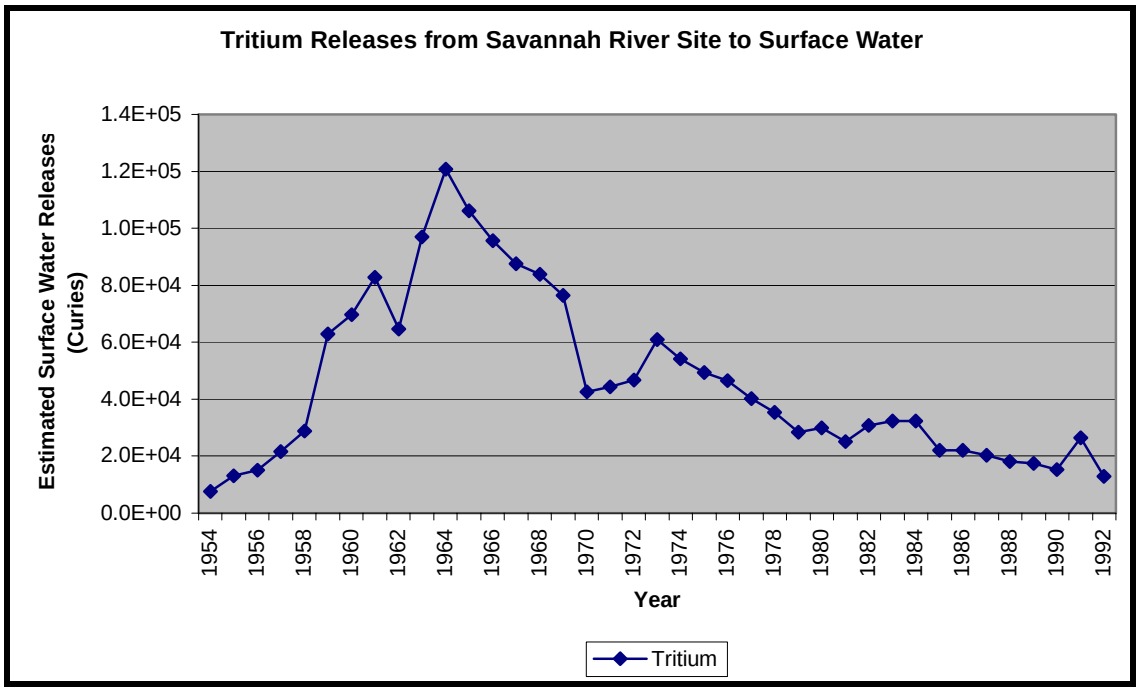

Figure 7-5 Tritium Release to Savannah River (Ci/y)

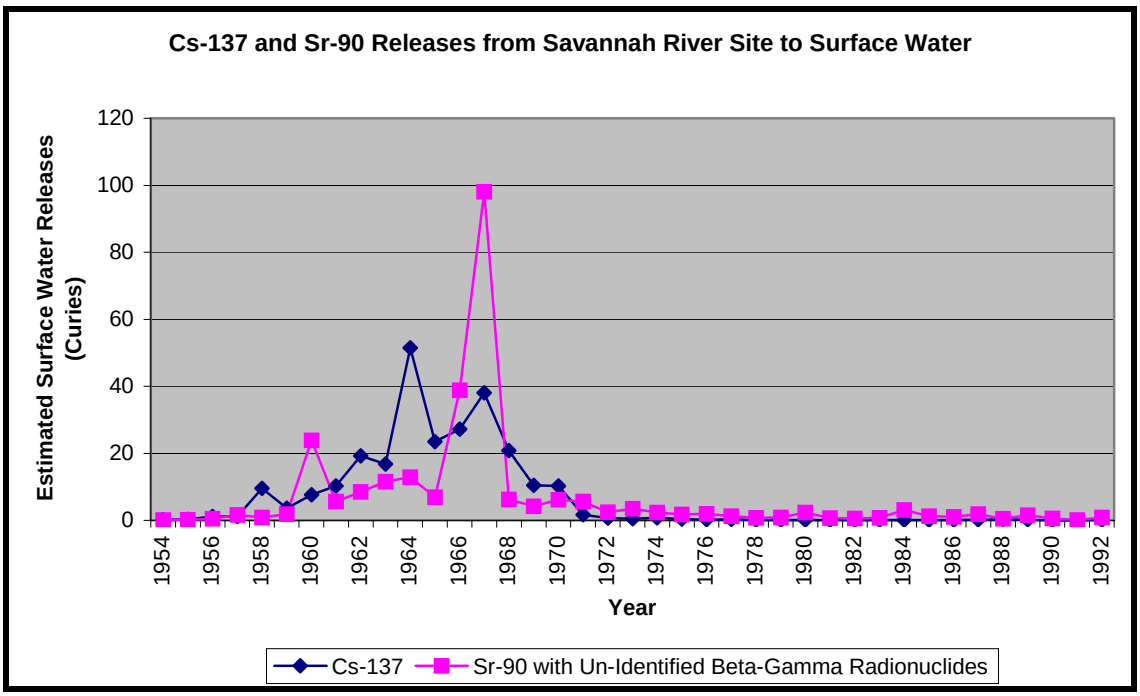

Figure 7-6 ^{137}Cesium and ^{90}Strontium Release to Savannah River (Ci/y

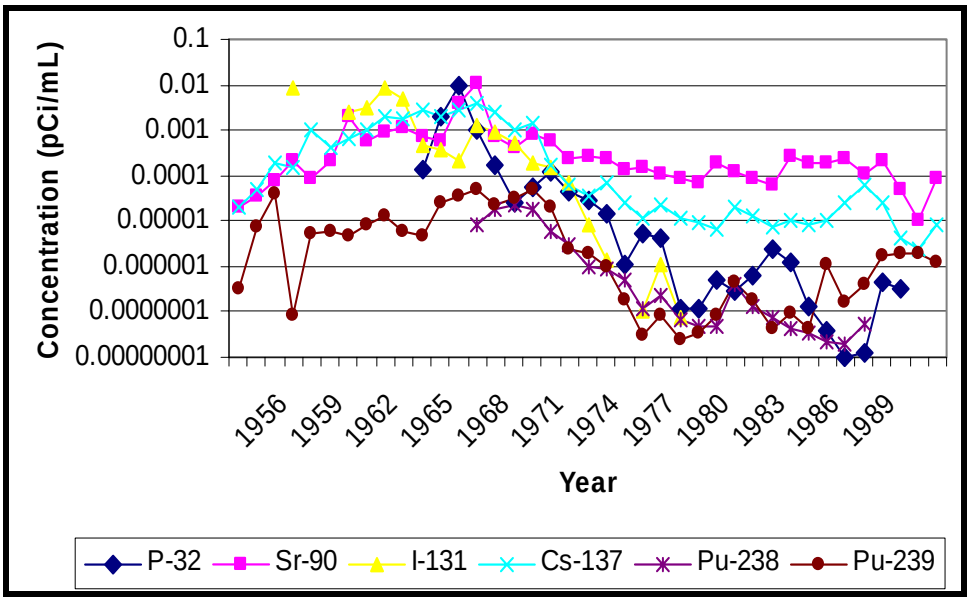

Figure 7-5 Estimated Concentrations of Selected Radionuclides in Savannah River (pCi/mL

Table 7-7 Savannah River Flow Rates and Annual Volumes as Determined for Burtons Ferry Bridge (Highway 301)

Year	Leap Year	Annual Mean Value* (cfs)	Water Volume (Liter)	Year	Leap Year	Annual Mean Value* (cfs)	Water Volume (Liter)
1954		7,382	$6.60x10^{+12}$	1974		11,101	$9.93x10^{+12}$
1955		5,974	$5.34x10^{+12}$	1975		15,408	$1.38x10^{+13}$
1956	L	6,309	$5.66x10^{+12}$	1976	L	13,914	$1.25x10^{+13}$
1957		8,312	$7.43x10^{+12}$	1977		11,646	$1.04x10^{+13}$
1958		11,038	$9.87x10^{+12}$	1978		10,522	$9.41x10^{+12}$
1959		9,748	$8.72x10^{+12}$	1979		13,252	$1.18x10^{+13}$
1960	L	13,112	$1.18x10^{+13}$	1980	L	13,201	$1.18x10^{+13}$
1961		10,909	$9.75x10^{+12}$	1981		6,599	$5.90x10^{+12}$
1962		10,580	$9.46x10^{+12}$	1982		7,169	$6.41x10^{+12}$
1963		11,138	$9.96x10^{+12}$	1983		12,348	$1.10x10^{+13}$
1964	L	20,497	$1.84x10^{+13}$	1984	L	12,759	$1.14x10^{+13}$
1965		12,785	$1.14x10^{+13}$	1985		7,167	$6.41x10^{+12}$
1966		11,175	$9.99x10^{+12}$	1986		6,175	$5.52x10^{+12}$
1967		10,573	$9.45x10^{+12}$	1987		8,955	$8.01x10^{+12}$
1968	L	9,624	$8.63x10^{+12}$	1988	L	5,364	$4.81x10^{+12}$
1969		10,945	$9.79x10^{+12}$	1989		7,966	$7.12x10^{+12}$
1970		8,208	$7.34x10^{+12}$	1990		11,860	$1.06x10^{+13}$
1971		10,686	$9.55x10^{+12}$	1991		11,670	$1.04x10^{+13}$
1972	L	11,235	$1.01x10^{+13}$	1992	L	11,860	$1.06x10^{+13}$
1973		14,431	$1.29x10^{+13}$				

* Flow Rate From USGS Station ID: 02197500

7.3.5 Comparison of Phase II Release Estimates and Phase III Source Terms

Because the estimates for concentrations in the Savannah River were based on water releases from the entire SRS, a comparison of the Phase II and Phase III bases is discussed here. The data used as input to Phase III of the SRS Dose Reconstruction Project were checked as part of a Quality Assurance Program. However, to assure appropriate agreement between the Phase II and Phase III analyses, the total releases for all significant radionuclides were compared.

7.3.5.1 Comparison of Phase II Modeled Releases to SRS Point-of-Release Data

For ^{3}H, ^{90}Sr, and ^{137}Cs, the annual medians (50th percentile) of the Phase II Savannah River release model are compared with the annual point-of-release estimates for these radionuclides as compiled from Category 1 and 3 releases documented in Cummins 1991a. The results of this comparison are summarized in Table 7-8.

Table 7-8 Comparison of Phase II Median Releases to Savannah River with SRS Point-of-Release

Radionuclide	Range of Median of Model to Point-of-Release Ratios	Mean, Median of Model to Point-of- Release Ratios
^{3}H	0.379 – 20.881	1.228*
^{90}Sr	0.008 – 6.383	1.379
^{137}Cs	0.001 – 0.972	0.234

*This ratio does not include 1954 estimates for ^{3}H.

It was expected that the median values estimated by the Phase II surface water model should be approximately equal to or smaller than the total releases reported by SRS. With a few exceptions, this was the case. An example exception is the 1954 ratio of the estimated median release to the total tritium release. The ratio is 20.881, as noted in Section 7.4.6. The Phase II report stated that releases were adjusted if it was believed that reported releases were too low. This extremely high ratio is probably a reflection of such an adjustment, since reporting of releases in the early years of operations was not as accurate as in later years.

The ratios as a function of time are presented in Figure 7-6. Note that the ratios are dramatically higher during the last years of operations. The late years may reflect that operational releases from facilities in general were reduced, but there were still releases of residual radioactivity from the site. In particular the releases for ^{90}Sr were elevated because unidentified beta-gamma activity was added to the ^{90}Sr inventory. Note that the variations in time are significant. This is due, in part, to the model that increased releases in years with large spring floods to account for the remobilization of radionuclides stored in previous years in the sediments and biota of the swamp. For these reasons, annual adjustment factors were used for Phase III rather than an average adjustment factor covering all years.

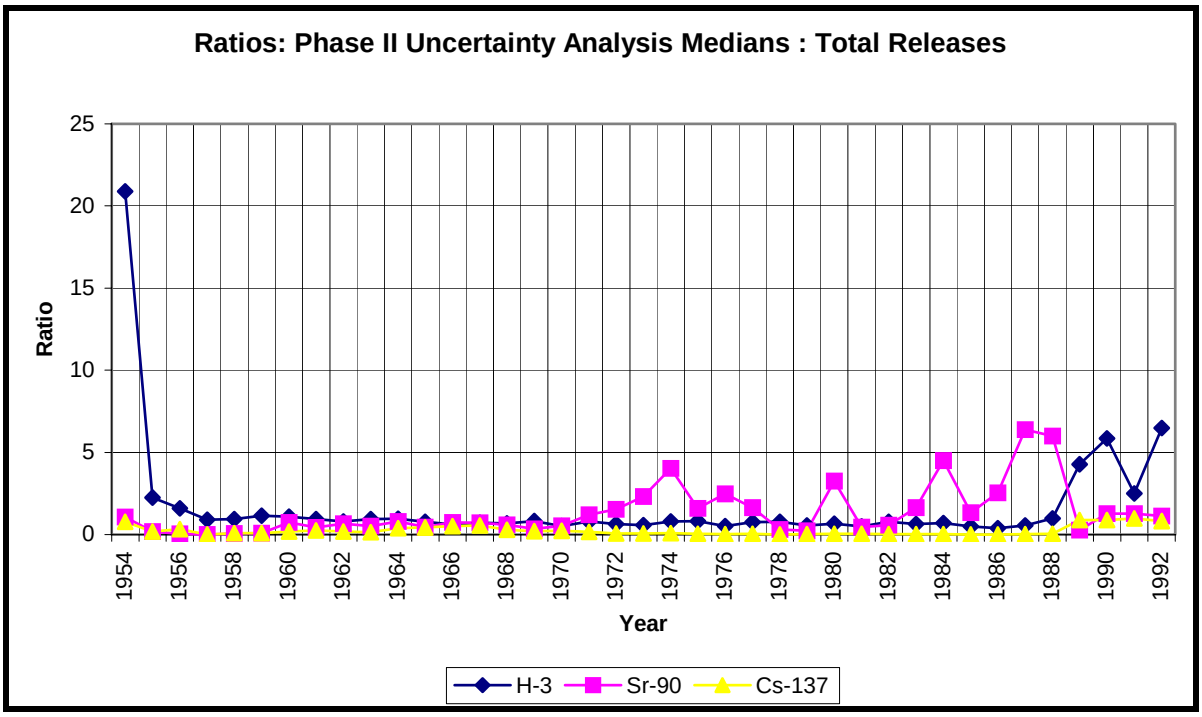

Figure 7-6 Annual Ratios of Phase II Median of Savannah River Release Model to SRS Point-of-Release Data.

7.3.5.2 Comparison of Phase III Releases with Phase II Screening Assumptions

Because of the approach adopted for Phase III, the releases to streams, seepage basins, and containment basins were compiled by radionuclide as point-of-release estimates, as discussed in Section 7.3.2.2.1. There are two comparisons of Phase III release estimates and Phase II release estimates that help to place the Phase III analysis in context:

1. the sum of Phase III releases for each radionuclide and all facilities over 36 years compared to the sum of 36-year, overall site releases for each radionuclide used in the Phase II screening analysis; and

2. the sum (36 years and all facilities) of the extrapolated releases used in Phase III compared to sum of 36-year, overall site releases for each radionuclide used in the Phase II screening analysis.

Table 7-9 shows these comparisons.

Table 7-9 Comparison of Phase III Releases with Phase II Screening Assumptions

Releases from Phase II Water-Level 1 Screening		Sum of 36-year Releases from Cummins Data - Basis for Phase III Point-of-Release Estimates			Sum of 36-year Phase III Releases to Savannah River	
Radio-nuclide	**Surface Water Release from SRS (Ci/36 yr)**	**Cat. 1+Cat. 3 Unless Otherwise Noted (Ci/36 yr)**	**Ratio, Screening to Phase III Basis**	**Check**	**Phase III Release to River (Ci/36 yr)**	**Ratio, Phase III River Release to Screening**
^{241}Am	1.00E-02					
^{140}Ba, ^{140}La	2.20E+02					
^{141}Ce, ^{144}Ce	$7.00\text{x}10^{+02}$	$7.08\text{x}10^{+02}$	0.99		$4.58\text{x}10^{+02}$	$6.54\text{x}10^{-01}$
^{244}Cm	8.00E-01					
^{134}Cs	$1.35\text{x}10^{+01}$	$1.35\text{x}10^{+01}$	1.00		2.87	$2.13\text{x}10^{-01}$
^{137}Cs	$1.95\text{x}10^{+03}$	$1.95\text{x}10^{+03}$	1.00		$2.57\text{x}10^{+02}$	$1.32\text{x}10^{-01}$
^{58}Co	2.73E+00					
^{60}Co	$8.40\text{x}10^{+01}$	$8.42\text{x}10^{+01}$	1.00		$5.40\text{x}10^{+01}$	$6.43\text{x}10^{-01}$
^{51}Cr	5.00E+03					
^{3}H	$1.50\text{x}10^{+06}$	$1.53\text{x}10^{+06}$	0.98	*	$1.73\text{x}10^{+06}$	1.16
^{131}I	$3.03\text{x}10^{+02}$	$3.02\text{x}10^{+02}$	1.00	*	$2.88\text{x}10^{+02}$	$9.50\text{x}10^{-01}$
^{129}I	1.20	3.00	see note	*	2.71	2.26
^{239}Np	1.44E+03					
^{32}P	$1.96\text{x}10^{+02}$	$1.96\text{x}10^{+02}$	1.00		$1.29\text{x}10^{+02}$	$6.60\text{x}10^{-01}$
^{239}Pu, ^{240}Pu	8.00	7.9	1.01		2.95	$3.69\text{x}10^{-01}$
^{238}Pu	4.00	4.0	0.98		$7.08\text{x}10^{-01}$	$1.77\text{x}10^{-01}$
^{103}Ru, ^{106}Ru	$1.80\text{x}10^{+03}$	$1.80\text{x}10^{+03}$	1.00		$1.30\text{x}10^{+03}$	$7.25\text{x}10^{-01}$
^{124}Sb, ^{125}Sb	2.40E+01					
^{89}Sr, ^{90}Sr	$6.20\text{x}10^{+02}$	$7.11\text{x}10^{+02}$	0.87	*	$4.60\text{x}10^{+02}$	$7.42\text{x}10^{-01}$
^{35}S	$1.75\text{x}10^{+03}$	$1.75\text{x}10^{+03}$	1.00		$1.53\text{x}10^{+03}$	$8.77\text{x}10^{-01}$
^{99}Tc	$5.30\text{x}10^{+01}$	$5.30\text{x}10^{+01}$	1.00		$5.47\text{x}10^{+01}$	1.03
^{232}Th	2.00E-01					
^{235}U, ^{238}U	$4.20\text{x}10^{+01}$	$4.15\text{x}10^{+01}$	1.01		$1.19\text{x}10^{+01}$	$2.83\text{x}10^{-01}$
^{91}Y	1.20E+02					
^{65}Zn	$1.50\text{x}10^{+02}$	$1.50\text{x}10^{+02}$	1.00		$9.64\text{x}10^{+01}$	$6.43\text{x}10^{-01}$
^{95}Zr, ^{95}Nb	$1.45\text{x}10^{+02}$	$9.64\text{x}10^{+02}$	0.15	*	$8.23\text{x}10^{+02}$	5.67
						Average Ratio
Tritium Group: ^{129}I, ^{131}I, ^{99}Tc, ^{35}S						1.28E+00
Strontium Group: ^{103}Ru, ^{106}Ru, ^{60}Co, ^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{32}P, ^{65}Zn, ^{141}Ce, ^{144}Ce, Uranium						6.21E-01
Cesium Group: ^{134}Cs, ^{137}Cs, Plutonium						2.23E-01

Comparison 1. The Table 7-9 column headed "Check" compares the unadjusted Phase III values to the Phase II screening values. A star notation indicates that an explanation is warranted. These explanations are provided below.

^{3}H. For tritium, the Phase II study states that both streams and seepage basins were included as the source of releases to the surface water pathway in the screening assessment. It appears from the data presented in the Phase II report that seepage basin data for ^{3}H (and ^{131}I) was not included in the screening assessment. This is indicated by the good agreement between the stream-only source terms. (Phase III estimates releases to streams, seepage basins, and containment basins.)

^{131}I. The entry from the Phase II screening assessment is Category 1 release only; i.e., release to streams only. This appears to be appropriate because of the short, 8-day half-life of ^{131}I. Any substantial holdup duration would cause the seepage basin inventory to decay away. The Phase III point-of-release data file only includes releases to streams.

^{129}I. In the Phase II report, the 1.2 Ci entry for ^{129}I in the table for the screening calculation was obtained by assuming that 3 Ci entered the seepage basin and 40% of that inventory was released from the basin to the stream (3 Ci * 0.4 = 1.2 Ci). Because Phase III modifies all of the other radionuclide inventories using an adjustment factor, 3 Ci was used.

^{89}Sr, ^{90}Sr. Although the Phase II screening value and the Phase III base value are different by about 15%, this appears to be due to an addition problem in the Phase II report. The screening spreadsheet value should have been about 720 Ci, based on the note in the spreadsheet indicating how the entry was obtained. However, this difference is not important. When ^{89}Sr, ^{90}Sr releases are applied in the dose reconstruction, unidentified beta-gamma releases were added to the ^{90}Sr inventory in the amount of 218.88 Ci (before multiplication by the adjustment factor for ^{90}Sr), this dwarfs any differences between the Phase III basis and screening values.

^{95}Zr, ^{95}Nb. The Phase II report stated that all estimates of reported releases of ^{95}Zr, ^{95}Nb, and ^{95}Zr, ^{95}Nb were combined to ensure a conservative approach. However, the value used in the Phase II screening seems to match only the total of ^{95}Zr and ^{95}Nb.

Comparison 2. The adjustment factors, applied on the basis of K_D, are reflected in the ratios of the Savannah River releases (Phase III) to the screening assessment releases (Phase II). Average ratios for three groups of radionuclides (^{3}H, ^{90}Sr, and ^{137}Cs groups) are given in Table 7-9.

The radionuclides scaled to ^{3}H have, on average, increased values compared with the screening assessment inventories (+28%). The Sr scaled nuclides have, on average, 62.1% of the screening value. The Cs-scaled nuclides have, on average, about 20% of the screening values. This is due to hold-up in the environment, based on use of different K_D values. These values compare, in general, with the adjustment factor values for each scaling group averaged over all the years, which are respectively: 0.749, 0.711, and 0.232. Since the ratio for each nuclide depends on applying the annual adjustment factor for the group to the annual releases for the radionuclide, the sum of the products depends upon the release history of the radionuclide. This accounts for the variability of the ratios within each group.

7.4 Modeling Concentrations for Lower Three Runs Creek

Unlike other streams draining the Savannah River Site, Lower Three Runs Creek can be routinely accessed by members of the public. Hence concentrations in the creek needed to be estimated so that potential exposures, in accordance with the scenario specifications, could be assessed.

7.4.1 A Simple Model for Lower Three Runs Creek (Step L-3)

Similar to the approach described in Section 7.3.1 annual concentration estimates of three radionuclides (^{3}H, ^{90}Sr, and ^{137}Cs) for the exposure location at Martin, SC, were computed by finding the ratio of (1) the annual release of each of these radionuclides into Lower Three Runs Creek and (2) the corresponding annual flow rates of Lower Three Runs Creek as determined from USGS monitoring stations. These calculated concentrations were then compared with concentrations of these nuclides as measured over the years at Martin, SC.

Annual flow rates for Lower Three Runs Creek at Martin, SC, were not available for the years 1954 through 1992, although they were available for the years 1998 through 2001. To estimate the flow rate at Martin for the time period of interest, the flow rate was estimated by ratio from the flow rate at a nearby location on the creek. The process for doing so is described in [ATL 2003].

Calculated Lower Three Runs Creek concentrations of ^{3}H, ^{90}Sr, and ^{137}Cs are compared with directly measured concentrations in Figure 7-7, Figure 7-8, and Figure 7-9. This comparison shows that concentrations in Lower Three Runs Creek based on release inventories and flow rates disagreed with measured concentrations. This disagreement was particularly evident for the case for ^{3}H and ^{137}Cs during the early years of site operation. Par pond was built on Lower Three Runs Creek in the 1960s and the dam would have affected flow rates and the discharge of radionuclides to areas below the dam.

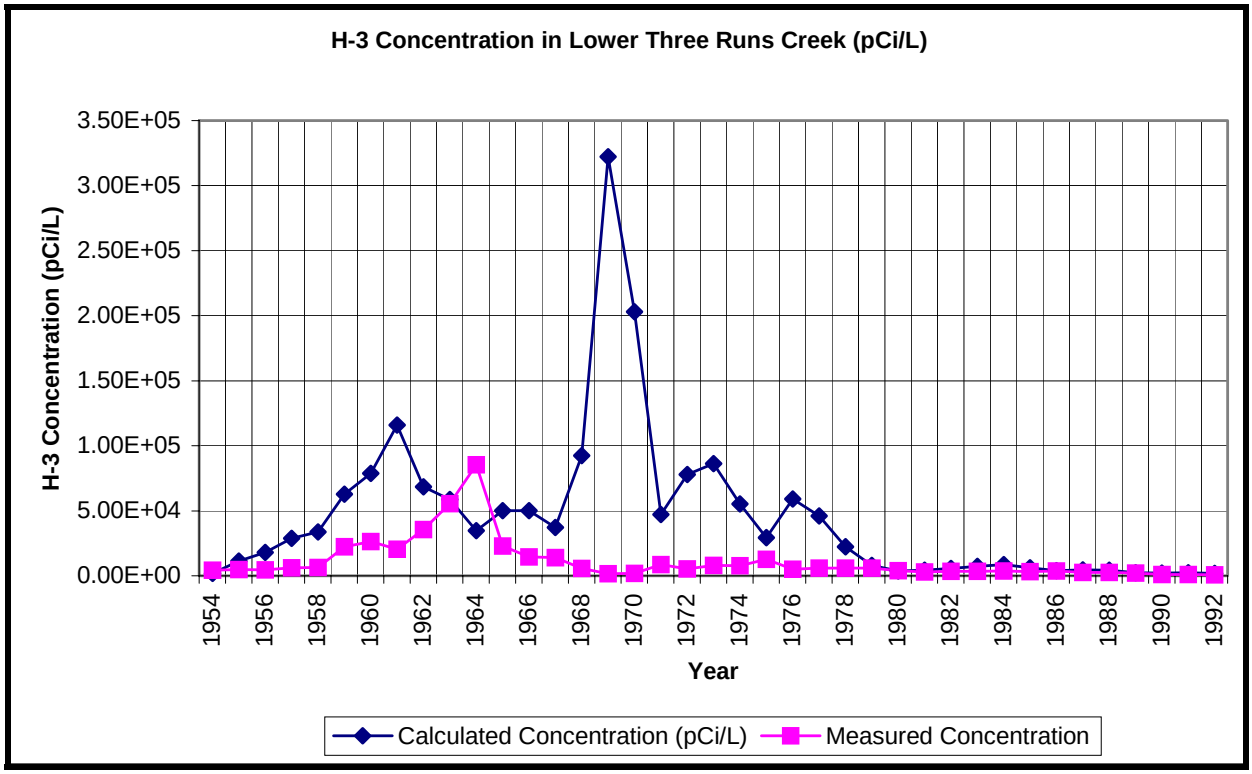

Figure 7-7 Comparison of Calculated to Measured Concentrations of ^{3}H in Lower Three Runs Creek

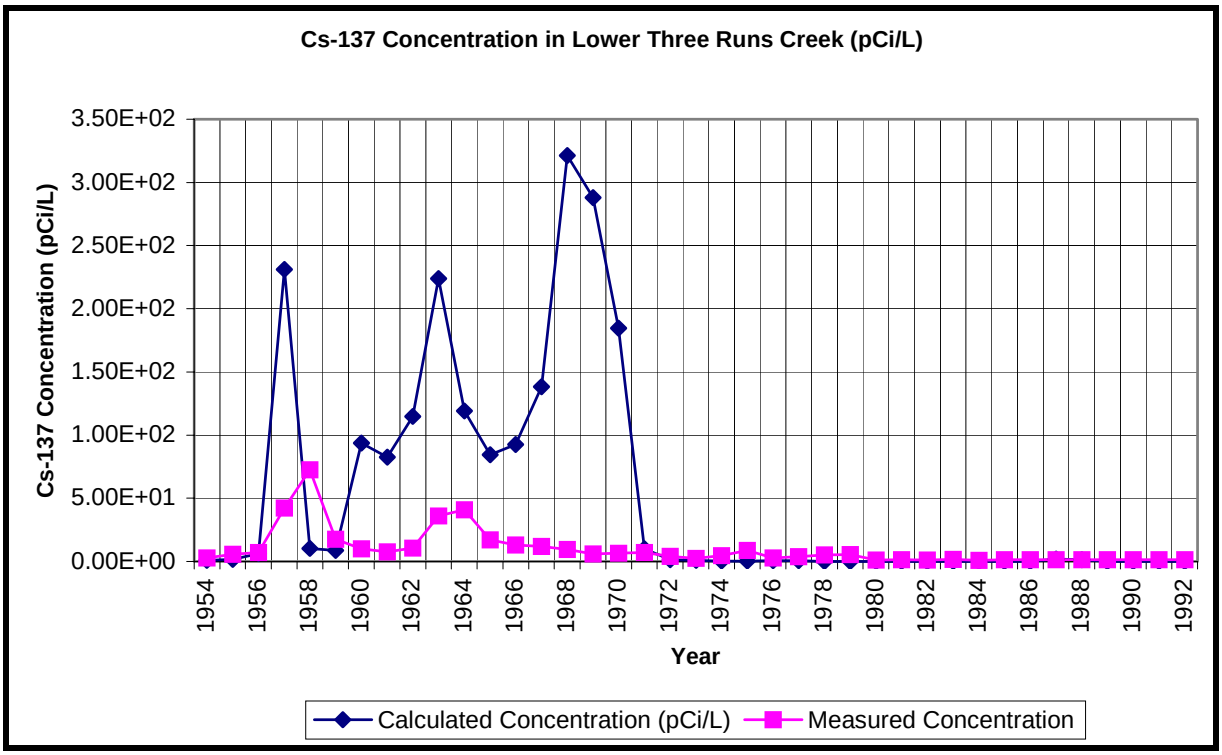

Figure 7-8 Comparison of Calculated to Measured Concentrations of ^{137}Cs in Lower Three Runs Creek

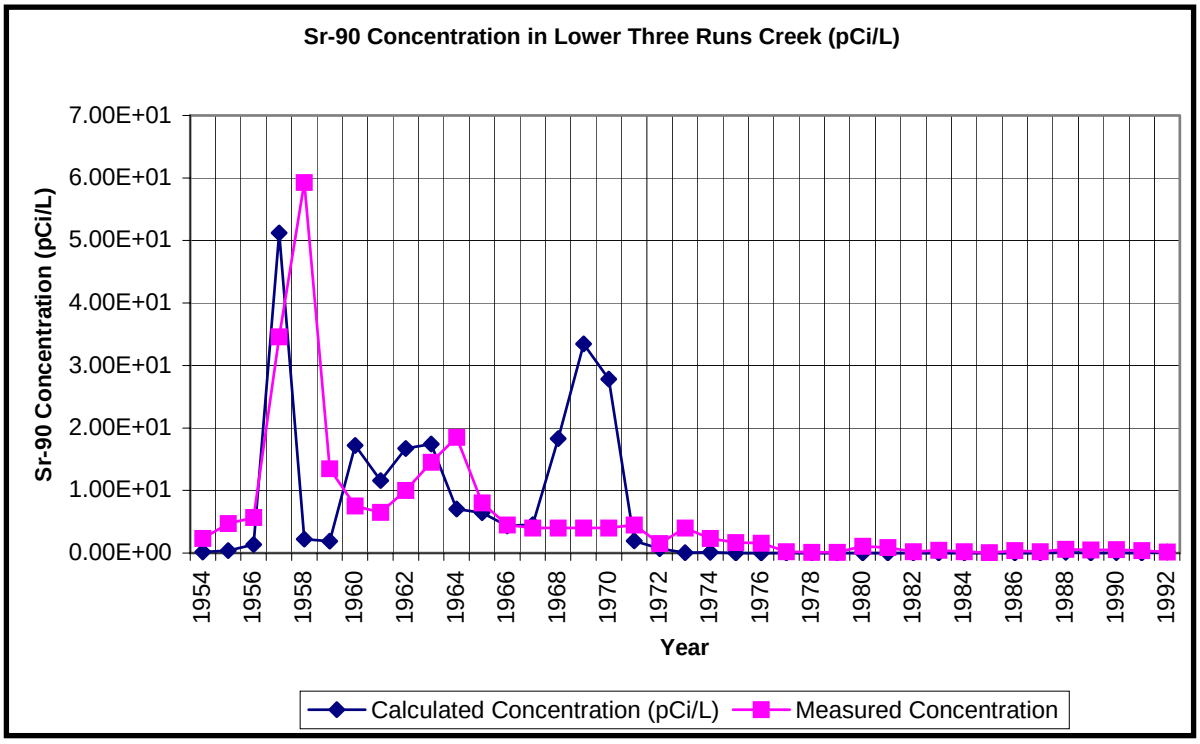

Figure 7-9 Comparison of Calculated to Measured Concentrations of ^{90}Sr in Lower Three Runs Creek

7.4.2 Use Available Measured Concentrations (Step L-4)

Because the concentrations estimated with a simple model did not agree with measurements, for Phase III the measured concentrations (at Martin, when possible) were used for three critical radionuclides (^{137}Cs, ^{90}Sr, and ^{3}H) to estimate doses at Martin from releases to Lower Three Runs Creek. This change was especially important for early years when concentrations in the creek were high, but the estimates based on release inventories gave excessively high concentrations.

Short of developing a physically-based model similar to that used in Phase II for releases into the Savannah River, there was no practical alternative to estimating concentrations from SRS releases in Lower Three Runs Creek. Although releases through Lower Three Runs Creek would be expected to experience the same types of loss mechanisms (sedimentation, decay, and sorption or uptake), as other site streams, the influence of these processes was thought to be smaller than for other streams mainly because Lower Three Runs Creek does not pass through the Savannah River Swamp.

The choice of using actual measured concentration in the river had the following advantages:

1. The inventory of radionuclides initially entered into the Lower Three Runs Creek from the site and the annual flow rates in Lower Three Runs Creek became non-important because radionuclide concentrations were obtained directly from the actual measured concentrations in the monitoring reports.
2. The transport mechanisms were reflected in the measured concentrations. Sediment retention, radionuclide decay, biota uptake, periodic flooding, absorption and dilution only influenced how the radionuclides were transported in the creek. The focus in Phase III is to assess the exposures to these radionuclides in the river. Thus the result of radionuclide transport was the most important issue.
3. These three radionuclides (^{137}Cs, ^{90}Sr, and ^{3}H), identified as important in the Phase II Level 1screening, were measured on a regular basis for most of the operational years.

The disadvantages include:

1. Not all of the radionuclides of interest (radionuclides that passed the Level 1 Screening criteria) were routinely measured.
2. Contributions from runoff of land-deposited SRS radionuclide releases to air and discharges from non-SRS sources, if present in any significant fashion, could not be effectively distinguished or separated from liquid releases to Lower Three Runs Creek from the SRS.

7.4.3 Complete Data Base for Measured Concentrations (Step L-5)

Annual data for ^{3}H, ^{90}Sr, and ^{137}Cs were compiled from a variety of sources to make the surface water source term for Lower Three Runs Creek.

7.4.3.1 ^{137}Cesium and ^{90}Strontium

Average annual Lower Three Runs Creek concentrations were determined for ^{137}Cs, and ^{90}Sr using a variety of references. For the years 1964 through 1992, annual average concentrations were determined using data published in SRS environmental reports [Ashley 1965, Ashley 1966, Ashley 1967, Ashley 1968, Ashley 1969, Ashley 1970, Ashley 1971, Ashley 1972, Ashley and Zeigler 1973, Ashley and Zeigler 1974, Ashley and Zeigler 1975, Ashley and Zeigler 1976, Ashley and Zeigler 1978a, Ashley and Zeigler 1978b, Ashley and Zeigler 1981, Ashley 1982, Zeigler 1983, Ashley and Zeigler 1984, Ashley 1984, DOE 1985, Zeigler 1986, Zeigler 1987, Zeigler 1988, Davis 1989, Cummins 1990]. For the years 1954 through 1963, no environmental reports were published. For these years, measured water

concentrations in Lower Three Run Creek for nonvolatile beta, radiostrontium, and radiocesium were obtained from Health Physics Regional Monitoring Semiannual Reports or Semiannual Progress Reports [Horton 1954, Horton 1955, Alexander and Horton 1956, Horton and Mealing 1956, Horton and Mealing 1957, Mealing 1957, Mealing and Horton 1957, Mealing 1958, Harvey 1959a, Harvey 1959b, Dupont 1959, Dupont 1960a, Dupont 1960b, Dupont 1961, Dupont 1962a, Dupont 1962b, Dupont 1963, Dupont 1964]. In these references, measured nonvolatile beta concentrations are available from 1954 to 1963 while radiostrontium and radiocesium concentrations are only available from the second half year of 1958 through 1963. Measured average concentrations in Lower Three Run Creek at Martin were cited from these semiannual reports except for the first half year of 1954, when no sampling location is specified.

From the second half year of 1958 to 1962, measured nonvolatile beta, radiostrontium, and radiocesium concentrations provided the basis to calculate average values of the ratios of the concentrations of radiostrontium and radiocesium to the concentrations of nonvolatile beta activity in Lower Three Runs Creek at Martin. These average values are presented in Table 7-10. The average value of the ratio of radiostrontium to non-volatile beta over the period 1958 through 1962 is 0.25. The average value of the ratio of radiocesium to non-volatile beta over this time period was 0.30.

Table 7-10 Ratio of Radiostrontium and Radiocesium to Nonvolatile Beta Activity in LTRC at Martin

Date	Location	NVB* (pCi/L)	Radiostrontium (pCi/L)	Strontium-NVB Ratio	Radiocesium (pCi/L)	Cesium-NVB Ratio
Jul-Dec 1958	Martin	130	28	0.22	38	0.29
Jan-Jun 1959	Martin	74	16	0.22	19	0.26
Jul-Dec 1959	Martin	49	11	0.22	16	0.33
Jan-Jun 1960	Martin	20	6	0.30	8	0.40
Jul-Dec 1960	Martin	40	9	0.23	12	0.30
Jan-Jun 1961	Martin	24	8	0.33	8	0.33
Jul-Dec 1961	Martin	27	5	0.19	7	0.26
Jan-Jun 1962	Martin	50	11	0.22	11	0.22
Jul-Dec 1962	Martin	30	9	0.30	10	0.33
Mean	Martin			0.25		0.30
Standard Deviation	Martin			0.05		0.05

*NVB- Non-volatile beta.

These ratios were used to scale average annual concentrations of ^{90}Sr and ^{137}Cs from average annual nonvolatile beta concentrations for the years 1954 through 1957 when radiostrontium and radiocesium data were not reported. The ratios were also used for 1958 because ^{90}Sr and ^{137}Cs data was not reported for the first half of this year. This scaling approach is the same approach used in Phase II to determine ^{137}Cs and ^{90}Sr concentrations for some years in SRS streams (see Chapter 5, p. 5-49, of Phase II).

7.4.3.2 Tritium

Average annual Lower Three Runs Creek concentrations were determined for tritium for the years 1964 through 1992 using data published in SRS environmental reports [Ashley

1965, Ashley 1966, Ashley 1967, Ashley 1968, Ashley 1969, Ashley 1970, Ashley 1971, Ashley 1972, Ashley and Zeigler 1973, Ashley and Zeigler 1974, Ashley and Zeigler 1975, Ashley and Zeigler 1976, Ashley and Zeigler 1978a, Ashley and Zeigler 1978b, Ashley and Zeigler 1981, Ashley 1982, Zeigler 1983, Ashley and Zeigler 1984, Ashley 1984, DOE 1985, Zeigler 1986, Zeigler 1987, Zeigler 1988, Davis 1989, Cummins 1990]. For the second half of 1958 through 1963, measured tritium concentrations in Lower Three Run Creek were obtained from Health Physics Regional Monitoring Semiannual Reports and Semiannual Progress Reports [Horton 1954, Horton 1955, Alexander and Horton 1956, Horton and Mealing 1956, Horton and Mealing 1957, Mealing 1957, Mealing and Horton 1957, Mealing 1958, Harvey 1959a, Harvey 1959b, Dupont 1959, Dupont 1960a, Dupont 1960b, Dupont 1961, Dupont 1962a, Dupont 1962b, Dupont 1963, Dupont 1964]. Measured average concentrations in Lower Three Run Creek at Martin were cited from these semiannual reports except for the first half year of 1954, when no sampling location is specified.

From 1954 to 1957, tritium releases were monitored in facility effluents but not in Lower Three Runs Creek. For these years, tritium concentrations were estimated using information in the Phase II report. The tritium activity discharged to Lower Three Runs Creek accounted for approximately 5% of the total tritium entering on-site streams. This is based on weekly measured values from 1959-1967 in the streams at the last onsite location before the streams emptied into the Savannah River. A documented annual creek flow rate from 1954 to 1958 could not be located. As a result, the flow rates for these years were estimated as discussed in Appendix S.

7.4.3.3 Interpretation of Monitoring Data in Lower Three Runs Creek

Monitoring data were used in the following manner:

If the concentration of a radionuclide of interest (i.e. tritium, cesium, or strontium) was reported, it was included directly. The reported concentration was used directly if the result was reported as an annual average. When concentration data was provided on a semi-annual basis, the average for the first and second half of the year was taken to represent the annual average concentration. The average was used because the environmental monitoring report only shows the average for the monitored period, although sometimes the number of samples taken was also reported as well as maximum and minimum concentrations for the period.

If the environmental report or other reference showed “ND”, “<MDA”, “Below Detection Limit”, or “Below Sensitivity,” one half of the reported detection limit or sensitivity was used for the indicated period of time. Detection limits or sensitivity are generally listed in every year’s environmental report for different analytical instrumentation, analytical parameters, and sample matrices. When a detection limit or sensitivity is referenced for a particular water sample, the detection limit or sensitivity of the corresponding analytical procedure for the particular radionuclide (i.e. tritium, radiocesium, or strontium) was used.

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8 FOOD CHAIN TRANSPORT

This chapter discusses the modeling of radionuclide migration in the food chain. The primary focus is uptake of radionuclides by plants and animals from contaminated environmental media. These contaminated media may include air, water, and soil. For uptake of radionuclides by terrestrial animals, contaminated media may also include plants. The primary reason for considering food chain transport is to estimate radionuclide concentrations in foodstuffs, both plant and animal products, that may be consumed by humans.

The starting point for estimating food chain transport is the radionuclide concentrations in air and water at various exposure locations. Previous chapters have discussed transport of radionuclides through the primary media of air and water; air transport is discussed in Chapter 6 and water transport is discussed in Chapter 7. For this study, food chain transport is simulated by several models that consider a variety of processes that include:

- For radionuclides transported by air:
  - Deposition of radionuclides onto vegetation and soil
  - Uptake of radionuclides by plants from soil and plant surfaces
  - Uptake of radionuclides by animals that consume plant products
- For radionuclides transported by water:
  - Deposition of radionuclides into sediments
  - Uptake of radionuclides by aquatic animals

In general, the radionuclide concentrations in soil used to model food chain transport need not correspond to concentrations used to model direct exposure and inhalation; however, for this study these concentrations generally correspond. Therefore this chapter also discusses contamination of soil, to promote a compact presentation. This chapter qualitatively describes the models used and summarizes the values for many of the variables used to generate point-estimates of radiation dose and risk. All of the variable values may be found in Appendix E and Appendix F.

8.1 Introduction

The complete mathematical formulations of the models used for this study are documented in the GENII Version 2 Software Design Document [GENII SDD] (1). These generic models are implemented in the GENII computer code. This chapter discusses the use of these models, as implemented in the GENII computer code, to simulate transport of radionuclides in the food chain in the vicinity of the SRS for the 39-year period studied. The mathematical formulations for most of models discussed in this chapter are documented in Chapter 9 of the GENII SDD.

Transport of radionuclides in the food chain may be viewed as transport into and out of different compartments in the food chain, as shown schematically in Figure 4-2 and 4-3. The food chain compartments considered in this study of the SRS are: soil, plants, terrestrial animals, and aquatic animals. Radionuclides enter these compartments either directly from contaminated air and water or by transfer from another food chain compartment. For example, radionuclides may enter edible plants by direct deposition of radionuclides from contaminated air or by uptake from soil contaminated by airborne radionuclides. The mathematical models use the principle of mass conservation to estimate the concentration in a food chain compartment based on the rates of radionuclide input (e.g., deposition, uptake) and removal (e.g., radioactive decay, weathering).

The generic models implemented in the GENII computer code allow radionuclides to enter soil, plants, and animals from contaminated water; for example, animals may take up radionuclides from contaminated drinking water. However, agricultural practices in the vicinity of the SRS did not include use of the Savannah River or Lower Three Runs Creek for irrigation of crops or watering of farm animals. Other water sources used for agricultural purposes were considered to have low levels of contamination; these other water sources, may have been slightly contaminated by deposition of radionuclides from air, but did not receive liquid releases of radionuclides from the SRS. Therefore, the only instance of contaminated water transferring radionuclides to a food chain compartment that has been modeled is the contamination of shoreline sediments.

The remainder of this chapter is organized according to the four food chain compartments considered in this study of releases from the SRS: soil, plants, terrestrial animals, and aquatic animals; in addition, two special models for tritium and carbon-14 migration in the food chain are discussed in a separate section.

8.2 Soil Concentration

Soil concentrations are calculated differently, depending on the major physical processes involved in a particular situation. As with other concentrations calculated, soil concentrations are based on conservation of mass. However, depending upon the nature of the soil, different radionuclide addition and removal processes may be applicable. Some of the physical processes that might apply to terrestrial soils include:

- deposition from air to surface soil,
- deposition from water to surface soil during irrigation,
- depletion by radioactive decay,
- leaching from surface soil,
- loss from surface soil during harvest of contaminated plants, and
- removal by resuspension of contamination and subsequent transport by wind.

For aquatic sediments the main process is deposition of radionuclides from contaminated water. Because irrigation with water contaminated by liquid releases from SRS facilities was not practiced during the period of time studied, deposition on farm land of radionuclides released to water by the SRS was not modeled. However, contamination of farm land by deposition of airborne radionuclides was modeled. Deposition of radionuclide contamination from water to sediments on the shoreline was modeled as a viable mechanism to contaminate soil.

8.2.1 Radionuclide Deposition from Air

Irrigation with contaminated water is not considered in this study because: 1) water from the Savannah River and Lower Three Runs Creek, which were contaminated by liquid releases from the SRS, was not used for irrigation and 2) contamination of other waters that might have been used for irrigation, such as reservoirs, ponds, and wells was considered to be slight. For this reason, the only source of radionuclide contamination in terrestrial soils is deposition of airborne radionuclides.

Two types of deposition are usually modeled: 1) dry deposition and 2) wet deposition. "*Dry deposition* refers to any physical removal process that does not involve precipitation." "*Wet deposition* refers to processes in which atmospheric chemicals are accumulated in rain, snow, or fog droplets and are subsequently deposited onto Earth's surface." (2).

Dry deposition may involve several processes including gravitational settling, impaction onto plant and soil surfaces, and absorption by soil and plant surfaces. For small particles and gases, gravitational settling is negligible. The model implemented by the GENII code uses an electrical analogy to calculate a net deposition velocity from three separate "resistances" (s/m): aerodynamic resistance, surface resistance, and transfer resistance and the gravitational settling velocity. The aerodynamic and surface resistances depend upon the wind speed, as detailed in the GENII Software Design Document (1). For this study the default values for transfer resistance were used: 10 s/m for gas (iodine) and 100 s/m for particles. To calculate the gravitational settling velocity for particles two key variables were the particle density and diameter; for the point estimates the values for these variables were chosen to be 2.0 g/cm^3 and 0.001 mm, respectively. The deposition velocity is calculated by combining the separate resistances and the gravitational settling velocity, if appropriate (not appropriate for gases and very fine particles). The dry deposition rate is then calculated from the deposition velocity and air concentration of each radionuclide for any given year:

$$R_{ai} = V_d C_{ai} \qquad (8\text{-}1)$$

Where R_{ai} is the rate of deposition from air, a, of radionuclide i (Bq/m^2/s)

V_d is the deposition velocity (m/s)

C_{ai} is the air concentration of radionuclide i in that year.

Clearly the concentration in air varies with the location of the exposure location at which the radionuclide deposition is to be calculated; however, for simplicity an index denoting this variability has not been included in the equation. The air concentrations of the radionuclides studied were obtained by the approach discussed in Chapter 5.

Wet deposition for gases considers that the gas is soluble in water, but partitions the gas between air and water according to Henry's Law. Henry's Law describes the ratio of the concentration of a chemical in air to the concentration in water at equilibrium. Wet deposition for particles uses the concept of a washout coefficient that describes the fraction of the air concentration of particles removed per unit distance of travel of precipitation. Default values build into the GENII code were used for the Henry's Law constants. The washout coefficient is computed based on the precipitation rate during a precipitation event. A key variable for wet deposition is the average daily rain rate, which was taken to be 11.4 mm/d, based on data from 1970-99 (3).

8.2.2 Radionuclide Concentration in Soil – Direct Exposure

To estimate the concentration of radionuclides in soil for determining dose resulting from direct exposure from the ground plane, most removal processes are not considered; the only removal process considered is radioactive decay. Thus a key variable in determining these concentrations is the decay constant for each radionuclide. These are well established and are incorporated into one of the many GENII databases.

For direct exposure calculations, the average concentration in the soil is used, considering the total air deposition rate, at a particular exposure location, and radioactive decay. Every year was considered separately and for this study the radionuclide concentration at the beginning of each year was assumed to be zero. Some long-lived radionuclides may have persisted in the soil from year to year, but the results of this study suggest that dose pathways for these radionuclides were not likely to be significant. The model used to estimate soil concentration assumes that radionuclides deposited from the air onto the soil surface is mixed uniformly to a certain depth. For this reason, the concentration of radionuclides in the soil depends on the depth to which mixing is assumed to occur and the bulk density of the soil. For this study, the mixing depth was set to 15 cm and the bulk soil density set to 1.6 g/cm^3; these values are frequently used as nominal values in studies of this type.

8.2.3 Radionuclide Concentration in Soil – Agricultural Exposure

To estimate the concentration of radionuclides in soil for determining dose resulting from agricultural pathways, such as uptake by plants, removal processes in addition to radioactive decay must be considered. Two additional removal processes are 1) loss of activity by harvest and 2) leaching of radionuclides from the soil. Loss of activity by harvest models the amount of radionuclides taken up by vegetation while growing and assumes it is removed at harvest. For this study it was conservatively assumed that no activity was removed by harvesting. Fresh water from precipitation and irrigation can dissolve radionuclides in the root zone of the soil and transport them to a lower depth, where the activity will be unavailable for uptake by roots or resuspension into the air. The model used to estimate removal of radionuclides from the upper layer of soil assumes equilibrium between the pore water and soil. The partitioning coefficient, K_D, (i.e., distribution coefficient) describes the ratio of the concentration in soil to the concentration in water. This coefficient depends on a number of factors including the chemical natures of the soils and the radionuclide ions. Appropriate values for the radionuclides modeled were carefully studied and selected, as shown in Table 8-1 and described in Appendix C. Additional important variables in the model include the annual precipitation rate, the surface soil moisture content fraction, and the bulk soil density. The surface soil moisture content fraction was estimated to be 0.22 using characteristics for sandy loam (porosity of 0.4), a saturated hydraulic conductivity of 540 m/y, and an infiltration rate of 0.373 m/y. As with the soil concentration used for direct exposure, the soil depth was set to 15 cm and the bulk soil density set to 1.6 g/cm^3. Since the K_D changes for each chemical species, these data yield a removal rate constant for the activity of each radionuclide in the surface soil layer. This removal rate constant is used in addition to and in a manner similar to the radioactive decay constant to estimate the loss of radioactivity in the soil layer by leaching; this provides an estimate of the annual average radionuclide concentration in the surface soil layer.

Table 8-1 Soil Distribution Coefficients for Surface Soil Leaching Calculations

Nuclide	Kd (mL/g)	Nuclide	Kd (mL/g)
^{3}H	0	^{99}Tc	2.49*
^{32}P	173*	^{103,106}Ru	55
^{35}S	7.5	$^{129, 131}$I	1.55*
^{60}Co	60	$^{134, 137}$Cs	59
^{65}Zn	200	^{141,144}Ce	490
^{89,90}Sr	3041*	^{231,234}Th†	3000
^{90}Y†	510	U (all isotopes)	1000
^{95}Zr	600	Pu (all isotopes)	4100
^{95}Nb	160	^{241}Am	2000

*This table lists the number of significant digits that were presented in the primary sources.
†These isotopes are daughters of the primary isotopes considered in the report

8.2.4 Radionuclide Concentration in Shoreline Sediments – Direct Exposure

The concentration of radionuclides in shoreline sediments depends on the deposition of radionuclides from the adjacent contaminated body of water. The removal of radionuclides is considered to be limited to radioactive decay. As with other soil concentrations, the average concentration over a year is used to estimate doses. The mathematical model describing the concentration in sediments is very similar to the

model for soil concentrations used for direct exposure. The key variable for this model, in addition to the decay constant for each radionuclide, is the deposition rate for sediments. The deposition rate is stated in terms of the transfer rate constant; for this study the transfer rate constant was set equal to the default value of 25,400 $L/m^2/y$ used in the GENII computer code (The original estimate had one significant figure, but three significant figures were retained by the GENII code to reflect the conversion from English to metric units and to allow trace back to the historical value). This value of the transfer rate constant was derived for several radionuclides by using measured values of concentrations in shoreline sediments and in the water column of the Columbia River. Two additional important variables determining the sediment concentration are the sediment density and the sediment depth; for this study the shoreline sediment density was set equal to the GENII code default of 240 kg/m^2 and the depth, as with other soil layers, was set equal to 15 cm.

8.3 Radionuclide Concentration in Terrestrial Vegetation

In general, contaminants may enter terrestrial vegetation by deposition on plant surfaces and by uptake through plant roots. Because the rate of contaminant entry into the plant is generally not affected by the concentration in the plant, concentration induced by direct deposition and by root uptake may be calculated separately. The total concentration of a radionuclide in a particular plant may then be calculated by summing the concentrations induced by direct deposition and by root uptake; since the mass of the plant is the same for both types of uptake, adding concentrations is equivalent to summing the radionuclide mass from each entry mechanism.

8.3.1 Plant Concentration from Direct Deposition

Deposition of radionuclides on the surfaces of plants (usually the leaves) can generally result from:

1) dry deposition from contaminated air,

2) wet deposition from contaminated air,

3) deposition of radionuclides resuspended from contaminated soil, and

4) deposition from irrigation with contaminated water.

As explained elsewhere in this Section, irrigation with contaminated water was not considered a viable pathway. Dry and wet deposition from contaminated air is discussed in Section 8.2.1. Deposition of radionuclides resuspended from contaminated soil is discussed in Section 8.3.1.1. Once these three deposition rates [1), 2), 3)] have been determined, the radionuclide concentration in the vegetation is computed using a mass balance relationship; processes removing radionuclides from the plant surfaces include radioactive decay and weathering. The calculation of concentration in vegetation from direct deposition is discussed in Section 8.3.1.2.

8.3.1.1 Deposition of Resuspended Activity

Resuspension of radionuclides deposited on soil and plant surfaces causes an incremental addition to the concentration in the air above the affected surfaces. Radionuclides are resuspended by turbulence in the air and by mechanical agitation of the surface, e.g., by automobile traffic, pedestrian traffic, and agricultural operations such as plowing, cultivating, and harvesting. For most studies of this type, the concentration of radionuclides in the air is considered to be in equilibrium with the surface concentration of radionuclides; i.e., the forces tending to resuspend activity are balanced by forces tending to cause the activity to settle on surfaces. For equilibrium conditions the relationship between air and soil concentration is given by:

$$C_{ar} = RF \cdot \Psi_S \quad (8\text{-}2)$$

Where C_{ar} is the concentration induced in the air by resuspension (Bq/m^3)
RF is the resuspension factor, a constant, (m^{-1})
Ψ_s is the areal concentration of radionuclides in the soil (Bq/m^2)

The areal concentration may be obtained from the mass-based concentration, C_s, by multiplying by the bulk soil density, ρ_s, and soil depth, d_s:

$$\Psi_s = C_s \cdot \rho_s \cdot d_s \quad (8\text{-}3)$$

The mass-based soil concentration, C_s (Bq/kg), is the average annual concentration obtained as described in Section 8.2.2. As with other cases involving the soil concentration, the soil depth was set to 15 cm and the bulk soil density set to 1.6 g/cm^3, so $\rho_s \cdot d_s$ has a value of 24 g/cm^2 or 240 kg/m^2.

Two separate values of resuspension factor were used in this study, one for farms and one for other environments. These values, representative of different land uses, were chosen from a compilation of measured resuspension factors (4). Because agricultural operations with heavy equipment, such as tractors, greatly disturbs the soil surface a resuspension factor value of 10^{-5} m^{-1} was chosen for agricultural exposure locations; this value is 100 times larger than the value of 10^{-7} m^{-1} chosen for urban, suburban, and non-agricultural rural exposure locations. Farming locations using the higher value of resuspension factor were taken to be: Girard (Rural Family #1), New Ellenton (Migrant Family), and Williston (Rural Family #2). All other exposure locations used the smaller value of resuspension factor.

Once the incremental addition to the concentration in the air above the affected surfaces is computed by equation (8-2), the deposition rate of this activity on plant surfaces is obtained from the product of the air concentration and a deposition velocity, similar to equation (8-1). The deposition velocity used for all radionuclides and all plants was chosen to be 0.001 m/s, which is a representative value.

8.3.1.2 Radionuclide Concentration in Plants from Direct Deposition

Radionuclide concentration in plants from direct deposition is calculated from a mass balance that considers radionuclide deposition from the air and removal by radioactive decay and weathering of the radionuclides from the plant surfaces. The net uptake of radionuclides is computed by integrating the uptake rate over the growing period for the particular crop. Radionuclide concentration is given by:

$$C_{dci} = [R_{aid} \cdot r_{dc} + R_{aiw} \cdot r_{dw} + C_{ci} \cdot RF_c \cdot V_{di} \cdot r_{ac}] \cdot [Tvc/Bc] \cdot [(1-\exp\{-\lambda_{ei} T_{gc}/365d/y\})/\lambda_{ei}] \quad (8\text{-}4)$$

Where,

C_{dci} = concentration from deposition, d, of radionuclide i in crop type c
R_{aid} = the rate of dry (d) deposition of radionuclide i from air (a)
R_{aiw}= the rate of wet (w) deposition of radionuclide i from air (a)
r_{dc} = the dry (d) deposition fraction for crop type c
r_{dw} = the wet (w) deposition fraction for crop type c
C_{ci} = the concentration of radionuclide i in the soil for crop type c
RF_c = resuspension factor for the soil for crop type c
V_{di} = deposition velocity for radionuclide i
r_{ac} = the deposition fraction for resuspension for crop type c
Tvc= the translocation factor for crop type c
Bc = the standing biomass for crop type c
$\lambda_{ei} = \lambda_{wi} + \lambda_i$ = effective loss rate contant (y-1), which is the sum of the weathering rate constant, λ_{wi}, and the radioactive decay constant, λ_i
T_{gc} = the growing period for crop type c

Growing periods for different types of crops are shown in Table 8-2. The dry and wet deposition rates are discussed in Section 8.2.1; deposition rates from resuspended activity are discussed in Section 8.3.1.1. Since plant surfaces do not generally cover the entire area subject to radionuclide deposition, a deposition fraction is applied to account for the fraction of the surface covered by vegetation; a standard value of 0.25 is used in this study for both dry and wet deposition calculations. Variables related to radionuclide removal from plants include the radioactive decay constant and the weathering constant. Radioactive decay constants are included in a data library in the GENII code. The weathering constant, which describes removal of radionuclides by precipitation, wind, and similar processes, is expressed as a weathering rate half-life; for this study a standard value of 14 days was selected for the weathering rate half-life.

Table 8-2 Values used for the point-estimate case for the variables: growing period (days), translocation factor, and standing biomass (kg/m2).

Crop Types	Growing Period (days)	Translocation Factor	Standing Biomass (kg/m^2)
Leafy vegetables	70	1	0.7
Root vegetables	70	0.1	0.7
Fruit and Grain	145	0.1	0.7
Poultry, Milk, and Egg Animal Feed	145	0.1	2.4
Beef and Milk Animal Forage	30	1	1.8

Although the radionuclides are absorbed through the plant surfaces, once inside the plant radionuclides migrate to different parts of the plant at different rates. Since the interest is in the edible portion of the crop, the fraction of absorbed radionuclides that migrate to that edible part, termed the "translocation factor", is an important quantity; the translocation factor has been measured for a variety of crops. Since the absorbed radionuclides spread throughout the plant, the concentration in the plant depends on the total biomass present; this is accounted for by the "standing biomass", which represents the total biomass per unit area of cultivated ground. Values of translocation factor and standing biomass used in this study for various crops are shown in Table 8-2.

8.3.2 Plant Concentration from Root Uptake

The plant concentration at harvest from root uptake is based on a radionuclide partitioning model that assumes equilibrium between the radionuclide concentration in the plant and the radionuclide concentration in the soil. The concentration of radionuclides in the plant is given by the following relation:

$$C_{rci} = [C_{ci} \cdot RP_{sc} \cdot Bv_{ci} \cdot fc]/P_3 \qquad (8\text{-}5)$$

Where C_{rci} = concentration of radionuclide i in crop type c from root uptake for a one-year period (Bq/kg wet weight)

C_{ci} = average concentration of radionuclide i in farmland soil for crop type c for the current one year period (Bq/m^2)

RP_{sc} = fraction of plant type c having roots in surface soil zone (dimensionless)

Bv_{ci}	=	concentration ratio for root uptake of radionuclide i in crop type c (Bq/kg dry plant per Bq/kg dry soil)
f_c	=	dry-to-wet ratio for plant type c (kg dry plant/kg wet plant)
P_3	=	areal soil density of farmland soil (kg/m^2)

The fraction of plant roots in the surface soil, RP_{sc}, was conservatively determined to be 1.0 for all plants, which indicates that the entire root system is in the soil zone where contamination is modeled to occur. Many crops have roots mainly in the surface soil zone. Assuming the entire root is in contaminated soil, when part may be in uncontaminated soil, will overestimate radionuclide uptake by the plant. Because this fraction was set to a value of 1.0, the fraction of the root below the surface soil (15 cm depth) was set to 0 in all cases. The areal density of farmland was set to 240 kg/m^2, consistent with values previously used for bulk soil density and soil depth. Values used for the concentration ratio for root uptake of radionuclide i in crop type c (Bq/kg dry plant per Bq/kg dry soil) are shown in Table 8-3. The source for these values is provided in Appendix E. The dry to wet ratio for various plant types is shown in Table 8-4.

A three-step process, shown in Figure 8.1, was used to select transfer factor values for this report (i.e., the concentration ratios shown in Table 8-3 and Table 8-5). The first step was to consider values based on local data. Where local data were not available, generic values were used. Among generic values, those that were applicable to conditions at the SRS were preferred; e.g., choosing an uptake factor of 1.7 for root vegetables, which was the average for sand and pH of 5, corresponding to conditions at the SRS. The first reference source for generic values was *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments* (5). Where (5) did not contain a generic value, the GENII default was used.

Table 8-3 Values of ratio of concentration in plants to concentration in soil (kg/kg) for various plant types and elements.

Element (i)	PLANT TYPE (c)			
	Cereal and Grain	Leafy Vegetables, Forage, and Hay	Other Vegetables and Root Vegetables	Fruit
P	3.5	3.5	3.5	3.5
S	1.5	1.5	1.5	1.5
Co	3.7E-03	0.20	0.11	7 E-03
Zn	1.6	3.3	12	0.9
Sr	0.15	1.7	1.7	0.2
Y	0.01	0.01	0.01	0.01
Nb	2.5 E-2	2.5 E-2	1.7E-02	2.5E-02
Zr	1E-03	1E-03	1E-03	1E-03
Tc	0.73	940	28	1.5
Ru	5E-03	0.2	0.04	0.04
I	2E-02	3.4E-03	0.02	0.02
Cs	0.02	5.31	0.9	0.22
Ce	3E-02	3E-02	3E-02	3E-02
Th	3.4E-05	1.1E-02	6.9E-03	2.5E-04
U	1.3E-03	2.3E-02	0.011	4 E-03
Pu	6E-05	2.2E-03	8.2E-04	4.5E-05
Am	2.2E-05	0.067	8.4E-04	2.5E-04

Table 8-4 Variable values for the dry-to-wet ratio for plant type c (kg dry plant/kg wet plant).

Crop Types (c)	Ratio of Dry to Wet Weight
Leafy vegetables	0.1
Root vegetables and Fruit	0.15
Grain	0.91
Poultry and Egg Animal Feed	0.91
Beef and Milk Animal Forage	0.22

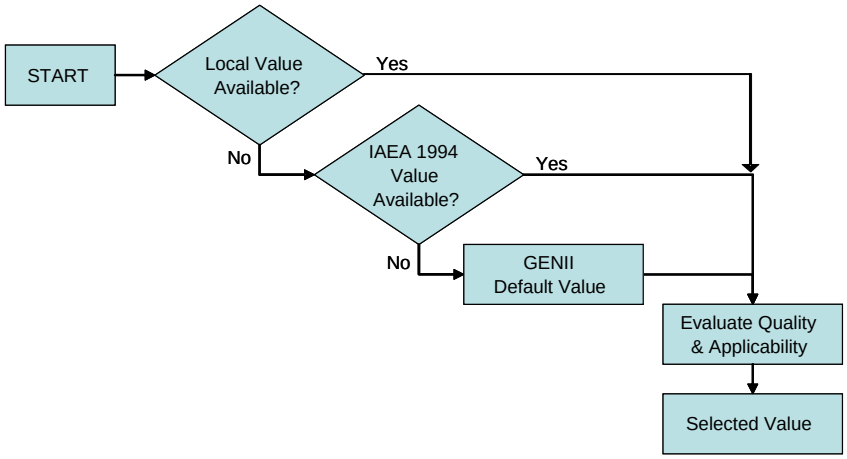

Figure 8-1 Process for Selecting Transfer Factor Values

8.4 Radionuclide Concentration in Terrestrial Animals

The concentration of radionuclides in food products from terrestrial animals (e.g., eggs, milk, and beef) depends on the amount of radionuclides ingested by those animals. In general, animals may ingest contaminated water, soil, and feed (food). For this study drinking water for either animals or humans was not considered to be contaminated in the vicinity of the SRS. This is because water contaminated with liquid releases from the SRS was not used for such purposes, while the water that was used was likely to be uncontaminated (well water) or only slightly contaminated (reservoirs and ponds). Consequently, uptake of radionuclides by terrestrial animals from drinking water was not modeled in this study. Because ingestion of soil was not considered to be a significant pathway for animal product contamination, it was not modeled in this study.

For ingestion of feed as the viable pathway for radionuclide ingestion, the concentration of radionuclides in animal products is given by equation (9.9) in the GENII SDD and which is adapted here:

$$C_{hai} = F_{ai} \cdot \sum_{f=1}^{N_{af}} C_{cfi} d_{af} U_{af} \qquad (8\text{-}5)$$

Where,

C_{hai} = concentration of radionuclide i in animal product a at harvest of the animal product for a one-year period (Bq/kg)

F_{ai} = transfer coefficient that relates daily intake rate by an animal to the concentration in an edible animal product a (e.g., Bq/(L milk) per Bq/d for milk, and Bq/(kg meat) per Bq/d for beef)

C_{cfi} = concentration of radionuclide i in animal feed type f at the time of consumption for a one-year period (Bq/kg wet weight)

N_{af} = number of feed types, f, fed to animal type a

d_{af} = fraction of animal type a feed type f intake that is contaminated (dimensionless)

U_{af} = daily feed intake rate for animal type a of feed type f (kg/d).

The calculation of the concentration in animal feed grown in the vicinity of the SRS has been discussed in Section 8.3. There were 5 types of animal feed considered for this study: poultry, milk, and egg animal feed and beef and milk animal forage. Although beef animal feed, in general, is a possibility, site specific information indicated that cattle farmers near the SRS used forage exclusively. Table 8-5 shows values for each feed type for d_{af} (the fraction of feed type f intake that is contaminated) and U_{af} (daily feed intake rate for feed type f (kg/d)). Table 8-6 shows the values of the transfer factors, F_{ai}, for the various radionuclides and the four animal types considered.

Table 8-5 Values used for the point-estimate case for the variables: fraction of feed that is contaminated and daily feed intake rate (kg/d)

Feed Types	Fraction Contaminated	Feed Intake Rate (kg/d)
Poultry Animal Feed	0.5	0.12
Milk Animal Feed	1.0	13
Egg Animal Feed	0.5	0.12
Beef Animal Forage	1.0	36
Milk Animal Forage	1.0	29

Table 8-6 Values of transfer factors used for the point estimate case; i.e., the ratio of concentration in animal products to daily rate of intake of radionuclides

Element (i)	ANIMAL PRODUCT (a)			
	Animal Milk (kg/L)	Beef Animal Meat (kg/kg)	Poultry (kg/kg)	Egg (kg/kg)
P	1.6E-02	5E-02	0.19	1.0
S	1.6E-02	2E-01	2.3	7.0
Co	3E-04	1E-02	2	0.1
Zn	0.01	0.1	7	3
Sr	2.8E-03	8E-03	0.08	0.2
Y	2E-05	1E-03	.01	.002
Nb	4.1E-07	3E-07	.0004	.001
Zr	5.5E-07	1E-06	6E-05	.0002
Tc	2.3E-05	1E-04	0.03	3
Ru	3.3 E-06	0.05	8	.005
I	0.01	0.04	0.01	3
Cs	7.9E-03	0.05	10	0.4
Ce	3E-05	2E-05	.003	6.5E-05
Th	5E-06	4E-05	.006	.004
U	4E-04	3E-04	1	1
Pu	1.1E-06	1E-05	.003	.0005
Am	1.5E-06	4E -05	.006	.004

8.5 Radionuclide Concentration in Aquatic Animals

Uptake of radionuclides by aquatic animals can be complex because these animals eat other organisms that are contaminated and may take up radionuclides directly from the water they inhabit. For fish, which is an important human food, the uptake of radionuclides is generally simplified. The simplified model states that the radionuclide concentration in a given type of aquatic food is equal to the product of the radionuclide concentration in water and a bioaccumulation factor, which is specific for the organism and radionuclide. This simplified approach, which is implemented in the GENII computer code, is stated by the equation:

$$C_{hqi} = C_{wi} \cdot B_{qi} \qquad (8\text{-}6)$$

Where,

C_{hqi} = concentration of radionuclide i in aquatic food type q at the time of harvest (Bq/kg);

C_{wi} = average concentration of radionuclide i in water over the year;

B_{qi} = bioaccumulation[1] factor for radionuclide i in aquatic food type q (Bq/kg in wet fish per Bq/L of water).

The concentration in water at the two water exposure locations used in the study is obtained as described in Chapter 7. The bioaccumulation factors for freshwater fish that have been used in this study are presented in Table 8-7; Appendix F contains a description of how these were obtained. Some are generic values, but several (marked with "‡") are specific to the SRS site.

Table 8-7 Bioaccumulation Factors Selected for Freshwater Fish Consumption (L/kg)

Element*	Factor	Element*	Factor
P	50,000†	Ru	10†
S	800†	I	40†
Co	300†	Cs	4,700‡
Zn	1,000†	Ce	30†
Sr	450‡	Th	100†
Y	30†	U	10†
Nb	300†	Pu	4,700‡
Zr	300†	Am	2,400‡
Tc	20†		

*The same factor is used for each isotope of an element.
†International Atomic Energy Agency (IAEA) default value based on several references (5).
‡Selected value calculated from data in (6), or from a combination of data from (6) and (5).

[1] Some authors reserve the term "bioaccumulation" for processes in which uptake of contaminants is from both water and food, while the term "bioconcentration" is used to describe uptake that depends only on the water concentration, as stated in equation (8-6). (2)

8.6 Effect of Delay and Storage Times on Concentrations

The expressions for radionuclide concentrations in plants, terrestrial animals, and aquatic animals presented respectively in Sections 8.2, 8.3, and 8.4 are correct for the time of harvest or collection. However, the consumption of these foods, by either humans or animals, may be delayed. Animal foods, such as forage or feed, may be stored after harvest and fed to the animals at a later time; during storage radionuclides will continue to undergo radioactive decay, which results in lower concentrations in the foods when they are consumed. Similarly human foods, such as vegetables, slaughtered meat, fish, and milk, may be delayed getting to market and table, because the food must be processed, or transported, or both. Again radioactive decay will reduce the radionuclide concentration in the foods consumed.

The concentration of the food consumed is given by the following expression:

$$C_{efi} = C_{hfi} \cdot \exp\{-\lambda_i T_d\} \qquad (8\text{-}7)$$

Where,

C_{efi} = the concentration in animal or human food at the time it is consumed;

C_{hfi} = the concentration in animal or human food at the time it is harvested;

λ_i = radioactive decay constant for radionuclide i in units commensurable with T_d;

T_d = the storage time for animal feed or the delay time for human food.

Radionuclide concentrations in animal and human food are derived according to the methods described in the three sections preceding this one. Radioactive decay coefficients are contained in a library file in the GENII code. Storage times for animal foods are listed in Table 8-8. These times were based on site specific information (7). Both beef and milk animals were allowed to forage all year long, so there was never any storage time associated with this type of animal food.

Table 8-8 Values used for the point-estimate case for the storage time for animal foods
A value for each animal feed type (f) used is shown.

Feed Types	Index (f)	Storage Time (d)
Poultry Animal Feed	2	180
Milk Animal Feed	3	90
Egg Animal Feed	4	180
Beef Animal Forage	5	0
Milk Animal Forage	6	0

Delay times between food product harvest and consumption are listed in Table 8-9 (plant products) and Table 8-10 (animal products). These delay times were based on a combination of generic and site specific data, as explained and referenced in Appendix F. In addition, the characteristics stated for the scenarios were used to interpret this source data and obtain values appropriate for this study. For example, longer delay times were assumed for persons living in cities or towns than for farmers or persons eating food grown in their own gardens or raised in their backyards. Three families consumed fish obtained from waters contaminated by liquid releases from the SRS: the Outdoors Person Family, Family Living Near the River, and Delivery Person Family; the delay time for fish consumed by these receptors was taken to

be one day. Fish consumed by other families was considered to be uncontaminated, because the waters they fished were not contaminated by liquid releases from the SRS.

Table 8-9 Delay Times for Consumption of Plant Products (days)

Location	Leafy Vegetables	Root Vegetables	Fruit	Grain
Girard	1	14	1	1
Waynesboro	NA*	14	NA	NA
Augusta	7	14	7	7
Jackson	1	14	1	1
New Ellenton	1	14	1	1
Barnwell	7	14	7	7
Martin	1	14	1	1
Allendale	NA	14	NA	NA
Williston	1	14	1	1
Onsite	NA	14	NA	NA

*NA – not applicable.

Table 8-10 Delay Times for Consumption of Terrestrial Animal Products (days)

Location	Beef	Poultry	Milk	Eggs
Girard	6	6	3	1
Waynesboro	NA*	NA*	NA*	NA*
Augusta	6	6	3	7
Jackson	6	6	3	1
New Ellenton	6	6	3	1
Barnwell	6	6	3	7
Martin	6	6	3	1
Allendale	NA‡	NA‡	NA‡	NA‡
Williston	6	6	3	1
Onsite	NA‡	6	NA‡	NA‡

*NA – not applicable; location for school only.
‡NA – not applicable; location for work only.

8.7 Special Models for Tritium and Carbon-14

The models describing uptake of radionuclides by vegetation and animals presented in Section 8.3 and 8.4 are largely based on an assumption that the radionuclides are trace elements in the plant and animal tissues; i.e., the concentrations of radionuclides and non-radioactive isotopes of the same element in the organism are small. Generally this is the case and the models are appropriate. However, for two important radionuclides, tritium and carbon-14, this assumption is not true. In the environment, carbon-14 behaves

much like its non-radioactive, more common isotope carbon-12. Similarly tritiated water, with each water molecule containing either one tritium atom and one normal hydrogen atom or two tritium atoms, behaves like normal water in the environment. A principal component of plant and animal tissue is carbon and both plants and animals contain significant percentages of water (plant tissue is usually 75% or higher water by weight).

The GENII code has incorporated special models for plant uptake of tritium and carbon-14, as described in Section 9.6 of the GENII SDD (1):

The concentrations of tritium or carbon-14 in environmental media (soil, plants, and animal products) are assumed to be related to the specific activity (Becquerels of radionuclide per kilogram of soluble element) in the contaminating medium (air or water). The fractional content of hydrogen or carbon in a plant or animal product is then used to compute the concentration of tritium or carbon-14 in the food product under consideration. The hydrogen contents in both the water and the non-water (dry) portion of the food product are used when calculating the tritium concentration. The creation of organically-bound tritium [OBT] in plant and animal products from intake of HTO [tritiated water] is also addressed.

The model for tritium also considers tritium released in elemental form. Further details of these special models may be found in the cited reference.

Because of the specialized nature of these models, the default values for various coefficients built into the GENII code were used. Until the results of this study were evaluated to estimate the significance of doses from tritium, it was not considered appropriate to evaluate whether site-specific characteristics warranted changes in these values or if any site-specific data to support such changes were available. Nevertheless, a few variables used in these models were specifically selected for this study.

The tritium model for uptake by plants has as a key parameter the absolute humidity of the air; this is because the relative fraction of tritiated water to normal water in the air is given by the ratio of the tritium concentration to the absolute humidity. The value selected for the point estimate case is a site-specific average over 42 years and has a value of 0.01125 kg/m3, with a standard deviation of 0.00053 kg/m3 (8). Tritium concentrations in animals are based on their uptake of tritium from contaminated water and food. Since the water consumed by livestock was considered to be uncontaminated (as explained elsewhere), the fraction of contaminated water was set to zero, which meant the uptake from water was zero. However, as explained in Section 8.4, livestock did consume contaminated crops; the quantities of crops consumed and fractions contaminated specified in Section 8.4 were also employed in the tritium model.

A key variable in determining the uptake of carbon-14 by plants from the atmosphere is the ratio of carbon-14 to normal carbon. The concentration of carbon-14 in the vicinity of the SRS is calculated according to the approach described in Chapter 5; the concentration of normal carbon in the atmosphere is based on a nominal value, which is built-into the code.

8.8 References

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9 EXPOSURE ROUTES AND PATHWAYS

This chapter discusses how the hypothetical receptors receive a radiation dose from SRS releases by coming into contact with contaminated media (air, water, soil, and food). The models used to derive doses from exposure to contaminated media are discussed in a semi-quantitative fashion, because the details of these models are fully explained in the Software Design Document (Chapter 10) for the GENII[1] code (1). These models do not calculate dose directly, but instead calculate "intake of radionuclides by each ingestion and inhalation exposure pathway, and exposure to radionuclides from external exposure pathways." Chapter 10 explains how these radionuclide intakes and exposures produce receptor doses.

This chapter also summarizes the values for the variables chosen to obtain the point-estimates of radiation dose and risk. Variable values related to receptor activities, in accordance with the scenarios discussed in Chapter 3, are summarized here; the complete rationale for their selection is given in Appendix E. Other variable values not related to receptor activities are detailed in Appendix F.

9.1 Introduction

Radionuclide releases from SRS facilities into the air (Chapter 5) and water (Chapter 7) are transported, by advection and dispersion in air (Chapter 6) and water (Chapter 7), to various exposure locations. These transported radionuclide releases produce contaminated media at the exposure locations (Chapter 3). Air, water, soil, and food are the contaminated media investigated in this study. Contamination of soil and foodstuffs by contaminated air and water is discussed in Chapter 8. At the various exposure locations the hypothetical receptors engage in activities specified in accordance with the scenarios described in Chapter 9 3, such as swimming, breathing, boating, and eating; these activities bring the receptors into contact with different kinds of contaminated media, which causes radiation exposure. The three radiation exposure routes considered in this study are:

1. INHALATION of contaminated air and contamination resuspended from soil
2. INGESTION of contaminated food, water, and soil
3. DIRECT EXPOSURE to contaminated air, water, and soil (including river sediment)

Although additional exposure routes may be important under some circumstances, they were not considered important for this dose reconstruction. For example, absorption of radionuclides through skin exposed to contaminated air or water is a possible exposure route, but is typically less than other exposure routes for the same contaminated media. Thus direct exposure from air immersion and water immersion is generally more significant than dermal absorption respectively in air and water for most beta-gamma emitters, such as Ar-41. Direct exposures by air and water immersion were included in this study, but dermal exposures were not included. Ingestion of contaminated drinking water was not included in this study; only inadvertent ingestion of water while swimming was modeled. The main rationale for this is that the main body of water directly contaminated by liquid releases from the SRS, the Savannah River, was not used for drinking water in any of the exposure scenarios. The Savannah River is used for municipal water supplies far downstream (e.g., Port Wentworth and Beaufort-Jasper), but this was not part of any scenario. Some contamination of local reservoirs near the SRS probably arose from deposition of airborne radionuclides into the surface-water basins feeding the reservoirs. However, a model for this type of contaminant transport was not readily available and the contamination level measured was found to be small and may not all have originated from the SRS (e.g., in 1981 the measured concentrations at the North Augusta Water Plant for undifferentiated alpha activity was 0.4 pCi/L and for undifferentiated beta activity was 3 pCi/L) (2).

[1] All references to GENII in this chapter refer to version 2 of GENII.

A total of eighteen potential exposure pathways were modeled in this study, as shown in Table 9-1. The Table is organized according to the exposure route (direct exposure, ingestion, and inhalation) and exposure pathway; it indicates for each exposure pathway whether the release was to water or air and the contaminated medium (air, water, soil, or foodstuffs) causing the exposure. The total dose is obtained by summing the incremental dose from each exposure pathway.

Table 9-1 Exposure Routes and Pathways for Air and Water Pathways

Exposure Route & Pathway	Air Release	Water Release	Contaminated Medium
Direct Exposure (External radiation):			
• Immersion in a plume of air	X		Air
• Exposure to contaminated soil	X		Soil
• Exposure to a contaminated shoreline		X	Soil (sediment)
• Exposure to contaminated water while swimming		X	Water
• Exposure to contaminated water while boating		X	Water
Ingestion:			
• Leafy vegetable consumption	X		Food
• Root vegetable consumption	X		Food
• Fruit consumption	X		Food
• Grain consumption	X		Food
• Beef consumption	X		Food
• Poultry consumption	X		Food
• Milk consumption	X		Food
• Egg consumption	X		Food
• Inadvertent soil consumption	X		Food
• Fish consumption		X	Food
• Inadvertent ingestion of water while swimming		X	Food
Inhalation:			
• Inhalation of contamination in the air	X		Air
• Inhalation of contamination resuspended from soil	X		Air

9.2 General Exposure Formula

Given the concentration of a radionuclide in a contaminated medium, the exposure models represent how the receptor comes into contact with radiation in a way that ultimately produces a radiation dose in the receptor. In particular the end point of these exposure models is to calculate “intake” of either (1) radioactive material through ingestion or inhalation routes or (2) radiation exposure from direct external radiation.

The exposure models determine different information depending upon the exposure route, as shown in Table 9-2.

Table 9-2 Intake for Direct Exposure, Ingestion, and Inhalation Exposure Routes

Exposure Route	Intake Calculated
Direct Exposure	Annual exposure [immersion in air (Bq/m^3) or water (Bq/L); proximity to soil or sediment (Bq/kg) or water (Bq/L); ground plane exposure (Bq/m^2)].
Ingestion	Annual radionuclide activity ingested (Bq in a year).
Inhalation	Annual radionuclide activity inhaled (Bq in a year).

As will be described in Chapter 10, these intake values will be multiplied by an appropriate dose conversion factor to obtain an incremental dose; i.e.,

$$\text{Dose} = \text{Intake} * \text{Dose Conversion Factor} \qquad (9\text{-}1)$$

However, the dose conversion factor depends upon the exposure route, the radionuclide, and sometimes other factors, such as solubility or lung clearance class. In addition, dose conversion factors are, in general, dependent on the age of the receptor. Because the scenario specifications clearly expressed a concern with the interaction of the age of the receptors and the time-history of releases from the site, doses were calculated using age-dependent dose conversion factors. This age dependency was represented by grouping the dose conversion factors into four age groups, as shown in Table 9-3:

Table 9-3 Age Groups Used for Dose Conversion Factors and Risks

Receptor Age Group	Age Group*
Infant/ Preschooler	0 – 5 year
School Age Child	5 – 15 year
Teenager/Young Adult	15 – 25 year
Adult	25 – 70 year

*Based on the Federal Guidance Report 13 (FRG-13) Cancer Risk Coefficients for Environmental Exposure to Radionuclides (3).

More details on dose conversion factors are presented in Chapter 10.

The exact nature of both the intake and the formula used to calculate the intake depend upon both the exposure route and the specific pathway described. The general formula for calculating the intake is:

$$I = C_m \cdot CR \cdot ED \cdot DAF \cdot AAF \qquad (9\text{-}2)$$

Where, I is the intake;

C_m is the concentration in the medium;
CR is the contact rate or uptake rate
ED is the exposure duration;
DAF is the daily activity factor;
AAF is the annual activity factor.

Table 9-4 describes each factor in the general intake equation and shows some examples of units for these various factors.

Table 9-4 Terms of the General Intake Equation*

General Term	Variable Abbreviation	Description	Example Units
Medium Concentration	C_m	Radionuclide concentration in the exposure medium.	Bq/L water Bq/m^3 air Bq/kg soil
Intake/Contact Rte	CR	Ingestion, inhalation, or exposure rate.	L water/d m^3 air/d
Exposure Duration	ED	Number of years over which the exposure is defined.	Y – (For this study, all exposures were calculated on an annual basis, so this was always 1Y.)
Daily Activity Factor	DAF	Daily activity pattern parameter (e.g. exposure events per day, hours of exposure per day).	hr/d events/d · h/event
Annual Activity Factor	AAF	Annual activity pattern parameter (e.g. days per year that exposure occurs).	days/year

*Based on Table 10.1 of the GENII SDD (1).

As stated previously, the methods for calculating the concentrations in contaminated media are described in other Chapters: Chapter 5 describes the calculation for air; Chapter 7 describes the calculation for water; Chapter 8 describes the calculation for food chain media, i.e., soil, plants, and animals. These concentrations depend upon the time history of releases from the site and their migration in and uptake by the various media. The other four factors (variables) in Equation 9-2 depend upon the behavior of the receptors, as specified by the scenarios. The contact rate for the ingestion route is the ingestion rate, kg of a particular food ingested per year. The contact rate for inhalation is the inhalation rate, m^3 of air inhaled per day. The contact rate for direct exposure is unity. For this study the exposure duration was one year, since the release rate (Bq/y) was adjusted for each year and since dose and risk conversion factors were adjusted for the ages of the receptors. The daily activity factor and annual activity factor varied depending on the exposure pathway. For example, for school children, attendance at school was characterized by a daily activity factor of 7 hours/day spent at school on a school day and an annual activity factor of 180 days/year of school attendance. Those variables that depend on receptor behavior, (e.g., time spent in a particular exposure location), are sometimes called usage factors. Values for these variables, along with a rationale for the choice of each value for the point estimate calculation, are listed in Appendix E. 7

Dose to each receptor could have been calculated by specifying the appropriate variables in Equation 9-2 for every applicable exposure pathway. However, such a calculation would have been very laborious and could not be easily automated. As Equation 9-2 indicates, the increment of dose from any exposure pathway is calculated by multiplying a number of factors; this property was used to perform an efficient, file-driven calculation. For each pathway, doses were calculated for an adult on the basis of a unit contact rate (e.g., 1 kg ingested per year) and/or a unit exposure duration (e.g., one hour). Then each dose based on unit inputs was scaled up by a factor representing the actual contact rates and exposure durations for a particular receptor; in addition, doses were scaled by adjustment factors accounting for the age-dependent dose conversion factors. The derivation and computational use of these exposure factors and adjustment factors are described in Appendices E and G, respectively. This approach made the calculation of doses more efficient, but had no effect on the values of the computed doses or the precision of those estimates.

The following sections briefly discuss the intake models and variables for each of the three exposure routes modeled.

9.3 Direct Exposure Pathways

Direct exposure pathways modeled in this study include:

1. Immersion in a plume of air.
2. Exposure to contaminated soil.
3. Exposure to a contaminated shoreline.
4. Immersion in contaminated water while swimming.
5. Exposure to contaminated water while boating.

As shown in Table 9-1, the first two exposure pathways are associated only with radionuclide releases to air, while the last three exposure pathways are associated only with radionuclide releases to water. Soil was considered to be contaminated by deposition of airborne radionuclides. Soil was not considered to be contaminated by deposition of water-borne radionuclides, because farmers in vicinity of the SRS did not use the Savannah River and Lower Three Runs Creek for irrigation (as explained in Chapter 3). The Savannah River and Lower Three Runs Creek were the only two water bodies contaminated by liquid releases from the SRS and accessible to the public. For exposure to a contaminated shoreline, the contaminated medium is shoreline sediment, deposited by one of the two water bodies receiving liquid releases from the SRS.

9.3.1 Immersion in a Plume of Air

External exposures from immersion in a contaminated plume of air result from the receptor absorbing radiation emitted by radionuclides in the plume. Gamma rays produce most of the immersion dose, although beta and alpha radiation may also contribute. The receptor is assumed to be at the center of a hemispherical cloud of radionuclides at a uniform concentration. Radiation emitted by atoms farther away from the receptor is more likely to be absorbed by the air and contaminants between the receptor and the emitting atoms. Therefore, nearby atoms contribute most to the dose and the dose calculated is not very sensitive to large-scale variations in concentration. Note that for this study, the use of a sector average model means the concentration is assumed to be constant in an entire 22.5º sector (360° divided by 16 sectors) at a given radius.

Key variables in determining the exposure from immersion in a contaminated plume of air are (1) the concentration of each radionuclide at a particular exposure location and (2) the time of exposure for a particular receptor at a particular location. In general shielding of a receptor may also be important, but it was conservatively assumed that indoor air concentrations equaled outdoor air concentrations. The approach used to calculate yearly air concentrations at various exposure locations is described in Chapter 5. The time spent by each receptor at various locations is provided in Table 9-5.

Table 9-5 Exposure Times (hours/year) for the Air Immersion Pathway

Individual	Adult Male	Adult Female	Child Born in 1955		Child Born in 1964	
			*Thru 1972**	*Starting 1973*	*Thru 1981*	*Starting 1982*
Rural Family One						
Girard	8,760	8,760	7,500	8,760	7,500	8,760
Waynesboro	0	0	1,260	0	1,260*	0
Rural Family Two						
Williston	8,760	8,760	8,760	8,760	8,760	8,760
Urban/Suburban Family						
Augusta	6,760	8,760	8,760	6,760	8,760	6,760
Onsite SRS	2,000	0	0	2,000	0	2,000
Delivery Family						
Martin	306	306	306	306	306	306
Onsite SRS	400	0	0	400	0	400
Allendale	1,600	0	0	1,600	0	1,600
Barnwell	6,454	8,454	8,454	6,454	8,454	6,454
Outdoors Person Family						
Onsite SRS	2,000	0	0	2,000	0	2,000
Jackson	6,760	8,760	8,760	6,760	8,760	6,760
Family Near River						
Martin	8,760	8,760	8,760	8,760	8,760	8,760
Migrant Worker Family						
New Ellenton	4,380	4,380	4,380	4,380	4,360	4,380

*During the indicated years (1969-1972 for the Child Born in 1955, and 1978-81 for the Child Born in 1964), the children born in 1955 and 1964 are classed as teenagers.

9.3.2 Exposure to Contaminated Soil

External exposures from being on a contaminated surface result from the receptor absorbing radiation emitted by radionuclides in the contaminated surface. Gamma rays produce most of this dose from a contaminated surface, also called ground-plane dose. The receptor is assumed to be standing on a slab of material contaminated at a uniform concentration. Radiation emitted by atoms on the surface of the slab is partially absorbed by the air between the receptor and emitting atoms; radiation emitted by atoms within the slab is partially absorbed by the intervening air and slab material (usually considered to be soil). More distant decaying atoms generally contribute less to dose than those closer to the receptor. The model also considers excitation of intervening atoms and secondary emission of radiation. Therefore nearby atoms contribute most to the dose and the dose calculated is not very sensitive to large-scale variations in concentration. Note that for this study, the use of a sector average model means the concentration is assumed to be constant in an entire 22.5º sector at a given radius.

Key variables in determining the intake for exposure to contaminated soil are:

1. Concentration of each radionuclide in the soil at a particular exposure location.
2. Time of exposure for a particular receptor at a particular location.
3. Shielding of a receptor provided by buildings.
4. Fractions of time spent indoors and outdoors at each exposure location.

The approach used to calculate yearly soil concentrations at various exposure locations is described in Chapter 8. The time spent by each receptor at various locations is provided in Table 9-6. (Note that the exposure times in Table 9-6 are smaller than in Table 9-4 because receptors were assumed not to be exposed to radiation from ground contamination when they were swimming or boating.) The outdoor shielding factor was set equal to 1.0 for all scenarios, exposure locations, individuals, and years; the indoor shielding factor was set to 0.7 (Appendix E). The hours spent indoors and outdoors were determined based on data from The Exposure Factors Handbook (4) and the scenario specifications provided by CDC (5). From the times spent indoors and outdoors at each location for each receptor, the fraction of time spent indoors and outdoors was calculated (these fractions must sum to unity); indoor and outdoor fractions are summarized in Table 9-7. In addition, Appendix E lists the hours spent indoors and outdoors for each receptor and exposure location, and the indoor and outdoor fractions calculated from these hours.

Table 9-6 Exposure Times (hours/year) for Ground Contamination External Exposure Pathway

Individual	Adult Male	Adult Female	Child Born in 1955		Child Born in 1964	
			*Thru 1972**	*Starting 1973*	*Thru 1981*	*Starting 1982*
Rural Family One						
Girard	8,739	8,739	7,479	8,739	7,479	8,739
Waynesboro	0	0	1,260	0	1,260*	0
Rural Family Two						
Williston	8,739	8,739	8,739	8,739	8,739	8,739
Urban/Suburban Family						
Augusta	6,643	8,643	8,643	6,643	8,643	6,643
Onsite SRS	2,000	0	0	2,000	0	2,000
Delivery Family						
Martin	189	189	189	189	189	189
Onsite SRS	400	0	0	400	0	400
Allendale	1,600	0	0	1,600	0	1,600
Barnwell	6,454	8,454	8,454	6,454	8,454	6,454
Outdoors Person Family						
Onsite SRS	1,740	0	0	1,740	0	1,740
Jackson	6,643	8,643	8,643	6,643	8,643	6,643
Family Near River						
Martin	8,447	8,447	8,447	8,447	8,447	8,447
Migrant Worker Family						
New Ellenton	4,370	4,370	4,370	4,370	4,370	4,370

*****During the indicated years (1969-1972 for the Child Born in 1955, and 1978-81 for the Child Born in 1964), the children born in 1955 and 1964 are classed as teenagers.

Table 9-7 Indoor and Outdoor Fractions for Ground Contamination Pathway

Member	Location	Outdoor Fraction	Indoor Fraction	Member	Location	Outdoor Fraction	Indoor Fraction
Rural Family One				***Urban/Suburban Family***			
Infant	Girard	0.15	0.85	Infant	Augusta	0.14	0.86
Preschooler	Girard	0.15	0.85	Preschooler	Augusta	0.14	0.86
School Child	Girard	0.18	0.82	School Child	Augusta	0.17	0.83
Teen	Girard	0.13	0.87	Teen	Augusta	0.14	0.86
Teen	Waynesboro	0.29	0.71	Adult Male	Augusta	0.13	0.87
Adult Male	Girard	0.31	0.69	Adult Male	SRS	0.13	0.87
Adult Female	Girard	0.14	0.86	Adult Female	Augusta	0.13	0.87
Rural Family Two				***Family Near River***			
Infant	Williston	0.15	0.85	Infant	Martin	0.14	0.86
Preschooler	Williston	0.15	0.85	Preschooler	Martin	0.14	0.86
School Child	Williston	0.18	0.82	School Child	Martin	0.18	0.82
Teen	Williston	0.15	0.85	Teen	Martin	0.15	0.85
Adult Male	Williston	0.31	0.69	Adult Male	Martin	0.13	0.87
Adult Female	Williston	0.14	0.86	Adult Female	Martin	0.13	0.87
Delivery Person Family				***Outdoor Person***			
Infant	Martin	0.45	0.55	Infant	Jackson	0.15	0.85
Infant	Barnwell	0.14	0.86	Preschooler	Jackson	0.15	0.85
Preschooler	Martin	0.45	0.55	School Child	Jackson	0.18	0.82
Preschooler	Barnwell	0.14	0.86	Teen	Jackson	0.15	0.85
School Child	Martin	0.45	0.55	Adult Male	Jackson	0.14	0.86
School Child	Barnwell	0.18	0.82	Adult Male	SRS	1.0	0
Teen	Martin	0.45	0.55	Adult Female	Jackson	0.14	0.86
Teen	Barnwell	0.15	0.85	***Migrant Worker Family***			
Adult Male	Martin	0.45	0.55	Infant	New Ellenton	0.15	0.85
Adult Male	Barnwell	0.13	0.87	Preschooler	New Ellenton	0.15	0.85
Adult Male	SRS	0.50	0.50	School Child	New Ellenton	0.18	0.82
Adult Male	Allendale	0.16	0.84	Teen	New Ellenton	0.15	0.85
Adult Female	Martin	0.45	0.55	Adult Male	New Ellenton	0.31	0.69
Adult Female	Barnwell	0.13	0.87	Adult Female	New Ellenton	0.14	0.86

9.3.3 Exposure to a Contaminated Shoreline

External exposure from being on the shore of a river or stream is similar to external exposure from contaminated soil. The principal differences for this study are: (1) the contamination on the shoreline results from contaminated sediment deposited there by contaminated water, rather than from contaminated air; (2) the deposited sediment geometry is comprised of two relatively narrow strips on either side of the river or stream; and (3) the time spent at the shoreline is much less than the time spent on contaminated ground. As with external exposure from contaminated soil, the concentration of radionuclides in the narrow strips is assumed to be constant for a given year.

Key variables for determining the intake for exposure to contaminated sediments on the shoreline are:

- Concentration of each radionuclide in the sediment at a particular shoreline location.
- Shoreline width factor.
- Shoreline use daily event frequency (frequency of shoreline use per day) at the shoreline location.
- Duration of each shoreline use (hours per event).
- Shoreline use annual event frequency (number of days per year the shoreline is used).

The approach used to calculate yearly average radionuclide concentrations in sediment at various shoreline exposure locations is described in Chapter 8. The shoreline width factor is taken to be 0.2 for all locations. Because the source of radiation is comprised of two strips rather than an infinite plane, the radiation level is only a fraction of the infinite plane value, which is accounted for by this factor. This is the default value used in the GENII code, the value recommended by the NRC for river shorelines (6), and the value used in past environmental analyses for SRS (7), (8), (9). Variables (3), (4), and (5) multiplied together equal the total time per year spent on the shoreline; values for these total times are provided in Table 9-7. Note that only the Delivery Family, Outdoors Family, and Near-River Family have any shoreline exposure. Although other scenarios may participate in shoreline activities, the shorelines are on bodies of water that receive no waterborne releases from the SRS; in these cases it was assumed that the water and shorelines were uncontaminated by SRS activities. Thus the shoreline exposure times for Rural Family One, Rural Family Two, the Urban/Suburban Family, and the Migrant Worker Family were all assumed to be zero.

For the remaining receptors, exposure times were determined as follows:

- All members of the Delivery Person Family split their shoreline use equally between Lower Three Runs Creek near Martin and the Savannah River at Smith Lake. Shoreline exposure rates are estimated using the following factors based on South Carolina recreational patterns cited in Hamby 1991 [pp.6 and 24](10):

  - Average number of shoreline usage events/year – 19.15
  - Average hours/shoreline usage event – 4.44

  85 hr/yr is the product of these values.

- The Outdoors Person Adult Male (and children when they become working adults) used the shoreline on the Savannah River downstream of SRS; this location represented job-related exposures associated with employment onsite at the SRS. This time includes time spent fishing and hunting. The exposure level assumes the adult male was “on the river” 8 hours/day (40 hours/week) during the summer (13 weeks)(5). It further assumes that half the time spent “on the river” was spent on the shoreline, and the other half was spent on a boat. This results in an exposure time of 260 hours/year on the shoreline for the adult male.

- The Family Living Near the River used the shoreline on the Savannah River downstream of the SRS; an exposure time of 365 hours a year assumed an average of one hour per day shoreline exposure for every day of the year

Locations and exposure times for shoreline external exposure are summarized in Table 9-8.

Table 9-8 Exposure Times (hours/year) for Shoreline External Exposure Pathway

Scenario	Shoreline Usage Location	Exposure Time (hours/year)
Rural Family One	Briar Creek near Girard	0 (all years and individuals)*
Rural Family Two	Savannah River upstream of SRS and farm ponds around Williston	0 (all years and individuals)*
Urban/Suburban Family	Savannah River at Augusta	0 (all years and individuals)*
Delivery Person	Lower Three Runs Creek (LTRC) at Martin (50%) and the Savannah River down stream of the LTRC confluence (50%).	For all years and individuals: 42.5 on LTRC shoreline at Martin 42.5 on Savannah
Outdoors Person	Savannah River: Upstream of SRS for the adult female and children. Downstream of SRS for the adult male.	260 for the adult male on the Savannah River downstream of the SRS; also used for children after they reach age 18.
Family Living Near the River	Savannah River Downstream of SRS for all individuals.	365 (all years and individuals)
Migrant Worker Family	Savannah River upstream of SRS and farm ponds around New Ellenton	0 (all years and individuals)*

*The dose from shoreline external exposure is assumed to be zero, because the exposure location received no waterborne releases from the SRS; in these cases it was assumed that the water was uncontaminated by SRS activities.

9.3.4 Immersion in Contaminated Water While Swimming

In this study doses from swimming were modeled through two separate but related exposure pathways: (1) external exposure by immersion in contaminated water, discussed here, and (2) inadvertent ingestion of contaminated water, discussed in Section 9.4.

External exposures from immersion in a contaminated body of water are similar in nature to exposures from immersion in a contaminated plume of air, as discussed in Section 9.3.1. A significant difference is that radiation is attenuated more rapidly in water because of its higher density.

Key variables in determining the exposure for immersion in a contaminated body of water are:

1. Concentration of each radionuclide in the water at a location used for swimming.
2. Swimming daily event frequency (frequency of swimming per day) at the particular swimming location.
3. Duration of each swimming event (hours per event).

4. Swimming event annual frequency (number of days per year swimming occurs).

The approach used to calculate annual radionuclide concentrations in water at two exposure locations is described in Chapter 8. Variables (2), (3), and (4) multiplied together equal the total time per year spent swimming and therefore immersed in contaminated water; values for these total times are provided in Table 9-8.

Note that only the Delivery Family and Near-River Family have any exposure due to swimming in contaminated water. Although other scenarios may participate in swimming activities, that swimming was specified to take place in bodies of water that receive no waterborne releases from the SRS; for these scenarios it was assumed that the water was uncontaminated by SRS activities. Thus the swimming exposure times for Rural Family One, Rural Family Two, the Urban/Suburban Family, the Outdoors Person Family, and the Migrant Worker Family were all assumed to be zero.

Consistent with the scenarios described in Chapter 3, swimming locations were: (1) Lower Three Runs Creek near Martin, SC, for the Delivery Person Family and (2) the Savannah River downstream of SRS for the Family Living Near the River. Time spent swimming were based on South Carolina recreational patterns cited in Hamby 1991 [p.6 and 24] (10). The Hamby values are based on "Outdoor Recreation Assessment and Policy Plan 1989," in the Georgia Recreation Planning Process, GA Department of Natural Resources, Atlanta, GA, 1990. Swimming times, not differentiated by age, represent warm-water fishing activity:

- Average number of lake swimming events/year – 8.12
- Average hours/lake swimming event – 2.61

This results in an exposure rate of 21.2 hours/year, which is applied to all individuals in the Delivery Person Family. For the Family Living Near the River, it was assumed that all members of the family spent one hour per day during the summer swimming in the river; this is more consistent with the characterization of this family as “always outdoors and in contact with the river” (5)

Locations and total time immersed in contaminated water while swimming summarized in Table 9-9.

Table 9-9 Exposure Locations and Times (hours/year) for Swimming External Exposure (Water Immersion) Pathway

Scenario	Swimming Location	Exposure Time (hours/year)
Rural Family One	Briar Creek near Girard	0 (all years and individuals)*
Rural Family Two	farm ponds around Williston	0 (all years and individuals)*
Urban/Suburban Family	Savannah River at Augusta	0 (all years and individuals)*
Delivery Person	Lower Three Runs Creek (LTRC) at Martin	21.2 (all years and individuals)
Outdoors Person	Savannah River upstream of SRS	0 (all years and individuals)*
Family Living Near the River	Savannah River Downstream of SRS	91 (all years and individuals)
Migrant Worker Family	Savannah River upstream of SRS and farm ponds around New Ellenton	0 (all years and individuals)*

* The dose from swimming external exposure (water immersion) is assumed to be zero, because the exposure location received no waterborne releases from the SRS; in these cases it was assumed that the water was uncontaminated by SRS activities.

9.3.5 Exposure to Contaminated Water While Boating

External exposure from being in a boat on a contaminated body of water is similar to external exposure from contaminated soil. The differences are that: (1) the contaminated water, not soil, is the source of radiation and (2) the boat, not buildings, partially shields the receptor from the radiation

Key variables for determining the intake for exposure to contaminated water while boating are:

1. Concentration of each radionuclide in the water at a location used for boating.
2. Shielding factor for boating exposures.
3. Boating daily event frequency (frequency of boating per day) at the particular boating location.
4. Duration of each boating event (hours per event).
5. Boating event annual frequency (number of days per year boating occurs).

The approach used to calculate annual radionuclide concentrations in water at two exposure locations is described in Chapter 8. The shielding factor accounts for the shielding from external radiation provided by the structure and composition of the boat; the shielding factor was assumed to have a value of 1.0 for all scenarios and receptors; this conservatively assumes the boat provides no shielding. Variables (3), (4), and (5) multiplied together equal the total time (in hours) per year spent boating and therefore exposed to direct radiation from contaminated water; values for these total times are provided in Table 9-10.

Table 9-10 Exposure Times (hours/year) and Locations for Boating External Exposure Pathway

Scenario	Boating Exposure Location	Exposure Time (hours/year)
Rural Family One	No boating activity	0 (all years and individuals)
Rural Family Two	No boating activity	0 (all years and individuals)
Urban/Suburban Family	Savannah River at Augusta	0 (all years and individuals)*
Delivery Person	Savannah River Downstream of SRS.	96 (all years and individuals)
Outdoors Person	Savannah River Downstream of SRS.	356 for adult male and children age 18 and over; 96 for adult female and children under age 18.
Family Living Near the River	Savannah River Downstream of SRS.	192 (all years and individuals)
Migrant Worker Family	No boating activity	0 (all years and individuals)

* The dose from boating external exposure is assumed to be zero, because the exposure location received no waterborne releases from the SRS; in this and similar cases it was assumed that the water was uncontaminated by SRS activities.

The scenarios specified no boating activity for Rural Family One, Rural Family Two, and the Migrant Worker Family. For the Delivery Person Family, the Family Living Near the River, and the Outdoors Person boating occurred on the Savannah River downstream of SRS. Boating times are estimated using the factors for boating based on South Carolina recreational patterns cited in Hamby 1991 (10) and shown below in Table 9-11. These values are based on "Outdoor Recreation Assessment and Policy Plan 1989,"

in the Georgia Recreation Planning Process, GA Department of Natural Resources, Atlanta, GA, 1990. The numbers apply to all age groups and include two categories – canoeing and boating/sailing.

Table 9-11 South Carolina Boating Usage Rates (adapted from Hamby 1991)

Boating Usage	Canoe Trails	Boating / Sailing
Events / Year (average)	6.13	18.77
Hours / Event (average)	2.25	4.38
Hours / Year	13.8	82.2
Total	96 hours/year	

The total rate (96 hours/year) was applied to all individuals in the Delivery Person Family. Twice this exposure time was assumed for the Family Living Near the River, because their contact with the water was specified as higher than normal. For the Outdoors Person family, all family members, but the Adult Male, were assumed to have the regional average exposure time, the same as the Delivery Person Family. However the Adult Male had both occupational and recreational exposure; the average recreational exposure of 96 hours/year was added to an occupational exposure of 260 hours/year for a total of 356 hours/year. For the Adult Male's occupational exposure the amount of time spent boating was assumed to be half the time spent "on the river," and the time spent "on the river" was cited in Lockridge 2002 (5) as 8 hours/day (i.e., 40 hours/week) during the summer (i.e., 13 weeks) (0.5 x 40 x 13 = 260 hours/year).

9.4 Ingestion Exposure Route

Ingestion exposure pathways modeled in this study include:

- Ingestion of plants by humans, including:
  Leafy vegetables
  Root vegetables
  Fruit
  Grain
- Ingestion of animal products by humans, including:
  Beef
  Poultry
  Milk
  Eggs
  Fish
- Inadvertent consumption of contaminated soil
- Inadvertent consumption of contaminated water while swimming.

As shown in Table 9-1, the all these exposure pathways are associated only with radionuclide releases to air, with the exception of ingestion of fish and inadvertent ingestion of water while swimming; these last two pathways are associated only with radionuclide releases to water. With the exception of fish, contamination of plants and animals resulted from the contamination of soil by deposition of airborne radionuclides. Soil was not considered to be contaminated by deposition of water-borne radionuclides, because farmers in vicinity of the SRS did not use the Savannah River and Lower Three Runs Creek for irrigation (as explained in Chapter 3). In this study, ingestion of beef was used to represent consumption of all types of meat and meat products, except poultry.

9.4.1 Food-Chain Ingestion Exposures

The general intake equation (9-2) can be simplified for ingestion of foodstuffs to be:

$$I = C_f \cdot U \cdot ED \cdot T \qquad (9\text{-}3)$$

Where, I is the intake;

C_f is the radionuclide concentration in the contaminated food;
U is the consumption rate of the food, i.e., the contact rate for ingestion
ED is the exposure duration, set to one year, since this study examines doses on an annual basis;
T is a special form of the annual activity factor representing the fraction of the food consumed that was produced in the vicinity of SRS and therefore was considered contaminated.

The general food intake equation (9-3) was adapted further for this study to reflect the receptor behaviors specified by the CDC scenarios. In particular, the scenarios specified the locations from which the receptors obtained their food. This was an important aspect of the scenario specifications, since different locations potentially experienced different contamination levels from SRS releases, because of differing distances from the sources and the inhomogeneous air dispersion patterns at the SRS. In general the radionuclide concentration in the food ($C_f \cdot$), the ingestion rate (U), and the fraction contaminated (T) may all be a function of the location where the food was produced. A more precise rendering of equation (9-3) is:

$$I_{total} = \sum I_L = C_{fL} \cdot U_L \cdot ED \cdot T_L \qquad (9\text{-}4)$$

Where all the variables are defined as before, but the index "L" refers to location and I_{total} represents the total intake of a particular radionuclide for a particular receptor for a particular food. For example, as shown in Table 9-176 and Table 9-187 the Outdoors Person Family consumed as much meat (modeled as beef) as most other scenarios. A large fraction (75%) of this meat came from the SRS, while the remainder (25%) came from Jackson. The fraction of contamination of the meat from Jackson was set to 0.5 to reflect production of meat products distant from the SRS (e.g., hot dogs, lunch meats, and other processed meats); the fraction of contamination of meat from the SRS was set to 1.0 to reflect consumption of game taken from the site.

The source location of various terrestrial foods for each scenario is shown in Table 9-12. In general, both the amount of food consumed from each source location and the fraction of the food contaminated varies with the location and type of food. Note that for four scenarios all foods originate at a single location unique to that scenario: Rural Family #1, Rural Family #2, Near River Family, and the Migrant Worker Family.

Chapter 8 describes how the concentrations in food were calculated. The following subsections briefly provide the values chosen for consumption rate, U, and fraction contaminated, T, for the nine types of food considered, as well as the rationale for these choices.

Table 9-12 Source Locations for Various Terrestrial Food Types (and Soil Ingestion) for Each Scenario*

CDC SCENARIO	FOOD TYPE								
	Beef	Poultry	Milk	Eggs	Leafy Veg.	Root Veg.	Fruit	Grain	Soil
Rural Family #1	G	G	G	G	G	G	G	G	G
Rural Family #2	W	W	W	W	W	W	W	W	W
Urban/Suburban	A	A	A/NE	A	A	A	A	A	A
Delivery Person	B/M	B/M	B/M	B/M	B/M	B/M	B/M	B/M	B/M
Outdoors Person	J/SRS	J	J	J	J	J	J	J	J
Near River	M	M	M	M	M	M	M	M	M
Migrant Worker	NE	NE	NE	NE	NE	NE	NE	NE	NE

*Key to locations: G – Girard; W – Williston; A – Augusta; NE – New Ellenton; B – Barnwell; M – Martin; J – Jackson; SRS – Onsite SRS.

9.4.1.1 Ingestion of Leafy and Root Vegetables and Fruit

The Exposure Factors Handbook (4) was used to determine consumption rates of leafy vegetables, root and other vegetables, and fruit. This reference is based on data from U.S. Department of Agriculture studies, including the periodic National Food Consumption Surveys (NFCS) and the Continuing Surveys of Food Intakes by Individuals (CSFII).

Ingestion rates determined for leafy and root vegetables and fruit are listed in Table 9-13. Exposure factors reflect the assumptions that (1) half the leafy vegetables, root vegetables, and fruit consumed by the Delivery Person Family were obtained from the Barnwell area and half from the Martin area, and (2) the Migrant Worker Family was in the SRS vicinity for only half of any year.

The fractions of foodstuffs contaminated (adjustment factors) are listed in Table 9-14. Note that for Rural Families One and Two the values change after 1959, but that values for all other scenarios are constant for the entire 39-year study period. The time dependencies of these values for different scenarios were mandated by the scenario specifications (5).

Table 9-13 Ingestion Rates (kg/yr) for Three Produce Categories

Individual	All Other Scenarios‡			Delivery Person Family (Barnwell/Martin)†			Migrant Worker Family		
	LV*	RV*	F*	LV	RV	F	LV	RV	F
Adult M	16.7	79.2	55.2	8.35/ 8.35	39.6/ 39.6	27.6/ 27.6	8.35	39.6	27.6
Adult F	16.7	57.2	56.6	8.35/ 8.35	28.6/ 28.6	28.3/ 28.3	8.35	28.6	28.3
1955 Child:									
Infant 1955	1.2	26.6	61.7	0.6/ 0.6	13.3/ 13.3	30.85/ 30.85	0.6	13.3	30.85
Preschool 1965-68	4.1	31.1	50.7	2.05/ 2.05	15.55/ 15.55	25.35/ 25.35	2.1	15.55	25.35
School 1960-66	8.1	41.9	52.0	4.05/ 4.05	20.95/ 20.95	26.0/ 26.0	4.05	20.95	26.0
Teen 1967-73	10.6	63.2	49.4	5.3/ 5.3	31.6/ 31.6	24.7/ 24.7	5.3	31.6	24.7
Adult 1974-92	16.7	79.2	55.2	8.35/ 8.35	39.6/ 39.6	27.6/ 27.6	8.35	39.6	27.6
1964 Child:									
Infant 1964	1.2	26.6	61.7	0.6/ 0.6	13.3/ 13.3	30.85/ 30.85	0.6	13.3	30.85
Preschool 1965-68	4.1	31.1	50.7	2.05/ 2.05	15.55/ 15.55	25.35/ 25.35	2.1	15.55	25.35
School 1969-75	8.1	41.9	52.0	4.05/ 4.05	20.95/ 20.95	26.0/ 26.0	4.1	20.95	26.0
Teen 1976-82	10.6	63.2	49.4	5.3/ 5.3	31.6/ 31.6	24.7/ 24.7	5.3	31.6	24.7
Adult 1983-92	16.7	79.2	55.2	8.35/ 8.35	39.6/ 39.6	27.6/ 27.6	8.4	39.6	27.6

*LV: Leafy Vegetables; RV: Root Vegetables; F: Fruit.
†The Delivery Person Family obtains half its produce from Martin and half from Barnwell; table entries represent this portion.
‡Rural Families One and Two, Urban/Suburban Family, Outdoors Person Family, Near Water Family

Table 9-14 Ingestion Rates (kg/y) and Fraction Contaminated (Adjustment Factor) for Leafy Vegetable, Root Vegetable, and Fruit Ingestion Exposure Pathways

Individual	Rural Families One And Two	All Other Scenarios*
Adult Male:		
Thru 1959	0.75	0.50
1960 & on	0.625	0.50
Adult Female:		
Thru 1959	0.75	0.50
1960 & on	0.625	0.50
1955 Child:		
Thru 1959	0.75	0.50
1960 & on	0.625	0.50
1964 Child:	0.625	0.50

* Urban/Suburban Family, Delivery Person Family, Outdoors Person Family, Near River Family, Migrant Worker Family

9.4.1.2 Ingestion of Grain

For the grain ingestion pathways, consumption rate data from the Exposure Factors Handbook (3) was used, as shown in Table 9-15. No data on local consumption was identified. This data was interpreted by assuming that most grain and grain products consumed by receptors in the vicinity of the SRS (i.e. breads, pastas, flours, etc.), would originate outside the local region. However, corn was expected to be consumed as a vegetable (e.g., corn on the cob). For purposes of modeling radionuclide uptake, corn is considered a grain rather than a vegetable. The Exposure Factors Handbook data is presented in terms of g/kg-day of consumption and was converted into kg/y by using Tables 7-2 and 7-3 from in the same source to determine mean body mass as a function of age and gender. The Exposure Factors Handbook also presents consumption rates based on geographic region; however, differentiation by age and gender was not given by geographic region and differences between regions were small, so regional data were not used.

The contaminated fraction for the Migrant Worker Family was set to 0.5 to account for the fact that the family was completely absent from the SRS vicinity for one-half the year. For all the remaining scenarios, the contaminated fraction was set equal to 1.0.

Table 9-15 Ingestion Rate of Corn (kg/y)

Individual	All Other Scenarios	Delivery Person Family	
		Martin	Barnwell
Adult Male	4.1	2.05	2.05
Adult Female	3.5	1.75	1.75
1955 Child:			
Infant 1955	1.2	0.6	0.6
Preschool 1956-59	2.9	1.45	1.45
School 1960-66	3.9	1.95	1.95
Teen 1967-73	3.6	1.8	1.8
Adult 1974-92	4.1	2.05	2.05
1964 Child:			
Infant 1964	1.2	0.6	0.6
Preschool 1965-68	2.9	1.45	1.45
School 1969-75	3.9	1.95	1.95
Teen 1976-82	3.6	1.8	1.8
Adult 1983-92	4.1	2.05	2.05

9.4.1.3 Ingestion of Beef

Beef was used to represent all non-poultry and non-fish meat that was eaten by the hypothetical receptors. As explained in the White Paper, "Treatment of Radionuclide Concentrations in Wild Game in Dose Reconstruction Modeling" (11) beef was used as a surrogate for venison from locally-hunted deer. The principal source of information on meat consumption was the Exposure Factors Handbook (4).

Values used to characterize the consumption of beef reflects the scenario specifications; in particular the scenarios specified that: (1) the Delivery Person Family ate beef obtained from both the Martin and Barnwell areas; (2) the Migrant Worker Family is in the SRS vicinity for only half the year; and (3) three-quarters of the "beef " eaten by the Outdoors Person Family was venison from deer taken on the SRS site and one-quarter came from Jackson as farm-raised beef or other meat. Beef consumption rates are listed for each receptor in Table 9-16.

The fraction of the beef consumed that was considered to be contaminated (adjustment factor) took into account a number of assumptions that are discussed and referenced in Appendix E. For several scenarios 50% of beef purchased at local groceries was considered locally grown and therefore contaminated. The fraction of beef that is contaminated is listed for each receptor in Table 9-17.

Table 9-16 Consumption Rate (kg/y) of Beef (Meat)

Individual	Rural Families One and Two, Urban/ Suburban Family, Near River Family	Delivery Person Family		Outdoors Person Family		Migrant Worker Family
		Martin	Barn-well	Jackson	SRS Onsite	New Ellenton
Adult Male	78.1	39.05	39.05	19.52	58.58	39.05
Adult Female	49.7	24.85	24.85	12.42	37.28	24.85
1955 Child:						
Infant 1955	25.2	12.6	12.6	6.3	18.9	12.6
Preschool 1956-59	31.4	15.7	15.7	7.85	23.55	15.7
School 1960-66	50.6	25.3	25.3	12.65	37.95	25.3
Teen 1967-73	75.6	37.8	37.8	18.9	56.7	37.8
Adult 1974-92	78.1	39.05	39.05	19.52	58.58	39.05
1964 Child:						
Infant 1964	25.2	12.6	12.6	6.3	18.9	12.6
Preschool 1965-68	31.4	15.7	15.7	7.85	23.55	15.7
School 1969-75	50.6	25.3	25.3	12.65	37.95	25.3
Teen 1976-82	75.6	37.8	37.8	18.9	56.7	37.8
Adult 1983-92	78.1	39.05	39.05	19.52	58.58	39.05

Table 9-17 Fraction of Beef and Poultry that is Contaminated (Adjustment Factors)

	SCENARIO							
	Rural Family One/ Two	Urban-Suburban Family	Delivery Person Family		Outdoors Person Family		Near River Family	Migrant Worker Family
Production Location →	Williston/Girard	Augusta	Martin	Barnwell	Jackson	SRS Onsite	Martin	New Ellenton
Adult Male:								
1955-1959	0.75	0.5	0.625	0.5	0.5	1.0	0.5	0.5
1960-1992	0.625	0.5	0.625	0.5	0.5	1.0	0.5	0.5
Adult Female:								
1955-1959	0.75	0.5	0.625	0.5	0.5	1.0	0.5	0.5
1960-1992	0.625	0.5	0.625	0.5	0.5	1.0	0.5	0.5
1955 Child:								
1955-1959	0.75	0.5	0.625	0.5	0.5	1.0	0.5	0.5
1960-1992	0.625	0.5	0.625	0.5	0.5	1.0	0.5	0.5
1964 Child:	0.625	0.5	0.625	0.5	0.5	1.0	0.5	0.5

9.4.1.4 Ingestion of Poultry

For the poultry ingestion pathway, consumption rates for specific age and gender categories from the Exposure Factors Handbook [Table 11-10] (4) were adapted to the age and gender categories used in the modeling by using the same approach as was used for beef consumption. The rates that result from this adjustment are shown in Table 9-18 for each scenario. The fraction of poultry that is considered to be contaminated for each scenario is based on the descriptions provided by the SRSHES (4) and are the same fractions contaminated as used for beef ingestion. These fractions contaminated are shown for each scenario in Table 9-17.

Table 9-18 Ingestion Rate of Poultry (kg/y)

	All Other Scenarios	Delivery Person Family		Outdoors Person Family	
		Martin	Barnwell	Onsite SRS	Jackson
Adult Male	11.9	11.9	11.9	11.9	11.9
Adult Female	9.1	9.1	9.1	9.1	9.1
1955 Child:					
Infant 1955	1.5	1.5	1.5	1.5	1.5
Preschool 1956-59	6.4	6.4	6.4	6.4	6.4
School 1960-66	8.0	8.0	8.0	8.0	8.0
Teen 1967-73	11.7	11.7	11.7	11.7	11.7
Adult 1974-92	11.9	11.9	11.9	11.9	11.9
1964 Child:					
Infant 1964	1.5	1.5	1.5	1.5	1.5
Preschool 1965-68	6.4	6.4	6.4	6.4	6.4
School 1969-75	8.0	8.0	8.0	8.0	8.0
Teen 1976-82	11.7	11.7	11.7	11.7	11.7
Adult 1983-92	11.9	11.9	11.9	11.9	11.9

9.4.1.5 Ingestion of Milk

For the milk ingestion pathway, consumption rates were adapted from The Exposure Factors Handbook (4); these milk consumption rates are listed in Table 9-19. Note that of the milk consumed by the Urban/Suburban Family, half came from cows in Augusta, GA, and half came from cows in New Ellenton, SC. Similarly, for the Delivery Person Family the milk supply was split evenly between Barnwell and Martin. Because the scenarios specified that all milk was obtained from sources local to SRS, the fraction contaminated was set to unity for all scenarios.

Table 9-19 Consumption Rates (kg/y) for Milk

Individual	Rural Families One and Two, Outdoors Person Family, Near River Family	Urban/ Suburban Family	Delivery Person Family	Migrant Worker Family
		Augusta/New Ellenton	Barnwell/ Martin	New Ellenton
Adult Male	73.7	36.85/36.85	36.85/36.85	36.9
Adult Female	55.5	27.75/27.75	27.75/27.75	27.8
1955 Child:				
Infant 1955	131.8	65.9/65.9	65.9/65.9	65.9
Preschool 1956-59	130.2	65.1/65.1	65.1/65.1	65.1
School 1960-66	146.5	73.25/73.25	73.25/73.25	73.3
Teen 1967-73	169.5	84.75/84/75	84.75/84/75	84.8
Adult 1974-92	73.7	36.85/36.85	36.85/36.85	36.9
1964 Child:				
Infant 1964	131.8	65.9/65.9	65.9/65.9	65.9
Preschool 1965-68	130.2	65.1/65.1	65.1/65.1	65.1
School 1969-75	146.5	73.25/73.25	73.25/73.25	73.3
Teen 1976-82	169.5	84.75/84/75	84.75/84/75	84.8
Adult 1983-92	73.7	36.85/36.85	36.85/36.85	36.9

9.4.1.6 Ingestion of Eggs

For the egg ingestion pathway, consumption rates were adapted from The Exposure Factors Handbook (4); these egg consumption rates are listed in Table 9-20. Note that of the eggs consumed by the Urban/Suburban Family all came from hens in Augusta, GA, even though some foodstuffs came from New Ellenton, SC. For the Delivery Person Family the egg supply was split evenly between Barnwell and Martin. The quantity of eggs consumed by the Migrant Worker Family was set to one-half the quantity consumed by other scenarios, since they were absent from the SRS vicinity for one-half of each year modeled. Because the scenarios specified that all eggs were obtained from sources local to SRS, the fraction contaminated was set to unity for all scenarios.

Table 9-20 Consumption Rates (kg/y) for Eggs

Individual	Rural Families One and Two, Outdoors Person Family, Near River Family	Urban/ Suburban Family Augusta/New Ellenton	Delivery Person Family Barnwell/ Martin	Migrant Worker Family New Ellenton
Adult Male	13.9	13.9/0	6.95/6.95	6.95
Adult Female	8.4	8.4/0	4.2/4.2	4.2
1955 Child:				
Infant 1955	1.8	1.8/0	0.90/0.90	0.90
Preschool 1956-59	7.7	7.7/0	3.85/3.85	3.85
School 1960-66	8.0	8.0/0	4.0/4.0	4.0
Teen 1967-73	10.8	10.8/0	5.4/5.4	5.4
Adult 1974-92	13.9	13.9/0	6.95/6.95	6.95
1964 Child:				
Infant 1964	1.8	1.8/0	0.90/0.90	0.90
Preschool 1965-68	7.7	7.7/0	3.85/3.85	3.85
School 1969-75	8.0	8.0/0	4.0/4.0	4.0
Teen 1976-82	10.8	10.8/0	5.4/5.4	5.4
Adult 1983-92	13.9	13.9/0	6.95/6.95	6.95

9.4.1.7 Ingestion of Fish

Radiation exposure through the aquatic food consumption pathway was modeled as occurring entirely from consumption of fish. Freshwater crustaceans (e.g., crayfish) and mollusks (e.g., fresh water mussel) that grew in waters contaminated by liquid releases from the SRS were not considered to be consumed in sufficient quantities to warrant modeling. Crabs, shrimp, oysters, and clams from estuarine waters were certainly consumed in significant quantities; however, because the habitat for these crustaceans and mollusks is located a significant distance downriver in brackish or salt water, far away from the SRS, the levels of radiation in those waters and animals, traceable to the SRS releases, would be quite small. Modeling these small doses was therefore not included in the study. Several references were consulted to determine fish consumption rates, including (4), (10), (12), (13), and (14). None of these studies of fish consumption, however, were local to South Carolina and Georgia; therefore consumption rates were based on the Exposure Factors Handbook (3). For the Delivery Person Family, the source of the catch was assumed to be split evenly between Lower Three Runs Creek and the Savannah River. The consumption rate for the Migrant Worker Family reflected their presence in the SRS vicinity for only one-half of each year. The consumption rates for fish are summarized in Table 9-21.

Table 9-21 Ingestion Rate (kg/yr) for Fish

Scenario:	Rural Family One	Rural Family Two	Urban/ Suburban Family	Delivery Person Family		Outdoors Person Family	Family Near the River	Migrant Worker Family
Location:	Briar Creek	Creeks, ponds local to Williston	Savannah River near Augusta	Lower Three Runs Creek	Savannah River (Smith Lake)	Savannah River (various locations)	Savannah River (various locations)	Creeks, ponds of New Ellenton
Individual								
Adult M	9.9	9.9	9.9	4.95	4.95	9.9	9.9	4.95
Adult F	9.9	9.9	9.9	4.95	4.95	9.9	9.9	4.95
Children:								
Infant	4.2	4.2	4.2	2.1	2.1	4.2	4.2	2.1
Preschool	4.2	4.2	4.2	2.1	2.1	4.2	4.2	2.1
School	5.0	5.0	5.0	2.5	2.5	5.0	5.0	2.5
Teen	4.5	4.5	4.5	2.25	2.25	4.5	4.5	2.25
Adult	9.9	9.9	9.9	4.95	4.95	9.9	9.9	4.95

All fish consumed by the two Rural Families, the Urban/Suburban Family, and the Migrant Worker Family were assumed to come from bodies of water uncontaminated by SRS releases to surface water. However, all fish consumed by the Delivery Person Family, the Outdoors Person Family, and the Family Near the River were assumed to come from bodies of water contaminated by SRS releases to surface water. Therefore the contaminated fraction (adjustment factor) was set to unity for the Delivery Person Family, the Outdoors Person Family, and the Near River Family; all others were set to zero.

9.4.2 Inadvertent Soil Ingestion

The total mass of contaminated soil consumed over each year (kg/y) was based on the Exposure Factors Handbook (4). Daily rates of 100 milligrams per day for children, and 50 milligrams per day for adults, were apportioned among the exposure locations according to the amount of time that each receptor spent at each location. Note that unlike most foodstuffs, the consumption rate of soil is higher for children than for adults. These soil ingestion rates are summarized in Table 9-22.

9.4.3 Inadvertent water consumption while swimming

The hourly ingestion rate of water, while swimming, was set equal to 0.05 L/hr, which is the EPA default value (see Appendix E). Based on the scenario specifications, swimming exposures were set to zero for all receptors except the Delivery Family and the Near River Family, because only these families swam in water contaminated by liquid releases from the SRS. The Delivery Person family swam on Lower Three Runs Creek near Martin, and the Family Near the River swam on the Savannah River downstream of the site. Swimming times were 21.2 hours/year for the Delivery Person Family, and 91 hours per year for the Family Near the River. Hence, the total amount of contaminated water ingested while swimming was 1.06 L/year for all members of the Delivery Person Family and 4.6 L/year for all members of the Family Near the River.

Table 9-22 Soil Ingestion Rates (kg/year) for Each Scenario by Location of Soil Ingestion; Children's Ingestion Rates are Shown by Age

Scenario→		Rural Family One		Rural Family Two	Urban/ Suburban		Delivery Person				Outdoors Person		Near River	Migrant Worker
Location→		Girard	Wayne -sboro	Willi-ston	Augusta	Onsite SRS	Martin	Onsite SRS	Allen-dale	Barn-well	Onsite SRS	Jackson	Martin	New Ellenton
Person	Age													
Adult M	All	0.0183	0	0.0183	0.0141	0.00418	0.000693	0.000836	0.00334	0.0135	0.00418	0.0141	0.0183	0.009125
Adult F	All	0.0183	0	0.0183	0.0183	0	0.000393	0	0	0.0177	0	0.0183	0.0183	0.009125
Children Born in 1955 and 1964	Infant <1	0.0365	0	0.0365	0.0365	0	0.00128		0	0.0352	0	0.0365	0.0365	0.01825
	Pre-school 1-4	0.0365	0	0.0365	0.0365	0	0.00128	0	0	0.0352	0	0.0365	0.0365	0.01825
	School-child 5-11	0.0365	0	0.0365	0.0365	0	0.00128	0	0	0.0352	0	0.0365	0.0365	0.01825
	Teen 12-17	0.0313	0.00525	0.0365	0.0365	0	0.00128	0	0	0.0352	0	0.0365	0.0365	0.01825
	Adult M ≥18	0.0183	0	0.0183	0.0141	0.00418	0.00693	0.000836	0.0034	0.0135	0.00418	0.0141	0.0183	0.009125

9.5 Inhalation Exposure Route

The inhalation exposure route consists of (1) inhalation of air contaminated directly by releases to the atmosphere from the SRS and (2) inhalation of radionuclides that have been resuspended from soil after initial deposition from contaminated air. The general intake equation (9-2) can be simplified for inhalation to be:

$$I = C_a \cdot U \cdot ED \cdot T \qquad (9\text{-}5)$$

Where, I is the intake;

C_a is the radionuclide concentration in air resulting either directly from releases or from resuspension;

U is the breathing rate (m^3/h), i.e., the contact rate for inhalation;

ED is the exposure duration, set to one year, since this study examines doses on an annual basis;

T is the fraction of time spent at a particular location giving rise to the specified air concentration of radionuclides.

Chapter 5 describes how the concentrations in air resulting directly from atmospheric releases from the SRS were calculated. Chapter 8 describes how concentrations in soil were calculated and how concentrations of radionuclides in air from resuspended soil were calculated. The following subsections briefly provide the values for chosen for breathing rate, U, and fraction of time spent at different locations with contaminated air or soil, T.

9.5.1 Air Inhalation

Inhalation rates by age were based on data from the Exposure Factors Handbook (4). Breathing rates in the Exposure Factors Handbook were averaged over several age intervals to obtain age-interval-weighted breathing rates for the age groupings used in this dose calculation. Inhalation rates (units of m^3 per year) were created for each receptor at each exposure location by multiplying a constant daily inhalation rate, appropriate for the age and gender of the receptor, by the number of days in a year that the receptor was at a particular exposure location.

For this phase of the dose reconstruction it was not considered appropriate to refine the calculation by modeling the potential differences between indoor and outdoor radionuclide concentrations. Instead indoor concentrations were considered to be equal to outdoor concentrations, which is likely to be a pessimistic assumption. Furthermore this may better reflect conditions early in the site history, when air conditioning and tightly sealed buildings were not as common as today. Table 9-23 lists the volume of air breathed per year at various exposure locations for each scenario; these inhalation volumes are also related to the age and gender of the various receptors.

Table 9-23 Breathing Rates (m3/y) for the Family Members of Each Scenario by Location of Exposure; Children's Breathing Rates are Shown by Age

Scenario→		Rural One		Rural Two	Urban/Suburban			Delivery Person			Outdoors Person		Near River	Migrant Worker
Location →		Girard	Waynes-boro	Williston	Augusta	Onsite SRS	Martin	Onsite SRS	Allen-dale	Barnwell	Onsite SRS	Jackson	Martin	New Ellenton
Person	Age*													
Adult M	All	5,548	0	5,548	4,281	1,267	194	253	1,013	4,088	1,267	4,281	5,548	2,774
Adult F	All	4,125	0	4,125	4,125	0	144	0	0	3,980	0	4,125	4,125	2,062
Child Born in 1955 or 1964	Infant <1	1,643	0	1,643	1,643	0	57	0	0	1,585	0	1,643	1,643	821
	Pre-school 1-4	2,811	0	2,811	2,811	0	98	0	0	2,712	0	2,811	2,811	1,405
	School-child 5-11	4,380	0	4,380	4,380	0	153	0	0	4,227	0	4,380	4,380	2,190
	Teen 12-17	5,045	848	5,892	5,892	0	206	0	0	5,686	0	5,892	5,892	2,946
	Adult M ≥18	5,548	0	5,548	4,281	1,267	194	253	1,013	4088	1,267	4,281	5,548	2,774

*Note that the year the breathing rate is to be applied may be calculated by summing the age and the birth year of the child.

9.5.2 Resuspended Soil

The same exposure variables that were used to calculate intake of radionuclides by breathing air contaminated directly by SRS releases to the atmosphere were used to calculate intake of radionuclides by breathing air contaminated by resuspension of contaminated soil. The only difference is that the air concentration used in equation (9-5) is the concentration based on resuspended radioactivity. As explained in Chapter 8, air concentration from resuspension is related to the soil concentration by a simple linear factor, the resuspension factor. For this study, higher values of the resuspension factor (producing higher air concentrations) were used for rural locations (Girard, New Ellenton, and Williston), while lower values were used for all other locations, which were assumed to have urban or suburban characteristics.

9.6 References

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10 DOSE AND RISK CALCULATIONS

10.1 Introduction

This chapter discusses the final step in obtaining estimates of doses and risks to the hypothetical receptors described in the scenarios. As indicated in Chapter 9, doses and risks are proportional to "intake of radionuclides by each ingestion and inhalation exposure pathway, and exposure to radionuclides from external exposure pathways."(1). The intakes, estimated according to the approaches outlined in Chapter 9, depend on the estimated concentrations of radionuclides in various environmental media: air, water, soil, plants, and animal products. Methods for estimating concentrations are presented in Chapter 5 for air, Chapter 7 for water, and Chapter 8 for the remaining media. Intakes also depend on the behaviors described in the scenario specifications (Chapter 3) that bring the receptors into contact with these contaminated environmental media. Because the doses and risks are proportional to intake, linear coefficients are used to relate intake to dose and risk. These coefficients have been developed over many decades by the health physics community through national and international radiation protection organizations.

10.2 Basic Radiation Concepts

Additional information about radiation assessment and protection principles, and terminology, can be obtained from Internet sites on radiation such as those established by EPA (http://www.epa.gov/radiation) and the University of Michigan (http://www.umich.edu/~nradinfo)

10.2.1 Types of Radiation

Radionuclides released by the SRS into the environment emit two basic kinds of radiation:

- Particle radiation - tiny fast-moving particles that have both energy and mass (weight)
- Electromagnetic radiation - pure energy with no weight.

Particle radiation includes alpha and beta particles. An alpha particle is the positively charged nucleus of a helium atom. Alpha particles lose energy quickly when they collide with matter; therefore, their ability to penetrate is slight. A sheet of paper or layer of skin may completely absorb such particles. However, if radionuclides emitting alpha particles are inside the body, the alpha particles may cause harm to body cells. Beta particles are free, mobile electrons. Beta particles have a greater ability to penetrate matter than alpha particles. Electromagnetic radiation emitted by radionuclides includes gamma rays and x-rays. This radiation has more ability to penetrate matter than most particle radiation. All the types of radiation emitted by radionuclides may damage living cells by ionizing atoms or molecules within the cells.

10.2.2 Radiation Dose

The term "dose" has several meanings, depending on how it is used. For this study, several different terms for "dose" are needed to describe the effects of radiation[1]. The most fundamental definition of dose is the *absorbed dose*, which a measure of the amount of energy imparted to matter (e.g. tissue) by the radiation. Units of the *absorbed dose* are the rad or gray; the gray, the SI unit of absorbed dose, is equivalent to one joule of energy absorbed by a kilogram of tissue (J/kg). One gray equals 100 rad.

Although the amount of energy absorbed per unit mass, as measured by the absorbed dose, is fundamental to determining the adverse impact of radiation on the absorbing tissue and ultimately on the health of the exposed person, the adverse impact also depends upon the type of radiation absorbed. This is because

[1] The terms discussed here are appropriate for the low doses and stochastic health effects usually associated with exposures to environmental radioactivity.

different types of radiation are more or less efficient in producing damage in tissue, given the same amount of energy absorbed per unit mass. These differences are included in the concept of an *equivalent dose*,[2] which may be defined as:

$$H = D \cdot W_R \qquad (10\text{-}1)$$

Where, H is the equivalent dose (Sievert)
D is the absorbed dose (Gray)
W_R is the weighting factor (dimensionless)

The SI unit of equivalent dose is called the *Sievert* (Sv); another unit commonly used in the United States is the "*rem*," or "Roentgen equivalent man," which is one one-hundredth of a Sievert. A *millirem* (mrem) is one one-thousandth of a rem. The weighting factor[3] accounts for differences in how energy is imparted to tissue by different types of radiation. X-rays, gamma rays, and beta particles are generally assigned weighting factors of one, while alpha particles are generally assigned weighting factors of twenty.

One difficulty of estimating radiation doses to humans is that human bodies are variable. To achieve agreement on standards for radiation protection, and to help comparisons of different radiation dose assessments, a concept was developed called a *standard man*, a surrogate human having organs of both sexes of reference radii and masses. Risk assessments are commonly performed using these standard physiological assumptions.

As discussed in previous chapters, especially Chapters 9, exposure to radiation may result from radionuclides inside or outside the body. Radionuclides were modeled as entering the body by inhalation and ingestion. Exposures to external radiation from radionuclides outside the body were modeled for:

- Immersion in a plume of air
- Exposure to contaminated soil
- Exposure to a contaminated shoreline
- Exposure to contaminated water while swimming
- Exposure to contaminated water while boating

The radiation exposure from these external sources tends to be uniform throughout the body of the exposed person, because the sources are large compared to the human body. This is generally different from therapeutic and diagnostic medical exposures, where the radiation is focused on a particular body organ or region. Once the human is removed from proximity to the medium (air, water, and soil) contaminated by radionuclides, the external radiation exposure ceases.

Exposure resulting from radionuclides within the body is substantially different. First, a radionuclide may lodge in or migrate to a particular organ of the body, where it may produce most of its damage. Second, although some types of radiation (alpha and beta) travel short distances, gamma rays may irradiate body organs some distance from the location of the radionuclides. Third, although some radionuclides may lodge in a particular organ (e.g., the lung for inhaled particles), in time they may migrate to organs that have a biochemical affinity for them (e.g., Sr tends to migrate to bones). Fourth, even though the uptake of a radionuclide by inhalation or ingestion may be a short-term or even one-time event, the radionuclides inside the body may continue to irradiate body organs. Finally, radionuclides inside the body may decay or be excreted over time, so their effect on the body lessens over time. To address this complex biological and physical situation, mathematical models are used to describe movement and retention of radioactive material in the body and the doses that are imparted to various

[2] Except where noted, ICRP-60 terminology is used in this chapter.
[3] In ICRP-60 and other ICRP recommendations preceding ICRP-60, a weighting factor was called a quality factor (2).

organs. A radionuclide taken into the body will impart a dose to a person not only for the first year of intake, but in all the following years until the radionuclide decays or is eliminated. To account for this long-lasting effect, the time-varying equivalent dose rate from radioactive material uptake at a given time is integrated (added) over an appropriate time period. For this study, the time period used is 70 years, representing a typical lifetime.[4] This integral of equivalent dose rate for internal radionuclides produces a *committed equivalent dose*, which is measured in Sieverts.

The models (sometimes called *biokinetic* models) used to describe the movement of radionuclides in the body and the resulting doses to various organs are quite complex, as indicated in the following summary:

> "The dosimetric methodology used in FGR-13 is that of the ICRP... The methodology considers two sets of anatomical regions within the body. A set of source regions is used to specify the location of radionuclide within the body. The set of target regions consists of those organs and tissues for which the radiation dose is of interest. For a specific radionuclide, the set of source regions consists of anatomical regions along the route of intake (respiratory and gastrointestinal tract), regions associated with the systemic behavior of the radionuclide, and regions along the routes of elimination of the radionuclide from the body. A region may consist of multiple compartments as necessary to represent the kinetics. Within each region the radionuclide is assumed to be uniformly distributed either by volume or, in some instances, by surface area. The mean absorbed dose to the target region is the fundamental dosimetric quantity.
>
> The energy deposition in the target regions is based on calculations of the radiation transport in an anthropomorphic phantom representing the newborn, 1 y, 5 y, 10 y, 15-y-old male, and adult male (with breasts, ovaries, and uterus added)." (3)

Somewhat simpler models are used to estimate the doses to various organs in the body from external radiation.

At one time, the usual practice was to calculate doses to individual bodily organs or tissues. But in 1977, the ICRP recommended in ICRP-26 the concept of a weighted mean whole-body dose (4). It provides a measure of the dose across multiple organs or tissues, and is determined by multiplying the dose received by each organ or tissue by a weighting factor, and then adding all of these weighted doses to arrive at a single representative dose. ICRP originally called this dose an *effective dose equivalent* (4). In a more recent recommendation (ICRP-60, issued in 1991), ICRP called this dose an *effective dose*(2). The effective dose may be defined as:

$$H_E = \sum_T W_T \cdot H_T \qquad (10\text{-}2)$$

Where, H_E is effective dose (Sv);

W_T is a weighting factor representing the ratio of the stochastic risk (cancers and hereditary effects) from irradiation of tissue T to that for the whole body when irradiated uniformly;

H_T is the equivalent dose in tissue T.

Values for tissue weighting factors recommended by ICRP in 1977 [ICRP-26] and 1991 [ICRP-60] are listed in Table 10-1. As shown, the weighting factors recommended in ICRP-60 are different from those

[4] ICRP-26 recommended a 50-year time period for members of the public as well as radiation workers. ICRP-60 recommends a 70-year time period for members of the public and a 50-year time period for radiation workers.

recommended in ICRP-26.[5] Additional information on these weighting factors may be found in original ICRP documents cited above and in the documentation for FGR-13 (3), (5), FGR-12 (6), and FGR-11 (7); information on how these are employed in the GENII-2 code may be found in Chapter 11 of the GENII SDD.

Table 10-1 ICRP-26 and ICRP-60 Tissue Weighting Factors

Organ or Tissue	ICRP-26 Weighting Factors	ICRP-60 Weighting Factors
Gonads	0.25	0.20
Breast	0.15	0.05
Colon		0.12
Red bond marrow	0.12	0.12
Lungs	0.12	0.12
Stomach		0.12
Urinary bladder		0.05
Liver		0.05
Esophagus		0.05
Thyroid	0.03	0.05
Bone surface	0.03	0.01
Skin		0.01
Remainder	0.30*	0.05†,‡

*The value 0.30 is applied to the average dose among the five remaining organs or tissues receiving the entire dose, excluding the skin, lens of the eye, and the extremities.
†The reminder consists of: adrenals, brain, small intestine, upper large intestine, kidney, muscle, pancreas, spleen, thymus, and uterus.
‡The value 0.05 is applied to the average dose to the remainder tissue group. However, if a member of the remainder receives a dose exceeding the highest dose in any of the 12 organs for which weighting factors are specified, a weighting factor of 0.025 is applied to that organ and weighting factor of 0.025 is applied to the average dose to the rest of the remainder.

The concept of effective dose is used for doses resulting from both external and internal exposures. Furthermore, for internal doses, the concept of effective dose is combined with the concept of committed dose, yielding the *committed effective dose*, which is sometimes shortened to *effective dose* and is the time integral of the effective dose rate. For both internal and external exposures, the effective dose depends on the age of the exposed individual. This is because the risk of cancer depends on the latency period over which cancer may develop. Persons exposed early in life have a higher risk of radiation-induced disease than persons exposed later in life, because these diseases have a greater time to develop and because other causes of mortality are less likely to arise. In addition, for internal exposures, the committed dose is higher for persons exposed earlier in life than those exposed later in life, because the residual

[5] These weighting factors were calculated under somewhat different assumptions. ICRP-26 weighting factors are based on the risk of fatal cancers and hereditary defects in the first two generations. ICRP-60 weighting factors are based on risks for both fatal and non-fatal cancers, the risk of hereditary defects over all future generations, and the relative loss of live expectancy given a fatal cancer or a severe generic disorder.

radionuclides have a longer time to irradiate body organs. In addition, the models used to derive the organ doses from internal incorporate age-dependent factors into the models, e.g., the size of various organs, metabolic rates. For all these reasons, the coefficients used to relate effective doses to internal or external exposures are age-dependent. In this study these age-dependent dose coefficients were used to estimate doses, so the changing ages of children in the various scenarios would be accounted for.

10.2.3 Risk from Radiation Exposure

As discussed in the preceding section, the concept of effective dose incorporates the risk of cancer incidence for various organs in the body. "The effective dose equivalent is intended to replace the complex dose distribution pattern from internal and external irradiation by an equivalent, uniform, whole-body dose." (8). One way to express risks is the probability of cancer *fatality* (*mortality*) occurring over a lifetime from exposure to radioactive material. Fatality (mortality) is the risk of dying of cancer. Another way to express risks is the probability of cancer *incidence (morbidity)* occurring over a lifetime from exposure to radioactive material. Incidence (morbidity) is the risk of getting radiation-related cancer whether or not the cancer is fatal. For the point estimate calculations described in Chapter 11, the effective dose equivalent, the individual organ doses, the cancer incidence risk, and the cancer fatality risk were all calculated and recorded on an annual basis for each receptor in each scenario. For the uncertainty analysis described in Chapter 12, only the effective dose equivalent over the 39-years studied, not the risk, was recorded for each receptor in each scenario, because of the large amount of data involved.

10.3 Calculation of Dose or Risk

Doses and risks are proportional to the intakes calculated according to the methods outlined in Chapter 9. The constant of proportionality (dose coefficient, dose conversion factor, or risk coefficient) depends on the type of exposure; i.e., whether the exposure is external, inhalation, or ingestion. For external exposure the dose coefficient depends on the geometry of the contaminated medium relative to the receptor; for example, the dose coefficient depends on whether the receptor is immersed in a plume of radioactive contaminants, is standing on the surface of contaminated ground, or is on a contaminated body of water. For internal exposure the dose coefficient depends upon whether the radioactive material was inhaled or ingested. In addition, for inhaled radionuclides, the dose coefficient depends upon the inhalation solubility class. The solubility class is important because in the metabolic models used to determine dose, the solubility of the nuclide determines how long it stays in the lungs and its ability to migrate to other organs in the body. The dose coefficient also depends on the age of the receptor for the reasons described at the end of Section 10.2.2. Finally, the dose coefficient depends on the identity of the particular radionuclide causing the exposure. Because different radionuclides emit different types of radiation (particles and electromagnetic waves) of different energies as they decay, the doses produced from internal or external exposure are unique for each radionuclide.

The constants of proportionality, the dose coefficients or dose conversion factors, have been compiled for a large number of radionuclides by assuming a unit concentration in the appropriate contaminated medium (Bq/m^3 for immersion or Bq/m^2 for ground plane) or a unit uptake (Bq for inhalation and ingestion). These dosimetric models and the resulting dose coefficients have been developed over many years and are promulgated by international standards organizations (e.g., ICRP), national standards organizations (e.g., NCRP), and federal agencies (e.g., EPA). For this report, the dose and risk coefficients are almost all based on EPA's April 2002[6] Update [FGR-13U] to Federal Guidance Report No.13 [FGR-13]. These coefficients are almost, but not quite, identical to those used by the ICRP:

[6] A supplement was first issued in 2000, but this supplement contained errors in the viewer and was replaced by the April 2002 version. The interactive viewer is entitled "Federal Guidance Report 13 CD Supplement, Cancer Risk Coefficients for Environmental Exposure to Radionuclides" EPA, rev 1 April 2002 and is avaialnble from the Office of Air and Radiation.

> "The age-specific dose coefficients [in FGR13]…were calculated using the biokinetic and dosimetric models used in the calculations of the risk coefficients. These models are consistent with those used by the ICRP in its recent series of publications tabulating dose coefficients for the general public, which is similar ICRP-60, but may be slightly different." (3)

However, for most radionuclides and organs, these differences are negligible, especially considering other uncertainties. These minor differences may be revealed by comparing the documentation for FGR-13 and ICRP-60.

Dose conversion factors are derived using models that represent the physics and biology of the interaction of the human body with radiation or radioactive material. For external exposure the models consider the geometry and physics of the exposure (immersion in air or water, exposure to a contaminated ground plane, exposure to shoreline strips of contamination) coupled with a representation of a standard human body absorbing the radiation. For internal exposure from inhaled or ingested radionuclides, the dose conversion factors are based on models representing the complex interactions of the radionuclide's physical and chemical attributes with human physiology. Once the dose conversion factors are developed, they may be applied to any dose assessment, thereby avoiding the need to repeat the complex modeling for every dose assessment. Conversion of doses to risks of cancer incidence and fatality are based on epidemiological data that relate radiation exposures to the incidence of cancer at various organ sites in exposed individuals and the subsequent mortality among those individuals.

Given the preceding discussion, the simple formula that relates dose to intake, stated in Chapter 9,

$$\text{Dose} = \text{Intake} * \text{Dose Conversion Factor} \qquad (9\text{-}1)$$

may be stated in a more general form:

$$ED_{iae} = I_{ie} \cdot DC_{iaec} \qquad (10\text{-}3)$$

Where,

ED_{iae} = Incremental equivalent dose from radionuclide i for age group a and exposure route e
I_{ie} = Intake of radionuclide i through exposure route e
DC_{iaec} = Dose conversion factor for radionuclide i for age group a exposure route e and inhalation class c inhalation class.

Equation (10-3) recognizes the explicit dependence of the dose conversion factor, DC_{iaec}, on the radionuclide, age of the receptor, exposure route, and inhalation class; however, equation (10-1) still retains the linear relationship between dose and intake. Similar equations can be used to generate risks of cancer incidence and fatality, by replacing the term ED_{iae}, by a cancer incidence term, RI_{iae}, or a cancer fatality term, RF_{iae}; in both cases the conversion factor, DC_{iaec}, must be appropriately adjusted. Doses and risks can be further disaggregated into contributions from specific organs. Intakes, as discussed in Chapter 9, are based on radioactive material inhaled or ingested or direct exposure to external penetrating radiation.

For exposures of persons from inhaling or ingesting radionuclides, the study used the following coefficients from FGR-13U:

- Age-dependent dose coefficients for 23 organs and bodily tissues, plus effective dose based on ICRP-60 weighting factors (see Table 10.2).
- Age-dependent cancer risk coefficients (fatality and incidence) for 15 cancer sites, plus the sum of cancers across all cancer sites.

Table 10-2 lists the organs and bodily tissues considered in the dose coefficients, and the cancer sites considered in the risk coefficients. Table 10-3 lists the age categories considered for the dose and risk coefficients. (Note that the age categories are different for the dose and risk coefficients.)

Table 10-2 Organs, Tissues, and Lung-Compartments, and Cancer Sites, Addressed in Dose and Risk Conversion Factors in the FGR-13 Update

Organs, Tissues and Lung-Compartments Addressed in Dose Conversion Factors			Cancer Sites Addressed in Risk Conversion Factors	
Adrenals	Kidneys	Skin	Esophagus	Breast
Bone Surface	Liver	Spleen	Stomach	Ovary
Brain	Extra-thoracic Region	Testes	Colon	Bladder
Breast	Lung	Thymus	Liver	Kidneys
Stomach Wall	Muscle	Thyroid	Lung	Thyroid
Small Intestine Wall	Ovaries	Uterus	Bone	Leukemia
Upper Lower Intestine Wall	Pancreas	Urinary Bladder Wall	Skin	Residual*
Lower Lower Intestine Wall	Red Bone Marrow	Effective Dose		Total

*Residual cancer sites.

Table 10-3 Age Categories Addressed in Dose and Risk Conversion Factors Presented in the FGR-13 Update

Dose Conversion Factors	Risk Conversion Factors
Infant	0-5 Years
1-Year Old	5-15 Years
5-Year Old	15-25 Years
10-year Old	25-70 Years
15-Year Old	0-110 Years
Adult	

For doses and risks from inhalation, the physical and chemical form of some radionuclides is specified; this is denoted by the subscript “c” in equation (10-1). The radionuclide “class” is important for some radionuclides, because the radionuclide’s chemical and physical form affects the rate at which the radionuclide is removed from the lungs and subsequently migrates elsewhere in the body or is excreted. The study assumed that most radionuclides were particulates assigned to one of three absorption types:

- Type F: Fast dissolution and a high level of absorption to blood.
- Type M: Intermediate rates of dissolution and levels of absorption to blood.
- Type S: Slow dissolution and a low level of absorption to blood.

It was assumed that some radionuclides existed as a gas or vapor, based on the Phase II information regarding releases. The assumptions for the lung absorption types used in this report are listed in Table 10-4 (3), (9).

Table 10-4 Assumptions for Lung Absorption Classes by Element

Element	Absorption Class*	Comments†
Americium (Am)	M	Default absorption type recommended in ICRP-72.
Argon (Ar)	NA	No absorption occurs for noble gases.
Carbon (C)	G	Type G was assumed because it was recommended in FGR-13 for CO_2.
Cesium (Cs)	F	Default absorption type recommended in ICRP-72.
Hydrogen (^3H - tritium)	HT: G HTO: V OBT‡: V	Type G was assumed for tritium released as a gas (HT) in accordance with FGR-13. Type G is also appropriate for tritium released as an organic. Type V is assumed for tritium released as water vapor (HTO) in accordance with FGR-13.
Iodine (I)	G	Iodine was released in several forms. Type G was assumed because it resulted in dose and risk conversion factors between those for a particulate and elemental I.
Plutonium (Pu)	M	Default absorption type recommended in ICRP-72.
Sulfur (S)	V	FGR-13 recommends Type V for sulfur dioxide. (Note that if S is released as a particulate, ICRP-72 recommends Type M.)
Strontium (Sr)	M	Default absorption type recommended in ICRP-72.
Thorium (Th)	S	Default absorption type recommended in ICRP-72.
Uranium (U)	M	Default absorption type recommended in ICRP-72

*F: fast; M: medium; S: slow; G: gas; V: vapor; NA: not applicable.
†Lung absorption classes are not listed for radioactive isotopes of elements released only into surface waters. Although GENII requires that lung absorption class assumptions be input for these isotopes, the assumed values are not used in the dose and risk calculations because inhalation exposure is not assessed for the surface water pathways considered in this report.
‡OBT: organic bound tritium.

For external exposures resulting from (1) immersion in a "cloud" of radionuclides in air, and (2) proximity to a contaminated ground surface, the study used the following coefficients from FGR-13U:

- Adult dose coefficients for 23 organs and bodily tissues, plus effective dose based on ICRP-60 weighting factors (see Table 10-1).
- Age-specific cancer risk coefficients (fatality and incidence) for 15 cancer sites, plus the sum of cancers across all cancer sites.

As noted, FGR-13U provides only adult dose conversion factors for these types of external exposures. The authors of FGR-13 believe that use of adult external dose coefficients for all age groups should normally result in small errors (usually <30%). The FGR-13 authors believe that these errors are likely to be negligible compared to the errors associated with the simplified exposure scenarios assumed to calculate the dose conversion factors (e.g., the phantoms were in constant position in relation to the

radiation source, and shielding was not considered) [FGR-13]. The risk coefficients for these types of external exposures use the same age ranges as those listed in Table 10-3.

For external exposures while swimming in water or while boating, dose and risk coefficients from FGR-12 were used because coefficients for immersion in contaminated water are not included in FGR-13U. These (adult) dose coefficients are provided for fewer organs than those in the FGR-13 update, and the weighting factors used to calculate effective dose equivalent are from ICRP-26 (because they are based on FGR-12) rather than ICRP-60 (see Table 10-1). Risk was estimated by multiplying the calculated doses for water immersion and boating by the following health effects conversion factors:

- Fatality: 0.05 Sv^{-1}
- Incidence: 0.06 Sv^{-1}

Finally, the dose and risk coefficients were grouped into four age groups: 0 to 5 years, 5 to 15 years, 15 to 25 years, and 25 to 70 years. This assumption allowed for better correlation between the doses and risks calculated as a function of age group. Dose and risk conversion factors for these calculations were determined by interpolating between appropriate dose and risk conversion factors obtained from the update to FGR-13 and from FGR-12. The three combined age groups are summarized in Table 10-5. Also listed is the exposure duration used for each age group.

Table 10-5 Exposure Groupings and Corresponding Combined Dose and Risk Factor Age Groups

Age / Gender	Exposure Group [Duration (years)]	Dose and Risk Factor Age Group
<1 male	Infant (male only) [1]	0 – 5
1 – 4 male	Preschool (male only) [4]	0 – 5
5 – 11 male	Schoolage (male only) [7]	5 – 15
12 – 17 male	Teenage (male only) [6]	15 - 25
18 – 70 male	Adult male [varies] *	25 – 70
18 – 70 female	Adult female [varies] *	25 – 70

*The exposure duration of the adult age groups depends on the year that the individual reaches age 18. Exposure duration lasts from the year of the 18th birthday until the end of 1992, when one child would be 38 and the other 29.

10.4 References

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11 POINT ESTIMATE RESULTS

This chapter summarizes the doses and risks calculated for each of the four hypothetical individuals (family members) comprising each of the seven exposure scenarios as described in Chapter 3. Each family consists of:

- An adult female.
- An adult male.
- A male child born in 1955.
- A male child born in 1964.

The chapter is organized into two main sections:

Section 11.1 is an introduction and overview of results. The introduction (Section 11.1.1) summarizes the exposure routes and pathways considered for each exposure scenario. The overview of results (Section 11.1.2) summarizes the range of radiation doses and cancer risks calculated for all hypothetical members of all scenarios, and identifies those exposure pathways and radionuclides that consistently caused the largest doses and cancer risks among the hypothetical family members.

Section 11.2 present radiation doses and cancer risks for each member of each family exposure scenario. It is divided into seven subsections – one for each exposure scenario. Each subsection addresses:

1. Effective dose and cancer risks for each family member, summed over the 39 years covered by this study.
2. Annual effective dose for each family member.
3. Radionuclides that dominated the radiation dose.
4. Effective dose for each family member from external exposure to radiation, and from ingesting and inhaling radionuclides.
5. The principal exposure pathways (e.g., eating contaminated foods) that led to the radiation dose.

Effective doses and cancer risks are presented in two significant figures. This format was chosen because it facilitates comparison of doses and risks that are far apart as well as those that are similar but not identical. Effective doses presented as the percent of the entire effective dose received over 39 years are shown to the nearest 0.1% although the calculations are likely not that accurate. Introduction and Overview of Results

11.1.1 Introduction

Radiation dose in this chapter is presented as effective dose. Effective dose represents the sum of equivalent doses calculated for up to 23 bodily tissues and organs (e.g., lungs, bone, thyroid) as weighted by a set of factors (Chapter 10) that have been recommended by the International Commission on Radiation Protection (ICRP) [ICRP-60]. These weighting factors account for the different sensitivity of different bodily tissues to radiation-induced cancers. Results are generally presented in units of milliSieverts (mSv). A milliSievert is one-one thousandth of a Sievert (Sv), the recommended international unit for radiation dose. We also often present equivalent results in units of millirem (mrem), the radiation dose unit most commonly used in the United States. A millirem is 0.01 milliSieverts[1] The

[1] One Sievert is equal to 100 rems. One milliSievert (1 mSv) = 1/1,000 Sv = 100 millirems (100 mrem). See Appendix D for additional information.

cancer incidence and cancer fatality risks presented in this chapter represent the sum of risks calculated for 14 organs (or cancer sites) of the body (see Chapter 10). Both cancer incidence and fatality risks, as presented here, result solely from exposure to radionuclides released from SRS activities. These risks are in addition to those risks of cancer that the person would have without this radiation exposure. We present cancer incidence and fatality risks in units of percent: For example, a person with a 1% cancer incidence risk would face a one-in-one hundred lifetime risk of developing cancer due to the radiation exposures discussed here.

Exposures, tabulated for 18 exposure pathways in Chapter 9, are used to compute doses and risks by the methods outlined in Chapter 10. Table 11-1[2] summarizes each pathway, provides a shorthand description of each pathway, distinguishes whether the pathway resulted from radionuclides released by SRS into either the air or into surface water, and identifies the exposure route resulting from each exposure pathway.

Table 11-1 Exposure Routes and Pathways for Air and Water Pathways

Exposure Route & Pathway	Shorthand Description	Air Releases	Water Releases
External radiation:			
Immersion in a plume of contaminated air	Air Immersion	X	
Exposure to soil contaminated with radionuclides deposited from the air	Ground Contamination	X	
Exposure to a shoreline contaminated with radionuclides deposited from water	Shoreline		X
Exposure to contaminated water while swimming	Swimming		X
Exposure to contaminated water while boating	Boating		X
Ingestion:			
Leafy vegetable consumption	Leafy Vegetables	X	
Root vegetable consumption	Root Vegetables	X	
Fruit consumption	Fruit	X	
Grain consumption	Grain	X	
Beef consumption*	Beef	X	
Poultry consumption*	Poultry	X	
Milk consumption	Milk	X	
Egg consumption	Eggs	X	
Inadvertent soil consumption	Soil	X	
Fish consumption	Fish		X
Inadvertent ingestion of water while swimming	Inadvertent		X

[2] We present radiation doses and risks for individual receptors as summed over all applicable pathways, as well as radiation doses received by each receptor from each pathway.

Exposure Route & Pathway	Shorthand Description	Air Releases	Water Releases
	Swimming Ingestion		
Inhalation:			
Inhalation of contamination in a plume of air	Air Inhalation	X	
Inhalation of contamination resuspended from soil after deposition from the air	Resuspended Soil	X	

*Beef consumption is a surrogate for consumption of all types of beef, including venison acquired through deer hunting on or near SRS. See Chapter 8 for an explanation of the reasons for this. Poultry consumption is a surrogate for consumptions of chicken and other fowl, including that acquired through bird hunting on or near SRS.

As shown, thirteen of these eighteen exposure pathways are associated with release of radionuclides by SRS into the air (*air pathways*), while five are associated with release into surface water (*water pathways*). Each hypothetical member of each exposure scenario may have received radiation exposures from some or all of these exposure pathways. Members of Rural Family One, Rural Family Two, the Urban/Suburban Family, and the Migrant Worker Family all received radiation exposures only from the air pathways. Members of the Delivery Person Family, the Outdoors Person Family, and the Family Living Near the River all received radiation exposures from the water as well as the air pathways.

11.1.2 Overview of Dose Results

Table 11-2 presents the effective dose received by each member of each hypothetical exposure scenario, as summed over the 39 years covered by this study. Doses for each scenario are presented for all air pathways; for all water pathways, and for air and water pathways combined.

The smallest radiation dose from all air pathways was received by the Child Born in 1964 of Rural Family One, while the largest radiation doses from all air pathways was received by the Child Born in 1955 of the Outdoors Person Family. The smallest radiation dose from all water pathways was received by the Child Born in 1955 of the Outdoors Person Family, while the largest radiation dose from all water pathways was received by the two adults of the Delivery Person Family. Considering combined air and water pathways, the smallest dose by any member of any exposure scenario was received by the Child Born in 1964 of the Rural Family Scenario, while the largest dose was received by the Child Born in 1955 of the Outdoors Person Family.

For any exposure scenario, most of the dose (i.e. from about 50 percent to more than 90 percent) received through all air pathways by the two adults and the Child Born in 1955 came from drinking milk and eating beef containing ^{131}I. Doses from tritium and ^{41}Ar were also important for these three family members. Most doses from tritium came from drinking milk and eating beef containing this radionuclide, while most doses from ^{41}Ar came from the air immersion pathway. ^{131}I, tritium, and ^{41}Ar were mostly released into the air during the very early days of SRS operation. In fact, about 99% of all ^{131}I released over 39 years had been released by the end of 1961.

Table 11-2 39-Year Effective Dose (mSv) for Each Member of Each Scenario

Scenario	Pathways	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Rural Family One	Air	0.30	0.42	1.6	0.072
	Water	___	___	___	_____
	All	0.30	0.42	1.6	0.072
Rural Family Two	Air	0.70	0.97	3.8	0.14
	Water	___	___	___	___
	All	0.70	0.97	3.8	0.14
Urban/Suburban Family	Air	0.33	0.73	2.7	0.11
	Water	___	____	___	___
	All	0.33	0.73	2.7	0.11
Migrant Worker Family	Air	0.45	0.62	2.2	0.083
	Water	____	____	___	____
	All	0.45	0.62	2.2	0.083
Delivery Person Family	Air	0.40	0.57	2.1	0.12
	Water	5.7	5.7	3.1	2.0
	All	6.1	6.3	5.2	2.1
Outdoors Person Family	Air	1.6	2.5	8.3	0.36
	Water	1.5	1.7	1.2	1.5
	All	3.0	4.2	9.4	1.8
Near Water Family	Air	0.31	0.42	1.7	0.088
	Water	1.8	1.8	1.4	1.7
	All	2.1	2.2	3.1	1.8

Small discrepancies are caused by rounding errors.

The Child Born in 1964 was born after the largest releases into the air from SRS. For this reason, his doses received through the air pathways were consistently smaller than those received by any other member of any family exposure scenario. The Child Born in 1964 received most of his dose from the air pathways from ingestion or inhalation of tritium, followed by external exposure to ^{41}Ar. The two ingestion pathways of most importance for this family member were the milk and beef ingestion pathways. ^{131}I was consistently the third most important radionuclide for this family member, mainly from eating milk and beef.

The dose received by any family member from all air pathways was highly dependent on that family member's assumed exposure locations, particularly the locations where the family member obtained food, lived, or worked. For example, the dose received by the Adult Female from all air pathways ranged across all seven scenarios from 0.30 to 1.6 mSv, or a factor of about five. This range in dose was notably larger than the range in dose that could be accounted for considering the differences in activities performed by the Adult Female in each scenario (e.g., a larger fraction of her foods was contaminated in some scenarios than in others). Radionuclide concentrations in the exposure locations depended on the meteorological parameters that influenced calculations of radionuclide dispersion in air. Among these parameters were

the distances from the release points and the distributions of average wind speeds and atmospheric stability conditions.

Almost the entire dose received by any family member from all water pathways came from eating fish containing radionuclides. The three radionuclides that contributed the most to these doses were ^{137}Cs, ^{32}P, and ^{90}Sr. The relative importance of any radionuclide depended on whether the fish came from the Savannah River or from Lower Three Runs Creek.

11.2 Detailed Results for Each Scenario

11.2.1 Rural Family One

This hypothetical family lived in Girard, GA, and spent much of their work, home activities, and recreation time outdoors (see Figure 11-1). The Adult Male was a farmer, and the Adult Female worked at home. The family hunted, fished, and swam around the Girard area and in the nearby area of Briar Creek. The family did no boating. The children attended grade school in Girard and high school in Waynesboro, GA. Otherwise, the children stayed in Girard and became farmers when they grew up.

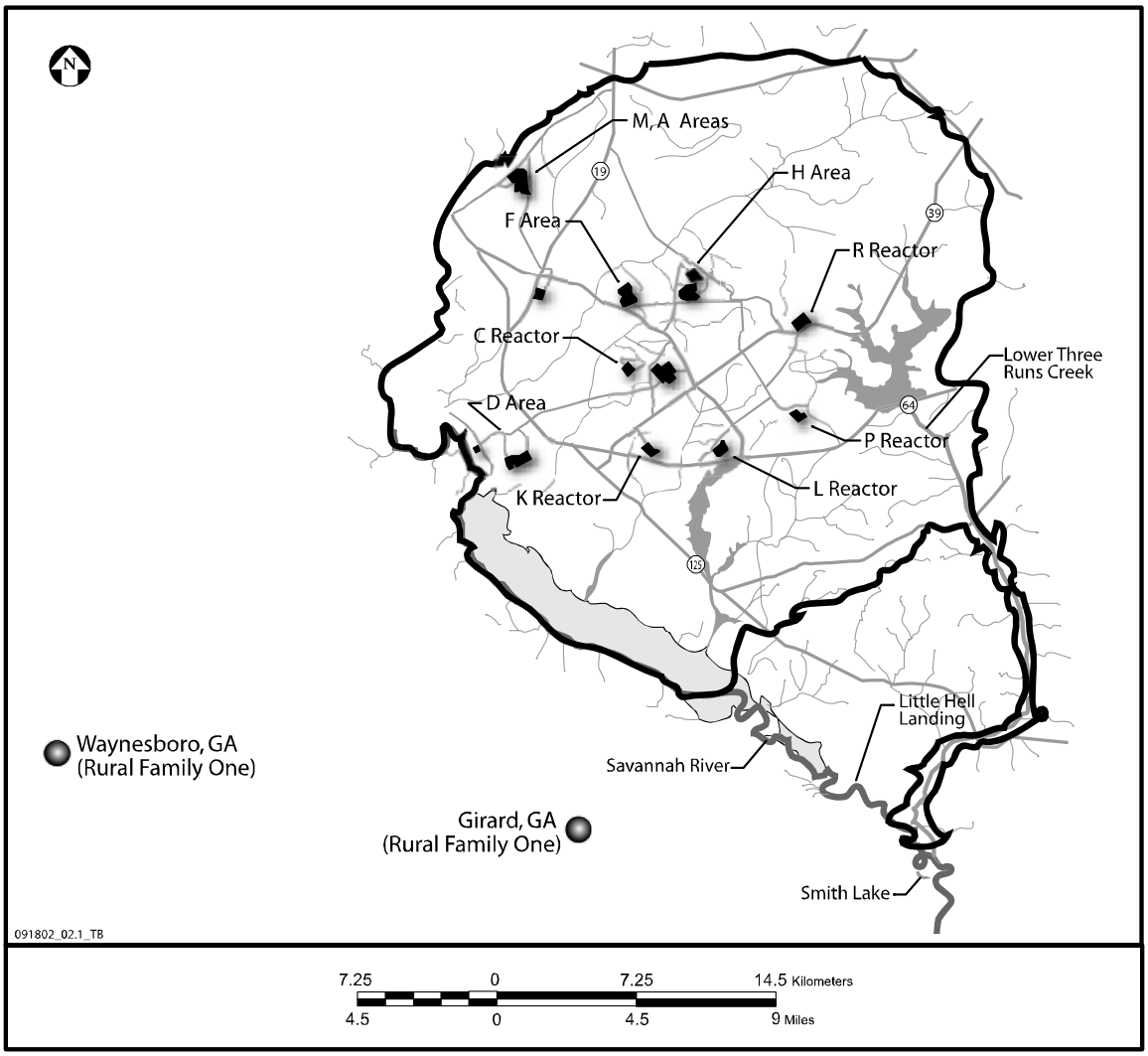

Figure 11-1 Exposure Locations for Rural Family One

All the family's milk and eggs came from cows and hens located in Girard. The fish eaten by the family was caught in Briar Creek or other nearby locations. Because Briar Creek is not located hydrologically downstream from SRS, none of the fish eaten by the family were affected by SRS release of radionuclides to surface water.

During the 1950s, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remaining half came from other sources such as stores in Girard. Half of this food was locally grown or produced, and the remaining half came from sources away from the SRS area. Beginning in 1960, only 25% of their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75% came from other sources such as stores. Half of this remaining food was grown or produced in Girard, and half came from sources outside the SRS area.[3] All of the locally-produced grain eaten by the family was corn.[4]

Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases.

11.2.1.1 Effective Dose and Total Risks

Table 11-3 lists the effective dose and cancer risks for each member of Rural Family One, as summed over the 39 years covered in this study. All of these doses and risks came from exposure to radionuclides that had been released by SRS into the air.

Table 11-3 39-Year Effective Dose and Cancer Risks for Rural Family One

Dose or Risk	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Effective Dose (mSv)	0.30	0.42	1.6	0.072
Cancer Incidence Risk (%)	0.00083	0.0011	0.016	0.0011
Cancer Fatality Risk (%)	0.00030	0.00038	0.0025	0.00069

The Child Born in 1955 received the largest dose and risks. He received an effective dose of 1.6 mSv (160 mrem), a cancer incidence risk of 0.016%, and a cancer fatality risk of 0.0025%. The Child Born in 1964 received the smallest dose and risks. The effective dose for the Child Born in 1964 was 4% of that for the Child Born in 1955.

Since dose is calculated in a risk-weighted fashion (effective dose), one would expect that the ratio of risk to dose would be a constant. For the adults, this seems to be so. However, as explained in Chapter 10, especially Section 10.2.2 and 10.3, internal conversion coefficients for dose and risk were considered to be age dependent. As a consequence, for the children the ratio of risk to dose is higher, which accounts for (1) the greater dose for a unit intake at younger ages and (2) the higher risk from childhood exposures, related partly to the longer latency period. However, the ratio of risk to dose for the children depends in a complex fashion on the time history of exposure and the particular radionuclides causing the exposure.

[3] It was assumed that locally-grown food was produced at the same location in Girard as the family residence. It was also assumed that all locally-grown vegetables and fruit, whether grown on the family farm or obtained by Girard stores from local farms, contained radionuclides from SRS operations. Similarly, it was assumed that all locally-produced beef and poultry was raised in Girard, and therefore contained radionuclides from SRS operations.

[4] This assumption was made for all receptors and scenarios. As discussed in Appendix F, although individuals in the SRS vicinity would have eaten grain products such as breads, pasta, or flours, almost all such grain products was likely grown or produced out of the SRS vicinity and was therefore unaffected by SRS operations. But individuals in the SRS vicinity could plausibly have eaten locally-grown corn. This could have occurred for persons living in a suburban as well as a rural environment. Therefore, corn was treated as a grain surrogate for purposes of the dose reconstruction assessment.

11.2.1.2 Effective Dose by Year

Figure 11-2 shows the percent of the entire 39-year effective dose received each year by each family member.[5] Figure 11-3 shows the annual dose received by each family member from 1954 through 1992. Note that the vertical axis (y-axis) of this figure is in units of Sieverts (rather than milliSieverts) and that its scale is logarithmic. A logarithmic scale is used because the annual doses range by a factor of more than 1000.[6]

Table 11-4 combines the information in these two figures. It lists the percent of the entire 39-year effective dose received each year by each family member, as well as their annual dose.

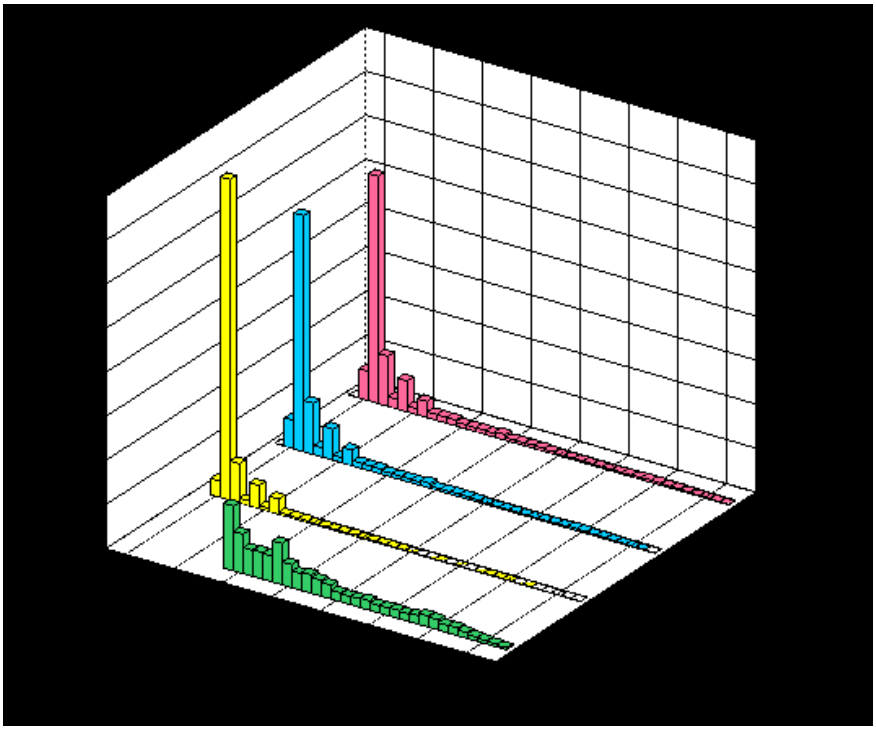

Figure 11-2 Percent of 39-Year Effective Dose by Year for Rural Family One

[5] Graphs and tables showing cancer incidence and fatality risks by year are available Appendix I.

[6] Each of the units on the scale of the vertical axis is ten times as large or as small as the next unit. As shown in Figure 11.2.1.3, for example, the Child Born in 1955 received an effective dose of 0.000058 Sv (0.058 mSv) in 1955 and an effective dose of 0.0012 Sv (1.2 mSv) in 1956. The dose received in 1956 was 21 times larger than the dose received in 1955.

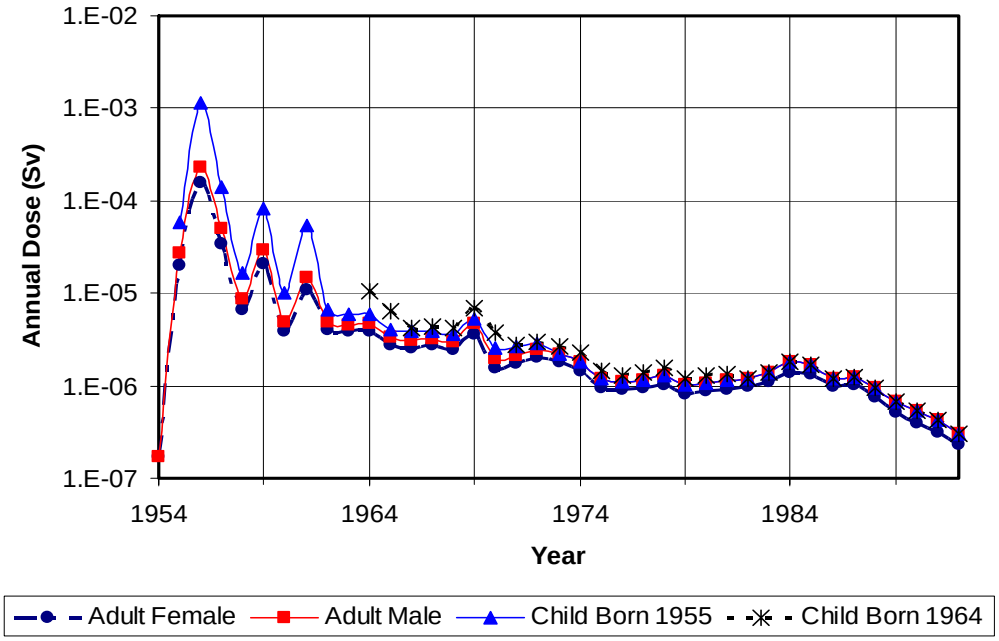

Figure 11-3 Annual Effective Dose (Sv) for Rural Family One

Table 11-4 Annual Effective Dose (mSv) for Rural Family One

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	Dose	%	Dose	%	Dose	%	Dose	%
1954	$1.7x10^{-04}$	0.1	$1.7x10^{-04}$	<0.1				
1955	0.020	6.6	0.027	6.5	0.058	3.6		
1956	0.16	51.6	0.23	53.6	1.2	72.8		
1957	0.034	11.3	0.049	11.6	0.14	8.9		
1958	0.0066	2.2	0.0086	2.0	0.017	1.1		
1959	0.021	7.0	0.030	7.0	0.082	5.2		
1960	0.0039	1.3	0.0048	1.1	0.010	0.6		
1961	0.011	3.6	0.015	3.5	0.055	3.4		
1962	0.0040	1.3	0.0048	1.1	0.0066	0.4		
1963	0.0038	1.3	0.0046	1.1	0.0059	0.4		
1964	0.0039	1.3	0.0048	1.1	0.0059	0.4	0.011	14.7
1965	0.0027	0.9	0.0033	0.8	0.0040	0.3	0.0064	8.9
1966	0.0026	0.9	0.0031	0.7	0.0039	0.2	0.0043	5.9
1967	0.0027	0.9	0.0032	0.8	0.0038	0.2	0.0044	6.1
1968	0.0024	0.8	0.0030	0.7	0.0036	0.2	0.0042	5.9
1969	0.0036	1.2	0.0047	1.1	0.0053	0.3	0.0068	9.4
1970	0.0016	0.5	0.0020	0.5	0.0025	0.2	0.0038	5.2
1971	0.0017	0.6	0.0021	0.5	0.0026	0.2	0.0027	3.8
1972	0.0020	0.7	0.0025	0.6	0.0029	0.2	0.0030	4.2
1973	0.0018	0.6	0.0022	0.5	0.0022	0.1	0.0026	3.6

Year	Adult Female Dose	%	Adult Male Dose	%	Child Born in 1955 Dose	%	Child Born in 1964 Dose	%
1974	0.0015	0.5	0.0018	0.4	0.0018	0.1	0.0022	3.1
1975	9.4×10^{-04}	0.3	0.0012	0.3	0.0012	0.1	0.0015	2.0
1976	9.1×10^{-04}	0.3	0.0011	0.3	0.0011	0.1	0.0013	1.8
1977	9.4×10^{-04}	0.3	0.0012	0.3	0.0012	0.1	0.0014	1.9
1978	0.0010	0.3	0.0013	0.3	0.0013	0.1	0.0015	2.1
1979	8.1×10^{-04}	0.3	0.0010	0.2	0.0010	0.1	0.0012	1.7
1980	8.7×10^{-04}	0.3	0.0011	0.3	0.0011	0.1	0.0013	1.8
1981	9.1×10^{-04}	0.3	0.0011	0.3	0.0011	0.1	0.0014	1.9
1982	9.7×10^{-04}	0.3	0.0012	0.3	0.0012	0.1	0.0012	1.7
1983	0.0011	0.4	0.0014	0.3	0.0014	0.1	0.0014	2.0
1984	0.0014	0.5	0.0018	0.4	0.0018	0.1	0.0018	2.5
1985	0.0013	0.4	0.0017	0.4	0.0017	0.1	0.0017	2.4
1986	9.9×10^{-04}	0.3	0.0012	0.3	0.0012	0.1	0.0012	1.7
1987	0.0010	0.3	0.0013	0.3	0.0013	0.1	0.0013	1.7
1988	7.4×10^{-04}	0.2	9.5×10^{-04}	0.2	9.5×10^{-04}	0.1	9.5×10^{-04}	1.3
1989	5.2×10^{-04}	0.2	6.8×10^{-04}	0.2	6.8×10^{-04}	<0.1	6.8×10^{-04}	0.9
1990	4.0×10^{-04}	0.1	5.3×10^{-04}	0.1	5.3×10^{-04}	<0.1	5.3×10^{-04}	0.7
1991	3.2×10^{-04}	0.1	4.2×10^{-04}	0.1	4.2×10^{-04}	<0.1	4.2×10^{-04}	0.6
1992	2.3×10^{-04}	0.1	3.1×10^{-04}	0.1	3.1×10^{-04}	<0.1	3.1×10^{-04}	0.4
Total	0.30	100	0.42	100	1.6	100	0.072	100

Most of the dose was received during the first years of site operation. In 1956 the Child Born in 1955 received 1.2 mSv (120 mrem), or 73% of his entire dose, the Adult Female received 0.16 mSv (16 mrem), or 52% of her entire dose, and the Adult Male received 0.23 mSv (23 mrem), or 54% of his entire dose. Doses received during 1955, 1957, 1959, and 1961 were also relatively large. By the end of 1961, all of these three family members had received at least 84% of their entire radiation dose.

The Child Born in 1964 received his largest annual dose in 1964, when he received 0.011 mSv (1.1 mrem) or 15% of his entire dose. It represented about 1% of the largest annual dose received by the Child Born in 1955.

After 1961, the annual dose received by the family members gradually decreased from roughly 0.004 - 0.006 mSv per year to roughly 0.0003 mSv per year. This point is shown in Figure 11-3. When each of the children reached age 18 (in 1973 and 1982, respectively), their annual doses equaled the Adult Male's. This occurred because their radiation exposures were modeled to be the same as the Adult Male's. Annual doses for the Adult Female were always smaller than those for the Adult Male because she always ate less food and inhaled less air.

Figure 11-4 lists the radionuclides that caused the largest doses over 39 years for each family member.

The two adults and the Child Born in 1955 were exposed to largely the same quantities and distributions of radionuclides.[7] ^{131}I caused radiation doses mainly from eating beef and milk. It was also a major

[7] Although the two adults received radiation doses during the year 1954, the Child Born in 1955 did not. But because the quantities of radionuclides discharged into the air were small compared to following years, the two adults and the Child Born in 1955 were each affected by nearly the same radionuclide source term.

contributor to inhalation doses and a secondary contributor to doses from external radiation. Tritium caused radiation doses from ingestion and inhalation. ^{41}Ar was the largest contributor to doses from external radiation, while ^{239}Pu (along with ^{131}I) was a major contributor to doses from inhalation. ^{14}C caused doses mainly through ingestion.

The Child Born in 1964 did not experience the very large releases of ^{131}I that occurred in the 1950s and early 1960s. Hence, ^{131}I dropped to third in order of importance for this child. Tritium accounted for most of his dose, primarily through ingestion and inhalation. ^{131}I was a secondary contributor to ingestion dose, followed by ^{14}C. ^{41}Ar caused nearly his entire external radiation dose. ^{238}Pu was an important contributor to inhalation dose.

Most of the radiation dose received by this family came from eating food containing radionuclides (Figure 11-5). Ingestion contributed from 70 to 93 percent of the dose. External exposure to radiation contributed from 2 to17 percent of the dose. Inhalation contributed from 5 to 14 percent of the dose.

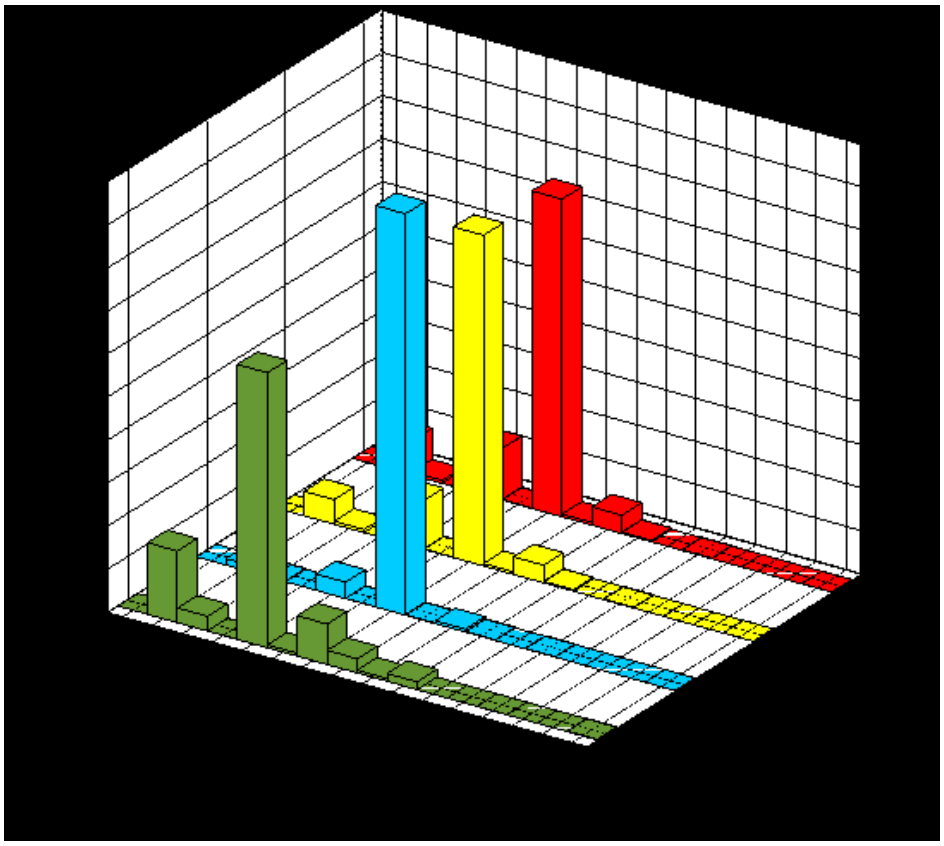

Figure 11-4 Percent of 39-Year Effective Dose by Dominant Isotopes for Rural Family One

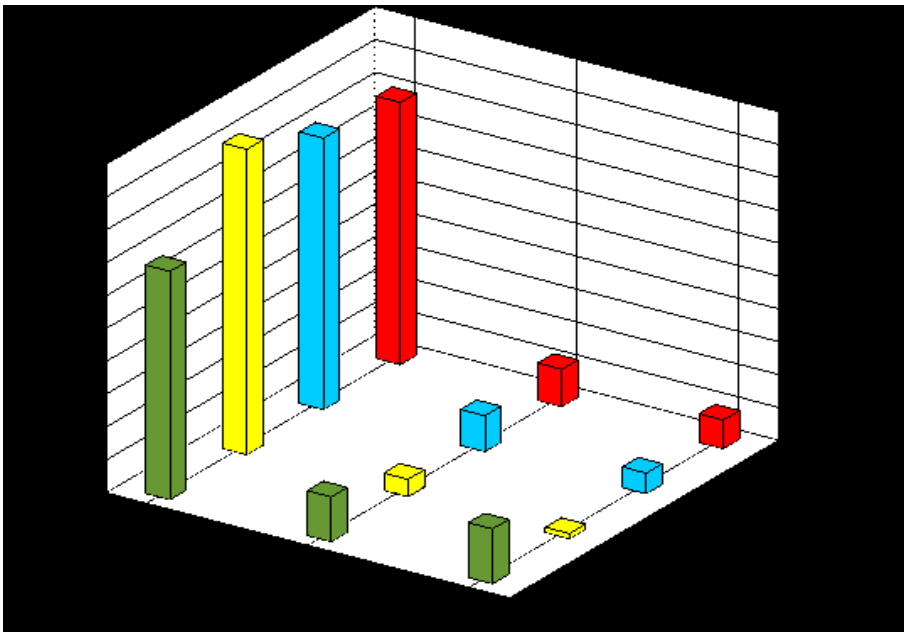

Figure 11-5 Percent of 39-Year Effective Dose by Exposure Route for Rural Family One

Compared to other family members, the Child Born in 1964 received a smaller dose from ingestion and a larger dose from external exposure to radiation and from inhalation. Again, this resulted from his missing the large releases of iodine and other radionuclides during the 1950s and early 1960s.

Table 11-5 lists the effective dose received over 39 years by each family member through each exposure pathway. Figure 11-6 illustrates the percent of effective dose. Tables of effective dose by radionuclide for each route and pathway are provided in Appendix K.

Family members received most of their dose from eating beef and milk. At least 50 percent of the dose received by the two adults came from eating beef, while 15 to 16 percent of their dose came from drinking milk. The Child Born in 1955 received most of his dose from drinking milk (44%) and from eating beef (43%). Beef and milk pathways contributed 51% of the dose received by the Child Born in 1964.

The next largest doses were generally from eating fruits and vegetables – i.e., from 6 to 15 percent of the entire dose over 39 years. Doses from eating grain, poultry, and eggs ranged from 0.4 to 4 percent of the entire dose. Except for the Child Born in 1964, eggs contributed less than 1% of the entire dose.

Table 11-5 Year Effective Dose (mSv) by Exposure Pathway for Rural Family One

		Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Route	**Pathway**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
External	Air Immersion	0.024	8.0	0.024	5.7	0.024	1.5	0.012	16.6
	Ground Contamina-tion	0.0024	0.8	0.0025	0.6	0.0024	0.1	$9.3x10^{-5}$	0.1
Ingestion	Beef	0.15	50.7	0.24	57.1	0.69	43.2	0.011	15.3
	Eggs	0.0014	0.5	0.0023	0.6	0.0021	0.1	0.0014	2.0
	Fruit	0.011	3.6	0.0105	2.5	0.043	2.7	0.0054	7.5
	Grain	0.0011	0.4	0.0013	0.3	0.0036	0.2	$6.3x10^{-4}$	0.9
	Leafy Vegetables	0.018	5.9	0.018	4.2	0.030	1.9	$9.7x10^{-4}$	1.3
	Milk	0.049	16.1	0.065	15.3	0.70	43.9	0.026	35.4
	Poultry	0.0010	0.3	0.0012	0.3	0.0013	0.1	$8.1x10^{-4}$	1.1
	Root Vegetables	0.0073	2.4	0.010	2.4	0.014	0.9	0.0044	6.1
	Soil*	$4.9x10^{-7}$	<0.1	$4.9x10^{-7}$	<0.1	$7.4x10^{-6}$	<0.1	$8.1x10^{-8}$	<0.1
Inhalation	Air Inhalation	0.031	10.1	0.041	9.7	0.082	5.1	0.0091	12.6
	Resuspended Soil	0.0040	1.3	0.0054	1.3	0.0037	0.2	$7.9x10^{-4}$	1.1
Total		0.30	100	0.42	100	1.59	100	0.0721	100

*Doses from the soil ingestion pathway were no more than 0.0005% of any family member's entire 39-year dose.

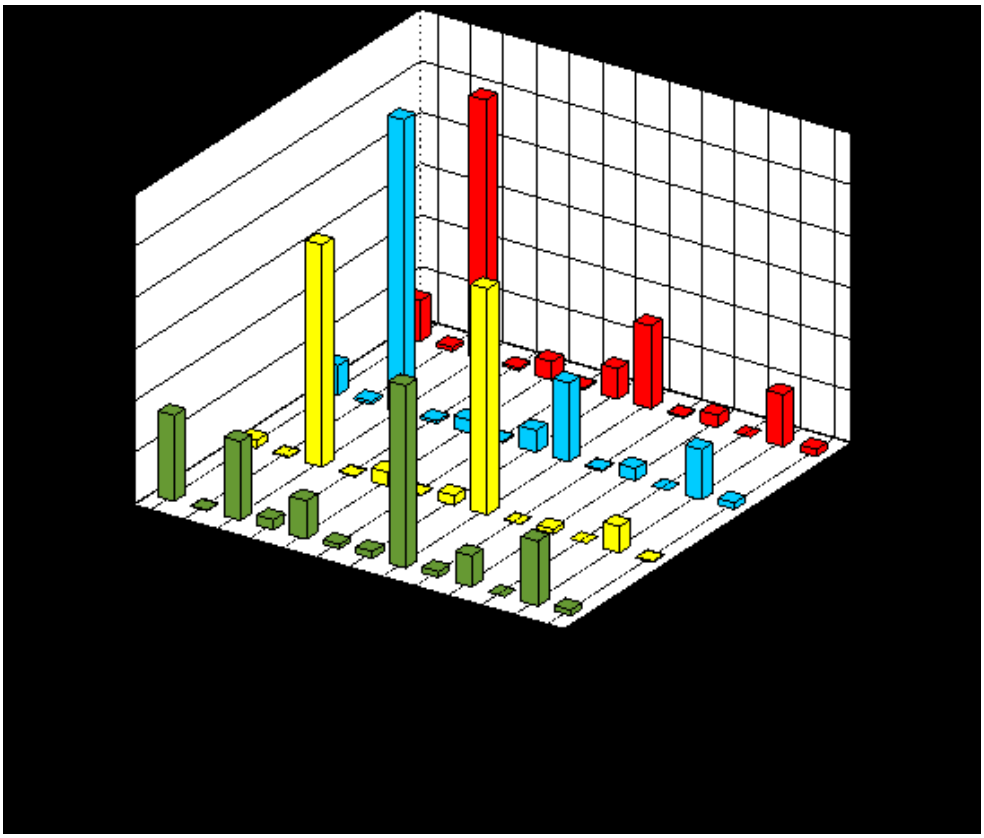

Figure 11-6 Percent of 39-Year Effective Dose by Exposure Pathway for Rural Family One

Differences in doses for the two adults arose because of differences in their eating patterns. For example, the Adult Male and Adult Female each ate the same quantities of leafy vegetables, and each received the same radiation dose from this pathway. But the Adult Male ate 1.6 times as much beef as the Adult Female (see Appendix F), and thus received 1.6 times the dose from this pathway.

The Child Born in 1955 received a larger ingestion dose than did the two adults, especially from drinking milk. His dose from drinking milk was ten times larger than the doses received by the two adults. His doses from most of the other pathways were also somewhat larger. Differences came primarily from changes, as the Child Born in 1955 aged, in his annual rates of eating foods, and, while growing from a child to an adult, his larger effective dose per quantity of radionuclide ingested (see Appendix D).

The Child Born in 1964 received a smaller ingestion dose than did any of the other family members. The distribution of dose among ingestion pathways was also different. The ingestion dose for the Child Born in 1964 was mostly caused by drinking milk and by eating beef containing tritium (see Appendix K).

Of the two external exposure pathways, at least ten times as much dose was received from exposure to radionuclides in the air than from radionuclides that had been deposited on soil or other surfaces.

External doses from air immersion were slightly larger for the two adults than for the Child Born in 1955. Because external radiation doses were determined as if all family members were always adults,[8] the small

[8] External radiation dose coefficients are given in [FGR-13U] only for adults, an approximation that the authors of [FGR-13U] concluded would result in relatively small errors. Consequently, doses from external radiation sources were calculated as if all family members were always adults (see Appendix D).

difference in dose between the two adults and this child resulted from: (1) differences in annual levels of exposure during the years the child attended high school in Waynesboro (the two adults always stayed in Girard); and (2) the additional year of radiation exposure (1954) experienced by the two adults.

For the two adults and the Child Born in 1955, the small differences in doses from external exposure to contaminated ground surfaces were largely caused by differences in the fractions of their time spent indoors and outdoors. Structures provided radiation shielding against exposures from contaminated ground surfaces. Because the Adult Male spent more time outdoors than the Adult Female, he received larger doses. But the Child Born in 1955 spent more time inside in his early years than he did after he grew (see Appendix D). The outcome of these competing influences was that his dose was slightly larger than that for the Adult Female and slightly smaller than that for the Adult Male

Doses from inhalation pathways resulted from: (1) breathing radionuclides that were in the air before being deposited on the ground, and (2) breathing radionuclides that had been resuspended from soil after being deposited on the ground. Clearly most inhalation doses resulted from the first pathway. Only 4 to 12 percent of all inhalation doses came from inhalation of radioactive particles after they had been resuspended from soil.

- For the air inhalation pathway, the Adult Male received a somewhat larger dose than did the Adult Female because he had a larger breathing capacity (see Appendix E). However, the Child Born in 1955 received about twice as much dose as the two adults. This resulted from two competing influences: The breathing rate of the Child Born in 1955 was small as an infant but increased as he grew to manhood; conversely, the dose received per unit quantity of radionuclide inhaled was generally larger during his earlier years than during his later years.[9]

- For the soil resuspension pathway, the inhalation doses for the Adult Male were again larger than those for the Adult Female. However, inhalation doses for the Child Born in 1955 were smaller than those for the two adults. This pattern is different than that seen for the air inhalation pathway. This occurred because the quantities and distributions of radionuclides affecting these individuals were different for this pathway than for the air inhalation pathway, in addition to competing influences such as those described above.[10]

11.2.2 Rural Family Two

This hypothetical family was similar to Rural Family One, except that this family lived in Williston, SC, instead of Girard, GA (Figure 11-7). They spent much of their work, home activities, and recreation time outdoors. The Adult Male was a farmer and the Adult Female worked at home. The family hunted, fished, and swam in the Williston area. This family did no boating. The children attended grade and high school in Williston. When they grew up, the children became farmers, adopting the same activities as did their adult male parent.

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[9] From [FGR-13U], for example, the effective dose coefficients for ^{131}I inhaled as a vapor are as follows in units of Sv per Bq inhaled: Infant (1.30×10^{-7}), 1-Year-Old (1.27×10^{-7}), 5-Year-Old ($7\ 34 \times 10^{-8}$); 10-Year-Old (3.71×10^{-8}), 15-Year-Old (2.43×10^{-8}), and Adult (1.54×10^{-8}). Doses per unit quantity of ^{131}I inhaled decrease for each successive age group.

[10] The Child Born in 1955 received a larger dose than the two adults for the air inhalation pathway but a smaller dose than the two adults for the resuspension pathway. This probably occurred because the family members were exposed to different quantities and distributions of radionuclides for the air inhalation pathway than for the resuspension pathway. For the air inhalation pathway, radionuclides were inhaled from a plume of radionuclides in air surrounding each family member. But radionuclides inhaled due to the resuspension pathway had to be first deposited on the soil and then dispersed back into the air due to wind or activities such as farming that disturbed the soil. Different radionuclides were deposited onto soil at different rates depending on their physical form (e.g., whether they existed as gasses or particulates). In addition, the concentrations of radionuclides in air from resuspension of radioactive particles from soil were 100 times smaller in Waynesboro, where the children attended high school, than in Girard (see Chapter 9).

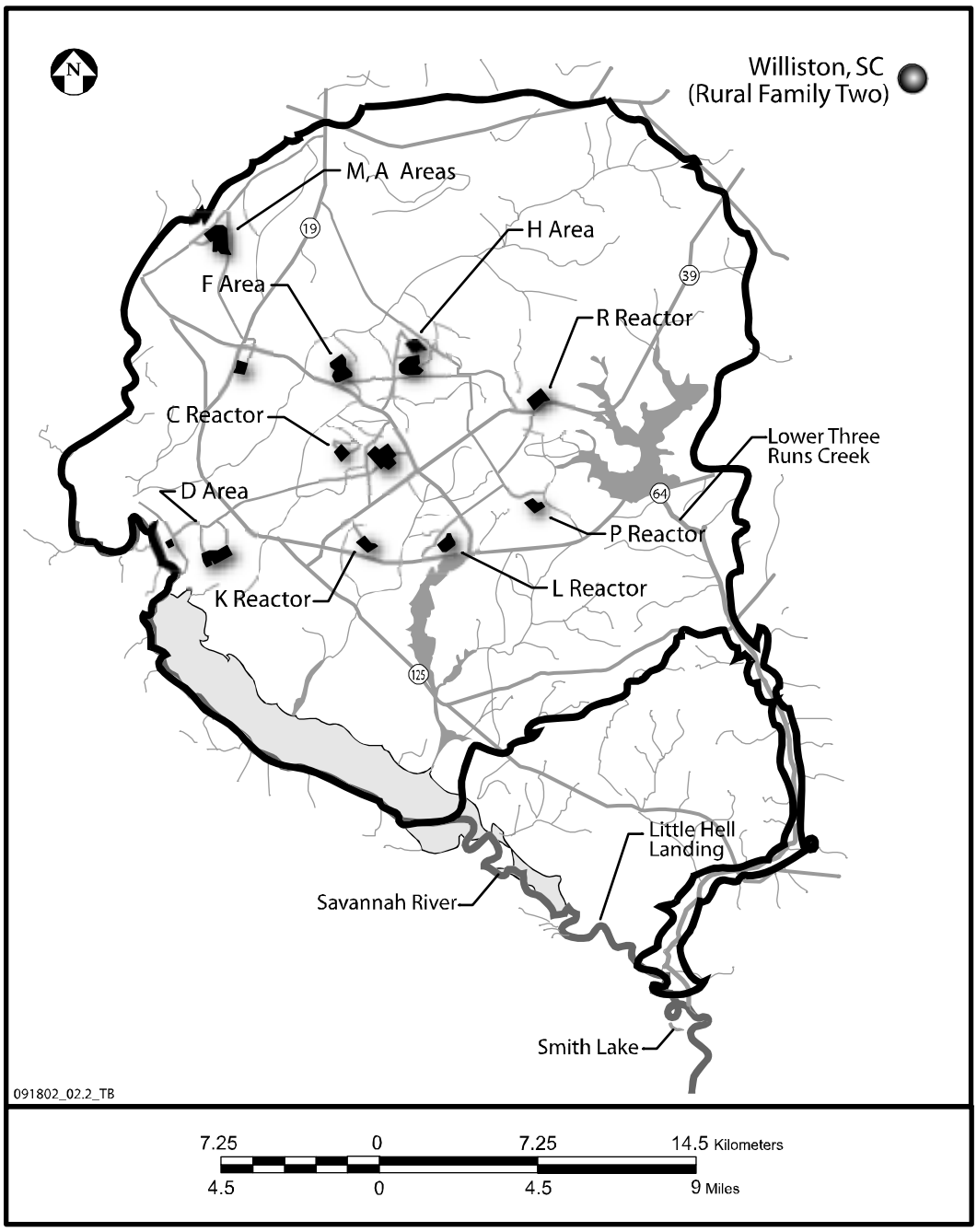

Figure 11-7 Exposure Location for Rural Family Two

All of the family's milk and eggs came from cows and hens located in Williston (on the family farm or nearby). All the fish eaten by the family was caught in streams and ponds in or near Williston. Because these streams and ponds are not located hydrologically downstream from SRS, none of the fish eaten by the family were affected by SRS release of radionuclides to surface water.

During the 1950s, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remaining half came from other sources such as stores in Williston. Half of this remaining food (i.e., food not grown or raised on the family farm) was grown or produced in Williston and the other half came from outside the SRS area. Beginning in 1960, only 25% of

their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75% was obtained from other sources such as stores in Williston. Half of this remaining food was locally-grown or produced, and half came from outside the SRS area.

All locally-grown grain eaten by the family was corn. Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases.

11.2.2.1 Effective Dose and Total Risks

Table 11-6 lists the effective dose and cancer risks for each member of Rural Family Two over 39 years of SRS operation. All doses and risks resulted from exposure to radionuclides that had been released into the air.

Table 11-6 39-Year Effective Dose and Cancer Risks for Rural Family Two

Dose or Risk	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Effective Dose (mSv)	0.70	0.97	3.8	0.14
Cancer Incidence Risk (%)	0.0019	0.0025	0.037	0.0021
Cancer Fatality Risk (%)	0.00064	0.00080	0.0056	0.0013

Doses and risks were about double those for Rural Family One (Table 11-3), which mainly resulted from the different exposure location (Williston vs. Girard and Waynesboro). The Child Born in 1955 received the largest dose and risks. He received an effective dose over 39 years of 3.8 mSv (380 mrem), a cancer incidence risk of 0.037%, and a cancer fatality risk of 0.0056%. The Child Born in 1964 again received the smallest dose and risks. The dose for the Child Born in 1964 was about 4% of that for the Child Born in 1955.

11.2.2.2 Effective Dose by Year

Figure 11-8 shows the percent of the entire 39-year effective dose received each year by each family member, while Figure 11-9 shows the annual effective dose (in units of Sieverts) received by each family member. Again, the vertical axis (y-axis) of Figure 11-9 is in logarithmic scale. The shapes of each figure are similar to corresponding figures for Rural Family One (Figure 11-2 and Figure 11-3). More detailed information is contained in Table 11-7 which lists the percent of the entire 39-year effective dose received each year by each family member, as well as their annual dose in milliSieverts.

Most of the dose was received during the early days of site operation. In 1956, the Child Born in 1955 received 2.8 mSv (280 mrem), or 74% of his entire dose over 39 years. During this year the Adult Female received 0.37 mSv (37 mrem), or 54% of her entire dose, and the Adult Male received 0.54 mSv (54 mrem), or 56% of his entire dose. The Child Born in 1964 received his largest dose in 1964 when he received 0.020 mSv (2 mrem), or 15% of his entire dose over 39 years.

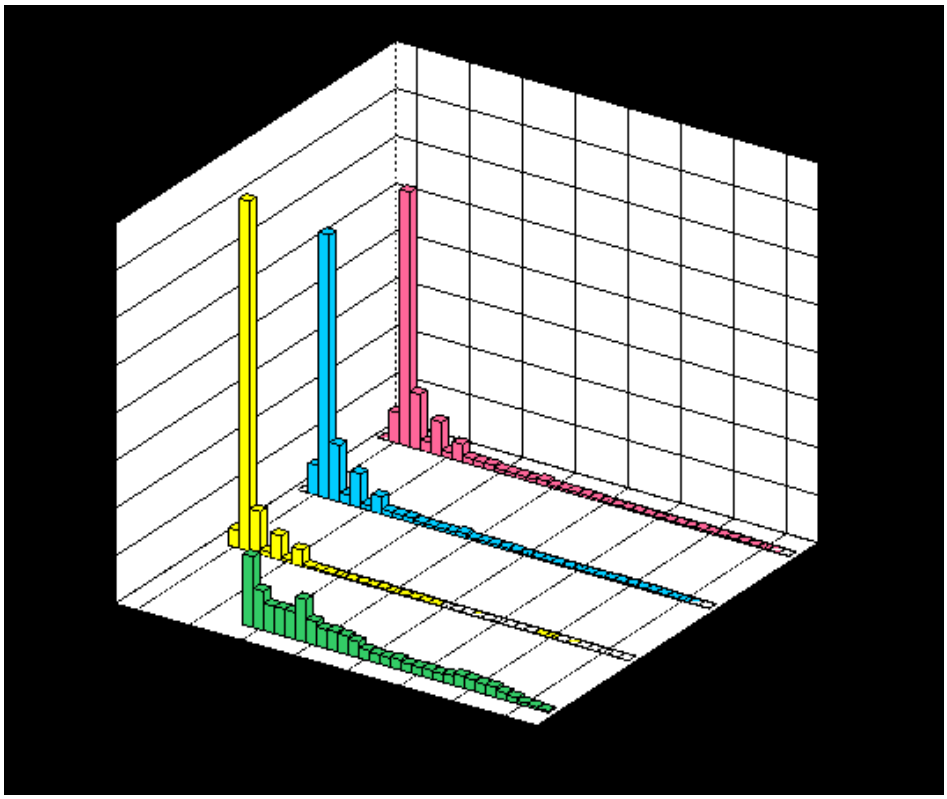

Figure 11-8 Percent of 39-Year Effective Dose by Year for Rural Family Two

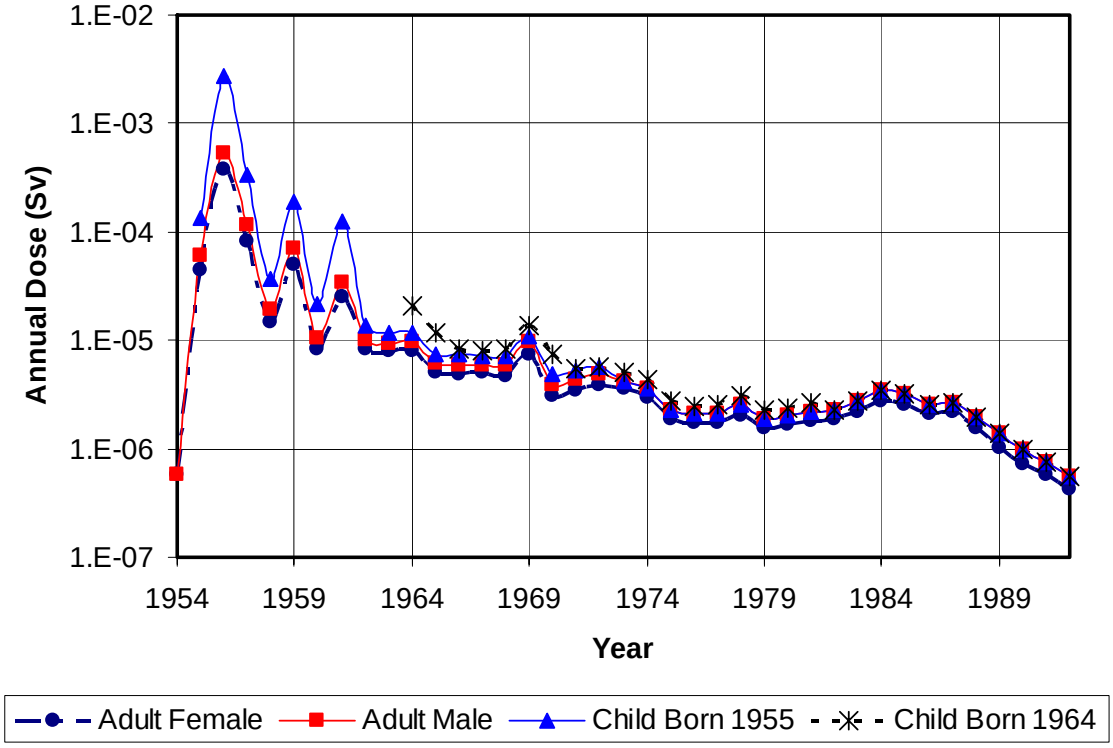

Figure 11-9 Annual Effective Dose (Sv) for Rural Family Two

Table 11-7 Annual Effective Dose (mSv) for Rural Family Two

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
1954	$5.7x10^{-04}$	0.1	$5.8x10^{-04}$	0.1				
1955	0.045	6.5	0.061	6.3	0.14	3.6		
1956	0.37	53.6	0.54	55.5	2.8	73.7		
1957	0.081	11.6	0.12	11.9	0.33	8.9		
1958	0.015	2.1	0.019	2.0	0.037	1.0		
1959	0.049	7.1	0.070	7.1	0.19	5.1		
1960	0.0084	1.2	0.010	1.1	0.022	0.6		
1961	0.025	3.6	0.035	3.6	0.13	3.4		
1962	0.0084	1.2	0.010	1.0	0.014	0.4		
1963	0.0079	1.1	0.0094	1.0	0.012	0.3		
1964	0.0080	1.1	0.0096	1.0	0.012	0.3	0.025	14.9
1965	0.0051	0.7	0.0061	0.6	0.0074	0.2	0.014	8.2
1966	0.0049	0.7	0.0059	0.6	0.0073	0.2	0.0094	5.7
1967	0.0051	0.7	0.0060	0.6	0.0071	0.2	0.0095	5.8
1968	0.0048	0.7	0.0058	0.6	0.0071	0.2	0.0094	5.7
1969	0.0075	1.1	0.0097	1.0	0.011	0.3	0.015	9.0
1970	0.0031	0.4	0.0038	0.4	0.0049	0.1	0.0083	5.0
1971	0.0035	0.5	0.0043	0.4	0.0053	0.1	0.0065	4.0
1972	0.0039	0.6	0.0048	0.5	0.0057	0.2	0.0068	4.1
1973	0.0036	0.5	0.0043	0.4	0.0043	0.1	0.0064	3.9
1974	0.0029	0.4	0.0036	0.4	0.0036	0.1	0.0055	3.4
1975	0.0018	0.3	0.0023	0.2	0.0023	0.1	0.0036	2.2
1976	0.0018	0.3	0.0021	0.2	0.0021	0.1	0.0031	1.9
1977	0.0017	0.3	0.0022	0.2	0.0022	0.1	0.0031	1.9
1978	0.0020	0.3	0.0026	0.3	0.0026	0.1	0.0036	2.2
1979	0.0015	0.2	0.0019	0.2	0.0019	0.1	0.0028	1.7
1980	0.0017	0.2	0.0020	0.2	0.0020	0.1	0.0029	1.8
1981	0.0018	0.3	0.0022	0.2	0.0022	0.1	0.0031	1.9
1982	0.0019	0.3	0.0023	0.2	0.0023	0.1	0.0028	1.7
1983	0.0022	0.3	0.0027	0.3	0.0027	0.1	0.0032	2.0
1984	0.0027	0.4	0.0035	0.4	0.0035	0.1	0.0041	2.5
1985	0.0025	0.4	0.0032	0.3	0.0032	0.1	0.0038	2.3
1986	0.0021	0.3	0.0026	0.3	0.0026	0.1	0.0035	2.1
1987	0.0022	0.3	0.0027	0.3	0.0027	0.1	0.0034	2.1
1988	0.0016	0.2	0.0020	0.2	0.0020	0.1	0.0025	1.5
1989	0.0010	0.1	0.0014	0.1	0.0014	<0.1	0.0019	1.1
1990	$7.4x10^{-04}$	0.1	$9.8x10^{-04}$	0.1	$9.8x10^{-04}$	<0.1	0.0010	0.6
1991	$5.7x10^{-04}$	0.1	$7.6x10^{-04}$	0.1	$7.6x10^{-04}$	<0.1	$8.3x10^{-04}$	0.5
1992	$4.2x10^{-04}$	0.1	$5.6x10^{-04}$	0.1	$5.6x10^{-04}$	<0.1	$5.6x10^{-04}$	0.3
Total	0.70	100	0.97	100	3.8	100	0.16	100

11.2.2.3 Dominant Radionuclides, Exposure Routes, and Pathways

Figure 11-10 shows the radionuclides that caused the largest doses over 39 years for each family member.

Generally similar radionuclides dominated dose to each family member as those for Rural Family One (see Figure 11-4). Yet there were small differences: For example, the two adults received larger doses from ^{238}Pu than from ^{14}C (unlike Rural Family One), and the distribution of dose from the principal radionuclides was slightly different (e.g., ^{131}I caused 74% of the dose to the Adult Male in Rural Family One and 79% of the dose to the Adult Male in Rural Family Two).

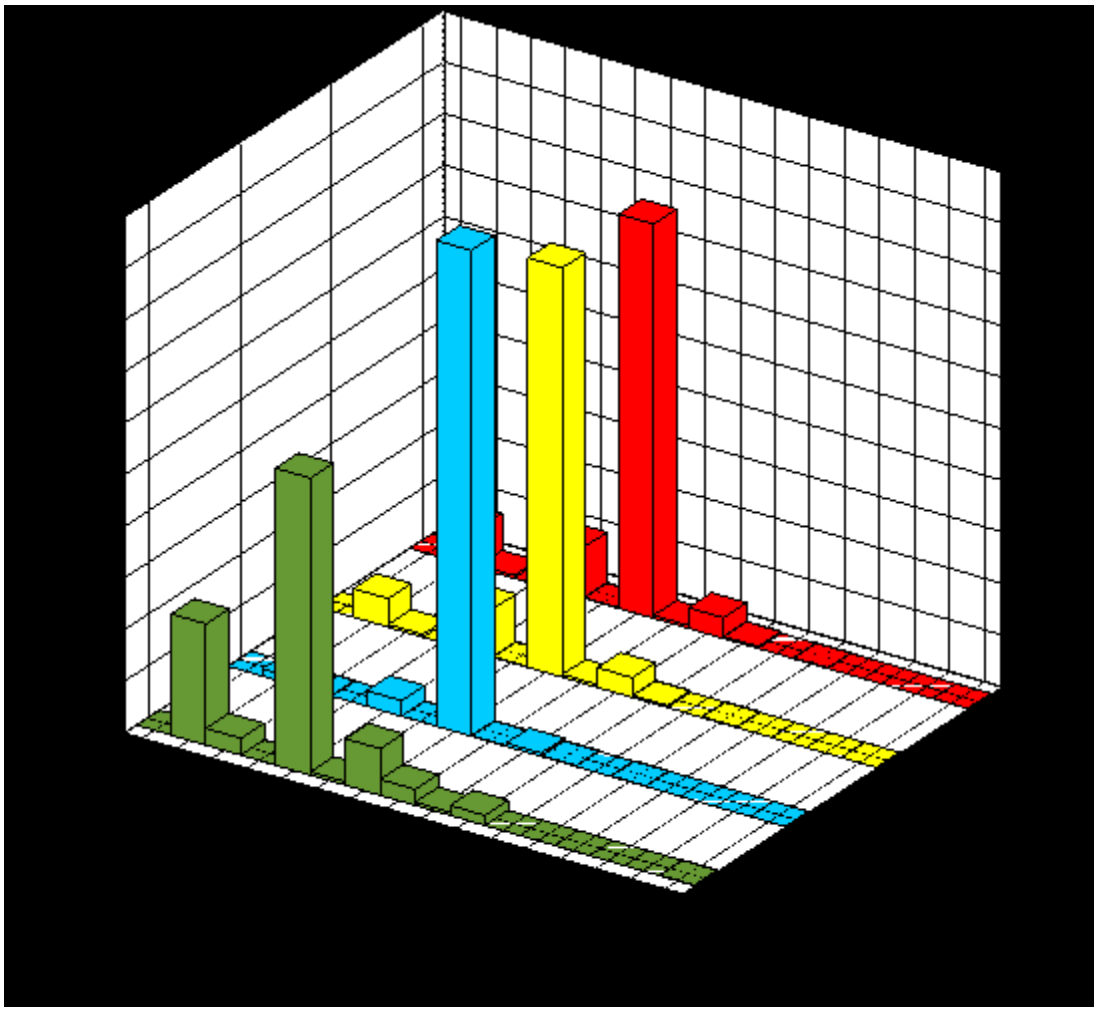

Figure 11-10 Percent of 39-Year Effective Dose by Dominant Isotopes for Rural Family Two

These differences occurred because Rural Families One and Two were located at different directions and distances from the points were radionuclides were released from SRS into the air. The distributions of average wind speeds and stability classes were different, resulting in different patterns of radionuclide dispersion in air. The average concentrations of radionuclides in air were different, over the 39 years considered in the study, at Waynesboro than they were at Girard.

Most of the radiation dose received by this family came from eating foods containing radionuclides (Figure 11-11). All family members received from 68 to 94 of their entire dose over 39 years from

ingestion. From 2 to 19 percent of their entire dose came from exposure to external radiation, and from 5 to 14 percent of their entire dose came from inhalation of radionuclides. This pattern of dose is similar to that seen for Rural Family One (Figure 11-5).

Table 11-8 lists the effective dose over 39 years, by pathway, for each family member. Figure 11-12 illustrates the percent of the effective dose received through each pathway over 39 years. Although the doses listed in Table 11-8 are larger for each pathway than those for Rural Family One (Table 11-5), the percent of dose caused by each pathway was similar.

For all family members, and especially the Child Born in 1955, most of their dose came from eating beef and milk (i.e., from 50 to 88 percent of their entire dose). For all family members, from 5 to 14 percent of their entire dose came from eating fruit and vegetables. A smaller dose was received from eating grain, poultry, and eggs. Eating these three foods contributed from 0.4 to 4 percent of each family member's entire dose. Relatively tiny doses came from inadvertently eating soil containing radionuclides – i.e., no more than 0.0005% of any family member's entire dose.

Most of the dose from external exposure to radiation came from immersion in a plume of air contaminated with radionuclides, rather than from radionuclides after they had been deposited on the ground. Similarly, most inhalation doses came from inhalation of radionuclides from this contaminated plume, as opposed to inhalation of radionuclides that had been resuspended from soil. This pattern is comparable to that seen for Rural Family One.

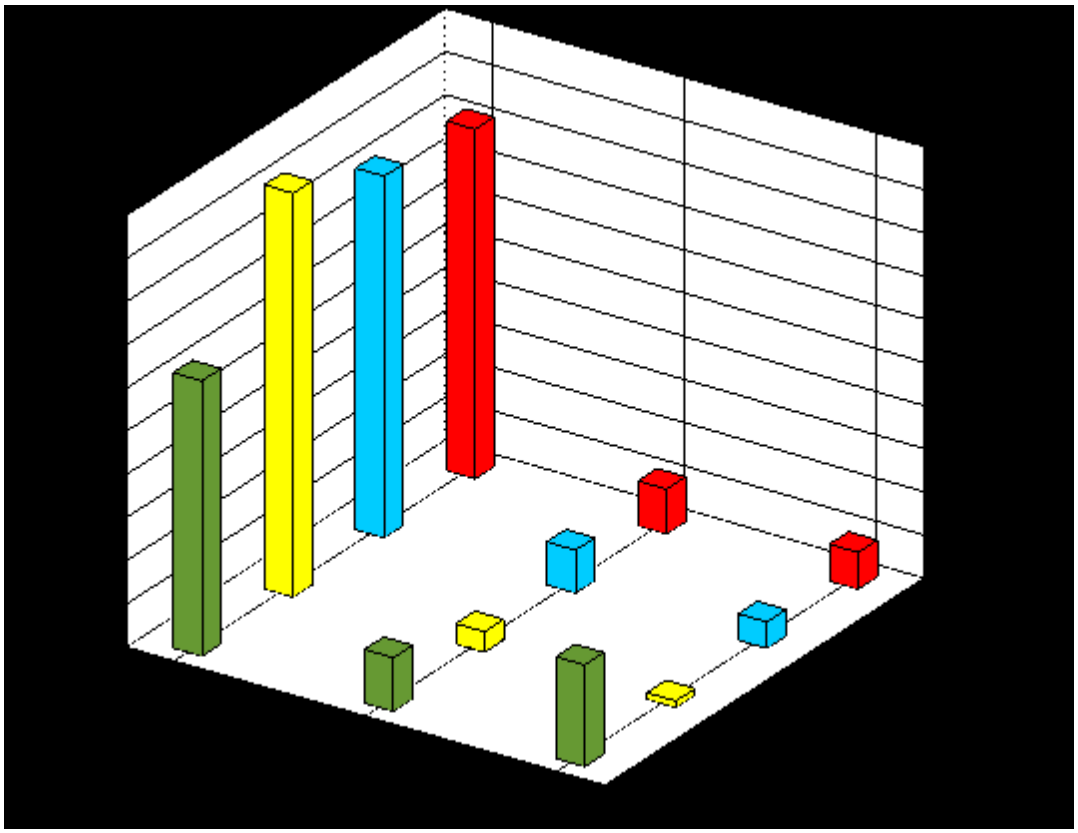

Figure 11-11 Percent of 39-Year Effective Dose by Exposure Route for Rural Family Two

Table 11-8 39-Year Effective Dose (mSv) by Exposure Pathway for Rural Family Two

		Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Route	**Pathway**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
External	Air Immersion	0.054	7.8	0.054	5.6	0.054	1.4	0.039	23.5
	Ground Contamination	0.0056	0.8	0.0060	0.6	0.0057	0.2	2.2×10^{-4}	0.1
Ingestion	Beef	0.36	52.4	0.57	58.8	1.64	43.7	0.024	14.6
	Eggs	0.0027	0.4	0.0044	0.5	0.0040	0.1	0.0029	1.8
	Fruit	0.023	3.3	0.023	2.3	0.10	2.7	0.011	6.8
	Grain	0.0023	0.3	0.0028	0.3	0.0082	0.2	0.0013	0.8
	Leafy Vegetables	0.042	6.0	0.042	4.3	0.071	1.9	0.0021	1.3
	Milk	0.11	16.1	0.15	15.3	1.66	44.2	0.053	32.4
	Poultry	0.0019	0.3	0.0024	0.2	0.0024	0.1	0.0017	1.0
	Root Vegetables	0.015	2.1	0.021	2.1	0.029	0.8	0.0086	5.2
	Soil*	1.2×10^{-6}	<0.1	1.2×10^{-6}	<0.1	1.8×10^{-5}	<0.1	1.9×10^{-7}	<0.1
Inhalation	Air Inhalation	0.063	9.0	0.084	8.7	0.17	4.6	0.019	11.4
	Resuspended Soil	0.0099	1.4	0.013	1.4	0.0093	0.2	0.0019	1.2
	Total:	0.70	100	0.97	100	3.8	100	0.16	100

*Doses from the soil ingestion pathway were no more than 0.0005% of any family member's entire 39-year dose.

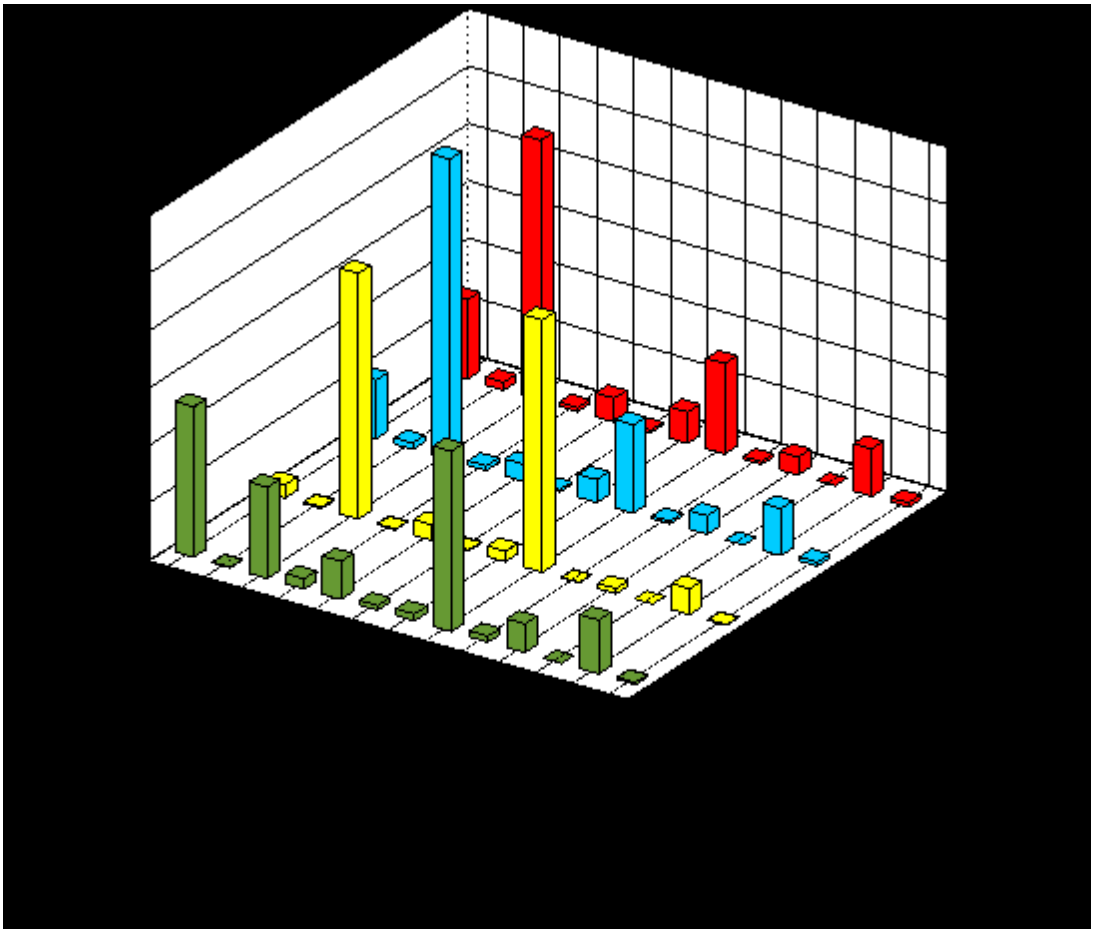

Figure 11-12 Percent of 39-Year Effective Dose (mSv) by Exposure Pathway for Rural Family Two

11.2.3 Urban/Suburban Family

This hypothetical family lived in Augusta, GA, and, except for employment for the Adult Male and for the children when they each reached age 18, all family members stayed in Augusta for all activities, including school and church (Figure 11-13). The Adult Male worked onsite at SRS for all 39 years. When the children grew up, they lived in Augusta and worked onsite at SRS (beginning in 1973 for the Child Born in 1955 and in 1982 for the Child Born in 1964). All family members swam, boated, and fished in the Savannah River flowing through Augusta upstream of SRS.

Half the family's milk came from cows located in the Augusta area, and half came from cows located in the New Ellenton area. All eggs came from hens located in the Augusta area. Half of the beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in the Augusta area, and half came from unaffected non-local sources. All of the corn eaten by the family was grown locally. Fish came from surface water sources assumed by be unaffected by releases from SRS (e.g., from the Savannah River upstream of SRS).

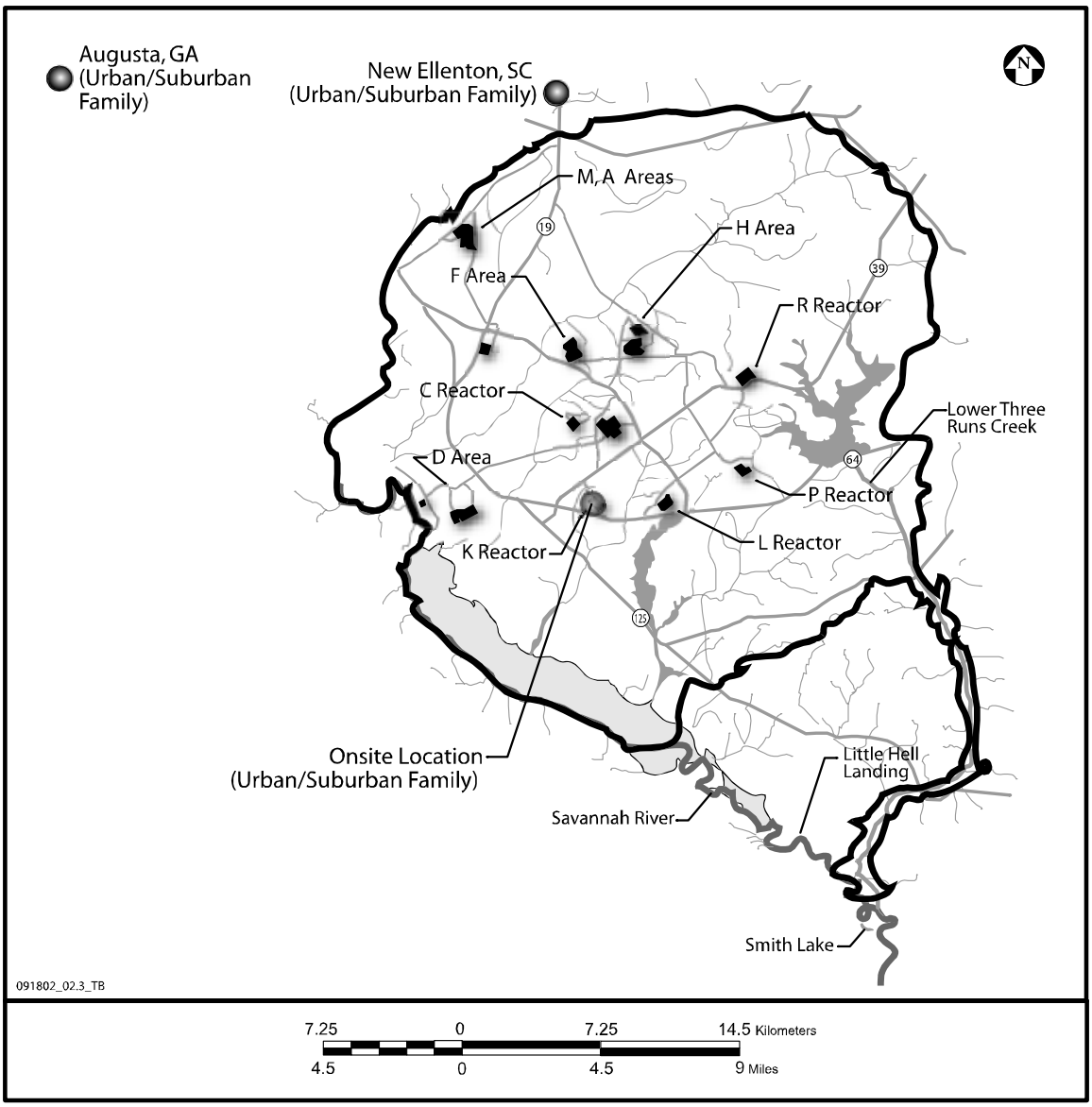

Figure 11-13 Exposure Locations for Urban/Suburban Family

11.2.3.1 Doses and Total Risks

Table 11-9 lists the effective dose and cancer risks determined for each member of the Urban/Suburban Family over 39 years of SRS operation. All doses and risks came from exposure to radionuclides that had been released into the air.

The Child Born in 1955 received the largest radiation dose and cancer risks in the scenario. He received an effective dose of 2.7 mSv (270 mrem), a cancer incidence risk of 0.027%, and a cancer fatality risk of 0.0041%. The Child Born in 1964 received the smallest dose and risks which is 4% of that for the Child Born in 1955.

Table 11-9 39-Year Effective Dose and Cancer Risks for Urban/Suburban Family

Dose or Risk	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Effective Dose (mSv)	0.33	0.73	2.7	0.11
Cancer Incidence Risk (%)	0.00090	0.0025	0.027	0.0016
Cancer Fatality Risk (%)	0.00032	0.0013	0.0041	0.00098

The Adult Male received more than twice the dose than did the Adult Female. This difference in dose between the two adults is more significant than was the case for Rural Family One (Table 11-3) and Rural Family Two (Table 11-6). The reason is as follows: For the Urban/Suburban Scenario the Adult Female spent her entire time in the Augusta area, while the Adult Male spent 2000 hours each year on the SRS site. But for the two rural family scenarios, the Adult Male and Adult Female both spent their entire time "at home" in Girard and Williston.

Effective Dose by Year

Figure 11-14 shows the percent of the entire 39-year effective dose received each year by each family member, while Figure 11-15 shows the annual effective dose (in units of Sieverts) received by each family member. Table 11-10 lists the percent of the entire 39-year effective dose received each year by each family member, as well as their annual dose. Again, most of the dose was received during the early days of site operation.

In 1956, the Child Born in 1955 received 2.0 mSv (200 mrem), or 73% of his entire dose. During this year, the Adult Female received 0.17 mSv (17 mrem), or 53% of her entire dose, and the Adult Male received 0.26 mSv (26 mrem), or 36% of his entire dose.[11] In 1964, the Child Born in 1964 received 0.014 mSv (1.4 mrem), or 13% of his entire dose. This dose was 1% of the largest annual dose received by the Child Born in 1955.

[11] This information was obtained from the tables of effective dose by year presented in Appendix I for each scenario and receptor.

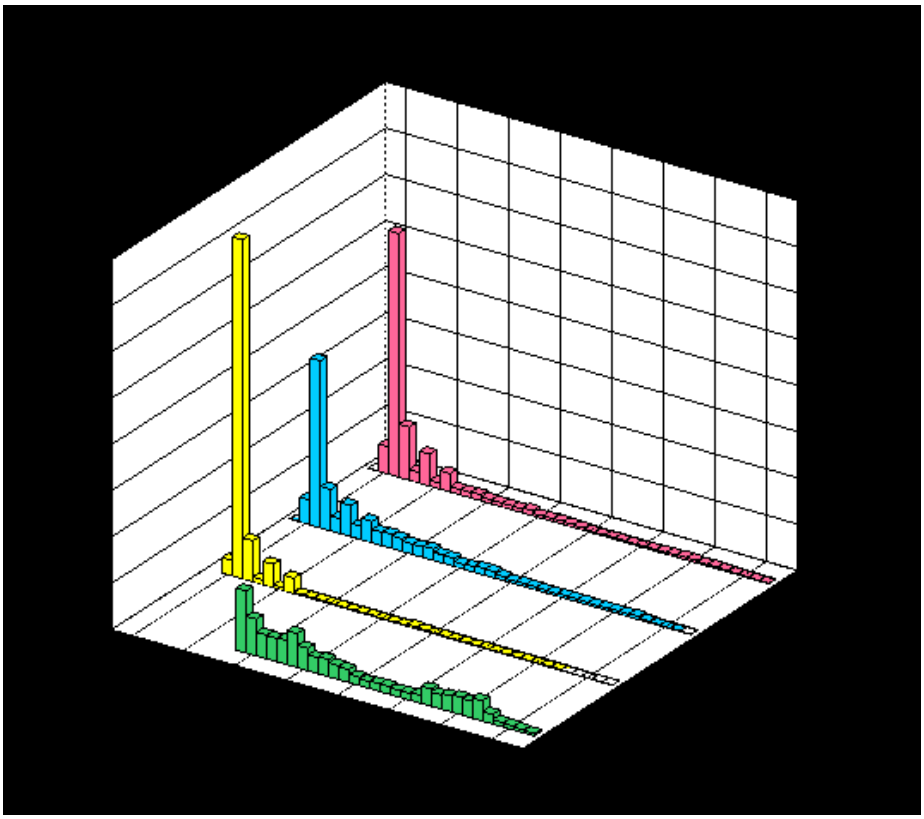

Figure 11-14 Percent of 39-Year Effective Dose by Year for Urban/Suburban Family

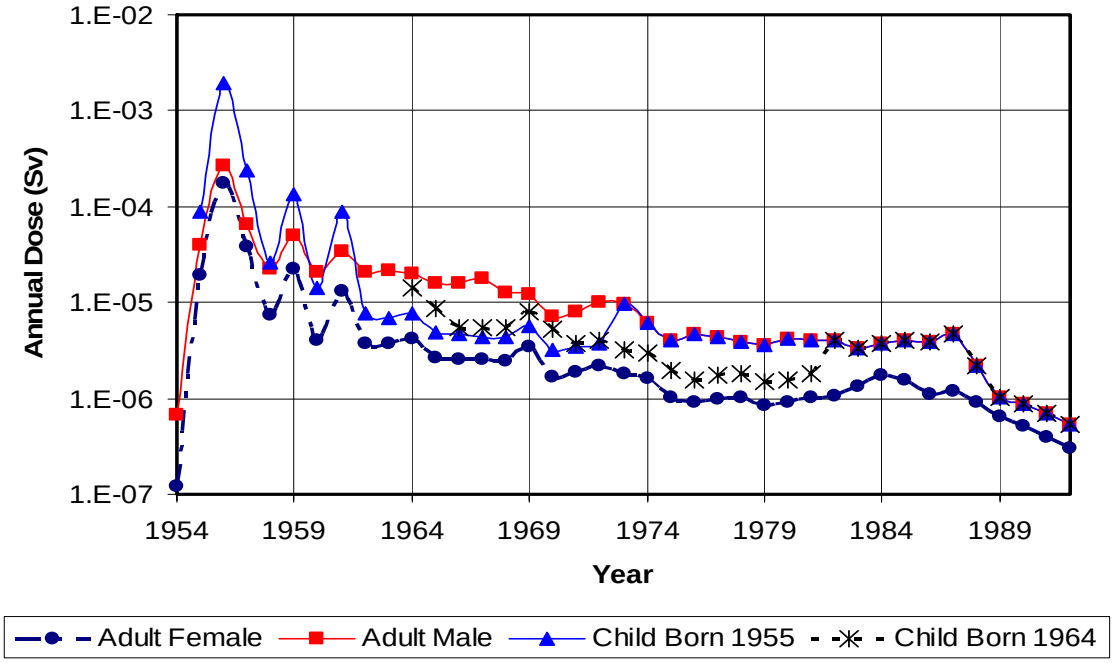

Figure 11-15 Annual Effective Dose (Sv) for Urban/Suburban Family

Table 11-10 Annual Effective Dose (mSv) for Urban/Suburban Family

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
1954	$1.2x10^{-04}$	0.0	$6.7x10^{-04}$	0.1				
1955	0.021	7.9	0.046	7.0	0.046	2.7		
1956	0.13	49.7	0.21	32.1	1.2	71.5		
1957	0.030	10.9	0.055	8.3	0.15	8.7		
1958	0.0062	2.3	0.021	3.2	0.018	1.0		
1959	0.018	6.7	0.043	6.5	0.084	5.0		
1960	0.0036	1.3	0.020	3.0	0.010	0.6		
1961	0.010	3.9	0.030	4.6	0.059	3.5		
1962	0.0034	1.3	0.020	3.1	0.0059	0.4		
1963	0.0033	1.2	0.022	3.3	0.0054	0.3		
1964	0.0037	1.4	0.019	2.9	0.0060	0.4	0.0081	9.5
1965	0.0024	0.9	0.016	2.4	0.0039	0.2	0.0064	7.5
1966	0.0023	0.8	0.016	2.4	0.0037	0.2	0.0041	4.8
1967	0.0023	0.8	0.018	2.7	0.0035	0.2	0.0041	4.8
1968	0.0022	0.8	0.013	1.9	0.0035	0.2	0.0042	4.9
1969	0.0039	1.4	0.013	2.0	0.0057	0.3	0.0072	8.4
1970	0.0015	0.5	0.0068	1.0	0.0025	0.1	0.0038	4.5
1971	0.0016	0.6	0.0077	1.2	0.0027	0.2	0.0028	3.3
1972	0.0019	0.7	0.0096	1.5	0.0030	0.2	0.0031	3.6
1973	0.0016	0.6	0.0096	1.5	0.0096	0.6	0.0025	3.0
1974	0.0014	0.5	0.0059	0.9	0.0059	0.3	0.0023	2.7
1975	0.0010	0.3	0.0040	0.6	0.0040	0.2	0.0015	1.7
1976	$9.1x10^{-04}$	0.3	0.0047	0.7	0.0047	0.3	0.0012	1.4
1977	$9.9x10^{-04}$	0.3	0.0042	0.6	0.0042	0.3	0.0014	1.6
1978	0.0010	0.4	0.0037	0.6	0.0037	0.2	0.0015	1.8
1979	$8.6x10^{-04}$	0.3	0.0035	0.5	0.0035	0.2	0.0012	1.4
1980	$9.0x10^{-04}$	0.3	0.0042	0.6	0.0042	0.2	0.0012	1.4
1981	0.0009	0.3	0.0039	0.6	0.0039	0.2	0.0014	1.7
1982	0.0009	0.3	0.0038	0.6	0.0038	0.2	0.0038	4.5
1983	0.0011	0.4	0.0031	0.5	0.0031	0.2	0.0031	3.6
1984	0.0015	0.5	0.0034	0.5	0.0034	0.2	0.0034	4.0
1985	0.0013	0.5	0.0038	0.6	0.0038	0.2	0.0038	4.5
1986	0.0010	0.4	0.0037	0.6	0.0037	0.2	0.0037	4.3
1987	0.0010	0.4	0.0045	0.7	0.0045	0.3	0.0045	5.3
1988	$9.3x10^{-04}$	0.3	0.0021	0.3	0.0021	0.1	0.0021	2.4
1989	$6.4x10^{-04}$	0.2	0.0010	0.1	0.0010	0.1	0.0010	1.1
1990	$5.1x10^{-04}$	0.2	$8.7x10^{-04}$	0.1	$8.7x10^{-04}$	<0.1	$8.7x10^{-04}$	0.9
1991	$3.9x10^{-04}$	0.1	$7.0x10^{-04}$	0.1	$7.0x10^{-04}$	<0.1	$7.0x10^{-04}$	0.7
1992	$3.0x10^{-04}$	0.1	$5.4x10^{-04}$	0.1	$5.4x10^{-04}$	<0.1	$5.4x10^{-04}$	0.6

Total	0.2702	100	0.6588	100	1.6789	100	0.0856	100

The pattern shown in Figure 11-15 differs notably from that shown for Rural Family One (Figure 11-3) and Rural Family Two (Figure 11-9). For the two rural families, the annual doses for all family members were similar after the mid 1960s. But for the Urban/Suburban Family, annual doses for some members differed after the mid 1960s, for the following reasons: Although the Adult Male always worked on the SRS site, the children spent their early years entirely in Augusta. But when the children began work in 1973 and 1982, respectively, their annual doses equaled those for the Adult Male. The Adult Female always stayed in Augusta.

11.2.3.2 Exposure Routes and Pathways

Figure 11-16 shows the radionuclides that were the largest contributors of dose over 39 years for each family member.

The major contributors to dose were essentially the same as those identified for Rural Family One (Figure 11-4) and Rural Family Two (Figure 11-9-Figure 11-10). Of interest is the larger importance of ^{41}Ar, compared to tritium, for the Adult Male.

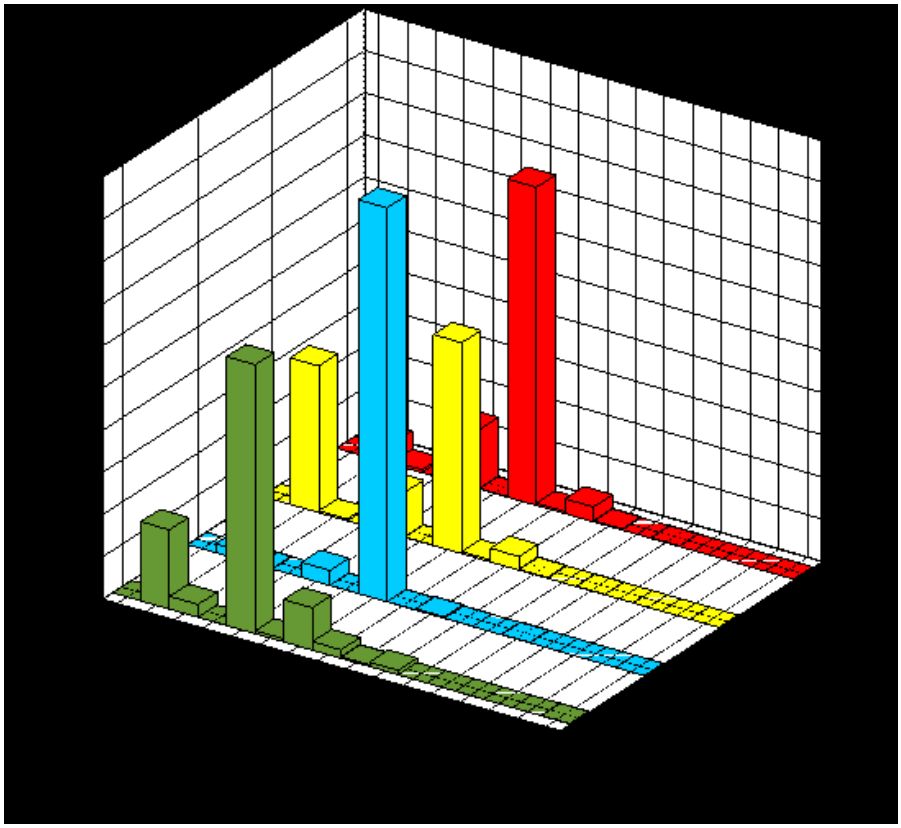

Figure 11-16 Percent of 39-Year Effective Dose by Dominant Isotopes for Urban/Suburban Family

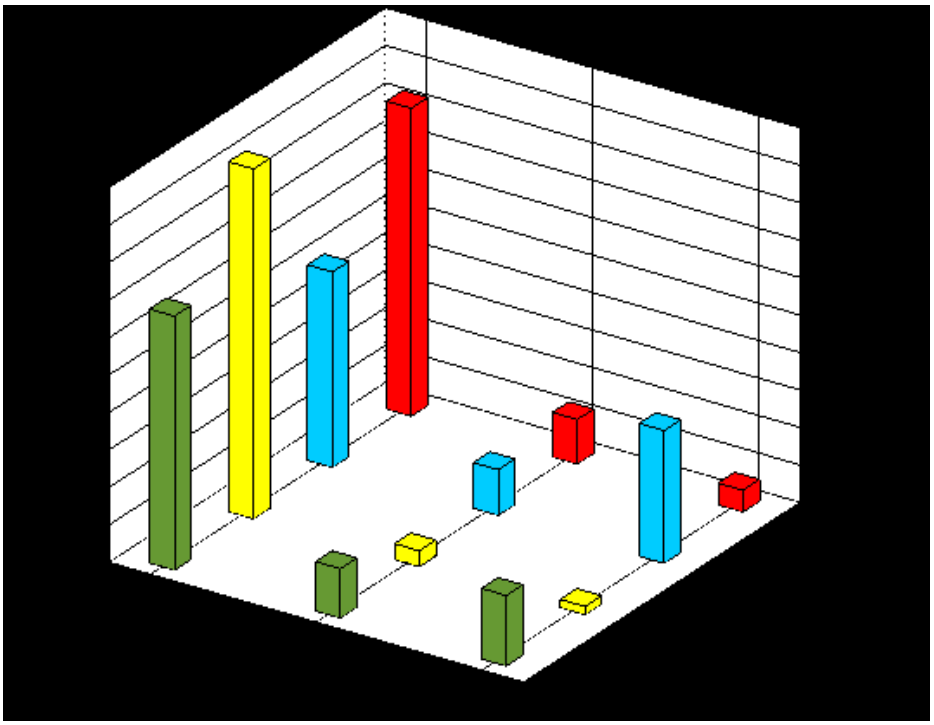

Figure 11-17 Percent of 39-Year Effective Dose by Exposure Route for Urban/Suburban Family

The larger dose from ^{41}Ar is partially illustrated by Figure 11-17. External exposure to radiation caused 36% of the entire dose for the Adult Male, a larger percent than that for any other member of the family.[12] Otherwise, doses from ingestion were again important. For all family members, from 52 to 93 percent of their entire 39-year dose came from eating foods containing radionuclides. Except for the Adult Male, the contribution to dose by ingestion was comparable to that seen for Rural Family One (Figure 11-5) and Rural Family Two (Figure 11-11).

Table 11-11 and Figure 11-18 show the dose, and percent of dose, over 39 years by pathway for each member of the family. The foods that contributed most to radiation dose were beef and milk. For all family members, from 48 to 91 percent of their entire dose came from eating beef and milk. The next largest doses generally came from eating fruit and vegetables (from 2 to 9 percent of their entire dose). Eating grain, poultry, and eggs contributed from 0.2 to 3 percent of their entire dose. Inadvertently eating soil containing radionuclides contributed no more than 0.0003% of any family member's entire dose.

Table 11-11 39-Year Effective Dose (mSv) by Exposure Pathway for Urban/Suburban Family

		Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Route	**Pathway**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
External	Air Immersion	0.017	6.2	0.257	38.6	0.0577	3.4	0.0207	23.6
	Ground Contamina-tion	0.0026	1.0	0.0052	0.8	0.0026	0.2	1.0×10^{-4}	0.1

[12] ^{41}Ar contributed 98% of the external exposure received by the Adult Male (see Appendix K).

Ingestion	Beef	0.12	42.6	0.18	27.4	0.51	30.4	0.0099	11.6
	Eggs	0.0017	0.6	0.0028	0.4	0.0026	0.2	0.0017	1.9
	Fruit	0.0075	2.8	0.0073	1.1	0.023	1.3	0.0050	5.9
	Grain	0.0011	0.4	0.0013	0.2	0.0029	0.2	7.3×10^{-4}	0.8
	Leafy Vegetables	0.0089	3.3	0.0089	1.3	0.014	0.8	8.5×10^{-4}	1.0
	Milk	0.065	24.1	0.087	13.1	0.93	55.7	0.027	31.7
	Poultry	0.0010	0.4	0.0012	0.2	0.0012	0.1	7.6×10^{-4}	0.9
	Root Vegetables	0.0065	2.4	0.0090	1.4	0.012	0.7	0.0041	4.8
	Soil*	5.5×10^{-7}	<0.1	1.1×10^{-6}	<0.1	8.3×10^{-6}	<0.1	9.0×10^{-8}	<0.1
Inhala-tion	Air Inhalation	0.039	14.5	0.090	13.6	0.12	6.9	0.014	16.6
	Resuspended Soil	0.0046	1.7	0.012	1.8	0.0044	0.3	9.2×10^{-6}	1.1
Total		0.27	100	0.66	100	1.7	100	0.086	100

* Doses from the soil ingestion pathway were no more than 0.0003% of any family member's entire 39-year dose.

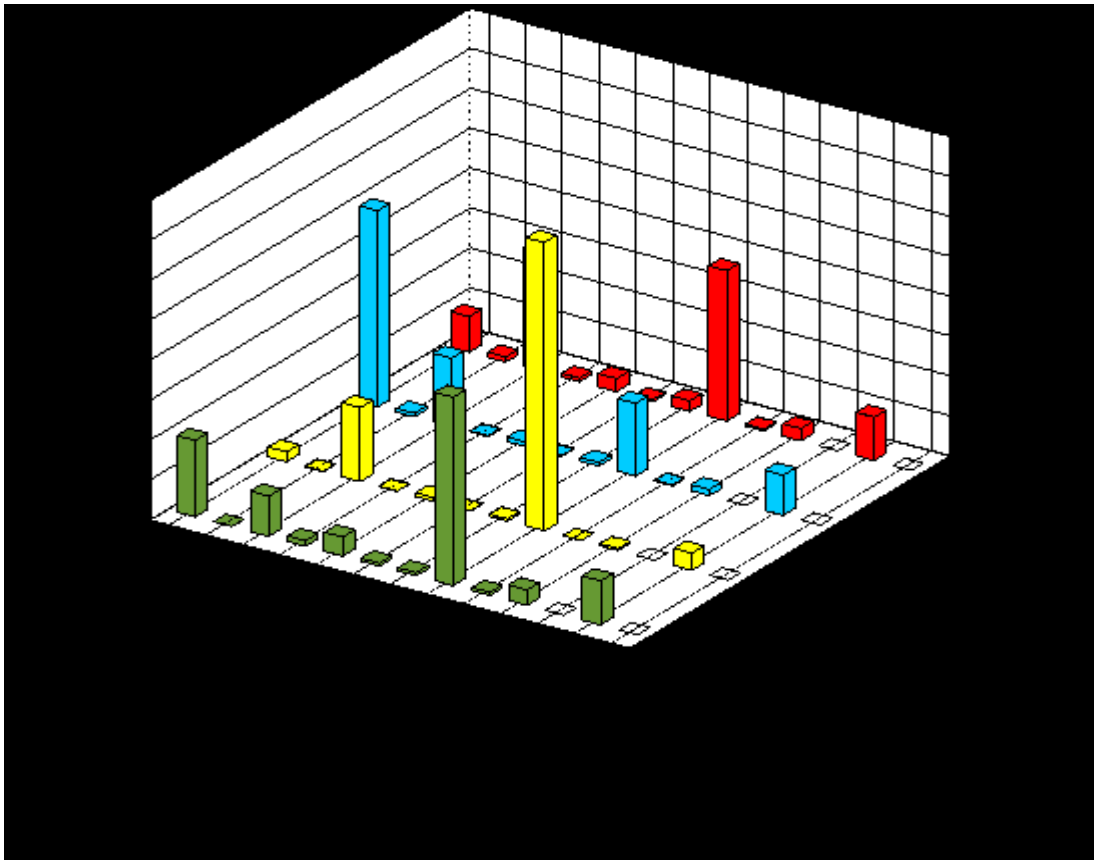

Figure 11-18 Percent of 39-Year Effective Dose for Exposure Pathway for Urban/Suburban Family

The large external radiation dose received by the Adult Male came from the 2000 hours he spent each year at work. It was assumed that all hours were spent near K-Reactor. The great bulk of his external exposures resulted from immersion in a plume of radionuclides in air, rather than from exposure to radionuclides that had been deposited on the ground.

For all family members, doses from inhalation mainly came from breathing radionuclides from the contaminated air plume, rather than breathing radionuclides that had been resuspended from soil after being deposited on the ground.

11.2.4 Migrant Worker Family

As a hypothetical rural family, all family members spent much of their work, home activities, and recreation time outdoors. Because the Adult Male and Adult Female worked as migrant farm workers, the family lived in New Ellenton for half of each year (Figure 11-19). The family did no boating but did enjoy other water sports such as fishing and swimming in local pools, ponds and creeks. The children attended schools in New Ellenton. When grown, the children became migrant farmers spending half of each year in New Ellenton.

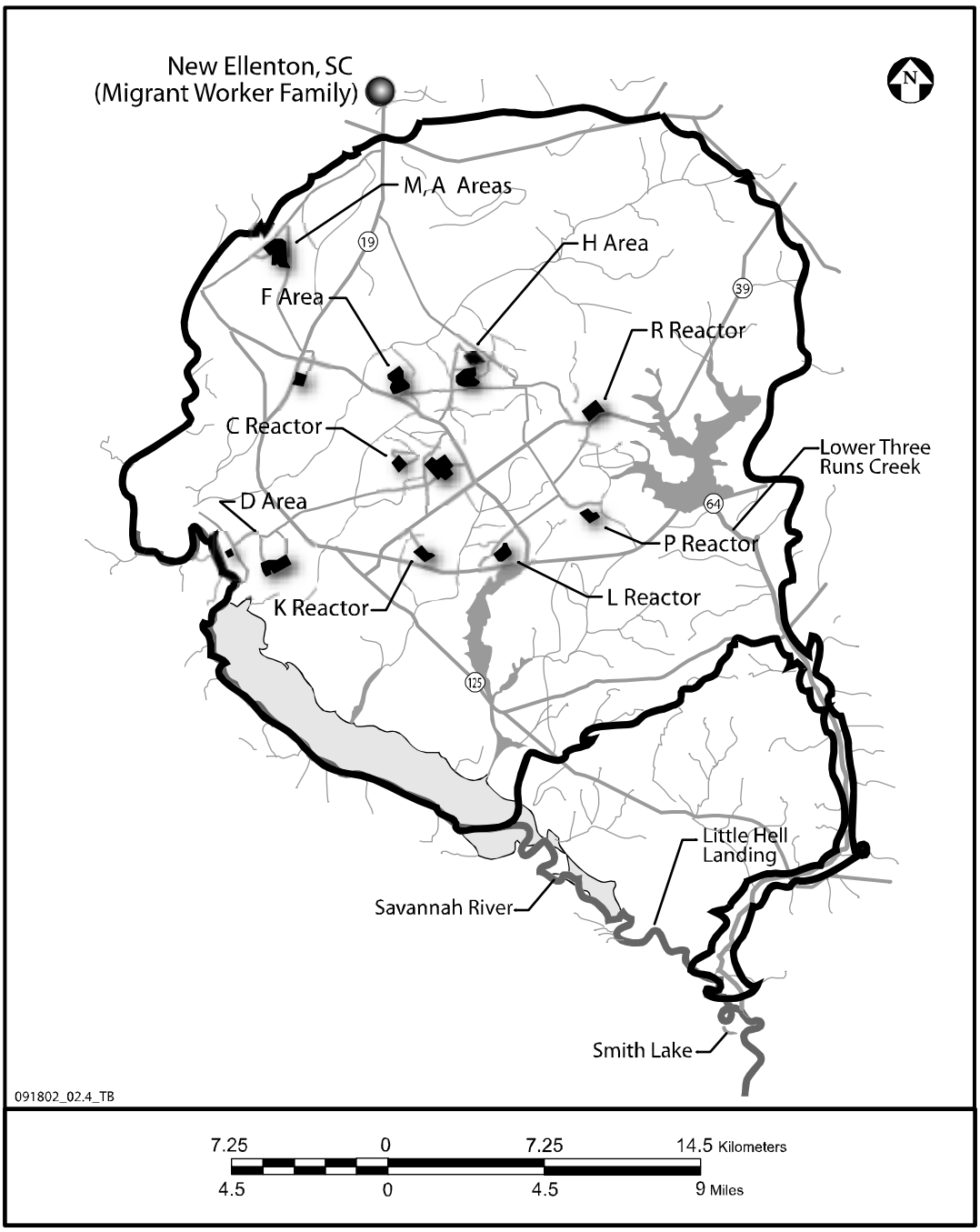

Figure 11-19 Exposure Location for Migrant Worker Family

During the six months of each year that the family lived in New Ellenton, all of their milk and eggs came from cows and hens located in New Ellenton. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in New Ellenton and half came from sources away from SRS. All of their corn was grown in New Ellenton. Because ponds and creeks in the vicinity of New Ellenton are not located hydrologically downstream from SRS, none of the fish eaten by the family was affected by SRS releases. Drinking water and water used to irrigate foods eaten by the family came from sources unaffected by SRS releases.

11.2.4.1 Doses and Total Risks

Table 11-12 lists the effective dose and cancer risks assessed for each member of the Migrant Worker Family over 39 years of SRS operation. All doses and risks came from exposure to radionuclides that had been released into the air.

The Child Born in 1955 received the largest dose and risks – i.e., an effective dose of 2.2 mSv (220 mrem), a cancer incidence risk of 0.022%, and a cancer fatality risk of 0.0034%. The Child Born in 1964 received the smallest dose and risks. The dose for the Child Born in 1964 was 4% of that for the Child Born in 1955.

Table 11-12 39-Year Effective Dose and Cancer Risks for Migrant Worker Family

Dose or Risk	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Effective Dose (mSv)	0.45	0.62	2.2	0.083
Cancer Incidence Risk (%)	0.0012	0.0016	0.022	0.0013
Cancer Fatality Risk (%)	0.00042	0.00052	0.0034	0.00078

Of interest is the relatively large doses received by these family members, compared to those received by members of the previous scenarios, even though the Migrant Worker Family was assumed to be in the vicinity of SRS only half of any year. The main reason is that the members of the Migrant Worker Family resided in New Ellenton, SC, which is immediately north of SRS, while members of other scenarios lived farther away from SRS, and in different directions. New Ellenton was the source of all of their milk and eggs, and half of their other foods.

11.2.4.2 Effective Dose by Year

Figure 11-20 shows the percent of the 39-year effective dose received each year by each family member, while Figure 11-21 shows the annual effective dose (in units of Sieverts) received by each family member. Table 11-13 lists the percent of the entire 39-year effective dose received each year by each family member, as well as their annual dose.

In 1956 the Child Born in 1955 received 1.6 mSv (160 mrem)), or 73% of his entire dose. During this year, the Adult Female received 0.23 mSv (23 mrem), or 52% of her entire dose, and the Adult Male received 0.34 mSv (34 mrem), or 54% of his entire dose.[13] In 1964, the Child Born in 1964 received 0.011 mSv (1.1 mrem), or 13% of his entire dose.

[13] This information was obtained from the tables of annual effective dose that are presented in Appendix I for each scenario.

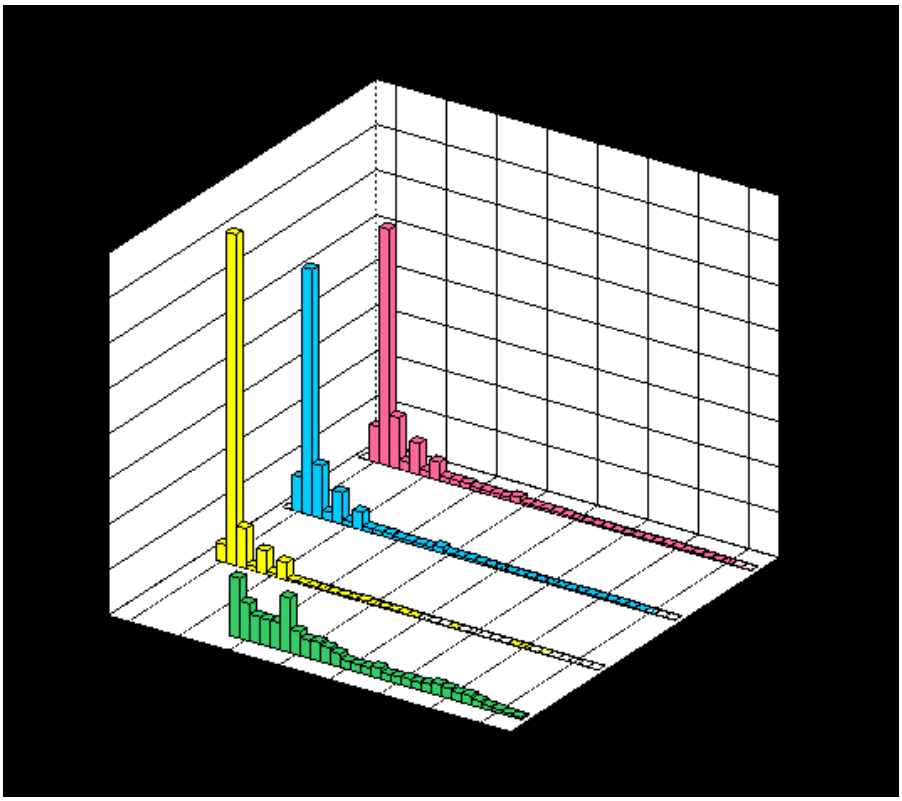

Figure 11-20 Percent of 39-Year Effective Dose by Year for Migrant Worker Family

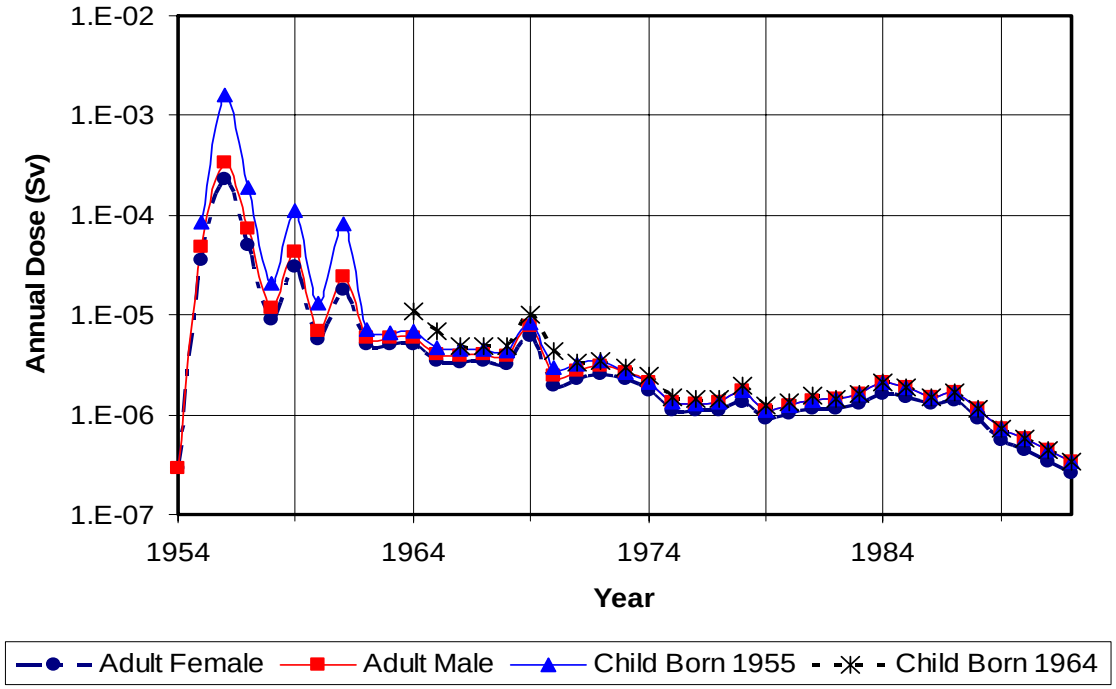

Figure 11-21 Annual Effective Dose (Sv) for Migrant Worker Family

Table 11-13 Annual Effective Dose (mSv) for Migrant Worker Family

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
1954	$2.9x10^{-04}$	0.1	$2.9x10^{-04}$	0.0				
1955	0.036	8.0	0.049	7.8	0.084	3.8		
1956	0.236	52.2	0.34	54.3	1. 6	73.1		
1957	0.050	11.3	0.072	11.6	0.19	8.8		
1958	0.0090	2.0	0.012	1.9	0.021	1.0		
1959	0.031	6.9	0.043	6.9	0.11	5.1		
1960	0.0056	1.3	0.0068	1.1	0.013	0.6		
1961	0.018	4.0	0.024	3.9	0.083	3.8		
1962	0.0051	1.1	0.0060	1.0	0.0072	0.3		
1963	0.0050	1.1	0.0058	0.9	0.0067	0.3		
1964	0.0051	1.1	0.0060	1.0	0.0069	0.3	0.011	13.2
1965	0.0035	0.8	0.0041	0.7	0.0046	0.2	0.0068	8.2
1966	0.0034	0.8	0.0039	0.6	0.0046	0.2	0.0050	6.0
1967	0.0035	0.8	0.0040	0.6	0.0045	0.2	0.0049	5.9
1968	0.0032	0.7	0.0038	0.6	0.0044	0.2	0.0049	5.9
1969	0.0060	1.3	0.0078	1.3	0.0084	0.4	0.010	12.1
1970	0.0020	0.4	0.0025	0.4	0.0030	0.1	0.0044	5.2
1971	0.0023	0.5	0.0028	0.4	0.0032	0.1	0.0033	4.0
1972	0.0026	0.6	0.0031	0.5	0.0034	0.2	0.0035	4.2
1973	0.0023	0.5	0.0027	0.4	0.0027	0.1	0.0030	3.6
1974	0.0018	0.4	0.0021	0.3	0.0021	0.1	0.0024	2.9
1975	0.0011	0.2	0.0014	0.2	0.0014	0.1	0.0015	1.8
1976	0.0011	0.2	0.0013	0.2	0.0013	0.1	0.0014	1.7
1977	0.0011	0.2	0.0013	0.2	0.0013	0.1	0.0015	1.7
1978	0.0014	0.3	0.0017	0.3	0.0017	0.1	0.0019	2.3
1979	$9.3x10^{-04}$	0.2	0.0011	0.2	0.0011	0.1	0.0012	1.5
1980	0.0010	0.2	0.0012	0.2	0.0012	0.1	0.0014	1.6
1981	0.0011	0.3	0.0014	0.2	0.0014	0.1	0.0015	1.8
1982	0.0012	0.3	0.0014	0.2	0.0014	0.1	0.0014	1.7
1983	0.0013	0.3	0.0016	0.3	0.0016	0.1	0.0016	2.0
1984	0.0016	0.4	0.0021	0.3	0.0021	0.1	0.0021	2.5
1985	0.0015	0.3	0.0019	0.3	0.0019	0.1	0.0019	2.3
1986	0.0013	0.3	0.0015	0.2	0.0015	0.1	0.0015	1.8
1987	0.0014	0.3	0.0017	0.3	0.0017	0.1	0.0017	2.0
1988	$9.2x10^{-04}$	0.2	0.0012	0.2	0.0012	0.1	0.0012	1.4
1989	$5.5x10^{-04}$	0.1	$7.2x10^{-04}$	0.1	$7.2x10^{-04}$	<0.1	$7.2x10^{-04}$	0.9
1990	$4.5x10^{-04}$	0.1	$5.9x10^{-04}$	0.1	$5.9x10^{-04}$	<0.1	$5.9x10^{-04}$	0.7
1991	$3.3x10^{-04}$	0.1	$4.4x10^{-04}$	0.1	$4.4x10^{-04}$	<0.1	$4.4x10^{-04}$	0.5
1992	$2.6x10^{-04}$	0.1	$3.4x10^{-04}$	0.1	$3.4x10^{-04}$	<0.1	$3.4x10^{-04}$	0.4
Total	0.45	100	0.62	100	2.2	100	0.083	100

This 1964 dose was less than 1% of the largest annual dose for the Child Born in 1955. The pattern of annual dose is comparable to that seen for Rural Family One (Figure 11-3) and Rural Family Two (Figure 11-9).

11.2.4.3 Dominant Radionuclides, Exposure Routes, and Pathways

Figure 11-22 shows the radionuclides that were the largest contributors of dose over 39 years for each member of the Migrant Worker Family. The dominant radionuclides were generally the same as those for Rural Family One (Figure 11-4) and Rural Family Two (Figure 11-10). But there were small differences. For example, ^{238}Pu was somewhat more important for the Child Born in 1955 for the Migrant Worker Family than for Rural Family Two; and Ru-106 was somewhat more important for the Child Born in 1964 for the Migrant Worker Family than for Rural Family Two.

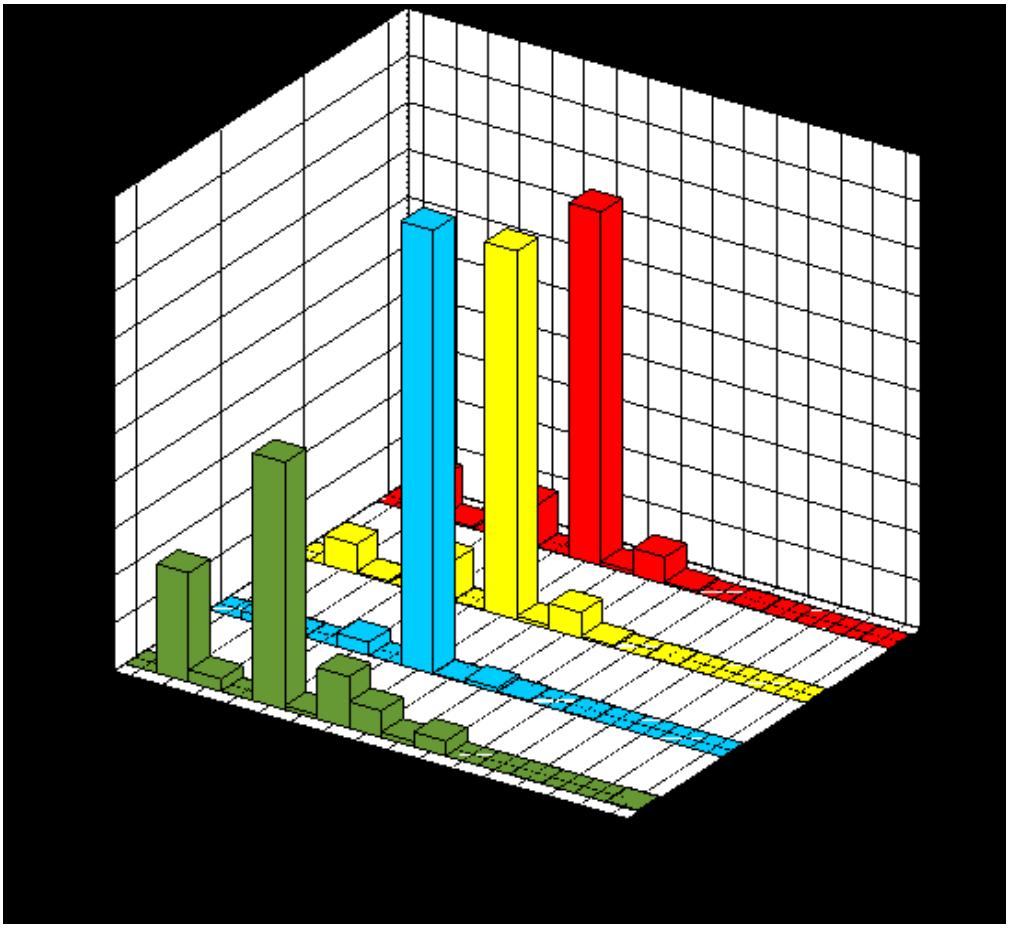

Figure 11-22 Percent of 39-Year Effective Dose by Dominant Isotopes for Migrant Worker Family

Most of the radiation dose received by this family came from eating food containing radionuclides (Figure 11-23). All family members received from 58 to 91 percent of their entire dose from ingestion. From 2 to 23 percent of their entire dose came from exposure to external radiation, and from 7 to 18 percent of their entire dose came from inhalation. This pattern of dose is similar to that seen for Rural Family One (Figure 11-5) and Rural Family Two (Figure 11-11).

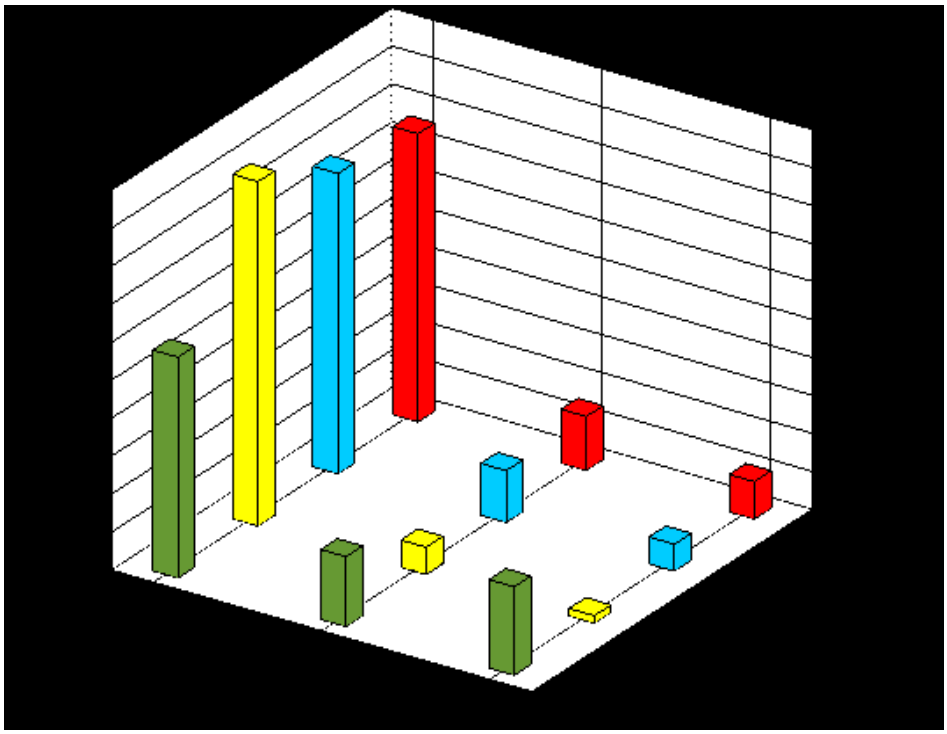

Figure 11-23 Percent of 39-Year Effective Dose by Exposure Route for Migrant Worker Family

Table 11-14 and Figure 11-24 show the effective dose, and percent of dose, by pathway and family member over 39 years. In general, the same pathways dominated radiation doses as those seen for Rural Family One (Table 11-5) and Rural Family Two (Table 11-8). Eating beef and drinking milk caused from 40 to 84 percent of their entire dose. Eating fruit and vegetables caused from 6 to 15 percent of their entire dose, and eating poultry, eggs, and grain caused from 1 to 3 percent of their entire dose. Inadvertently eating soil contributed no more than 0.0008% of any family member's entire dose.

Most external radiation doses came from immersion in a plume of contaminated air, rather than from radionuclides that had been deposited on the ground. Most inhalation doses came from breathing radionuclides directly from the plume of contaminated air, rather than breathing radionuclides that had been resuspended from soil.

Table 11-14 39-Year Effective Dose (mSv) by Exposure Pathway for Migrant Worker Family

		Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Route	**Pathway**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
External	Air Immersion	0.039	8.7	0.039	6.2	0.039	1.8	0.019	23.1
	Ground Contamina-tion	0.0054	1.2	0.0058	0.9	0.0054	0.2	$2.2x10^{-4}$	0.3
Ingestion	Beef	0.23	52.1	0.37	58.7	1.0	48.2	0.015	17.8
	Eggs	0.0010	0.2	0.0017	0.3	0.0016	0.1	0.0010	1.2
	Fruit	0.015	3.2	0.014	2.3	0.064	2.9	0.0061	7.4
	Grain	0.0020	0.4	0.0024	0.4	0.0075	0.3	$9.7x10^{-4}$	1.1
	Leafy Vegetables	0.027	6.0	0.027	4.3	0.045	2.1	0.0012	1.5
	Milk	0.052	11.6	0.069	11.0	0.79	36.2	0.019	22.4
	Poultry	0.0011	0.3	0.0014	0.2	0.0015	0.1	$9.0x10^{-4}$	1.1
	Root Vegetables	0.0091	2.0	0.013	2.0	0.019	0.9	0.0049	5.9
	Soil*	$1.1x10^{-6}$	<0.1	$1.1x10^{-6}$	<0.1	$1.7x10^{-5}$	<0.1	$1.8x10^{-7}$	<0.1
Inhala-tion	Air Inhalation	0.054	12.1	0.073	11.6	0.15	6.9	0.013	16.2
	Resuspend-ed Soil	0.0098	2.2	0.013	2.1	0.0091	0.4	0.0019	2.3
Total		0.45	100	0.62	100	2.29	100	0.083	100

* Doses from the soil ingestion pathway were no more than 0.0008% of any family member's entire 39-year dose.

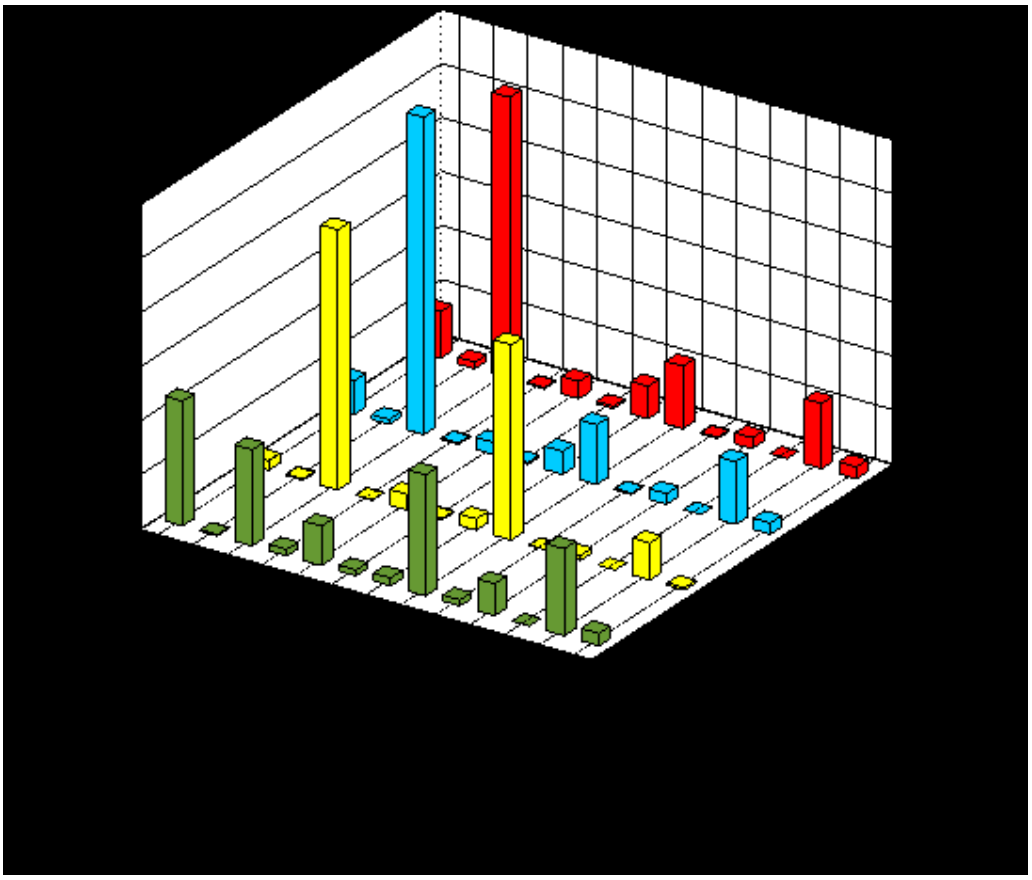

Figure 11-24 Percent of 39-Year Effective Dose by Exposure Pathway for Migrant Worker Family

11.2.5 Delivery Person Family

This hypothetical family lived in Barnwell, SC, where the children attended grade and high school. Because the Adult Male worked as a delivery driver for a bottling plant in Allendale, SC, he spent portions of his time in Allendale and onsite at SRS, where he made periodic deliveries. (When the children reached 18 they lived in Barnwell and became delivery drivers like the Adult Male.) The Adult Female worked at home. All family members attended religious services in Martin, SC, for a few hours per week. All family members swam, fished, and spent time along the shoreline at Lower Three Runs Creek near Martin. The Adult Male hunted deer and fowl in the Martin vicinity. The family boated in the Savannah River, catching fish in Smith Lake and spending time along its shoreline (Figure 11-25).

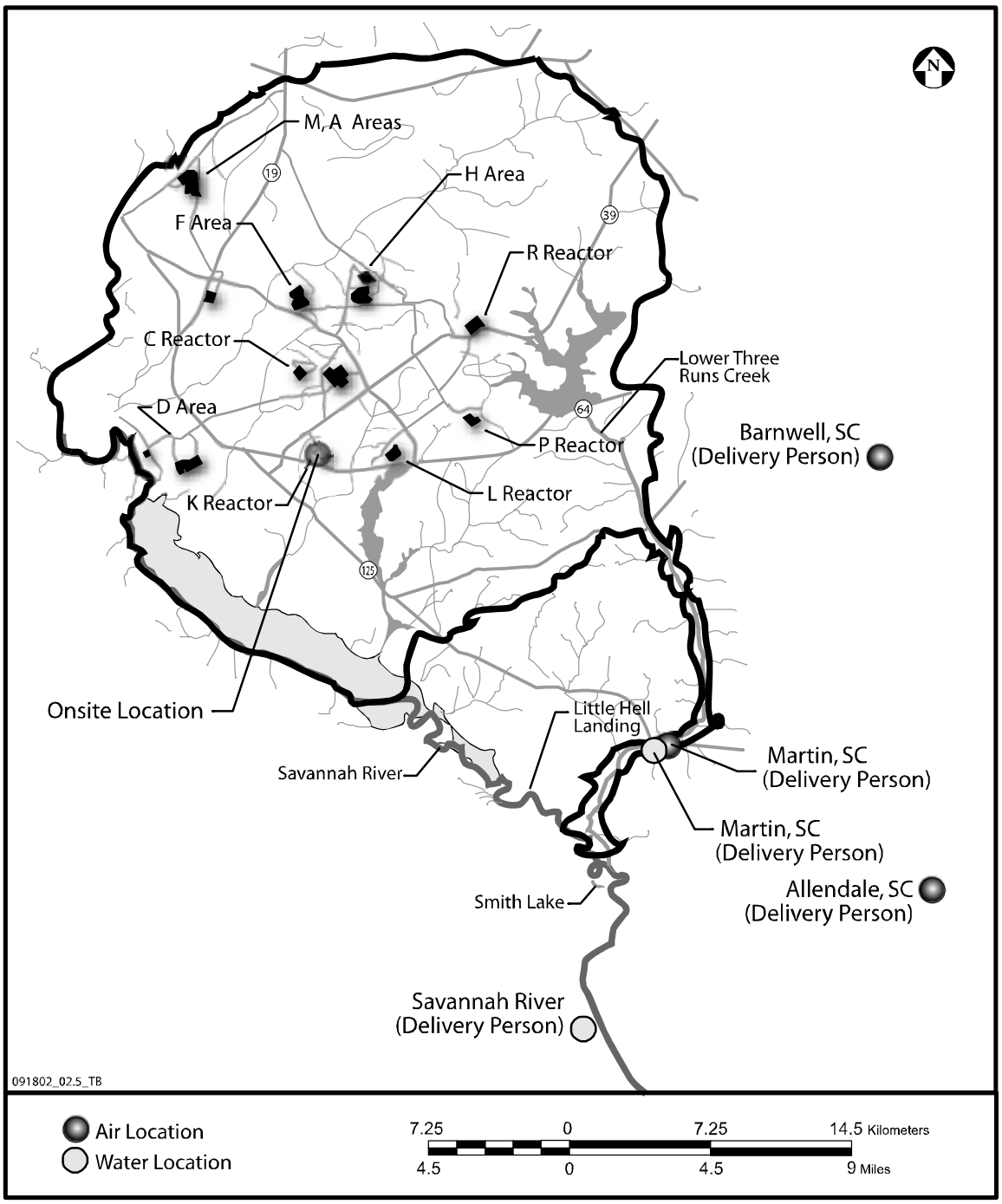

Figure 11-25 Exposure Locations for Delivery Person Family

Half the family's milk and eggs came from cows and hens located in Barnwell, and half from cows and hens located in Martin. In addition, half the family's beef and poultry came from Barnwell and half from Martin. Half of the beef and poultry from Barnwell was actually produced in the Barnwell area (and therefore possibly contained radionuclides from SRS), and half was acquired (e.g., by stores) from sources away from the SRS area.

Of the beef and poultry from Martin, 25% consisted of meat from hunting deer and wild fowl. [14] That is, 25% of the beef from Martin consisted of locally-hunted venison while

25% of the poultry from Martin consisted of locally-hunted wild fowl. Of the remaining 75% of the beef and poultry from Martin, half was produced in the Martin area, and half was acquired (e.g., by stores) from sources well away from SRS.[15]

Half the leafy vegetables, root vegetables, and fruit came from Barnwell and half from Martin. Half of this produce from Barnwell was locally-grown, as was half of this produce from Martin.[16] Half of the corn eaten by the family was grown in Barnwell and half was grown in Martin. Half of the fish was caught in Lower Three Runs Creek at Martin, and half was caught in Smith Lake.

11.2.5.1 Effective Dose and Total Risk

Table 11-15 lists the effective dose and cancer risks for each member of the Delivery Person Family over 39 years of SRS operation. The doses and risks included those from radionuclides released into surface water as well as radionuclides released into the air.

Table 11-15 39-Year Effective Dose and Risks for Delivery Person Family

Dose or Risk	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Effective Dose (mSv)				
Air Pathways	0.40	0.57	2.1	0.12
Water Pathways	5.7	5.7	3.1	2.0
All Pathways	6.1	6.3	5.2	2.1
Cancer Incidence Risk (%)				
Air Pathways	0.0012	0.0017	0.022	0.0018
Water Pathways	0.027	0.027	0.048	0.031
All Pathways	0.028	0.029	0.070	0.033
Cancer Fatality Risk (%)				
Air Pathways	0.00050	0.00074	0.0038	0.0011
Water Pathways	0.020	0.020	0.032	0.021
All Pathways	0.020	0.021	0.036	0.022

The Adult Male received an effective dose of 6.3 mSv (630 mrem), the Adult Female received an effective dose of 6.1 mSv (610 mrem), and the Child Born in 1955 received an effective dose of 5.2mSv (520 mrem). The dose for the Child Born in 1964 was about one-half to one-third of the dose for the other

[14] Recall from Chapter 8 and Appendix D that consumption of game animals was modeled as consumption of additional beef and poultry.

[15] Combining the venison and wild fowl obtained from hunting with other beef and poultry obtained in Martin, it was assumed that 62.5% of all beef (including venison) obtained from Martin potentially contained radionuclides from SRS, as did 62.5% of all poultry (including wild fowl) eaten by the family.

[16] In other words, 50% of the vegetables and fruit obtained from Barnwell potentially contained radionuclides released by SRS, as did 50% of the vegetables and fruit obtained from Martin.

family members. The Child Born in 1955 had the largest cancer risks in this scenario; the Child Born in 1964 had the smallest.

Although the doses received from only the air pathways were comparable for most Delivery Family members to those received by Rural Family One members, the addition of the water pathways raised the overall doses received by the Delivery Family members to levels much larger than those received by Rural Family One members. The distribution of dose between all air pathways and all surface water pathways is shown in Figure 11-26. Except for the Child Born in 1955, surface water pathways caused at least 91% of the entire dose over 39 years. For that child, however, air pathways contributed 41% of his entire dose while water pathways contributed 59%.

In the previous four scenarios based on air pathways only, the Child Born in 1955 always received the largest dose. But here, when doses through all water pathways are added to those through all air pathways, the Adult Male received the largest dose. This dose resulted mainly from eating fish containing radionuclides (see below).

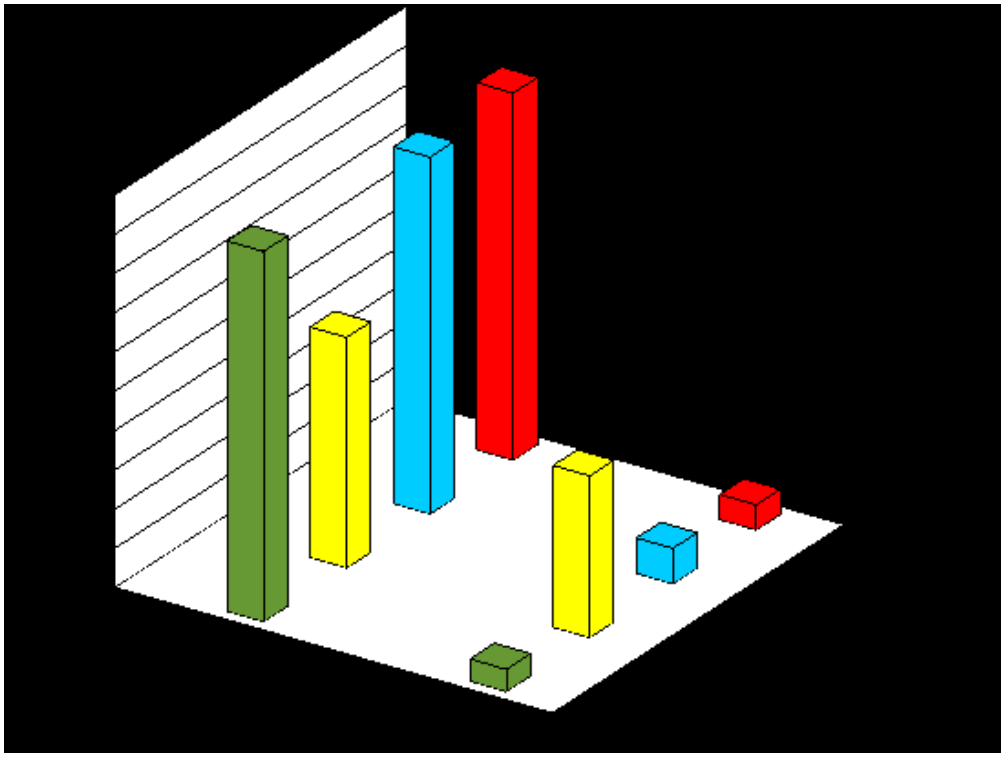

Figure 11-26 Distribution of 39-Year Effective Dose (%) Between Air and Water Pathways for Delivery Person Family

11.2.5.2 Effective Dose by Year

The percent of the entire dose contributed each year for each family member is shown in Figure 11-27, while Figure 11-28 shows the annual dose for each member of the Delivery Person Family. Table 11-16 lists the percent of the entire 39-year effective dose received each year by each family member, as well as their annual dose. These two figures and table include doses from all air and all water pathways.

The Child Born in 1955 received the largest annual dose of any family member: In 1956, he received 1.6 mSv (160 mrem), or 30% of his entire dose. In 1958, the Adult Female and Adult Male each received

their largest annual dose: the Adult Female received 1.0 mSv (100 mrem), or 17% of her entire dose, while the Adult Male also received 1.0 mSv (100 mrem), or 16% of his entire dose. The largest annual dose for the Child Born in 1964 occurred in 1964 when he received 0.55 mSv (55 mrem), or 15% of his entire dose.

Figure 11-29 shows the annual effective dose received by each family member from all air pathways. Annual doses from the air pathways followed a similar pattern as those for previous scenarios. Most doses were received during the early days of operation. During 1956, the Adult Female received 0.18 mSv (18 mrem), or 46% of her dose from all air pathways, the Adult Male received 0.26 mSv (26 mrem), or 46% of his dose from all air pathways, and the Child Born in 1955 received 1.5 mSv (150 mrem), or 71% of his dose from all air pathways. In 1964, the Child Born in 1964 received 0.017 mSv (1.7 mrem), or 15% of his dose from all air pathways.

Figure 11-29 shows that the annual doses received by the two children eventually merged with doses received by the Adult Male, when the children began work in Allendale and at SRS when each child reached age 18. The dose curves for the Adult Male and two children tended to "separate" from that for the Adult Female in later years, although the separation is not as pronounced as that seen Figure 11-15 for the Urban/Suburban Family. This occurred because the Adult Male and grown children of the Delivery Family spent much less time on the SRS site than did the Adult Male and grown children of the Urban/Suburban Family.[17]

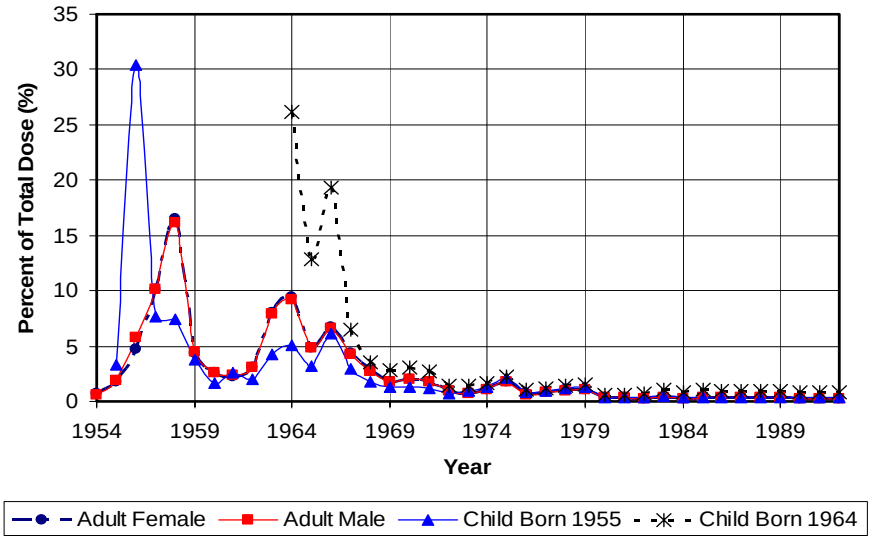

Figure 11-27 Percent of 39-Year Effective Dose by Year for Delivery Person Family – Air + Water Pathways

[17] For the Urban/Suburban scenario, the Adult Male (and two children when they each reached age 18) spent 2,000 hours per year on the SRS site. But for the Delivery Family Scenario, the Adult Male (and two children when they each reached age 18) spent only 400 hours per year on the SRS site.

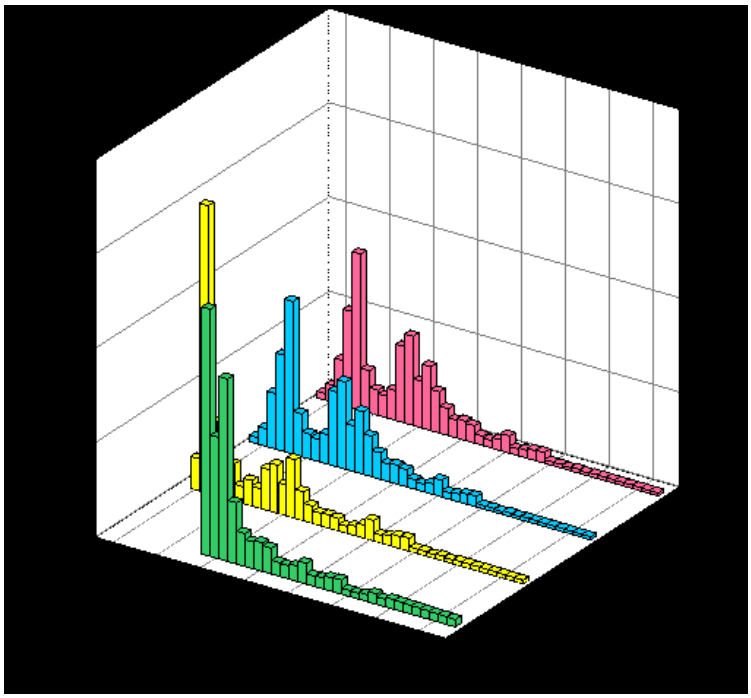

Figure 11-28 Annual Effective Dose (Sv) for Delivery Person Family – Air + Water Pathways

Table 11-16 Annual Effective Dose (mSv) for Delivery Person Family

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
1954	0.040	0.6	0.040	0.6				
1955	0.11	1.7	0.12	1.8	0.17	3.3		
1956	0.29	4.7	0.37	5.8	1.58	30.4		
1957	0.62	10.2	0.64	10.2	0.40	7.7		
1958	1.0	16.5	1.0	16.1	0.39	7.5		
1959	0.27	4.4	0.28	4.5	0.20	3.8		
1960	0.16	2.6	0.16	2.6	0.088	1.7		
1961	0.14	2.3	0.15	2.3	0.13	2.6		
1962	0.19	3.1	0.19	3.1	0.10	2.0		
1963	0.49	8.0	0.50	7.9	0.22	4.3		
1964	0.57	9.4	0.58	9.2	0.26	5.0	0.55	26.2
1965	0.30	4.9	0.30	4.8	0.17	3.2	0.271	12.9
1966	0.41	6.7	0.41	6.6	0.32	6.1	0.40	19.3
1967	0.26	4.3	0.27	4.3	0.16	3.0	0.14	6.5
1968	0.17	2.8	0.17	2.8	0.092	1.8	0.073	3.5
1969	0.11	1.8	0.11	1.8	0.065	1.2	0.060	2.8
1970	0.12	2.0	0.12	2.0	0.069	1.3	0.064	3.0
1971	0.11	1.8	0.11	1.8	0.063	1.2	0.057	2.7
1972	0.059	1.0	0.060	1.0	0.034	0.6	0.030	1.5
1973	0.046	0.8	0.048	0.8	0.048	0.9	0.029	1.4

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
1974	0.066	1.1	0.067	1.1	0.067	1.3	0.034	1.6
1975	0.11	1.8	0.11	1.7	0.11	2.1	0.046	2.2
1976	0.040	0.7	0.041	0.6	0.041	0.8	0.023	1.1
1977	0.049	0.8	0.050	0.8	0.050	1.0	0.024	1.2
1978	0.062	1.0	0.063	1.0	0.063	1.2	0.030	1.4
1979	0.067	1.1	0.067	1.1	0.067	1.3	0.032	1.5
1980	0.020	0.3	0.021	0.3	0.021	0.4	0.013	0.6
1981	0.020	0.3	0.021	0.3	0.021	0.4	0.013	0.6
1982	0.015	0.2	0.015	0.2	0.015	0.3	0.015	0.7
1983	0.022	0.4	0.023	0.4	0.023	0.4	0.023	1.1
1984	0.016	0.3	0.016	0.3	0.016	0.3	0.016	0.8
1985	0.020	0.3	0.021	0.3	0.021	0.4	0.021	1.0
1986	0.020	0.3	0.020	0.3	0.020	0.4	0.020	1.0
1987	0.019	0.3	0.020	0.3	0.020	0.4	0.020	0.9
1988	0.019	0.3	0.020	0.3	0.020	0.4	0.020	0.9
1989	0.019	0.3	0.019	0.3	0.019	0.4	0.019	0.9
1990	0.018	0.3	0.018	0.3	0.018	0.3	0.018	0.9
1991	0.017	0.3	0.017	0.3	0.017	0.3	0.017	0.8
1992	0.017	0.3	0.017	0.3	0.017	0.3	0.017	0.8
Total	6.1	100	6.3	100	5.2	100	2.1	100

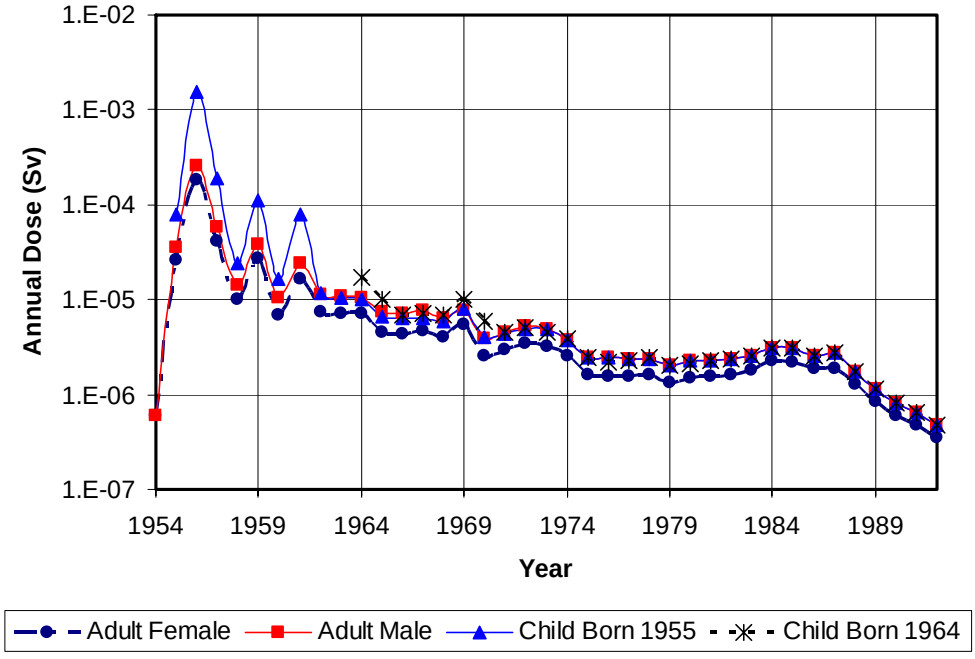

Figure 11-29 Annual Effective Dose (Sv) for Delivery Person Family – Air Pathways Only

Figure 11-30 shows the annual dose from all water pathways. The Adult Female, Adult Male, and Child Born in 1955 each received their largest annual doses from the water pathways in 1958, although doses received in 1964 and 1966 were also relatively large. Doses for these family members were, in 1958:

- Adult Female: 1.0 mSv (100 mrem) – 18% of her dose from all water pathways.
- Adult Male: 1.0 mSv (100 mrem) – 18% of his dose from all water pathways.

Child Born in 1955: 0.36 mSv (36 mrem) – 12% of his dose from all water pathways. The Child Born in 1964 received his largest annual dose – 0.53 mSv (53 mrem) -- from the water pathways in 1964. This dose was 27% of his dose from all water pathways. Another year of relatively large dose for this child was 1966.[18]

The annual doses from the water pathways for the Adult Male and Adult Female were nearly equivalent, mainly because the Adult Male and Adult Female each ate the same annual quantities of fish containing radionuclides.[19] When the children reached age 18, they each ate the same annual quantities of fish as did the two adults. Hence, the curve for the Child Born in 1955 merges with those for the two adults in 1973, and the curve for the Child Born in 1964 merges with those for the two adults in 1982.

The pattern for annual dose from all water pathways (Figure 11-30) is clearly different than the pattern from all air pathways (Figure 11-29). Whereas the annual dose received from the air pathways peaked during the 1950s and early 1960s, and thereafter declined significantly, the annual dose from the water pathways varies over a smaller range. Except for the earliest years, the annual dose from the water pathways was also larger than those from the air pathways. This point is illustrated in Figure 11-31 which shows the annual dose from all air pathways and all water pathways for the Child Born in 1955. Except for the years 1955, 1959, and 1961, annual doses from the water pathways were larger than those for the air pathways. Doses from the air pathways also dropped over the years more abruptly than did doses from the water pathways.

[18] Annual doses received by each family member through all water pathways are listed in Appendix I.
[19] The Adult Female curve on Figure 11.2.5.6 is not seen because the curve for the Adult Male is superimposed over that for the Adult Female.

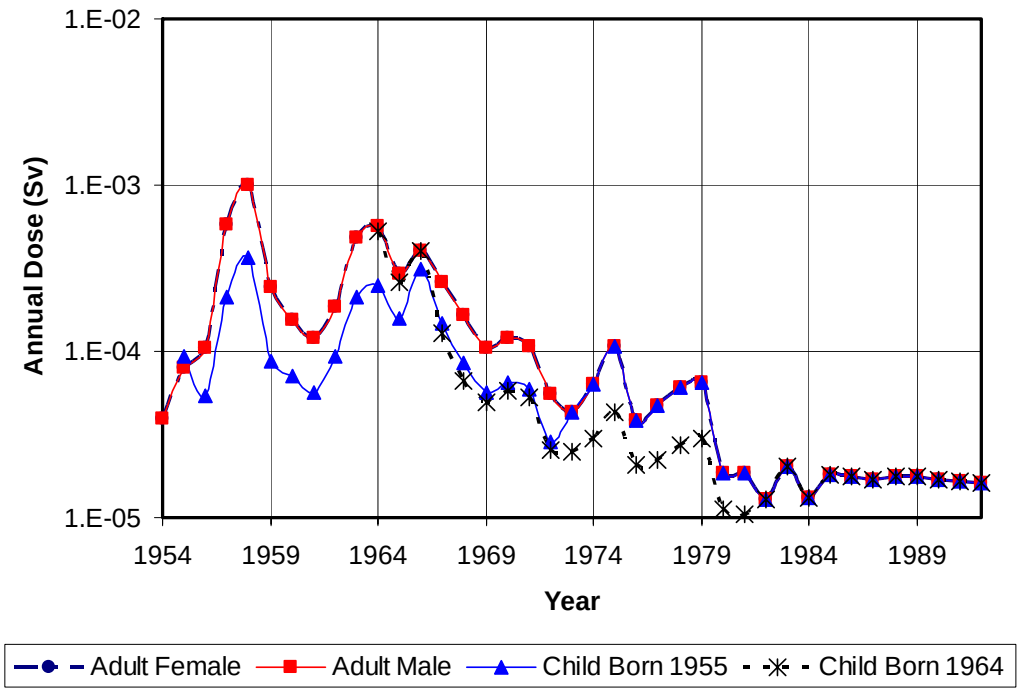

Figure 11-30 Annual Effective Dose (Sv) for Delivery Person Family – Water Pathways Only

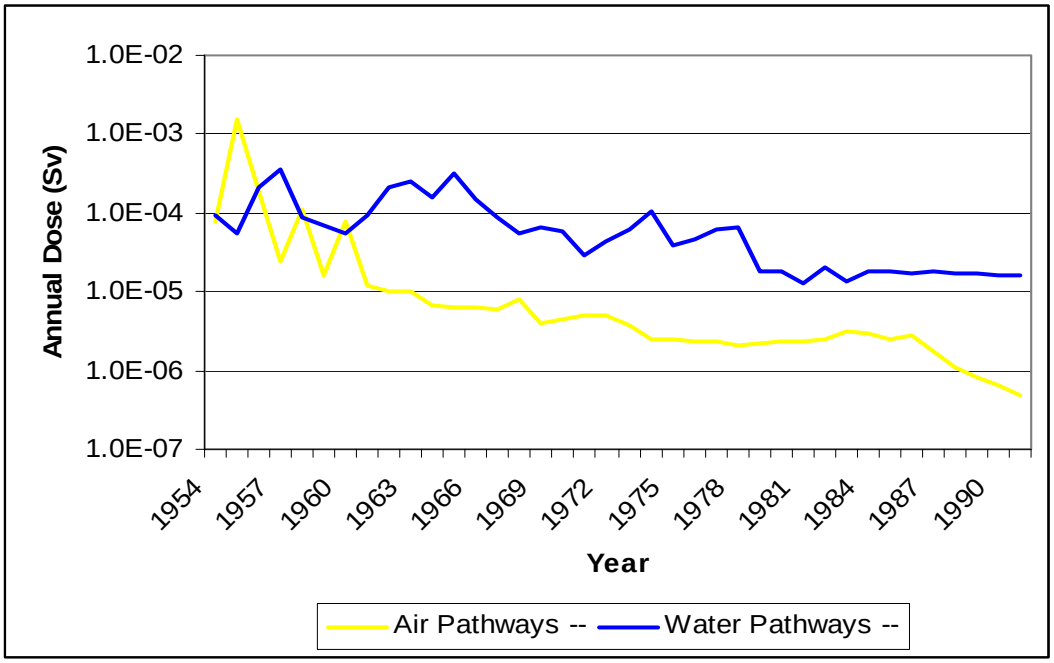

Figure 11-31 Annual Effective Dose (Sv) for Child Born in 1955, Delivery Person Family – Air vs. Water Pathways

11.2.5.3 Dominant Radionuclides, Exposure Routes, and Pathways

Figure 11-32 lists the radionuclides that caused the largest doses for each member of the Delivery Person Family. These radionuclides were different from those dominating dose for the previous scenarios.

For example, although ^{131}I caused most of the dose for the two adults and the Child Born in 1955 of the Urban/Suburban Family (Figure 11-16), ^{137}Cs caused most of the dose for these members of the Delivery Person Family. Although tritium (followed by ^{41}Ar) caused most of the dose for the Child Born in 1955 of the Urban/Suburban Family, ^{137}Cs caused most of the dose for this member of the Delivery Person Family. For all Delivery Person Family members the doses from ^{137}Cs, ^{90}Sr, and ^{32}P came mainly from eating fish containing these radionuclides.

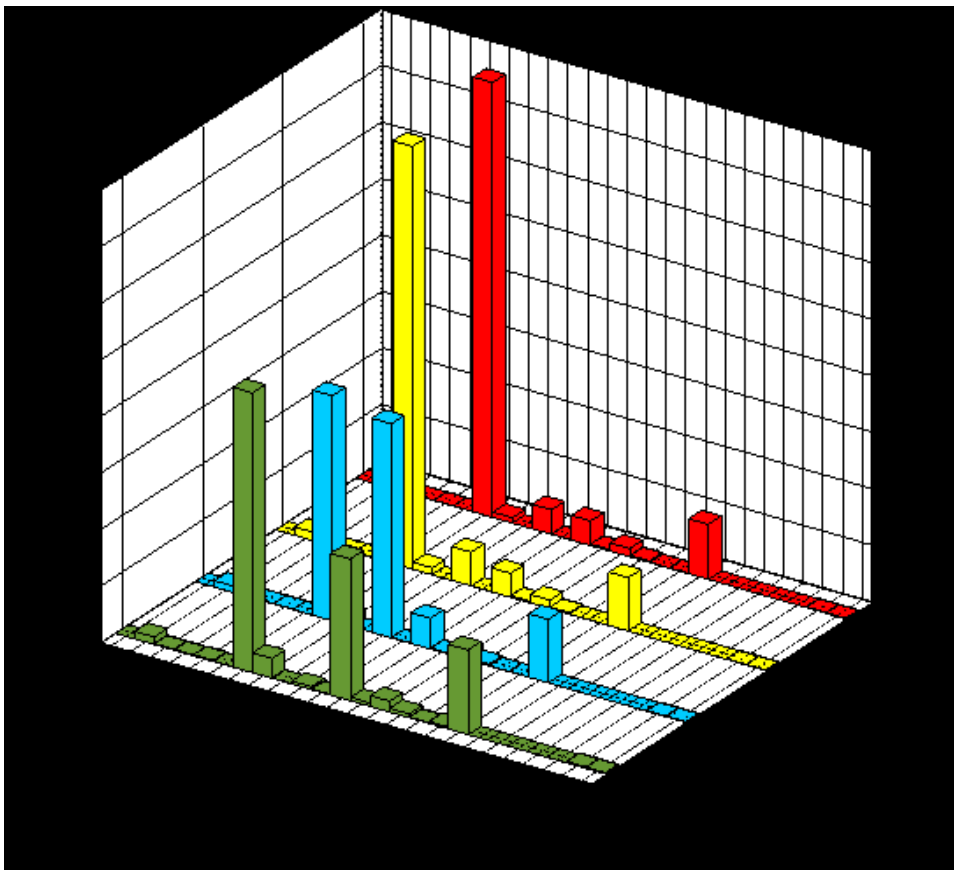

Figure 11-32 Percent of 39-Year Effective Dose by Dominant Isotopes for Delivery Person Family

As shown in Figure 11-33, at least 95% of the entire dose for any member of the Delivery Person Family came from ingestion. External exposure accounted for 2 to 3 percent of the entire dose; inhalation accounted for 1 to 3 percent of the entire dose.

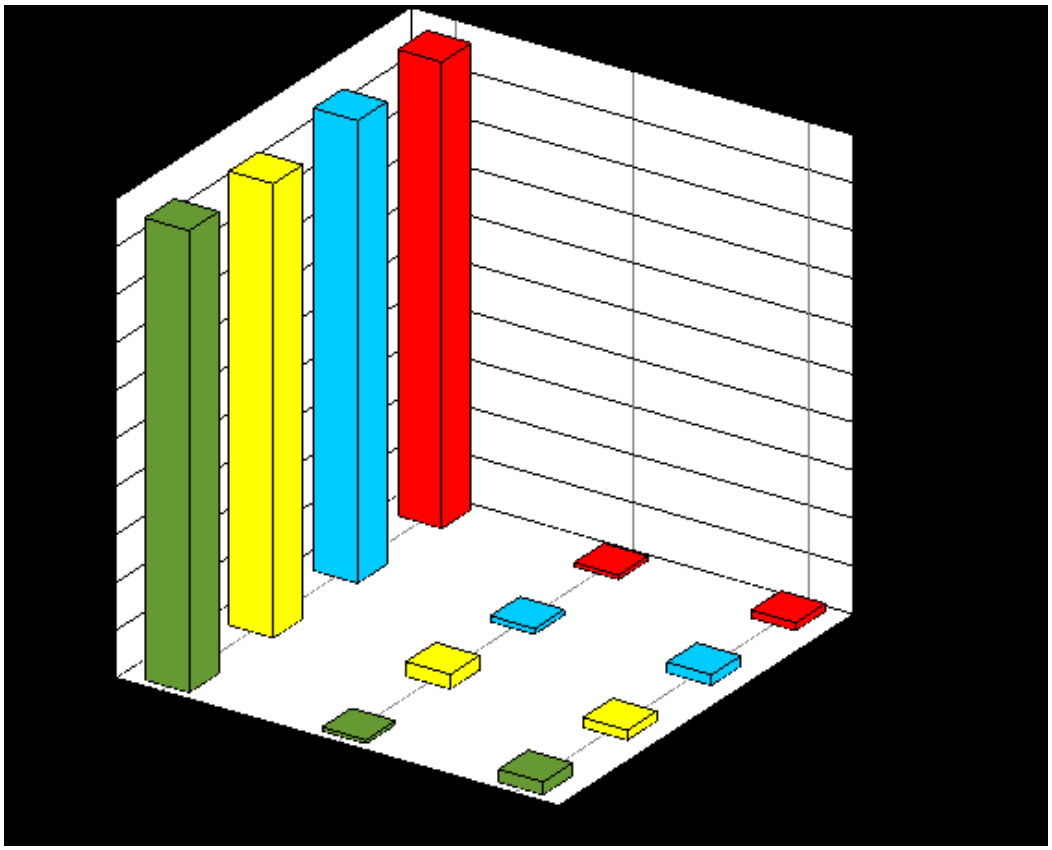

Figure 11-33 Percent of 39-Year Effective Dose by Exposure Route for Delivery Person Family

The dose from ingestion mainly came from eating fish, followed by beef and milk (Table 11-17 and Figure 11-34). At least 90% of the entire dose received by the two adults and the Child Born in 1964 came from eating fish, and from 3 to 6 percent of their dose came from eating beef and milk. Nearly 58% of the entire dose received by the Child Born in 1955 came from eating fish, while 13% of his dose came from eating beef and 22% of his dose came from drinking milk. For all family members, doses from eating vegetables, fruit, grain, eggs, and poultry were comparatively small. Combined doses from eating fruit and vegetables represented no more than 1.5% of any family member's entire dose, and combined doses from eating grain, eggs, and poultry represented no more than 0.2% of any family member's entire dose. Still smaller doses came from inadvertently drinking water while swimming: for all family members they represented less than 0.1% of the entire dose. Doses from inadvertently eating soil were again very small – contributing no more than 0.0003% of the entire dose of any family member over 39 years.

The dose from external radiation exposure primarily came from being immersed in a plume of air containing radionuclides. External doses from air immersion caused from 1 to 1.5 percent of the entire dose received by each family member. Also of interest were the doses caused by activities performed along a contaminated shoreline.[20] Shoreline external doses contributed roughly one percent of the entire dose received by each family member.

[20] Recall that this scenario is modeled in GENII as external exposure to radionuclides deposited from river or water onto shoreline sediments. The model used in GENII uses a transport rate constant of 35,400 L/m^2/y for all radionuclides, a value that was chosen for use in GENII based on river and sediment samples mostly obtained from the Columbia River. The model also took into account that exposures would occur from radionuclides deposited on a finite plane surface (the narrow width of the shoreline) as opposed to an large, semi-infinite plane surface.

Inhalation doses from breathing a cloud of air containing radionuclides were again much larger than the inhalation doses received from breathing radionuclides that had been resuspended from soil.

Table 11-17 39-Year Effective Dose (mSv) by Exposure Pathway for Delivery Person Family

		Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Route	**Pathway**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
External	Air Immersion	0.055	0.9	0.093	1.5	0.060	1.2	0.028	1.3
	Boating	$8.2x10^{-5}$	<0.1	$8.2x10^{-5}$	<0.1	$8.2x10^{-5}$	<0.1	$5.2x10^{-5}$	<0.1
	Ground Contamination	0.0047	0.1	0.0046	0.1	0.0047	0.1	$1.8x10^{-4}$	<0.1
	Shoreline	0.044	0.7	0.044	0.7	0.044	0.8	0.029	1.4
	Swimming	$5.9x10^{-5}$	<0.1	$5.9x10^{-5}$	<0.1	$5.8x10^{-5}$	<0.1	$2.6x10^{-5}$	<0.1
Ingestion	Beef	0.16	2.6	0.25	3.9	0.69	13.3	0.015	0.7
	Eggs	0.0023	<0.1	0.0038	0.1	0.0034	0.1	0.0023	0.1
	Fish	5.7	92.8	5.7	90.2	3.0	57.9	1.9	92.9
	Fruit	0.011	0.2	0.011	0.2	0.038	0.7	0.0069	0.3
	Grain	0.0016	<0.1	0.0019	<0.1	0.0031	0.1	$8.8x10^{-4}$	<0.1
	Inadvertent swimming ingestion	$7.7x10^{-4}$	<0.1	$7.7x10^{-4}$	<0.1	0.0011	<0.1	$8.0x10^{-4}$	<0.1
	Leafy Vegetables	0.016	0.3	0.016	0.2	0.025	0.5	0.0012	0.1
	Milk	0.080	1.3	0.11	1.7	1.14	21.9	0.041	2.0
	Poultry	0.0014	<0.1	0.0017	<0.1	0.0018	<0.1	0.0011	0.1
	Root Vegetables	0.0089	0.1	0.012	0.2	0.016	0.3	0.0056	0.3
	Soil*	$9.8x10^{-7}$	<0.1	$9.5x10^{-7}$	<0.1	$1.5x10^{-5}$	<0.1	$1.6x10^{-7}$	<0.1
Inhalation	Air Inhalation	0.059	1.0	0.077	1.2	0.16	3.1	0.017	0.8
	Resuspended Soil	$8.2x10^{-5}$	<0.1	$1.0x10^{-4}$	<0.1	$7.7x10^{-5}$	<0.1	$1.6x10^{-5}$	<0.1
Total		6.1	100	6.3	100	5.2	100	2.1	100

* Doses from the soil ingestion pathway were on the order of 10^{-7} to 10^{-5} mSv for each family member. These doses were no more than 0.0003% of any family member's entire 39-year dose.

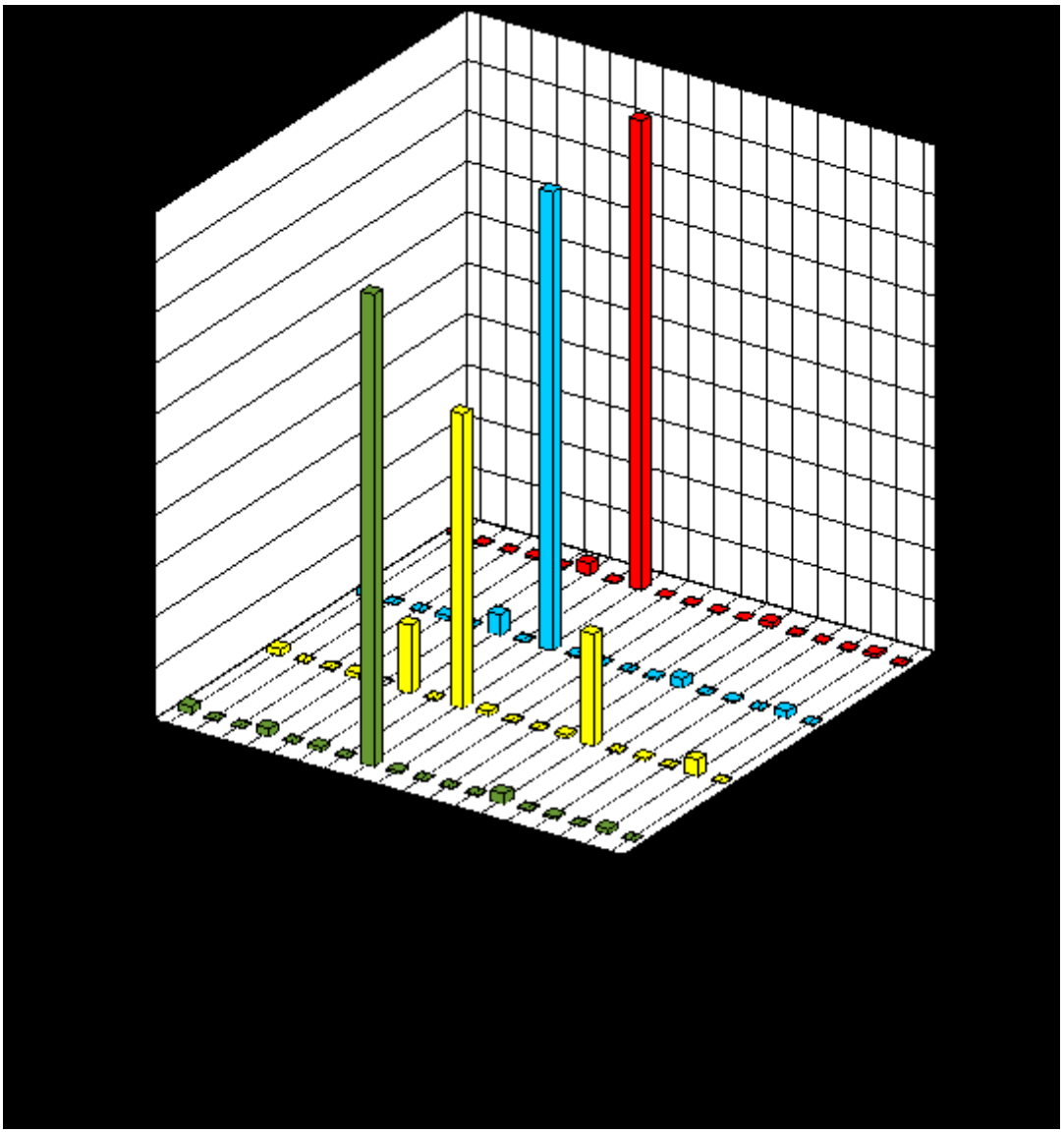

Figure 11-34 Percent of 39-Year Effective Dose by Exposure Pathway for Delivery Person Family

11.2.6 Outdoors Person Family

This hypothetical family lived in Jackson, SC, and all family members stayed there for most activities, including school and religious services. When the children grew up, they also lived in Jackson. The Adult Male worked onsite at SRS as a hunter, for 2000 hours out of each year, as did the children when they reached age 18. His job required him to spend 260 hours each year boating on the Savannah River. The Adult Male took game animals in the form of deer and birds, and caught fish from the Savannah River.[21] The children performed similar activities after they started work (Figure 11-35).

[21] It was assumed that he would be exposed to radionuclides discharged into the Savannah River from all surface water sources from SRS, including Lower Three Runs Creek. To determine exposures from air pathways, it was assumed a single onsite exposure location to represent all the locations that he might have occupied while working.

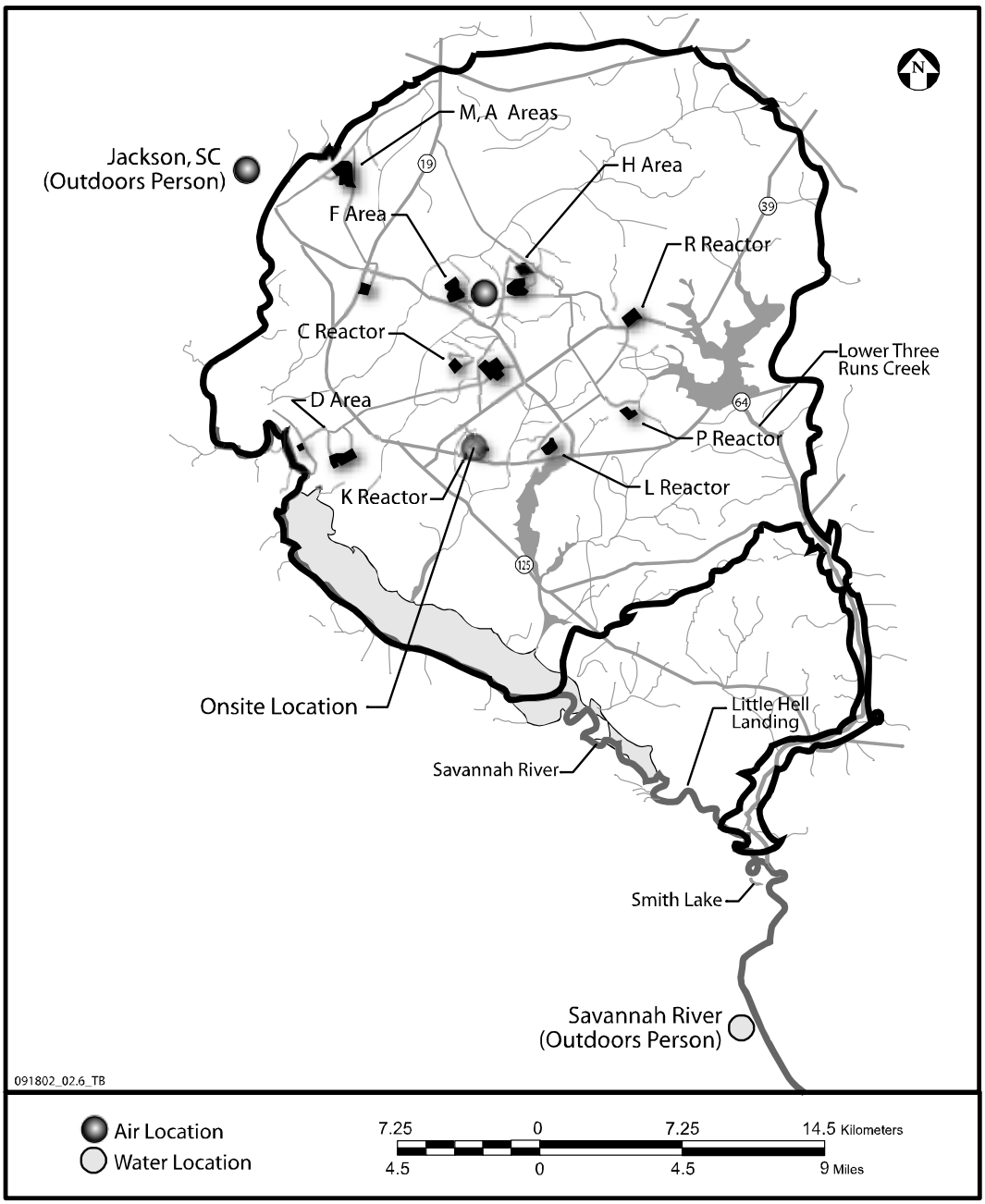

Figure 11-35 Exposure Locations for Outdoors Person Family

All family members (including the adult male) swam, camped, and fished on the Savannah River near the Jackson, SC, boat ramp (upstream of the site). They boated, however, in the Savannah River downstream of the discharge from SRS.

All milk and eggs came from cows and hens located in Jackson. Hence, it was assumed that all milk and eggs contained radionuclides released by SRS into the air. Half the leafy and root vegetables and fruit were grown in Jackson, and half came from sources away from the SRS area. All of the family corn was grown in Jackson.

Three-quarters of the family's beef and poultry consisted of venison and wild fowl that was hunted by the Adult Male on the SRS site. All of this meat contained radionuclides from SRS operations. Their remaining beef and poultry came from other sources such as stores. Of this remaining 25%, half was produced in Jackson (and therefore contained radionuclides from SRS operations and half came from sources away from the SRS area. All fish taken from the Savannah River contained radionuclides from SRS operations.[22]

11.2.6.1 Effective Dose and Total Risks

Table 11-18 lists effective dose and cancer risks for the Outdoors Person Family over 39 years of SRS operation. These doses and risks included those from exposure to radionuclides released into the air as well as to radionuclides released into surface water. The Child Born in 1955 received the largest dose (9.4 mSv, or 940 mrem) and risks while the Child Born in 1964 received the smallest dose (1.8 mSv, or 180 mrem) and risks.

Table 11-18 39-Year Effective Dose and Cancer Risks for Outdoors Person Family

Total Dose or Risk	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Effective Dose (mSv)				
Air Pathways	1.6	2.5	8.3	0.36
Water Pathways	1.5	1.7	1.2	1.5
All Pathways	3.0	4.2	9.4	1.8
Cancer Incidence Risk (%)				
Air Pathways	0.0042	0.0071	0.082	0.0053
Water Pathways	0.0063	0.0072	0.018	0.030
All Pathways	0.011	0.014	0.10	0.035
Cancer Fatality Risk (%)				
Air Pathways	0.0013	0.0025	0.012	0.0030
Water Pathways	0.0048	0.0055	0.011	0.020
All Pathways	0.0061	0.0080	0.024	0.023

Doses and risks from the air pathways were larger than those for the family members in any other scenario. The Child Born in 1955 received the largest doses from the air pathways: 8.3 mSv (830 mrem) over 39 years. The next largest doses were received by the Adult Male who received 2.5 mSv (250 mrem), and the Adult Female who received 1.6 mSv (160 mrem); the Child Born in 1964 received the smallest dose through the air pathways: 0.36 mSv (36 mrem).

One reason that the doses received by these family members through all air pathways were larger than those for comparable members of other scenarios was because it was assumed that three-quarters of the meat eaten by these family members was venison obtained from the SRS site. The exposure location assumed for deer hunting was much closer to the assumed SRS airborne release points than any other

[22] To determine exposures from consumption of fish, it was assumed that the fish would be taken from areas below the confluence of the Savannah River with Lower Three Runs Creek, so that the fish would be affected by radionuclides discharged into the Savannah River from all SRS surface sources, including Lower Three Runs Creek.

exposure location assumed in this study. From about half to three-quarters of the entire 39-year dose from all air pathways received by any family member came from eating beef (see below). In addition, much of the remaining food eaten by the family came from Jackson, which is located close to (and west-north-west) of the assumed SRS airborne release points.

All family members received comparable doses from the water pathways. The Adult Male received the largest dose; his incremental increase was because he spent much more time than the other family members along the Savannah River shoreline and boating in the Savannah River. His dose from all water pathways was 1.7 mSv (170 mrem) over 39 years. The Adult Female and Child Born in 1964 each received 1.5 mSv (150 mrem), while the Child Born in 1955 received 1.2 mSv (120 mrem). These doses were smaller than those received from the water pathways by members of the Delivery Person Family (Table 11-15).

The percent distribution of dose between air and surface water pathways is shown in Figure 11-36 for the Outdoors Person Family. The water pathways caused a smaller percent of overall dose for members of the Outdoors Person Family than for members of the Delivery Person Family (Figure 11-26). The main difference is Lower Three Runs Creek.

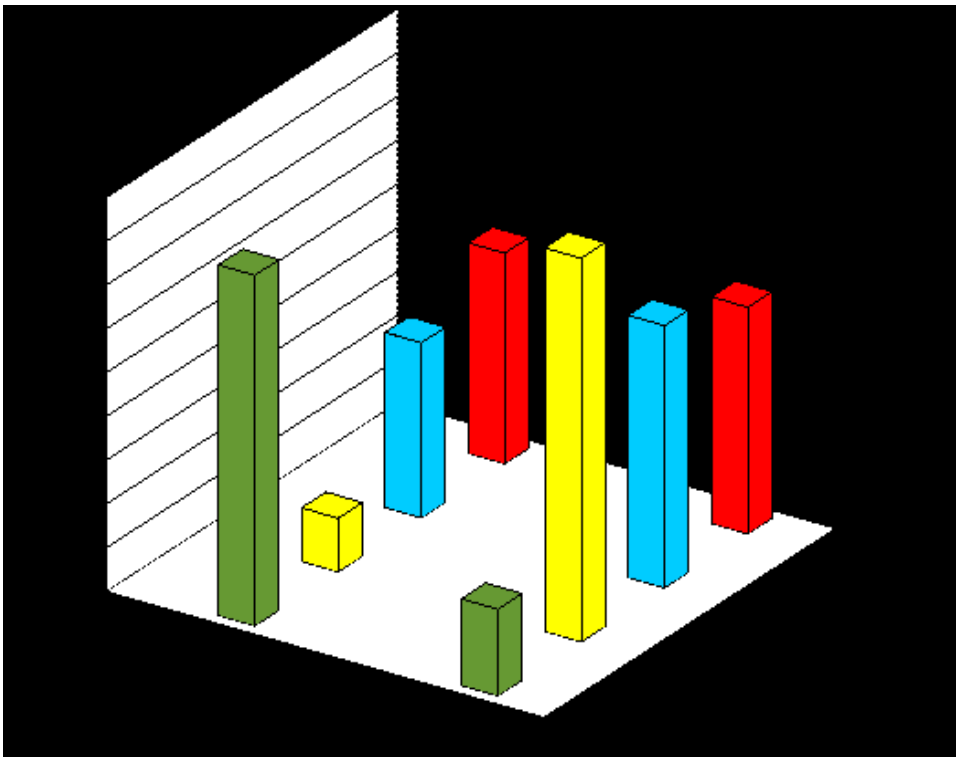

Figure 11-36 Percent Distribution of 39-Year Effective Dose (%) Between Air and Water Pathways for Outdoors Person Family

Members of the Delivery Person family swam in, spent time along the shoreline of, and ate fish taken from Lower Three Runs Creek and the Savannah River. But members of the Outdoors Person Family were not affected by radionuclides in Lower Three Runs Creek. They swam in the Savannah River upstream of SRS's discharge. The Adult Male received shoreline exposures (along the Savannah River) as part of work, as did the two children when they each reached age 18. (The Adult Female spent her entire time along the Savannah River shoreline upstream of SRS's discharge.) All family members

received exposures from boating in the Savannah River as well as exposures from eating fish taken from the Savannah River.

11.2.6.2 Effective Dose by Year

Figure 11-37 shows the percent of the entire dose received by each family member from all (air + water) pathways, while Figure 11-38 shows the percent annual effective dose received by each family member through all pathways. Table 11-19 lists the percent of the entire 39-year effective dose received each year by each family member, as well as their annual dose.

Two large peaks in dose are seen for the years 1956 and 1966, while two smaller peaks are seen for the years 1959 and 1961 (Figure 11-38). The Child Born in 1955 received his largest dose in 1956, when he received 5.9 mSv (590 mrem), or 63% of his entire dose over 39 years. The Adult Female and Adult Male also received their largest doses during this year. The Adult Female received 0.86 mSv (86 mrem), or 28% of her entire dose, while the Adult Male received 1.3 mSv (130 mrem), or 30% of his entire dose. The Child Born in 1964 received his largest dose in 1966, when he received 0.70 mSv (70 mrem), or 38% of his entire dose.

The patterns of annual dose and percent of dose are different from those seen for the Delivery Person Scenario (see Figure 11-27 and Figure 11-28).

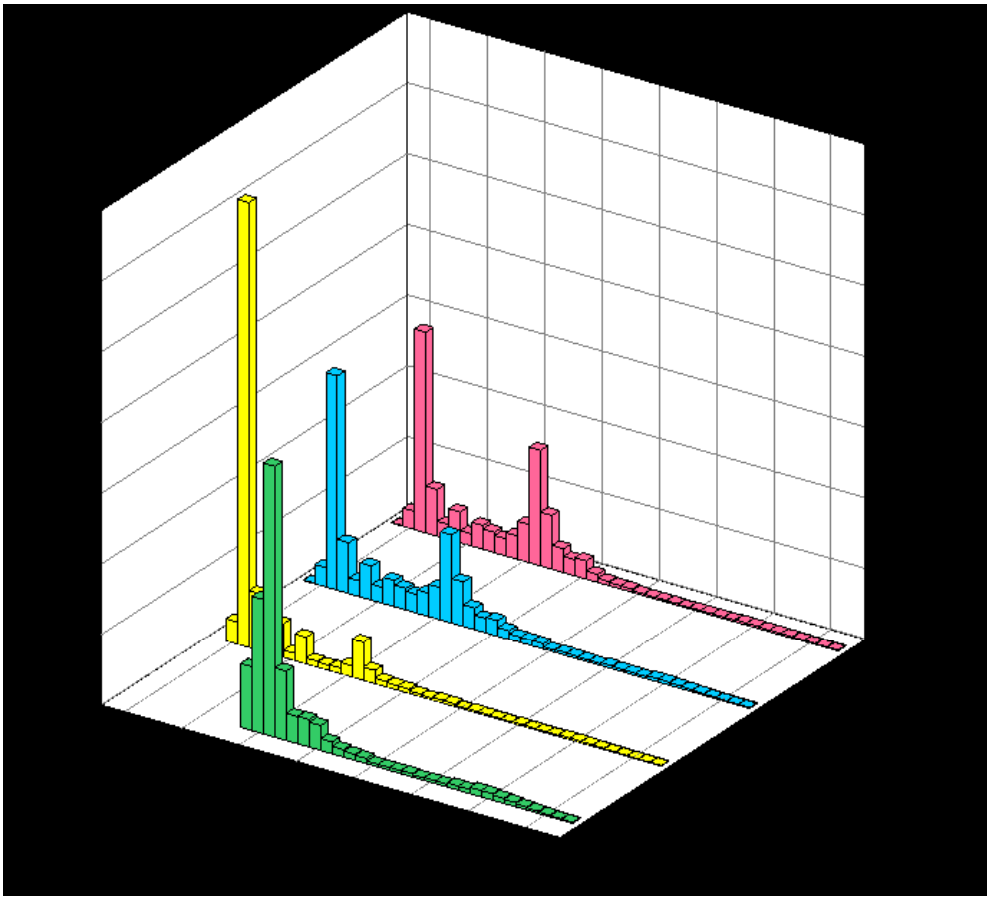

Figure 11-37 Percent of 39-Year Effective Dose by Year for Outdoors Person Family – Air + Water Pathways

Annual doses from all air pathways for the Outdoors Person Family are shown in Figure 11-39. The pattern is familiar. During 1956, the Child Born in 1955 received 5.9 mSv (592 mrem), or 72% of his dose from all air pathways, the Adult Female received 0.84 mSv (84 mrem), or 53% of her dose from all air pathways, and the Adult Male received 1.3 mSv (130 mrem), or 50% of his dose from all air pathways. In 1964, the Child Born in 1964 received 0.045 mSv (4.5 mrem), or 12% of his dose from all air pathways.

Figure 11-40 shows annual effective doses received by each member of the Outdoors Person Family through the water pathways. Annual doses rose to a peak in 1966, and then dropped. After the mid 1970s annual doses fluctuated for all family members between about 0.001 and 0.01 mSv per year. Annual doses through all water pathways were, during 1966:

- Adult Female: 0.48 mSv (48 mrem) -- 33% of her dose from all water pathways.
- Adult Male: 0.50 mSv (50 mrem) -- 30% of his dose from all water pathways.
- Child Born in 1955: 0.48 mSv (48 mrem) -- 42% of his dose from all water pathways.
- Child Born in 1966: 0.68 mSv (68 mrem) -- 47% of his dose from all water pathways.

The annual pattern of dose shown in Figure 11-40 for the water pathways is different than that for the Delivery Person Scenario (Figure 11-30). Whereas for the Delivery Person Scenario the annual doses fluctuated over a range of about 0.01 to 1 mSv, the doses from the water pathways for the Outdoors Person Scenario built to a peak and varied over a larger range. Except for a few years on either side of 1966, annual doses from the water pathways tended to be smaller than those from the air pathways. This second point is illustrated in Figure 11-41, which shows the annual dose from all air pathways and all water pathways for the Child Born in 1955 of the Outdoors Person Family. This pattern is clearly different from that seen for the Child Born in 1955 of the Delivery Person Family (Figure 11-31).

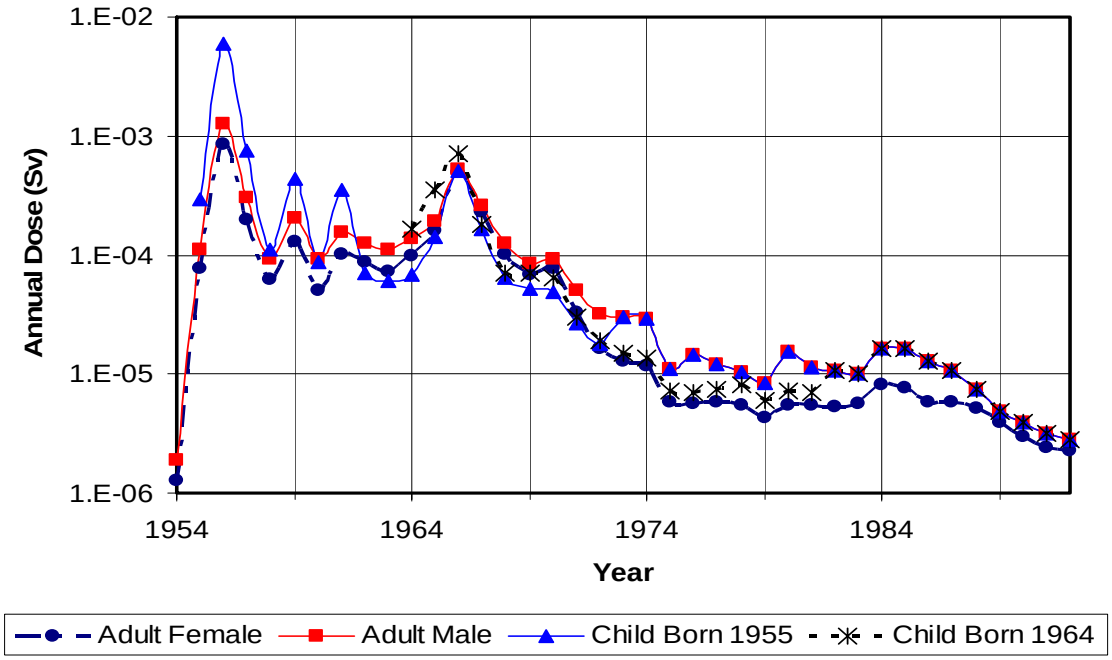

Figure 11-38 Annual Effective Dose (Sv) for the Outdoors Person Family – Air + Water Pathways

Table 11-19 Annual Effective Dose (mSv) for Outdoors Person Family

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	Dose	%	Dose	%	Dose	%	Dose	%
1954	0.0013	0.0	0.0019	0.0				
1955	0.077	2.5	0.11	2.7	0.29	3.1		
1956	0.86	28.3	1.3	30.3	5.9	62.9		
1957	0.20	6.5	0.30	7.2	0.76	8.0		
1958	0.062	2.1	0.09	2.2	0.11	1.2		
1959	0.13	4.3	0.20	4.8	0.44	4.7		
1960	0.050	1.7	0.093	2.2	0.087	0.9		
1961	0.10	3.3	0.15	3.6	0.35	3.7		
1962	0.087	2.8	0.13	3.0	0.070	0.7		
1963	0.072	2.4	0.11	2.6	0.060	0.6		
1964	0.098	3.2	0.14	3.3	0.068	0.7	0.16	9.0
1965	0.16	5.3	0.19	4.5	0.14	1.5	0.35	19.1
1966	0.49	16.3	0.53	12.5	0.50	5.3	0.70	38.4
1967	0.23	7.5	0.26	6.3	0.17	1.8	0.18	9.8
1968	0.10	3.3	0.13	3.0	0.065	0.7	0.070	3.8
1969	0.067	2.2	0.084	2.0	0.052	0.5	0.071	3.9
1970	0.077	2.5	0.092	2.2	0.049	0.5	0.064	3.5
1971	0.033	1.1	0.050	1.2	0.027	0.3	0.030	1.7
1972	0.016	0.5	0.032	0.8	0.018	0.2	0.019	1.0
1973	0.013	0.4	0.030	0.7	0.030	0.3	0.015	0.8
1974	0.012	0.4	0.029	0.7	0.029	0.3	0.014	0.7
1975	0.0058	0.2	0.011	0.3	0.011	0.1	0.0071	0.4
1976	0.0056	0.2	0.014	0.3	0.014	0.2	0.0071	0.4
1977	0.0059	0.2	0.012	0.3	0.012	0.1	0.0074	0.4
1978	0.0056	0.2	0.010	0.2	0.010	0.1	0.0081	0.4
1979	0.0043	0.1	0.0084	0.2	0.0084	0.1	0.0059	0.3
1980	0.0055	0.2	0.015	0.4	0.015	0.2	0.0072	0.4
1981	0.0055	0.2	0.011	0.3	0.011	0.1	0.0071	0.4
1982	0.0054	0.2	0.011	0.3	0.011	0.1	0.011	0.6
1983	0.0057	0.2	0.010	0.2	0.010	0.1	0.010	0.6
1984	0.0082	0.3	0.016	0.4	0.016	0.2	0.016	0.9
1985	0.0076	0.3	0.016	0.4	0.016	0.2	0.016	0.9
1986	0.0058	0.2	0.013	0.3	0.013	0.1	0.013	0.7
1987	0.0058	0.2	0.011	0.3	0.011	0.1	0.011	0.6
1988	0.0052	0.2	0.0074	0.2	0.0074	0.1	0.0074	0.4
1989	0.0045	0.1	0.0055	0.1	0.0055	0.1	0.0055	0.3
1990	0.0030	0.1	0.0039	0.1	0.0039	<0.1	0.0039	0.2
1991	0.0024	0.1	0.0032	0.1	0.0032	<0.1	0.0032	0.2
1992	0.0022	0.1	0.0029	0.1	0.0029	<0.1	0.0029	0.2
Total	3.0	100	4.2	100	9.4	100	1.83	100

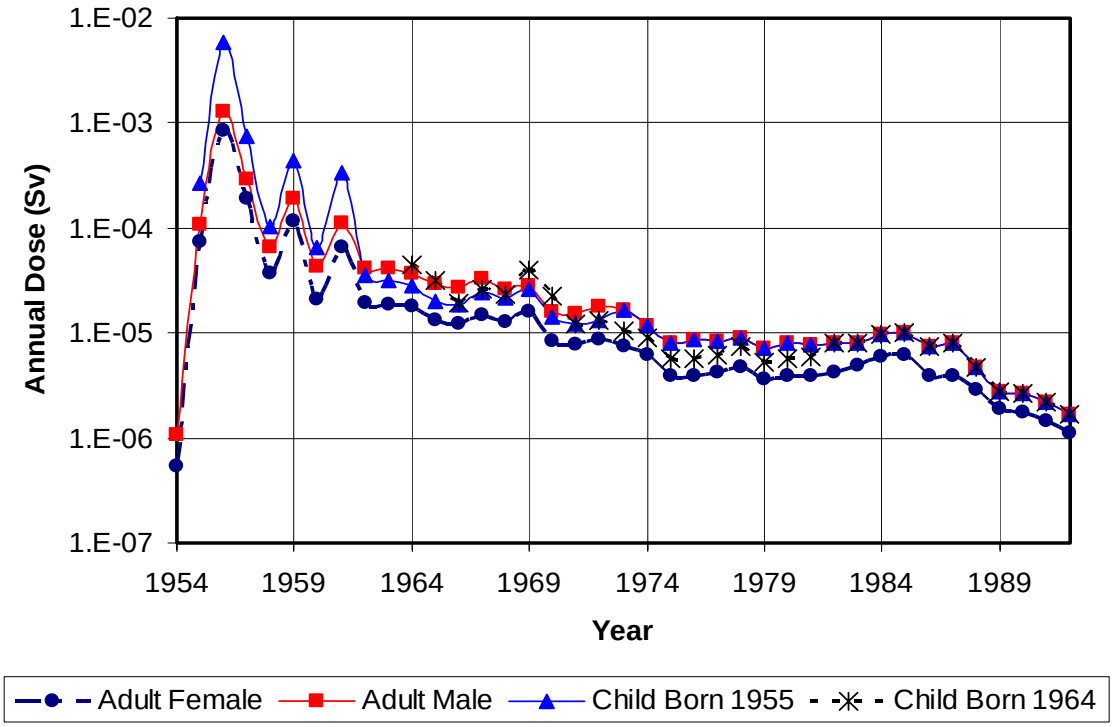

Figure 11-39 Annual Effective Dose (Sv) for the Outdoors Person Family – Air Pathways Only

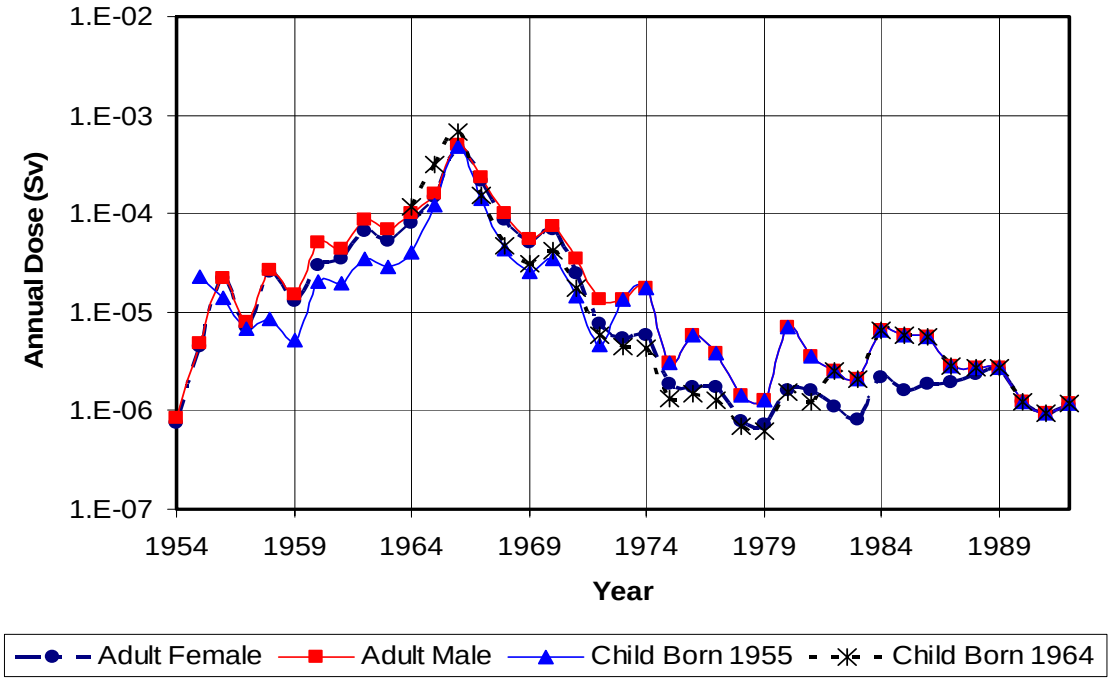

Figure 11-40 Annual Effective Dose (Sv) for Outdoors Person Family – Water Pathways Only

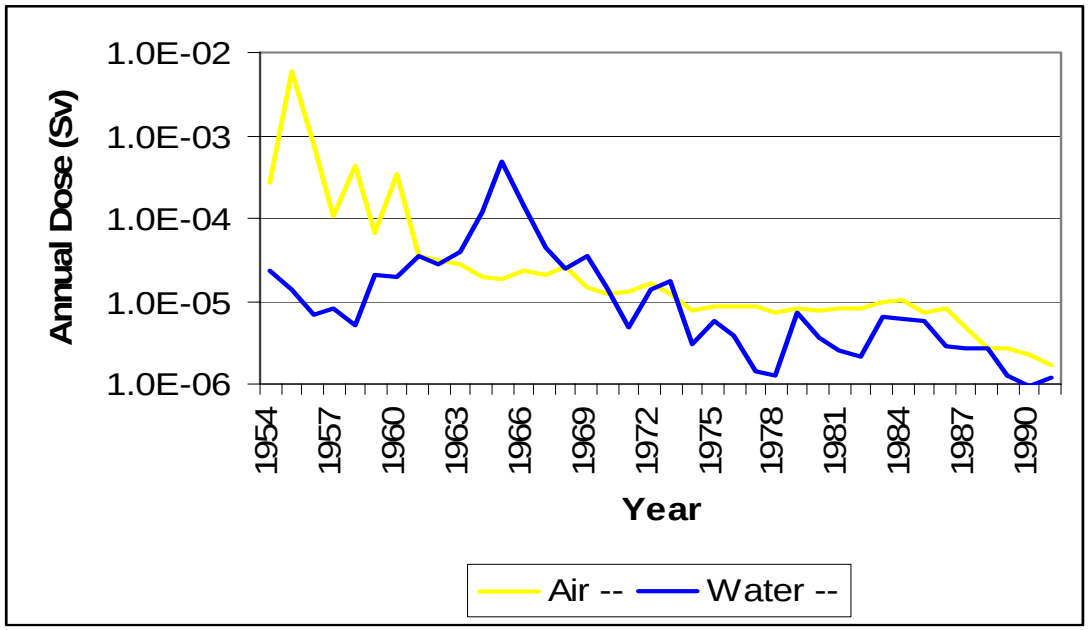

Figure 11-41 Annual Effective Dose (Sv) for Child Born in 1955, Outdoors Person Family – Air vs. Water Pathways

11.2.6.3 Exposure Pathways and Dominant Radionuclides

Figure 11-42 lists the radionuclides causing the largest doses over 39 years for each member of the Outdoors Person Family. For the two adults and the Child Born in 1955, the largest contributor to dose was ^{131}I. This radionuclide caused radiation dose principally from eating foods such as beef and milk. The next two important radionuclides were generally ^{137}Cs and ^{32}P, radionuclides that caused radiation dose principally from eating fish. For the Child Born in 1964, ^{32}P was the largest contributor to radiation dose. It again caused dose mostly from eating fish, as did ^{137}Cs and ^{32}P. Tritium caused dose to this family member mainly from inhaling air and eating foods containing this radionuclide.

Each family member received most of their dose from ingestion (Figure 11-43). From 83 to 95 percent of the dose received by each family member came from ingestion, from 2 to 13 percent came from external exposure to radiation, and from 2 to 4 percent came from inhalation.

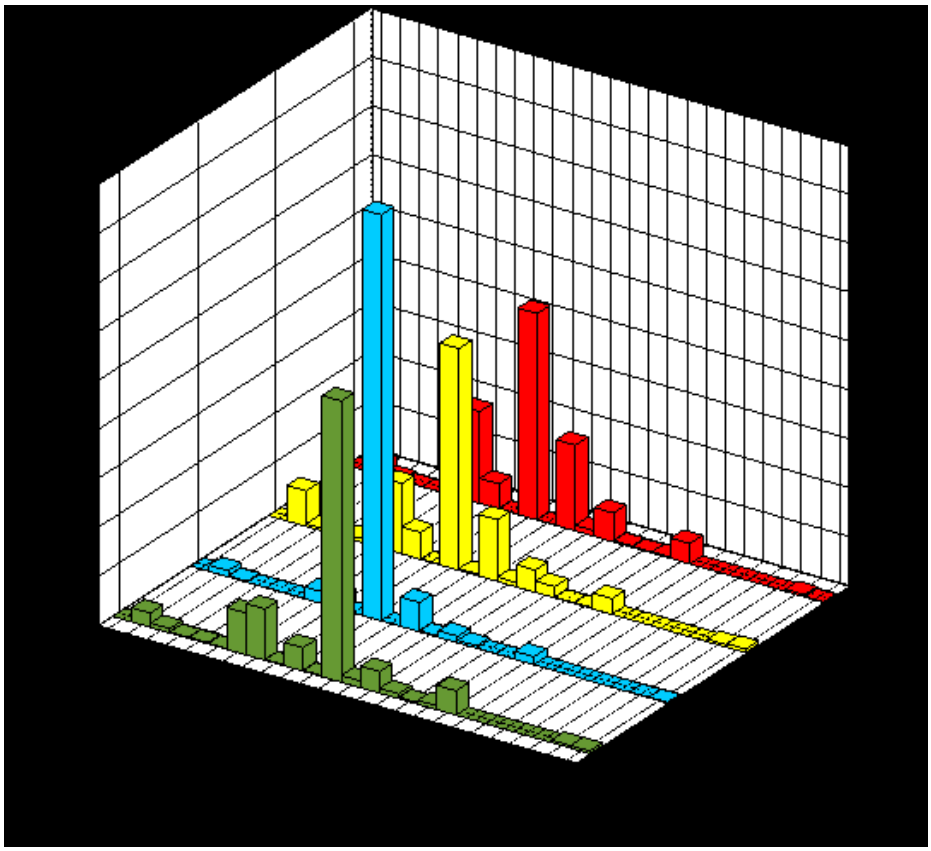

Figure 11-42 Percent of 39-Year Effective Dose by Dominant Isotopes for Outdoors Person Family

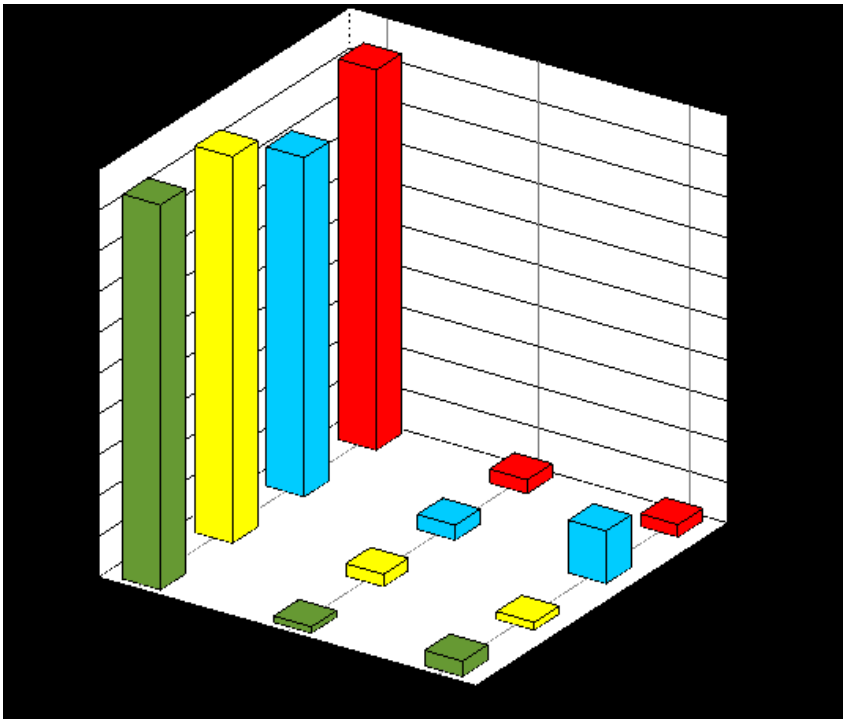

Figure 11-43 Percent of 39-Year Effective Dose by Exposure Route for Outdoors Person Family

As shown in Table 11-20 and Figure 11-44, eating fish was a significant contributor to dose for all family members – i.e., from 12 to 79 percent of any family member's entire dose. It was not, however, as significant as the dose received from eating fish by the members of the Delivery Person Family (Table 11-17). Doses to members of the Outdoors Person family from eating fish were smaller than doses to members of the Delivery Person Family by a factor of up to 3.9. Each member in the Outdoors Person Family ate the same amount of fish as the comparable member of the Delivery Person Family. The doses were different because members of the Delivery Person family ate fish from Lower Three Runs Creek and the Savannah River, while members of the Outdoors Person Family ate fish only from the Savannah River.

Eating beef and milk was a strong contributor to dose for members of the Outdoors Person Family, ranging from 13 to 80 percent of any member's entire dose. The beef and milk pathways were less important for the Child Born in 1964 than for the other family members because he missed the large radionuclide releases into the air during the 1950s and early 1960s. By comparison, doses from eating fruit and vegetables were small, ranging from 1 to 3 percent of any family member's entire dose. Doses from eating eggs, grain, and poultry contributed no more than 1% of any family member's entire dose. Doses from inadvertently eating soil contributed to no more than 0.0004% of any family member's entire dose.

Of interest is the external radiation dose received by the Adult Male (Table 11-20). He received a larger external dose from air immersion than did the Adult Male for the Urban/Suburban Family (Table 11-11). Although they both spent the same amount of time onsite at SRS, the Urban/Suburban Family home in Augusta was farther away from SRS than was the Outdoors Person home in Jackson. In addition, the Adult Male of the Outdoors Person Family received a relatively large dose from shoreline exposure (0.23 mSv, or 23 mrem), contributing about 5% of his entire dose over 39 years. This dose reflected the 260 hours per year he spent along the Savannah River shoreline while at work. By contrast, his doses from boating were relatively small despite the 356 hours per spent boating in the Savannah River.

External radiation doses for the three other members of the Outdoors Person Family ranged from 2 to 4 percent of their entire dose. Most of their external radiation dose came from immersion in a plume of radionuclides in air. Boating in the Savannah River contributed less than 0.1% of their entire dose. Doses from external exposure to radionuclides on the ground were larger, as were doses from shoreline exposures.[23] Still, doses from these pathways were smaller than air immersion doses.

Inhalation doses from breathing a plume of air containing radionuclides were again much larger than the inhalation doses received from breathing radionuclides that had been resuspended from soil.

[23] Except for the Adult Female, who did not experience any shoreline exposures to radionuclides.

Table 11-20 Effective Dose (mSv) by Exposure Pathway for Outdoors Person Family

		Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Route	**Pathway**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
External	Air Immersion	0.084	2.8	0.31	7.3	0.12	1.3	0.053	2.9
	Boating	8.2×10^{-5}	<0.1	3.1×10^{-4}	<0.1	1.3×10^{-4}	<0.1	7.2×10^{-5}	<0.1
	Ground Contamin-ation	0.010	0.3	0.012	0.3	0.011	0.1	4.2×10^{-4}	<0.1
	Shoreline	--	--	0.23	5.4	0.053	0.6	0.017	0.9
Ingestion	Beef	1.1	34.8	1.7	39.3	4.5	47.8	0.16	8.9
	Eggs	0.0041	0.1	0.0068	0.2	0.0062	0.1	0.0039	0.2
	Fish	1.5	48.2	1.5	34.6	1.1	11.8	1.4	79.3
	Fruit	0.028	0.9	0.028	0.7	0.12	1.3	0.012	0.7
	Grain	0.0038	0.1	0.0046	0.1	0.015	0.2	0.0018	0.1
	Leafy Vegetables	0.052	1.7	0.052	1.2	0.088	0.9	0.0024	0.1
	Milk	0.20	6.6	0.27	6.3	3.1	32.4	0.075	4.1
	Poultry	0.011	0.4	0.014	0.3	0.014	0.1	0.010	0.6
	Root Vegetables	0.018	0.6	0.025	0.6	0.037	0.4	0.0099	0.5
	Soil*	2.2×10^{-6}	<0.1	2.4×10^{-6}	<0.1	3.4×10^{-5}	<0.1	3.8×10^{-7}	<0.1
Inhalation	Air Inhalation	0.10	3.4	0.16	3.7	0.29	3.1	0.030	1.6
	Resuspend-ed Soil	1.9×10^{-4}	<0.1	2.6×10^{-4}	<0.1	1.8×10^{-4}	<0.1	3.7×10^{-5}	<0.1
Total		3.0	100	4.2	100	9.4	100	1.8	100

* Doses from the soil ingestion pathway were on the order of 10^{-7} to 10^{-5} mSv for each family member. These doses were no more than 0.0004% of any family member's entire 39-year dose.

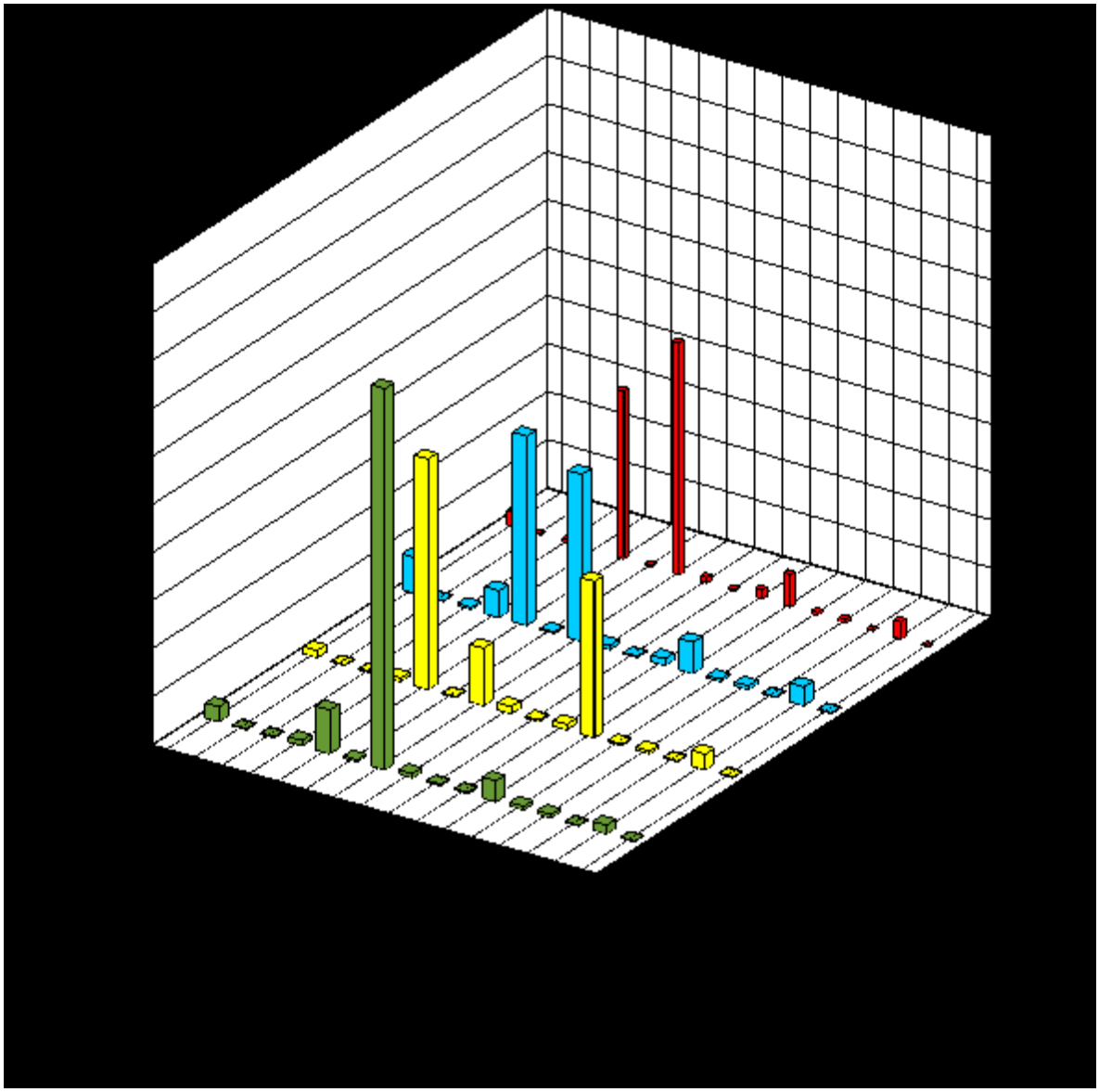

Figure 11-44 Percent of Effective Dose by Exposure Pathways for Outdoors Person Family

11.2.7 Near River Family

This hypothetical family lived in Martin, SC (Figure 11-45). All members spent much of their work, home activities, and recreation time outdoors. The family lived, worked, and went to school and church in Martin, and participated in outdoor activities such as hunting, fishing, and boating. This family spent twice as much time boating (in the Savannah River) as did other families. Each family member spent an average of an hour per day of each year on the Savannah River shoreline, and an average of an hour a day swimming during the summer in the Savannah River.[24] When the children grew up, they continued to live in Martin. The family's milk and eggs all came from cows and hens located in Martin. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in Martin and

[24] All boating, swimming, and shoreline activities took place below the confluence of the Savannah River with Lower Three Runs Creek.

half came from sources outside the SRS vicinity. All of the corn eaten by the family was grown in Martin. All of the fish eaten by the family was caught in the Savannah River below its confluence with Lower Three Runs Creek. Drinking water and any irrigation used to produce the food eaten by the family came from sources unaffected by SRS releases.

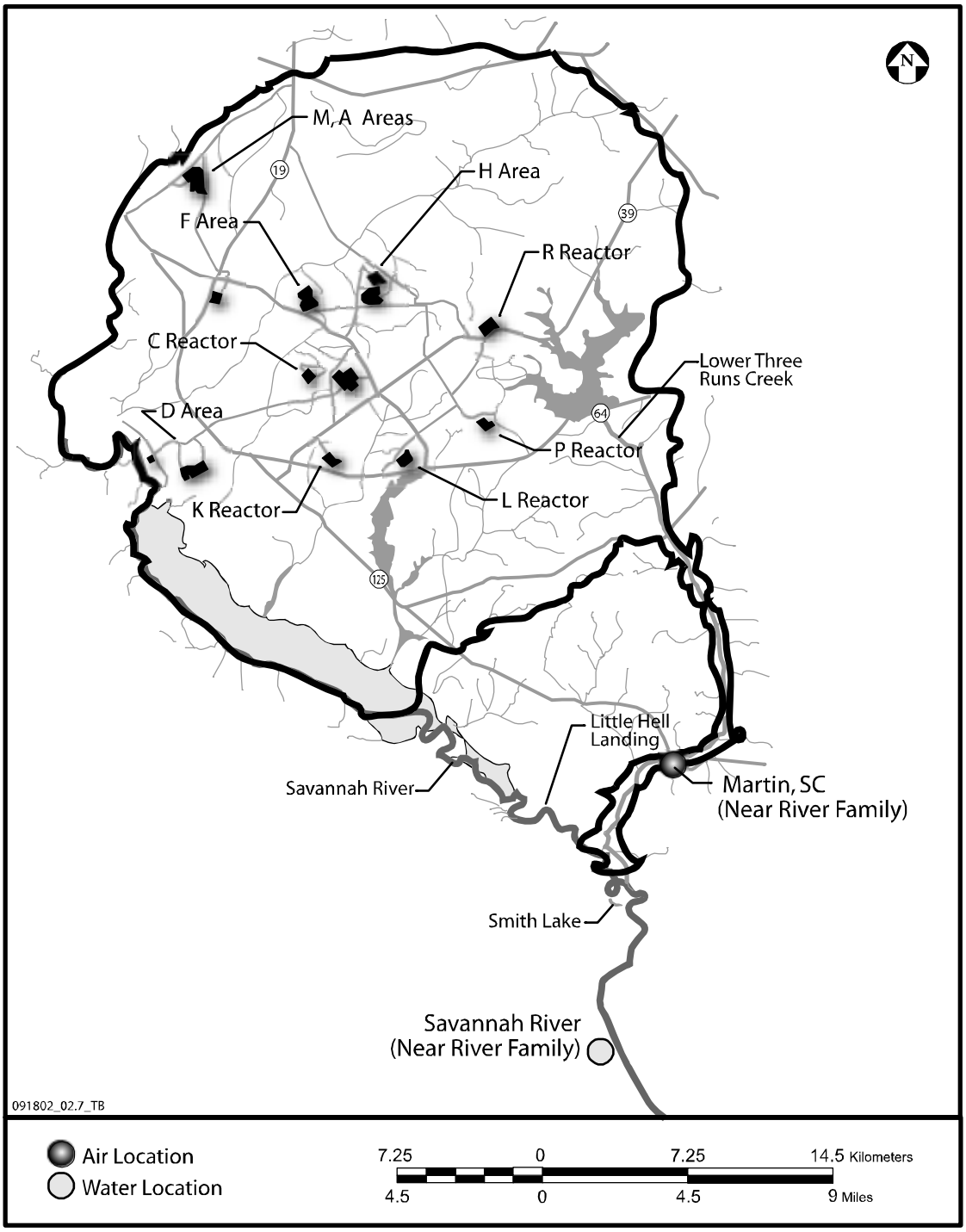

Figure 11-45 Exposure Location for Near Water Family

11.2.7.1 Doses and Total Risks

Table 11-21 lists effective dose and cancer risks for the Near River Family over 39 years of SRS operation. Doses and risks included those from exposure to radionuclides released into the air as well as to radionuclides released into surface water. The Child Born in 1955 received the largest doses and risks; the Child Born in 1964 received the smallest doses and risks.

Doses from all air pathways are similar to those received by members of Rural Family One (Table 11-3). Doses from all water pathways are only a little larger than those received by members of the Outdoors Person Family but much smaller than those received by members of the Delivery Person Family. The members of the Near River Family spent more time in contact with the Savannah River than did the Outdoors Person family, but did not spend time in nor eat fish taken from Lower Three Runs Creek.

Nonetheless, for the two adults and the Child Born in 1964, most radiation doses resulted from the water pathways as illustrated in Figure 11-46. For these family members the water pathways contributed from 81 to 95 percent of their entire dose over 39 years. For the Child Born in 1955, however, the water pathways contributed only 45% of his entire dose over 39 years.

Table 11-21 39-Year Effective Dose and Cancer Risks for Near River Family

Total Dose or Risk	Adult Female	Adult Male	Child Born in 1955	Child Born in 1964
Effective Dose (mSv)				
Air Pathways	0.31	0.42	1.7	0.088
Water Pathways	1.8	1.8	1.4	1.7
All Pathways	2.1	2.2	3.1	1.8
Cancer Incidence Risk (%)				
Air Pathways	0.00089	0.0012	0.017	0.0013
Water Pathways	0.0076	0.0076	0.021	0.033
All Pathways	0.0085	0.0088	0.038	0.034
Cancer Fatality Risk (%)				
Air Pathways	0.00036	0.00044	0.0028	0.00084
Water Pathways	0.0057	0.0057	0.014	0.021
All Pathways	0.0061	0.0062	0.017	0.022

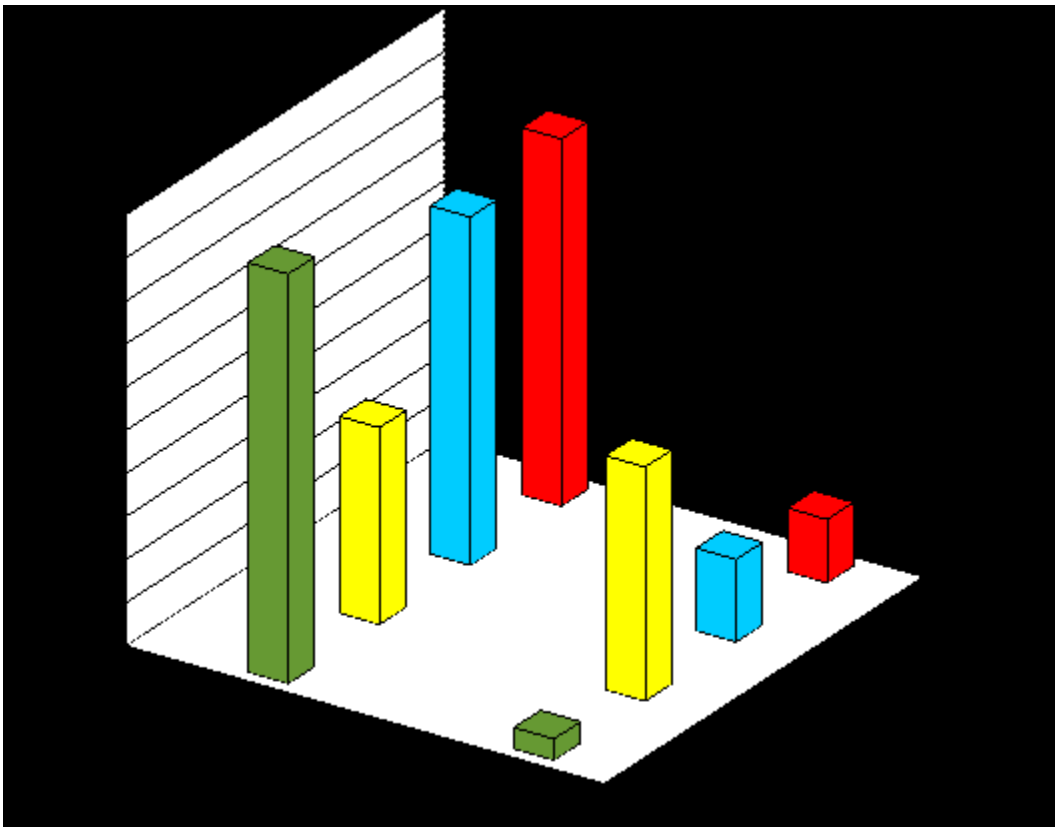

Figure 11-46 Distribution of 39-Year Effective Dose (%) Between Air and Water Pathways for Near River Family

11.2.7.2 Effective Dose by Year

Figure 11-47 shows the percent of the entire dose received by each family member, while Figure 11-48 shows the annual effective dose received by each family member. Table 11-22 lists the percent of the entire 39-year effective dose received each year by each family member, as well as their annual dose. Both the two figures and the table include combined doses from all (air + water) pathways.

Two large peaks in dose are seen for the years 1956 and 1966 (Figure 11-47 and Figure 11-48). These two figures appear similar to corresponding figures for annual dose and percent of entire dose for the Outdoors Person Family (Figure 11-37 and Figure 11-38). Largest dose for the Child Born in 1955 occurred in 1956, while the largest dose for the two adults and the Child Born in 1964 occurred in 1966. In 1956, the Child Born in 1955 received 1.2 mSv (120 mrem), or 40% of his entire dose. In 1966, the Adult Female received 24% (0.51 mSv, or 51 mrem) of her entire dose, the Adult Male received 23% (0.51 mSv, or 51 mrem) of his entire dose, and the Child Born in 1964 received 40% (0.71 mSv, or 71 mrem) of his entire dose.

Figure 11-49 shows the effective dose received by each receptor from only the air pathways. In 1956, the Adult Female received a dose of 0.15 mSv (15 mrem) from the air pathways, the Adult Male received a dose of 0.21 mSv (21 mrem), and the Child Born in 1955 received a dose of 1.2 mSv (120 mrem). After the 1950s, annual doses through all air pathways for these family members typically ranged from about 0.001 to 0.005 mSv per year. The Child Born in 1964 received his largest annual dose (0.013 mSv, or 1.3 mrem) in 1964. Annual doses thereafter fell -- by about a factor of ten by 1988.

As shown in Figure 11-50, annual doses from the water pathways followed a similar pattern to those shown in Figure 11-40 for the Outdoors Person Family. Annual doses from all water pathways built to a maximum in 1966 for all family members:

- Adult Female: 0.50 mSv (50 mrem) – 28% of her dose from all water pathways.
- Adult Male: 0.50 mSv (50 mrem) – 28% of her dose from all water pathways.
- Child Born in 1955: 0.51 mSv (51 mrem) – 35% of his dose from all water pathways.
- Child Born in 1964: 0.70 mSv (70 mrem) – 42% of his dose from all water pathways.

Unlike the situation for the Outdoors Person Family (Figure 11-40), however, after the early 1970s, each member of the Near River Family received essentially equivalent annual doses (Figure 11-50). This pattern of dose occurred because all members of the

Near River Family spent all their time in the Martin area, and all spent the same amount of time swimming and boating in the Savannah River, and spending time along its shoreline.[25]

The result of the combined doses from the air and water pathways was two large peak doses that occurred in 1956 for the air pathways and 1966 for the water pathways. After the early to mid 1960s, most of the doses for each family member were caused by the water pathways as illustrated in Figure 11-51 for the Child Born in 1955.

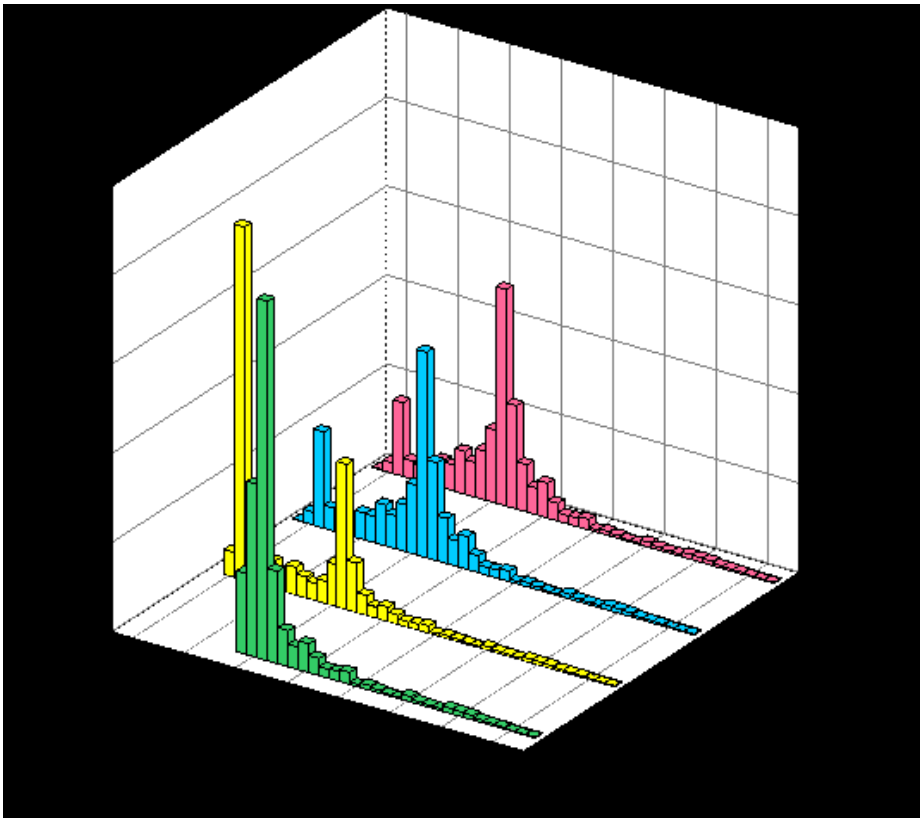

Figure 11-47 Percent of 39-Year Effective Dose for Near River Family – Air + Water Pathways

[25] By contrast, the children of the Outdoors Person Family, after they each reached age 18, worked on the SRS site. The Adult Female of the Outdoors Person Family always stayed at home.

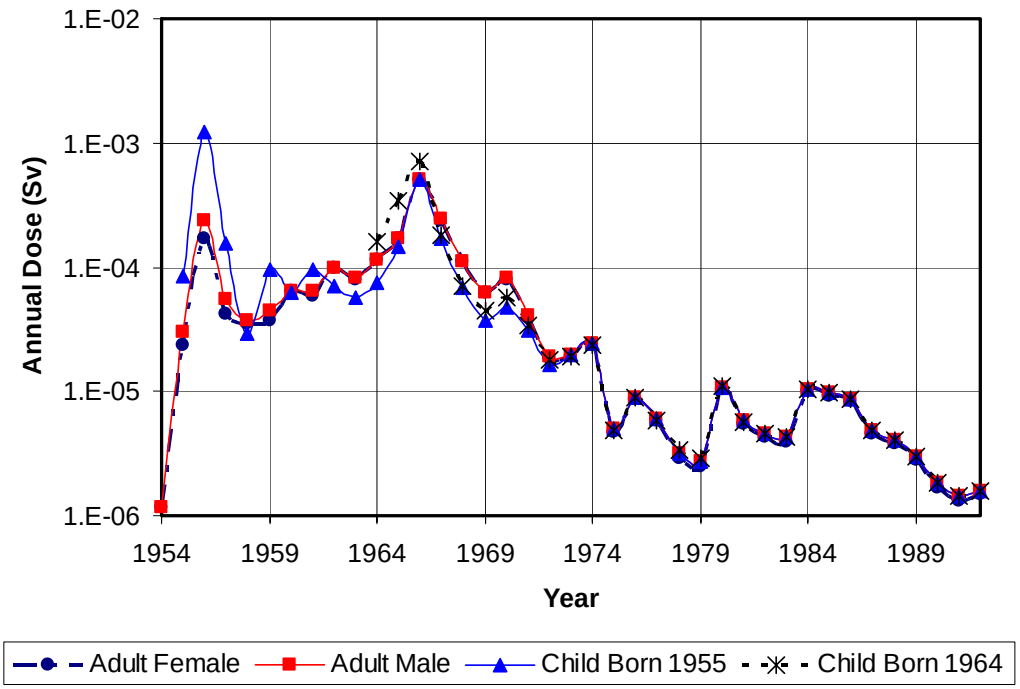

Figure 11-48 Annual Effective Dose (Sv) for Near River Family – Air + Water Pathways

Table 11-22 Annual Effective Dose (mSv) for Near River Family

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	Dose	%	Dose	%	Dose	%	Dose	%
1954	0.0011	0.1	0.0011	0.1				
1955	0.024	1.1	0.031	1.4	0.084	2.7		
1956	0.17	8.2	0.24	10.7	1.24	39.6		
1957	0.041	2.0	0.055	2.5	0.16	5.0		
1958	0.035	1.7	0.037	1.7	0.030	0.9		
1959	0.037	1.8	0.045	2.0	0.095	3.0		
1960	0.064	3.1	0.065	3.0	0.063	2.0		
1961	0.060	2.8	0.064	2.9	0.095	3.0		
1962	0.099	4.7	0.10	4.5	0.071	2.3		
1963	0.080	3.8	0.081	3.7	0.058	1.8		
1964	0.11	5.4	0.11	5.2	0.076	2.4	0.16	9.1
1965	0.17	8.1	0.17	7.7	0.15	4.6	0.34	19.5
1966	0.51	24.3	0.51	23.0	0.51	16.3	0.71	40.4
1967	0.24	11.5	0.24	11.0	0.17	5.5	0.18	10.4
1968	0.11	5.2	0.11	5.0	0.067	2.1	0.071	4.0
1969	0.062	2.9	0.063	2.8	0.037	1.2	0.044	2.5
1970	0.080	3.8	0.081	3.7	0.048	1.5	0.057	3.2
1971	0.040	1.9	0.041	1.8	0.031	1.0	0.034	1.9
1972	0.018	0.9	0.019	0.9	0.017	0.5	0.018	1.0

	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Year	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
1973	0.019	0.9	0.019	0.9	0.019	0.6	0.019	1.1
1974	0.024	1.1	0.024	1.1	0.024	0.8	0.024	1.3
1975	0.0047	0.2	0.0049	0.2	0.0049	0.2	0.0048	0.3
1976	0.0087	0.4	0.0089	0.4	0.0089	0.3	0.0089	0.5
1977	0.0058	0.3	0.0060	0.3	0.0060	0.2	0.0059	0.3
1978	0.0029	0.1	0.0032	0.1	0.0032	0.1	0.0034	0.2
1979	0.0025	0.1	0.0027	0.1	0.0027	0.1	0.0029	0.2
1980	0.0105	0.5	0.011	0.5	0.0107	0.3	0.011	0.6
1981	0.0055	0.3	0.0058	0.3	0.0058	0.2	0.0057	0.3
1982	0.0043	0.2	0.0046	0.2	0.0046	0.1	0.0046	0.3
1983	0.0039	0.2	0.0043	0.2	0.0043	0.1	0.0043	0.2
1984	0.010	0.5	0.0105	0.5	0.011	0.3	0.011	0.6
1985	0.0093	0.4	0.0097	0.4	0.0097	0.3	0.0097	0.6
1986	0.0084	0.4	0.0087	0.4	0.0087	0.3	0.0087	0.5
1987	0.0045	0.2	0.0048	0.2	0.0048	0.2	0.0048	0.3
1988	0.0038	0.2	0.0040	0.2	0.0040	0.1	0.0040	0.2
1989	0.0034	0.2	0.0036	0.2	0.0036	0.1	0.0036	0.2
1990	0.0017	0.1	0.0018	0.1	0.0018	0.1	0.0018	0.1
1991	0.0013	0.1	0.0014	0.1	0.0014	<0.1	0.0014	0.1
1992	0.0015	0.1	0.0016	0.1	0.0016	<0.1	0.0016	0.1
Total	2.1	100	2.2	100	3.1	100	1.7586	100

Figure 11-49 Annual Effective Dose (Sv) for Near River Family – Air Pathways Only

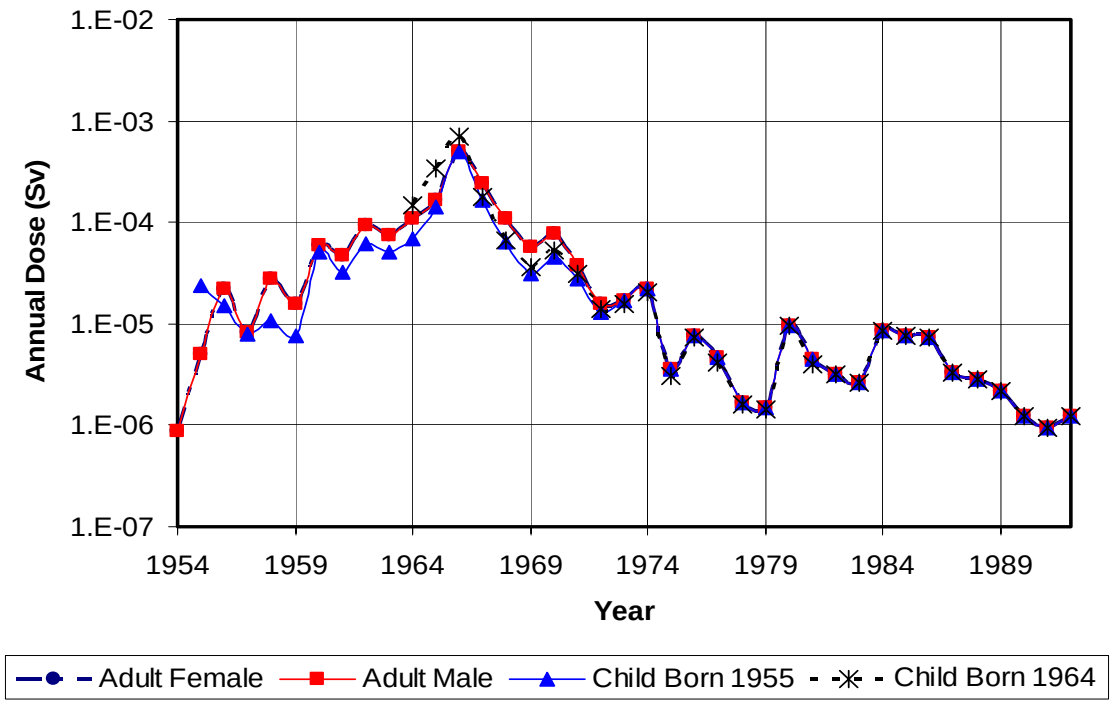

Figure 11-50 Annual Effective Dose (Sv) for Near River Family – Water Pathways Only

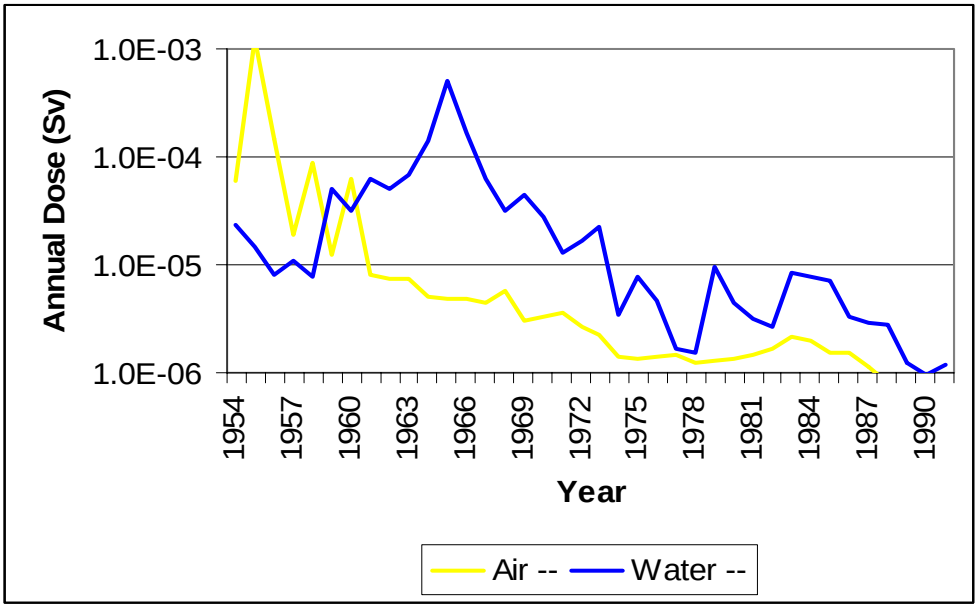

Figure 11-51 Annual Effective Dose (Sv) for Child Born in 1955, Near River Family – Air vs. Water Pathways

11.2.7.3 Dominant Radionuclides, Exposure Routes, and Pathways

Figure 11-52 shows the radionuclides that were the largest contributors of dose over 39 years for each family member. For the two adults, the dominant radionuclides were ^{137}Cs and ^{32}P. The importance of these two radionuclides reflects the importance of the water pathways for the Near River Family. Doses from these two radionuclides mainly resulted from eating fish. For the Child Born in 1955, ^{131}I again caused most of his radiation dose. This dose was caused mainly by eating foods containing ^{131}I, and occurred mostly during the 1950s and early 1960s. The Child Born in 1964 missed the large releases of iodine that occurred during the 1950s. Most of his dose was caused by eating fish containing ^{32}P, ^{137}Cs, and ^{90}Sr.

Similar to previous scenarios, each family member received most of their dose from ingestion (Figure 11-53). From 81 to 86 percent of the dose received by each family member came from ingestion, from 12 to 17 percent came from external exposure to radiation, and from 1 to 3 percent came from inhalation.

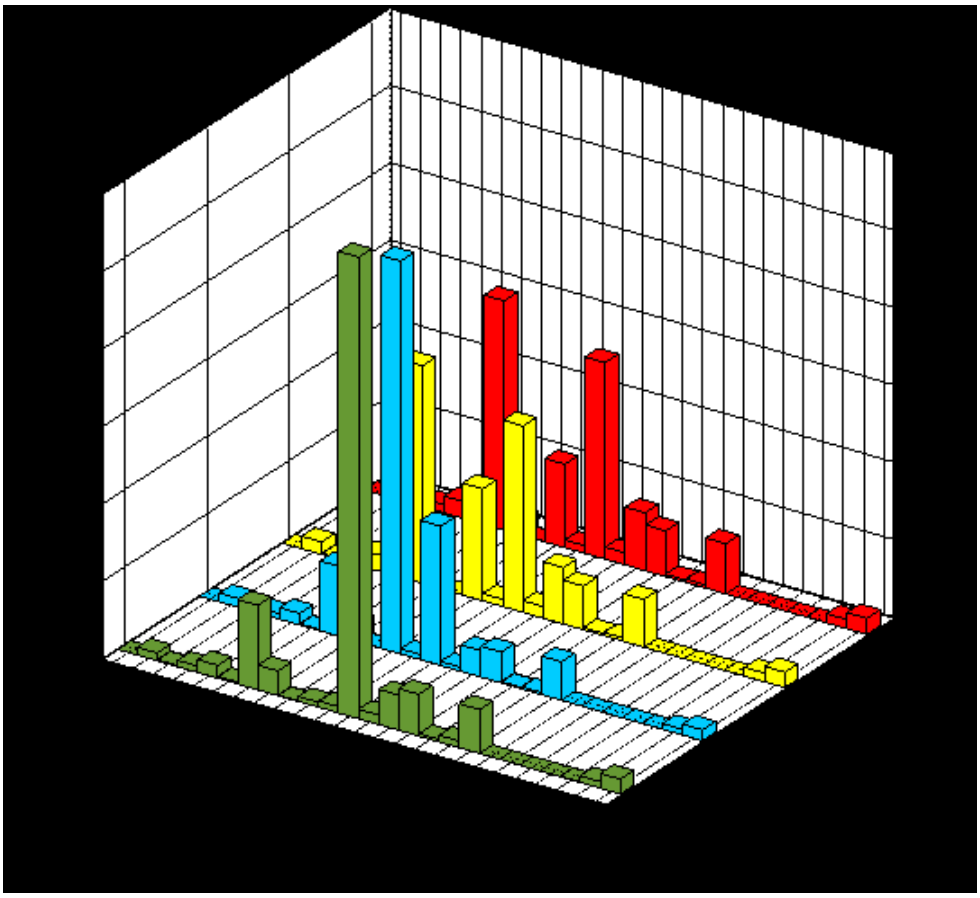

Figure 11-52 Percent of 39-Year Effective Dose by Dominant Isotopes for Near River Family

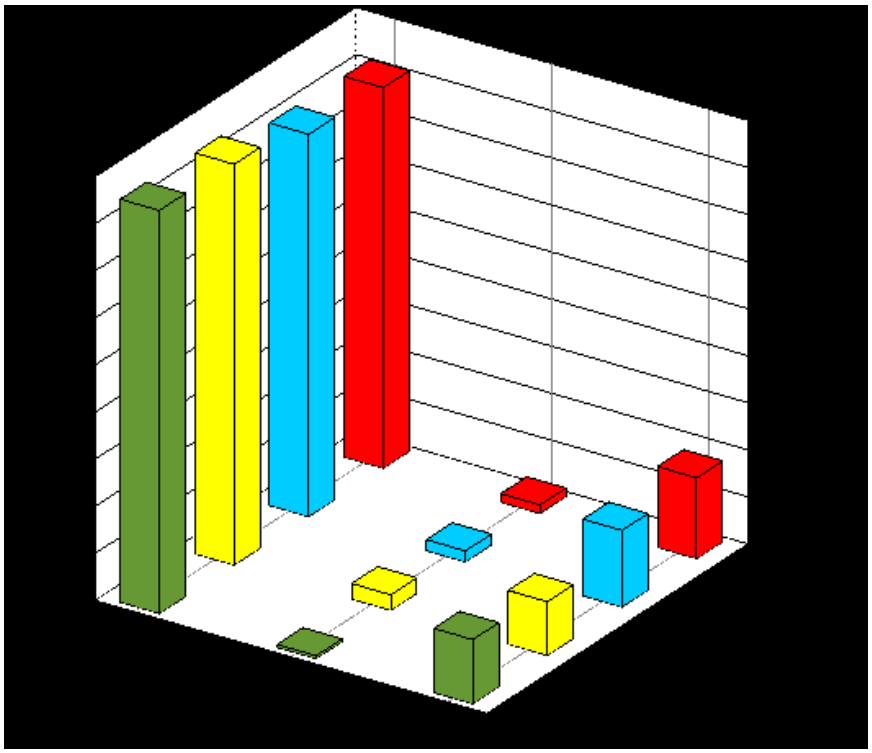

Figure 11-53 Percent of 39-Year Effective Dose by Exposure Route for Near River Family

All family members received most of their dose from eating fish, beef, and milk (Table 11-23 and Figure 11-54). Eating fish accounted for 35 to 82 percent of their entire dose over 39 years, eating beef accounted for 0.6 to 19 percent of their entire dose, and drinking milk accounted for about 2 to 28 percent of their entire dose. These three combined pathways caused from 79 to 85 percent of the entire dose received by any family member. Doses from eating vegetables and fruit were smaller: these combined pathways contributed from 0.7 to 2.4 percent of any family member's entire dose. Doses from eating poultry, eggs, and grain were smaller still, no more than 0.2% of any family member's entire dose. Doses from inadvertently consuming water while swimming in the Savannah River were about as large as those from eating poultry -- i.e., 0.1% of the entire dose. Doses from inadvertently eating soil contributed no more than 0.0003% of any family member's entire dose.

For all family members, most of the external dose came from exposure to radioactive material that had been deposited on the shoreline of the Savannah River. Each family member spent 365 hours per year along the shoreline, a larger time than members of other scenarios. Doses from shoreline exposure contributed from 10 to 16 percent of any family member's entire dose. In contrast, doses from other external radiation exposure pathways associated with boating and swimming accounted for less than 0.1% of any family member's entire dose. Doses from these two water pathways were, for the two adults and the Child Born in 1955, more than 10 times smaller than the doses received by these family members from external exposure to radionuclides that had been deposited from the air onto the ground. These latter doses still contributed no more than 0.1% of any family member's entire dose. Otherwise, external radiation doses from immersion in a plume of air containing radionuclides accounted for no more than about 2% of any family member's entire dose.

Doses from inhaling radionuclides showed a familiar pattern. For all family members, doses from breathing radionuclides from a contaminated plume were much larger than doses from breathing radionuclides after they had been resuspended after being deposited onto soil.

Table 11-23 39-Year Effective Dose (mSv) by Exposure Pathway for Near River Family

		Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
Route	**Pathway**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**	**Dose**	**%**
External	Air Immersion	0.036	<0.1	0.036	1.6	0.036	1.1	0.018	1.0
	Boating	$1.6x10^{-4}$	<0.1	$1.6x10^{-4}$	<0.1	$1.6x10^{-4}$	<0.1	$1.0x10^{-4}$	<0.1
	Ground Contamina-tion	0.0029	0.1	0.0029	0.1	0.0029	0.1	$1.2x10^{-4}$	<0.1
	Shoreline	0.32	15.6	0.32	14.6	0.32	10.2	0.22	12.7
	Swimming	$1.6x10^{-4}$	<0.1	$1.6x10^{-4}$	<0.1	$1.6x10^{-4}$	<0.1	$9.8x10^{-5}$	<0.1
Ingestion	Beef	0.13	6.5	0.21	9.5	0.59	18.8	0.011	0.6
	Eggs	0.0018	0.1	0.0030	0.1	0.0027	0.1	0.0018	0.1
	Fish	1.46	71.0	1.46	66.2	1.1	35.4	1.4	82.3
	Fruit	0.010	0.5	0.0098	0.4	0.037	1.2	0.0056	0.3
	Grain	$7.0x10^{-4}$	<0.1	$8.4x10^{-4}$	<0.1	0.0023	0.1	$4.0x10^{-4}$	<0.1
	Inadvertent swimming ingestion	0.0011	0.1	0.0011	0.1	0.0019	0.1	0.0017	0.1
	Leafy Vegetables	0.016	0.8	0.016	0.7	0.026	0.8	0.0010	0.1
	Milk	0.062	3.0	0.083	3.7	0.89	28.3	0.033	1.9
	Poultry	0.0010	<0.1	0.0013	0.1	0.0013	<0.1	$8.4x10^{-4}$	<0.1
	Root Vegetables	0.0070	0.3	0.0097	0.4	0.013	0.4	0.0045	0.3
	Soil*	$6.4x10^{-7}$	<0.1	$6.4x10^{-7}$	<0.1	$9.7x10^{-6}$	<0.1	$1.1x10^{-7}$	<0.1
Inhalation	Air Inhalation	0.039	1.9	0.052	2.4	0.10	3.3	0.012	0.7
	Resuspende d Soil	$5.3x10^{-5}$	<0.1	$7.2x10^{-5}$	<0.1	$5.0x10^{-5}$	<0.1	$1.0x10^{-5}$	<0.1
Total		2.1	100	2.2	100	3.1	100	1.8	100

*Doses from the soil ingestion pathway were no more than 0.0003% of any family member's entire 39-year dose.

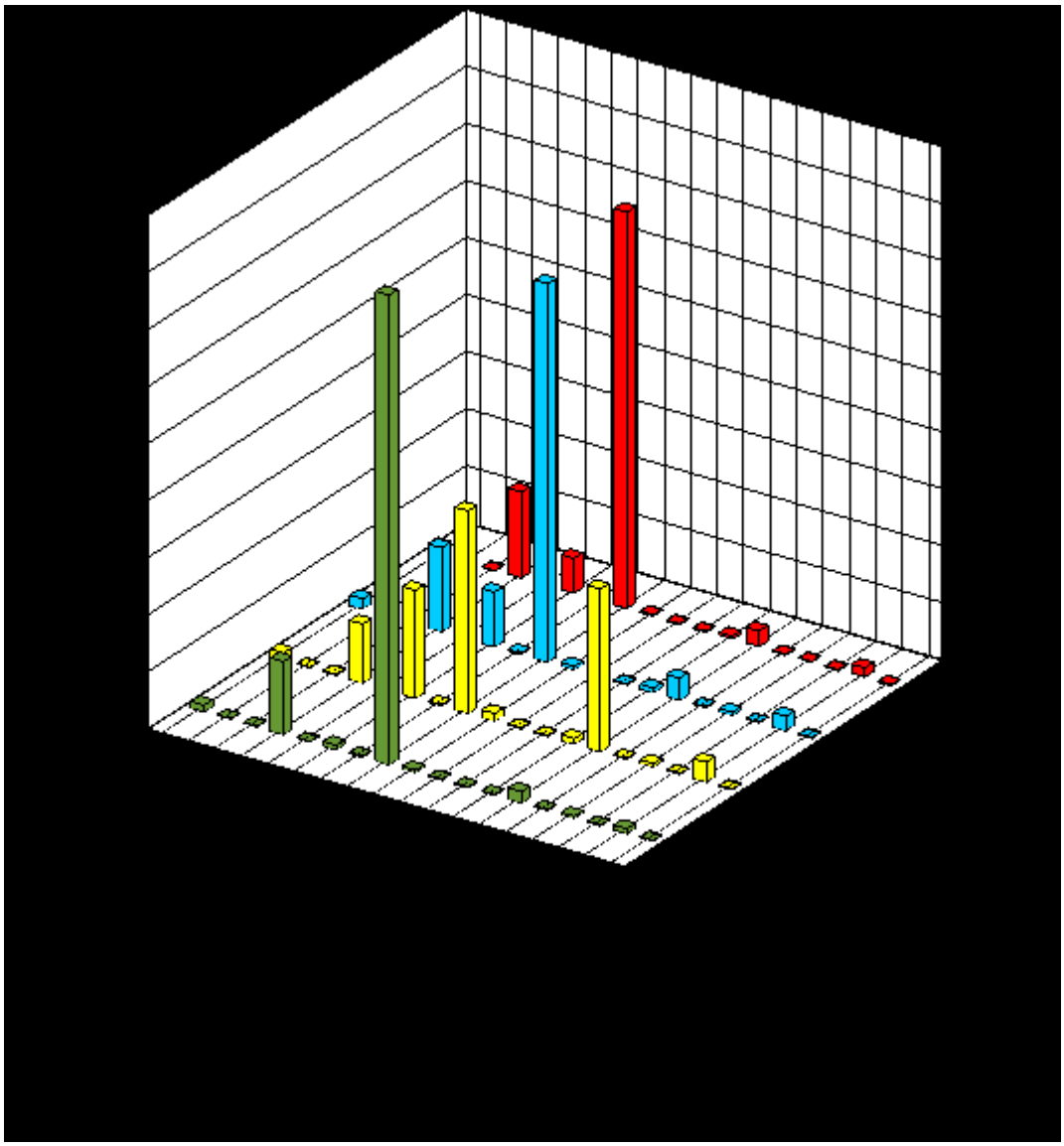

Figure 11-54 Percent of 39-Year Effective Dose by Exposure Pathway for Near River Family

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12 UNCERTAINTY ANALYSIS AND RESULTS

12.1 Introduction

Chapter 11, *Point-Estimate Results*, provided the results of the base-case dose assessment. In that particular analysis, a single value of dose was determined for each member of 7 hypothetical 4-member families (a total of 28 receptors). Each family was subjected to a different exposure scenario. These doses were obtained based on point estimates (single representative values) assigned to the variables involved in the analyzed models. This point-estimate analysis is frequently referred to as a deterministic analysis.

While the single-point estimates used in a deterministic estimate of dose may be considered "representative" or "realistic," they do not capture the inherent uncertainty in the variables of interest. By nature, many of the natural processes and phenomena that investigators attempt to represent with equations and numbers will vary with time, space, and environmental conditions. Likewise, many of the variables used to represent or describe a natural process will change with time, space, and the environmental conditions.

In addition to the uncertainty in the natural phenomena, there is uncertainty associated with our understanding of how the phenomena used to represent natural processes are related (the conceptual models), their mathematical descriptions, and their computational implementation. When these uncertainties are considered, the reconstructed dose is uncertain; instead of a single-point estimate of dose for each receptor (as described in Chapter 11), multiple values (a probability distribution of dose) result. Simply, the uncertainty approach involves treating specified input variables as sets of values rather than as single values in the computation. The computation is repeated multiple times using various combinations of the input variable values. This results in a set of dose estimates rather than a single value. This set can then be used to describe the uncertainty associated with the result from the deterministic approach.

In the dose reconstruction for the Savannah River Site, the analysts focused on the uncertainty associated with the variables that are used to describe a particular process (e.g., the bio-uptake factors, consumption of foodstuffs, and particle size). This approach is the most common way to address uncertainty because it does not require development of alternative conceptual models or computational codes. In addition, this approach enables an analysis of the sensitivity (i.e., what changes in the results [dose] are produced by specific changes in the input variables). In this report, the term "uncertainty analysis" is used to describe three types of evaluation:

1. Description of the uncertainty in dose (i.e., how much variability is estimated for dose given uncertainty in the input variables).
2. Description of how the uncertainty in dose depends on the uncertainty for each uncertain input variable.
3. Description of the sensitivity of dose to variations in input variables.

Sometimes the terms "probabilistic" or "stochastic" analysis are used to describe these evaluations.

12.1.1 Overall Description of Uncertainty Analysis

Uncertainty analysis is sometimes referred to as probabilistic analysis or Monte Carlo analysis. It involves multiple computations that use the same code but change the values of the input variables with each computation. The input values are selected randomly from either sets of observations or distributions,

using observations and judgment based upon experience. Section 12.1.1.2 describes this selection process. The selected values for the input variables of interest are then used in the computation, and the value for each of the sampled variables changes with each computation. For example, if 10 values are selected for each variable, the computation is repeated 10 times. It should be noted that each individual computation is a deterministic analysis similar to the point-estimate case but with different values for the variables.

In this analysis, the effect of 14 variables on dose was investigated. This required a series of computations that changed the values of these variables with each computation. As explained below, each computation is called a realization and yields a dose estimate based on a particular choice of values for all the input variables.

In an uncertainty analysis, the aggregate results are generally of interest rather than the result from any one computation. This set of results can be described in terms of simple statistics to give the representative values (e.g., mean), range, and nature of the distribution. In exercises such as dose reconstruction or risk analysis, uncertainty analysis provides insight into the uncertainty associated with the results.

Uncertainty analysis can be approached in a variety of ways. The most common approach is the Monte Carlo approach, which is based on random selection of the variable values from specified distributions. Section 12.1.1.2 describes the details of the Monte Carlo approach.

12.1.1.1 Rationale – Why We Do It; What Are We Trying to Determine?

The primary task of this project was to estimate the dose to 28 hypothetical individuals resulting from exposure to releases from the Savannah River Site (SRS). This estimation was performed using two methods: a point-estimate analysis and an uncertainty analysis. The point-estimate analysis used a representative value for each of the model input variables and resulted in an estimate of dose, cancer incidence risk, and cancer fatality risk for each of the 28 hypothetical receptors specified in the 7 scenarios. The point-estimate analysis included all credible exposure pathways given the behaviors specified in the scenarios and the land-use, water-use, and agricultural practices in the region surrounding the SRS during the period studied. The point-estimate analysis included only those radionuclides that survived the Level 1 screening of the Phase II report. Chapter 11 describes the point-estimate results. The point-estimate results provided a very detailed picture of what caused the dose and risk to each receptor including:

- How doses and risks changed in time.
- What radionuclides contributed most to dose and risks for a particular receptor.
- What pathways contributed most to dose and risks for a particular receptor.
- How the behaviors specified in the various scenarios influenced doses and risks.

An uncertainty analysis was undertaken with the objective of quantifying the uncertainty associated with the estimated doses. To reduce the computational and data-handling burden, risks were not carried along as part of the calculation; however, risks can be estimated from the doses using adult risk factors. Because the uncertainty analysis involves repeating the dose assessments of the point-estimate analysis many times, a daunting amount of computation would be required if all input variables were considered in the uncertainty analysis. To reduce the effort associated with defining a distribution for each variable, the dose-assessment model used for the uncertainty analysis was simplified. Section 12.2 describes this simplification.

Because the results of the point-estimate analysis were used to guide these simplifications, the point-estimate analysis played the role of a screening analysis. As such, the point-estimate analysis was used to determine which pathways and radionuclides were very minor contributors to dose and could be excluded from the uncertainty analysis. In addition, the point-estimate results helped to determine which variables could be considered to be fixed, rather than uncertain, in the uncertainty analysis as described in Section 12.3.

12.1.1.2 Approach – Monte Carlo Sampling of Inputs to Provide Distributions of Dose

In uncertainty analysis, a randomly generated value selected from the probability distribution of each uncertain variable is assigned to that variable; other variables considered to be certain are assigned their nonrandom values. The values assigned to all variables comprise the set of values for one realization (i.e., one set of input variables for one computer run) that results in a random value as the outcome for that particular realization. Depending on the number of uncertain variables involved in the model and the sampling method adopted, the number of realizations required for good statistical estimates may range from a few to a few thousand. A distribution of dose would be obtained after estimating the dose for each of the realizations considered.

The process of random sampling falls into two categories: simple random sampling (Monte Carlo sampling [MCS]) and stratified sampling (e.g., Latin Hypercube Sampling [LHS]) (1). In MCS, each uncertain variable is assigned a range and probability distribution (mathematically described as a probability density function) that may be based on observations, judgment, or a combination of the two. The probability density functions for each of the uncertain variables of interest are then randomly sampled, resulting in a set of values for each of the input variables of interest. Generally, many thousands of samples are required to adequately represent the probability density function when using simple random sampling. A large number of samples is needed to obtain values over the entire range of the variable.

The LHS technique divides the probability density function associated with an uncertain variable into several strata ("bins") to ensure the probability of choosing a random value from each stratum is the same. Compared to the Monte Carlo sampling technique, LHS is more efficient and enables more complete sampling from the probability density function with a limited number of samples. This technique requires more computer memory because all samples are generated at once to ensure appropriate distribution and independence or correlation among the variables. In this analysis, the computation time for each realization was sufficiently long to make LHS the preferred sampling technique because fewer realizations are required.

12.2 Development of a Simplified Model

Uncertainty analyses can be very computationally intensive, requiring a number of individual computations (realizations) that is many times the number of input variables. Each realization requires another computation using the preprocessor, GENII v.2 Code, and postprocessor as described in Chapter 4. To make the problem more manageable, it was decided to focus the uncertainty analysis on those radionuclides and pathways that were most important in the determination of the point estimate. This simplification reduced the computation time and the amount of data handling.

All the various contributors to dose, as described in Chapter 11, were evaluated. These include specific pathways such as dose from eating vegetables or dose from a specific radionuclide such as Cs-137. Each pathway and/or radionuclide contribution was compared with the total dose for a particular receptor. The contributors to dose by pathway and radionuclide were arranged in order from least to greatest. The smallest contributor was eliminated, then the next smallest was eliminated, and the process was repeated

until the cumulative contribution of eliminated pathways and/or radionuclides to the total dose was just under 5 percent. This process was performed on all 28 receptors.

The set of radionuclides and pathways satisfying the 5-percent criterion for all receptors was chosen as the set for simplifying the analysis. Because the pathways and radionuclides were not mutually exclusive (e.g., removing both soil ingestion and uranium takes out uranium dose from soil ingestion only once, but it was counted twice for the cumulative percent), the actual reduction in total dose was always less than 3 percent. With the removal of a particular radionuclide or pathway, a number of input variables were also eliminated from the computation. This helped to reduce the number of variables that needed to be evaluated for inclusion in the uncertainty analysis.

It should be noted that eliminating radionuclides and pathways from the analysis of a particular scenario in effect changed the conceptual model that was evaluated for the scenario. The effect of this change in the conceptual model was evaluated by comparing the point estimate of total dose (all pathways and radionuclides) to the estimate of total dose from the simplified model (reduced set of pathways and radionuclides). The total dose (using the simplified model but using the exact same input variable values as the point estimate) is designated "Run 0."

Table 12-1 presents the comparison of dose for each receptor from both the original point estimate and from the simplified computation ("Run 0"). Because the simplified computation provides doses within 3 percent of the more complete model, this simplification was considered to be acceptable (Table 12-1 shows that the largest deviation is 2.6 percent for the Child Born in 1964 for the Migrant Family scenario).

Table 12-1 Comparison of Dose Estimates from Complete and Simplified Models

Scenario	Family Member	Point Estimate (milliSieverts)	Run 0 (milliSieverts)	Ratio, Run 0 over Point Estimate
Delivery Family	Adult Female	6.106	6.091	0.997
Delivery Family	Adult Male	6.283	6.266	0.997
Delivery Family	Child Born 1955	5.200	5.180	0.996
Delivery Family	Child Born 1964	2.090	2.081	0.996
Migrant Family	Adult Female	0.447	0.438	0.979
Migrant Family	Adult Male	0.624	0.614	0.983
Migrant Family	Child Born 1955	2.178	2.160	0.992
Migrant Family	Child Born 1964	0.083	0.081	0.974
Near Water Family	Adult Female	2.091	2.057	0.984
Near Water Family	Adult Male	2.205	2.170	0.984
Near Water Family	Child Born 1955	3.137	3.099	0.988
Near Water Family	Child Born 1964	1.759	1.734	0.986
Outdoor Family	Adult Female	3.030	3.001	0.990
Outdoor Family	Adult Male	4.216	4.169	0.989
Outdoor Family	Child Born 1955	9.435	9.383	0.994
Outdoor Family	Child Born 1964	1.826	1.810	0.991

Scenario	Family Member	Point Estimate (milliSieverts)	Run 0 (milliSieverts)	Ratio, Run 0 over Point Estimate
Rural Family One	Adult Female	0.303	0.299	0.985
Rural Family One	Adult Male	0.423	0.418	0.987
Rural Family One	Child Born 1955	1.589	1.580	0.994
Rural Family One	Child Born 1964	0.072	0.071	0.981
Rural Family Two	Adult Female	0.696	0.685	0.985
Rural Family Two	Adult Male	0.974	0.961	0.987
Rural Family Two	Child Born 1955	3.751	3.729	0.994
Rural Family Two	Child Born 1964	0.140	0.137	0.979
Urban Family	Adult Female	0.330	0.325	0.986
Urban Family	Adult Male	0.731	0.723	0.989
Urban Family	Child Born 1955	2.686	2.675	0.996
Urban Family	Child Born 1964	0.107	0.106	0.983

12.3 Input Variables and Realizations

As discussed in the previous sections, the input variables involved in the computational model for the uncertainty analysis fall into two categories: 1) input variables that are considered as uncertain and 2) input variables that are considered as certain or fixed. While all input variables have an inherent uncertainty, the analysis described in Section 12.4 identified those variables that have the largest effect on the uncertainty of the resultant dose. This analysis reduced the number of input variables that will be considered as uncertain in the uncertainty analysis to 14, leaving the remaining input variables to be considered as certain (fixed) and thus treated as point estimates or fixed values.

Certain and uncertain input variables are introduced to the computational model differently. Certain input variables are represented by a single value, whereas an uncertain input variable is represented by a probability distribution and its associated statistics. Because an uncertain input variable cannot be represented by a single value, a set of values sampled from the variable's probability distribution is used to represent the variable of interest. The degree of representativeness depends on the sampling technique and the number of samples taken from the probability distribution.

As noted in Section 12.1.1.2, random sampling techniques fall into two categories: 1) simple random sampling (SRS), also known as MCS, and 2) the stratified sampling, also known as the LHS. The MCS technique does the sampling completely at random with each sample taken sequentially, whereas the LHS technique performs the sampling by a constraining value selection based on previously constructed realizations. By not allowing samples to be drawn from previously sampled intervals for a variable, LHS provides a more representative sampling of the distributions with a smaller sample size.

MCS is a computationally time-intensive sampling technique. The samples are chosen completely at random within the range of the probability distribution. This necessitates large numbers of random samples for highly skewed or long-tailed probability distributions to reasonably represent the uncertain nature of the variable under consideration.

LHS is more efficient than MCS because it is designed to accurately recreate the input distribution with fewer samples than the MCS method. However, LHS is a memory-intensive technique because the entire set of samples for all variables is collected at once.

All input values (fixed and sampled) are collected together in a matrix format. One set of input values from this collection, with a single value for each variable, is referred to as a realization. Each realization, when used in the computer code, results in a single value for the output variable (e.g., dose). When an uncertainty analysis is performed, the computer code is run iteratively, each time using a different combination of input variable values as determined by the sampling. For an uncertainty analysis involving n uncertain variables, 3n realizations (computer runs) are generally considered to be adequate when using LHS sampling.

12.3.1 Description

LHS was adopted as the sampling technique for the uncertainty analysis. After examining two general-purpose commercial software packages for risk analysis—Crystal Ball 2000 (2) and @RISK (3), it was decided to use the LHS computer code developed by Sandia National Laboratories for the U.S. Nuclear Regulatory Commission (4). This decision was based on the need to be able to define correlations among the uncertain variables. The LHS computer code requires each uncertain variable to be identified by its probability density function (probability distribution) and two quantiles for that distribution: the 0.001 quantile (0.1 percentile) and the 0.999 quantile (99.9 percentile).

Table 12-2 provides the 14 variables that were considered to be uncertain for the uncertainty analysis. For each variable, Table 12-2 contains the type of probability distribution and some of the statistics for that distribution, including the 0.001 and 0.999 quantiles. These quantiles were obtained from built-in functions of Microsoft Excel although these quantiles may lay outside the range of reality for a particular variable they were the required input for the LHS code

The 14 uncertain variables involved in the uncertainty analysis were considered to be independent of one another. Therefore, during the preparation of the input data file for the LHS code (discussed in the previous section), a particular “flag” was used to indicate that no correlation existed among the variables involved. This flag resulted in small correlation coefficients (less than 0.2) when the correlation coefficient matrix associated with the 40 X 14 output matrix (the output matrix with 40 realizations) was examined.

12.4 Overall Description of the Simplification Approach

This section describes the process by which 14 variables were selected for uncertainty/sensitivity analysis from an initial list of 331 possible variables.

12.4.1 Reasons for Limiting the Scope

A standard reference on radiological assessment (Till and Meyer, 1983) states:

> “The first step in an uncertainty analysis is to limit the scope. This requires an explicit statement of the objectives of the assessment and a determination of relevant radionuclides, exposure pathways, and model parameters. Limiting the scope of an uncertainty analysis avoids exhausting financial, physical, and human resources on aspects of assessment models that are not significant.”

For this analysis, the scope was limited to focus attention on variables with the greatest potential for affecting variation in the dose to receptors. This avoided unnecessary use of resources for insignificant aspects of the models.

Table 12-2 The Fourteen Uncertain Variables Considered for Uncertainty Analysis

Variable	Description	Units	Dist. Type	Pt. Estimate	Log Mean	Log Std. Dev.	Median	0.001 Quantile	0.999 Quantile
Water Pathway									
CLBFF, Cs-137	Bioconcentration in fish	L/kg	Lognormal	4,700	8.46	1.20	4.70E+03	116	1.90E+05
CLBFF, Sr-90	Bioconcentration in fish	L/kg	Lognormal	450	6.11	2.03	4.50E+02	0.849	2.39E+05
CLBFF, P-32	Bioconcentration in fish	L/kg	Lognormal	50,000	10.82	0.89	5.00E+04	3.15E+03	7.93E+05
Air Pathway									
LEAFRS, RESFAC;1	Soil resuspension factor—farm	1/m	Lognormal	0.00001	-11.51	2.62	1.00E-05	3.03E-09	3.30E-02
RADIUS	Particle radius	µm	Lognormal	0.5	-0.69	0.41	5.00E-01	0.143	1.75
WTIM	Weathering rate constant from plant	d	Lognormal	14	2.64	1.40	1.40E+01	0.183	1.07E+03
DPVRES	Deposition velocity from air to plant surfaces	m/s	Lognormal	0.001	-6.91	1.26	1.00E-03	2.07E-05	4.84E-02
DEPFR1, 2	Deposition retention fraction for plants	Fraction	Lognormal	0.25	-1.39	0.59	2.50E-01	4.07E-02	1.54
GRWPA, 5&6	Growing period for animal forage	d	Lognormal	30	3.40	0.44	3.00E+01	7.65	118
CLFMT, I-131	Cattle intake-to-beef transfer factor	d/kg	Lognormal	0.04	-3.22	0.50	4.00E-02	8.49E-03	0.188
F	Release factor		Lognormal	1	0.00	0.20	1.00E+00	0.539	1.86
CONSUM, 5	Animal feed consumption rate— beef animal forage	kg/d	Normal	36	36.00*	8.63*		9.33	62.7
CLFMK, I-131	Cow intake-to-milk transfer factor	d/L	Lognormal	0.01	-4.61	0.91	1.00E-02	6.06E-04	0.165
BIOMA2, 5&6	Animal forage standing biomass (wet)	kg/m^2	Lognormal	0.3	-1.20	0.08	3.00E-01	0.233	0.386

* Mean and standard deviation for normal probability distribution.

By limiting the analysis scope to those radionuclides, pathways, and input variables most influencing dose and dose variation, the computational burden was focused on the most important model aspects (some of this simplification is described in Section 12.2). By screening the input variables to select those influencing variations in dose most, the development of probability distributions was focused on the most important variables.

12.4.2 Variable Selection Process—Overview

The point estimates provided in Chapter 11 are based on a single value chosen for each input variable. All input variables were considered to be fixed, or "certain," even though a range of values may have been considered in determining the single representative value for each variable. These representative values were chosen to be consistent with the specified scenarios, and site characteristics. When a range of values was available for a variable, the representative value was chosen in such a way that it did not intentionally underestimate or overestimate the dose.

In the uncertainty analysis, all of the "certain" input variables used to generate the point estimates could be considered as uncertain variables with their own probability distributions because, in fact, all input variables are uncertain. However, in most examples of environmental analysis, only a few input variables dominate the results. This variable selection process is intended to reduce the number of variables treated as uncertain to focus attention on those that appear to have the most effect on variations in dose.

Two categories of input variables were categorically excluded from consideration as uncertain:

1. The variable values representing the behavior of the receptors (e.g., the amount of milk consumed at a particular age) were derived from the scenario specifications. Because the scenarios were hypothetical and specified by the CDC and the SRSHES, and because the specified behaviors represented a range of plausible variation, these variable values were considered to be fixed for the purposes of this study.
2. This study has used a set of dose and risk factors established by national and international radiation protection organizations over many decades. These factors were treated as fixed because the uncertainty in these factors was considered small compared to that in other input variables and the uncertainty in these variables would be similar for any dose estimate.

Figure 12-1 shows the sequence of steps used by the variable selection approach to reduce the number of input variables considered in the uncertainty analysis.

At the beginning of the selection process, all input variables except those categorically excluded were considered to be candidates for treatment as uncertain variables. This stepwise process was intended to eliminate variables as candidates for the "uncertain" category based on a defined and defensible criterion at each step in the process. The following criteria were used at the six steps of the selection process:

1. Eliminate variables concerned with exposure pathways that are not used for modeling the SRS.
2. Eliminate variables that are only used for radionuclides and pathways that are minor contributors to dose.
3. Eliminate variables that are only used for radionuclides and pathways whose fractional contribution to dose squared is small.
4. Eliminate any remaining variables in categories already determined as fixed, such as variables associated with scenario specifications or dose and risk coefficients.

5. Combine input variables that may be specified separately but are more appropriately considered the same for this study.
6. Eliminate variables with small contributions to variance.

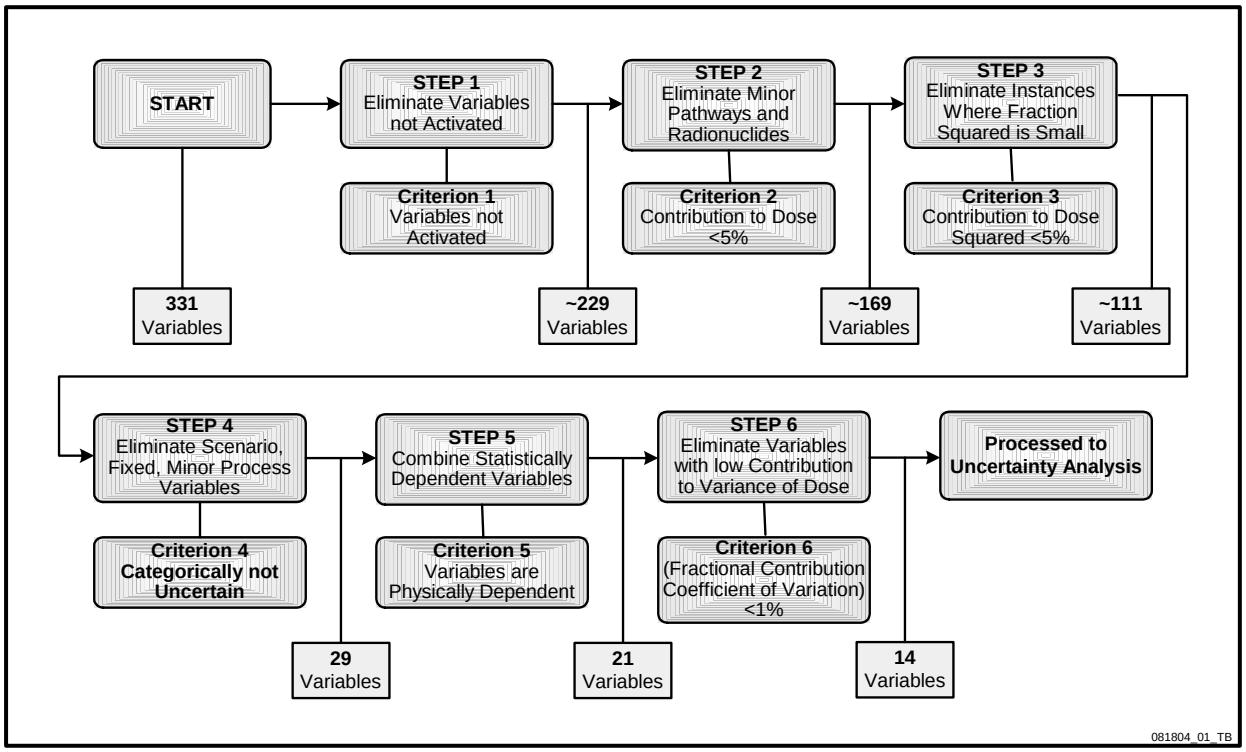


Figure 12-1 Steps Involved in Variable Reduction and Uncertainty Model Simplification

Each of these steps is described in more detail below. In accounting for the number of variables, Appendix F provides tables that list 331 separate variables. These lists are taken as the starting point of this process to reduce the number of variables considered as uncertain. However, there is a subjective element in counting the variables. For example, the variable "ARMETFILE" is the name of the file containing the 20-year average meteorological data that is read into GENII. These meteorological data were not counted among the input variables required to be specified because 1) they were computed separately and not included in the variable tables and 2) they were kept constant for all computations.

The main reason for performing the uncertainty analysis is to estimate the confidence interval for the estimated dose to each receptor. The confidence interval is a commonly used measure to describe the uncertainty in a variable. A key factor in determining the confidence interval is the variance of the dose (or equivalently the standard deviation of the dose, which is the square root of variance). Some of the screening steps are based on the fact that even though a variable may be important in determining the value of dose, it may have little influence on the variance of the dose.

12.4.2.1 Start

The 331 variables were specified to obtain the point estimate of dose for each receptor. Although each variable was carefully evaluated and specified, counting them is somewhat subjective. As stated in Section 12.4.2, some variables are just the name of a file containing extensive but fixed values—these variables were not included in the count. Other variables were indexed by exposure location or radionuclide and were specified for each location and radionuclide with potentially different values. In

this description, they were counted as a single variable if a single value was used for every instance. Additional inputs to the dose modeling that were not counted as variables include 1) air releases by year, isotope, and source; 2) computer grid coordinates; and 3) water concentrations by year, isotope, and location. In addition to the variable lists in Appendix F, a variable "F" was added to the lists which accounts for uncertainty in radionuclide releases.

12.4.2.2 Step 1—Eliminate Unused Variables

Because of the scenario specifications and the assumptions made for modeling, the point-estimate analysis did not use all the input variables employed by GENII to model the transport and exposure processes. For example, Appendix F shows that food chain transport variables associated with irrigation are not used due to the lack of evidence that the Savannah River had ever been used for irrigation in the region. Variables such as irrigation time (IRTIMA, IRTIMR, IRTIMT) and irrigation rate (RIRR, RIRRA, RIRRR) are not specified for the point-estimate analysis and need not be considered in the uncertainty analysis. As part of the scenario implementation, beef cattle were assumed to consume no contaminated feed (beef cattle consumed contaminated forage-grass); therefore, about 30 food chain variables were eliminated. Also note that cerium, technetium, niobium, zinc, cobalt, sulphur, phosphorus, yttrium (a decay product of niobium), and zirconium are only released to water, so their terrestrial uptake factors may be eliminated; this eliminates eight variables for each element. Approximately 102 variables were eliminated in this step, leaving approximately 229 potential uncertain variables.

12.4.2.3 Step 2—Screen Out Minor Contributors to Dose

As described in detail in Section 12.2, a simplified model was obtained by screening out radionuclides and pathways whose combined contribution to total dose was less than 5 percent. The actual reduction in dose was always less than 3 percent for any receptor. The following radionuclides and pathways were eliminated from the model on this basis:

1. Air Release:
   a. Radionuclides: americium-241, cesium-137, iodine-129, strontium-89, strontium-90, and all isotopes of uranium.
   b. Pathways: ground contamination, grain, and soil ingestion.
2. Water Release:
   a. Radionuclides: iodine-129, niobium-95, strontium-89, and all isotopes of uranium.
   b. Pathways: Boating, swimming immersion, and swimming inadvertent ingestion.

By eliminating these pathways and isotopes, it was unnecessary to consider about 60 associated variables as uncertain. For example, terrestrial uptake factors for various forms of vegetation and animals, and for the isotopes americium-241, cesium-137, iodine-129, strontium-89, strontium-90, and all uranium isotopes, could be eliminated from consideration as uncertain variables. Because uptake factors are generally element-specific and not isotope-specific, the uptake factors for iodine remained because iodine-131 was not screened out. Therefore, 8 terrestrial uptake factors for each of the elements americium, cesium, strontium, thorium (a decay product of uranium), and uranium were eliminated, thereby reducing the number of potential uncertain variables by 40. In addition, six variables related to grain and eight variables associated with direct exposure to contaminated soil were reclassified. Another six variables related to grain and aquatic uptake were eliminated. Approximately 60 variables were eliminated in this step, leaving approximately 169 potential uncertain variables.

12.4.2.4 Step 3—Screen Out Instances Where Fraction Squared Is Small

Appendix L discusses a mathematical approach in which the dose for any receptor is considered to be approximated by a linear function of each of the input variables, expanded about their nominal values (i.e., the point-estimate values). Quite a bit is known about the point-estimate dose, including the fractional contribution to the total dose from each radionuclide and through each pathway. Mathematically, the fraction of dose F(ij) is known for each pathway (i) and each radionuclide (j). This information has been used in the variable selection process described in Section 12.2 to eliminate pathways and radionuclides from the model.

The approach discussed in Appendix L shows that the variance of the dose is proportional to the square of the sum of the fractional contributions to dose, where the sum is taken over all pathways and all radionuclides for which the variable has an impact on dose. Note that a particular variable may not have an impact on the dose resulting from a particular radionuclide or pathway. For example, the variable characterizing the uptake of cesium-137 by fish does not have any impact on the dose from iodine from drinking milk. As an approximation, it was assumed that if the sum of the squares of the fractions for all isotopes of a given pathway were small, then the pathway and its associated variables would not contribute significantly to the variance of dose. Similarly, it was assumed that if the sum of the squares of the fractions for all pathways of a given isotope were small, then the radionuclide and its associated variables would not contribute significantly to the variance of dose.

For air releases, four receptors were used as indicators to test for these conditions. The receptors were the Adult Female and Child Born in 1964 for Rural Family #2 and for the Migrant Worker Family. As discussed in Chapter 11, for air releases, the two adults and Child Born in 1955 had similar contributors to total dose; however, the Child Born in 1964 was different because that receptor missed the large iodine releases early in the SRS history. Consequently, fractional dose contributions to both the Adult Female and Child Born in 1964 were examined for this step of the variable reduction. Rural Family #2 was selected because it had fractional contributions to dose typical for most of the scenarios receiving doses from air releases only; however, the Migrant Family was somewhat of an outlier and was included for that reason. From these instances, certain radionuclides and pathways were found to be insignificant contributors to the variance of dose. The incremental contribution to total dose by every radionuclide-pathway pair was computed and then renormalized by the total dose from the pathways and radionuclides remaining after the model simplification described in Section 12.2. (As shown by the ratios in Table 12-1, this adjustment in fractional contribution was small when compared to the fractional contributions stated in Chapter 11.) These renormalized fractional values were then squared, and the squared fractional values were renormalized by the largest value. The renormalized squared fractions were then summed over pathways and radionuclides. In general, if any of the resulting sums were smaller than 0.01, then the variables associated with those radionuclides and pathways were eliminated. On this basis the variables associated with the following pathways or radionuclides were thus eliminated:

- Carbon-14.
- Plutonium-238,239.
- Ruthenium-106.
- Resuspended soil inhalation.
- Poultry ingestion.
- Eggs ingestion.
- Fruit ingestion.
- Root vegetable ingestion.

For the Child Born in 1964 for Rural Family #2, the sum for root vegetable ingestion slightly exceeded the 0.01 criterion.

Two receptors included in water exposure scenarios were used as indicators to test for these conditions. These were the Adult Female and Child Born in 1964 for the Delivery Family. The Delivery Family was chosen because it had the largest doses from water releases; the Adult Female and Child Born in 1964 were chosen for the reasons stated previously. From these instances in which water release doses dominated, the following pathways and radionuclides were found to be insignificant contributors (as stated above) to the variance of dose:

- Shoreline direct exposure.
- Cesium-144.
- Cobalt-60.
- Cesium-134.
- Hydrogen-3.
- Iodine-131.
- Plutonium-238,239.
- Ruthenium-106.
- Zinc-65.
- Zirconium-95.

By eliminating variables associated with these pathways and radionuclides that are insignificant contributors to the variance of dose, approximately 58 variables were reclassified as fixed. For example, 7 uptake factors each for the elements plutonium and ruthenium were eliminated, thereby reducing the number of potential uncertain variables by 14. Elimination of the egg and poultry pathways reduced the number of variables by about 22. Elimination of water-release radionuclides reduced the number of uncertain variables by nine. Elimination of variables associated with ingestion of fruit and root vegetables reduced the variable count by about 12. This left about 111 potential uncertain variables.

12.4.2.5 Step 4—Eliminate Health Effects Variables and Scenario-Based Variables

A number of the remaining potential uncertain variables were reclassified as variables to be considered certain or fixed for a variety of reasons. The following represent some of the important reasons for these categorical reassignments:

- Holdup times are unimportant for long-lived radionuclides; the dose from phosphorus-32 could be affected because it has a relatively short half-life (14.5 days), but it is a relatively small contributor.
- Holdup times for food delivery and processing were assigned as part of completion of the scenario specifications; because the scenarios are mandated, these variables are considered to be certain.
- It was independently determined that, for these scenarios, radionuclide uptake by vegetation from soil is small compared to radionuclide uptake by vegetation from direct deposition; therefore, all variables associated with modeling soil uptake are considered fixed. Approximately 48 variables were reclassified on this basis.
- Variables associated with household use of river water were considered to be fixed; although volatilization of radionuclides was considered for the Near Water Family, it accounted for a very small fraction of the total dose.

The variables that relate to these points were considered fixed and therefore were eliminated at this step. Approximately 82 variables were thus eliminated, thereby leaving approximately 29 potentially uncertain variables.

12.4.2.6 Step 5—Combine Variables that May be Considered Together

Further reduction in the number of variables considered to be uncertain was accomplished by noting that for three pairs of variables only one value, albeit an uncertain value, need be assigned to the pair:

1. BIOMA2, 5 and BIOMA2, 6.
2. GRWPA, 5 and GRWPA, 6.
3. DEPFR1 and DEPFR2.

For the first two pairs, the variables referred to values for milk and beef animal forage. Because the same grass was used for both milk and beef animal forage, these variables could be assumed to be equal. For the third pair of variables, dry- and wet-deposition fractions were assumed to be equal.

In the following two cases, the value of one variable in a pair was derived from the sampled value of the other variable in the pair by multiplying the first variable by a constant; essentially, the pair of variables is assumed to be different by a multiplicative constant and perfectly correlated as explained in the following:

1. CONSUM,5—the consumption rate of forage by beef cattle was assumed to be the fraction 36/29 the value of CONSUM,6—the consumption rate of forage by milk cattle. This is the ratio of the point estimate values. The assumption means that whatever causes the beef cattle to eat more, it will have the same effect on dairy cows.

2. RESFAC,1—the resuspension factor for rural locations is assumed to be 100 times the value of RESFAC,2—the resuspension factor for urban locations. It is essentially assumed that whatever forces produce more resuspension in the city and suburbs (e.g., higher wind) will do the same on the farm. For the point-estimate case, it was assumed that the resuspension factor in the rural areas was 100 times that in the city due to plowing and other agricultural activities. LEAFRS is essentially the same variable as RESFAC, so those variables were set equal to the corresponding values for RESFAC.

Both particle radius and density are factors in determining deposition of radionuclides, but the equation uses radius squared. Because radius should have a more significant effect if varied, it was chosen as the uncertain variable, and density was considered fixed.

The net effect of these various consolidations was to eliminate 8 variables and leave 21 independent candidates for variables to be treated as uncertain. These variables are listed in Table 12-3.

Table 12-3 Characteristics of Input Variable Distributions

	Variable	Description	Units	Type	p1*	p2*
Water Pathway						
1	CLBFF, Cs-137	Bioconcentration in fish	L/kg	Lognormal	8.4553	1.1975
2	CLBFF, Sr-90	Bioconcentration in fish	L/kg	Lognormal	6.1092	2.0300
3	CLBFF, P-32	Bioconcentration in fish	L/kg	Lognormal	10.8198	0.8945
Air Pathway						
4	CLFMK, I-131	Cow intake-to-milk transfer factor	d/L	Lognormal	-4.6051702	0.9069765
5	CLFMT, I-131	Cattle intake-to-beef transfer factor	d/kg	Lognormal	-3.2188758	0.5015594
6	ABSHUM	Absolute Humidity	kg/m^3	Normal	0.01125	0.00053
7	BIOMA2, 5&6	Animal feed standing biomass (wet)-beef & milk animal forage	kg/m^2	Lognormal	-1.20397	0.0813929
8	BIOMA2, 3	Animal feed standing biomass (wet)-Milk animal feed	kg/m^2	Lognormal	1.43156†	0.02909†
9	BIOMAS, 1	Standing biomass (wet) - Leafy vegetables	kg/m^2	Lognormal	0.03486‡	
10	WTIM	Weathering rate constant from plant	d	Lognormal	2.63906	1.40311
11	CONSUM, 5&6§	Animal feed consumption rate-Beef & milk animal forage	kg/d	Normal	36.0000	8.6300
12	CONSUM, 3	Animal feed consumption rate-Milk animal feed	kg/d	Lognormal	1.71†	0.262†
13	DRYFAC, 1	Dry/wet ratio - Leafy vegetables	fraction	Lognormal	0.10875†	0.00218†
14	GRWP, 1	Growing period - Leafy vegetables	d	Lognormal	0.16861‡	
15	GRWPA, 5&6	Growing period for animal feed - Beef & milk animal forage	d	Lognormal	3.40119738	0.4423365
16	GRWPA, 3	Growing period for animal feed - Milk animal feed	d	Lognormal	0.05103‡	
17	DEPFR1,2	Dry & wet deposition retention fraction to plants	fraction	Lognormal	-1.3862944	0.5873942
18	LEAFRS, RESFAC;1§	Resuspension factor from soil to plant surfaces - farm	1/m	Lognormal	-11.512925	2.6214129
19	DPVRES	Deposition velocity from soil to plant surfaces	m/s	Lognormal	-6.9077553	1.2555349
20	RADIUS	Particle Radius	µm	Lognormal	-0.6931	0.4055
21	F	Release Factor		Lognormal	0	0.2

§ Related by a constant factor.

* p1 and p2 are the log mean and log standard deviation of their corresponding lognormal distributions, respectively, except for variables No. 6 and 11 that they are the arithmetic mean and the arithmetic standard deviation of the normal distribution, respectively.

†Arithmatic mean and arithmetic standard deviation.

‡Ratio of arithmetic standard deviation over arithmetic mean.

12.4.2.7 Step 6 – Retain Only Variables Contributing Substantially to Variance

The final step in reducing the number of input variables to be used in the uncertainty analysis was based on a factor (Column D in Table 12-4) that is the squared product of 1) the coefficient of variation for the variable (Column A in Table 12-4 and 2) the fractional contribution to dose from all pathways and radionuclides (Column B in Table 12-4) for which the variable is involved.

The coefficient of variation is equal to the standard deviation of the distribution describing the variable divided by the arithmetic mean of the distribution. The coefficient of variation is a relative measure of the variability of a random variable with respect to its mean value. Because the coefficient of variation (CV) measures relative variability, it allows comparison of variability across variables with different units and different absolute magnitudes. A variable with a small CV is very repeatable and reliable, experiencing little relative change from one measurement to another. A variable with a large CV is much more uncertain.

The data used to determine probability distributions for the 21 variables remaining at this step were gathered from a variety of published sources (with the exception of one case for which a personal communication was used). Appendix M provides details of the development of these probability distributions.

Table 12-4 shows the 21 variables, the coefficient of variation, the fractional contribution, the product of these squared, and the rank of the variable based on the combined factor. The following observations are based on this table:

- For the water-release variables, the range in the determining factor (Column D) is less than two orders of magnitude between the largest and smallest value; therefore, all three variables were retained.
- For the air-release variables, the highest ranked variable was the resuspension factor (the determining factor is 664) because the fractional contribution was relatively large and the coefficient of variation was over 31. This is an extremely large value that ranges over several orders of magnitude.
- Consider eliminating any variable with a determining factor less than 0.01: For the air release, the determining factor value falls off rapidly, and if the criterion of less than 0.01 was used, all variables of rank less than 10 would be excluded.
- The cutoff for rank was chosen to be 10. However, the variable of rank 11 was also included because it participated in dose from milk and meat as well as the companion variables—growing period (GRWPA,5) and forage consumption (CONSUM,5).

Based on these considerations, a final number of 14 variables were considered to be uncertain. Table 12-2 provides the statistical characteristics of these 14 variables, and Section 12.3 discusses how they were used.

Appendix N provides the input data used for the computations (LHS and GENII computer codes).

Table 12-4 Final Screening Step

		Variable	Coefficient of Variation (Standard Deviation /Mean)	Fractional Contribution to Total for Medium	Approximate Contribution to Variance	Square of Contribution to Variance	Rank for Medium
Water Pathway			***A***	***B***	***C***	***D***	
✓	1	CLBFF, Cs-137	1.788E+00	5.25E-01	9.38E-01	8.79E-01	2
✓	2	CLBFF, Sr-90	7.786E+00	1.59E-01	1.24E+00	1.53E+00	1
✓	3	CLBFF, P-32	1.107E+00	2.68E-01	2.96E-01	8.79E-02	3
Air Pathway							
✓	4	CLFMK, I-131	1.130E+00	1.38E-01	1.56E-01	2.43E-02	10
✓	5	CLFMT, I-131	5.348E-01	5.09E-01	2.72E-01	7.41E-02	7
	6	ABSHUM	4.711E-02	6.05E-01	2.85E-02	8.12E-04	13
✓	7	BIOMA2, 5&6	8.153E-02	6.93E-01	5.65E-02	3.19E-03	11
	8	BIOMA2, 3	2.032E-02	3.45E-01	7.01E-03	4.91E-05	16
	9	BIOMAS, 1	3.486E-02	6.09E-02	2.12E-03	4.50E-06	17
✓	10	WTIM	2.482E+00	8.16E-01	2.03E+00	4.10E+00	3
✓	11	CONSUM, 5	2.397E-01	6.93E-01	1.66E-01	2.76E-02	9
	12	CONSUM, 3	1.532E-01	3.45E-01	5.28E-02	2.79E-03	12
	13	DRYFAC, 1	2.000E-02	6.09E-02	1.22E-03	1.48E-06	18
	14	GRWP, 1	1.686E-01	6.09E-02	1.03E-02	1.05E-04	15
	15	GRWPA, 5&6	4.649E-01	6.93E-01	3.22E-01	1.04E-01	6
	16	GRWPA, 3	5.103E-02	3.45E-01	1.76E-02	3.10E-04	14
✓	17	DEPFR1,2	6.419E-01	8.16E-01	5.24E-01	2.74E-01	5
✓	18	LEAFRS, RESFAC;1	3.104E+01	8.30E-01	2.58E+01	6.64E+02	1
✓	19	DPVRES	1.959E+00	8.16E-01	1.60E+00	2.55E+00	4
✓	20	RADIUS	2.913E+00	1.00E+00	2.91E+00	8.49E+00	2
✓	21	F	2.000E-01	1.00E+00	2.00E-01	4.00E-02	8

✓ = retain for final analysis

12.5 Results of Uncertainty Analysis

The computer runs provided 40 dose values (corresponding to 40 realizations) for each receptor, as provided in Appendix O. In other words, the dose for each receptor was computed 40 times as a function of 40 (random) realizations of the variables considered to be uncertain plus all the other input variables considered to be fixed. Each set of 40 output values was examined statistically to determine an empirical

probability distribution and values representative of the central tendency (e.g., mean and median) for the dose to each receptor.

12.5.1 Description of Dose Distributions

The lognormal probability distribution was assumed to be a potentially good fit to the 40 random dose values associated with each receptor. This was assumed because all except 1 of the 14 probability distributions for the 14 uncertain input variables considered were lognormal (see Table 12-2). Also, the point-estimate value for each of these 14 variables from the deterministic analysis had been set equal to the median of the distribution for the corresponding variable in the uncertainty analysis. For this reason, the medians of the 28 distributions (1 for each receptor) were expected to be "close" to those point estimates found in the deterministic analysis contained in Chapter 11. In addition, the following is a well-known property of lognormal distributions: If a random variable is defined as the product of two or more independent random variables and each of these is described by a lognormal distribution, then the product will also be described by a lognormal distribution.

Using the computer software "Crystal Ball" (1), the best fit to the probability distributions for the total dose to 14 out of the 28 receptors was determined to be lognormal. The lognormal distribution was the second or third best fit to the dose distributions for the remaining receptors. However, even when the lognormal distribution was not the first choice, the best-fit distributions were similar to the lognormal. The fact that the dose distributions for all the receptors are not lognormal is attributed to the fact that the dose is computed by a complex mathematical model of the uncertain input variables involved in the uncertainty analysis. Except for very simple functions of random variables (e.g., multiplication by a constant), the function of several random variables is seldom characterized by the same probability distribution as the underlying input variables, even if they are all the same. For example, for the Adult Female member of the Delivery Family, the best fit to the distribution of dose from only air releases and the best fit to the distribution of dose from only water releases are gamma distributions; however, the best fit to the total dose from all releases, which is the sum of these air and water doses, is a lognormal distribution.

Table 12-5 displays descriptive statistics for the sample of 40 total dose realizations for each of the 28 receptors. The table lists the mean, median, minimum, maximum, and the standard deviation of total dose for each receptor. Note that the mean dose is larger than the median dose for every receptor. Because we have a sample of 40 values of dose, there are 20 values smaller than the median and 20 values larger than the median. If we had a symmetric distribution of dose, the smaller values and larger values would extend about equally on either side of the median value. In our case, however, the lower values are limited by zero because dose cannot be negative and the higher values extend out to relatively high values. For example, for the Child Born in 1955 for the Urban Family, the difference between the maximum value of dose (30.8 milliSieverts) and the median dose (2.55 milliSieverts) is 28.3 milliSieverts; however, the difference between the median dose (2.55 milliSieverts) and the minimum dose (0.345 milliSieverts) is only 2.20 milliSieverts. Figure 12-2 and Figure 12-3 show this skewing toward higher values, depicting as examples the dose distributions for the Adult Female in the Rural Family 2 and the Delivery Family, respectively. The distributions are displayed both as histograms and as a fitted lognormal distribution. Because the distribution is not symmetrical and is skewed toward higher values, the mean dose is larger than the median dose.

The range of the distribution of dose depends on the choice of both the scenario and family member. For example, for the Child Born in 1955 for the Urban Family, the ratio of maximum dose to minimum dose is over 89; for the Child Born in 1964 for the same family, the ratio of maximum dose to minimum dose is only about 4. Similarly, the ratio by which the mean dose exceeds the median dose depends on both the scenario and family member. The minimum value of this ratio is 1.07 for the Child Born in 1964 for the

Urban Family, and the maximum value of this ratio is 1.69 for the Child Born in 1955 for the same family.

Table 12-5 Statistics on Total Effective Dose Equivalent for Different Receptors*

Family	Family Member	Mean (mSv)‡	Median (mSv)‡	Minimum† (mSv)‡	Maximum† (mSv)‡	Standard Deviation (mSv)
Delivery Family	Adult Female	12.812	9.072	1.813	60.911	12.23
Delivery Family	Adult Male	13.001	9.281	1.737	61.183	12.26
Delivery Family	Child Born 1955	10.164	7.993	1.767	35.010	7.76
Delivery Family	Child Born 1964	4.498	3.159	0.712	15.146	3.73
Migrant Family	Adult Female	0.793	0.562	0.138	4.615	0.90
Migrant Family	Adult Male	1.117	0.756	0.184	6.770	1.29
Migrant Family	Child Born 1955	3.676	2.489	0.417	24.269	4.45
Migrant Family	Child Born 1964	0.127	0.093	0.043	0.732	0.13
Near Water Family	Adult Female	3.431	2.738	1.138	9.896	2.04
Near Water Family	Adult Male	3.574	2.929	1.183	10.084	2.06
Near Water Family	Child Born 1955	4.815	4.311	1.293	18.333	3.03
Near Water Family	Child Born 1964	2.850	2.290	0.867	14.090	2.31
Outdoor Family	Adult Female	4.687	4.263	1.272	11.751	2.46
Outdoor Family	Adult Male	6.055	5.546	2.026	14.246	2.95
Outdoor Family	Child Born 1955	13.331	10.988	2.529	60.270	10.21
Outdoor Family	Child Born 1964	2.951	2.309	0.893	14.158	2.31
Rural Family One	Adult Female	0.502	0.387	0.090	3.005	0.53
Rural Family One	Adult Male	0.712	0.538	0.120	4.406	0.76
Rural Family One	Child Born 1955	2.681	1.697	0.281	17.410	3.34
Rural Family One	Child Born 1964	0.093	0.077	0.037	0.340	0.06
Rural Family Two	Adult Female	1.174	0.890	0.199	7.162	1.28
Rural Family Two	Adult Male	1.655	1.198	0.267	10.502	1.85
Rural Family Two	Child Born 1955	6.362	4.006	0.642	41.579	0.798
Rural Family Two	Child Born 1964	0.190	0.153	0.072	0.796	0.14
Urban Family	Adult Female	0.447	0.284	0.083	2.204	0.39
Urban Family	Adult Male	0.895	0.698	0.263	3.276	0.55
Urban Family	Child Born 1955	4.314	2.551	0.345	30.820	5.57
Urban Family	Child Born 1964	0.115	0.107	0.054	0.215	0.03

* The number of decimal places for values in the table are to allow easy display; the values should be considered to have a precision no greater than two significant digits.
† These minimum and maximum values are for this sample; another set of realizations will likely have different values. However, any sample minimum value is greater than or equal to the population minimum value, while any sample maximum value is less than or equal to the population maximum value.
‡ mSv = milliSieverts.

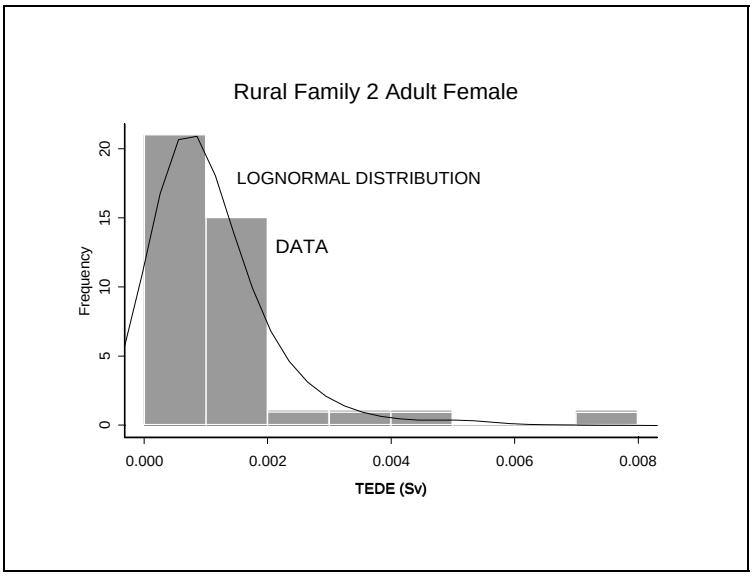


Figure 12-2 Histogram and Fitted Distribution for Dose to Adult Female, Rural Family 2

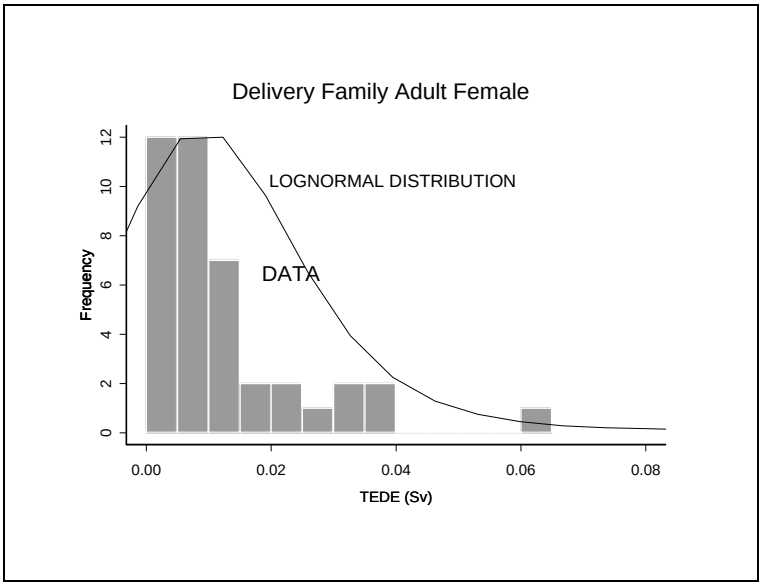


Figure 12-3 Histogram and Fitted Distribution for Dose to the Adult Female, Delivery Family

12.5.2 Quantified Confidence Bands for Doses

A primary motivation for the uncertainty analysis is to quantify the uncertainty associated with the dose to each receptor. One way to characterize this uncertainty is to state the confidence limits around the mean dose. Confidence limits define an interval around a parameter (e.g., the mean) so that the parameter is expected to be within the interval to a specified probability. Another way of looking at this is that the mean is estimated based on a finite set of values randomly sampled from a continuous distribution (i.e., in our case, we have a sample of 40 doses for each receptor out of an infinite number of possible values of

dose). The estimated parameter has two sources of uncertainty: 1) the underlying variability of the distributed values and 2) the finite sample size.

A standard statistical text (2) states the following:

$$\overline{X} - t_{1-\alpha/2}(n-1)\frac{S}{\sqrt{n}} \le \mu \le \overline{X} + t_{1-\alpha/2}(n-1)\frac{S}{\sqrt{n}} \qquad (12\text{-}1)$$

where, μ is the population mean
$\overline{X}$ is the sample mean
$t_{1-\alpha/2}(n-1)$ is the Student's t-distribution with (n-1) degrees of freedom for a 100(1-α)% total confidence level [100(α/2)% and 100(1-α/2)% confidence limits on the left and right sides of the distribution, respectively]
S is the unbiased estimator of the standard deviation
n is the number of observations (sample size).

If the sample variance is computed by the formula:

$$\hat{\sigma}^2 = \sum_{i=1}^{n} \frac{(X_i - \overline{X})^2}{n} \qquad (12\text{-}2)$$

then the unbiased estimator for the population variance is given by:

$$S^2 = \frac{n}{n-1}\hat{\sigma}^2 \qquad (12\text{-}3)$$

and the standard deviation, of either the sample or population, may be found by taking the square root of the corresponding variance.

For our computations, n=40. Then the fraction in equation (12-3) is 40/39 = 1.0256; if we take the square root to find S, then the fraction becomes $1.0256^{1/2}$= 1.0127. This relates the unbiased estimator to the sample standard deviation. This is a small correction, but it is made due to its ease of accomplishment.

Table 12-6 shows the values for t distribution for some typical confidence levels (1-α) and the 40 realizations.

Table 12-6 Values for t Distribution for Some Typical Confidence Intervals

α	Lower Bound	Upper Bound	Confidence Level	t(40-1)
0.1	5%	95%	90%	1.684875315
0.05	2.50%	97.50%	95%	2.022688932
0.02	1%	99%	98%	2.425840648

Since n=40, $40^{1/2}$ = 6.32455532. Then for α = 0.05,

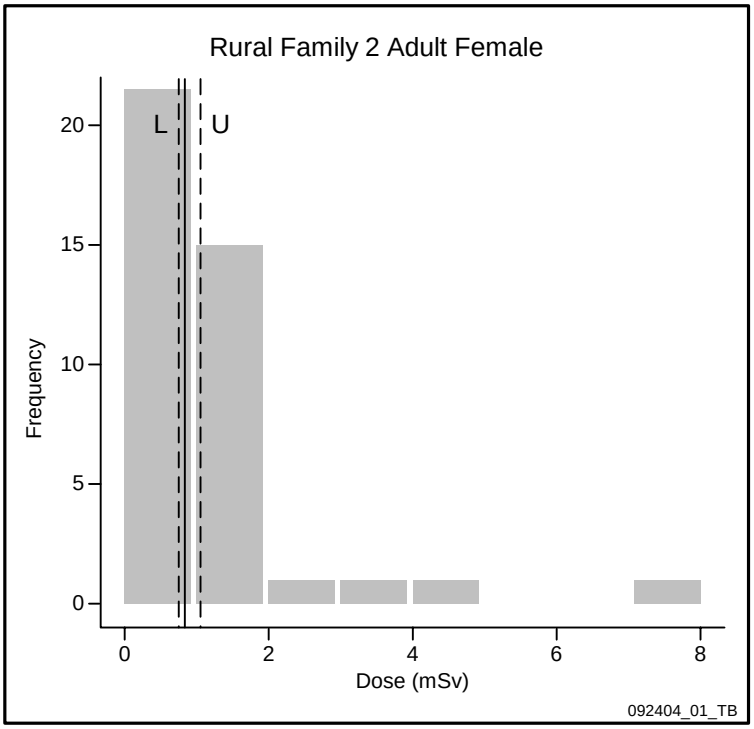
$$\overline{X} - 0.319815 \cdot S \le \mu \le \overline{X} + 0.319815 \cdot S \qquad (12\text{-}4)$$

Or the actual mean of dose is between the sample mean plus and minus about 1/3 of the sample standard deviation with a 95-percent confidence level. For example, for the Adult Female of the Delivery Family,

the sample mean dose is 0.012812 Sievert; the actual mean dose is expected to be between 0.008899 Sievert and 0.016724 Sievert with a confidence level of 95 percent.

The median dose is closer to the point-estimate dose than to the mean dose because the medians of the lognormal distributions of input variables were set equal to the point-estimate values for those input variables. One way to make the same type of confidence statements about the median dose that have been made about the mean dose is to assume that the total dose distribution for each receptor is described by a lognormal distribution. A special property of the lognormal distribution is that the mean of the natural logarithm of the sampled doses is equal to the natural logarithm of the median dose. Therefore, equation 12-4 may be used to establish confidence limits around the ln (ln is used to represent the natural logarithm) median; by taking the inverse logarithm, one obtains the median and its confidence limits (i.e., raising e (the base of the natural logarithms) to the ln median and to the ln confidence limits provides the median and its associated confidence limits).

Table 12-7 displays the mean and median for all 28 receptors and also gives the upper and lower confidence bounds for each statistic at the 95-percent level. Figure 12-4 shows the confidence intervals around the median for one receptor (the Adult Female for Rural Family 2) overlaid on the histogram of dose.



U= Upper Bound
L= Lower Bound

Figure 12-4 Confidence Intervals Overlaid on Histogram of Dose

For the mean values, the confidence bounds are almost symmetrical; the confidence intervals on either side of the mean range from 9- to 41-percent of the mean value depending upon the scenario and family member. For the median values, assuming a lognormal distribution, the confidence bounds are skewed toward higher values (i.e., the difference between the upper bound and the median is generally a higher fraction of the median than the difference between the median and the lower bound). The lower bound of the confidence interval ranges from 9- to 26-percent of the median value; the upper bound of the confidence interval ranges from 9- to 36-percent of the median value.

Table 12-7 95% Confidence Intervals for Mean and Median of Total Effective Dose Equivalent for Each Receptor

Family	Family Member	Mean (mSv)‡	Lower Limit of 95% CI* for Mean (mSv)‡	Upper Limit of 95% CI for Mean (mSv)‡	Median † (mSv)‡	Lower Limit of 95% CI for Median (mSv)‡	Upper Limit of 95% CI for Median (mSv)‡
Delivery Family	Adult Female	12.812	8.899	16.724	8.662	6.464	11.608
Delivery Family	Adult Male	13.001	9.081	16.921	8.872	6.643	11.849
Delivery Family	Child Born 1955	10.164	7.681	12.646	7.826	6.173	9.923
Delivery Family	Child Born 1964	4.498	3.305	5.691	3.290	2.541	4.259
Migrant Family	Adult Female	0.793	0.504	1.082	0.554	0.431	0.713
Migrant Family	Adult Male	1.117	0.705	1.529	0.770	0.595	0.997
Migrant Family	Child Born 1955	3.676	2.252	5.100	2.465	1.871	3.246
Migrant Family	Child Born 1964	0.127	0.086	0.167	0.102	0.085	0.122
Near Water Family	Adult Female	3.431	2.778	4.083	2.953	2.480	3.517
Near Water Family	Adult Male	3.574	2.916	4.232	3.103	2.618	3.677
Near Water Family	Child Born 1955	4.815	3.846	5.784	4.150	3.493	4.932
Near Water Family	Child Born 1964	2.850	2.113	3.588	2.326	1.913	2.826
Outdoor Family	Adult Female	4.687	3.900	5.475	4.129	3.505	4.865
Outdoor Family	Adult Male	6.055	5.113	6.997	5.434	4.676	6.316
Outdoor Family	Child Born 1955	13.331	10.065	16.596	10.688	8.640	13.222
Outdoor Family	Child Born 1964	2.951	2.214	3.688	2.437	2.017	2.945
Rural Family One	Adult Female	0.502	0.332	0.672	0.367	0.289	0.465
Rural Family One	Adult Male	0.712	0.470	0.954	0.521	0.410	0.662
Rural Family One	Child Born 1955	2.681	1.612	3.750	1.765	1.333	2.337
Rural Family One	Child Born 1964	0.093	0.074	0.113	0.083	0.072	0.096
Rural Family Two	Adult Female	1.174	0.767	1.582	0.841	0.658	1.076

Family	Family Member	Mean (mSv)‡	Lower Limit of 95% CI* for Mean (mSv)‡	Upper Limit of 95% CI for Mean (mSv)‡	Median † (mSv)‡	Lower Limit of 95% CI for Median (mSv)‡	Upper Limit of 95% CI for Median (mSv)‡
Rural Family Two	Adult Male	1.655	1.064	2.246	1.166	0.905	1.501
Rural Family Two	Child Born 1955	6.362	3.808	8.915	4.150	3.121	5.519
Rural Family Two	Child Born 1964	0.190	0.144	0.236	0.164	0.141	0.192
Urban Family	Adult Female	0.447	0.322	0.572	0.349	0.281	0.433
Urban Family	Adult Male	0.895	0.718	1.073	0.784	0.670	0.918
Urban Family	Child Born 1955	4.314	2.532	6.096	2.659	1.955	3.616
Urban Family	Child Born 1964	0.115	0.104	0.125	0.111	0.101	0.121

* CI = confidence interval.
† Calculated based on the natural log values of total effective dose equivalent.
‡ mSv = milliSievert.

Although the confidence intervals may be a substantial fraction of the central tendency value (the mean or the median), the upper confidence limits are not larger than the central tendency value (i.e., the confidence interval is always smaller than the interval 0 to twice the mean). This may seem counterintuitive to many who consider the dose estimates of this kind to be accurate only to an order of magnitude, if that. However, these confidence intervals reflect only the uncertainty in the input variables to the models and do not reflect the uncertainty in the models themselves or the approximations made in applying the models. In a sense, it is more correct to characterize these confidence bounds as a measure of precision rather than as a measure of accuracy.

For the dose distributions, the largest value of the coefficient of variation is approximately 1.3. This value is much smaller than the largest value of the coefficient of variation for the input variables, which was approximately 31 for the resuspension factor. The reason the uncertainty in resuspension factor is attenuated when processed by the dose models is that resuspension does not cause much dose for these scenarios. Inhalation of resuspended contamination has already been shown to be a minor pathway (see Section 12.2). In addition, resuspended contamination can cause dose by depositing on growing vegetation and becoming incorporated into the food chain. For the scenarios analyzed, however, direct deposition of contamination is always much more effective in causing dose than resuspended deposition.

12.5.3 Comparison of Results from Point Estimate and Uncertainty Analyses

Table 12-8 and Table 12-9 show for each receptor from the deterministic analysis the point-estimate dose compared to the results of the uncertainty analysis—the run 0 dose, the mean dose, and the median dose. As discussed previously in Section 12.2, the point-estimate dose is very close to the run 0 dose for each receptor -- as would be expected because the same values for the input variables are used. However, the mean dose from the uncertainty analysis is generally larger (and in some cases, substantially so) than the point-estimate dose for each receptor. The ratio of the mean dose to the point-estimate dose ranges from a high value of 2.15 (115 percent higher) for the Delivery Family Child Born in 1964 to a low value of 1.07 (7 percent higher) for the Urban Family Child Born in 1964. The median dose from the uncertainty analysis is generally higher than the point-estimate dose, but usually by a smaller amount than the corresponding mean dose. However, for the Urban Family receptors, the median doses are smaller than the point-estimate dose. The ratio of the median dose to the point-estimate dose ranges from a high value of 1.54 (54 percent higher) for the Delivery Family Child Born in 1955 to a low value of 0.86 (14 percent smaller) for the Urban Family Adult Female.

As discussed in Section 12.4.1, for the dose distributions obtained from the uncertainty analysis, it is not surprising that the median doses are generally smaller than the mean doses. However, it was somewhat surprising that the median doses were mostly larger (sometimes substantially so) than the point-estimate doses. After all, the point estimates of dose were developed using “representative” values for all the input variables, and a selected set of input variables were represented by distributions. All but one of the input distributions were chosen to be lognormal distributions (the other was a normal distribution). The median of each lognormal distribution was set equal to the point-estimate value of the corresponding input variable. Then the distribution of doses was generated based on 1) the distributions of input variables for those chosen to be uncertain and 2) the point-estimate values for those input variables chosen to be fixed. Because the medians of the input distributions were the point-estimate values, it could be expected (in a very approximate fashion) that the medians of the uncertain doses would be closer to the point-estimate values than the means of the uncertain doses. In some cases, however, they are greater than the point estimates by over 50 percent.

To examine this result, some additional analysis was performed. The dose to the Adult Female for the Delivery Person Family has been a focus of consideration because the water release dose (water dose) for

the point estimates is known to be 94 percent of the total dose. This receptor was chosen for closer scrutiny because it has dose dominated by this single release mode and because the median of the uncertain dose—9.072 milliSieverts—is 1.486 times the point-estimate dose of 6.106 milliSieverts.

An initial conjecture is that the air doses add to the water doses in a random fashion and provide a "floor" for the total dose. This more-or-less average addition could cause the low values of the total doses to be elevated and therefore increase the median. This conjecture does not seem to be confirmed by the data. The median for just the water doses is 8.539 milliSieverts. This implies that only 5.9 percent of the median dose is contributed by the air releases. Therefore, the air releases hardly seem capable of elevating the median of the dose. To look at it another way, the mean value of the air release dose is 0.469 milliSieverts. If this mean value of air dose is added to the water doses, it will not substantially affect the median total dose. Although the fraction of the air dose increases substantially for lower total doses, the highest it ever gets is a little over 0.4. For most values, the fraction is less than 0.1 and for many it is less than 0.05. This is not the answer.

Table 12-8 Statistics on Total Effective Dose Equivalent for Different Receptors

Family	Family Member	Point Estimate (mSv)*	Run 0 (mSv)*	Mean (mSv)*	Median (mSv)*
Delivery Family	Adult Female	6.106	6.091	12.812	9.072
Delivery Family	Adult Male	6.283	6.266	13.001	9.281
Delivery Family	Child Born 1955	5.200	5.180	10.164	7.993
Delivery Family	Child Born 1964	2.090	2.081	4.498	3.159
Migrant Family	Adult Female	0.447	0.438	0.793	0.562
Migrant Family	Adult Male	0.624	0.614	1.117	0.756
Migrant Family	Child Born 1955	2.178	2.160	3.676	2.489
Migrant Family	Child Born 1964	0.083	0.081	0.127	0.093
Near Water Family	Adult Female	2.091	2.057	3.431	2.738
Near Water Family	Adult Male	2.205	2.170	3.574	2.929
Near Water Family	Child Born 1955	3.137	3.099	4.815	4.311
Near Water Family	Child Born 1964	1.759	1.734	2.850	2.290
Outdoor Family	Adult Female	3.030	3.001	4.687	4.263
Outdoor Family	Adult Male	4.216	4.169	6.055	5.546
Outdoor Family	Child Born 1955	9.435	9.383	13.331	10.988
Outdoor Family	Child Born 1964	1.826	1.810	2.951	2.309
Rural Family One	Adult Female	0.303	0.299	0.502	0.387
Rural Family One	Adult Male	0.423	0.418	0.712	0.538
Rural Family One	Child Born 1955	1.589	1.580	2.681	1.697
Rural Family One	Child Born 1964	0.072	0.071	0.093	0.077
Rural Family Two	Adult Female	0.696	0.685	1.174	0.890
Rural Family Two	Adult Male	0.974	0.961	1.655	1.198
Rural Family Two	Child Born 1955	3.751	3.729	6.362	4.006
Rural Family Two	Child Born 1964	0.140	0.137	0.190	0.153
Urban Family	Adult Female	0.330	0.325	0.447	0.284
Urban Family	Adult Male	0.731	0.723	0.895	0.698
Urban Family	Child Born 1955	2.686	2.675	4.314	2.551
Urban Family	Child Born 1964	0.107	0.106	0.115	0.107

Table 12-9 Comparison of Mean Dose and Median Dose with Point-Estimate Dose for each Receptor

Family	Family Member	Pt. Estimate (mSv)*	Mean (mSv)*	Ratio, Mean over Point Estimate	Median (mSv)*	Ratio, Median over Point Estimate
Delivery Family	Adult Female	6.106	12.812	2.098	9.072	1.486
Delivery Family	Adult Male	6.283	13.001	2.069	9.281	1.477
Delivery Family	Child Born 1955	5.200	10.164	1.955	7.993	1.537
Delivery Family	Child Born 1964	2.090	4.498	2.153	3.159	1.512
Migrant Family	Adult Female	0.447	0.793	1.773	0.562	1.255
Migrant Family	Adult Male	0.624	1.117	1.790	0.756	1.211
Migrant Family	Child Born 1955	2.178	3.676	1.688	2.489	1.143
Migrant Family	Child Born 1964	0.083	0.127	1.524	0.093	1.119
Near Water Family	Adult Female	2.091	3.431	1.641	2.738	1.309
Near Water Family	Adult Male	2.205	3.574	1.621	2.929	1.328
Near Water Family	Child Born 1955	3.137	4.815	1.535	4.311	1.374
Near Water Family	Child Born 1964	1.759	2.850	1.621	2.290	1.302
Outdoor Family	Adult Female	3.030	4.687	1.547	4.263	1.407
Outdoor Family	Adult Male	4.216	6.055	1.436	5.546	1.316
Outdoor Family	Child Born 1955	9.435	13.331	1.413	10.988	1.165
Outdoor Family	Child Born 1964	1.826	2.951	1.616	2.309	1.264
Rural Family One	Adult Female	0.303	0.502	1.656	0.387	1.277
Rural Family One	Adult Male	0.423	0.712	1.683	0.538	1.270
Rural Family One	Child Born 1955	1.589	2.681	1.687	1.697	1.067
Rural Family One	Child Born 1964	0.072	0.093	1.295	0.077	1.067
Rural Family Two	Adult Female	0.696	1.174	1.688	0.890	1.279
Rural Family Two	Adult Male	0.974	1.655	1.700	1.198	1.231
Rural Family Two	Child Born 1955	3.751	6.362	1.696	4.006	1.068
Rural Family Two	Child Born 1964	0.140	0.190	1.362	0.153	1.094
Urban Family	Adult Female	0.330	0.447	1.353	0.284	0.859
Urban Family	Adult Male	0.731	0.895	1.224	0.698	0.954
Urban Family	Child Born 1955	2.686	4.314	1.606	2.551	0.950
Urban Family	Child Born 1964	0.107	0.115	1.068	0.107	0.996

*mSv = milliSieverts.

The components of the water dose seem to provide a more plausible explanation of the behavior of uncertain doses. For each realization, the doses resulting from cesium-137, strontium-90, and phosphorus-32 were listed as well as their sum. The median of the "sum" is 8.419 milliSieverts. This sum accounts for most of the water-dose median (8.419/8.539 = 0.986) and most of the total-dose median (8.419/9.072 = 0.928). The median of doses for each isotope were found separately, and the sum of these medians is 5.857 milliSieverts. This is much closer to the point-estimate dose of 6.106 milliSieverts. This appears to suggest that if the three isotopic components of dose were summed separately, they would correspond closely to the base case. However, because these doses are summed for each realization, the sum is, on average, larger than the point estimate. Because the uptake factors for these three isotopes vary

independently and randomly, the total dose can be considered approximately to be the sum of three lognormal distributions. The smaller, but substantial, doses from strontium-90 and phosphorus-32 essentially make a "floor" on the dose from cesium-137 and boost the median (as shown) by a factor of about 50 percent over what would occur if the uptake factors were correlated.

In summary, it appears that the confidence intervals do not include the point estimates. This appears to be a result of both the assumptions regarding the input variable distributions and the mathematical form of the dose model. This also shows the utility of performing an uncertainty analysis, which may give a different perspective on the problem than a point estimate.

12.6 Secondary Results

The primary result of the overall uncertainty analysis was to establish distributions of dose estimates that incorporated uncertainty in the input variables and to establish the statistical confidence intervals about the mean values of those distributions. However, the large amount of data generated in performing this uncertainty analysis can be used to provide additional insights into how doses and the uncertainties in doses depend on the uncertain variables analyzed. This additional information can be useful in determining how to refine the modeling approaches or how to prioritize the need for additional site data.

In Chapter 11 dose to various receptors was explored by identifying important factors such as radionuclides, year of exposure, exposure pathways, and exposure routes. These results provided information on the structure of the model. These point estimate dose results and the conclusions drawn from them also depended on the choices made for the value of each input variables, i.e., one value for each input variable. In this chapter the dependence of dose on the distributions chosen to describe each uncertain input variable is explored; i.e., the attention here is on the dependence of dose on the uncertain input variables. These analyses are based upon the sampled input variables and results of the uncertainty analysis described in previous sections. By aligning the input variable values with the respective resultant dose values, several statistical techniques can be used to evaluate how a change in an input variable changes the output (dose).

The dependence of dose on the uncertain input variables can be considered to have two components: (1) how effective a change in an input variable is in producing a change in dose and (2) how widely a particular input variable changes. Big variations in dose may be produced in three ways: (1) dose may be very sensitive to a particular variable, so even modest variations in that input variable produce substantial variations in dose; (2) dose may be moderately sensitive to a particular variable, but the variable is very uncertain, so large variations in dose are produced; (3) dose may be very sensitive to a highly variable input, so extremely large variations in dose are produced. The two components describing the dependence of dose on uncertain input variable are sometimes characterized by two coefficients: (1) a sensitivity coefficient and (2) a variance or uncertainty coefficient. Broadly speaking, the sensitivity coefficient is the ratio of the fractional change in dose to the fractional change of an input variable. The variance or uncertainty coefficient is the fraction of uncertainty in dose attributable to the uncertainty in an input variable. Both of these aspects are explored in the Sections that follow.

Sections 12.6.1 and 12.6.2 discuss how some general statistical methods can be used to describe the relationships between dose and input variables. Scatter plots are used to give a graphical assessment of the input-dose relationship. The correlation coefficient (assuming a linear relationship) was used to quantify the relationship between dose and input variables. Section 12.6.3 describes how the variability in dose depends on input variables (i.e., variance or uncertainty considerations); Section 12.6.4 describes how the dose depends on input variables (i.e., sensitivity considerations). Only a few examples were analyzed and described here. An extensive analysis of this type is beyond the scope of the current study. More extensive analyses of this type may be appropriate in the future. The limited analyses described

here generally reinforce the understanding of the generation of doses by SRS releases obtained from the modeling and results described in previous Chapters.

The names and characteristics of the uncertain variables analyzed are described in Table 12-2. However, to facilitate this discussion, the variable names and their physical meaning are repeated in Table 12-10 here.

Table 12-10 Names of Uncertain Variables and Their Physical Meaning

Variable Name	Physical Meaning
Water Pathway	
CLBFF, Cs-137	Bioconcentration factor for Cs-137 in fish
CLBFF, Sr-90	Bioconcentration factor for Sr-90 in fish
CLBFF, P-32	Bioconcentration factor for P-32 in fish
Air Pathway	
LEAFRS	Soil resuspension factor; determines the amount of radioactivity deposited on the ground that is resuspended; affects urban and rural scenarios.
RADIUS	Radius of particles that can deposit on the soil and plant surfaces.
WTIM	Weathering rate constant determines the rate at which deposited radioactivity is removed by weathering processes from crop surfaces.
DPVRES	Deposition velocity from air to plant surfaces for resuspended activity.
DEPFR1, 2	Dry and wet deposition fraction; how much of the radioactivity deposited on plant surfaces is retained and absorbed by the plant.
GRWPA, 5&6	Growing period for animal forage; the longer the growing period, the more exposure the plant has to air deposition of radionuclides.
CLFMT I-131	Uptake of I-131 by beef muscle; transfer to meat from cattle food.
F	Release factor characterizes the uncertainty in air and water releases of radionuclides from the SRS.
CONSUM, 5	Animal forage consumption rate; scales forage consumption by milk and beef animals.
CLFMK I-131	Uptake of I-131 by milk; transfer to milk from cow food.
BIOMA2	Animal forage standing biomass (wet) describes how much grass is in the field per unit area.

12.6.1 Scatter Plots

Figure 12-5 shows examples of scatter plots for the Delivery Family Adult Female. Simple scatter plots of the dose versus a sampled input variable (e.g., CLBFF-Cs, the bioconcentration of cesium in fish) can give a quick visual display of the importance of a particular variable in affecting the dose. For example, the left and right plots are, respectively, the plot of dose versus the cesium-bioconcentration in fish and the plot of dose versus the suspended particle radius. The pattern in the left plot resembles that of a line, indicating a strong linear relationship between the uptake of cesium in fish and the resultant dose to the Delivery Family Adult Female. The much more random “snow” pattern in the right plot indicates that the dose to the Delivery Family Adult Female is not significantly affected by the resuspended soil-particle radius.

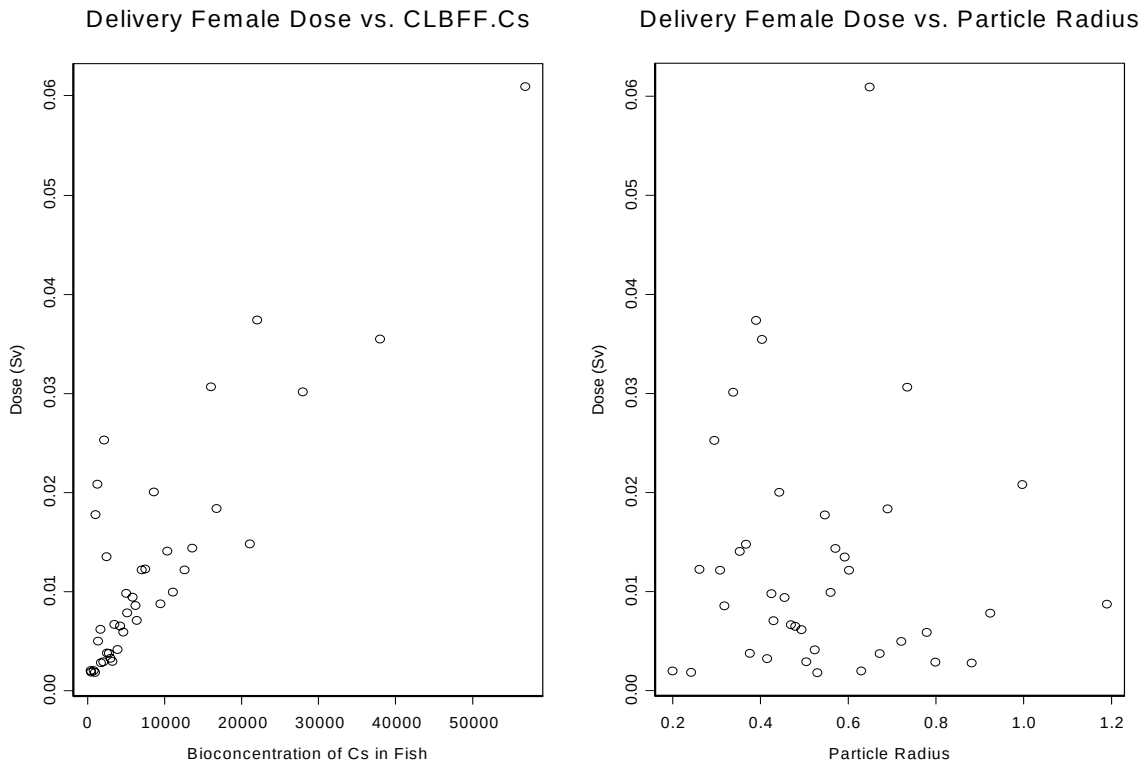


Figure 12-5 Examples of Scatter Plots for the Delivery Family Adult Female: Dose vs. Bioconcentration of Cesium in Fish (Left Plot) and Dose vs. Particle Radius (Right Plot)

12.6.2 Correlation Coefficients

Correlation coefficients are another way of expressing the relationship between input variables and the dose. Again, this analysis focused on linear relationships and did not consider nonlinear relationships such as dose as a function of the square of the particle radius. The correlation coefficient is a quantitative, statistical measure that represents the strength of the linear relation between two random variables (5). In this case, the two random variables are the dose and the input variable selected for examination. Correlation coefficients range between -1.0 and +1.0. A value of +1.0 indicates a perfect direct relationship; a value of -1.0 indicates a perfect negative relationship. For example, the size of one's bank account may have a correlation of +1 with the size of one's paycheck, but a correlation of -1 with the size of one's expenditures.

Correlation coefficients for the CLBFF-Cs and radius scatter plots given above are 0.864 and -0.032, respectively. This quantitatively demonstrates that CLBFF-Cs is over 10 times more effective in changing the dose than is the radius.

12.6.3 Stepwise Regression Analysis

The dose to the 28 hypothetical individuals considered in this analysis is the summation of incremental doses through various exposure pathways and from various radionuclides. These doses depend on many environmental and behavioral variables. Thus, in determining the most important variables, it is important to consider them together for the purpose of establishing an order of most to least significant within the

group. This can be accomplished with the stepwise regression analysis technique. In this type of analysis, the relationship of the dose to all of the sampled input variables is represented as a polynomial; that is, the statistical model for the dose is a sum of linear terms where each term is a product of a coefficient and an input variable.

A main focus of the stepwise regression analysis is to determine the best value of the coefficient for each input variable. This statistical model is built in a stepwise fashion by sequentially adding (or subtracting) one independent variable at a time. The result of this analysis is a statistical model that describes the dose as a function of a small set of independent variables (e.g., Dose ~ f(CLBFF-Cs +CLBFF-Sr)) which are the most important in affecting dose; input variables with coefficients that are relatively small are generally deleted from the model. Because this kind of analysis can be very computationally intensive, statistical software (S-Plus; Insightful, 2002) was used. As the software performed the stepwise regression, it automatically checked the coefficient of determination (R^2) and the statistical level of significance. Variables that do not have significant correlation with the dose or result in an increase in the R^2 are generally left out.

The statistic R^2, the coefficient of determination, is a "measure of the proportion of the total variability in the dependent variable that is accounted for by the regression equation" (6). A value of 1 for R^2 suggests that all the variability in the dependent variable (dose) is accounted for by the variability in the selected independent variables. A low value for R^2 is often interpreted to mean that the variability in the dependent variable is not linked to the variation in the independent variables. This is true to some extent. A low R^2 is many times a reflection of a small range of variation of the independent variable. Or, it might indicate that some of the variables should be considered in a nonlinear fashion (e.g., X^2 or 1/x).

The stepwise regression analysis was conducted for the hypothetical families that consume fish (Delivery, Near Water, and Outdoor Family) by considering all 14 of the sampled input variables. For those hypothetical families that did not consume fish (Migrant, Rural Families 1 and 2, Urban/Suburban), the stepwise regression analysis was conducted without any of the bioconcentration factors in fish (i.e., CLBFF for cesium, strontium, and phosphorus).

Table 12-10 and Table 12-11 present the results of the stepwise regression analysis, respectively, for the Delivery Family (which ate fish) and Rural Family 2 (which did not). Table 12-12 presents the stepwise regression analysis results for each of the Adult Females representing all scenarios. The five most important variables are listed in order of importance. The rank ordering is based upon the correlation coefficient and the contribution to the R^2. In general, for those variables that contribute more than 0.1 to the multiple R^2, there is little uncertainty concerning their rank. In this analysis, this generally applies to the top three variables. Variables ranked fourth and fifth made a very small contribution to the multiple R^2 and thus might change with a different sampling using the Latin Hypercube Sampling program.

Table 12-10 Delivery Family Stepwise Regression Results Listing Input Variables in Order of Influence and the Sum of R^2 for the Variables Listed

Adult Female	Adult Male	Child Born 1955	Child Born 1964
CLBFF-Cs	CLBFF-Cs	CLBFF-Sr	CLBFF-Sr
CLBFF-Sr	CLBFF-Sr	CLBFF-Cs	CLBFF-Cs
F	F	CLFMK I-131	CLBFF-P
CLBFF-P	BIOMA2	CLFMT I-131	BIOMA2
BIOMA2	CLBFF-P	LEAFRS	F
R^2 = 0.98	R^2 = 0.98	R^2 = 0.96	R^2 = 0.97

Note: Refer back to Table 12-2 for descriptions of the variables.

Table 12-11 Rural Family 2 Regression Results Listing Input Variables in Order of Influence and the Sum of R^2 for the Variables Listed

Adult Female	Adult Male	Child Born 1955	Child Born 1964
DEPRF1,2	LEAFRS	LEAFRS	LEAFRS
LEAFRS	DEPRF1,2	F	F
F	F	DEPFR 1,2	DEPFR 1,2
DPVRES	DPVRES	DPVRES	DPVRES
CONSUM	CONSUM	CONSUM	CONSUM
R^2 = 0.597	R^2 = 0.576	R^2 = 0.793	R^2 = 0.5793

Note: Refer back to Table 12-2 for full descriptions of the variables.

Table 12-12 Stepwise Regression Results for the Adult Female of Each Scenario

Delivery Female[1]	Migrant Female	Near Water Female[1]	Outdoor Female[1]	Rural Family 1 Female	Rural Family 2 Female	Urban Female
CLBFF-Cs	LEAFRS	LEAFRS	CLBFF-Cs	DEPRF1,2	DEPRF1,2	DEPRF 1,2
CLBFF-Sr	DEPFR 1,2	DEPRF 1,2	CLBFF-Sr	LEAFRS	LEAFRS	WTIM
F	F	F	CLBFF-P	F	F	CLFMK I-131
BIOMA2	DPVRES	DPVRES	DEPRF1,2	DPVRES	DPVRES	CLMFT I-131
CLBFF-P	CONSUM	CONSUM	CLFMT I-131	CONSUM	CONSUM	CONSUM
R^2 = 0.98	R^2 =0.692	R^2 =0.692	R^2 =0.939	R^2 =0.593	R^2 =0.597	R^2 =0.731

[1] Ate Fish
Note: Refer back to Table 12-2 for full descriptions of the variables.

In the case of the Delivery Family (Table 12-11), the most important variables to the dose are the bioconcentration factors for cesium, strontium, and phosphorus in fish, suggesting that much of the variability in dose to the Delivery Family is from the variability of the uptake factors for cesium, strontium, and phosphorus by fish. As described in Chapter 3, the Delivery Family gets 50 percent of its fish from Lower Three Runs Creek, which drains from the area with P and R reactors. This list of variables may be shortened even more by dropping CLBFF-P, because CLBFF-Cs and CLBFF-Sr yield an R^2 of 0.91, which is most of the variation.

After strontium and cesium in fish, the important variables for the Delivery Family Child Born in 1955 are those variables associated with uptake of iodine-131by beef cattle and milk cows (CLFMT I-131 and CLFMK I-131), reflecting the relatively large releases of iodine-131 in the early years of site operation.

The most important variables for the Rural Family 2 (Table 12-12) are related, as expected, to ingestion. However, the variable LEAFRS (resuspension factor) could also impact inhalation dose. The variable CONSUM (forage consumption rate) is associated with the uptake of radionuclides (especially I-131) by beef cattle and milk cows. The R^2 values for this set of stepwise regression analyses (approximately 0.6

for each receptor) indicate that the relationship between the independent variables and the dose may not be linear or that there is a small range for one of the variables (CONSUM has a range of 9 to 62; less than 1 order of magnitude).

Table 12-13 compares the stepwise regression results for the Adult Female in each of the seven scenarios; this is intended to show how results are scenario dependent, but comparisons based on other family members may identify different variables. In general, the results of the stepwise regression analysis are consistent with the scenarios as they are defined. Specifically, of the hypothetical families that eat fish, the Delivery Family got its fish from Lower Three Runs Creek and the Savannah River, which exposed them to cesium, strontium, and phosphorus releases from the SRS at relatively higher concentrations than those families obtaining fish from only the Savannah River. The members of the Outdoor Family fished along the Savannah River shoreline adjacent to the SRS and were thus exposed to radionuclides transported through the wetlands area. Thus, it is reasonable that the most significant variables in determining the variation in dose to these families are the variations in bioconcentration factors for cesium and strontium.

In contrast, although the Near Water Family got its fish from the Savannah River, the consumption of fish was smaller than for the Outdoor Family. The bioconcentration factors cesium, strontium, and phosphorus in fish were not among the most important variables for this scenario. Instead, the Near Water and Migrant families exhibit a similar ranking of important variables. The most important variables for these families are related to exposure by air and consumption of locally grown fruits, vegetables, milk and beef. Although these families lived on opposite sides of the SRS, the similarity in the sensitivity rankings suggest that exposure through pathways related to air transport did not vary substantially around the circumference of the SRS.

The two Rural families showed the same sensitivities to input variables. Like the Migrant and Near Water families, the most important variables affecting variation in dose are those related to airborne transport and uptake through farm products.

The first-ranked variable for the Migrant and Near Water families is LEAFRS. This variable contributed 0.41 to the total R^2. The second-ranked variable DEPRF1,2 contributed 0.15. By contrast, the contribution to the total R^2 for the two Rural families was 0.23 for DEPFR1,2 and 0.21 for LEAFRS. The reasons for these differences in variable ranking and their relative contribution are not clear.

The ranking of variables for the Urban/Suburban Family is different from those families living in more rural settings closer to the SRS. This family's primary exposure to radionuclides from the site was through the milk produced in the New Ellenton area. DEPRF1,2 is the most significant variable with a contribution of 0.4 to the total R^2. Other variables are for removal of deposited radionuclides from plant surfaces (WTIM) and the uptake of I-131 into milk and beef (CLFMT I-131 and CLFMK I-131).

Several scenarios show sensitivity to the release factor, an expected result: the more released, the higher the dose.

12.6.4 Sensitivity Coefficients

In Section 12.6.3, the most important variables were ranked in order of their contribution to the coefficient of determination, R^2. This ranking actually is for the contribution to the variability in the dose, not the sensitivity, per se. To rank the variables in terms of their sensitivity coefficient (how a fractional change in the dose reflects a fractional change in the input variable), the uncertain variables were transformed to dimensionless quantities by dividing by the mean of each respective distribution. The transformed variables were used in the stepwise regression analysis, and while the variables found to be

dominant remained the same, the ranking changed. In this analysis, the sensitivity coefficients are based on the slope of a least-squares-fit between dose and the input variable.

Table 12-13 presents the variable rankings and their sensitivity coefficients for the Delivery Family and Rural Family 2 Adult Females. These rankings are related to how important the variables are in determining the dose; these rankings reflect only slightly the degree of uncertainty in the input variables themselves.

Table 12-13 Variable Rankings and Their Sensitivity Coefficients

Delivery Family Adult Female		Rural Family 2 Adult Female	
Variable	**Sensitivity Coefficient**	**Variable**	**Sensitivity Coefficient**
F	0.66	F	0.92
BIOMA2	-0.65	DEPFR 1,2	0.84
CLBFF-Cs	0.64	CONSUM	0.38
CLBFF-Sr	0.13	LEAFRS	0.15
CLBFF-P	0.01	DPRVES	0.09

Note: Change in sign for BIOMA2 that is more consistent with the analytical model.

12.7 Summary

The following are some of the key aspects of the uncertainty analysis:

- Forty realizations were used to investigate the uncertainty behavior of dose for each of 28 hypothetical receptors.
- In general, the distribution of dose for each receptor behaved similar to a lognormal distribution.
- Consistent with the shape of a lognormal distribution, the mean of each dose distribution was higher than the median of the distribution.
- The confidence intervals were estimated for the mean and median. The sizes of these intervals were not large compared to the corresponding mean and median. This appears to reflect the sample size (40) and the underlying uncertainty quantified for the dose distributions. Also, modeling uncertainty was not estimated; only uncertainty related to the input variables was quantified.
- In general, the mean and median for the uncertainty analysis are larger than the corresponding point estimate of dose. This appears to reflect the interaction among the uncertain variablesand the complexity of the dose model.
- The calculated confidence intervals do not contain the point estimates of dose for the reasons cited in the previous bullet.
- The sensitivity analysis generally shows the same dominance of the milk and beef ingestion pathways for those scenarios dominated by dose from air release (as did the point-estimate analysis). Similarly, for doses from water releases, the fish ingestion dominates—specifically, the fish bioconcentration factors for cesium-137, strontium-90, and phosphorus-32.

12.8 References

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13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Introduction

This chapter discusses conclusions and recommendations based on the analyses described in the preceding chapters. Most of the conclusions relate to the results of the analyses, not the methods used to obtain results. The recommendations are intended to address unresolved issues that have arisen during the course of the work. The Savannah River Site Health Effects Subcommittee (SRSHES) raised some of these unresolved issues during presentations and discussions on this work. Other unresolved issues arise from the analysis but have not been resolved because they are beyond the scope of the current task. In general, while the resolution of these issues is not expected to change the major conclusions of this work, it is expected to enhance confidence in the conclusions.

13.2 Conclusions

The following bullets summarize the major conclusions of this dose reconstruction. These conclusions are then described in greater detail in the subsequent subsections.

- Doses and risks are small for all receptors and scenarios relative to doses and risks from background radiation over the 39-year period of the study.
- For people who ate fish from the Savannah River or Lower Three Runs Creek, fish ingestion was the most significant pathway, and the most important radionuclides were generally ^{137}Cs, ^{32}P, and ^{90}Sr.
- For people who did not eat fish from bodies of water contaminated by releases of radionuclides to water, milk and beef were the most significant pathways and ^{131}I and tritium were the most important radionuclides.
- Immersion in ^{41}Ar was a generally small, but constant contributor to dose; however, for some receptors, it was the largest fraction of a small dose.
- Larger doses occurred in years corresponding to larger releases from the Savannah River Site (SRS), especially ^{131}I; for the Adult Male, Adult Female, and Child Born in 1955, a large fraction of the total dose was received during the years 1955-1961.
- There were important differences in doses, pathway significance, and radionuclide significance between children born in 1955 and children born in 1964—those born in 1955 experienced the large I releases early in the site history, while those born in 1964 did not experience them.
- Doses caused by ingesting fish from Lower Three Runs Creek were significantly higher than doses caused by ingesting fish from the Savannah River.
- For air releases, the variations in air dispersion of radionuclides from the site generally produced a significant, but not dominant, variation in estimated doses.
- Consideration of uncertainty in the variables used to estimate doses could cause an estimated dose to be higher or lower than the corresponding point-estimate result. The mean of the distribution of total dose for any receptor ranged between 2.15 to 1.07 times the corresponding point-estimate dose; thus, the means of the uncertain doses were close to the corresponding point-estimate values.
- The use of hypothetical scenarios to demonstrate the interactions of a range of receptor behaviors with the site and release characteristics was an effective analytical tool.

13.2.1 Doses and Risks Are Small

Calculated doses and risks to the hypothetical receptors appear to be small. The largest point-estimate dose was 9.4 milliSieverts (mSv) (0.94 rem) over the 39-year period studied for the Outdoor Family Child Born in 1955; the corresponding risk of cancer incidence is 0.10 percent, and the corresponding risk of cancer fatality is 0.024 percent. By way of comparison, the annual average radiation exposure for a member of the U.S. population is about 3.6 mSv (0.36 rem) (1), mainly from naturally occurring sources of radiation and medical sources (e.g., x rays). An annual background dose of 3.6 mSv over a period of 39 years would produce a dose of 140 mSv (14 rem).

Although estimated doses (and the risks of cancer incidence) were higher when uncertainties in variables were considered, the increases are not sufficient to change this conclusion. For example, when uncertainties were considered, the Outdoor Family Child Born in 1955 received the largest mean dose of 13 mSv (1.3 rem) and the largest median dose of 11 mSv (1.1 rem). However, the maximum dose for the same receptor was 60.3 mSv (6 rem) and the minimum dose for the same receptor was 2.53 mSv (0.25 rem).

13.2.2 Important Exposure Pathways and Radionuclides

Chapter 11 discusses the point-estimate doses for each receptor within each of the seven scenarios, including the contributions to these doses by the various radionuclides and exposure pathways. Although each scenario and each receptor within the scenario demonstrated unique characteristics, some generalizations can be made about the radionuclides and exposure pathways contributing most to dose. For any given realization in the uncertainty analysis, the importance of the various radionuclides and scenarios could be different; however, the same general trends that occur in the point-estimate analysis appear to be present. Other conclusions from the uncertainty analysis are presented in Section 13.2.8.

For scenarios exposed to water releases through ingestion of fish taken from the Lower Three Runs Creek and the Savannah River downstream of the SRS (Delivery Family, Outdoors Family, and Near River Family), the dominant radionuclides were ^{137}Cs, ^{90}Sr, and ^{32}P. Table 13-1 shows the fraction of dose resulting from fish ingestion for the 12 receptors in the 3 scenarios exposed to water releases. In many cases (8 out of 12), the percentage of dose from fish ingestion is greater than 50 percent. For 83 percent of the receptors (10/12), fish ingestion was the largest source of dose. Beef ingestion edged out fish ingestion for the two remaining receptors.

Table 13-2 shows the percent of total dose over 39 years for a selected set of radionuclides. ^{137}Cs, ^{90}Sr, and ^{32}P were the dominant radionuclides for exposures to water releases by fish ingestion. This is shown most clearly by the large percentage of dose from these isotopes for all members of the Delivery Person Family. However, for the Child Born in 1955 for the Delivery Person Family, ^{131}I (from ingestion of terrestrial foods contaminated by air releases) was a significant source of dose; for the Children Born in 1964 in the Outdoors Family and the Near River Family, ^{32}P was the most important isotope. For the Adults in the Near River Family, ^{137}Cs was the most important radionuclide. For the Adults in the Outdoors Family, ^{131}I was the most important radionuclide.

Thus, it can be seen that the fish ingestion pathway accounted for a large fraction of the dose for most of the receptors exposed to water releases. The important radionuclides producing dose through this pathway depended, in part, on the timing of the exposure; for Children Born in 1964, important radionuclides tended to shift from ^{137}Cs to ^{32}P for water resources (see Section 13.2.5 for additional discussion). In addition, for the Children Born in 1955, ^{131}I, which is not related to fish ingestion, was an important isotope (the most important isotope for two scenarios).

Table 13-1 Percent of Total Dose from Fish Ingestions for Various Receptors in the Three Scenarios Exposed to Water Releases

Scenario	Receptor	Percent of Total Dose from Fish Ingestion
Delivery Person Family	Adult Female	92.8*
	Adult Male	90.2*
	Child Born in 1955	57.9*
	Child Born in 1964	92.9*
Outdoors Family	Adult Female	48.2*
	Adult Male	34.6
	Child Born in 1955	11.8
	Child Born in 1964	79.3*
Near River Family	Adult Female	71.0*
	Adult Male	66.2*
	Child Born in 1955	35.4*
	Child Born in 1964	82.3*

*For these receptors, fish ingestion was the largest source of dose.

Table 13-2 Percent of Total Dose from Fish Ingestions for Various Receptors in the Three Scenarios Exposed to Water Releases

Scenario	Receptor	Percent of Total Dose				
		^{137}Cs	^{90}Sr	^{32}P	^{131}I	Sum
Delivery Person Family	Adult Female	77.0	9.7	4.3	4.3	95.3
	Adult Male	74.8	9.5	4.2	6.0	94.5
	Child Born in 1955	39.8	11.3	5.4	37.9	94.4
	Child Born in 1964	49.5	25.1	15.0	*	89.6
Outdoors Family	Adult Female	18.8	*	17.5	42.2	59.7
	Adult Male	14.4	*	12.6	45.3	57.9
	Child Born in 1955	2.5	1.6	6.0	82.9	93.0
	Child Born in 1964	8.5	5.0	57.5	4.7	75.7
Near River Family	Adult Female	29.7	6.5	25.4	10.8	72.4
	Adult Male	28.1	6.2	24.1	14.5	72.9
	Child Born in 1955	9.0	5.0	18.0	50.8	82.8
	Child Born in 1964	10.9	5.7	59.7	*	76.3

*5% or less.

Thus, it can be seen that the fish ingestion pathway accounted for a large fraction of the dose for most of the receptors exposed to water releases. The important radionuclides producing dose through this pathway depended, in part, on the timing of the exposure. For the Children Born in 1964, the important radionuclides tended to change from ^{137}Cs to ^{32}P for water releases (see Section 13.2.5 for additional discussion). In addition, for the Children Born in 1955, ^{131}I, which is not related to fish ingestion, was an important isotope (the most important isotope for two scenarios).

13.2.3 Important Exposure Pathways and Radionuclides for Air Releases

(Note: the general comments made in the initial paragraph of Section 13.2.2 apply here as well.) For scenarios not exposed to water releases by ingesting fish (Rural Families One and Two, Urban/Suburban Family, Migrant Family), the most significant radionuclides were ^{131}I and tritium, and the most significant exposure pathways were ingestion of milk and beef.

Table 13-3 shows the percent of total dose from beef and milk ingestion, and the combination for scenarios not exposed to water releases from the SRS. Of these receptors, 75 percent (12/16) obtained more than half their dose from these two pathways. For the remaining four receptors, these two pathways together accounted for the largest fraction of dose with air immersion also an important pathway.

Table 13-3 Percent of Total Dose from Beef and Milk Ingestion, and the Combination, for Scenarios not Exposed to Water Releases from the SRS

Scenario	Receptor	Percent of Total Dose from Beef Ingestion	Percent of Total Dose from Milk Ingestion	Sum of Percent from Two Pathways
Rural Family One	Adult Female	50.7	16.1	66.8
	Adult Male	57.1	15.3	72.4
	Child Born in 1955	43.2	43.9	87.1
	Child Born in 1964	15.3	35.4	50.7
Rural Family Two	Adult Female	52.4	16.1	68.5
	Adult Male	58.8	15.3	74.1
	Child Born in 1955	43.7	44.2	87.9
	Child Born in 1964	14.6	32.4	47.0
Urban/Suburban Family	Adult Female	42.6	24.1	66.7
	Adult Male	27.4	13.1	40.5
	Child Born in 1955	30.4	55.7	86.1
	Child Born in 1964	11.6	31.7	43.3
Migrant Family	Adult Female	52.1	11.6	63.7
	Adult Male	58.7	11.0	69.7
	Child Born in 1955	48.2	36.2	84.4
	Child Born in 1964	17.8	22.4	40.2

*Since the Migrant Worker Family was only present near the SRS for six months, it may be more appropriate for comparison purposes to double these doses.

Table 13-4 shows the percent of total dose from ^{131}I, tritium, and ^{41}Ar, and their combination, for scenarios not exposed to water releases from the SRS. In these families, the Adult Male, Adult Female, and Child Born in 1955 had most of their dose from ^{131}I from a combination of ingesting milk and beef. In these same families, the Child Born in 1964 had most of its dose from tritium from a combination of ingesting milk and beef.

Table 13-4 Percent of Total Dose from Beef and Milk Ingestion, and the Combination, for Scenarios Not Exposed to Water Releases from the SRS

Scenario	Receptor	Percent of Total Dose			
		^{131}I	Tritium	^{41}Ar	Total
Rural Family One	Adult Female	73.8	12.0	8.0	93.8
	Adult Male	76.9	11.3	5.7	93.9
	Child Born in 1955	93.3	3.8	1.5	98.6
	Child Born in 1964	9.3	63.9	16.6	89.8
Rural Family Two	Adult Female	76.5	9.9	7.7	94.1
	Adult Male	79.4	9.4	5.5	94.3
	Child Born in 1955	94.2	3.0	1.4	98.6
	Child Born in 1964	10.4	59.9	18.8	89.1
Urban/ Suburban Family	Adult Female	75.5	14.1	5.1	94.7
	Adult Male	50.0	10.6	34.8	95.4
	Child Born in 1955	93.5	3.5	2.1	99.1
	Child Born in 1964	9.9	63.9	18.8	92.6
Migrant Family*	Adult Female	74.7	8.9	8.6	92.2
	Adult Male	77.9	8.4	6.2	92.5
	Child Born in 1955	93.7	2.8	1.8	98.3
	Child Born in 1964	10.7	52.4	23.1	86.2

*Since the Migrant Worker Family was only present near the SRS for six months, it may be more appropriate for comparison purposes to double these doses.

Thus, it can be seen that two ingestion pathways (milk and beef ingestion) accounted for a large fraction of the dose for most of the receptors exposed only to air releases of radionuclides. The important radionuclides producing dose through these pathways depended, in part, on the timing of the exposure; for the Children Born in 1964, important radionuclides tended to shift from ^{131}I to tritium for air releases (see Section 13.2.5 for additional discussion); for the other receptors, ^{131}I was the most important radionuclide.

13.2.4 Significance of Immersion Dose from ^{41}Ar

Releases of ^{41}Ar produced a small but persistent dose for all receptors from immersion in the plume. Generally, doses of 0.02 to 0.09 mSv (2 to 9 millirem [mrem]) over 39 years were produced. An exception was the Adult Male for the Outdoors Family who received 0.31 mSv (31 mrem) over 39 years. In most cases, this air-immersion dose was minor, but for receptors with small doses from other sources, it could be a significant contributor. For example, for the Child Born in 1964, air-immersion dose from

^{41}Ar accounted for almost 17 percent of the total dose in Rural Family One and almost 24 percent of the total dose in Rural Family Two and the Urban/Suburban Family. Immersion dose accounted for almost 39 percent of the dose to the Adult Male in the Urban/Suburban Family principally because he worked a significant amount of time onsite. For scenarios exposed to water releases, the percentage of dose from air immersion was generally small (less than 10 percent) for all receptors.

13.2.5 Major Dose Fraction for many Receptors from Large Releases in 1955-1961

Large releases of ^{131}I that occurred at the SRS in a period around 1955 to 1961 produced a major fraction of the dose in many receptors. This is shown in the tables of annual effective dose as a function of time in Chapter 11 (i.e., Tables 11-4, 11-7, 11-10, 11-13, 11-16, 11-19, and 11-22). Because the Children Born in 1964 did not experience these large ^{131}I releases, their doses tended to result from other radionuclides, principally tritium and ^{137}Cs. The Adult Female, Adult Male, and Child Born in 1955 for those scenarios exposed only to air releases had a majority of their dose from ^{131}I releases during this time frame. For those scenarios exposed to water releases, the Adult Female, Adult Male, and Child Born in 1955 had a significant fraction of dose delivered in later years (mid-1960's), when the liquid releases were greater. In some cases, the majority of the dose came from these later water releases, but this depends on the degree to which doses from fish ingestion dominate.

13.2.6 Differences in Children Born in 1955 and 1964

Significant differences exist between doses for Children Born in 1955 and Children Born in 1964, and these differences are observed to greater or lesser degrees in all seven scenarios. These differences in doses include the magnitude of the doses, the radionuclides primarily responsible for producing the doses, and the exposure pathways through which the doses are received. Table 13-5 compares for Children Born in 1955 to the Children Born in 1964 for each scenario: 1) the total doses, 2) the radionuclide/pathway pair contributing most to this dose, and 3) the fraction of the total dose accounted for by this major radionuclide/pathway pair.

For the first four scenarios in Table 13-5, which are only exposed to air releases from the SRS, the differences between the Child Born in 1955 and the Child Born in 1964 are similar. Considering the Child Born in 1955, for three out of four scenarios the pathway was beef ingestion and the radionuclide was ^{131}I; for the remaining scenario, the pathway was milk ingestion but the radionuclide remained ^{131}I. The contribution to total dose was about 40 percent in three cases and 70 percent in one case. This shows that that the large ^{131}I releases early in the site history dominate the dose mechanisms for the Children Born in 1955. Considering the Child Born in 1964, for three out of four scenarios the pathway was milk ingestion and the radionuclide was tritium; for the remaining scenario, the pathway was air immersion and the radionuclide was ^{41}Ar. The contribution to total dose was about 25 percent in three cases and 37 percent in one case. This behavior illustrates that because the Children Born in 1964 did not experience the large ^{131}I releases early in the site history, radionuclides other than ^{131}I and its dominant pathways became more evident. However, the dominance of doses caused by these other radionuclides is smaller than those caused by the early releases of ^{131}I. Both ^{41}Ar and tritium were more persistently released over time than ^{131}I.

For the last three scenarios in Table 13-5, the children are exposed to both air and water releases from the SRS. For the Outdoor Family and the Near River Family, the air release of ^{131}I caused the dominant dose for the Children Born in 1955; however, the dominant pathway for the Outdoor Family is beef ingestion and milk ingestion for the Near River Family. For the Children Born in 1964 for the Outdoor Family and the Near River Family, the dominant pathway is fish ingestion and the dominant radionuclide is ^{32}P; in both scenarios, about 60 percent of the dose is produced this way. For the Delivery Person Family, unlike the other scenarios in Table 13-2, the Children Born in 1955 and 1964 have the same dominant pathway

and dominant radionuclide; for both, about 40-50 percent of the dose is caused by fish ingestion and ^{137}Cs. This is the result of the very high doses produced by ingesting fish taken from Lower Three Runs Creek.

Table 13-5 Comparison of the Dominant Cause of Dose for Children Born in 1955 and Children Born in 1964 for all Seven Scenarios

Scenario	Child Born in	Dose (mSv/mrem)	Major Radionuclide-Pathway Pair		Percent of Total Dose
Rural Family One	1955	1.6/160	^{131}I	Beef Ingestion	42
	1964	0.072/7.2	Tritium	Milk Ingestion	29
Rural Family Two	1955	3.8/380	^{131}I	Beef Ingestion	43
	1964	0.14/14	Tritium	Milk Ingestion	26
Urban/Suburban Family	1955	2.7/270	^{131}I	Milk Ingestion	70
	1964	0.11/11	Tritium	Milk Ingestion	37
Migrant Worker Family*	1955	2.2/220	^{131}I	Beef Ingestion	37
	1964	0.083/8.3	^{41}Ar	Air Immersion	23
Delivery Person Family	1955	5.2/520	^{137}Cs	Fish Ingestion	40
	1964	2.1/210	^{137}Cs	Fish Ingestion	49
Outdoors Family	1955	9.4/940	^{131}I	Beef Ingestion	46
	1964	1.8/180	^{32}P	Fish Ingestion	57
Near River Family	1955	3.1/310	^{131}I	Milk Ingestion	27
	1964	1.8/180	^{32}P	Fish Ingestion	60

*Since the Migrant Worker Family was only present near the SRS for six months, it may be more appropriate for comparison purposes to double these doses.

In short, for all but the Delivery Person Family, the scenarios show a distinct difference in the size and dominant causes of dose between the Children Born in 1955 and 1964.

13.2.7 Importance of Lower Three Runs Creek Fish Ingestion Dose

The annual concentration of a radionuclide in the Savannah River was estimated by dividing the estimated total liquid release of the radionuclide from the SRS in a given year by the annual volume of flow in the Savannah River. For Lower Three Runs Creek, measured concentrations were used for tritium, ^{137}Cs, and ^{90}Sr. Generally, the concentrations in Lower Three Runs Creek were substantially higher than in the Savannah River. For example, the ratios of peak concentrations in the two bodies of water were 23, 10, and 6, respectively, for tritium, ^{137}Cs, and ^{90}Sr. As a consequence, eating fish taken from Lower Three Runs Creek produced higher doses for those receptors so exposed. Table 13-6 demonstrates this trend quantitatively and shows doses to the Adult Female in three scenarios: Rural Family One, the Near River Family, and the Delivery Family.

These three families received, respectively, 0, 100, and 50 percent of their fish from the Savannah River and, respectively, 0, 0, and 50 percent of their fish from Lower Three Runs Creek. When the doses from water releases for the Adult Females in the Near River Family and the Delivery Family are compared, there is a significant difference in dose (i.e., 1.8 mSv [180 mrem] for the Near River Family versus 5.7

mSv [570 mrem] for the Delivery Family). This difference in dose was produced by ingesting the same quantity of fish in both scenarios. However, for the Delivery Family Adult Female, 50 percent of the fish ingested came from Lower Three Runs Creek; for the Near River Family Adult Female, 100 percent of the fish ingested came from the Savannah River. By replacing 50 percent of the fish consumed from the Savannah River with fish from Lower Three Runs Creek, the dose from water releases was increased by more than a factor of three. By assuming the dose is linearly proportional to the quantity consumed from the two sources, an algebraic manipulation shows that if a scenario obtained 100 percent of the fish it consumes from Lower Three Runs Creek, the dose to the Adult Female would be 9.6 mSv (960 mrem). This implies that the contamination level in the water (and therefore in the fish ingested) is on average a factor of 5 greater in Lower Three Runs Creek than in the Savannah River. This is generally consistent with the concentration data presented in Chapter 7 for Cs-137 concentrations in the two bodies of water.

Table 13-6 Comparison of Fish Consumption and Dose for the Adult Female by Family Location

% of Dose From Fish Consumed from Different Sources	Rural Family #1	Near River Family	Delivery Family
Lower Three Runs Creek	0	0	50
Savannah River	0	100	50

	Dose (mSv/mrem)	Percent	Dose (mSv/mrem)	Percent	Dose (mSv/mrem)	Percent
Total Dose	0.3/30	100	2.1/211	100	6.1/610	100
Water Release Dose	0/0	0	1.8/180	85	5.7/570	93
Air Release Dose	0.3/30	100	0.3/31	15	0.4/40	7

13.2.8 Variations in Air Dispersion Significant but not Dominant

In this study, careful attention was paid to the geographical locations of the releases to air from the SRS, the geographical locations of various receptors, and the air-dispersion patterns at the SRS. One might be tempted to compare total doses from air releases to measure the impact of air dispersion; however, total dose from air releases is not a good indicator of the importance of air-dispersion variability because it does not directly reflect the concentrations experienced at the residence location for a particular receptor. The following are some of the complicating factors that prevent total dose from being a good indicator of air dispersion at the primary exposure locations:

- For several scenarios, foodstuffs (milk, deer meat, and beef) were brought to the residence location from other exposure locations (including the SRS) as mandated by the scenario specifications.
- In other cases, the receptor (especially the Adult Male) experienced exposure at a work location (including the SRS).

However, dose to the Adult Female by air immersion is a relatively good indicator of the differences due to variations in air dispersion. This is because the Adult Female was assumed to stay most of the time at the residence location (except for small amounts of time spent in recreation or at church) and because air

immersion is a good surrogate for the time integral of concentration of gamma-emitting radionuclides at the residence location.

Table 13-7 compares air-immersion doses for the Adult Female in all seven scenarios. Note that the ratio of these doses to the average dose over the seven scenarios is generally different by less than a factor of 2. The largest deviation from the average is for the Urban/Suburban Family, which has a dose smaller than the average by a factor of 2.6.

Table 13-7 Air-Immersion Doses for the Adult Female in Each Scenario as a Measure of the Effects of Air-Dispersion Differences

Scenario	Air Immersion Dose for Adult Female (mSv/mrem)	Ratio of Dose to Average Dose
Rural Family One	0.024/2.4	0.544
Rural Family Two	0.054/5.4	1.223
Urban/Suburban Family	0.017/1.7	0.385
Migrant Family*	0.039/3.9	0.883
Delivery Person Family	0.055/5.5	1.246
Outdoors Family	0.084/8.4	1.903
Near River Family	0.036/3.6	0.816
Average	0.044/4.4	

*Since the Migrant Worker Family was only present near the SRS for six months, it may be more appropriate for comparison purposes to double this dose.

Comparing the dose for each scenario to the average is parallel to quantifying “tallness” by comparing a person’s height to the average height. Although comparing the maximum dose to the minimum dose accentuates the differences in the variation across the site, the ratio in this case is 4.9—a significant but not dominant contributor to variations among receptors. The ratio of maximum total dose to minimum total dose is over 130 as shown in Table 11-2. This implies that many factors other than air dispersion have a significant effect on determining total dose to each receptor. That is, the variations that accentuate differences (e.g., time spent at different locations, quantities of foods ingested from different locations) are more significant than the air-dispersion differences related to average meteorological conditions, receptor locations, and source locations. However, this conclusion excludes consideration of onsite exposures. Due to the proximity of the onsite location to the air-release sources, significantly higher contamination and concentration levels were experienced onsite.

13.2.9 Variable Uncertainty Generally Raises Dose Estimates Slightly

Chapter 12 provides a description of the uncertainty analysis. Consideration of uncertainty in the variables used to estimate doses could cause an estimated dose to be higher or lower than the corresponding point-estimate result. Comparison of the results from the uncertainty analysis to the point-estimate analysis shows that on average the estimated doses from the uncertainty analysis are higher. Table 12-9 compares the mean and median doses from the uncertainty analysis to the point-estimate dose for each of the 28 specified receptors. The ratios of the mean doses to the corresponding point-estimate doses range from a high of 2.15 to a low of 1.07; similarly, the ratio of the median doses to the corresponding point-estimate doses range from a high of 1.54 to a low of 0.86. Thus, the means and medians of the uncertain doses were close to the corresponding point-estimate values. These results

illustrate the behavior of the central tendencies (the means and medians) of the estimated dose distributions.

As discussed in Section 12.5.1, the lognormal distribution is a reasonable fit to the uncertain distributions of dose for each receptor. It is not surprising that most of the uncertain dose distributions could be well described by a lognormal distribution because most of the variables modeled as uncertain in the uncertainty analysis were assigned lognormal distributions based on the information available. Although the receptor doses are not simple functions of the uncertain variables, the general shape of the lognormal distributions used to describe those variables is evident in the receptor dose distributions. Lognormal distributions are skewed toward higher values. For this type of distribution, the mean is always higher than the median. This behavior is evident if the extreme values of the dose distributions are examined. For example, on average, the ratio of the maximum dose from the uncertainty analysis to the point-estimate dose for the same receptor is 7.8. The maximum value of this ratio is 11.5 for the Urban/Suburban Family Child Born in 1955. In addition, on average the ratio of the minimum dose from the uncertainty analysis to the point-estimate dose for the same receptor is 0.36; the minimum value of this ratio is 0.13 for the Urban/Suburban Family Child Born in 1955. In other words, on average, the maximum value is 7.8 time higher than the point estimate while the minimum value is 2.8 times smaller than the point-estimate value.

The medians of the lognormal distributions describing the uncertain input variables were set equal to the variable value used to generate the point estimate. However, except for the Urban/Suburban Family, all the median doses were higher than their corresponding point-estimate doses. This somewhat surprising result seems to be related to several aspects of the analysis, including the properties of the models used to compute the dose and the large uncertainty for some variables. In particular, for scenarios in which exposure to liquid releases by fish ingestion was a dominant pathway, variations in the uptake factors for ^{137}Cs, ^{90}Sr, and ^{32}P seemed to combine in a manner that assured the median doses would be higher than the point-estimate doses.

Although the dose estimates derived by considering uncertainty in the input variables were larger than the point-estimate doses, the means and medians of the uncertain doses were generally no more than a factor of 2 larger than the point-estimate doses. Although this underscores the importance of performing an uncertainty analysis, the basic conclusion of low doses and risks does not change when uncertainty is considered.

13.2.10 Effectiveness of Scenarios

As described in Chapters 1, 3, and 4, the definition and use of hypothetical scenarios to span the range of realistic receptor behavior was an important aspect of implementing this dose reconstruction. The scenarios defined sets of hypothetical receptors whose doses and risks would reflect the interaction of the receptor behaviors with the site and release characteristics. As indicated by many of the conclusions listed previously, this strategy was successful in illustrating how the released radioactive materials interacted with different behavior patterns to yield a range of doses produced by different radionuclides and pathways. In particular, the hypothetical scenarios disclosed:

- A range of 39-year doses that spanned two orders of magnitude.
- Generally higher doses for scenarios in which receptors were exposed to liquid and air releases from the SRS than for scenarios in which receptors were exposed only to air releases. For scenarios exposed to liquid and air releases, fish ingestion was generally the most important pathway and ^{137}Cs the most important radionuclide; for scenarios exposed only to air releases, milk and beef ingestion were the most important pathways, and ^{131}I was generally the most important radionuclide.

- The Children Born in 1955 had substantially different doses and causes for doses than the Children Born in 1964.
- The scenario for obtaining fish from Lower Three Runs Creek experienced higher doses than scenarios for obtaining fish from the Savannah River or from waters not affected by liquid releases from the SRS.

Because use of the scenarios was able to provide this kind of information, use of hypothetical scenarios in this context is supported and the utility of the scenario definitions is confirmed.

13.3 Recommendations

Unresolved technical issues have arisen during the course of the work from two sources: 1) meetings of the SRSHES and 2) the analytical team performing the work. Some of these unresolved issues were raised at public meetings during which this work was presented and discussed. These public meetings were held in the following cities:

- Charleston, South Carolina—March 2003.
- Savannah, Georgia—September 2003.
- Columbia, South Carolina—August 2004.

Other unresolved issues arose during the development of the approach and the analysis of results. These issues have not been addressed to date because they fall generally beyond the scope of the present task. Performing this work is not likely to change the major conclusions listed in the previous section. However, performing this work can be expected to resolve a number of technical issues and thereby enhance confidence in the current conclusions. The following is a list of the recommendations which are then described briefly in the subsequent subsections:

- Look at large, acute releases to see if the pattern of doses would be changed significantly.
- Examine the buildup of long-lived radionuclides in soil to determine if terrestrial doses change significantly.
- Model contamination in reservoirs to see if it causes significant doses.
- Compare modeled concentrations in foodstuffs (fruit, vegetables, grain, beef, deer, etc.) with monitoring data for model validation.
- Perform an auxiliary analysis to determine if the breast-feeding of infants changes dose substantially.
- Perform an auxiliary analysis to determine how in-utero doses change total dose and cancer risk.
- Model consumption of venison more carefully to see if the result changes.
- Model dose from the consumption of drinking water taken from the Savannah River for municipal water supplies some distance downstream from the SRS (i.e., the municipal water intakes at Port Wentworth, Georgia, and Hardeeville, South Carolina, for Beaufort and Jasper Counties).
- Obtain technical peer review of the study by publishing papers on the methods and results in peer-reviewed journals.

The following sections discuss each recommendation briefly.

13.3.1 Acute Releases vs. Annual Average Releases

This present analysis was performed assuming that the reported SRS annual releases occurred uniformly throughout each year. In fact, the Phase II report clearly documents that these annual reported releases

included some acute releases (i.e., relatively large releases over short periods of time). Because the acute releases were subject to air-dispersion conditions during the time of their release, the doses from such acute releases may not have been accurately portrayed by using the multi-year average meteorology that is more appropriate for routine, relatively constant releases. It is recommended that the importance of modeling air releases as acute instead of chronic, annual releases be determined by computing doses for the largest acute releases in two ways: 1) modeled as acute releases with air-dispersion conditions corresponding to the time of release and 2) modeled as chronic releases using the multi-year average meteorology. Differences in dose estimates for the two computational approaches would help to determine whether the approach used in this study has sufficient precision. Only a few of the largest acute releases would need to be studied (10-25) to make the determination. One problem in performing this evaluation is that air-dispersion conditions were not measured onsite in the early years when many of the larger acute releases occurred. This may introduce additional uncertainty into the evaluation because onsite air-dispersion conditions would need to be extrapolated from nearby but offsite weather stations.

13.3.2 Evaluate Soil Buildup of Long-Lived Radionuclides

A preliminary evaluation was performed while developing the analytical approach to estimate the importance of the buildup of long-lived radionuclides in soil. Because soil buildup did not appear to be significant, the dose modeling was performed without taking into account residual contamination that might have remained in the soil from one year to later years (i.e., the dose from each year was assumed to result only from the releases during that year). A more detailed examination could confirm that this dose from residual radioactivity in the soil was indeed negligible. Because dose pathways associated with such soil buildup were not significant, it is unlikely that the residual doses will be significant. For example, uptake of radionuclides by plant roots from the soil was much smaller than uptake from radionuclides deposited on plant surfaces; also, ground plane dose, which would be increased by residual soil contamination, was a very minor pathway. It is recommended that for a few scenarios (air-release-only scenarios will likely show the largest effect) doses be computed by accounting for soil buildup of radionuclides from one year to the following years to quantify the importance of this effect.

13.3.3 Evaluate Significance of Reservoir Contamination

Air releases of radionuclides could contaminate bodies of water used for drinking in two ways: 1) direct deposition of radionuclides from the air into the body of water (lake, pond, or reservoir) and 2) deposition of radionuclides onto the surface water basin of the water body and subsequent migration to the water body by surface runoff. These transport pathways were not modeled because more direct pathways (i.e., deposition of airborne radionuclides onto crops in the food chain and ingestion of fish from water bodies contaminated directly by SRS water releases) appeared to be more likely to produce significant doses. It is recommended that airborne contamination of otherwise uncontaminated water bodies be modeled to determine the significance of the contamination produced and the potential doses from the contamination. This will indicate whether the dose estimates produced by this study have sufficient precision.

13.3.4 Compare Modeled Contamination in Foodstuffs to Monitoring Data

As a means of enhancing confidence in this intermediate-phase dose reconstruction, a partial validation of the modeling of releases and environmental transport may be desirable. A partial validation of these aspects of the modeling could be accomplished by comparing intermediate modeling results (such as contamination levels in soil and food) to field measurements. These field measurements are contained in the annual site Environmental Reports. Additional computer computations would be required to obtain these intermediate results because they were not permanently recorded during the previous calculations. It is recommended that this partial validation effort be pursued.

13.3.5 Evaluate Significance of Breast-Feeding Infants

The current study did not model the pathway of breast milk ingestion by infants; instead, ingestion of contaminated cow's milk was modeled. There are methods by which the breast-milk pathway could be modeled. The modeling of the cow's milk pathway, as currently implemented, may be more conservative (i.e., may produce a higher dose). It is recommended that the breast milk pathway be evaluated by some comparative modeling to determine its significance.

13.3.6 Evaluate Significance of In-Utero Doses

Some approaches are available to estimate the fetal doses in-utero from pregnant women experiencing environmental exposures to radiation and radioactivity. The current approach did not include this pathway. It is recommended that some of the scenarios with higher dose levels be analyzed first to determine if the fetal doses are significant.

13.3.7 Refine Modeling of Deer Meat Ingestion

The current approach models contaminated venison as "beef" taken from cattle grazing at the various exposure locations incorporated into the analysis. A more precise approximation to venison contamination may be obtainable by modeling uptake of radionuclides by deer ingestion of various plant species typically ingested by deer; such an approach would require modeling the uptake of radionuclides by these additional plant species. Because ingestion of contaminated beef produced large doses from ^{131}I, a likely outcome from this more precise approach dose from venison ingestion may actually be lower calculated doses to humans. However, it is recommended that this more precise approach be pursued to remove a persistent criticism of the current approach.

13.3.8 Estimate Doses from Drinking Water from the Savannah River

None of the scenarios specified for this study considered receptors located far downstream on the Savannah River (e.g., Port Wentworth, Georgia, and Hardeeville, South Carolina, for Beaufort and Jasper Counties) where river water is used for municipal water supplies. The radionuclide content of this drinking water is carefully monitored to comply with the applicable limits on radionuclide concentrations in drinking water promulgated by the U.S. Environmental Protection Agency. Nevertheless, the residual radioactivity content will produce a dose, although it is likely to be small. A problem in estimating doses from this pathway is that the contribution of radionuclides in the drinking water from the SRS may be difficult to distinguish from the contribution of radionuclides from other sources. It is recommended that doses from this pathway be estimated to address this concern raised by the SRSHES.

13.3.9 Obtain Technical Peer Review

It is recommended that technical peer review be obtained for the methods and results of this study. An important avenue to obtain this type of peer review is by publishing papers on the methods used and the results obtained in peer-reviewed technical journal. In addition, further peer review may be acquired by presenting papers on this study at technical conferences. By vetting this study in the technical literature, confidence in the results will be enhanced.

13.4 References

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APPENDIX A MERGING AIR RELEASE SOURCES INTO FOUR VIRTUAL SOURCES

The report addressing Phase II of the Savannah River Site (SRS) Dose Reconstruction Project identified approximately 15 major locations for actual sources of radionuclide release to air (1).[1] To make the computational work for this Phase III effort more tractable, Advanced Technologies and Laboratories International, Inc. (ATL) represented appropriate groups of individual sources by a set of four virtual sources. This appendix summarizes the thought processes that were used when performing this merger and the effects that the merger had on the precision and accuracy of the Phase III study.

A.1 Description of the Problem

Like most dose assessments, radiation doses received by a set of hypothetical humans were calculated for Phase III of the SRS Dose Reconstruction Project by summing up incremental doses from various sources, radionuclides, years, exposure pathways, and exposure locations. If this assessment had been performed in a direct fashion without combining sources, the total number of incremental doses that would have been calculated, written to a computer file, and summed up was estimated to be between 100,000 and 10,000,000. This large amount of data created several potential problems related to 1) data handling and processing; 2) computer run time, both for generating the doses and processing the results; and 3) quality assurance and quality control of the raw data output and its processing.

Figure A-1 shows approximately 15 separate, major sources for air release identified in the Phase II report (SRL is the Savannah River Laboratory, CS Area is the Central Shops Area, and CMX-TNX is a complex used to test equipment and chemical processes). For Phase III, an analysis was performed to determine a way to combine several of these sources. This would proportionally reduce the size of the computational problem and its attendant disadvantages in a manner that preserved the integrity of the assessment. Reducing the number of sources from 15 to 4 reduced the computational size to 27 percent of the original size (i.e., 4/15 = 0.27).

Table A-1 lists the main sources for air releases at the SRS. These sources each emitted a mix of radionuclides, and emission rates of the various radionuclides varied with time. For the Phase III study, these time variations were accounted for by analyzing on an annual basis the release of the radionuclides to air over the 39-year span of nuclear material production.

For any given exposure location (e.g., the residence of one of the hypothetical families), the concentration of a given radionuclide was calculated as the sum of the concentrations induced at that location by each of the separate sources. For short time periods (e.g., 30 minutes), the concentration induced by a source at a given exposure location depends upon the following factors:

- The release rate of the contaminant (e.g., curies per year).
- The height of the release (stack height).
- Wind speed.
- Wind direction.
- Atmospheric stability class.
- Distance from the source to the exposure location.

[1]The actual number of sources of radionuclide release into the air depends on how the larger and smaller sources of release are grouped.

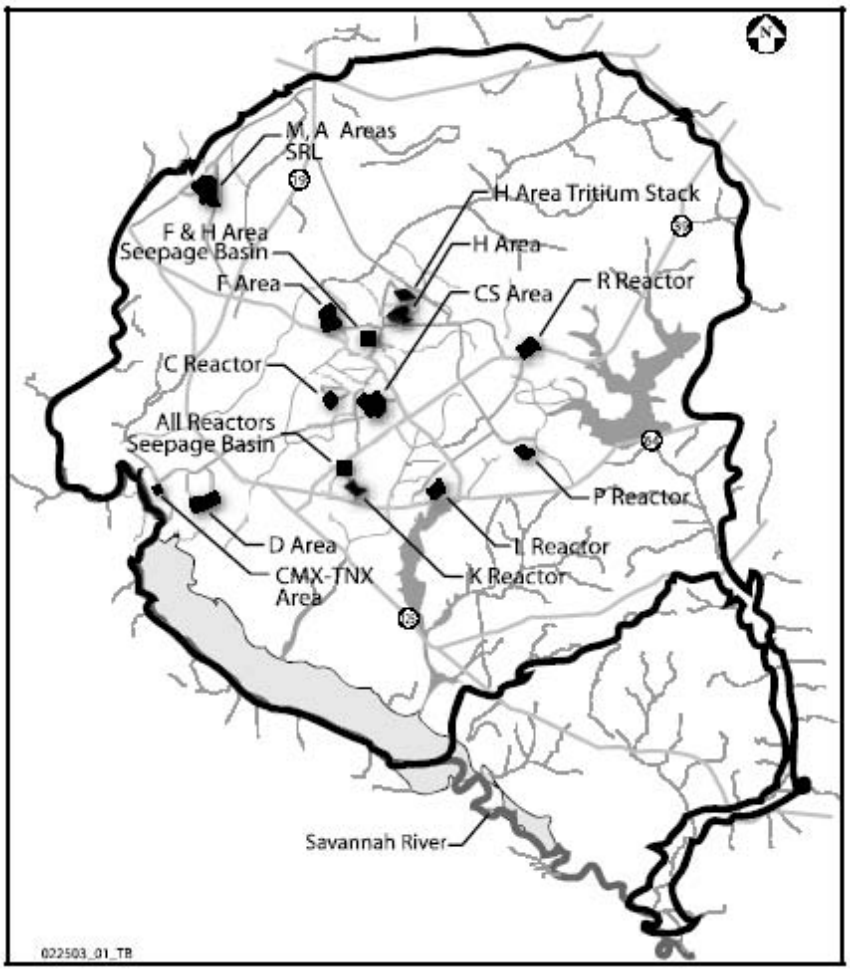


Figure A-1 Major Sources for Air Releases

For the long-term, annual releases of interest in this study, an appropriate model—the sector average approximation—was used to estimate the concentrations induced by each source at the exposure locations. This probabilistic approach sums up the concentrations produced by each wind speed, wind direction,[2] and stability class weighted by the frequency with which these conditions occur (the joint frequency distribution). This calculation obtains an average concentration produced by the source at the exposure location of interest over a long time period. The resulting formula for concentration is based on the standard Gaussian plume model (2).

The joint frequency distribution is a set of data for a specific location that represents a summary of meteorological conditions over a specified period of time such as a year. The joint frequency distribution is computed by compiling meteorological data, usually determined and recorded for each hour, over an

[2] Wind direction is usually determined in terms of either 16 or 36 sectors. Each sector represents a pie-shaped slice of an imaginary circle surrounding the source. In the older 16-sector approximation, each pie-shaped wedge describes a 22.5^{o} arc (360°/16 sectors) corresponding to the 16 major compass directions (N, NE, NNE, E, etc.). In the newer 36-sector approximation, each pie-shaped wedge describes a 10° arc (360°/36 sectors).

Table A-1 Main Sources for Air Releases of Radionuclides at SRS

Facility Type	Designation	Principal Radionuclides Released			
		^{3}H	β-Emitters	α-Emitters	Activation Products
Reactors	C	X	X		X
	K	X	X		X
	L	X	X		X
	P	X	X		X
	R	X			X
Separations Facilities	F-Canyon	X	X	X	X
	H-Canyon	X	X	X	X
	H Tritium Stack	X			
Waste Facilities	All Reactors Seepage Basin Evaporation*	X			
	CMX-TNX	X			
	D-Area	X			
	F & H Seepage Basin Evaporation†	X			
Other Facilities	A-Area	X	X	X	X
	M-Area	X		X	
	SRL	X‡	X‡	X‡	

*The "All Reactors Seepage Basin Evaporation" is already a virtual source. Each reactor had its own seepage basin. The location of this virtual source was chosen to be close to the centers of the locations of the reactors.
†The "F & H Seepage Basin Evaporation" is already a virtual source, but the seepage basins for F and H are only about one mile apart.
‡Releases from the SRL may have been included with A-Area releases for at least some years.

appropriate time interval and computing the frequency of occurrence of each joint frequency category. Each joint frequency category represents a band of wind speeds, directions, and stability conditions.

Because this Phase III study is concerned with annual releases, it was preferable to use the joint frequency distribution computed for each year. However, because the meteorological data tower has only been operational at the SRS since the early 1970's, no annual data were available for about 20 of the early years (3). In addition, the historical meteorological data from the on-site tower was made available for this study as five-year averages. Therefore, a 20-year average was used to represent the joint frequency distribution for all 39 years. This appeared reasonable in light of the general practice used by the SRS for estimating environmental consequences. For example, the SRS Environmental Report for 1991 (4) states that the meteorological measurements made over the five-year period (1982-1986) were used and that comparisons with other time periods "show very little change in dispersion conditions."

The 20-year average joint frequency distribution that was obtained from the SRS was provided in terms of 16 sectors, where each sector describes a 22.5-degree arc around the circumference of the SRS meteorological data tower.

A.2 Description of the Analyses

The central issue was whether combining separate sources at an artificial location (a virtual source) would provide sufficient accuracy. This issue was addressed in two ways due to the different characteristics of the source groups. For strong sources (e.g., the separations facilities and reactors), it was important to show that the concentrations estimated for offsite exposure locations did not have large errors due to sources being consolidated within a particular source group and represented by a virtual source. For weak sources (e.g., the seepage basins and waste facilities), the precision of the concentration estimate (and hence, the dose estimate) based on representing the weak release at a virtual source was not as significant due to the small contribution from the weak sources compared to the contribution from the strong sources.

An underlying assumption for this analysis was that radionuclide concentration was a suitable surrogate for individual dose in determining whether coalescence of sources was acceptable. Because some of the exposure pathways depend on radionuclides deposited on soil or vegetation, consideration of radionuclides deposited from the contaminant plume may be important. However, the quantity of radionuclide deposited depends on the air concentration of the radionuclide. If the deposition rate is moderate (which is the case for our assumed values of particle size and density), then plume depletion will not be a major factor and the air concentration will be a good surrogate for individual dose.

Approximating a group of actual sources by a virtual source reduces the precision of the analysis. However, in evaluating this apparent lack of *precision*, one should bear in mind the great difficulty in achieving *accuracy* (i.e., correspondence between calculated doses and doses actually received). The following factors limit the accuracy of the dose reconstruction in general and the doses from air releases:

- The released quantities of radionuclides are estimated with substantial uncertainties (e.g., Figure 1-7 in the Phase II report shows uncertainty bands around annual ^{131}I releases that range up to a factor of 10) (1).
- The receptors and their behavior are hypothetical, chosen to provide realistic dose estimates that have a good chance of bounding doses actually received.
- Many of the model parameters are not known precisely (e.g., radionuclide uptake rates by biota); furthermore, these parameters may have significant variability in time and across the region modeled.
- The site history is known to include many acute releases; doses from large acute releases may deviate significantly from doses calculated on the basis of average annual releases.

Because of these and other factors, a high degree of precision (i.e., correspondence between the calculated concentrations based on multiple separate sources and those calculated based on virtual sources) in the air dispersion modeling was not warranted due to other factors which limited the overall accuracy of the analysis.

A.2.1 The Initial Analysis

Initially, four virtual sources were evaluated with each virtual source corresponding to the types of facilities listed in Table A-1. Table A-2 lists the groups of facilities comprising these four original virtual sources. Each of these virtual sources was placed approximately at the centers of the locations of the constituent sources.

Table A-2 Definitions of Original Virtual Source Groupings

Original Group	Facilities in Group
Group $1_{original}$	A-Area, M-Area, SRL
Group $2_{original}$ (Separation Facilities)	F-Canyon, H-Canyon, H Tritium Stack
Group $3_{original}$ (Reactors)	C-, K-, L-, P- and R-Reactors
Group $4_{original}$ (Seepage Basins and Other Facilities)	All Reactors Seepage Basin Evaporation, CMX-TNX, D Area F & H Seepage Basin Evaporation

The waste facility group (Group $4_{original}$) was a set of sources cited in the Phase II report and in references (e.g., [5]) on which the Phase II report was based. However, these sources were not included in the Phase II estimates of release. For completeness, these sources were added to the Phase III assessment even though they are not major sources.

To determine how precisely the virtual sources represented the actual sources, concentrations induced by the actual and virtual source locations were compared with unit source strengths at each location. Because air dispersion was approximated using averaged meteorological conditions, the relationship between the release rate of a source and the concentration induced at an exposure location was fixed. This relationship can be represented by a *dilution factor* (e.g., units of y/m^3), which is the ratio of the concentration at the exposure location divided by a unit release rate. In air-transport modeling, it is often represented as the relationship X/Q, where X is the concentration at the exposure location (e.g., curies per cubic meter) and Q is the release rate (e.g., curies per year).

The initial analysis determined the concentrations induced at each of 9 offsite exposure locations by each of the 15 individual sources. Figure A-2 shows the nine offsite exposure locations. These concentrations were expressed as 135 (135 = 9 x 15) dilution factors assuming unit release rates (e.g., 1 curie per year) from each source. These dilution factors were obtained using Version 2 of the GENII code.[3] In addition to the 135 dilution factors from the original sources, 36 additional dilution factors were determined for the 4 original virtual source locations.

In considering the initial analysis, it was determined that, because Group $3_{original}$ (reactors) and Group $4_{original}$ (seepage basins and other areas) were comprised of sources dispersed widely around the site, the original virtual sources did not represent all constituent sources with sufficient precision for all of the exposure locations. This lack of precision occasioned a reexamination of the initial grouping of virtual sources.

In rethinking the analysis, the following four facts were noted and corresponding adjustments made to the source groupings:

[3]All further reference to the GENII code is to Version 2 of the code. The original version of GENII was created by members of Pacific Northwest National Laboratory in the late 1980's. Version 2 incorporates improved transport models, exposure options, dose and risk estimates, and user interfaces. It implements dosimetry models recommended by the International Commission on Radiological Protection and is designed to function within the Framework for Risk Analysis Multimedia Environmental Systems (FRAMES) (6).

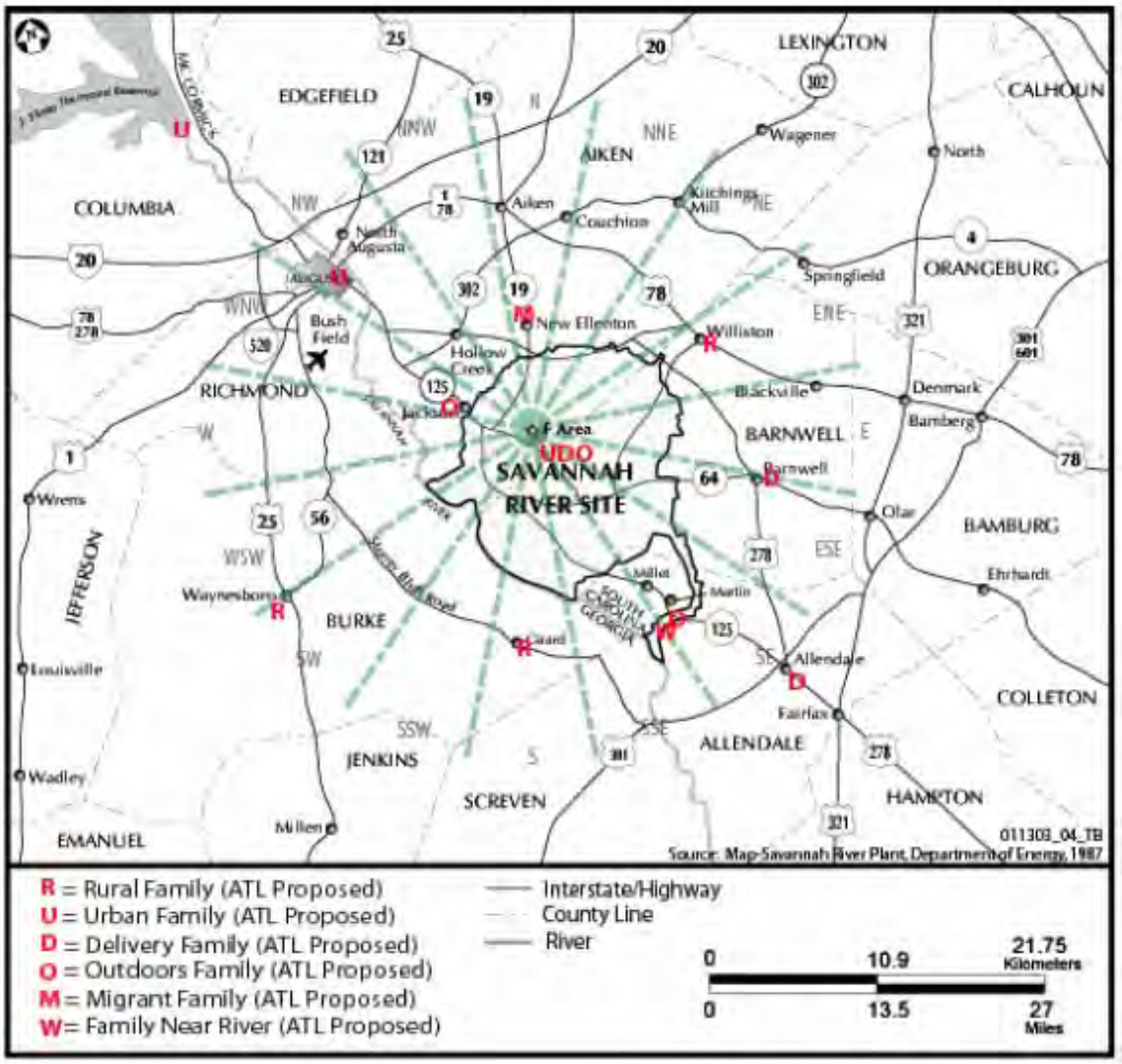


Figure A-2 Exposure Locations

1. The initial grouping for reactors was abandoned; the reactors were instead represented by two virtual sources—one for P- and R-Reactors, and one for C-, K-, and L-Reactors.
2. Because the releases from the R-Reactor occurred only for a short time, the virtual source location for the P- and R-Reactors was weighted toward the P-Reactor location. The weighting factor is approximately 0.85. Purely geometric considerations determined the remainder of the virtual source locations.
3. Although no releases are tabulated separately in the Phase II database for the Savannah River Laboratory, site history and recent environmental reports verify that releases actually occurred from this location. For this reason, coordinates for this location were used to calculate the location of the virtual source for that group.

4. Representation of the Group 4 original minor sources by a single virtual source did not provide a satisfactory overall level of precision. Nevertheless, inclusion of these sources was deemed appropriate (even if accomplished in an approximate fashion) because a fundamental component of the Phase III approach was to recognize and model the spatial distribution of the various sources. Because these are minor sources, another way to represent them was available. First, this waste facility group primarily released ^{3}H into the air. Second, these releases were a small percentage of their respective facility releases. For example, the total ^{3}H releases from the reactor seepage basins when compared to total ^{3}H releases from the reactors on a yearly basis were, at most, 6.39 percent. This occurred in 1976 (5). Releases from the F&H Area seepage basin equaled, at most, 4.91 percent of the total ^{3}H releases for the F-Canyon, H-Canyon, and H- Tritium Stack, also in 1976 (5). Furthermore, the ratio of annual ^{3}H releases from the entire waste facility group to the annual total site release of ^{3}H was a small fraction; the maximum value of the ratio was 7.14 percent, also in 1976 (5). Finally, the ratio of the average annual ^{3}H release from the waste facility group to the average annual ^{3}H release from the entire site was small—2.36 percent (average taken from 1957-1990).[4]

To mitigate any reduced precision resulting from consideration of these sources, the ^{3}H source terms from these minor sources were incorporated into the four virtual sources as follows:

- Incorporate ^{3}H releases from F & H seepage basin evaporation into the F & H Canyon virtual source.
- Incorporate the D-Area releases and the CMX-TNX releases in the virtual source for C-, K-, and L-Reactors (closest neighbor).
- Partition ^{3}H releases from the all-reactor seepage basin evaporation between the virtual sources for the C-, K-, L-Reactors and the P- and R-Reactors according to the ratio of their respective reactor releases.

In addition to these adjustments for ^{3}H releases, releases of alpha and beta-gamma activity from the D-Area were added to the virtual source for the C-, K, and L-Reactors. These releases are documented for the years 1986-92 and are small compared to releases in these categories for the site as a whole (4, 5, 7, 8).

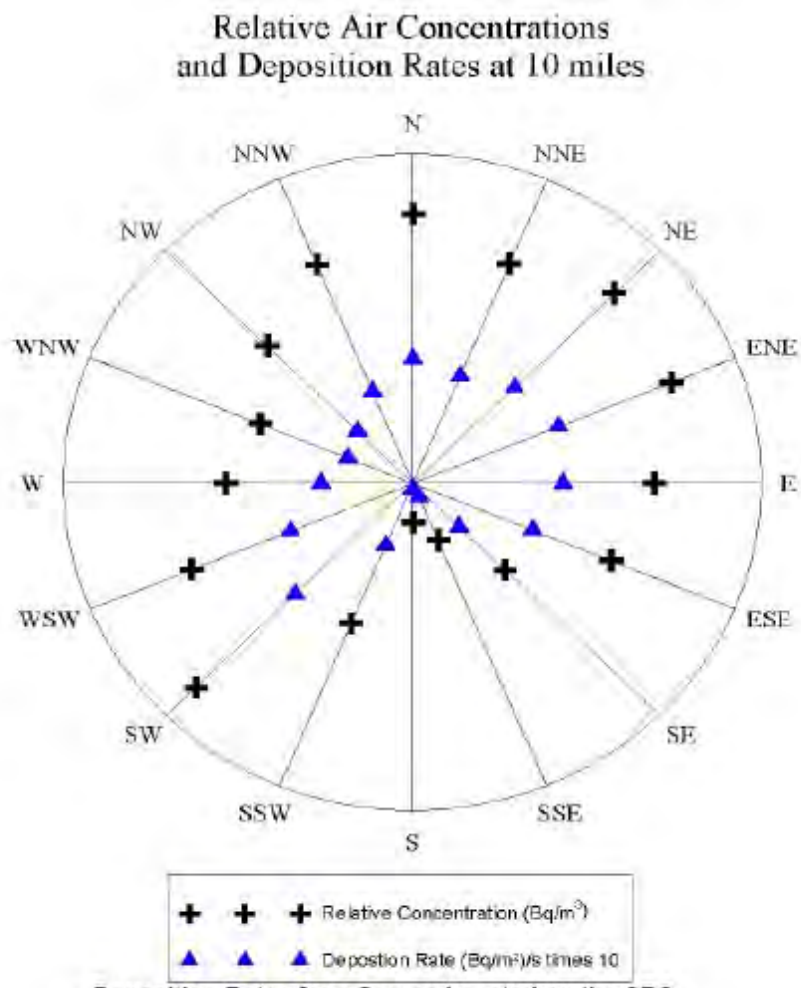
The use of the 16-sector joint frequency distribution for SRS presented some modeling concerns. Comparisons of concentrations produced by actual versus virtual sources were made more difficult because of the discontinuous behavior of the sector average approximation. Because the sector average approximation treats each 22.5-degree sector as having a uniform concentration within the sector at a given radius, the transition between sectors can show a substantial discontinuity. Figure A-3 shows this discontinuity schematically. However, this calculated discontinuity in concentration is a modeling artifact and does not represent actual conditions. If smaller and smaller sectors were chosen for the analysis (e.g., one degree), then the magnitude of any discontinuities would become quite small.

The GENII code models sources at different locations by centering a polar coordinate grid over each source. This coordinate grid is then used to calculate concentrations at various exposure locations. However, when the coordinate grid is moved between two nearby sources, the concentrations at exposure locations near a radial grid line may change substantially—not because of any physical phenomenon, but because the exposure location moves from one sector to another as the grid moves from one source to another. For example, when the center of the grid was moved between the virtual source for Group $2_{original}$ and the F-Canyon, Waynesboro changed from the sector centered on 247.5 degrees (WSW) to the sector centered on 225 degrees (SW). This produced a difference in calculated concentrations of about 31%. When the center of the grid was moved between the virtual source for Group $2_{original}$ and the H-Canyon,

[4] References used for calculating this average were (5) and (7).

the sector for Waynesboro remained 247.5° (WSW). This produced a difference in concentrations of only 3.8%. Since the F-Canyon and H-Canyon sources are approximately equidistant from the virtual source, this difference in behavior is related to the coarseness of the sector average approximation and does not represent a real physical difference in behavior.

Figure A-3 Plot, in Polar Coordinates, of Concentrations and



Deposition Rates for a Source Located on the SRS

The radii correspond to the center of the sectors modeled. Note the large concentration gradients while traversing from the SW radius toward S. This means there is a substantial change in estimated concentration if one moves from the sector centered on SSW to either S or SW. A movement on the grid of a few meters could induce such a change; however, the estimated change is due to the coarseness of the grid, not physical reality. Also note that the deposition rate tracks proportionally to the concentration.

Similarly, the exposure location for Girard, Georgia, was originally assumed to be at the actual site of the town. Assuming a radial grid over a source located in the rough center of the SRS, the boundary between the 202.5-degree (SSW) and 180-degree (S) sectors runs very close to the actual site of the town. By moving the center of the source only slightly in one direction or the other, the sector which modeled radiation concentrations at Girard shifted between the SSW sector and the S sector. Figure A-3 shows this shift between sectors resulted in large apparent changes in radionuclide concentrations that were due more to the coarseness of the grid than physical reality.

To make the Phase III analysis easier to interpret, the coordinates of two exposure locations, Waynesboro and Girard, were adjusted slightly to minimize this modeling artifact. For Waynesboro, the location was moved from the city center to the actual location of the present high school (2-3 kilometers to the southeast). For Girard, the location was moved from the town center to a spot further to the east along Stony Bluff Road, about 3 miles west of the Savannah River.

A.2.2 The Second Analysis

From the perspectives gained in the first analysis, the number of separate sources to be analyzed was reduced from 15 to 11 because the 4 waste facility sources (Group $4_{original}$) were subsumed into other sources. The second analysis proceeded in two parts: Part 1, a comparison of concentrations produced by actual and virtual sources within redefined groups (Section A.2.2.1); and Part 2, a quantitative confirmation of the qualitative argument that a weak source can be moved to a virtual location with little effect on concentration and dose (Section A.2.2.2).

A.2.2.1 Part 1: Comparison of Concentrations

In this analysis, the concentration induced at each offsite exposure location by each source in a group was compared to the concentration induced by the virtual source representing that group, assuming a unit release rate for the individual sources and virtual source. If the virtual source concentration differed from the original source concentration by no more than 25 percent for every original source, then the virtual source was considered acceptable.

Given all the uncertainties in the dose reconstruction project, 25 percent was a relatively stringent criterion that was intuitively appealing. If no individual source in the group differed from the virtual source by more than 25 percent, the combination of several individual sources would differ by no more than 25 percent from the equivalent virtual source. This behavior was examined on a hypothetical basis by comparing the concentrations induced by a combination of n sources to the concentration induced by a virtual source representing the n sources, assuming each source had a concentration of 1/n.

A.2.2.1.1 Description of the Basic Computations

The GENII code was run multiple times to estimate the concentrations at 9 offsite exposure locations for the 11 actual sources and 4 virtual sources for a total of 135 dilution factors (9 x [11 + 4]). All sources were assumed to have a unit concentration of a contaminant that did not degrade by radioactive decay, deposition, chemical reaction, or any other depleting physicochemical process. Appropriate stack heights were used for actual sources and for the virtual sources derived from them.

A.2.2.1.2 Definition of Groups and Virtual Sources

Table A-3 defines the groupings for the second analysis.

Table A-3 Definitions of Final Virtual Source Groupings

Final Group	Facilities in Group
Group 1	A-Area, M-Area, SRL
Group 2	F-Canyon, H-Canyon, H Tritium Stack, F&H Seepage Basins
Group 3	C-Reactor, K-Reactor, L-Reactor, Reactor Seepage Basin release attributable to C, K, and L-Reactors, D-Area, CMX-TNX
Group 4	P-Reactor, R-Reactor, Reactor Seepage Basin release attributable to P- and R-Reactors

The coordinates of the virtual sources were chosen to be at the approximate centers of the actual sources in the group. But for Group 4, the virtual source location was shifted heavily toward P-Reactor because it operated over a much longer time period than R-Reactor.

Table A-4 lists the Universal Transverse Mercator (UTM) coordinates of the actual sources, the virtual sources, and the exposure locations.

Table A-4 Rectangular Coordinates (UTM) of Sources and Exposure Locations

Location	X UTM (m)*	Y UTM (m)*	Release Height (m)*
Source Locations			
A-Area	431,683	3,689,063	10
C-Reactor	436,947	3,679,014	61
D-Area	431,034	3,673,822	0
F-Canyon	436,755	3,683,149	61
H-Canyon	440,168	3,683,317	61
F+H Seepage Basin Evap.	438,774	3,682,115	0
K-Reactor	438,077	3,674,736	61
L-Reactor	441,899	3,674,615	61
M-Area	431,250	3,688,966	10
P-Reactor	445,841	3,676,587	61
R-Reactor	446,034	3,681,659	61
SRL	431,346	3,689,543	10
H (Tritium Stack)	439,880	3,683,221	61
All Reactors – Seepage Basin	437,764	3,675,000	0
CMX-TNX Area	429,183	3,674,784	0
Virtual Source Locations			
Group 1	431,467	3,689,255	10
Group 2	438,459	3,683,233	61
Group 3	438,990	3,676,350	61

Location	X UTM (m)*	Y UTM (m)*	Release Height (m)*
Source Locations			
Group 4	446,010	3,679,087	61
Offsite Exposure Locations			
Girard, GA	442,700	3,653,500	
Waynesboro, GA	406,000	3,660,100	
Augusta, GA	411,800	3,703,350	
Jackson, SC	426,900	3,687,700	
New Ellenton, SC	436,150	3,697,250	
Barnwell, SC	466,650	3,678,500	
Martin, SC	455,350	3,659,300	
Allendale, SC	471,100	3,652,200	
Williston, SC	460,800	3,695,850	

*m = meters.

A.2.2.1.3 Comparison of Concentrations from Actual and Virtual Sources

Tables A-5 through A-8 show the results of the quantitative analysis. Columns with headings that include "% Delta" show percentage differences (percent error) between dilution factors for actual and virtual sources. The percent error was computed to show the direction of the deviation between concentrations predicted by the virtual and actual sources:

$$\text{Actual Source \% error} = [(D_V - D_A)/D_A] \times 100$$

Where D_V is the dilution factor for the virtual source and a particular exposure location, D_A is the dilution factor for the actual source and the same exposure location. The actual source is assumed to be the baseline (i.e., a negative value in the table means the virtual source is underestimating the release, while a positive number means the virtual source is overestimating the release).

In Table A-5, the first three columns list the dilution factors for each of the actual sources— A-Area, M-Area, and SRL, respectively. The fourth column lists the dilution factors for the Group 1 virtual source. The next three columns, marked A % Delta, M % Delta, and SRL% Delta, provide the percent error involved when the virtual source is used instead of the actual source. The next column, marked Sum: A, M, SRL, is a dilution factor that represents the concentrations that would result if each actual source had a magnitude of 1/3; in other words, the combined source strength of the three sources is unity. The next column, marked Sum % Delta, lists the percent error between that produced by the virtual source and the combined effect of the actual sources assuming each has equal strengths that sum to unity. Other tables in this group follow the same format.

The deviations shown in Tables A-5 through A-8 are frequently quite small. For Group 1, the maximum deviation is -9 percent for the exposure location Jackson and the M-Area source. For Group 2, the maximum deviation is -15 percent for the exposure location Jackson and the F-Canyon source. For Group 3, the maximum deviation is -27 percent for the exposure location Jackson and the C Reactor source. For Group 4, the maximum deviation is +17 percent for the exposure location Augusta and the R-Reactor

Table A-5 Comparison of Dilution Factors for Group 1 Individual Sources and Virtual Source

Exposure Location	A-Area	M-Area	SRL	Virtual Source	A % Delta	M % Delta	SRL % Delta	Sum: A, M, SRL	Sum % Delta
Girard, GA	7.881E-06	7.872E-06	7.761E-06	7.827E-06	-0.69	-0.58	0.84	7.838E-06	-0.14
Waynesboro, GA	1.687E-05	1.704E-05	1.681E-05	1.687E-05	0.00	-1.01	0.36	1.691E-05	-0.22
Augusta, GA	2.196E-05	2.225E-05	2.252E-05	2.225E-05	1.29	-0.01	-1.23	2.224E-05	0.01
Jackson, SC	1.320E-04	1.502E-04	1.381E-04	1.377E-04	4.14	-9.08	-0.29	1.401E-04	-1.74
New Ellenton, SC	6.377E-05	6.129E-05	6.595E-05	6.430E-05	0.82	4.68	-2.57	6.367E-05	0.98
Barnwell, SC	1.171E-05	1.158E-05	1.155E-05	1.162E-05	-0.80	0.32	0.57	1.161E-05	0.03
Martin, SC	8.530E-06	8.484E-06	8.394E-06	8.463E-06	-0.79	-0.24	0.82	8.469E-06	-0.07
Allendale, SC	5.919E-06	5.891E-06	5.855E-06	5.887E-06	-0.55	-0.07	0.54	5.888E-06	-0.03
Williston, SC	1.749E-05	1.721E-05	1.735E-05	1.739E-05	-0.59	1.02	0.21	1.735E-05	0.21

Table A-6 Comparison of Dilution Factors for Group 2 Individual Sources and Virtual Source

Exposure Location	F-Canyon	H-Canyon	H Tritium Stack	Virtual Source	F % Delta	H % Delta	H Tritium Stack % Delta	Sum: F, H, H Tritium Stack	Sum % Delta
Girard, GA	7.36E-06	6.49E-06	6.51E-06	6.467E-06	-13.80	-0.38	-0.61	6.785E-06	-4.93
Waynesboro, GA	1.18E-05	1.10E-05	1.11E-05	1.141E-05	-3.80	3.57	2.86	1.131E-05	0.88
Augusta, GA	1.10E-05	1.01E-05	1.02E-05	1.054E-05	-4.14	3.92	3.45	1.043E-05	1.07
Jackson, SC	2.73E-05	2.09E-05	2.13E-05	2.372E-05	-15.20	12.03	10.38	2.315E-05	2.40
New Ellenton, SC	2.74E-05	2.45E-05	2.45E-05	2.716E-05	-0.72	9.69	9.80	2.546E-05	6.26
Barnwell, SC	1.34E-05	1.51E-05	1.50E-05	1.421E-05	5.70	-6.47	-5.42	1.450E-05	-2.06
Martin, SC	8.45E-06	7.84E-06	7.82E-06	8.733E-06	3.27	10.27	10.52	8.033E-06	8.02
Allendale, SC	5.47E-06	5.77E-06	5.75E-06	5.613E-06	2.62	-2.74	-2.40	5.660E-06	-0.84
Williston, SC	1.41E-05	1.59E-05	1.57E-05	1.494E-05	5.91	-6.60	-5.26	1.524E-05	-1.99

Table A-7 Comparison of Dilution Factors for Group 3 Individual Sources and Virtual Source

Exposure Location	C-Reactor	K-Reactor	L-Reactor	Virtual Source	C % Delta	K % Delta	L % Delta	Sum of All Reactors	Sum % Delta
Girard, GA	8.52E-06	1.03E-05	9.17E-06	8.373E-06	-1.76	-22.89	-9.50	9.327E-06	-11.39
Waynesboro, GA	8.97E-06	9.24E-06	8.43E-06	8.843E-06	-1.43	-4.43	4.72	8.877E-06	-0.38
Augusta, GA	1.01E-05	9.14E-06	8.52E-06	9.157E-06	-9.76	0.15	6.92	9.239E-06	-0.90
Jackson, SC	2.67E-05	2.04E-05	1.81E-05	2.107E-05	-26.56	3.29	14.06	2.172E-05	-3.07
New Ellenton, SC	2.09E-05	1.65E-05	1.46E-05	1.781E-05	-17.07	7.19	17.91	1.733E-05	2.68
Barnwell, SC	1.37E-05	1.41E-05	1.63E-05	1.466E-05	6.89	3.89	-11.26	1.468E-05	-0.16
Martin, SC	9.52E-06	1.12E-05	1.28E-05	1.094E-05	12.99	-2.16	-17.06	1.117E-05	-2.08
Allendale, SC	5.83E-06	6.34E-06	6.90E-06	6.310E-06	7.64	-0.51	-9.27	6.355E-06	-0.71
Williston, SC	1.30E-05	1.22E-05	1.33E-05	1.294E-05	-0.21	5.97	-3.06	1.283E-05	0.90

Table A-8 Comparison of Dilution Factors for Group 4 Individual Sources and Virtual Source

Exposure Location	P-Reactor	R-Reactor	Virtual Source	P % Delta	R % Delta	Sum of P & R	Sum % Delta
Girard, GA	8.32E-06	6.85E-06	7.515E-06	-10.70	8.90	7.583E-06	-0.90
Waynesboro, GA	7.55E-06	7.15E-06	7.345E-06	-2.79	2.65	7.350E-06	-0.07
Augusta, GA	8.18E-06	7.01E-06	8.455E-06	3.22	17.13	7.595E-06	10.17
Jackson, SC	1.30E-05	1.43E-05	1.368E-05	4.75	-4.75	1.368E-05	0.00
New Ellenton, SC	1.50E-05	1.89E-05	1.669E-05	10.16	-13.10	1.693E-05	-1.47
Barnwell, SC	1.98E-05	1.98E-05	2.000E-05	1.25	1.05	1.977E-05	1.15
Martin, SC	1.14E-05	9.21E-06	1.022E-05	-11.25	9.85	1.029E-05	-0.70
Allendale, SC	7.24E-06	6.56E-06	6.900E-06	-4.91	4.93	6.900E-06	0.01
Williston, SC	1.57E-05	1.89E-05	1.721E-05	8.83	-9.82	1.730E-05	-0.49

source. Although the maximum deviation for Group 3 is slightly in excess of the 25-percent target criterion, it is not considered to be a serious concern because the excess is only 2 percent.

Recall that a positive ("+") percent error means the virtual source predicts a higher concentration than is predicted by the actual source (i.e., an over-prediction); a negative ("-") percent error means the virtual source underestimates concentration. Because the virtual source locations were chosen to be approximately at the centers of the group of individual actual sources and because the exposure locations are widely distributed around the site, the direction of the error tends to be evenly distributed between overprediction and underprediction. For example, the column labeled "L % Delta" in Table A-7 has five negative entries (underestimates) and four positive entries (overestimates). Furthermore, the sum of the

column is –6.5 percent, even though the largest entry is +17.9 percent. This implies that overestimates in some exposure locations are approximately balanced by underestimates at other locations. One may also look at the rows corresponding to an exposure location in each of Tables A-5 through A-8. Of the 36 rows (9 locations x 4 virtual sources), only 5 have all the errors in the same direction; all the rest have a mix.

However, there may be a bias for large errors. Out of the four maximum errors in the tables describing the four virtual sources, three are negative. This indicates that the virtual source underpredicted the concentration induced by the actual source for three out of the four maximum errors. A conjecture that could explain this apparent bias is related to the fact that the maximum error is expected for those exposure locations closest to the site. Consider a hypothetical situation where the virtual source is located in the middle of a line connecting two actual sources, A and B. Further suppose that the exposure location is at a point on the same line, but to the left of A. The increase in concentration at the exposure location induced by changing from the virtual source to source A is larger than the decrease in concentration induced by changing from the virtual source to source B, even though the change in distances are the same. This is because the dependence of concentration on distance is nonlinear. This is the suspected reason why the maximum errors, where small distances are involved, are biased toward underestimation.

In addition to this comparison of the concentration induced by each actual source to the concentration induced by the virtual source, the combined effect of a unit release at every source was compared to the effect of the virtual source with its strength equal to the combined strength of all actual sources. That is, if there were n sources in the group, each with a unit release, the strength of the virtual source was assumed to be n. This is a particular example of what may actually occur. In general, the individual sources in a group represented by a virtual source have strengths that vary in time. To analyze the error involved in such a situation would be complex. However, the error is capped by the comparisons made above where the virtual source was compared to each individual source in turn (i.e., the percent error from an entire group can never be larger than the maximum error exhibited by any single individual source).

Because it was not feasible to evaluate all possible permutations of source strength, the condition of all sources having the same strength was chosen as an example. Although this choice of source strengths was but one of an infinite number of choices, it did demonstrate (as expected) that a virtual source would represent a group of sources more precisely than an individual source. This is because underestimates for some sources were often balanced by overestimates for others. As can be seen in Tables A-5 through A-8, the columns marked “Sum” provide the dilution factors induced by the combination of the actual sources. The columns marked “Sum % Delta” indicate the percentage deviations between the combination of actual sources and the virtual source.

These deviations are also very small. For Group 1, the maximum deviation is 2 percent for the exposure location Jackson. For Group 2, the maximum deviation is 8 percent for the exposure location Martin. For Group 3, the maximum deviation is 11 percent for the exposure location Girard. For Group 4, the maximum deviation is 10 percent for the exposure location Augusta. As expected, the concentrations from the combined actual sources are closer to those of the equivalent virtual sources because underestimates and overestimates in concentrations using the virtual source to represent each actual source tended to cancel each other. This led to a more precise estimate for the group than for many of the individual sources taken separately.

Figures A-4 through A-7 illustrate graphically the concentration comparisons discussed above. The dilution factors for the actual and virtual sources are plotted on the y-axis for each of the exposure locations shown on the x-axis. With few exceptions, the concentrations implied by these dilution factors would all be very close.

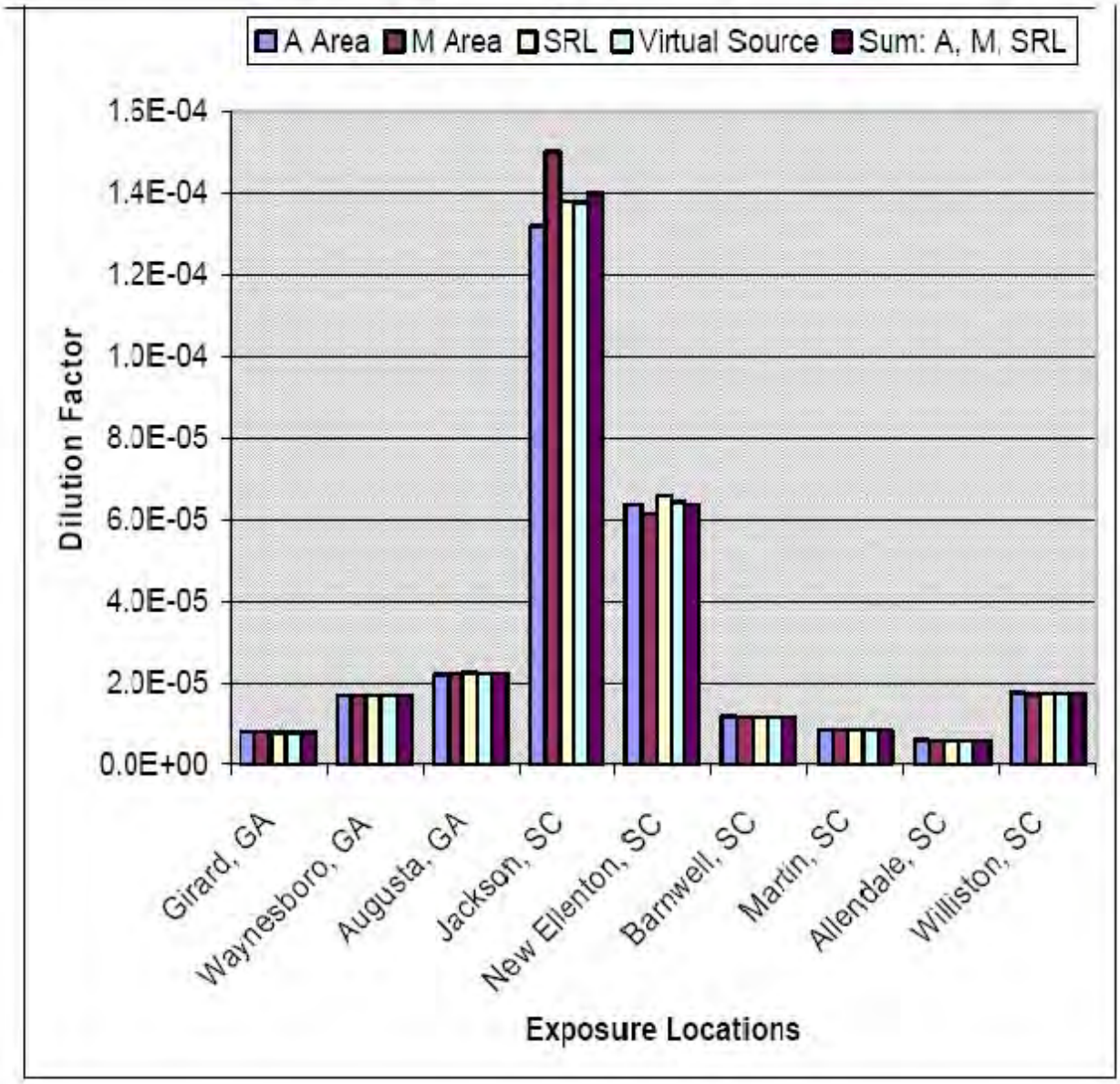


Figure A-4 Group 1 Comparisons

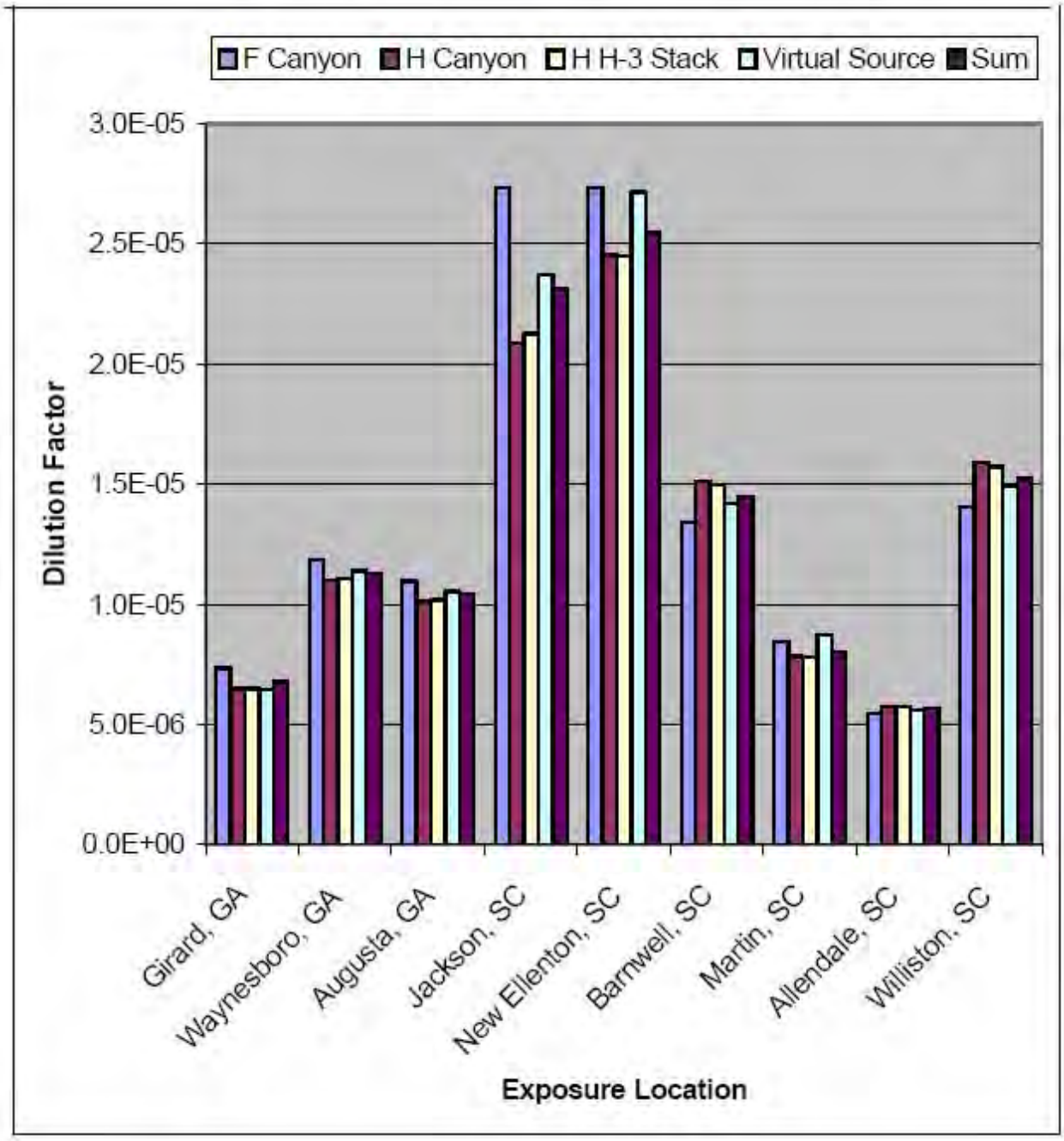


Figure A-5 Group 2 Comparisons

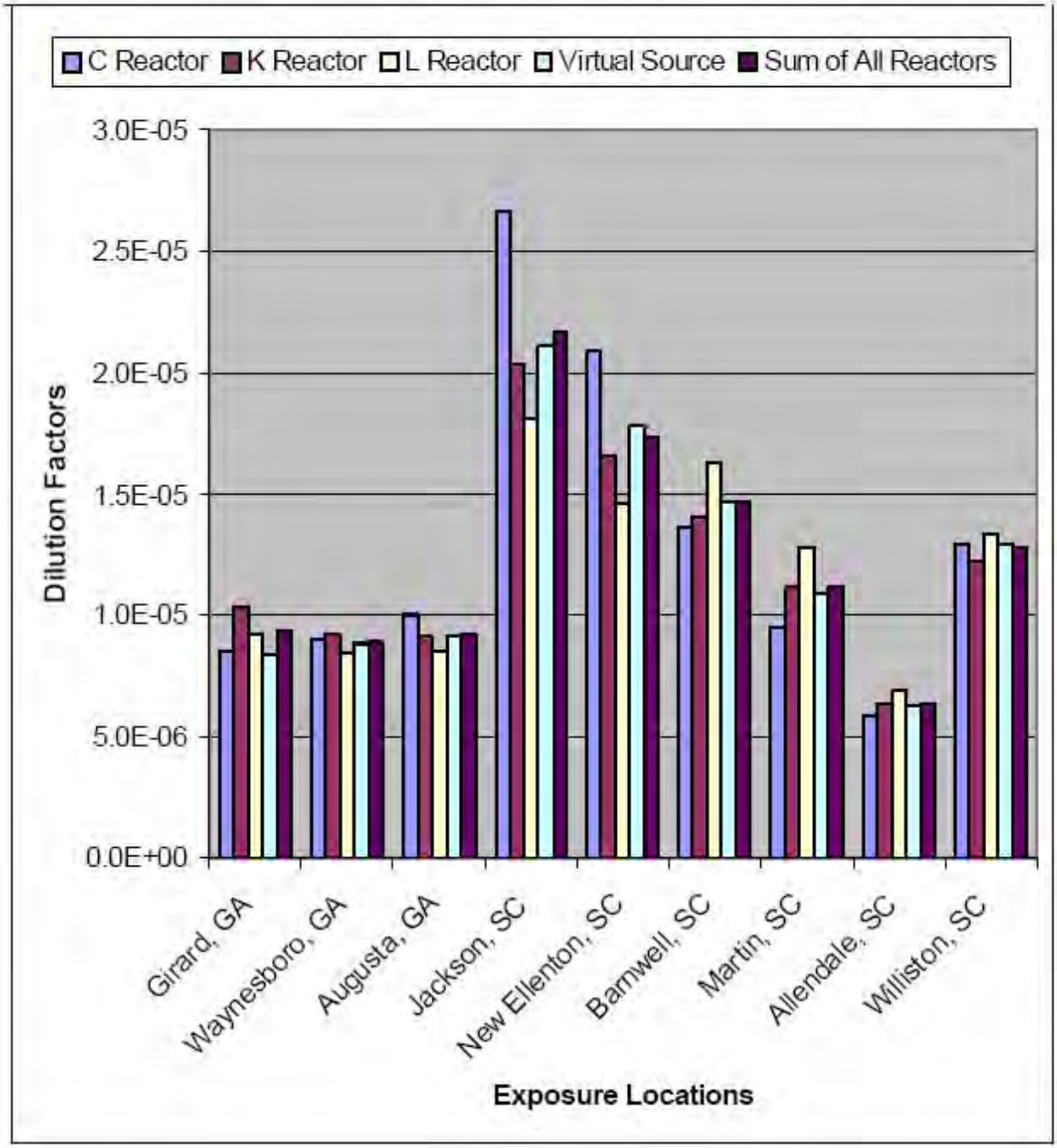


Figure A-6 Group 3 Comparisons

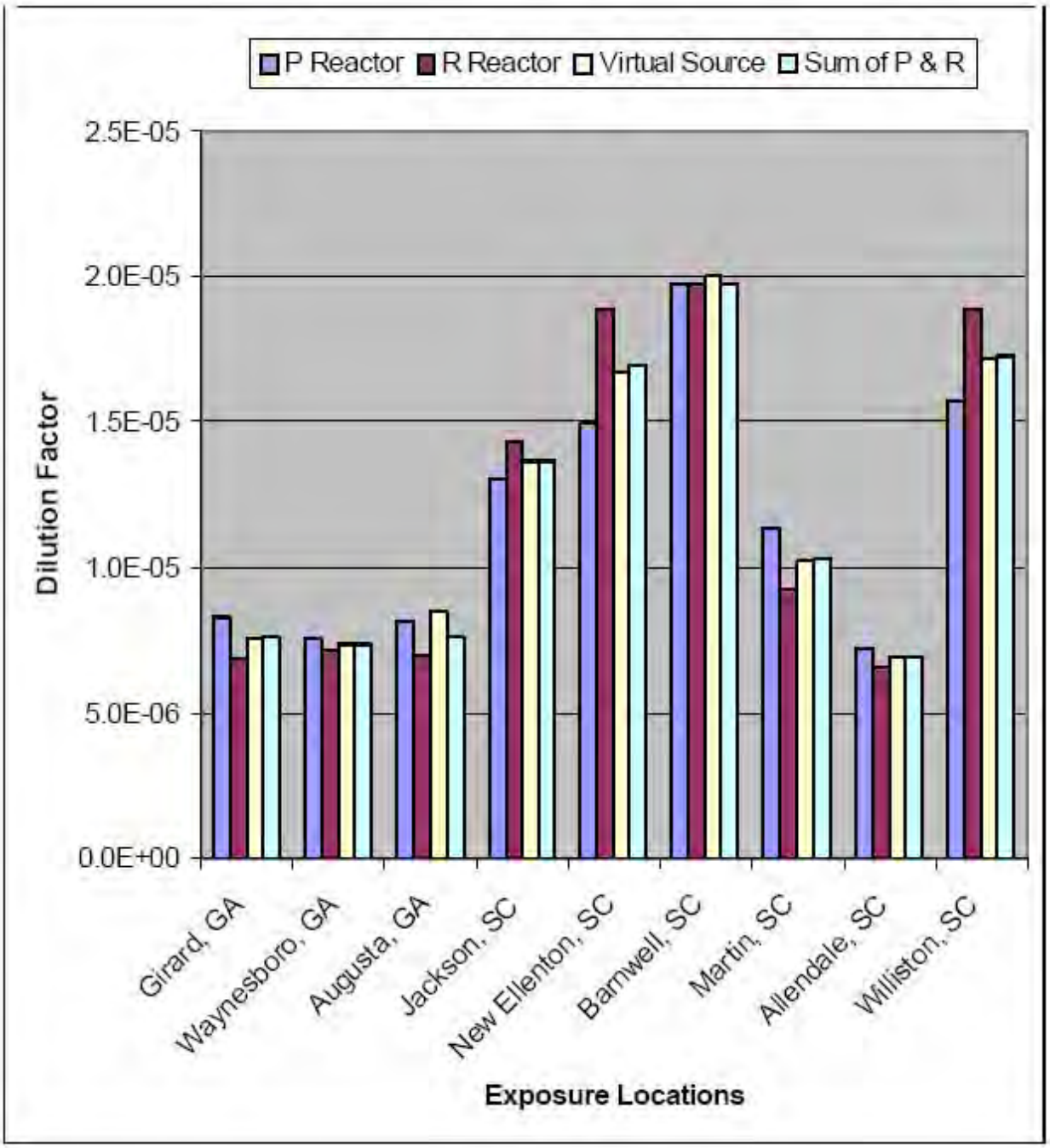


Figure A-7 Group 4 Comparisons

A.2.2.2 Part 2: Analysis of Weak Sources

This discussion expands and quantifies the qualitative discussion in Section A.2.1, item 4. Consider the effect of source strength on the concentrations induced by individual sources compared to concentrations induced by their representative virtual source. To analyze this problem, consider two actual sources represented by a virtual source. Then,

$$C_V = (S_1 + S_2)\, D_V \qquad \text{(A-1)}$$

and

$$C_1 = S_1 D_1 \qquad \text{(A-2)}$$
$$C_2 = S_2 D_2 \qquad \text{(A-3)}$$

Where,

C is the concentration induced at an exposure location;

D is the dilution factor; and

S is the source strength.

The subscripts V, 1, and 2, represent the virtual source, source 1, and source 2, respectively, where source 1 is a strong source and source 2 is a weak source.

The actual concentration, C_A, is:

$$C_A = C_1 + C_2 = S_1D_1 + S_2D_2 \qquad \text{(A-4)}$$

The fractional error, F, is given by:

$$F = (C_V - C_A)/ C_A = [\{(S_1 + S_2)\, D_V\}/(S_1D_1 + S_2D_2)] - 1 \qquad \text{(A-5)}$$

Recall that Source 1 is a strong source and Source 2 is a weak source. Therefore, it is convenient, with some manipulation, to express the fractional error in this form:

$$F = \frac{D_V / D_1}{\frac{S_1}{S_1 + S_2}\left(1 + \frac{S_2}{S_1} \cdot \frac{D_2}{D_1}\right)} - 1 \qquad \text{(A-6)}$$

If it is assumed that $S_2 < S_1$ (i.e., the relative strength of S_2 is very small), then $S_1/(S_1+S_2) \approx 1$. If it is further assumed that $S_2D_2 < S_1D_1$ (i.e., the small size of S_2 is sufficient to more than compensate for the fact that source 2 may be closer to the exposure location, causing D_2 to be larger than D_1), this analytic approximation may be used (9):

$$(1 + x)^{-1} = 1 - x + x^2 - x^3 + x^4 - \ldots \qquad (-1<X<1) \qquad \text{(A-7)}$$

to obtain:

$$F \cong \left[\left(\frac{D_V}{D_1}\right)\left(1 - \frac{S_2}{S_1} \cdot \frac{D_2}{D_1}\right)\right] - 1 \qquad \text{(A-8)}$$

This means that the fractional error for the combined strong and weak individual sources is equal approximately to the ratio of the dilution factors of the virtual and strong sources (D_V/D_1) multiplied by a factor depending on the characteristics of the strong and weak sources, minus 1. Note that if $S_2 = 0$, the error is just the ratio of the dilution factors for the virtual and strong sources, minus 1.

The ratio S_2/S_1 limits the magnitude of the error induced by the weak source. That is, even if the dilution factors for sources 2 and 1 are not very close, their ratio will be multiplied by the relative strengths of sources 2 and 1. Suppose source 2 induces 10 times the concentration at the exposure location (an extremely large difference) compared to source 1. If the relative strength of source 2 is 0.01 of source 1 (1 percent), then the error induced by the weak source only amounts to 10 percent of the error that would be present from the strong source alone. This quantifies why a weak source with a strength that is only a few percent of a nearby larger source may be subsumed into that larger source. For modeling of air sources at the SRS, this implies that weak, ground-level sources could be combined with nearby elevated virtual sources. This was done as indicated in Section A.2.1, item 4.

A.3 Conclusions

The analysis shows very good agreement between the virtual sources and individual actual source locations. The largest error was 27 percent. This was the only case where the error exceeded 25 percent, and then by only 2 percent. This error was for a single-source/exposure-location combination, which is considered to be a stringent comparison. Comparisons between virtual sources and the combined effects of several actual sources, each assumed to have unit strength, showed even better agreement. The maximum error was 11 percent, with most values lower. Although the direction of the errors for the virtual source compared to various actual sources was generally balanced between positive and negative, for the larger errors the virtual sources appeared to underestimate the concentration that would be induced by the actual sources. This appears to be linked to the nonlinear behavior of the air-dispersion relations. However, even the maximum errors are not considered to be excessive.

Given that this choice of virtual sources provides an excellent portrayal of the concentrations induced by the actual sources, the four virtual sources defined in Table A-3 were used for Phase III.

A.4 References

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APPENDIX B RADIONUCLIDE SOURCE TERMS USED FOR PHASE III ANALYSIS

This appendix lists the source term that was used for Phase III of the Savannah River Site (SRS) Dose Reconstruction Project. It contains tables of the annual quantities of radionuclides that were released into air and surface during the 39 years of production of nuclear materials at SRS – i.e., 1954 through 1992.

The first four of the tables lists the annual quantities (units of Curies[1]) of sixteen radionuclides released into the air at SRS from four virtual sources. These four virtual sources were derived as discussed in detail in Appendix A. The table citations and the SRS facilities comprising these four virtual sources are:

- Table B-1 -- A-Area, M-Area, Savannah River Laboratory (SRL)
- Table B-2 -- F-Canyon, H-Canyon, H-Tritium Stack, F&H Seepage Basins
- Table B-3 -- C-Reactor, K-Reactor, L-Reactor, Reactor Seepage Basin release attributable to C-, K-, and L-Reactors, D-Area, CMX-TNX
- Table B-4 -- P-Reactor, R-Reactor, Reactor Seepage Basin release attributable to P- and R-Reactors.

The next two tables list those radionuclides released into surface water. Table B-5 lists the annual concentrations (units of picoCuries per milliliter, or pCi/ml)[2] of twenty-two radionuclides discharged into the Savannah River from all SRS surface water sources. Table B-6 lists the annual concentrations (again, units of pCi/ml) of three radionuclides discharged into Lower Three Runs Creek. The concentrations represent average annual concentrations as they were assumed to exist in either the Savannah River or Lower Three Runs Creek for purposes of the exposure assessment.

In these tables, the following nomenclature is used for specific radionuclides:

- ^{3}H – tritium (T) released in an oxide form (i.e., as HTO).
- ^{3}H-EL – tritium released in elemental form (HT).
- ^{129}I-E – I in elemental form (I_2).
- ^{129}I-O – ^{129}I in organic form (e.g., CH_3).
- ^{131}I-E – ^{131}I in elemental form (I_2).
- ^{131}I-O – ^{131}I in organic form (e.g., CH_3).

[1] Where one Curie (Ci) equals 3.7E+10 Becquerels (Bq), and 1 Bq equals one nuclear disintegration per second.
[2] Where 10^{12} picoCuries (pCi) equals 1 Ci, and 1000 milliliters (ml) equals 1 liter.

Table B-1 Radionuclides Released to Air from A-Area, M-Area, and SRL (Ci)

Radio-nuclide	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	0.00	0.00	0.00	0.00	0.00	6260	5500	2670	382	0.00
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.00	0.00	0.00	0.00	2.93	0.10	0.018	0.35	0.12	0.009
^{131}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20×10^{-04}	3.00×10^{-04}	2.42×10^{-04}
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	0.00	0.00	0.00	0.00	0.01	0.49	0.08	0.09	0.22	0.18
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-1 Radionuclides Released to Air from A-Area, M-Area, and SRL (Ci) (continued)

Radio-nuclide	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	197	60.0	380	110	120	120	120	289	220	733
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	1.65	0.73	0.018	0.17	0.019	0.0038	0.088	0.018	0.025	0.031
^{131}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	0.00	0.00	0.00	0.00	5.00×10^{-04}	4.60×10^{-04}	6.10×10^{-04}	6.60×10^{-04}	0.00	1.90×10^{-05}
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	0.050	0.090	0.005	0.012	0.0016	0.010	0.0059	0.0014	6.70×10^{-04}	7.00×10^{-06}
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-1 Radionuclides Released to Air from A-Area, M-Area, and SRL (Ci) (continued)

Radio-nuclide	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.0026	0.00	0.00	0.00	0.00
^{3}H	527	603	77.7	4.0	0.00	0.00	0.00	15.0	5.00	0.00
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.026	0.0077	0.013	0.0050	0.0087	0.0032	0.0042	0.0032	0.0020	0.0027
^{131}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	6.78×10^{-05}	1.02×10^{-05}	8.7×10^{-06}	1.85×10^{-05}	1.35×10^{-05}	9.94×10^{-06}	1.47×10^{-05}	7.11×10^{-07}	8.64×10^{-06}	7.21×10^{-06}
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	3.50×10^{-05}	3.10×10^{-05}	2.30×10^{-05}	7.00×10^{-06}	0.00	0.00	3.60×10^{-05}	1.00×10^{-05}	1.90×10^{-05}	1.85×10^{-04}
^{234}U	0.00	1.66×10^{-06}	1.21×10^{-06}	9.07×10^{-06}	1.12×10^{-06}	1.11×10^{-06}	4.36×10^{-08}	0.00	1.45×10^{-06}	2.24×10^{-06}
^{235}U	0.00	7.56×10^{-08}	5.51×10^{-08}	4.12×10^{-07}	5.11×10^{-08}	5.05×10^{-08}	1.98×10^{-09}	0.00	6.6×10^{-08}	1.02×10^{-07}
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	1.62×10^{-06}	1.18×10^{-06}	8.84×10^{-06}	1.1×10^{-06}	1.08×10^{-06}	4.25×10^{-08}	0.00	1.41×10^{-06}	2.18×10^{-06}

Table B-1 Radionuclides Released to Air from A-Area, M-Area, and SRL (Ci) (continued)

Radio-nuclide	1984	1985	1986	1987	1988	1989	1990	1991	1992
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	2.38x10-07	0.00	$2.34x10^{-08}$
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	$1.19x10^{-06}$	$6.73x10^{-06}$	$3.94x10^{-06}$
^{3}H	0.00	33.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.0021	0.0011	0.0025	0.0043	0.0021	$3.34x10^{-04}$	$1.24x10^{-04}$	$2.96x10^{-05}$	$5.75x10^{-05}$
^{131}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	$5.77x10^{-06}$	$9.28x10^{-06}$	$2.19x10^{-05}$	$2.79x10^{-05}$	$1.23x10^{-05}$	$8.18x10^{-06}$	$3.52x10^{-0}5$	$5.24x10^{-05}$	$5.78x10^{-05}$
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	$5.10x10^{-05}$	$1.60x10^{-05}$	$2.60x10^{-05}$	$3.20x10^{-05}$	$3.40x10^{-05}$	$1.00x10^{-06}$	$1.18x10^{-04}$	$2.59x10^{-04}$	$5.26x10^{-05}$
^{234}U	0.00	$5.64x10^{-06}$	$4.84x10^{-05}$	$1.1x10^{-05}$	$1.38x10^{-06}$	$4.17x10^{-07}$	$9.9x10^{-06}$	$6.19x10^{-05}$	$2.54x10^{-06}$
^{235}U	0.00	$2.57x10^{-07}$	$2.2x10^{-06}$	$4.99x10^{-07}$	$6.28x10^{-08}$	$1.9x10^{-08}$	$4.5x10^{-07}$	$2.81x10^{-06}$	$1.15x10^{-07}$
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	$5.5x10^{-06}$	$4.72x10^{-05}$	$1.07x10^{-05}$	$1.35x10^{-06}$	$4.07x10^{-07}$	$9.65x10^{-06}$	$6.03x10^{-05}$	$2.47x10^{-06}$

Table B-2 Radionuclides Released to Air from F-Canyon, H-Canyon, H-Tritium Stack, and F&H Seepage Basins (Ci)

Radio-nuclide	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	0.00	35.0	35.0	35.0	35.0	56.0	56.0	56.0	56.0	56.0
^{137}Cs	0.00	1.35	0.24	0.063	0.026	0.14	0.12	0.048	0.037	0.025
^{3}H	0.00	$1.47\text{x}10^{+04}$	$2.20\text{x}10^{+05}$	$5.69\text{x}10^{+05}$	$1.13\text{x}10^{+06}$	$4.14\text{x}10^{+05}$	$3.43\text{x}10^{+05}$	$3.50\text{x}10^{+05}$	$3.82\text{x}10^{+05}$	$3.94\text{x}10^{+05}$
^{3}H-EL	0.00	$1.47\text{x}10^{+04}$	$2.20\text{x}10^{+05}$	$5.68\text{x}10^{+05}$	$1.13\text{x}10^{+06}$	$4.52\text{x}10^{+05}$	$3.44\text{x}10^{+05}$	$3.43\text{x}10^{+05}$	$4.24\text{x}10^{+05}$	$3.98\text{x}10^{+05}$
^{129}I-E	0.00	0.013	0.022	0.032	0.054	0.030	0.034	0.042	0.030	0.074
^{129}I-O	0.00	0.050	0.088	0.13	0.22	0.12	0.14	0.17	0.12	0.30
^{131}I-E	0.00	273	6437	1311	79.3	737	29.9	385	3.80	1.10
^{131}I-O	0.00	1140	27352	5432	325	3065	124	1565	15.25	4.42
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	0.00	12.5	0.049	0.065	0.032	0.036	0.11	0.018	0.015	0.0047
^{106}Ru	0.00	25.1	6.34	1.24	0.62	9.99	8.85	3.91	2.78	3.89
^{89}Sr	0.00	0.32	0.043	0.016	0.018	0.24	0.040	0.031	0.025	0.027
^{90}Sr	0.00	34.0	8.44	1.68	0.0059	0.079	0.013	0.010	0.0083	0.0089
^{234}U	0.00	0.81	0.030	$9.53\text{x}10^{-04}$	0.0023	$5.72\text{x}10^{-04}$	0.0011	0.0046	0.0032	0.018
^{235}U	0.00	0.023	0.0073	$1.24\text{x}10^{-04}$	$9.74\text{x}10^{-05}$	$3.80\text{x}10^{-04}$	0.0011	$5.64\text{x}10^{-04}$	$3.98\text{x}10^{-04}$	0.0015
^{236}U	0.00	0.057	0.0021	$6.70\text{x}10^{-05}$	$1.61\text{x}10^{-04}$	$4.02\text{x}10^{-05}$	$8.04\text{x}10^{-05}$	$3.22\text{x}10^{-04}$	$2.22\text{x}10^{-04}$	0.0013
^{238}U	0.00	0.54	0.52	0.0082	0.0041	0.029	0.081	0.037	0.026	0.086

Table B-2 Radionuclides Released to Air from F-Canyon, H-Canyon, H-Tritium Stack, and F&H Seepage Basins (Ci) (continued)

Radio-nuclide	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	46.0	46.0	46.0	46.0	36.0	36.0	36.0	36.0	36.0	36.0
^{137}Cs	0.067	0.018	0.048	0.018	0.040	0.085	0.042	0.0093	0.024	0.0026
^{3}H	$5.13\text{x}10^{+05}$	$1.79\text{x}10^{+05}$	$1.82\text{x}10^{+05}$	$1.55\text{x}10^{+05}$	$2.28\text{x}10^{+05}$	$1.54\text{x}10^{+05}$	$1.48\text{x}10^{+05}$	$2.08\text{x}10^{+05}$	$2.70\text{x}10^{+05}$	$1.76\text{x}10^{+05}$
^{3}H-EL	$5.05\text{x}10^{+05}$	$1.71\text{x}10^{+05}$	$1.71\text{x}10^{+05}$	$1.89\text{x}10^{+05}$	$2.41\text{x}10^{+05}$	$1.49\text{x}10^{+05}$	$1.39\text{x}10^{+05}$	$2.02\text{x}10^{+05}$	$2.90\text{x}10^{+05}$	$1.74\text{x}10^{+05}$
^{129}I-E	0.10	0.10	0.038	0.046	0.042	0.048	0.038	0.018	0.016	0.026
^{129}I-O	0.40	0.40	0.15	0.18	0.17	0.19	0.15	0.074	0.063	0.10
^{131}I-E	2.29	3.95	7.12	4.39	5.00	7.77	7.34	5.24	0.58	0.40
^{131}I-O	9.18	15.96	28.43	17.61	20.38	31.12	29.70	21.17	2.36	1.61
^{238}Pu	0.00	0.00	0.00	$3.49\text{x}10^{-04}$	0.0013	1.89	0.028	0.029	0.022	0.030
^{239}Pu	0.0075	0.092	0.041	0.014	0.0076	0.20	0.012	0.011	0.0051	0.0019
^{106}Ru	2.62	2.76	4.59	0.42	20.1	13.73	0.68	5.69	7.32	3.19
^{89}Sr	0.030	0.015	0.016	0.011	0.026	0.087	0.042	0.027	0.10	0.011
^{90}Sr	0.0099	0.0049	0.0053	0.0035	0.0085	0.029	0.014	0.0091	0.033	0.0035
^{234}U	0.041	0.0022	0.0035	0.0027	0.053	0.10	0.0088	0.0076	0.0079	0.0047
^{235}U	0.0026	0.0022	$9.04\text{x}10^{-04}$	$8.37\text{x}10^{-04}$	0.0014	0.0035	$7.64\text{x}10^{-04}$	$2.65\text{x}10^{-04}$	$3.76\text{x}10^{-04}$	$2.46\text{x}10^{-04}$
^{236}U	0.0029	$1.53\text{x}10^{-04}$	$2.50\text{x}10^{-04}$	$1.91\text{x}10^{-04}$	0.0037	0.0071	$6.21\text{x}10^{-04}$	$5.34\text{x}10^{-04}$	$5.54\text{x}10^{-04}$	$3.33\text{x}10^{-04}$
^{238}U	0.14	0.17	0.065	0.061	0.032	0.12	0.046	0.0091	0.017	0.012

Table B-2 Radionuclides Released to Air from F-Canyon, H-Canyon, H-Tritium Stack, and F&H Seepage Basins (Ci) (continued)

Radio-nuclide	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
^{241}Am	0.00	0.00	0.00	$3.39x10^{-04}$	0.0012	$3.55x10^{-04}$	0.0011	$4.94x10^{-04}$	$4.98x10^{-04}$	$2.57x10^{-04}$
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	33.0	27.0	28.0	26.0	23.0	23.0	27.0	28.0	33.0	37.0
^{137}Cs	0.0013	0.0011	0.0013	0.0019	0.0020	0.0027	0.0026	0.0031	0.0010	0.0010
^{3}H	$1.10x10^{+05}$	$8.67x10^{+04}$	$7.00x10^{+04}$	$9.64x10^{+04}$	$7.65x10^{+04}$	$8.29x10^{+04}$	$8.56x10^{+04}$	$1.53x10^{+05}$	$1.41x10^{+05}$	$2.04x10^{+05}$
^{3}H-EL	$5.84x10^{+05}$	$2.63x10^{+05}$	$8.34x10^{+04}$	$1.13x10^{+05}$	$1.35x10^{+05}$	$9.19x10^{+04}$	$8.16x10^{+04}$	$1.19x10^{+05}$	$1.41x10^{+05}$	$2.34x10^{+05}$
^{129}I-E	0.034	0.028	0.030	0.028	0.026	0.026	0.032	0.028	0.012	0.0082
^{129}I-O	0.14	0.11	0.12	0.11	0.10	0.10	0.13	0.11	0.047	0.033
^{131}I-E	0.41	0.026	0.033	0.013	0.014	0.018	0.0054	0.010	0.023	0.018
^{131}I-O	1.65	0.11	0.13	0.053	0.056	0.073	0.022	0.041	0.091	0.073
^{238}Pu	0.0064	0.0027	0.022	0.0067	0.0093	0.0018	0.0037	0.0061	0.0054	0.0035
^{239}Pu	0.0039	$6.98x10^{-04}$	$3.22x10^{-04}$	$1.40x10^{-04}$	$3.03x10^{-04}$	$5.36x10^{-04}$	0.0017	0.0038	0.0023	$9.67x10^{-04}$
^{106}Ru	0.15	0.04	0.28	0.16	32.9	0.059	0.061	0.091	0.24	0.10
^{89}Sr	0.0083	0.0038	0.0035	0.0031	0.0029	0.0018	0.0019	0.0022	0.0017	0.0020
^{90}Sr	0.0028	0.0014	0.0012	0.0011	0.0016	$7.33x10^{-04}$	0.0012	$9.26x10^{-04}$	0.0010	$7.64x10^{-04}$
^{234}U	$1.86x10^{-04}$	$9.3x10^{-05}$	$3.10x10^{-04}$	$9.92x10^{-04}$	0.0016	0.0012	0.0018	0.0055	0.0020	$6.76x10^{-04}$
^{235}U	$3.73x10^{-04}$	$2.03x10^{-04}$	$2.15x10^{-04}$	$7.22x10^{-05}$	$1.40x10^{-04}$	$1.11x10^{-04}$	$1.83x10^{-04}$	$2.92x10^{-04}$	$4.04x10^{-04}$	$1.95x10^{-04}$
^{236}U	$1.31x10^{-05}$	$6.54x10^{-06}$	$2.18x10^{-05}$	$6.97x10^{-05}$	$1.14x10^{-04}$	$8.41x10^{-05}$	$1.30x10^{-04}$	$3.85x10^{-04}$	$1.43x10^{-04}$	$4.75x10^{-05}$
^{238}U	0.029	0.016	0.016	0.0041	0.0085	0.0068	0.011	0.014	0.028	0.014

Table B-2 Radionuclides Released to Air from F-Canyon, H-Canyon, H-Tritium Stack, and F&H Seepage Basins (Ci) (continued)

Radio-nuclide	1984	1985	1986	1987	1988	1989	1990	1991	1992
^{241}Am	$1.42x10^{-04}$	$4.26x10^{-04}$	$1.54x10^{-04}$	$2.04x10^{-04}$	$1.18x10^{-04}$	$2.01x10^{-04}$	$1.28x10^{-04}$	$1.53x10^{-04}$	$1.13x10^{-04}$
^{41}Ar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{14}C	34.0	31.0	25.0	17.0	13.0	18.0	0.67	0.62	0.0031
^{137}Cs	0.0019	0.0052	0.0029	1.07	0.0018	0.0010	0.0021	$3.20x10^{-04}$	$2.16x10^{-04}$
^{3}H	$3.10x10^{+05}$	$2.05x10^{+05}$	$1.66x10^{+05}$	$1.72x10^{+05}$	$1.69x10^{+05}$	$9.78x10^{+04}$	$9.68x10^{+04}$	$6.21x10^{+04}$	$5.31x10^{+04}$
^{3}H-EL	$2.43x10^{+05}$	$2.04x10^{+05}$	$1.24x10^{+05}$	$3.26x10^{+05}$	$1.87x10^{+05}$	$9.67x10^{+04}$	$7.77x10^{+04}$	$6.29x10^{+04}$	$5.58x10^{+04}$
^{129}I-E	0.0070	0.013	0.017	0.014	0.013	0.010	0.0026	0.0020	$7.00x10^{-04}$
^{129}I-O	0.028	0.052	0.070	0.058	0.050	0.042	0.010	0.0081	0.0028
^{131}I-E	0.060	0.013	0.0056	0.0027	$1.05x10^{-04}$	$7.82x10^{-05}$	$3.12x10^{-08}$	$4.68x10^{-09}$	$8.20x10^{-06}$
^{131}I-O	0.24	0.052	0.023	0.011	$4.28x10^{-04}$	$3.14x10^{-04}$	$1.25x10^{-07}$	$1.87x10^{-08}$	$3.28x10^{-05}$
^{238}Pu	0.0018	$7.30x10^{-04}$	0.0027	0.0026	0.0011	0.0012	$4.50x10^{-04}$	$3.54x10^{-04}$	$5.94x10^{-04}$
^{239}Pu	$6.18x10^{-04}$	$6.67x10^{-04}$	$4.09x10^{-04}$	$4.98x10^{-04}$	$9.64x10^{-04}$	0.0022	0.0039	$4.67x10^{-04}$	$9.21x10^{-04}$
^{106}Ru	0.17	0.054	0.062	0.047	0.031	0.0033	0.0012	$4.44x10^{-04}$	$1.81x10^{-06}$
^{89}Sr	0.0026	0.0013	$6.90x10^{-04}$	$4.60x10^{-04}$	$7.82x10^{-04}$	$4.05x10^{-04}$	0.00	0.00	$2.06x10^{-04}$
^{90}Sr	$9.53x10^{-04}$	$6.96x10^{-04}$	$2.30x10^{-04}$	$1.62x10^{-04}$	$4.93x10^{-04}$	$4.87x10^{-04}$	0.0074	0.0028	0.0014
^{234}U	0.0012	0.0012	$7.04x10^{-04}$	$3.60x10^{-04}$	$3.38x10^{-04}$	$4.59x10^{-04}$	$8.06x10^{-04}$	$3.97x10^{-04}$	$2.32x10^{-04}$
^{235}U	$1.01x10^{-04}$	$1.15x10^{-04}$	$6.71x10^{-05}$	$3.67x10^{-04}$	$6.48x10^{-05}$	$2.19x10^{-04}$	$2.28x10^{-04}$	$1.12x10^{-04}$	$6.69x10^{-05}$
^{236}U	$8.61x10^{-05}$	$8.70x10^{-05}$	$4.95x10^{-05}$	$2.53x10^{-05}$	$2.38x10^{-05}$	$3.23x10^{-05}$	$5.67x10^{-05}$	$2.79x10^{-05}$	$1.63x10^{-05}$
^{238}U	0.0060	0.0071	0.0042	0.028	0.0045	0.016	0.016	0.0081	0.0049

Table B-3 Radionuclides Released to Air from C-Reactor, K-Reactor, L-Reactor, Reactor Seepage Basin Release Attributable to C-, K-, and L-Reactors, D-Area, and CMX-TNX (Ci)

Radio-nuclide	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	0.00	$8.00 \times 10^{+04}$	$1.50 \times 10^{+05}$	$1.70 \times 10^{+05}$	$2.00 \times 10^{+05}$	$2.60 \times 10^{+05}$	$2.40 \times 10^{+05}$	$2.40 \times 10^{+05}$	$2.50 \times 10^{+05}$	$2.70 \times 10^{+05}$
^{14}C	0.00	27.0	28.0	28.0	28.0	48.0	48.0	48.0	48.0	48.0
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	0.00	3800	$1.49 \times 10^{+04}$	$4.13 \times 10^{+04}$	$6.33 \times 10^{+04}$	$1.19 \times 10^{+05}$	$1.66 \times 10^{+05}$	$1.19 \times 10^{+05}$	$1.69 \times 10^{+05}$	$2.33 \times 10^{+05}$
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.18	2.06	15.8	35.7	26.7	25.9	9.92	16.1	6.10	7.33
^{131}I-O	0.076	0.88	6.76	15.3	11.5	11.1	4.25	6.91	2.62	3.14
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.0032	0.0052	0.019	0.033
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-3 Radionuclides Released to Air from C-Reactor, K-Reactor, L-Reactor, Reactor Seepage Basin Release Attributable to C-, K-, and L-Reactors, D-Area, and CMX-TNX (Ci) (continued)

Radio-nuclide	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	$2.20x10^{+05}$	$2.10x10^{+05}$	$2.10x10^{+05}$	$2.40x10^{+05}$	$1.50x10^{+05}$	$1.00x10^{+05}$	$7.33x10^{+04}$	$8.20x10^{+04}$	$1.10x10^{+05}$	$1.15x10^{+05}$
^{14}C	42.0	48.0	48.0	48.0	37.0	34.0	35.0	34.0	34.0	34.0
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	$3.68x10^{+05}$	$3.25x10^{+05}$	$2.73x10^{+05}$	$2.98x10^{+05}$	$2.65x10^{+05}$	$1.60x10^{+05}$	$1.79x10^{+05}$	$1.65x10^{+05}$	$2.12x10^{+05}$	$1.82x10^{+05}$
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	4.35	2.48	1.49	7.24	4.89	7.32	2.82	0.62	0.43	0.10
^{131}I-O	1.87	1.06	0.64	3.10	2.10	3.14	1.21	0.27	0.19	0.043
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$7.33x10^{-06}$
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	0.0077	0.0040	0.0069	0.0012	0.0014	$7.91x10^{-04}$	$3.45x10^{-04}$	$8.00x10^{-05}$	$2.50x10^{-04}$	$4.67x10^{-04}$
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-3 Radionuclides Released to Air from C-Reactor, K-Reactor, L-Reactor, Reactor Seepage Basin Release Attributable to C-, K-, and L-Reactors, D-Area, and CMX-TNX (Ci) (continued)

Radio-nuclide	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	$5.55\text{x}10^{+04}$	$4.19\text{x}10^{+04}$	$5.61\text{x}10^{+04}$	$4.67\text{x}10^{+04}$	$3.55\text{x}10^{+04}$	$3.65\text{x}10^{+04}$	$4.73\text{x}10^{+04}$	$4.22\text{x}10^{+04}$	$3.62\text{x}10^{+04}$	$1.62\text{x}10^{+04}$
^{14}C	31.4	26.5	28.0	25.0	22.7	22.0	26.0	27.0	31.0	35.3
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	$1.70\text{x}10^{+05}$	$9.86\text{x}10^{+04}$	$1.03\text{x}10^{+05}$	$1.32\text{x}10^{+05}$	$1.12\text{x}10^{+05}$	$1.11\text{x}10^{+05}$	$1.16\text{x}10^{+05}$	$9.52\text{x}10^{+04}$	$1.24\text{x}10^{+05}$	$1.48\text{x}10^{+05}$
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.0048	$9.83\text{x}10^{-04}$	$6.96\text{x}10^{-04}$	0.0012	$6.14\text{x}10^{-04}$	$9.56\text{x}10^{-04}$	0.0011	0.0034	0.0047	0.0026
^{131}I-O	0.0021	$4.21\text{x}10^{-04}$	$2.98\text{x}10^{-04}$	$4.97\text{x}10^{-04}$	$2.63\text{x}10^{-04}$	$4.10\text{x}10^{-04}$	$4.55\text{x}10^{-04}$	0.0015	0.0020	0.0011
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	$5.05\text{x}10^{-06}$	$9.96\text{x}10^{-06}$	$7.10\text{x}10^{-06}$	$4.49\text{x}10^{-06}$	$2.50\text{x}10^{-06}$	$1.34\text{x}10^{-06}$	$3.56\text{x}10^{-06}$	$7.62\text{x}10^{-06}$	$2.37\text{x}10^{-06}$	$5.22\text{x}10^{-06}$
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	$1.87\text{x}10^{-04}$	$2.21\text{x}10^{-04}$	$5.49\text{x}10^{-04}$	$3.59\text{x}10^{-04}$	$1.21\text{x}10^{-04}$	$1.21\text{x}10^{-04}$	0.0012	$7.52\text{x}10^{-04}$	$6.05\text{x}10^{-04}$	0.0016
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-3 Radionuclides Released to Air from C-Reactor, K-Reactor, L-Reactor, Reactor Seepage Basin Release Attributable to C-, K-, and L-Reactors, D-Area, and CMX-TNX (Ci) (continued)

Radio-nuclide	1984	1985	1986	1987	1988	1989	1990	1991	1992
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	$1.25\text{x}10^{+04}$	$2.05\text{x}10^{+04}$	$3.01\text{x}10^{+04}$	$4.88\text{x}10^{+04}$	$1.17\text{x}10^{+04}$	0.0	0.0	0.0	251
^{14}C	33.0	30.0	10.3	16.0	7.5	0	0	0	0.14
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	$2.11\text{x}10^{-05}$	0.00	$3.05\text{x}10^{-05}$
^{3}H	$1.78\text{x}10^{+05}$	$2.23\text{x}10^{+05}$	$8.62\text{x}10^{+04}$	$4.55\text{x}10^{+04}$	$5.21\text{x}10^{+04}$	$4.10\text{x}10^{+04}$	$6.62\text{x}10^{+04}$	$6.33\text{x}10^{+04}$	$4.59\text{x}10^{+04}$
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	$6.96\text{x}10^{-04}$	$8.88\text{x}10^{-04}$	0.0023	0.0013	$6.88\text{x}10^{-04}$	0.00	0.00	$5.46\text{x}10^{-08}$	$7.46\text{x}10^{-07}$
^{131}I-O	$2.98\text{x}10^{-04}$	$3.81\text{x}10^{-04}$	$9.71\text{x}10^{-04}$	$5.67\text{x}10^{-04}$	$2.95\text{x}10^{-04}$	0.00	0.00	$2.34\text{x}10^{-08}$	$3.20\text{x}10^{-07}$
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	$6.00\text{x}10^{-06}$	$3.4\text{x}10^{-06}$	$6.15\text{x}10^{-06}$	$5.76\text{x}10^{-06}$	$7.81\text{x}10^{-06}$	$2.27\text{x}10^{-05}$	$2.41\text{x}10^{-05}$	$2.36\text{x}10^{-05}$	$5.32\text{x}10^{-07}$
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	$2.03\text{x}10^{-05}$	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	$3.05\text{x}10^{-04}$	$2.99\text{x}10^{-04}$	$5.61\text{x}10^{-04}$	$4.15\text{x}10^{-04}$	0.0017	$2.05\text{x}10^{-04}$	$3.58\text{x}10^{-04}$	$2.38\text{x}10^{-04}$	$1.92\text{x}10^{-04}$
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Radionuclides Released to Air from P-Reactor, R-Reactor, and Reactor Seepage Basin Release Attributable to P- and R-Reactors (Ci)

Radio-nuclide	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	$5.00\text{x}10^{+04}$	$6.00\text{x}10^{+04}$	$1.00\text{x}10^{+05}$	$1.20\text{x}10^{+05}$	$1.40\text{x}10^{+05}$	$1.80\text{x}10^{+05}$	$1.60\text{x}10^{+05}$	$1.80\text{x}10^{+05}$	$1.80\text{x}10^{+05}$	$1.80\text{x}10^{+05}$
^{14}C	0.00	21.0	21.0	21.0	21.0	34.0	34.0	34.0	34.0	34.0
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	0.00	2800	$1.47\text{x}10^{+04}$	$2.26\text{x}10^{+04}$	$3.77\text{x}10^{+04}$	$5.28\text{x}10^{+04}$	$9.25\text{x}10^{+04}$	$7.13\text{x}10^{+04}$	$1.36\text{x}10^{+05}$	$1.03\text{x}10^{+05}$
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.18	1.37	10.5	23.8	17.8	17.2	10.8	10.7	73.5	32.4
^{131}I-O	0.076	0.59	4.50	10.2	7.64	7.39	4.64	4.59	31.5	13.9
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	0.00	0.00	0.00	0.00	0.00	0.00	$5.10\text{x}10^{-04}$	0.0030	0.074	0.0058
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Radionuclides Released to Air from P-Reactor, R-Reactor, and Reactor Seepage Basin Release Attributable to P- and R-Reactors (Ci) (continued)

Radio-nuclide	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	$1.50\text{x}10^{+05}$	$6.00\text{x}10^{+04}$	$7.00\text{x}10^{+04}$	$8.00\text{x}10^{+04}$	$7.00\text{x}10^{+04}$	$4.00\text{x}10^{+04}$	$3.67\text{x}10^{+04}$	$5.90\text{x}10^{+04}$	$5.62\text{x}10^{+04}$	$6.96\text{x}10^{+04}$
^{14}C	22.0	16.0	16.0	16.0	14.0	17.0	17.0	17.0	17.0	17.0
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	$1.36\text{x}10^{+05}$	$6.95\text{x}10^{+04}$	$4.88\text{x}10^{+04}$	$4.64\text{x}10^{+04}$	$2.87\text{x}10^{+04}$	$3.31\text{x}10^{+04}$	$4.66\text{x}10^{+04}$	$4.64\text{x}10^{+04}$	$4.95\text{x}10^{+04}$	$6.72\text{x}10^{+04}$
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.18	0.033	0.0099	0.040	1.10	1.97	0.070	0.099	0.061	0.044
^{131}I-O	0.076	0.014	0.0043	0.017	0.47	0.84	0.030	0.042	0.026	0.019
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$1.59\text{x}10^{-06}$
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	0.0017	0.0025	$9.00\text{x}10^{-04}$	$1.30\text{x}10^{-05}$	0.0011	$3.75\text{x}10^{-04}$	$3.18\text{x}10^{-04}$	$6.00\text{x}10^{-05}$	$9.10\text{x}10^{-05}$	$1.32\text{x}10^{-04}$
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Radionuclides Released to Air from P-Reactor, R-Reactor, and Reactor Seepage Basin Release Attributable to P- and R-Reactors (Ci) (continued)

Radio-nuclide	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	$5.21\text{x}10^{+04}$	$2.30\text{x}10^{+04}$	$2.67\text{x}10^{+04}$	$1.84\text{x}10^{+04}$	$1.74\text{x}10^{+04}$	$1.65\text{x}10^{+04}$	$2.24\text{x}10^{+04}$	$1.97\text{x}10^{+04}$	$2.40\text{x}10^{+04}$	$2.46\text{x}10^{+04}$
^{14}C	15.7	12.5	13.0	12.0	11.3	11.0	13.0	14.0	16.0	17.7
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	$7.21\text{x}10^{+04}$	$6.85\text{x}10^{+04}$	$4.68\text{x}10^{+04}$	$4.00\text{x}10^{+04}$	$3.61\text{x}10^{+04}$	$4.71\text{x}10^{+04}$	$3.36\text{x}10^{+04}$	$2.74\text{x}10^{+04}$	$2.78\text{x}10^{+04}$	$3.25\text{x}10^{+04}$
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.0024	$4.84\text{x}10^{-04}$	$3.43\text{x}10^{-04}$	0.0016	$2.50\text{x}10^{-04}$	0.0086	0.0071	0.0053	0.018	0.0081
^{131}I-O	0.0010	$2.08\text{x}10^{-04}$	$1.47\text{x}10^{-04}$	$6.73\text{x}10^{-04}$	$1.07\text{x}10^{-04}$	0.0037	0.0031	0.0023	0.0079	0.0035
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	$1.16\text{x}10^{-06}$	$4.18\text{x}10^{-06}$	$4.36\text{x}10^{-06}$	$2.40\text{x}10^{-06}$	$8.30\text{x}10^{-07}$	$4.00\text{x}10^{-07}$	$3.50\text{x}10^{-07}$	$1.07\text{x}10^{-06}$	$4.50\text{x}10^{-07}$	$4.00\text{x}10^{-07}$
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	$5.80\text{x}10^{-05}$	$1.23\text{x}10^{-04}$	$1.39\text{x}10^{-04}$	$1.09\text{x}10^{-04}$	$2.70\text{x}10^{-05}$	$3.90\text{x}10^{-05}$	$1.70\text{x}10^{-04}$	$1.53\text{x}10^{-04}$	$2.60\text{x}10^{-05}$	$4.70\text{x}10^{-05}$
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Radionuclides Released to Air from P-Reactor, R-Reactor, and Reactor Seepage Basin Release Attributable to P- and R-Reactors (Ci) (continued)

Radio-nuclide	1984	1985	1986	1987	1988	1989	1990	1991	1992
^{241}Am	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{41}Ar	$2.35\text{x}10^{+04}$	$3.12\text{x}10^{+04}$	$5.31\text{x}10^{+04}$	$3.89\text{x}10^{+04}$	$1.78\text{x}10^{+04}$	0.00	0.00	0.00	0.00
^{14}C	16.0	15.0	10.3	8.00	3.52	0.00	0.00	0.00	0.046
^{137}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{3}H	$5.47\text{x}10^{+04}$	$4.18\text{x}10^{+04}$	$4.62\text{x}10^{+04}$	$5.44\text{x}10^{+04}$	$5.71\text{x}10^{+04}$	$8.93\text{x}10^{+04}$	$1.21\text{x}10^{+04}$	$1.16\text{x}10^{+04}$	438
^{3}H-EL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.019	0.014	0.0014	0.015	$3.39\text{x}10^{-04}$	0.00	0.00	$1.82\text{x}10^{-08}$	$2.49\text{x}10^{-07}$
^{131}I-O	0.0081	0.0059	$6.20\text{x}10^{-04}$	0.0064	$1.45\text{x}10^{-04}$	0.00	0.00	$7.80\text{x}10^{-09}$	$1.07\text{x}10^{-07}$
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	$6.30\text{x}10^{-07}$	$1.60\text{x}10^{-06}$	$2.84\text{x}10^{-06}$	$2.77\text{x}10^{-06}$	$1.94\text{x}10^{-06}$	$3.79\text{x}10^{-06}$	$7.95\text{x}10^{-06}$	$7.60\text{x}10^{-06}$	$1.69\text{x}10^{-09}$
^{106}Ru	0.00	0.00	0.00	0.00	0.00	0.00	$1.02\text{x}10^{-05}$	0.00	0.00
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{90}Sr	$7.40\text{x}10^{-05}$	$1.11\text{x}10^{-04}$	$3.82\text{x}10^{-04}$	$2.98\text{x}10^{-04}$	$2.59\text{x}10^{-04}$	$4.10\text{x}10^{-05}$	$1.17\text{x}10^{-04}$	$7.43\text{x}10^{-05}$	$5.93\text{x}10^{-05}$
^{234}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{235}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{236}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-5 Radionuclides Discharged into Savannah River From All SRS Surface Water Sources (pCi/ml)

Radio-nuclide	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
^{144}Ce	0.00	0.00	0.00	0.00	0.00	0.00	0.0079	0.0033	0.0024	0.0041
^{60}Co	9.63×10^{-06}	7.44×10^{-06}	3.70×10^{-06}	4.24×10^{-06}	1.06×10^{-05}	2.96×10^{-05}	5.12×10^{-04}	2.85×10^{-04}	8.78×10^{-04}	2.97×10^{-04}
^{134}Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{137}Cs	2.13×10^{-05}	4.96×10^{-05}	1.96×10^{-04}	1.56×10^{-04}	9.65×10^{-04}	4.13×10^{-04}	6.48×10^{-04}	0.0011	0.0020	0.0017
^{3}H	1.16	2.47	2.66	2.91	2.93	7.23	5.94	8.50	6.85	9.74
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-O	0.00	0.00	0.00	0.0084	0.00	0.00	0.0024	0.0030	0.0083	0.0047
^{95}Nb	0.00	0.00	0.00	0.00	0.00	0.00	0.0084	0.0021	0.0022	0.0035
^{32}P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{238}Pu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{239}Pu	3.18×10^{-07}	7.10×10^{-06}	3.89×10^{-05}	8.38×10^{-08}	5.07×10^{-06}	5.62×10^{-06}	4.55×10^{-06}	8.51×10^{-06}	1.29×10^{-05}	5.72×10^{-06}
^{106}Ru	7.22×10^{-06}	4.69×10^{-04}	1.45×10^{-04}	7.21×10^{-05}	1.59×10^{-04}	0.0013	0.011	0.0027	0.0085	0.0069
^{35}S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0069	0.048	0.016
^{89}Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00×10^{-04}	0.0024	0.0020
^{90}Sr	1.93×10^{-05}	3.74×10^{-05}	7.49×10^{-05}	2.08×10^{-04}	8.65×10^{-05}	2.16×10^{-04}	0.0020	5.78×10^{-04}	9.03×10^{-04}	0.0012
^{99}Tc	2.23×10^{-04}	6.20×10^{-04}	4.18×10^{-04}	1.91×10^{-04}	1.49×10^{-04}	2.06×10^{-04}	1.44×10^{-04}	1.54×10^{-04}	1.40×10^{-04}	1.48×10^{-04}
^{234}U	0.00	9.45×10^{-07}	9.45×10^{-06}	4.83×10^{-08}	6.49×10^{-07}	9.51×10^{-07}	3.31×10^{-07}	2.73×10^{-06}	1.53×10^{-06}	5.91×10^{-07}
^{235}U	0.00	1.14×10^{-07}	9.52×10^{-07}	2.35×10^{-09}	6.85×10^{-08}	9.84×10^{-08}	1.80×10^{-07}	1.72×10^{-07}	3.07×10^{-07}	4.66×10^{-07}
^{236}U	0.00	6.64×10^{-08}	6.64×10^{-07}	3.39×10^{-09}	4.57×10^{-08}	6.68×10^{-08}	2.33×10^{-08}	1.92×10^{-07}	1.07×10^{-07}	4.15×10^{-08}
^{238}U	0.00	7.40×10^{-06}	5.97×10^{-05}	1.10×10^{-07}	4.34×10^{-06}	6.21×10^{-06}	1.35×10^{-05}	9.26×10^{-06}	2.16×10^{-05}	3.53×10^{-05}
^{65}Zn	0.00	0.00	0.00	0.00	0.00	0.00	2.73×10^{-04}	9.05×10^{-04}	0.0022	0.0017
^{95}Zr	0.00	0.00	0.00	0.00	0.00	0.00	0.0038	9.79×10^{-04}	0.0010	0.0017

Table B-5 Radionuclides Discharged into Savannah River From All SRS Surface Water Sources (pCi/ml) (continued)

Radio-nuclide	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
^{144}Ce	0.0052	0.0030	0.0018	0.0015	0.0049	6.47×10^{-04}	9.99×10^{-04}	7.68×10^{-04}	4.57×10^{-04}	9.25×10^{-04}
^{60}Co	2.54×10^{-04}	4.84×10^{-04}	3.90×10^{-04}	1.47×10^{-04}	2.57×10^{-04}	5.76×10^{-05}	4.86×10^{-05}	6.48×10^{-04}	3.37×10^{-05}	1.26×10^{-05}
^{134}Cs	0.00	9.76×10^{-05}	4.33×10^{-05}	8.26×10^{-05}	0.00	0.00	0.00	2.68×10^{-05}	8.61×10^{-06}	3.82×10^{-06}
^{137}Cs	0.0028	0.0021	0.0027	0.0040	0.0024	0.0011	0.0014	1.77×10^{-04}	6.25×10^{-05}	3.44×10^{-05}
^{3}H	6.58	9.31	9.58	9.27	9.74	7.82	5.80	4.65	4.65	4.74
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-O	4.90×10^{-04}	3.91×10^{-04}	2.18×10^{-04}	0.0012	8.67×10^{-04}	4.98×10^{-04}	1.90×10^{-04}	1.59×10^{-04}	7.11×10^{-05}	8.44×10^{-06}
^{95}Nb	0.0053	0.0012	0.0023	0.0027	0.0013	4.94×10^{-04}	0.0017	6.33×10^{-04}	0.0014	0.0025
^{32}P	1.34×10^{-04}	0.0020	0.0091	9.97×10^{-04}	1.68×10^{-04}	2.61×10^{-05}	5.63×10^{-05}	1.17×10^{-04}	4.57×10^{-05}	2.70×10^{-05}
^{238}Pu	0.00	0.00	0.00	8.36×10^{-06}	1.76×10^{-05}	2.27×10^{-05}	1.74×10^{-05}	6.13×10^{-06}	3.08×10^{-06}	9.87×10^{-07}
^{239}Pu	4.54×10^{-06}	2.43×10^{-05}	3.48×10^{-05}	4.77×10^{-05}	2.27×10^{-05}	3.00×10^{-05}	4.75×10^{-05}	2.02×10^{-05}	2.29×10^{-06}	1.90×10^{-06}
^{106}Ru	0.011	0.0053	0.0072	0.0048	0.0070	0.0020	0.0039	0.0050	0.0054	0.0070
^{35}S	0.0051	0.0062	0.0087	0.014	0.033	0.014	0.0038	0.0015	1.88×10^{-04}	1.02×10^{-04}
^{89}Sr	0.0028	3.16×10^{-04}	4.93×10^{-04}	0.0010	0.0020	0.0020	0.0034	6.83×10^{-04}	4.23×10^{-04}	3.60×10^{-04}
^{90}Sr	7.01×10^{-04}	6.06×10^{-04}	0.0039	0.010	7.30×10^{-04}	4.30×10^{-04}	8.37×10^{-04}	5.82×10^{-04}	2.41×10^{-04}	2.66×10^{-04}
^{99}Tc	8.29×10^{-05}	1.07×10^{-04}	1.06×10^{-04}	1.31×10^{-04}	1.34×10^{-04}	1.46×10^{-04}	1.29×10^{-04}	1.53×10^{-04}	1.12×10^{-04}	8.02×10^{-05}
^{234}U	2.17×10^{-06}	2.45×10^{-06}	1.05×10^{-06}	7.75×10^{-07}	6.33×10^{-06}	1.62×10^{-06}	8.69×10^{-07}	3.10×10^{-07}	0.00	9.07×10^{-08}
^{235}U	6.49×10^{-07}	7.47×10^{-07}	3.21×10^{-06}	4.92×10^{-06}	2.15×10^{-06}	6.49×10^{-07}	8.43×10^{-07}	1.28×10^{-07}	5.38×10^{-08}	2.38×10^{-08}
^{236}U	1.52×10^{-07}	1.72×10^{-07}	7.35×10^{-08}	5.45×10^{-08}	1.71×10^{-07}	3.62×10^{-08}	6.11×10^{-08}	2.18×10^{-08}	0.00	6.37×10^{-09}
^{238}U	4.72×10^{-05}	5.43×10^{-05}	2.48×10^{-04}	3.82×10^{-04}	1.54×10^{-04}	4.68×10^{-05}	6.43×10^{-05}	9.47×10^{-06}	4.18×10^{-06}	1.71×10^{-06}
^{65}Zn	8.74×10^{-04}	3.61×10^{-04}	5.50×10^{-04}	5.65×10^{-04}	5.75×10^{-04}	7.51×10^{-05}	3.73×10^{-05}	2.26×10^{-04}	0.00	0.00
^{95}Zr	0.0025	5.73×10^{-04}	0.0011	0.0013	6.55×10^{-04}	2.32×10^{-04}	8.20×10^{-04}	5.97×10^{-04}	0.0011	0.0021

Table B-5 Radionuclides Discharged into Savannah River From All SRS Surface Water Sources (pCi/ml) (continued)

Radio-nuclide	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
^{144}Ce	0.0011	1.75×10^{-04}	1.15×10^{-04}	8.23×10^{-05}	7.15×10^{-05}	4.87×10^{-04}	1.15×10^{-04}	2.15×10^{-04}	5.93×10^{-05}	5.68×10^{-05}
^{60}Co	2.00×10^{-04}	5.00×10^{-05}	9.34×10^{-05}	7.85×10^{-05}	5.31×10^{-06}	1.00×10^{-05}	6.13×10^{-05}	1.21×10^{-05}	2.33×10^{-05}	3.37×10^{-05}
^{134}Cs	6.11×10^{-06}	2.26×10^{-06}	6.56×10^{-07}	1.01×10^{-06}	7.76×10^{-07}	1.61×10^{-06}	2.57×10^{-07}	5.39×10^{-07}	2.33×10^{-07}	1.81×10^{-07}
^{137}Cs	7.07×10^{-05}	2.63×10^{-05}	1.17×10^{-05}	2.36×10^{-05}	1.11×10^{-05}	8.75×10^{-06}	6.53×10^{-06}	1.96×10^{-05}	1.31×10^{-05}	7.02×10^{-06}
^{3}H	5.46	3.59	3.73	3.87	3.77	2.40	2.54	4.27	4.82	2.93
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	0.00	0.00	0.00	0.00	0.00	0.00	2.15×10^{-05}	3.25×10^{-05}	4.59×10^{-05}	2.17×10^{-05}
^{131}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-O	1.36×10^{-06}	0.00	1.02×10^{-07}	1.05×10^{-06}	7.27×10^{-08}	0.00	0.00	0.00	0.00	0.00
^{95}Nb	0.0020	1.07×10^{-04}	6.92×10^{-04}	2.42×10^{-04}	4.82×10^{-05}	2.74×10^{-05}	5.33×10^{-04}	3.07×10^{-04}	3.60×10^{-04}	4.82×10^{-04}
^{32}P	1.46×10^{-05}	1.16×10^{-06}	5.17×10^{-06}	4.45×10^{-06}	1.18×10^{-07}	1.18×10^{-07}	5.15×10^{-07}	2.78×10^{-07}	6.05×10^{-07}	2.35×10^{-06}
^{238}Pu	8.50×10^{-07}	5.21×10^{-07}	1.15×10^{-07}	2.36×10^{-07}	6.85×10^{-08}	4.90×10^{-08}	4.69×10^{-08}	4.10×10^{-07}	1.27×10^{-07}	7.58×10^{-08}
^{239}Pu	1.02×10^{-06}	1.86×10^{-07}	3.13×10^{-08}	8.26×10^{-08}	2.49×10^{-08}	3.57×10^{-08}	8.33×10^{-08}	4.51×10^{-07}	1.91×10^{-07}	4.23×10^{-08}
^{106}Ru	0.010	7.62×10^{-04}	0.0030	0.0014	6.48×10^{-04}	3.43×10^{-04}	0.0058	0.0018	7.85×10^{-04}	4.62×10^{-04}
^{35}S	5.54×10^{-04}	2.38×10^{-05}	3.33×10^{-05}	5.66×10^{-05}	2.84×10^{-06}	5.78×10^{-05}	7.81×10^{-07}	8.02×10^{-06}	2.71×10^{-05}	7.38×10^{-06}
^{89}Sr	1.83×10^{-04}	4.80×10^{-05}	3.91×10^{-05}	4.53×10^{-05}	1.12×10^{-05}	1.63×10^{-06}	1.24×10^{-05}	9.07×10^{-06}	5.96×10^{-06}	1.30×10^{-05}
^{90}Sr	2.37×10^{-04}	1.29×10^{-04}	1.54×10^{-04}	1.14×10^{-04}	8.39×10^{-05}	7.31×10^{-05}	2.00×10^{-04}	1.19×10^{-04}	8.61×10^{-05}	6.41×10^{-05}
^{99}Tc	1.43×10^{-04}	1.03×10^{-04}	7.50×10^{-05}	1.24×10^{-04}	1.48×10^{-04}	7.82×10^{-05}	1.06×10^{-04}	1.59×10^{-04}	2.25×10^{-04}	1.06×10^{-04}
^{234}U	4.68×10^{-08}	5.52×10^{-09}	1.70×10^{-08}	1.54×10^{-08}	9.41×10^{-09}	1.19×10^{-08}	3.52×10^{-08}	9.06×10^{-08}	3.95×10^{-08}	7.06×10^{-09}
^{235}U	5.08×10^{-08}	2.49×10^{-08}	1.05×10^{-08}	9.29×10^{-09}	3.29×10^{-09}	4.34×10^{-09}	2.20×10^{-08}	8.03×10^{-08}	2.37×10^{-08}	1.30×10^{-08}
^{236}U	3.29×10^{-09}	3.87×10^{-10}	1.19×10^{-09}	1.08×10^{-09}	6.59×10^{-10}	8.37×10^{-10}	2.48×10^{-09}	6.21×10^{-09}	2.71×10^{-09}	4.97×10^{-10}
^{238}U	3.87×10^{-06}	1.92×10^{-06}	7.91×10^{-07}	6.99×10^{-07}	2.41×10^{-07}	3.19×10^{-07}	1.66×10^{-06}	6.10×10^{-06}	1.78×10^{-06}	1.00×10^{-06}
^{65}Zn	3.64×10^{-04}	6.60×10^{-05}	8.70×10^{-05}	8.31×10^{-05}	1.72×10^{-06}	1.57×10^{-06}	3.86×10^{-05}	5.58×10^{-06}	8.11×10^{-06}	1.40×10^{-05}
^{95}Zr	0.0018	1.15×10^{-04}	0.0011	3.55×10^{-04}	6.69×10^{-05}	4.68×10^{-05}	8.54×10^{-04}	4.23×10^{-04}	5.58×10^{-04}	5.57×10^{-04}

Table B-5 Radionuclides Discharged into Savannah River From All SRS Surface Water Sources (pCi/ml) (continued)

Radio-nuclide	1984	1985	1986	1987	1988	1989	1990	1991	1992
^{144}Ce	$3.71x10^{-05}$	$5.84x10^{-05}$	$1.92x10^{-04}$	$1.31x10^{-04}$	$1.01x10^{-04}$	$1.36x10^{-07}$	0.00	0.00	0.00
^{60}Co	$1.05x10^{-04}$	$6.04x10^{-05}$	$6.07x10^{-05}$	$1.17x10^{-05}$	$1.01x10^{-06}$	0.00	0.00	0.00	$5.04x10^{-09}$
^{134}Cs	$2.98x10^{-07}$	$8.73x10^{-08}$	$1.13x10^{-07}$	$1.97x10^{-07}$	$7.60x10^{-07}$	$2.47x10^{-08}$	0.00	0.00	$1.68x10^{-09}$
^{137}Cs	$1.07x10^{-05}$	$8.03x10^{-06}$	$9.99x10^{-06}$	$2.47x10^{-05}$	$6.08x10^{-05}$	$2.56x10^{-05}$	$4.05x10^{-06}$	$2.46x10^{-06}$	$7.96x10^{-06}$
^{3}H	2.83	3.45	4.01	2.55	3.78	2.47	1.45	2.54	1.22
^{129}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{129}I-O	$2.37x10^{-05}$	$3.04x10^{-05}$	$2.66x10^{-05}$	$2.79x10^{-05}$	$7.88x10^{-05}$	$1.87x10^{-04}$	$1.21x10^{-05}$	0.00	$1.34x10^{-05}$
^{131}I-E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{131}I-O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
^{95}Nb	0.0019	0.0018	$4.46x10^{-04}$	$1.49x10^{-04}$	$3.04x10^{-05}$	$3.59x10^{-09}$	0.00	0.00	0.00
^{32}P	$1.19x10^{-06}$	$1.27x10^{-07}$	$3.93x10^{-08}$	$1.01x10^{-08}$	$1.22x10^{-08}$	$4.42x10^{-07}$	$3.13x10^{-07}$	0.00	0.00
^{238}Pu	$4.20x10^{-08}$	$3.35x10^{-08}$	$2.21x10^{-08}$	$2.03x10^{-08}$	$5.37x10^{-08}$	0.00	0.00	0.00	$9.82x10^{-10}$
^{239}Pu	$9.37x10^{-08}$	$4.50x10^{-08}$	$1.10x10^{-06}$	$1.63x10^{-07}$	$4.07x10^{-07}$	$1.74x10^{-06}$	$1.92x10^{-06}$	$1.88x10^{-06}$	$1.26x10-^{06}$
^{106}Ru	$6.57x10^{-04}$	0.0018	0.0039	$7.82x10^{-04}$	$2.28x10^{-04}$	$9.84x10^{-06}$	0.00	0.00	0.00
^{35}S	$1.16x10^{-06}$	$4.38x10^{-06}$	$2.40x10^{-06}$	$2.14x10^{-06}$	$6.40x10^{-07}$	$1.33x10^{-07}$	$2.60x10^{-05}$	0.00	$1.99x10^{-08}$
^{89}Sr	$6.48x10^{-06}$	$2.85x10^{-06}$	$4.93x10^{-06}$	$7.15x10^{-06}$	$3.44x10^{-05}$	0.00	0.00	0.00	0.00
^{90}Sr	$2.66x10^{-04}$	$1.90x10^{-04}$	$1.83x10^{-04}$	$2.38x10^{-04}$	$1.04x10^{-04}$	$2.06x10^{-04}$	$5.11x10^{-05}$	$1.09x10^{-05}$	$8.32x10^{-05}$
^{99}Tc	$1.16x10^{-04}$	$1.49x10^{-04}$	$1.31x10^{-04}$	$1.37x10^{-04}$	$3.87x10^{-04}$	$9.17x10^{-04}$	$8.13x10^{-04}$	$3.53x10^{-04}$	$9.00x10^{-04}$
^{234}U	$4.83x10^{-09}$	$3.55x10^{-09}$	$1.69x10^{-09}$	$2.12x10^{-08}$	$1.45x10^{-09}$	0.00	0.00	0.00	$6.15x10^{-11}$
^{235}U	$4.06x10^{-09}$	$2.80x10^{-09}$	$1.35x10^{-08}$	$1.29x10^{-09}$	$3.34x10^{-09}$	$6.60x10^{-10}$	$1.50x10^{-09}$	$3.84x10^{-09}$	$1.89x10^{-09}$
^{236}U	$3.39x10^{-10}$	$2.50x10^{-10}$	$1.19x10^{-10}$	$1.49x10^{-09}$	$9.59x10^{-11}$	0.00	0.00	0.00	$4.32x10^{-12}$
^{238}U	$3.08x10^{-07}$	$2.12x10^{-07}$	$1.04x10^{-06}$	$6.83x10^{-08}$	$2.57x10^{-07}$	$5.13x10^{-08}$	$1.17x10^{-07}$	$2.99x10^{-07}$	$1.46x10^{-07}$
^{65}Zn	$3.94x10^{-06}$	$6.22x10^{-07}$	$2.40x10^{-05}$	$1.66x10^{-05}$	$5.87x10^{-06}$	0.00	0.00	0.00	0.00
^{95}Zr	0.0028	0.0021	$3.93x10^{-04}$	$1.07x10^{-04}$	$2.32x10^{-05}$	$3.18x10^{-08}$	0.00	0.00	0.00

Table B-6 Annual Radionuclide Concentrations for Exposure Pathways Involving Lower Three Runs Creek (pCi/ml)

	1954	**1955**	**1956**	**1957**	**1958**	**1959**	**1960**	**1961**	**1962**	**1963**
^{137}Cs	0.0028	0.0057	0.0070	0.042	0.073	0.018	0.010	0.0075	0.011	0.036
^{3}H	4.35	4.79	4.48	6.26	6.60	22.5	26.5	20.5	35.5	55.5
^{90}Sr	0.0023	0.0047	0.0057	0.035	0.059	0.014	0.0075	0.0065	0.010	0.015
	1964	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**
^{137}Cs	0.041	0.017	0.013	0.012	0.0095	0.0060	0.0065	0.0070	0.0040	0.0025
^{3}H	85.5	23.0	14.5	14.0	5.75	1.50	2.00	8.50	5.50	8.00
^{90}Sr	0.019	0.0080	0.0045	0.0040	0.0040	0.0040	0.0040	0.0045	0.0015	0.0040
	1974	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**
^{137}Cs	0.0045	0.0087	0.0028	0.0039	0.0051	0.0055	0.0012	0.0013	0.0010	0.0016
^{3}H	7.77	12.6	5.00	6.00	5.80	5.90	4.00	3.10	3.60	3.50
^{90}Sr	0.0023	0.0017	0.0016	2.10×10^{-04}	1.20×10^{-04}	1.10×10^{-04}	0.0011	8.80×10^{-04}	1.90×10^{-04}	4.40×10^{-04}
	1984	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	
^{137}Cs	9.30×10^{-04}	0.0014	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	
^{3}H	3.70	3.30	3.70	2.60	2.70	2.10	1.08	1.20	0.86	
^{90}Sr	2.10×10^{-04}	6.00×10^{-05}	4.00×10^{-04}	2.20×10^{-04}	5.90×10^{-04}	4.70×10^{-04}	5.20×10^{-04}	4.06×10^{-04}	1.86×10^{-04}	

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APPENDIX C SUPPLEMENTAL INFORMATION FOR CREATION OF RADIONUCLIDE SOURCE TERMS

This appendix presents supplemental and background information pertaining to preparation of a source term for Phase III of the Savannah River Site (SRS) dose reconstruction project. This appendix is composed of five sections:

- **Section C.1:** Summary of Phase II Screening Analysis.
- **Section C.2:** Phase III Assumptions for Partitioning Mixed Isotopic Activity.
- **Section C.3:** Phase III Adjustment Factors for Surface Water Transport.
- **Section C.4:** Comparison of Phase II and Phase III Source Terms for Air Release.
- **Section C.5:** Comparison of Phase II and Phase III Source Terms for Water Release.

Appendix B lists the source term used for Phase III. This appendix contains tables of the annual quantities of radionuclides that were released into air and surface water during the 39 years of production of nuclear materials at the SRS (i.e., 1954 through 1992).

Annual quantities of 16 radionuclides released into the air are provided in terms of 4 virtual sources. Appendix A discusses the derivation of these four virtual sources. The four virtual sources consist of releases to air from the following groups of SRS facilities:

1. A-Area, M-Area, Savannah River Laboratory (SRL).
2. F-Canyon, H-Canyon, H-Tritium Stack, F&H Seepage Basins.
3. C-Reactor; K-Reactor; L-Reactor; Reactor Seepage Basin release attributable to C-, K-, and L-Reactors; D-Area; CMX-TNX.
4. P-Reactor, R-Reactor, Reactor Seepage Basin release attributable to P- and R-Reactors.

Two additional tables in Appendix B list the radionuclides released into surface water. One table lists the annual concentrations (units of picocuries per milliliter, or pCi/mL) of 22 radionuclides discharged into the Savannah River from all SRS surface-water sources. The second table lists annual concentrations (pCi/mL) of three radionuclides discharged into the Lower Three Runs Creek.

The Phase III derivation of the source term is addressed in Chapter 5 for release of radionuclides to air, and in Chapter 7 for release of radionuclides to surface water.

C.1 Summary of Phase II Screening Analysis

This appendix section summarizes the screening analysis that was performed for Phase II of the SRS Dose Reconstruction Project. A master list of radionuclides that had been released into the air and surface water was identified from SRS records, interviews, and workshops. In addition, estimates were made of the average annual radionuclide release rates. However, the master list of radionuclides was too large for efficient analysis, and a screening assessment was performed to identify smaller lists of key radionuclides that were the dominant contributors to radiation dose and cancer risk. This screening assessment was performed using a two-step method recommended by the National Council on Radiation Protection and Measurements (NCRP) (1,2). This two-step method featured, for both air and water, 1) a screening considering the summation of six exposure pathways, and 2) a screening considering each of the exposure pathways plus the sum total of all six pathways (1,2,3).

C.1.1 Screening Calculations

To apply both steps of the NCRP method, it was first necessary to determine the concentration of the radionuclide of interest in the transporting medium (air or water). The concentration in air was estimated by a simple dilution equation (3):

$$C_a = f\ Q/V \qquad \text{(Eqn. C1-1)}$$

Where:

C_a = The atmospheric concentration of the radionuclide (becquerels per cubic meter [Bq/m^3]).
Q = The release rate from the facility (becquerels per second [Bq/s]).
V = The volumetric flow rate of the exhaust vent (cubic meters per second [m^3/s]).
f = The fraction of time the wind blows toward the receptor (dimensionless).

The release rate, Q, for each radionuclide was based in Phase II on estimates of the quantity released during a one-year period. An average annual release was used that was calculated from compilations of SRS references. Conservative assumptions were made concerning the flow rate from the exhaust vent (0.3 cubic meter per second) and the fraction of time the wind blew toward a receptor (25 percent) (3). In effect, it was assumed for Phase II that all radionuclides were released into the air from a single SRS stack.

The concentration in surface water was estimated as (3):

$$C_w = W_O / Q_O \qquad \text{(Eqn. C1-2)}$$

Where:

C_w = The radionuclide concentration in the receiving surface water (Bq/m^3).
Q_O = The flow rate of an effluent discharge at the point of release (m^3/s).
W_O = The radionuclide release rate at the point of release (Bq/s).

The volume of contaminated water released to all site streams was assumed to be 7.7x10^{+09} m^3 per year, based on site reports (3).

After the concentration of each radionuclide (i) in air or water ($C_{a\ or\ w}$) was determined, the screening value (SV_i) for each radionuclide was determined as (3):

$$SV_i = C_{i(a\ or\ w)}\ SF_{i(a\ or\ w)} \qquad \text{(Eqn. C1-3)}$$

Where:

SV_i = The screening value for radionuclide (i) (sievert [Sv] or millirem [mrem]).
$C_{i(a\ or\ w)}$ = The concentration of radionuclide (i) in air or water (Bq/m^3).
$SF_{i(a\ or\ w)}$ = The screening factor for radionuclide (i) in air or water (Sv per Bq/m^3).

The screening factors were those provided in Tables B-1 and C-1 of NCRP Report No. 123 (2) for air and surface water. For Step One of the screening assessment, the screening factor was a term representing the sum of the effective doses received from a set of exposure pathways associated with radionuclides released to air or to surface water. The following six exposure pathways were for release to air (3):

- Inhalation of contamination in air.
- Inhalation of contamination resuspended from soil.
- Immersion in a plume of air.
- Eating produce after deposition of radionuclides on the ground (including plant surfaces).
- Eating meat after deposition of the radionuclides on the ground (including plant surfaces).
- Drinking milk from local cows after deposition of radionuclides on the ground (including plant surfaces.)

The following six exposure pathways were for release to surface water (3):

- Drinking from the surface water.
- Eating fish caught in the surface water.
- Drinking milk produced on land that had been irrigated with the surface water.
- Eating produce produced on land that had been irrigated with the surface water.
- Eating meat produced on land that had been irrigated with the surface water.
- External exposure to radionuclides deposited from the surface water to the ground (e.g., as from irrigation).

Table C-1 lists some of the Phase II assumptions that were used in these exposure pathway assessments (3).

Table C-1 Selected Assumptions Used in Screening Assessments

Exposure Pathway	Selected Parameters	Assumed Value
Inhalation	Breathing rate	8,000 m^3/y
	Resuspension factor	$2x10^{-8}$ m^{-1}
External exposure	Annual exposure to contaminated ground surface	8,000 h/y
Ingestion	Vegetables, fruit, and grain consumption	100 kg/y
	Water consumption	800 L/y
	Fish consumption	20 kg/y
	Milk consumption	300 L/y
	Soil ingestion	0.25 g/d

Source: Phase II (3).

For Step Two of the screening assessment, two sets of screening factors were considered for air and for water. Each set represented the effective dose received from each of the six exposure pathways as well as the sum of the effective dose from all six of the exposure pathways (3).

The product of the average concentration of each radionuclide with the screening factor for that radionuclide was a term called the *screening value* (units of Sv). In Step One, a single screening value for release to air and a single screening value for release to water were calculated for each radionuclide. In Step Two, seven screening values were calculated for air and seven screening values were calculated for water for each radionuclide representing each of the applicable exposure pathways plus their respective summations. Both screening steps included the following significant simplifications:

- Releases were averaged over 36 years (from 1954 to 1989).
- Concentrations at the point of release were used rather than concentrations plausibly at the locations of individuals.
- Standard human behavior patterns (e.g., consumption rates of foods) were assumed.
- Adult rather than age-dependent dose conversion factors were used (3).

For these and other reasons, the screening values thus calculated were not plausible representations of doses to actual humans. Rather, the screening values were highly conservative estimates meant only to identify those radionuclides that should be considered in further analyses.[1]

C.1.2 Screening Results for Step One of the Phase II Screening Analysis

After the calculations described in Section C.1.1 were performed, total screening values were determined for air and water. The total screening values are the sums of the screening values determined for each radionuclide. Each radionuclide was ranked in importance for air and surface-water pathways by dividing the screening value determined for each radionuclide by the total screening value (for air or for water) and multiplying by 100 (percent). Those radionuclides that contributed more than 0.1 percent of the total screening values for air or for water were identified as key radionuclides for further analysis. Table C-2 and C-3 document the results of Step One of the Phase II screening analysis for release to air and water, respectively (3).[2]

Table C-2 Results from Step One of Phase II Screening Assessment for Air

Radionuclide	Estimated Annual Air Release (Bq/y)	Concentration at Point of Release (Bq/m^3)†	All Pathways Screening Factor (Sv/y)	Screening Value (Sv/y)	Percent of Total Screening Value (%)
^{241}Am	$2.07x10^{+08}$	$2.19x10^{+01}$	1.00	5.48	0.15
^{41}Ar	$6.58x10^{+15}$	$6.95x10^{+08}$	$1.50x10^{-06}$	$2.61x10^{+02}$	7.12
^{82}Br	$4.11x10^{+07}$	4.35	$2.30x10^{-04}$	$2.50x10^{-04}$	<0.01
^{14}C	$3.08x10^{+12}$	$3.26x10^{+05}$	$2.60x10^{-04}$	$2.12x10^{+01}$	0.58
$^{141,144}Ce^{*}$	$4.34x10^{+09}$	$4.58x10^{+02}$	$5.20x10^{-03}$	$5.96x10^{-01}$	0.02
^{134}Cs	$4.73x10^{+07}$	5.00	$1.30x10^{-01}$	$1.60x10^{-01}$	<0.01
^{137}Cs	$3.60x10^{+09}$	$3.80x10^{+02}$	$2.20x10^{-01}$	$2.09x10^{+01}$	0.57
^{60}Co	$9.25x10^{+07}$	9.78	$1.70x10^{-01}$	$4.10x10^{-01}$	0.01

[1]The report describing the NCRP screening method notes: "The assumptions and methods incorporated into all of the screening procedures presented in this Report are such that actual doses should not be underestimated by more than one order of magnitude. In most situations, the actual dose will be significantly less than the values calculated for screening" (1).

[2] The results in these tables were obtained from an Excel spreadsheet (Rad-Screening.xls) that is linked to the electronic version of the Phase II report. For both air and water, the results of Step One of the screening assessment as presented in this Excel spreadsheet are somewhat different from those results presented in Tables 3A-2a and 3A-3a of Chapter 3 of the Phase II report (3).

Radionuclide	Estimated Annual Air Release (Bq/y)	Concentration at Point of Release (Bq/m^3)†	All Pathways Screening Factor (Sv/y)	Screening Value (Sv/y)	Percent of Total Screening Value (%)
^{242}Cm	$2.36x10^{+06}$	$2.50x10^{-01}$	$4.00x10^{-02}$	$2.46x10^{-03}$	<0.01
^{244}Cm	$9.20x10^{+07}$	9.72	$5.40x10^{-01}$	1.29	0.04
^{154}Eu	$2.41x10^{+07}$	2.54	$4.20x10^{-07}$	$2.63x10^{-07}$	<0.01
^{155}Eu	$6.03x10^{+06}$	$6.37x10^{-01}$	$1.70x10^{-08}$	$2.67x10^{-09}$	<0.01
^{3}H	$2.52x10^{+16}$	$2.66x10^{+09}$	$1.90x10^{-06}$	$1.25x10^{+03}$	34.05
^{129}I	$5.86x10^{+09}$	$6.19x10^{+02}$	$5.60x10^{-01}$	$8.54x10^{+01}$	2.33
^{131}I	$2.57x10^{+12}$	$2.68x10^{+05}$	$2.80x10^{-02}$	$1.87x10^{+03}$	51.20
^{133}I	$3.70x10^{+08}$	$3.85x10^{+01}$	$2.20x10^{-04}$	$2.12x10^{-03}$	<0.01
^{135}I	$4.81x10^{+09}$	$5.01x10^{+02}$	$2.50x10^{-05}$	$3.13x10^{-03}$	<0.01
^{85}Kr	$1.54x10^{+16}$	$1.63x10^{+09}$	$2.80x10^{-09}$	1.14	0.03
^{85m}Kr	$1.54x10^{+14}$	$1.63x10^{+07}$	$2.00x10^{-07}$	$8.15x10^{-01}$	0.02
^{87}Kr	$2.57x10^{+13}$	$2.72x10^{+06}$	$1.00x10^{-06}$	$6.79x10^{-01}$	0.02
^{88}Kr	$1.03x10^{+13}$	$1.09x10^{+06}$	$5.40x10^{-06}$	1.47	0.04
^{99}Mo	$2.36x10^{+10}$	$2.46x10^{+03}$	$2.30x10^{-04}$	$1.42x10^{-01}$	<0.01
^{95}Nb	$1.13x10^{+09}$	$1.18x10^{+02}$	$1.20x10^{-03}$	$3.53x10^{-02}$	<0.01
^{185}Os	$1.85x10^{+06}$	$1.93x10^{-01}$	$2.80x10^{-03}$	$1.35x10^{-04}$	<0.01
$^{239,240}Pu^{*}$	$3.60x10^{+09}$	$3.80x10^{+02}$	1.00	$9.51x10^{+01}$	2.60
^{238}Pu	$1.03x10^{+09}$	$1.09x10^{+02}$	$8.90x10^{-01}$	$2.42x10^{+01}$	0.66
$^{103,106}Ru^{*}$	$1.75x10^{+09}$	$1.85x10^{+02}$	$9.60x10^{-03}$	$4.43x10^{-01}$	0.01
^{125}Sb	$2.14x10^{+07}$	2.23	$1.00x10^{-08}$	$5.57x10^{-09}$	<0.01
^{75}Se	$1.95x10^{+05}$	$2.03x10^{-02}$	$1.40x10^{-02}$	$7.12x10^{-05}$	<0.01
$^{89,90}Sr$	$1.58x10^{+09}$	$1.67x10^{+02}$	$1.90x10^{-01}$	7.95	0.22
^{99}Tc	$1.04x10^{+11}$	$1.10x10^{+04}$	$1.30x10^{-11}$	$3.56x10^{-08}$	<0.01
$^{235,238}U^{*}$	$1.03x10^{+09}$	$1.09x10^{+02}$	$3.40x10^{-01}$	9.23	0.25
^{131m}Xe	$1.13x10^{+13}$	$1.19x10^{+06}$	$1.10x10^{-08}$	$3.29x10^{-03}$	<0.01
^{133}Xe	$5.14x10^{+14}$	$5.43x10^{+07}$	$4.30x10^{-08}$	$5.84x10^{-01}$	0.02
^{135}Xe	$2.06x10^{+14}$	$2.17x10^{+07}$	$3.00x10^{-07}$	1.63	0.04
^{95}Zr, $^{95}Nb^{*}$	$3.25x10^{+09}$	$3.43x10^{+02}$	$4.10x10^{-03}$	$3.52x10^{-01}$	0.01
Total annual screening value from radionuclides released to air:				$3.66x10^{+03}$	100

*$^{141,144}Ce$ screened as ^{144}Ce; $^{239,240}Pu$ screened as ^{239}Pu; $^{103,106}Ru$ screened as ^{106}Ru; $^{235,238}U$ screened as ^{235}U; ^{95}Zr, ^{95}Nb screened as ^{95}Zr.
†Before multiplication by the 0.25 wind direction frequency factor.
Source: Phase II (3).

Table C-3 Results from Step One of Phase II Screening Assessment for Surface Water

Radionuclide	Estimated Annual Surface Water Release (Bq)	Estimated Concentration at Point of Release (Bq/m^3)	Screening Factor for Surface Water Pathway (Sv per Bq/m^3)	Estimated Screening Value (Sv/y)	Percent of Total Screening Value
^{241}Am	$1.03x10^{+07}$	$1.33x10^{-03}$	$2.00x10^{-06}$	$2.67x10^{-09}$	$7.0x10^{-04}$
^{140}Ba, ^{140}La*	$2.26x10^{+11}$	$2.94x10^{+01}$	$9.50x10^{-09}$	$2.79x10^{-07}$	0.07
$^{141,144}Ce$*	$7.19x10^{+11}$	$9.34x10^{+01}$	$3.70x10^{-08}$	$3.46x10^{-06}$	0.91
^{244}Cm	$8.22x10^{+08}$	$1.07x10^{-01}$	$9.00x10^{-07}$	$9.61x10^{-08}$	0.03
^{134}Cs	$1.39x10^{+10}$	1.80	$1.10x10^{-06}$	$1.98x10^{-06}$	0.52
^{137}Cs	$2.00x10^{+12}$	$2.60x10^{+02}$	$1.10x10^{-06}$	$2.86x10^{-04}$	75.23
^{58}Co	$2.81x10^{+09}$	$3.64x10^{-01}$	$1.80x10^{-08}$	$6.56x10^{-09}$	$1.7x10^{-03}$
^{60}Co	$8.63x10^{+10}$	$1.12x10^{+01}$	$6.10x10^{-07}$	$6.84x10^{-06}$	1.80
^{51}Cr	$5.14x10^{+12}$	$6.67x10^{+02}$	$3.70x10^{-10}$	$2.47x10^{-07}$	0.06
^{3}H	$1.54x10^{+15}$	$2.00x10^{+05}$	$1.40x10^{-11}$	$2.80x10^{-06}$	0.74
^{131}I	$3.11x10^{+11}$	$4.04x10^{+01}$	$8.60x10^{-08}$	$3.48x10^{-06}$	0.91
^{129}I	$1.23x10^{+09}$	$1.60x10^{-01}$	$1.40x10^{-06}$	$2.24x10^{-07}$	0.06
^{239}NP	$1.48x10^{+12}$	$1.92x10^{+02}$	$1.20x10^{-09}$	$2.31x10^{-07}$	0.06
^{32}P	$2.01x10^{+11}$	$2.62x10^{+01}$	$8.20x10^{-07}$	$2.15x10^{-05}$	5.64
$^{239,240}Pu$*	$8.22x10^{+09}$	1.07	$1.70x10^{-06}$	$1.82x10^{-06}$	0.48
^{238}Pu	$4.11x10^{+09}$	$5.34x10^{-01}$	$1.50x10^{-06}$	$8.01x10^{-07}$	0.21
$^{103,106}Ru$ *	$1.85x10^{+12}$	$2.40x10^{+02}$	$2.20x10^{-08}$	$5.29x10^{-06}$	1.39
$^{124,125}Sb$*	$2.47x10^{+10}$	3.20	$1.20x10^{-08}$	$3.84x10^{-08}$	0.01
$^{89,90}Sr$ *	$6.37x10^{+11}$	$8.28x10^{+01}$	$4.30x10^{-07}$	$3.56x10^{-05}$	9.35
^{35}S	$1.80x10^{+12}$	$2.34x10^{+02}$	$1.10x10^{-08}$	$2.57x10^{-06}$	0.68
^{99}Tc	$5.45x10^{+10}$	7.07	$6.90x10^{-08}$	$4.88x10^{-07}$	0.13
^{232}Th	$2.06x10^{+08}$	$2.67x10^{-02}$	$8.90x10^{-06}$	$2.38x10^{-07}$	0.06
U*	$4.32x10^{+10}$	5.61	$3.90x10^{-07}$	$2.19x10^{-06}$	0.57
^{91}Y	$1.23x10^{+11}$	$1.60x10^{+01}$	$8.20x10^{-09}$	$1.31x10^{-07}$	0.03
^{65}Zn	$1.54x10^{+11}$	$2.00x10^{+01}$	$1.30x10^{-07}$	$2.60x10^{-06}$	0.68
^{95}Zr, ^{95}Nb *	$1.49x10^{+11}$	$1.94x10^{+01}$	$7.40x10^{-08}$	$1.43x10^{-06}$	0.38
Total screening value from radionuclides released to surface water				$3.81x10^{-04}$	100

*^{140}Ba and ^{140}La were screened as ^{140}Ba; $^{141,144}Ce$ as ^{144}Ce; $^{239,240}Pu$ as ^{239}Pu; $^{103,106}Ru$ as ^{106}Ru; $^{124,125}Sb$ as ^{125}Sb; $^{89,90}Sr$ as ^{90}Sr; uranium as ^{235}U and ^{238}U; and ^{95}Zr, ^{95}Nb as ^{95}Zr.
Source: Phase II Rad-Screening.xls Excel spreadsheet (3).

From Table C-2, ^{131}I and ^{3}H contributed about 51 and 34 percent, respectively, of the total screening value; ^{41}Ar contributed about 7 percent; and ^{129}I and ^{239,240}Pu each contributed between 2 and 3 percent of the total screening value. From Table C-3, ^{137}Cs and ^{90}Sr contributed about 75 and 9 percent of the total screening value, respectively.

Through this process, the Phase II study identified the following key radionuclides for release to air pathways: ^{241}Am, ^{41}Ar, ^{14}C, ^{137}Cs, ^{3}H, ^{129}I, ^{131}I, ^{238}Pu, ^{239,240}Pu, ^{103,106}Ru, ^{89,90}Sr and U (3). The key radionuclides for release to water pathways were ^{137}Cs, ^{60}Co, ^{3}H, ^{129}I, ^{131}I, ^{32}P, ^{238}Pu, ^{239,240}Pu, ^{89}Sr, ^{90}Sr, ^{35}S, ^{99}Tc, U, ^{91}Y, ^{65}Zn, and ^{95}Zr, ^{95}Nb (3).

C.1.3 Screening Results for Step Two of the Phase II Screening Analysis

In Step Two of the Phase II screening assessment, a smaller list of radionuclides was identified for release to air and water by a process, summarized in Table C-4 and Table C-5 (from Phase II), that determined the relative importance of the above key radionuclides by exposure pathway. The percent contribution of each radionuclide to the total screening value for each exposure pathway was the basis for ranking the radionuclides. The radionuclides that ranked among the top three for at least two of the seven exposure pathways were selected for detailed source term development in the Phase II study. These radionuclides are shown in **bold** in Tables C-4 and C-5.

Table C-4 Results of Phase II Screening Analysis for Air Release Screening Pathways*

Radionuclide†	All Path-ways	Inha-lation	Ingestion			Ground Contami-nation	Plume Immer-sion	No. of Path-ways‡
			Milk	Produce	Meat			
^{241}Am								0
^{41}Ar	**X**						**X**	**2**
^{14}C								0
^{137}Cs						X		1
^{3}H	**X**	**X**	**X**	**X**	**X**			**5**
^{129}I	**X**		**X**		**X**			**3**
^{131}I	**X**	**X**	**X**	**X**	**X**	**X**		**6**
^{239,240}Pu	**X**	**X**		**X**				**3**
^{238}Pu		X						1
^{103,106}Ru						X		1
^{89,90}Sr								0
U						**X**		**1§**

*Results of Step Two in the Phase II screening analysis. The radionuclides that ranked among the top three for at least two of the seven exposure pathways were selected for detailed source term development.
†The radionuclides identified in the Step One of the Phase II screening analysis that contributed greater than 0.1 percent of the screening value for all exposure pathways.
‡Number of times that a particular radionuclide ranked high in at least two air exposure pathways.
§Uranium was included in the detailed source development in the Phase II study because of its concentrated use in the M-Area and its potential chemical toxicity.
Source: Phase II (3).

On the other hand, although ^{134}Cs, ^{103,106}Ru, and ^{141,144}Ce were not included in the Phase II list of key radionuclides for surface water pathways, it appears that they should have been included. The screening

value for these three radionuclides exceeded the 0.1-percent criterion used for Step One of the Phase II screening assessment.

From this assessment, Table C-6 lists the radionuclides considered for Phase III. Radionuclides cited in Phase II as aggregated quantities were separated into separate isotopes using the assumptions and procedures outlined in Section C.2 of this appendix.

Table C-5 Results of Phase II Screening Analysis for Water Release Screening Pathways*

Radionuclide†	All Pathways	Ingestion					Ground Contamin-ation	Number of Pathways‡
		Water	Fish	Milk	Produce	Meat		
^{137}Cs	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**7**
^{60}Co	**X**						**X**	**2**
^{3}H	**X**	**X**						**2**
^{129}I								0
^{131}I	**X**			**X**				**2**
^{32}P	**X**	**X**	**X**					**3**
^{239,240}Pu								0
^{238}Pu								0
^{89,90}Sr	**X**	**X**	**X**	**X**	**X**	**X**		**6**
^{35}S						X		1
^{99}Tc					X			1
U							**X**	**1§**
^{91}Y								0
^{65}Zn	X							1
^{95}Zr, ^{95}Nb								0

*Results of Step Two in the Phase II screening analysis. The radionuclides that ranked among the top three for at least two of the seven exposure pathways were selected for detailed source term development.
†The radionuclides identified in the Step One of the Phase II screening analysis that contributed greater than 0.1% of to the screening value for all exposure pathways.
‡Number of times that a particular radionuclide ranked high in at least two surface water exposure pathways.
§Uranium was included in the detailed source development in the Phase II study because of its concentrated use in the M-Area and its potential chemical toxicity.
Source: Phase II (3).

Table C-6 Radionuclides Considered for Phase III

Released to the Air		Released to Surface Water	
^{3}H	^{131}I	^{3}H	^{129}I
^{14}C	$^{134, 137}Cs$	^{32}P	^{131}I
^{41}Ar	U	^{35}S	^{134}Cs
$^{89,90}Sr$	^{238}Pu	^{60}Co	^{137}Cs
$^{103,106}Ru$	$^{239,240}Pu$	^{65}Zn	$^{141, 144}Cr$
^{129}I	^{241}Am	^{95}Zr, ^{95}Nb	U
		^{99}Tc	^{238}Pu
		$^{103,106}Ru$	$^{239,240}Pu$

C.1.4 Phase III Analysis of Phase II Screening Assessment

The Phase II screening assessment was reviewed for Phase III. For the air pathways, although $^{103,106}Ru$ was included in the list of key radionuclides, it did not appear to actually meet the 0.1 percent screening value criterion for Step One of the screening assessment. Its screening value was only 0.012 percent of the total (3).

For the surface water pathways, although ^{91}Y was included in the list of key radionuclides, it did not appear to actually meet the 0.1 percent screening value criterion for Step One of the screening assessment. Its screening value was only 0.03 percent of the total (3). Similarly, ^{129}I had a screening value of 0.05 percent, which was smaller than the 0.1 percent criterion set forth in Phase II.[3]

C.2 Phase III Assumptions for Partitioning Mixed Isotopic Activity

This appendix section addresses the assumptions and procedures used in Phase III to partition radionuclide activities reported[4] as aggregated quantities into individual isotopes. Partitioning assumptions and procedures are discussed herein for:

- $^{89,90}Sr$.
- ^{95}Zr, ^{95}Nb.
- $^{134, 137}Cs$.
- U.
- Pu.
- $^{241,243}Am$.
- Unidentified alpha and unidentified beta-gamma activity.

[3] The bases for the release estimates could not be determined for Phase III. The Phase III source term (0.358 Ci) was significantly smaller than that used in the Phase II report (1.20 Ci). Even assuming the larger source term, ^{129}I did not pass the 0.01 percent screening criterion used in the Phase II report.

[4] Aggregated quantities were reported in the Phase II report (3) and various SRS references.

C.2.1 $^{89,90}Sr$

^{89}Sr and ^{90}Sr are shown as an aggregated constituent ($^{89,90}Sr$) for liquid released from SRL to seepage basins, liquid released from D-Area to streams, liquid released to seepage basins in the Central Shops, and atmospheric releases from the F- and H-Areas (4).

^{89}Sr and ^{90}Sr are fission products generated from the bombardment of ^{235}U, ^{238}U, and ^{239}Pu with neutrons. The number of curies related to the generation of ^{89}Sr and ^{90}Sr in the production reactors was calculated, assuming a typical fuel element composition (5). Table C-2 summarizes the activity associated with each of these strontium isotopes (5).

Table C-7 Accumulated Fission Yields of Strontium Isotopes

Isotope	Half-Life or Ratio	Activity (Curies) Remaining at Various Times After End of Irradiation				
		0 Seconds	24 Hours	100 Days	200 Days	2 Years
^{89}Sr	53.21 days	$9.080x10^{+7}$	$8.962x10^{+7}$	$2.468x10^{+7}$	$6.707x10^{+6}$	$6.685x10^{+3}$
^{90}Sr	28.28 years	$2.219x10^{+6}$	$2.219x10^{+6}$	$2.204x10^{+6}$	$2.189x10^{+6}$	$2.113x10^{+6}$
$^{89}Sr/^{90}Sr$	Ratio	40.92	40.38	11.20	3.06	0.0032
$^{89}Sr/(^{89}Sr + ^{90}Sr)$:		98%	98%	92%	75%	0.3%

Source: Carlton et al, 1994 (5).

The percentages listed in Table C-7 were used to partition $^{89,90}Sr$ data into ^{89}Sr and ^{90}Sr for the following situations:

- Separations Areas: Fuel and target elements were stored in the reactor basins for a nominal period of 200 days after completion of irradiation before being processed in F- and H-Areas (5). For F- and H-Areas, it was assumed that releases to the atmosphere occurred 200 days after completion of irradiation in the reactors. $^{89,90}Sr$ atmospheric releases were therefore partitioned to 75 percent ^{89}Sr and 25 percent ^{90}Sr for these releases.

- Administration (A) Area: Environmental releases of $^{89,90}Sr$ in A-Area were attributed to releases from SRL to the SRL seepage basins. SRL conducted research using various forms of uranium and plutonium. Strontium isotopes were generated as a result. SRL also worked with ^{252}Cf for several years, and ^{90}Sr is a daughter product of this isotope. The proportion of ^{89}Sr to ^{90}Sr could not be determined for SRL operations; therefore, it was assumed that all of the environmental releases attributed to $^{89,90}Sr$ were ^{90}Sr. This assumption was conservative because the ingestion effective dose conversion factors used for this study are larger for ^{90}Sr than they are for ^{89}Sr (6). So are the inhalation effective dose conversion factors for all lung absorption classes (6).

- D-Area: D-Area was used to separate light water from the heavy water moderator withdrawn from the reactors (6). This process was assumed to occur within one year after receipt of the moderator from the reactors. The typical delay time between removal of the moderator from the reactor and processing in D-Area was unclear; therefore, it was conservatively assumed that all of the environmental releases attributed to $^{89,90}Sr$ were ^{90}Sr. Again, ^{90}Sr has larger inhalation and ingestion effective dose conversion factors than does ^{89}Sr (6).

- Central Shops: The Central Shops (CS) were used for repairing equipment from the reactors and separations areas. Before repair, the equipment was cleaned with water that was held for decay before discharge to seepage basins. Discharge of the water to seepage basins was assumed to occur approximately two years after the cleaning water was used and became contaminated with the ^{89,90}Sr. Table C-7 shows that a delay time of two years resulted in decay of ^{89}Sr by 13.7 half-lives, or a factor of about 13,000. Therefore, the activity (curies) of ^{89,90}Sr from Central Shops was attributed to ^{90}Sr.

C.2.2 ^{95}Zr, ^{95}Nb

^{95}Zr and ^{95}Nb are fission products. ^{95}Nb is also the daughter product of ^{95}Zr. ^{95}Zr has a half-life of 64.02 days, and ^{95}Nb has a half-life of 34.98 days. Table C-8 shows that these isotopes are initially generated as fission products in equal mass amounts (7).

Table C-8 Accumulated Fission Yields of ^{95}Zr and ^{95}Nb

Fission with Neutron Energy	Accumulated Yield	
	^{95}Zr	^{95}Nb
^{235}U with 0.0253 eV	0.06	0.06
^{235}U with 1.0 MeV	0.06	0.06
^{238}U with 1.0 MeV	0.05	0.05
^{239}Pu with 0.0253 eV	0.05	0.05
^{239}Pu with 1.0 MeV	0.05	0.05

Source: KAERI, 2003 (7).

The activity of a radioactive isotope in terms of the number of radioactive transformations per unit time is given as:

$$A = \lambda N \qquad \text{(Eqn. C.2-1)}$$

Where:

A = Activity (e.g., disintegrations per second).
λ = Radioactive decay constant (ln 2/half-life).
N = Number of atoms of a radioactive isotope.

Assuming that equal masses of ^{95}Zr and ^{95}Nb are produced in the reactors and assuming that the reactors operate with the neutron thermal energies shown in Table C-8, the initial activity of each isotope is given by:

$$A_{t=0} = \lambda N_o \qquad \text{(Eqn. C.2-2)}$$

Where N_o = The number of each isotope produced per fission event.

At any time t greater than 0, equation 2 applies:

$$A(t) = \lambda N_o e^{-\lambda} \qquad \text{(Egn. C.2-3)}$$

Because the fission yields (the number of atoms emitted) of ^{95}Zr and ^{95}Nb are equal, their contribution to the gross activity of ^{95}Zr, ^{95}Nb is calculated to be 35 percent for ^{95}Zr and 65 percent for ^{95}Nb immediately upon their generation in the reactor (an estimate based on the half-lives of the isotopes).

The half-life of the daughter is not much smaller than the half-life of the parent isotope. The time (t_{max}) at which the maximum activity of ^{95}Nb will occur (based on its production from the decay of ^{95}Zr) is 67 days, calculated from the following:

$$t_{max} = \frac{\ln \frac{\lambda_{Nb}}{\lambda_{Zr}}}{\lambda_{Nb} - \lambda_{Zr}} \qquad \text{(Eq. C2-4)}$$

After 67 days, the activity of ^{95}Nb begins to decline at the same rate as the decline in the activity of ^{95}Zr (this is called transient equilibrium). This ratio can be calculated by the following (8):

$$\frac{A_{Nb}}{A_{Zr}} = \frac{\lambda_{Nb}}{\lambda_{Nb} - \lambda_{Zr}} = 2.2 \qquad \text{(Eq. C2-5)}$$

Based on the decay chain and the calculated ratio after the 67-day maximum, the ratio of isotopic activity approaches a constant value where 31 percent of the total activity is due to ^{95}Zr and 69 percent of the activity is due to ^{95}Nb. These percentages are appropriate for operations that would occur after the removal of the fuel and targets from the reactors. By SRS process area, then, the following isotopic fractions were used:

Reactor areas:	35 percent ^{95}Zr 65 percent ^{95}Nb
All other areas:	31 percent ^{95}Zr 69 percent ^{95}Nb

These assumed values were based on assumptions meant to best reflect actual operating conditions and environmental releases. In determining the potential dose to individuals from these same isotopes, Carlton and Denham used more conservative assumptions that are based on their impact on dose (9).

C.2.3 ^{134,137}Cs

Cesium isotopes (^{134}Cs and ^{137}Cs) were generated at the SRS as reactor fission products. (Technically, ^{134}Cs is an activation product because it is produced by neutrons interacting with ^{133}Cs, which is a stable fission product.) At times, ^{137}Cs was separated from other fission products for further use as an energy source. Combined $^{134, 137}$Cs is documented in environmental releases reported from D-Area (4). ^{134}Cs has a half-life of 2.06 years while ^{137}Cs has a half-life of 30.1 years. Table C-9 shows the yields of ^{134}Cs and ^{137}Cs resulting from fission of uranium and plutonium by neutrons of different energies (7).

Because the yield of ^{134}Cs is small compared with that of ^{137}Cs, ^{137}Cs was expected to contribute nearly all of the activity of $^{134, 137}$Cs. Therefore, the activity measured for $^{134, 137}$Cs was attributed to ^{137}Cs.

Table C-9 Accumulated Fission Yields of Cesium Isotopes

Fissile with Neutron Energy	Accumulated Yield	
	^{134}Cs	^{137}Cs
^{235}U with 0.0253 eV	$1x10^{-07}$	0.06
^{235}U with 1.0 MeV	$5x10^{-07}$	0.06
^{238}U with 1.0 MeV	$3x10^{-09}$	0.06
^{239}Pu with 0.0253 eV	$1x10^{-05}$	0.07
^{239}Pu with 1.0 MeV	$1x10^{-05}$	0.07

Source: KAERI, 2003 (7).

C.2.4 Uranium

The relative abundance of the various uranium isotopes released into air and water was dependent on a number of factors. The primary factor was the enrichment. Enrichment increases the relative abundance of the lower weight isotopes (^{234}U and ^{235}U) and decreases the proportion of the higher weight isotopes (^{238}U). A second factor was whether the uranium had been subjected to neutron irradiation in a reactor. Reactor irradiation would have resulted in the production of ^{236}U. While it is fairly certain that the uranium used at SRS facilities (in particular, the reactors and separations facilities) was irradiated in reactors, only limited information exists concerning uranium enrichment levels. Therefore, the analysis of the isotopic composition of uranium found in air and water discharges is largely based on general assumptions.

However, due to two key properties of the various uranium isotopes (half life and dose conversion), changes to the composition would not have a substantive effect on the results of the SRS dose reconstruction. Because all of the uranium isotopes have very long half-lives (240,000 years and longer) in comparison to the period being studied (39 years), radioactive decay could not have had a significant effect on the relative abundance of the isotopes after they were released. In addition, inhalation and ingestion effect dose conversion factors for the four uranium isotopes fall within a ~15 percent range; therefore, the doses received from equal amounts of the different isotopes would be about the same (6).

Until the mid-1990s, alpha-emitting radioisotopes were detected using instrumentation that measured gross alpha activity. This gross alpha count was attributed to a combination of (primarily) uranium and plutonium isotopes. The fraction of the gross alpha assigned to each of these elements varied depending on the facility or process emitting the alpha radioactivity. In M-Area (where reactor fuel was manufactured), alpha radioactivity was solely attributed to uranium. When the SRS conducted dose calculations, assumptions were made about the type of uranium present (natural, enriched, or depleted), with the corresponding isotopic fractions used (10). This approach is used below to estimate the curie fraction of each uranium isotope for the applicable SRS facilities.

In Cummins et al, "U-Nat" (natural uranium) represents "$^{235,238}U$" (4). ^{235}U and ^{238}U represent the majority of the mass of naturally occurring uranium. However, it should not be assumed that all uranium measured in environmental releases at the SRS was natural uranium. Despite this nomenclature, uranium actually occurs in three basic forms in the SRS environment—natural, depleted, and enriched. Natural uranium is processed to remove ^{238}U so that a higher concentration of ^{235}U is achieved, thus creating enriched uranium. The enrichment process creates a byproduct called depleted uranium. Depleted uranium was either disposed of as a waste or reused in target materials for producing plutonium isotopes. Evans et al provides approximate isotopic compositions for each of these waste forms (11). Note that for

enriched uranium, two basic types of fuel were manufactured and used at the SRS—Type M and Type F. Because it is unclear as to how much Type M fuel versus Type F fuel was used, Table C-10 shows an average isotopic composition for enriched fuel assuming the same mass of Type M and Type F fuel. Note that these compositions include ^{234}U and ^{236}U. Although the original data sources only reference ^{235}U and ^{238}U, it was assumed for Phase III that these other uranium isotopes were also present.

Table C-10 Isotopic Composition of Savannah River Uranium Wastes

Isotopic Composition (Weight %)*	Isotope			
	^{234}U	^{235}U	^{236}U	^{238}U
Natural	0.0055	0.7200	N/A†	99.2745
Depleted	N/A†	0.2	N/A†	99.8
Enriched‡	1.45	81.55	9.8	7.2
Half-Life (years)§	$2.45 \times 10^{+5}$	$7.03 \times 10^{+8}$	$2.34 \times 10^{+7}$	$4.47 \times 10^{+9}$

*Evans et al. 1992 (11).
†N/A – data not available.
‡Average of Isotopic Composition for Type M and Type F fuels.
§KAERI, 2003 (7).

Using the above weight percentages, the contribution to the activity for each isotope was calculated using Equation C1-1 and presented in Table C-11.

Table C-11 Activity Fraction for Specific Isotopes in Uranium Wastes

Activity Fraction (%)	Isotope			
	^{234}U	^{235}U	^{236}U	^{238}U
Natural	49.49	2.25	N/A*	48.26
Depleted	N/A*	1.27	N/A*	98.73
Enriched	91.73	1.79	6.45	0.03

*N/A – data not available.

The Phase III radiological assessment takes into account the isotopic distributions listed in Table C-11 as addressed below for each major group of SRS facilities.

- Reactor Areas: Any release of uranium in the reactor areas to streams and seepage basins was assumed to occur after the storage of spent fuel (containing enriched uranium) and target materials (containing depleted uranium) in spent fuel basins and disassembly basins (11). Basin purge water was normally discharged to the plant streams and seepage basins along with the reactor secondary cooling water. Uranium releases from the reactors to the atmosphere occurred due to the venting of "harps" (storage containers located underwater in the reactor basin which contained failed fuel and target elements) to the reactor stack (9). The ratio of enriched to depleted uranium that was used in the production reactors is not known and cannot be calculated. Because more enriched uranium (on a mass basis) than depleted uranium was probably used in the reactors, the activity fractions from Table C-11 for enriched uranium were used for environmental releases from the reactors.

- Separations Areas: Based on Evans et al., the F-Area facilities separated ^{239}Pu from uranium targets primarily comprised of depleted uranium (11). Therefore, activity fractions in Table C-11 associated with depleted uranium were used for environmental releases from F-Area. In H-Area, ^{235}U was recovered from enriched fuel. According to Evans et al., enrichment levels in H-Area fuel ranged

from 1.1 percent to 94 percent ^{235}U (11). Therefore, the activity fractions in Table C-11 associated with enriched uranium were used for environmental releases from H-Area.

- M-Area: Reactor fuel and targets were fabricated in M-Area. Atmospheric releases of uranium were very small compared to the releases from F-Area. These releases were in the form of natural and depleted uranium, although it is unclear to what proportion these two forms of uranium were released (11). For the purposes of Phase III, natural uranium activity fractions from Table C-11 were assumed for atmospheric releases because ^{234}U is present in natural uranium in measurable quantities and is known to have been emitted from the SRS. Because depleted uranium has been found in stream sediments (11), the activity fractions for depleted uranium from Table C-11 were used for all liquid releases.

- A-Area (SRL): SRL worked with all forms of uranium. An average of the activity fractions for all three forms of uranium was used, assuming that an equal mass of natural, depleted, and enriched uranium was released. This assumption resulted in the following percentages of uranium isotopic activity: 91.44 percent for ^{234}U; 1.8 percent for ^{235}U; 6.4 percent for ^{236}U; and 0.36 percent for ^{238}U.

- CMX-TNX: Some natural uranium was used in fuel and target development at TNX (11). For this reason, activity fractions from Table C-11 for natural uranium were used for releases from CMX-TMX.

- D-Area: The rework of degraded moderator from reactor areas was the most likely source of alpha activity, which is assumed to be uranium (11). The moderator most likely contained a mixture of uranium isotopes representing both depleted and enriched uranium. To be consistent with the assumptions for the reactor areas, activity fractions from Table C-11 for enriched uranium were used for environmental releases from D-Area.

C.2.5 Plutonium

^{238}Pu, ^{239}Pu, and ^{240}Pu were the primary plutonium isotopes of interest in environmental releases at the SRS. ^{239}Pu and ^{240}Pu were often reported as ^{239}Pu because these two isotopes were indistinguishable in alpha spectroscopy measurements (12). All three of these isotopes were produced by the reactors and were present in F- and H-Area processes. The most common form of plutonium produced at the SRS was weapons-grade plutonium. Weapons-grade plutonium had an isotopic composition similar to that shown in Table C-12.

Table C-12 Isotopic Composition of Weapons-Grade Plutonium

Mass and Activity Fractions	Plutonium Isotopes				
	Pu-238	Pu-239	Pu-240	Pu-241*	Pu-242
Mass Fraction	0.00012	0.938	0.058	0.0035	0.00022
Activity Fraction (using Equation C.2-1)	0.0047	0.1337	0.0302	0.8313	0.0000

* ^{241}Pu plus ^{241}Am.
Source of Mass Fractions: Mark, 1993 (13).

Two issues that were resolved were the partitioning assumptions for activity described as combined $^{239,240}Pu$ and activity described as total plutonium.

Activity described in Phase II as $^{239,240}Pu$ was assumed to be ^{239}Pu. From Table C-12, the activity fraction of ^{240}Pu is about 20 percent of that of ^{239}Pu. Also, the inhalation and ingestion effective dose conversion factors used in this report are similar for ^{240}Pu to those for ^{241}Pu (6).

With respect to total plutonium, despite comprising a very small mass fraction of weapons-grade plutonium, ^{241}Pu (plus its daughter product ^{241}Am) contributes approximately 83 percent of the activity (Table C-12). ^{241}Am is addressed as a separate constituent; therefore, ^{241}Pu is indirectly addressed in the dose assessments. Also, the ingestion and inhalation dose coefficients for ^{241}Pu are much smaller than those for ^{238}Pu, ^{239}Pu, and ^{240}Pu (6). Because ^{239}Pu was the primary plutonium product at the SRS and has similar ingestion and inhalation effective dose conversion factors as ^{238}Pu and ^{240}Pu (6), all "Total Plutonium" releases to the environment were assumed to be ^{239}Pu.

C.2.6 ^{241,243}Am

^{241}Am is a daughter product of ^{241}Pu and has a half-life of 432.2 years. ^{243}Am has a half-life of 7,370 years. ^{241}Am and ^{243}Am are reported as "^{241,243}Am" in environmental reports through 1992 because at that time these two isotopes could not be easily distinguished in laboratory analyses. In recent years, improved laboratory techniques allowed for separate measurement of these two isotopes. Based on these new techniques, it appears that any americium that appeared in SRS environmental samples was ^{241}Am. ^{243}Am is used as a tracer in laboratory analyses but does not appear to be attributable to the original environmental samples (14).

^{241}Am is an unwanted byproduct in the production of plutonium; however, on occasion, it was isolated and used for medical applications and well-logging sources. In addition, ^{237}Np could be produced through alpha decay of ^{241}Am (15). Very small quantities of ^{243}Am could have been generated as a byproduct of producing medical isotopes; however, as stated above, these quantities appear to be immeasurable.

For Phase III, $^{241, 243}$Am was assumed to be 100 percent ^{241}Am.

C.2.7 Unidentified Alpha Emitters/Unidentified Beta-Gamma Emitters

Many of the radioactive releases at the SRS were detected using gross alpha and gross beta-gamma activity measurements. If the isotopes were known due to process knowledge, then the measurements were assigned to the isotopes in the environmental release reports. If the isotopes were not known, then the environmental release reports reflected unidentified alpha and unidentified beta + gamma measurements (11). The unknown constituents comprising unidentified alpha and unidentified beta + gamma measurements were most likely a combination of several isotopes.

The SRS could not assign the unidentified alpha and unidentified beta-gamma activity measurements to specific isotopes. For this reason, these unidentified measurements were attributed to single isotopes to allow for conservative estimates of their dose contribution. Unknown alpha activity was assigned to ^{239}Pu, which has larger dose conversion factors than the uranium isotopes for many of the exposure pathways (6). In addition, ^{239}Pu is one of the more prevalent plutonium isotopes at the SRS. Other transuranic isotopes have been produced and used at the SRS (such as ^{237}Np, ^{244}Cm and ^{252}Cf) that have contributed to the measurement of unidentified alpha, but these isotopes were primarily produced during brief periods and have dose conversion factors 100 to 1,000 times smaller than ^{239}Pu (6). Therefore, using ^{239}Pu for unidentified alpha values was a conservative assumption.

Many isotopes could contribute to unidentified beta-gamma activity measurements. For conservatism, unidentified beta-gamma activity was attributed to ^{90}Sr, which was commonly found in environmental releases throughout the SRS facilities. With a half-life of 28 years, ^{90}Sr will also remain in the environment longer than most of the other beta- and gamma-emitting isotopes of concern.

C.3 Adjustment Factors for Surface Water Transport to Savannah River

This section describes the method by which the uncertainties and loss mechanisms associated with transport of radionuclides by surface water from their points of release to the Savannah River were addressed. The Phase II Report describes a model for estimates of release of ^{3}H, ^{90}Sr, and ^{137}Cs to the Savannah River based on environmental monitoring data and other parameters and processes that affect the transport of the contaminants in surface water. For Phase III of the SRS dose reconstruction project, the results of the Phase II model for these three radionuclides were extrapolated to all other radionuclides of interest.

Using the approach described herein, radionuclide concentrations in the Savannah River at an appropriate exposure location were determined. These concentrations were determined considering the discharge of radionuclides from all major surface water bodies draining the SRS, including Lower Three Runs Creek. Nonetheless, the approach described herein was not used to determine possible radiation exposures from public access to Lower Three Runs Creek. These exposures were determined by another method as addressed in Chapter 7 of this report.

C.3.1 Introduction

Figure C-1 depicts the major facilities releasing radionuclides to surface water bodies on the SRS site. These facilities include:

- The C-, P-, K-, L-, and R-Reactor areas.
- The H- and F-Separations areas.
- The A-Area.
- The M-Area.
- The D-Area and CMS-TNX.
- The Central Shops (CS) Area.

The reactor areas were the sources of most radionuclides released to surface water. Releases from the reactor and separations areas included radionuclides discharged directly to onsite streams as well as to reactor and separations areas seepage basins. Radionuclides released into seepage basins were delayed in transit through ground water before being released via surface seeps into onsite streams. This delay allowed for radioactive decay. Surface water releases of radionuclides were highest in the early to middle 1960's and decreased into the 1980s.

Also, Figure C-1 shows the five major onsite streams that received radionuclides from SRS facilities. Water from Upper Three Runs Creek, Fourmile Branch, Pen Branch, and Steel Creek passes through the Savannah River Swamp before it discharges into the Savannah River. Water from Lower Three Runs Creek does not pass through the swamp. Finally, Figure C-1 shows Road A which passes through the SRS from the southeast to the northwest. Road A is significant because environmental monitoring stations are located where Road A crosses the above five SRS streams. These Road A monitoring stations are the final points on the SRS site of routine stream monitoring before discharge of the stream water to the Savannah River.

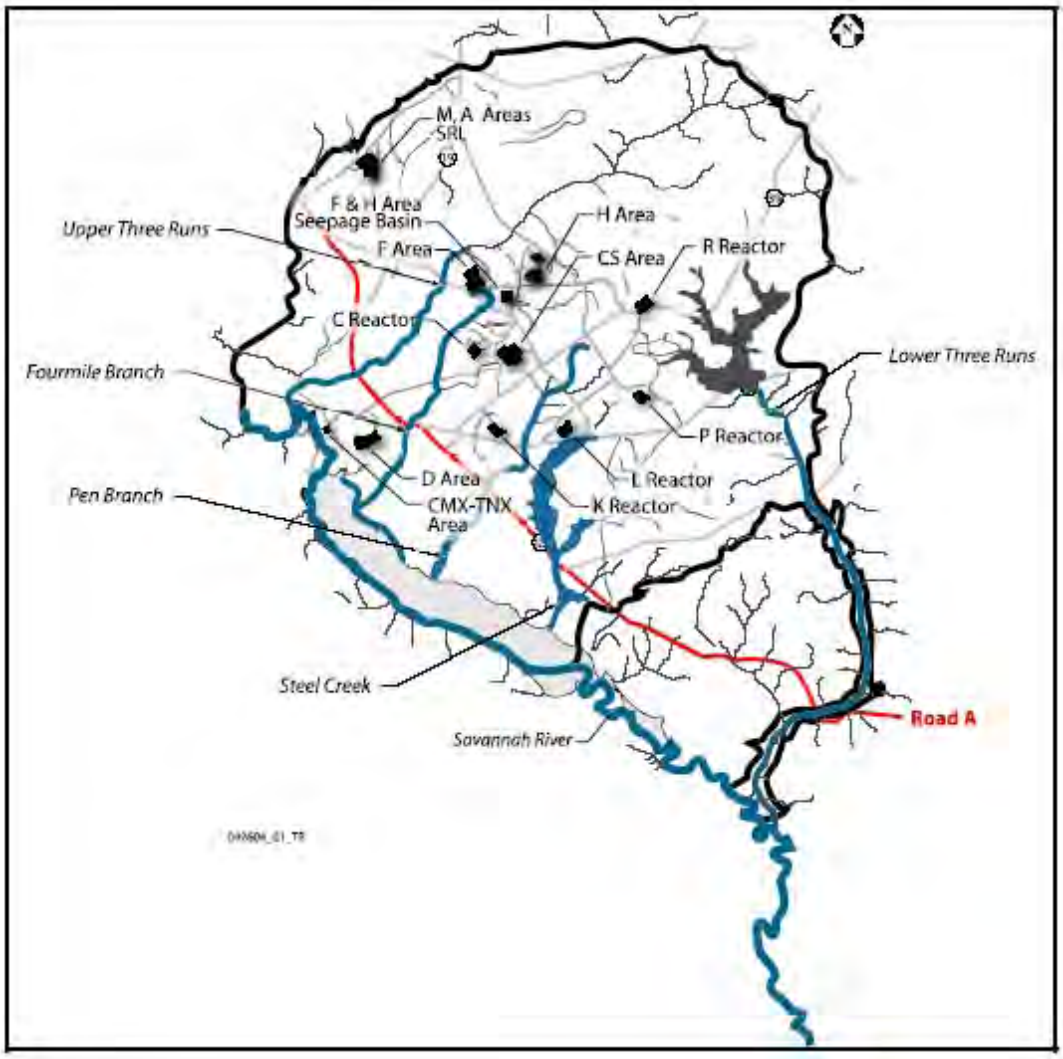

Figure C-1 Major SRS Sources of Release to Surface Water

Figure C-1 serves to point out the following difficulties inherent in deriving a radionuclide source term for surface water:

- Releases to surface water were not dispersed (in the sense that releases to air were dispersed) but eventually drained to one of the streams that flowed into the Savannah River.
- Each stream flowing offsite could have contained the contribution of more than one SRS facility or Area.
- Radionuclides discharged to streams were not immediately transported to locations on the Savannah River where the radionuclides could have been contacted by humans. Streams containing radionuclides had to flow for several miles before being discharged to the Savannah River. On the way, many radionuclides were sorbed into stream and swamp sediments, reducing the inventory eventually released offsite.

- Although radionuclides released to the air could be dispersed to all points of the compass by wind vectors, radionuclides released to surface waters on the SRS were channeled by streams and rivers. This means that radiation exposures could only occur at well-defined geographic locations such as publicly accessible locations below site discharge points into the Savannah River.
- Much liquid effluent was discharged over the years to seepage basins rather than directly to rivers. Transport of radionuclides through the ground water from the seepage basins to site steams was delayed through sorption and the usual slow ground-water flow.
- All but one of the major onsite streams discharging radionuclides to the Savannah River passed through the Savannah River Swamp. Due to sedimentation processes characteristic of wetlands, many radionuclides were deposited into swamp sediments. The swamp, however, historically flooded about 20 percent of the time. Flooding tended to increase releases from the swamp to the Savannah River.

Because of these considerations, a source term was developed for Phase III that estimated radionuclide concentrations at an exposure location downstream of the points of radioactive discharge from all SRS streams. These concentrations reflect the concentrations that exist **after** the radionuclides were transported through surface water from the various points of the SRS site release to the exposure location.[5]

The starting point for this effort was the Phase II estimates of release to surface water (3). This reference identified nearly two dozen key radionuclides that had been released to surface water from SRS facilities during the years of nuclear material production. Phase II also developed a model for discharge into the Savannah River for three of these radionuclides (^{3}H, ^{137}Cs, and ^{90}Sr).

For the Phase III report, the task was to complete the estimates of release into the Savannah River for all the other key radionuclides that were identified in Phase II for release to surface water. This task included the following projects:

- Reviewing the Phase II information and supplementing its estimates of release to surface water for several radionuclides.
- Partitioning radionuclides reported as aggregated quantities (e.g., combined ^{89}Sr and ^{90}Sr) into individual isotopes consistent with the approach described in Section C.2 of this appendix.
- Developing a procedure that accounted for the delay experienced by all key radionuclides while being transported from their various points of release to the Savannah River.

This Phase III procedure used a set of annual adjustment factors that extended to other radionuclides the Phase II modeled releases of ^{3}H, ^{90}Sr, and ^{137}Cs to the Savannah River. In this way, annual radionuclide concentrations in the Savannah River were determined for the 22 radionuclides listed in Table C-13.

[5] This approach is different from that used for release of radionuclides to air. Annual radionuclide quantities released from four groups of SRS facilities were determined as discussed in Chapter 5. (These annual releases are listed in Appendix B as the source term for radionuclides released to air.) Then, the transport of these radionuclides by wind to exposure locations around the SRS site was estimated using a Gaussian plume model as discussed in Chapter 6. The output of the Gaussian plume model was the concentrations of radionuclides annually existing in air and deposited onto the ground at these exposure locations.

Table C-13 Radionuclides Considered for Savannah River Source Term

^{144}Ce	^{131}I	^{89}Sr	^{236}U
^{134}Cs	^{95}Nb	^{90}Sr	^{238}U
^{137}Cs	^{32}P	^{35}S	^{65}Zn
^{60}Co	^{238}Pu	^{99}Tc	^{95}Zr
^{3}H	^{239}Pu	^{234}U	
^{129}I	^{106}Ru	^{235}U	

C.3.2 Phase II Modeled Release to Savannah River of ^{3}H, ^{90}Sr, and ^{137}Cs

Chapter 5 of Phase II discusses in detail how the accounting of releases to the surface water pathway ***at the point of release*** is not an accurate estimate of the actual releases from the SRS site to the Savannah River. In addition to direct releases to onsite streams, waters were released to seepage basins which held the waste for some period of time. These waste waters would seep into the soil and eventually reach the surface at the nearby streams. The southwestern edge of the SRS site along the Savannah River consists of a wetland, which slows the flow of water to the Savannah River as well as acts as a sink for dissolved constituents that are sorbed or taken up by minerals, sediments, plants, and other biota in the swamp. In addition to these physicochemical means of reducing the releases to the Savannah River, radioactive decay affects the concentrations of constituents that would reach the Savannah River.

As described in Chapter 5 of the Phase II report, a relatively simple model was used to project the release to the Savannah River of ^{3}H, ^{90}Sr, and ^{137}Cs based on concentrations of these constituents measured at the sampling stations along Road A (the sampling point closest to the river) (3). These three radionuclides were identified in Phase II as important possible contributors to either offsite release or dose, and had been monitored extensively during the years of nuclear material production.

The Phase II model explicitly considers the following factors (3):

- Transport of radionuclides through surface water as dissolved and suspended constituents.
- Release of previously retained radionuclides by periodic flooding of the Savannah River Swamp.
- Measurement uncertainty.

The effects of the various physical and chemical interactions of released radionuclides with the soil, biota, and other features of the SRS generally decreased the modeled radionuclide quantities reaching the Savannah River. On the other hand, when incorporated into the Phase II model, many of the radionuclide measurement uncertainties increased the modeled quantities discharged to the Savannah River (3).

The mathematical procedures used to estimate the transport of radionuclides to the Savannah River considered dissolved radionuclides as well as the transport of radionuclides attached to suspended and bottom sediments of various sizes. The dissolved concentration at any location was found using a mass conservation equation obtained from Till, 1983 (16):[6]

$$C_{x,t} = \frac{Q(x-\Delta x,\ t-\Delta t)C(x-\Delta x,\ t-\Delta t)e^{-\lambda\Delta t}}{Q_{x,t}} \qquad \text{(Eq. C.3-1)}$$

[6] Terminology for this discussion is from Phase II.

Where:

Cx,t	=	dissolved radionuclide concentration at location x and time t,
Qx,t	=	flow rate at location x and time t,
λ	=	radionuclide decay constant
Δx,t	=	travel time in stream (s)
Δx	=	change in location (m)
x	=	distance (m)
t	=	time (s)

The travel time in the stream (Δx,t) was the time it took the radionuclide to move from Road A (its last point of measurement) to the Savannah River. The travel time depended on the flow rate and velocity of the particular stream, and the distance from Road A to the Savannah River.[7] The final activity of the radionuclide entering the Savannah River was reduced by radioactive decay that occurred during this travel time.

The flow rate of the dissolved radionuclide (pCi/s) was determined by multiplying the concentration in water (pCi/m3) by the flow rate of the water (m3/s) (3).

The concentration of radionuclides attached to sediment (Cp) was calculated from the dissolved radionuclide concentration and the distribution coefficient (K_d) by (3):

$$Cpx,t = K_d \; Cx,t. \qquad \text{(Eq. C.3-2)}$$

Where Cp is in units of pCi/g and the distribution coefficient, K_d, is a measure of the amount of radionuclide sorbed on sediment:

$$K_d = \frac{\text{amount of radionuclide sorbed on sediment}}{\text{amount of radionuclide left in solution}} \qquad \text{(Eq. C.3-3)}$$

And the sediment transport rate in water was given as (16):

$$ST = aQb \qquad \text{(Eq. C.3-4)}$$

Where ST is the sediment transport rate (units of g/s), and the parameters (a and b) are constants estimated for each sediment size range. For Phase II, it was assumed that a = 0.0004 and b = 3 based on studies at the SRS (17).

From this, the flow rate of the radionuclide absorbed in transported sediment (Ci/s) was given as the product of the concentration in sediment (pCi/g) and the sediment transport rate (g/s). The total flow rate was the sum of that flow rates for dissolved and suspended radionuclides, and this sum multiplied by the number of seconds in a year gave the yearly activity transported to the Savannah River (3).

In addition to these mathematical relationships, the model used to project the release of these radionuclides to the Savannah River considered periodic flooding of the Savannah River Swamp and sampling and measurement uncertainties (3). The Savannah River Swamp flooded about 20 percent of the time (74 days per year on the average) during the period from 1958 to 1967. It was assumed that additional releases to the Savannah River occurred from the swamp when flooding occurred. This uncertainty was considered a source of bias that increased releases for radionuclides like cesium and

[7] For example, this distance was 12 km for Fourmile Branch.

strontium that were retained in the swamp. Detailed records existed for annual rainfall amounts. For most years, releases were increased for cesium and strontium by 20 percent (with a range of 10 to 30 percent). For years having high rainfall (e.g., 1964 and 1971), a value of 40 percent (with a range of 25 to 60 percent) was assumed. For years having low rainfall, it was assumed that the swamp flooded only 10 percent of the time (with a range of 5 to 15 percent) (3).

Uncertainties associated with the release estimates were considered from analytical errors in the measurement of flow and in sampling and determination of radionuclide concentrations in water. (Because ^{3}H was not impacted heavily by flow through the Savannah River Swamp, sampling and analytical uncertainties were the major sources of uncertainty in the release estimates for ^{3}H.) The effluent volume to the site streams was monitored reasonably well by both the SRS and the USGS (3). Estimates of error for the routine concentration measurements varied with the radionuclide, the sample preparation, and the counting procedure (3).

Table C-14 summarizes the factors that were considered in estimating the releases of ^{3}H, ^{137}Cs, and ^{90}Sr to site streams and their discharge to the Savannah River. Several time periods were considered due to changes in sampling procedures and analytical methods. In addition, the retention within the swamp varied among the radionuclides as described above (3).

Table C-14 Factors Considered in the Uncertainty Estimates for Surface Water Source Terms for Key Radionuclides

Radio-nuclide	Time Period	Measured Effluent Release	Measured in Stream at Road A	Estimated Measurement Uncertainty	Effect of Swamp	
					K_d Values	Flooding
^{3}H	1954-1957	yes	No	50%	none	none
	1958-1959	yes	Yes	40%	none	none
	1960-1973	yes	Yes	25%	none	none
	1974-1992	yes	Yes	15%	none	none
^{137}Cs	1954-1958	no	No	60%	10,000*	1.1 to 1.4†
	1959-1973	yes	Yes	50%	10,000*	1.1 to 1.4†
	1974-1992	yes	Yes	25%	10,000*	1.1 to 1.4†
^{90}Sr	1954-1960	some	No	60%	100*	1.1 to 1.4†
	1961-1973	yes	Yes	50%	100*	1.1 to 1.4†
	1974-1992	yes	Yes	25%	100*	1.1 to 1.4†

*The median estimate is listed; the range of K_d values is: cesium (50–80,000) and strontium (8–4000).

†Based on rainfall amounts for each year; in general, the swamp flooding occurred about 20 percent of the time each year when the average rainfall was about 47 inches. In 1964, very heavy rainfall (73 in) and extensive flooding occurred; in 1954, it was quite dry (28 in) and little swamp flooding occurred.

Source: Phase II (3).

Measurements specific for ^{137}Cs and ^{90}Sr were not made in early years. Before circa 1960, only nonvolatile beta activity was measured. To estimate annual ^{137}Cs releases for times when specific measurements were not made, a ratio was calculated of ^{137}Cs to nonvolatile beta activity when both measurements were made at the same time and location. This ratio was used, along with nonvolatile beta activity measurements, to estimate levels of ^{137}Cs activity in site streams at Road A when ^{137}Cs-specific measurements were not made. A similar procedure was used for ^{90}Sr. Using this information, a stochastic

uncertainty analysis of the model was performed on the three radionuclides, leading to a range of values calculated each year for each radionuclide (3).

C.3.3 Development of Savannah River Source Term for Phase III

C.3.3.1 Challenges

The development of a mathematical model that accounted for the transport of radionuclides through onsite surface water bodies until they were discharged into the Savannah River was considered desirable. However, as discussed in Section C.3.1., this approach contained numerous challenges and would have been difficult to develop and validate. The complex nature of radionuclide transport by surface water at the SRS requires consideration of the loss mechanisms, time delays, and uncertainties that influence radionuclide concentrations reaching the Savannah River. Transport of released radionuclides across the SRS into the Savannah River is neither simple nor direct.

These difficulties were apparent to the preparers of the Phase II report who created a model that estimated releases of ^{3}H, ^{90}Sr, and ^{137}Cs into the Savannah River. This model started with monitoring data measured at onsite sampling points where Road A crossed onsite streams and projected discharge into the Savannah River considering transport of radioactive constituents in dissolved and particulate forms, the retention of radionuclides in the Savannah River Swamp and their release during heavy floods, and sampling and measurement uncertainties.

The Phase II work led to consideration, for Phase III, of extending the Phase II model to the other key radionuclides identified in the Phase II screening assessment. Unfortunately, direct modeling similar to that performed in the Phase II study was not possible. Because the concentrations of most radionuclides were below detectable limits at the Road A intersections, the basis of the Phase II model for the remaining radionuclides was unavailable.

It was also considered unreasonable to merely assume point-of-release information (as reported by Cummins et al [4] and by annual SRS environmental reports) as a source term for discharge into the Savannah River. This approach would have presented concentrations in the Savannah River that were generally higher than was actually the case. The approach would have been a conservative one, but it would not have represented the storage of radionuclides in the swamp and their release during floods. In addition, this approach would not have represented measurement uncertainty.

C.3.3.2 Summary of Approach

In light of the challenges discussed above, a modification of the Phase II modeling approach was used for Phase III to determine annual release of radionuclides to the Savannah River. This approach was used to determine annual concentrations of radionuclides in the Savannah River from all bodies of surface water releasing radionuclides into the river. The annual concentrations were used to determine the levels of radiation doses and cancer risks that may have been associated with these releases.[8]

For Phase III, the annual concentrations of radionuclides released into the Savannah River were determined by using annual adjustment factors as shown in the following equation:

$$CSri(t) = APORi(t) / VSR(t) \; AFi(t) \qquad \text{(Eqn. C.3-5)}$$

[8] Five exposure pathways were considered in Phase III for release of radionuclides to surface water: consumption of fish taken from contaminated river or creek water, external exposure while occupying the shoreline of the contaminated river or creek, external exposure from swimming in the river, inadvertent ingestion of water while swimming in the river, and external exposure from boating on the river.

Where:

CSri(t) = Annual concentration of radionuclide i in the Savannah River at the designated exposure location.

APORi(t) = Activity of radionuclide i annually released into all SRS streams seepage basins, and containment basins, as determined at the point of release.

VSR(t) = Annual volume of Savannah River water flowing through or past a designated exposure location on the Savannah River.

AFi(t) = Annual adjustment factor for radionuclide i.

Adjustment factors were developed for each year for three classes of radionuclides encompassing different ranges of the soil-to-water distribution coefficient (K_d). The adjustment factors are the ratio of the median of the Phase II modeling results for each year, respectively, for ^{3}H, ^{90}Sr, and ^{137}Cs, to the activity released from SRS facilities for each year, respectively, for ^{3}H, ^{90}Sr, and ^{137}Cs, as determined at the points of release. That is, the adjustment factors were calculated as follows:

$$AFi(t) = \frac{\text{Annual median of Phase II modeled discharge to Savannah River of } ^{3}H, ^{90}Sr, \text{ or } ^{137}Cs \text{ (Ci)}}{\text{Annual } ^{3}H, ^{90}Sr, \text{ or } ^{137}Cs \text{ release at point of release (Ci)}} \qquad \text{(Eq. C.3-6)}$$

The adjustment factors thus calculated were used for other radionuclides having similar K_ds (i.e., Table C-15):

Table C-15 Application of Adjustment Factors to Radionuclides

Adjustment Factors Determined For:	Were Applied To:
^{3}H	^{3}H, ^{35}S, ^{99}Tc, ^{129}I, ^{131}I
^{90}Sr	^{32}P, ^{60}Co, ^{65}Zn, ^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{106}Ru, ^{144}Ce, U
^{137}Cs	^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu

For equation C.3-5, the annual volume of the Savannah River was determined using data from the U.S. Geological Survey (USGS). In equation C.3-5, the annual activity of ^{3}H and ^{137}Cs that was released was the same annual activity for these two radionuclides that was assumed in the denominator of equation C.3-6. Hence, the annual activity released into the Savannah River was the same for these radionuclides as that modeled in Phase II. But for ^{90}Sr, two different point-of-release data files were compiled—one for developing the annual adjustment factors and one for estimating annual discharge of ^{90}Sr to the Savannah River (see Section C.4.1).

C.3.4 Components of Phase III Approach

This section discusses important components of the Phase III approach to estimate the annual concentrations of radionuclides in the Savannah River resulting from production of nuclear materials at the SRS.

Section C.3.4.1 briefly discusses the environmental studies, reports, and other data used to compile point-of-release activity estimates for the radionuclides identified in Table C-13. As part of this process, the activities for radionuclides identified as mixtures of isotopes were partitioned among specific isotopes.

Section C.3.4.2 provides Phase III estimates of the annual Savannah River flow rate over the period from 1954 to 1992.

Section C.3.4.3 addresses the use of soil-to-water distribution coefficients for grouping radionuclides for application of the adjustment factors.

Section C.3.4.4 calculates and presents the Phase III adjustment factors.

C.3.4.1 Annual Radionuclide Release at Points of Release

The principal reference used to develop the annual radionuclide point-of-release data files was Cummins et al (4). This reference was used for releases during the years 1954 through 1989, while SRS environmental reports were used for the years 1990 through 1992 (18-20). To develop the data files, a guiding decision had to be made about the specific releases to be included.

Liquid releases from the site can be placed into the following three categories (4):

- Category 1 - Direct releases to onsite streams.
- Category 2 - Migration from seepage basins into onsite streams.
- Category 3 - Direct releases to seepage and containment basins.

Although one might think that the total release to site streams should be the sum of Categories 1 and 2, the Phase II report generally used the sum of Categories 1 and 3 to represent the liquid source terms in the screening assessment.[9] There appear to be at least two reasons for this choice: (1) because migration from the seepage basins is distributed in time and space, measurements of concentrations immediately downstream of the seepage basins may under-represent the total flux from the seepage basins to the streams; and (2) the sum of Categories 1 and 3 should be a conservative estimate of liquid releases to site streams.

For these reasons, the annual sums of releases from Categories 1 and 3 were chosen as representative of SRS releases to site streams. This has two implications: (1) the adjustment factors based on modeled releases of ^{3}H, ^{90}Sr, and ^{137}Cs used the sums of Categories 1 and 3 as the denominators of the adjustment factors; and (2) these adjustment factors were applied to the sums of Categories 1 and 3 for radionuclides having similar K_d's.

This decision meant that ^{3}H evaporated from seepage and containment basins was excluded from the point-of-release data file created for ^{3}H released to water. Evaporated ^{3}H was included in the Phase III atmospheric releases (Chapter 5).

It also meant that the estimated ^{137}Cs desorption from the Fourmile Creek bed that was reported by Cummins et al (4) was not included in the data files. The activity reported in this desorption was already included in the Category 1 and 3 releases as described above. Use of desorption estimates would have caused double counting.

Based on these assumptions, point-of release data files were compiled for each of the 22 radionuclides considered for release to the Savannah River. For all radionuclides except ^{90}Sr, a single data file was

[9] Exceptions are ^{3}H and ^{131}I, where only release to streams was considered for the screening assessment.

constructed for each radionuclide. But two data files were constructed for ^{90}Sr: one for developing the annual adjustment factors (Equation C.3-6) and one for estimating annual discharge of ^{90}Sr to the Savannah River (Equation C.3-5).

There were reasons why two different point-of-release data files were complied for ^{90}Sr. One reason was that the adjustment factor determined for ^{90}Sr was applied to several other radionuclides as shown in Table C-15. Therefore, it was important to assure that any assumptions pertaining to the annual release of ^{90}Sr were not overweight projections of other radionuclides that may have similar K_d's but are otherwise dissimilar. Another reason was that much of the release data for ^{90}Sr were given as an aggregated mix of ^{89}Sr and ^{90}Sr, or as unidentified beta-gamma activity (see below). However, Phase II modeled releases into the Savannah River based only on environmental monitoring data for ^{90}Sr, and not on mixed ^{89,90}Sr activity or on unidentified beta-gamma activity (3).

The data sets used to develop the two point-of-release data files for ^{90}Sr are listed in Table C-16. Each data set consisted of all indicated activity that was annually released into streams, seepage basins, and containment basins.

Table C-16 Data Sets Used for ^{90}Sr

^{90}Sr Point-of-Release Data Used to Determine ^{90}Sr Discharge to Savannah River (Equation C.3-5)	^{90}Sr Point-of-Release Data Used for Adjustment Factors (Equation C.3-6)
^{90}Sr data	^{90}Sr data
^{90}Sr activity partitioned from ^{89,90}Sr data	^{90}Sr activity partitioned from ^{89,90}Sr data
Unidentified beta-gamma activity	

The Phase III assumptions and procedures for partitioning aggregated radionuclide quantities into individual radionuclides are in Section C.2 of this appendix.

C.3.4.2 Savannah River Flow Rate

Annual flow rates for the Savannah River were obtained from two sources—the United States Geological Survey (USGS) and Hayes and Marter (21,22). For the years 1954 through 1969, and for the years 1983 through 1992, the USGS provided flow rates for the Savannah River as measured at Burtons Ferry Bridge (U.S. Highway 301) near Millhaven, Georgia (21). This monitoring station is located about 500 feet downstream of the bridge on U.S. Highway 301 linking Screven County, Georgia, with Allendale County, South Carolina. Hence, it is downstream of all surface water discharge points into the Savannah River.

No information was available from the USGS for this monitoring station for the years 1970 through 1982. For these years, flow rates were projected from flow rates measured at Augusta, Georgia. The projected flow rates were obtained from Hayes and Marter (22). These authors determined a correlation coefficient of 0.98 when data for the Burtons Ferry Bridge and Augusta monitoring stations were fitted to the following equation: $y = mx + b$

Where:

y is the projected flow rate at Burtons Ferry Bridge.
x is the measured flow rate at Augusta.

m and b are coefficients obtained from the regression analysis (m = 1.1486 ± 0.0330 and b = -202 ± 298 (22).

The flow rates assumed for this report are listed in Table C-17 in units of cubic feet per second (cfs). Also, the Savannah River volumes used for this report are listed as calculated assuming 365 days per year (except for 366 days per year every leap year), and as converted to liters.

Table C-17 Savannah River Flow Rates and Annual Volumes as Determined for Burtons Ferry Bridge (U.S. Highway 301)

Year	Leap Year	Annual Mean Value* (cfs)	Water Volume (Liter)	Year	Leap Year	Annual Mean Value* (cfs)	Water Volume (Liter)
1954		7,382	$6.60x10^{+12}$	1974		11,101	$9.93x10^{+12}$
1955		5,974	$5.34x10^{+12}$	1975		15,408	$1.38x10^{+13}$
1956	L	6,309	$5.66x10^{+12}$	1976	L	13,914	$1.25x10^{+13}$
1957		8,312	$7.43x10^{+12}$	1977		11,646	$1.04x10^{+13}$
1958		11,038	$9.87x10^{+12}$	1978		10,522	$9.41x10^{+12}$
1959		9,748	$8.72x10^{+12}$	1979		13,252	$1.18x10^{+13}$
1960	L	13,112	$1.18x10^{+13}$	1980	L	13,201	$1.18x10^{+13}$
1961		10,909	$9.75x10^{+12}$	1981		6,599	$5.90x10^{+12}$
1962		10,580	$9.46x10^{+12}$	1982		7,169	$6.41x10^{+12}$
1963		11,138	$9.96x10^{+12}$	1983		12,348	$1.10x10^{+13}$
1964	L	20,497	$1.84x10^{+13}$	1984	L	12,759	$1.14x10^{+13}$
1965		12,785	$1.14x10^{+13}$	1985		7,167	$6.41x10^{+12}$
1966		11,175	$9.99x10^{+12}$	1986		6,175	$5.52x10^{+12}$
1967		10,573	$9.45x10^{+12}$	1987		8,955	$8.01x10^{+12}$
1968	L	9,624	$8.63x10^{+12}$	1988	L	5,364	$4.81x10^{+12}$
1969		10,945	$9.79x10^{+12}$	1989		7,966	$7.12x10^{+12}$
1970		8,208	$7.34x10^{+12}$	1990		11,860	$1.06x10^{+13}$
1971		10,686	$9.55x10^{+12}$	1991		11,670	$1.04x10^{+13}$
1972	L	11,235	$1.01x10_{+13}$	1992	L	11,860	$1.06x10^{+13}$
1973					14,431	$1.29x10^{+13}$	

* Flow rate from USGS Station ID: 02197500.

C.3.4.3 Effect of the Distribution Coefficient, K_d, On Release Estimates

The soil-to-water distribution coefficient, K_d, is a measure of the partitioning between solid and liquid phases that a radionuclide experiences as it passes through environmental media. As radioactive contaminants move through the soils, sediments, and the swamp at the SRS site, they are attracted to various surfaces. This attraction results in a delay (retardation) of the transport of the contaminant through

the system, relative to the flow of water. The amount of a particular radionuclide that will reach the Savannah River will be, in part, a reflection of this retardation phenomenon and its radiological half-life.

Even though the K_d values for all of the radionuclides considered in this analysis span many orders of magnitude, the radionuclides have been combined into three groups, based upon their K_d (units of milliliters to grams [mL/g]):

1. $K_d < 10$.
2. $10 < K_d < 1{,}000$.
3. $K_d > 1000$.

These groups correspond to the nominal K_d values used in the Phase II modeling: 0, 100, and 10,000 mL/g, respectively. All radionuclides assigned to a particular group were assigned the same annual adjustment factor calculated for that group. Table C-18 summarizes the grouping.

Table C-18 Grouping of Radionuclides According to K_d Values

Radionuclide	Soil-to-Water Distribution Coefficient, K_d (mL/g)			Adjustment Factor‡
	Phase II Value	Soil Value*	Swamp Value†	
^{3}H	**0**	0		^{3}H
$^{129,131}I$		1.55		^{3}H
^{99}Tc		2.49		Hydrogent-3
^{35}S		7.5		^{3}H
$^{103,106}Ru$		55		^{90}Sr
^{60}Co		60		^{90}Sr
$^{89,90}Sr$	**100**	3,040	1,676	^{90}Sr
^{95}Nb		160		^{90}Sr
^{32}P		173		^{90}Sr
^{65}Zn		200		^{90}Sr
$^{141,144}Ce$		490	255	^{90}Sr
^{95}Zr		600		^{90}Sr
U		1,000	170	^{90}Sr
Pu		4,100		^{137}Cs
$^{134,137}Cs$	**10,000**	59		^{137}Cs

*Source: Kaplan, 2003 (23).
†Source: Kaplan and Serkiz, 2000 (24).
‡The annual adjustment factors are listed in Table C-20.

In reviewing the K_d's assumed for Phase II and used to group radionuclides by annual adjustment factor, the K_d assumed for ^{90}Sr appeared to be low compared to other values cited in the literature, and the K_d assumed for ^{137}Sc appeared to be high. K_d values used for the Phase II modeling were orders of magnitude different from site-specific values recently reported by the SRS (23). In the Phase II modeling, a range of K_ds having a median value of 10,000 mL/g were used for cesium, whereas the range of values used for strontium had a median value of 100 mL/g. Median K_ds reported by Kaplan et al for agricultural soils are

59 mL/g for cesium and 3,041 mL/g for strontium, respectively (23). However, another report by Kaplan reports K_d values that appear to be more appropriate for the swampy soils at issue in the holdup of radionuclides released from the SRS. For example, a "reasonably conservative" value cited for the strontium K_d in the swamp was 1,676 mL/g (24). But, without further explanation of and examination of the Phase II model, it is difficult to characterize the apparent reversal of cesium and strontium K_d values. Other uncertainties, such as measurement uncertainty and uncertainty in the release from the swamp during flooding, were also considered in the estimation of releases for ^{3}H, ^{90}Sr, and ^{137}Cs. These uncertainties are not the same from one radionuclide to another.

C.3.4.4 Adjustment Factor Development

Adjustment factors were calculated by dividing the median values of the Phase II release model by the point-of-release inventories discussed in Sections C.3.3.2 and C.4.2. Table C-19 lists these values and inventories. Table C-20 lists the resultant adjustment factors.

Note that the adjustment factor initially calculated for ^{3}H in year 1954 was 20.8814, which is 3 times larger than the next highest ^{3}H adjustment factor and about 20 times larger than the median value of all adjustment factors over 39 years. This large factor was calculated because of the inclusion of estimated releases from D-Area in the Phase II modeling of ^{3}H release to the Savannah River. In 1954, 17,530 curies of ^{3}H from D-Area was assumed to be released to a stream (3). This D-Area release, however, is not documented in Cummins et al (4).

In Phase III, ^{3}H release from D-Area was thought to be the only reason for such a large adjustment factor in 1954. Consequently, the other radionuclides in this group (i.e. $^{129,131}I$; ^{99}Tc; and ^{35}S) should not be similarly adjusted as this could result in significant overestimation of their true releases. Another reason for not using such a large adjustment factor for the ^{3}H group in 1954 was that the functionality of D-Area was heavy water rework, and site effluent release data (4) did not show that iodine, technetium, and sulfur were released from that facility in 1954. The factor 1.0 was thus used for the ^{3}H group in 1954 to avoid overestimation of other radionuclide releases.

Table C-19 Phase II Median Values and Point of Release Inventories Used for Adjustment Factors

Year	Point of Release Inventories			Phase II Median Values		
	^{3}H	^{137}Cs	^{90}Sr	^{3}H	^{137}Cs	^{90}Sr
1954	$3.66x10^{+02}$	$1.80x10^{-01}$	$3.90x10^{-02}$	$7.64x10^{+03}$	$1.41x10^{-01}$	$4.13x10^{-02}$
1955	$5.87x10^{+03}$	1.37	$8.16x10^{-01}$	$1.32x10^{+04}$	$2.65x10^{-01}$	$1.45x10^{-01}$
1956	$9.39x10^{+03}$	3.43	$1.04x10^{+01}$	$1.50x10^{+04}$	1.11	$3.60x10^{-01}$
1957	$2.24x10^{+04}$	$8.40x10^{+02}$	$1.96x10^{+02}$	$2.16x10^{+04}$	1.16	1.54
1958	$2.88x10^{+04}$	$1.04x10^{+02}$	$1.58x10^{+01}$	$2.88x10^{+04}$	9.51	$8.30x10^{-01}$
1959	$5.17x10^{+04}$	$4.14x10^{+01}$	$2.18x10^{+01}$	$6.29x10^{+04}$	3.59	1.80
1960	$6.09x10^{+04}$	$4.36x10^{+01}$	$2.36x10^{+01}$	$6.98x10^{+04}$	7.60	$1.76x10^{+01}$
1961	$8.11x10^{+04}$	$4.06x10^{+01}$	9.85	$8.28x10^{+04}$	$1.03x10^{+01}$	4.22
1962	$7.23x10^{+04}$	$1.03x10^{+02}$	$1.04x10^{+01}$	$6.47x10^{+04}$	$1.92x10^{+01}$	6.78
1963	$9.66x10^{+04}$	$1.23x10^{+02}$	$2.10x10^{+01}$	$9.69x10^{+04}$	$1.68x10^{+01}$	$1.07x10^{+01}$
1964	$1.17x10^{+05}$	$1.30x10^{+02}$	$1.41x10^{+01}$	$1.21x10^{+05}$	$5.15x10^{+01}$	$1.13x10^{+01}$
1965	$1.28x10^{+05}$	$5.56x10^{+01}$	$1.17x10^{+01}$	$1.06x10^{+05}$	$2.35x10^{+01}$	5.22

Year	Point of Release Inventories			Phase II Median Values		
	^{3}H	^{137}Cs	^{90}Sr	^{3}H	^{137}Cs	^{90}Sr
1966	$1.33x10^{+05}$	$5.36x10^{+01}$	6.12	$9.56x10^{+04}$	$2.72x10^{+01}$	4.46
1967	$1.04x10^{+05}$	$6.87x10^{+01}$	6.72	$8.75x10^{+04}$	$3.80x10^{+01}$	4.82
1968	$1.07x10^{+05}$	$7.08x10^{+01}$	9.19	$8.39x10^{+04}$	$2.08x10^{+01}$	5.46
1969	$7.88x10^{+04}$	$5.14x10^{+01}$	$1.02x10^{+01}$	$7.64x10^{+04}$	$1.04x10^{+01}$	3.58
1970	$6.61x10^{+04}$	$4.43x10^{+01}$	7.26	$4.25x10^{+04}$	$1.02x10^{+01}$	3.89
1971	$4.47x10^{+04}$	$1.05x10^{+01}$	3.14	$4.44x10^{+04}$	1.69	3.81
1972	$6.09x10^{+04}$	9.14	1.25	$4.68x10^{+04}$	$6.28x10^{-01}$	1.92
1973	$8.69x10^{+04}$	7.48	$9.01x10^{-01}$	$6.10x10^{+04}$	$4.44x10^{-01}$	2.07
1974	$5.61x10^{+04}$	8.09	$4.27x10^{-01}$	$5.41x10^{+04}$	$7.01x10^{-01}$	1.72
1975	$5.15x10^{+04}$	7.75	$9.12x10^{-01}$	$4.93x10^{+04}$	$3.61x10^{-01}$	1.46
1976	$7.32x10^{+04}$	8.94	$4.76x10^{-01}$	$4.64x10^{+04}$	$1.46x10^{-01}$	1.18
1977	$4.59x10^{+04}$	6.58	$5.55x10^{-01}$	$4.03x10^{+04}$	$2.45x10^{-01}$	$9.04x10^{-01}$
1978	$3.76x10^{+04}$	$1.04x10^{+01}$	2.06	$3.55x10^{+04}$	$1.04x10^{-01}$	$6.20x10^{-01}$
1979	$4.52x10^{+04}$	6.27	2.68	$2.84x10^{+04}$	$1.04x10^{-01}$	$6.24x10^{-01}$
1980	$3.54x10^{+04}$	1.83	$1.55x10^{-01}$	$3.00x10^{+04}$	$7.72x10^{-02}$	$5.05x10^{-01}$
1981	$3.94x10^{+04}$	2.81	1.04	$2.51x10^{+04}$	$1.16x10^{-01}$	$4.61x10^{-01}$
1982	$3.15x10^{+04}$	2.85	$6.98x10^{-01}$	$3.08x10^{+04}$	$8.36x10^{-02}$	$3.95x10^{-01}$
1983	$4.06x10^{+04}$	3.43	$2.35x10^{-01}$	$3.24x10^{+04}$	$7.74x10^{-02}$	$3.84x10^{-01}$
1984	$3.58x10^{+04}$	6.13	$9.44x10^{-02}$	$3.23x10^{+04}$	$1.22x10^{-01}$	$4.25x10^{-01}$
1985	$3.40x10^{+04}$	6.23	$1.70x10^{-01}$	$2.21x10^{+04}$	$5.14x10^{-02}$	$2.25x10^{-01}$
1986	$4.52x10^{+04}$	$1.13x10^{+01}$	$1.28x10^{-01}$	$2.21x10^{+04}$	$5.51x10^{-02}$	$3.26x10^{-01}$
1987	$2.75x10^{+04}$	$1.54x10^{+01}$	$5.69x10^{-02}$	$2.04x10^{+04}$	$1.98x10^{-01}$	$3.63x10^{-01}$
1988	$1.44x10^{+04}$	6.39	$4.40x10^{-02}$	$1.82x10^{+04}$	$2.92x10^{-01}$	$2.63x10^{-01}$
1989	$3.97x10^{+03}$	$2.10x10^{-01}$	$1.68x10^{-02}$	$1.76x10^{+04}$	$1.82x10^{-01}$	$2.56x10^{-01}$
1990	$2.62x10^{+03}$	$4.83x10^{-02}$	$4.28x10^{-01}$	$1.53x10^{+04}$	$4.29x10^{-02}$	$5.41x10^{-01}$
1991	$1.06x10^{+04}$	$2.64x10^{-02}$	$8.91x10^{-02}$	$2.64x10^{+04}$	$2.57x10^{-02}$	$1.14x10^{-01}$
1992	$2.00x10^{+03}$	$1.02x10^{-01}$	$7.86x10^{-01}$	$1.30x10^{+04}$	$8.46x10^{-02}$	$8.84x10^{-01}$

Table C-20 Liquid Effluent Adjustment Factors by Radionuclide Group and Year

Year	Group 1 ^{3}H	Group 2 ^{90}Sr	Group 3 ^{137}Cs	Year	Group 1 ^{3}H	Group 2 ^{90}Sr	Group 3 ^{137}Cs
1954	1.0000*	1.0582	0.7813	1976	0.6346	2.4755	0.0163
1955	2.2482	0.1773	0.1927	1977	0.8775	1.6271	0.0372
1956	1.6024	0.0345	0.3224	1978	0.9418	0.3006	0.0101
1957	0.9645	0.0079	0.0014	1979	0.6284	0.2326	0.0165
1958	1.0004	0.0527	0.0918	1980	0.8490	3.2573	0.0423
1959	1.2175	0.0824	0.0867	1981	0.6378	0.4416	0.0412
1960	1.1465	0.7467	0.1744	1982	0.9787	0.5655	0.0294
1961	1.0203	0.4284	0.2528	1983	0.7962	1.6370	0.0226
1962	0.8954	0.6499	0.1871	1984	0.9031	4.5042	0.0200
1963	1.0024	0.5079	0.1362	1985	0.6496	1.3263	0.0083
1964	1.0340	0.8037	0.3964	1986	0.4893	2.5464	0.0049
1965	0.8273	0.4443	0.4223	1987	0.7426	6.3833	0.0128
1966	0.7190	0.7290	0.5078	1988	1.2619	5.9846	0.0456
1967	0.8421	0.7171	0.5530	1989	4.4292	15.1968	0.8696
1968	0.7872	0.5945	0.2933	1990	5.8478	1.2652	0.8899
1969	0.9703	0.3495	0.2026	1991	2.5013	1.2751	0.9724
1970	0.6430	0.5361	0.2313	1992	6.4926	1.1252	0.8279
1971	0.9923	1.2122	0.1611				
1972	0.7686	1.5321	0.0687	**Mean**	1.3325	1.7623	0.2339
1973	0.7021	2.3023	0.0593	**Median**	0.9589	0.8037	0.0918
1974	0.9644	4.0233	0.0866	**Max**	6.4926	15.1968	0.9724
1975	0.9589	1.5961	0.0467	**Min**	0.4893	0.0079	0.0014

*Originally this value was calculated as 20.8814.

C.3.5 Analysis of Adjustment Factor Approach

Clearly, the use of these adjustment factors provided only an approximate estimate of the loss of contamination during transport from the point of release to the Savannah River. Because of differences in the chemistry and the half-lives of each radionuclide, the use of a K_d-based adjustment to the releases can result in over-estimation, as well as underestimation, of the releases to the Savannah River. Nonetheless, because the Phase II modeling considers environmental depletion and delay, as well as measurement uncertainty, the ratio of the modeled annual releases from the site to the recorded annual releases from all SRS facilities represents the net effect of the modeled factors. The resultant medians (50th percentile)

from the Phase II model were taken to be a representative means for extrapolating the Phase II model to the radionuclides that were not modeled explicitly in Phase II.

To check the decision to extrapolate releases to the Savannah River using adjustment factors, two large-scale comparisons were made. First, the Phase II modeled release data were compared to SRS point-of-release data for the radionuclides ^{3}H, ^{90}Sr, and ^{137}Cs. Second, Savannah River concentrations as calculated using the Phase III extrapolated releases were compared against available monitoring information for four radionuclides.

C.3.5.1 Comparison of Phase II Modeled Releases to SRS Point-of-Release Data

For ^{3}H, ^{90}Sr, and ^{137}Cs, the annual median (50th percentile) of the Phase II Savannah River release model was compared with the annual point-of-release estimates for these radionuclides as compiled from Category 1 and 3 releases documented in Cummins, 1991 (4). Table C-21 summarizes the results of this comparison.

Table C-21 Comparison of Phase II Median Releases to Savannah River with SRS Point-of-Release Data (Categories 1 and 3 of Cummins, 1991 [4])

Radionuclide	Range of Median of Model to Point-of-Release Ratios	Mean, Median of Model to Point-of-Release Ratios
^{3}H	0.379 – 20.881	1.228*
^{90}Sr	0.008 – 6.383	1.379
^{137}Cs	0.001 – 0.972	0.234

*This ratio does not include 1954 estimates for ^{3}H.

It was expected that the median values estimated by the Phase II surface water model should be approximately equal to, or smaller than, the total releases reported by the SRS. With a few exceptions, this was the case. An example exception is the 1954 ratio of the estimated median release to the total ^{3}H release. (The ratio is 20.881 as noted in Section C.4.4.) The Phase II report stated that releases were adjusted if it was believed that reported releases were too low (3). This extremely high ratio is probably a reflection of such an adjustment because reporting of releases in the early years of operations was not as accurate as in later years.

Figure C-2 presents the ratios as a function of time. As depicted on Figure C-2, the ratios are dramatically higher during the last years of operations. These later years may reflect that operations in general were reduced, but there were still releases from the site. In addition, Figure C-2 shows that the variations in time are significant. This is due, in part, to the model that increased releases in years having large spring floods to account for the remobilization of radionuclides stored in previous years in the sediments and biota of the swamp. For this reason, annual adjustment factors are preferable to an average adjustment factor covering all years.

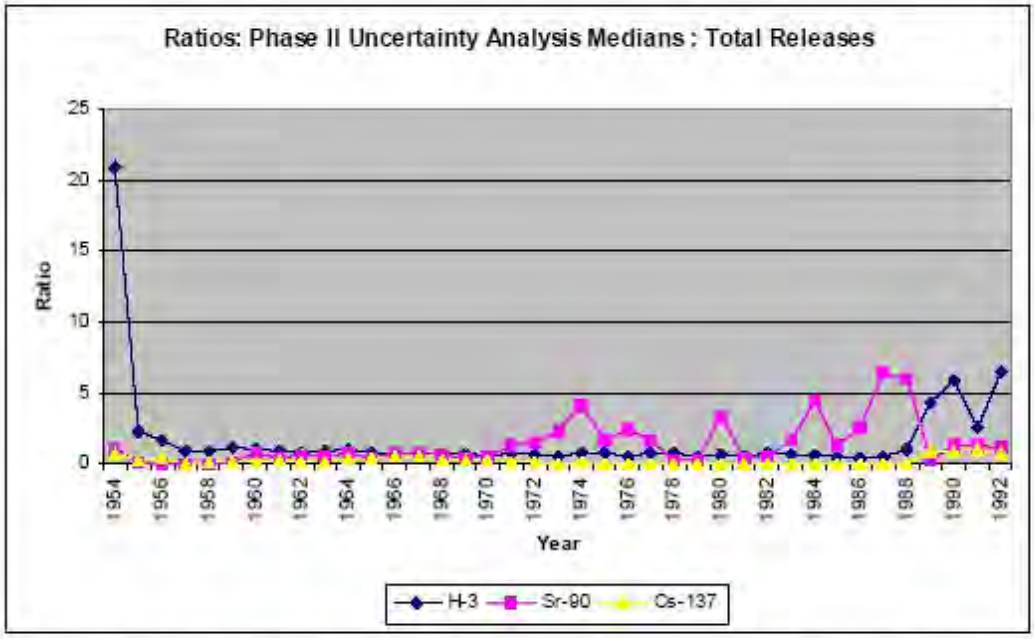

Figure C-2 Annual Ratios of Phase II Median of Savannah River Release Model to SRS Point-of-Release Data

C.3.5.2 Comparison of Modeled to Measured Concentrations

It is instructive to compare the modeled and measured concentrations in the Savannah River. Two sets of modeled radionuclide concentrations were prepared for ^{3}H, ^{90}Sr, ^{137}Cs, and ^{131}I —the four radionuclides for which monitoring data in the Savannah River were generally available. These modeled concentration sets were developed using calculated concentrations based on the following:

- Releases to streams and migration from seepage basins.
- Application of the Phase III model.

These comparisons are not definitive for the following reasons:

- The measured concentrations are highly variable in time and may not be representative of an annual mean value.
- The measured concentrations were frequently made at or near the limits of detection for the instruments used.
- The limits of detection changed in time.
- Only a few radionuclides were measurable for a significant portion of the 39-year study period.
- As described in the Phase II report, the modeled releases are uncertain because the exact behavior of the sediment, swamp, river, streams, and biota has not been precisely modeled and probably cannot be precisely modeled.

Nevertheless, the modeled releases provide information that can be used to judge the efficacy of the Phase III approach for estimating radionuclide release to the Savannah River.

The first concentration set was comprised essentially of Category 1 and Category 2 releases as described in Section C.4.1. These releases were divided by the Savannah River flow (Section C.4.2) as determined at the Burtons Ferry Bridge downstream of the SRS where Highway 301 crosses the Savannah River. This concentration set represents essentially no consideration of holdup in site streams and the Savannah River Swamp before discharge to the Savannah River (no use of adjustment factors). The second concentration set consisted of those concentrations for the four radionuclides that were determined using the Phase III release model described in Section C.3.3.2.

These modeled concentrations were compared against measured concentrations in the Savannah River as obtained at the Highway 301 bridge.[10] These measurements represent annual averages. For the years 1964 through 1992, the concentrations were obtained from SRS environmental reports (25-49). For the years 1960 through 1963, no environmental reports were published. For these years, measured water concentrations were obtained from Health Physics Regional Monitoring Semiannual Reports or Semiannual Progress Reports (50-55).

Figures C-3 and C-4 present the results of this comparison. For ^{3}H (Figure C-3), the two sets of modeled concentrations generally resulted in smaller annual concentrations than those measured at U.S. Highway 301. The difference between the modeled and measured concentrations is especially seen from 1960 through 1975; thereafter, agreement is good. For many of the years between 1960 through 1975, the Phase III set of concentrations is slightly larger than the set comprising release to streams and migration from seepage basins.

For ^{90}Sr (Figure C-4), except for the years 1961 and 1962, there appears to be reasonable consistency between the modeled and measured sets of concentrations. However, for many years (particularly in the 1960's), the concentrations as used in the Phase III study are larger than those comprising the set representing release to streams and migration from seepage basins.

For ^{137}Cs (Figure C-5), except for the years 1960 through 1963, and 1978, there appears to be a reasonable level of consistency between the Phase III model and measured concentrations. Note that the modeled concentrations considering release to streams and migration from seepage basins are larger than the Phase III modeled concentrations and measured concentrations for most of the 1960's.

For ^{131}I (Figure C-6), there is little difference between either set of modeled concentrations. Both modeled sets appear to be reasonably consistent with measured concentrations.

As discussed above, these comparisons are not definitive. Nonetheless, these do appear to provide support to the conclusion that the modeling approach used for the Phase III study was a reasonable way to proceed.

[10] SRS environmental reports refer to this monitoring location as the River-10 location. This location is at Savannah River mile 120.

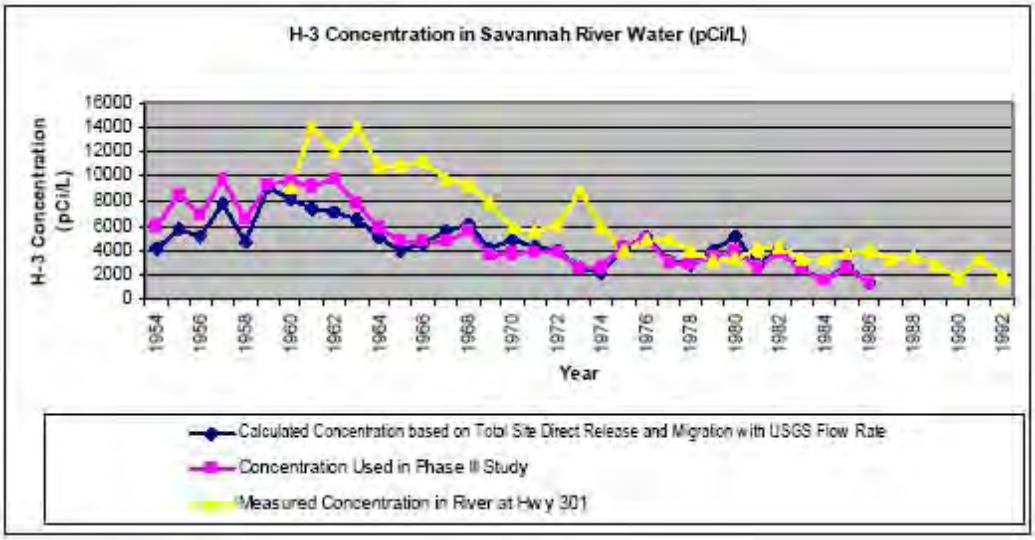

Figure C-3 ^{3}H Concentrations in Savannah River

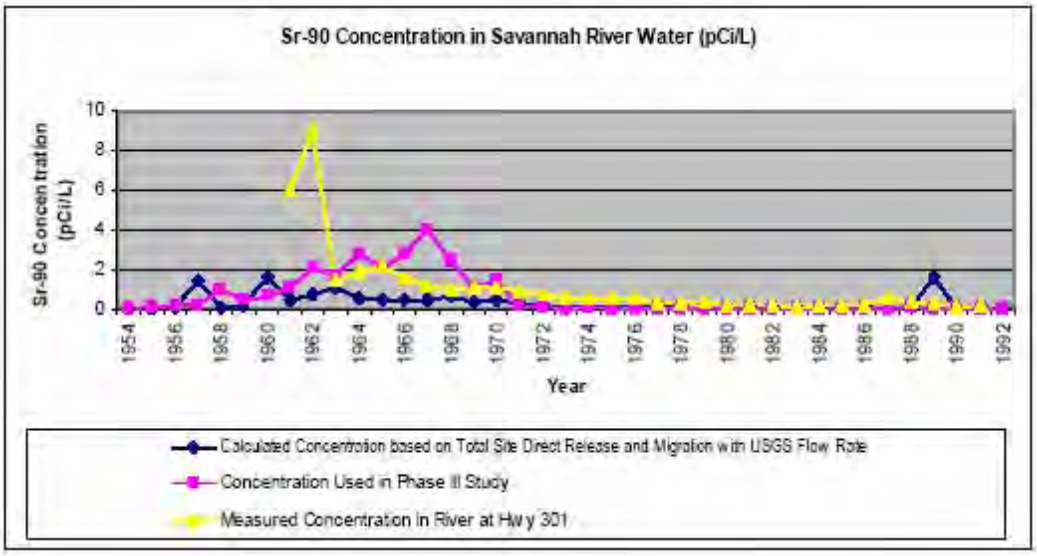

Figure C-4 ^{90}Sr Concentrations in Savannah River

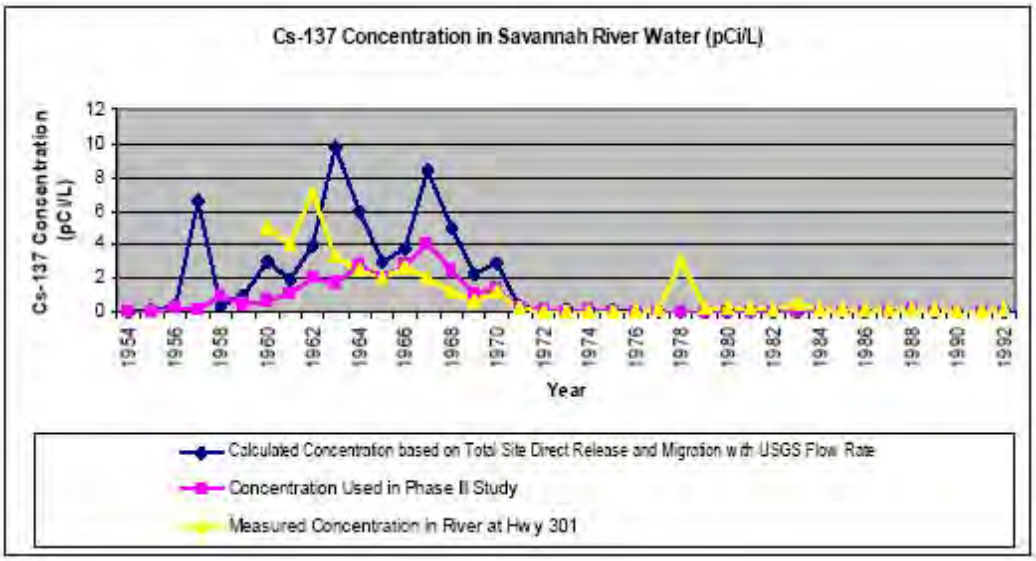

Figure C-5 ^{137}Cs Concentrations in Savannah River

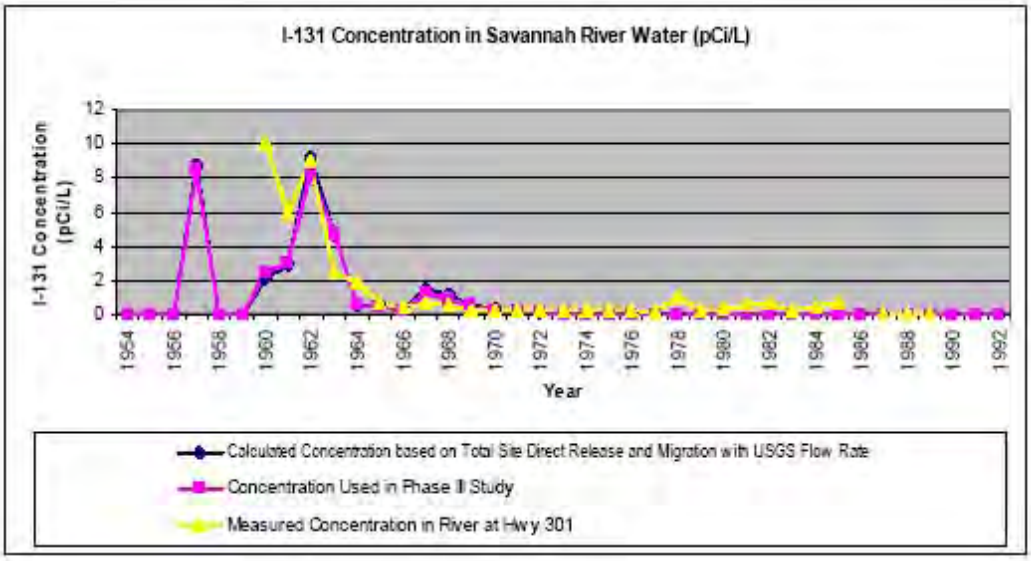

Figure C-6 ^{131}I Concentrations in Savannah River

C.4 Comparison of Phase II and Phase III Source Terms for Air Release

The purpose of this appendix section is to record the similarities and differences between the Phase II and Phase III estimates of release of radionuclides to the air. Where there are significant differences, the rationale for the differences is stated.

The Phase II report presents data about release to air at several levels of detail. For example, the total releases for a 36-year period of SRS operation are considered for the screening analysis described in Chapter 3, while annual releases to air for particular isotopes and facilities are presented in Chapter 4 (3). In addition, supplementary data are provided in Excel spreadsheets that are linked to the electronic version of the report. Some of these spreadsheets provide releases by facility on a weekly basis.

For Phase III of the SRS Dose Reconstruction Project, annual releases to air are compiled for 16 radionuclides for a 39-year period of SRS operation (see Appendix B). The radionuclides are assumed to be released from four virtual sources as described in Appendix A. For ^{3}H and iodine isotopes, releases are complied according to the assumed chemical form of these isotopes when released.

Data used as input to the Phase III dose and cancer risk assessment were checked in accordance with a Quality Assurance Program. However, to assure an appropriate degree of consistency between the Phase II report and Phase III assumptions, the total releases for all significant radionuclides were compared. This comparison was made more difficult by the large amount of data in the Phase II report and the different ways in which it was employed. For example, the total releases used in Chapter 3 of the Phase II report to screen radionuclides were largely raw releases based on primary sources (e.g., Cummins, 1991[4]). (Section C.1 of this appendix summarizes the Phase II screening assessment.) In Chapter 4, releases were modified for some radionuclides to account for errors in instrumentation and problems with undersampling releases (3). As a result, the total and annual release rates recommended in Phase II are substantially larger than those given in the primary references for some radionuclides (e.g., ^{131}I, total plutonium, and uranium) (3).

In the following discussion, the total releases used for the Phase II screening assessment are compared with the total releases used for Phase III of the SRS dose reconstruction project. The Phase II information was obtained from the Rad-screening.xls Excel worksheet which is linked to the electronic version of the Phase II report. After comparing the releases, the reasons for significant differences are discussed.

Table C-22 presents the total releases to air over 39 years (1954-1992) from the four virtual sources considered in Phase III. These total releases have been summed from annual releases from each virtual source using the four Excel spreadsheets that were used as input to the dose and cancer risk assessments performed for Phase III. These spreadsheets are AB5492A.xls, AG5492B.xls, AO5492.xls, and AQre92A.xls.

Table C-23 presents the total release into the air that was used in the Phase II screening assessment as well as the total release used for the Phase III source term. The Phase II totals are over 36 years while the Phase III totals are over 39 years. Also, many of the radionuclides are aggregated groups of radionuclides (e.g., ^{89,90}Sr). The Phase II release estimates were provided in terms of these radionuclide groups. The totals provided in the Phase III column in Table C-23 are the sums of the activities for the individual isotopes listed in Table C-22 (e.g., the ^{89,90}Sr value [$4.7 \times 10^{+1}$]in the Phase III column in Table C-23 is the sum of the ^{89}Sr [1.15] and ^{90}Sr [$4.58 \times 10^{+1}$]) values in Table C-22.

Table C-22 Total 39-Year Release to Air (Ci) for Phase III Assessment by Virtual Source

Radionuclide*	C-, K-, L-Reactors, D-Area, CMX-TNX†	F- and H-Areas†	A- & M-Areas & SRL	P- & R-Reactors†	Total from All Virtual Sources
^{241}Am	0	$5.88x10^{-3}$	$2.61x10^{-7}$	0	$5.88x10^{-3}$
^{41}Ar	$3.91x10^{+6}$	0	0	$2.45x10^{+6}$	$6.36x10^{+6}$
^{14}C	$1.12x10^{+3}$	$1.24x10^{+3}$	0	$6.12x10^{+2}$	$2.97x10^{+3}$
^{137}Cs	$5.15x10^{-5}$	3.51	$2.65x10^{-3}$	$7.03x10^{-6}$	3.51
^{3}H	$5.37x10^{+6}$	$8.47x10^{+6}$	$1.84x10^{+4}$	$1.91x10^{+6}$	$1.58x10^{+7}$
^{3}H-EL	0	$9.35x10^{+6}$	0	0	$9.35x10^{+6}$
^{129}I-E	0	1.13	0	0	1.13
^{129}I-O	0	4.54	0	0	4.54
^{131}I-E	$1.78x10^{+2}$	$9.30x10^{+3}$	6.36	$2.02x10^{+2}$	$9.69x10^{+3}$
^{131}I-O	$7.61x10^{+1}$	$3.92x10^{+4}$	0	$8.66x10^{+1}$	$3.94x10^{+4}$
^{238}Pu	0	2.08	0	0	2.08
^{239}Pu	$1.57x10^{-4}$	$1.32x10^{+1}$	$3.40x10^{-3}$	$4.63x10^{-5}$	$1.32x10^{+1}$
^{106}Ru	$2.03x10^{-5}$	$1.58x10^{+2}$	0	$1.02x10^{-5}$	$1.58x10^{+2}$
^{89}Sr	0	1.15	0	0	1.15
^{90}Sr	$9.33x10^{-2}$	$4.4x10^{+1}$	1.25	$9.28x10^{-2}$	$4.58x10^{+1}$
^{234}U	0	1.13	$1.59x10^{-4}$	0	1.13
^{235}U	0	$5.09x10^{-2}$	$7.23x10^{-6}$	0	$5.10x10^{-2}$
^{236}U	0	$7.93x10^{-2}$	0	0	$7.93x10^{-2}$
^{238}U	0	2.25	1.55x10-4	0	2.25

*^{3}H means tritium released in an oxide form as in evaporated water, while ^{3}H-EL means tritium released in an elemental form. Similarly ^{129}I-E and ^{131}I-E mean iodine isotopes released in an elemental form, while ^{129}I-O and ^{131}I-O mean iodine released in an organic form.
†Includes evaporated ^{3}H from reactor and separations areas seepage basins—see Appendix A.

In addition, the Phase II totals listed in Table C-23 are those obtained from the Excel spreadsheet supporting the Phase II screening assessment (Rad-screening.xls). The values in this spreadsheet do not in all cases match those provided in Table 3A-2a of the Phase II report (3).

Table C-23 lists the numerical difference between the Phase III values and Phase II values as well as the percent difference (determined as: (Phase III – Phase II) x 100 / Phase III). An X marking the Note column means that further discussion is provided below.

Table C-23 Comparison of 39-Year Phase III Total Releases (Ci) to 36-Year Phase II Releases Used for Phase II Screening Assessment (Ci)

Radionuclide	Phase III Total from All Virtual Sources	Phase II Total Used for Screening Assessment	Difference (Phase III – Phase II)	Percent Difference (Phase III –Phase II) x 100/Phase III	Note
^{241}Am	$5.88x10^{-3}$	0	$+ 5.88x10^{-3}$	+ 100	X
^{41}Ar	$6.36x10^{+6}$	$6.40x10^{+6}$	$- 4.00x10^{+4}$	- 0.638	
^{14}C	$2.97x10^{+3}$	$3.00x10^{+3}$	$- 3.00x10^{+1}$	- 0.901	
^{137}Cs	3.51	3.50	$+ 1.00x10^{-2}$	+ 0.316	
^{3}H	$2.51x10^{+7}$	$2.45x10^{+7}$	$+ 6.00x10^{+5}$	+ 2.44	
^{129}I	5.67	5.70	$- 3.00x10^{-2}$	- 0.448	X
^{131}I	$4.91x10^{+4}$	$2.50x10^{+3}$	$+ 4.66x10^{+4}$	+ 94.9	X
^{238}Pu	2.08	1.00	+ 1.08	+ 51.8	X
^{239}Pu	$1.32x10^{+1}$	3.5	+ 9.70	73.6	X
^{103,106}Ru *	1.58x10+2	1.70	$+ 1.56x10^{+2}$	98.9	X
^{89,90}Sr *	4.70x10+1	1.54	$+ 4.55x10^{+1}$	96.7	X
U*	3.51	1.00	+ 2.51	71.5	X

*In the Phase II study, ^{103,106}Ru was screened assuming that all activity was ^{106}Ru. ^{89,90}Sr activity was screened assuming that all activity was ^{90}Sr, and uranium activity was screened assuming that all activity was ^{235}U. For Phase III, activity reported as uranium was partitioned among the uranium isotopes (^{234}U, ^{235}U, ^{236}U, and ^{238}U) as discussed in Section C.2 of this appendix.

^{241}Am

The Excel spreadsheet summarizing the Phase II screening assessment (rad_screening.xls) is confusing regarding the analysis of ^{241}Am. This spreadsheet contains several separate tables. In the Level 1 screening table, there is no value placed in the column with the heading "Atmospheric Release Rate from SRS," "Ci/36 y." Table C-23 reflects this entry of zero. However, the next column in the Level 1 screening table with the heading "Ci/y" contains the value $5.60x10^{-03}$, which is converted in the next column to $2.07x10^{+08}$ Bq/y. This value is then combined with a hypothetical flow rate from a stack to calculate a concentration and then a screening value of 5.48 Sv. In the Level 2 screening table, the atmospheric release rate is given as $2.1x10^{+09}$ Bq/y with a corresponding screening value of 5.5 Sv. Thus, even though the Level 2 screening release rate is a factor of 10 larger, the screening value is the same. Because the air screening factor provided in NCRP Report No. 123 (p. 97 of NCRP 1996 [2]) is 1.0 for ^{241}Am for all air release pathways, the values in the Level 1 screening table are regarded as being consistent although the values in the Level 2 screening table have an anomalous release rate.

It appears to be more than a coincidence that the value ($5.60x10^{-03}$ Ci) listed for Ci/y in the Level 1 screening table is only slightly smaller than the total Phase III value over 39 years ($5.88x10^{-03}$ Ci). (Because the Level 1 screening was for only 36 years, we would expect that value to be slightly smaller.) In any event, the total ^{241}Am activity assumed in the Phase III source term is consistent with data from various site reports, including Cummins 1991 (4) and Carlton 1997 (9).

It is also interesting to note that if one divides the total Phase III ^{241}Am release (5.88×10^{-03} Ci) by 39 years, one arrives at an average release rate of approximately 1.51×10^{-04} Ci/y. This release rate is smaller by a factor of about 37 than the value stated in the Phase II Level 1 screening table (5.60×10^{-03}). Assuming this smaller release rate, the Level 1 screening value would also have been reduced by a factor of 37 (i.e., 0.15 Sv). This screening value would not have exceeded 0.1 percent of the total screening value as summed over all radionuclides. This value of 0.1 percent was the criterion used in Phase II to determine key radionuclides for further analysis.

^{131}I and ^{129}I

The Phase III value is about 20 times larger for ^{131}I than the Phase II screening assessment value. The reason for this is that after performing the screening assessment, the Phase II study further investigated releases of ^{131}I from SRS facilities. In Chapter 4-2 of the Phase II report, it is argued that iodine releases were underestimated due to limitations of the sampling and detection equipment (3). A model to account for these uncertainties was constructed and the results were quantified in a supplemental Excel spreadsheet linked to the Phase II report (Revised_I-131_Releases(F,H).xls). Median values (50th percentile) from these increased estimates of ^{131}I releases sum to over 48,000 Ci from the F- and H-Separations areas. These increased releases were then added to the modified ^{131}I releases from the reactors (Phase II supplemental spreadsheet Est_I-131_Releases_(Reactors).xls). For Phase III, annual ^{131}I release rates were used that were consistent with the modified annual release rates developed in Chapter 4-2 of Phase II rather than the annual release rates used in the Phase II screening assessment. This accounts for the almost 20-fold increase in ^{131}I releases used for the Phase III calculations.

It is also interesting to note the following statement from p. 4.2-18 of the Phase II report:

> The revised estimates of ^{131}I releases have been criticized by SRS staff (56) because they found good agreement between environmental concentrations predicted using the originally reported release estimates for 1956 and contemporary environmental measurements. They also cited similar comparisons made in an earlier plant report (57). As was discussed above, in the 1950s, both the effluent and environmental concentrations of ^{137}I were estimated using sampling media that were not highly reliable. Uncertainties in meteorological modeling, even for flat terrain, are on the order of a factor of 3-4 without consideration of plume depletion. In view of the quality of both sets of measurements and the uncertainties involved, the comparisons between predicted and measured concentrations in 1956 are not conclusive. When Reinig made comparisons in 1959, he had no knowledge of the unreliability of the sampling systems.

Furthermore, it is interesting to note that the Phase II report made no similar adjustment to the ^{129}I releases, although it is expected that some of the same instrumentation and sampling issues would have applied to that isotope. Given the limited description of the model used in the Phase II report, it is not clear whether the large difference in decay constant between ^{131}I (half-life is 8.04 d) and ^{129}I (half-life is $1.57 \times 10^{+7}$ y) accounts for the application of the correction only to ^{131}I. For Phase III, the total ^{129}I releases are consistent with those recorded by the site and listed in the Phase II screening assessment.

^{238}Pu, ^{239}Pu, ^{235,238}U

Phase III values for plutonium and uranium isotopes are larger than comparable values from the Phase II screening assessment. After the Phase II screening assessment was performed, plutonium and uranium isotopes were adjusted from the screening values used in the Phase II report based on considerations articulated in Chapter 4-4 of Phase II. (The Phase II report accounted for uncertainties such as transmission line losses, filter efficiencies, and acute accidental releases.) The adjusted Phase II estimates of release of plutonium and uranium from the F- and H-Separations areas are provided in a Phase II

supplemental Excel spreadsheet (Estimated_Source_Term.xls). These estimates are listed as 5th, 50th, and 95th percentile values. The 50th percentile of the sum of total plutonium (^{238}Pu and ^{239}Pu) released from F- and H-Areas over 36 years was 15.2 Ci. The 50th percentile of the sum of total uranium released from F- and H-Areas over 36 years was 3.48 Ci.

The median (50th percentile) values from a Phase II supplemental Excel spreadsheet (Estimated_Source_Term.xls) were used as the bases for Phase III assessments of plutonium and uranium releases from the F- and H-Separation Areas. To this plutonium and uranium activity (which covered 1954 through 1989) was added small quantities of plutonium and uranium reported in SRS environmental reports for the years 1990 through 1992 (18-20). These releases were then partitioned into appropriate plutonium and uranium isotopes according to the isotopic partitioning considerations delineated in Section C.2 of this appendix. In addition, about 0.08 Ci of unidentified alpha activity was assumed to be ^{239}Pu.

^{103,106}Ru

The Excel spreadsheet linked to the electronic version of Phase II (Rad-Screening.xls) shows that the total release over 36 years as apparently used for ^{103,106}Ru was different for Steps One and Two of the Phase II screening assessment. For Step One of the assessment (Air Step-1 on the spreadsheet), releases over 36 years were given as 1.7 Ci (about 6.3x10^{+10} Bq). But for Step Two of the screening assessment (Air Step-2 on the spreadsheet), the release rate for ^{103,106}Ru is given as 1.6x10^{+11} Bq/y. If this value is multiplied by 36 (the number of years used by Phase II for screening) and divided by 3.7x10^{+10} to convert to Ci, the value is 155.7 Ci. This value is much larger than the 1.7 Ci listed in the Air Step-1 table on the worksheet. Furthermore, another Phase II Excel spreadsheet linked to Chapter 4-2 of Phase II (Ann_B-G_Part_Releases.xls) lists ^{103,106}Ru releases for F- and H-Canyons. The sum of these F- and H-Canyon releases is 158 Ci, which is consistent with the Air Step-2 table on the Rad-Screening.xls worksheet. Finally, Figure 4.2-15 of the Phase II report shows the time history of ruthenium releases. The values shown in that graph are clearly inconsistent with 1.7 Ci released. Therefore, if the entry from the Air Step-2 table equal to 158 Ci is used to represent the Phase II value, it will match up well with the Phase III release values.

^{89,90}Sr

The value compiled for ^{89}Sr plus ^{90}Sr for use in the Phase III dose reconstruction is similar to the 1.5 Ci used in the Phase II screening evaluation. However, as discussed in Section C.2 of this appendix, unidentified beta-gamma activity for Phase III was assumed to be ^{90}Sr. This activity was added to reported releases of ^{90}Sr and to ^{90}Sr activity determined from partitioning activity reported as ^{89,90}Sr in SRS reports. The additional ^{90}Sr activity resulting from adding the unidentified beta-gamma activity was about 45 Ci over the period of consideration.

C.5 Comparison of Phase II and Phase III Source Terms for Water Releases

The purpose of this appendix section is to record the similarities and differences between the Phase II and Phase III estimates of release of radionuclides to surface water. Where there are significant differences, the rationale for the differences is stated.

The Phase II report presents data on releases at several levels of detail. For example, total releases for a 36-year period of operation were considered for the screening analysis described in Chapter 3; annual values for a particular isotope and facility were presented in Chapter 5 (3). In addition, some of the spreadsheets in the supplementary data provided releases by facility on a weekly or monthly basis (3). Because of the approach adopted for the Phase III dose reconstruction, the liquid releases to two receiving

bodies of water are compiled by radionuclide. The two bodies of water represent locations for exposure to water released radionuclides for receptors in various receptor groups (scenarios).

The data used as input to Phase III of the SRS Dose Reconstruction Project was checked as part of a Quality Assurance Program. However, to assure appropriate agreement between the Phase II and Phase III reports, the total releases for all significant radionuclides were compared.

C.5.1 Background

A relatively simple model was used in Phase II to estimate the releases to the Savannah River for ^{3}H, ^{90}Sr, and ^{137}Cs. Because it was necessary to consider more radionuclides than the three that had been modeled in Phase II, a means to extend those considerations to additional radionuclides was sought. Direct modeling similar to that performed in Phase II was not possible because most of the concentrations of most radionuclides were below detectable limits at the Road A intersections. For this reason, the basis for the Phase II modeling was unavailable. Therefore, for Phase III, the Phase II modeling results for the three radionuclides were extrapolated to the additional radionuclides. Adjustment factors were developed for each year for three classes of radionuclides encompassing different ranges of K_d. These adjustment factors are the ratio of: (1) the median of the Phase II modeling results for each year, respectively, for ^{3}H, ^{90}Sr, and ^{137}Cs to (2) the annual activity released from SRS facilities into surface water, respectively, for ^{3}H, ^{90}Sr, and ^{137}Cs as determined at the point of release.

Liquid releases from the site were placed into the following three categories (4):

- Category 1 - Direct releases to onsite streams.
- Category 2 - Migration from seepage basins into onsite streams.
- Category 3 - Direct releases to seepage basins.

For Phase III, the annual sum of the Categories 1 and 3 releases were chosen as being representative of SRS releases to site streams. This had two implications: (1) the adjustment factors based on modeled releases of ^{3}H, ^{90}Sr, and ^{137}Cs used the sum of Categories 1 and 3 as the denominator of the adjustment factor, and (2) these adjustment factors were applied to the sum of Categories 1 and 3 for radionuclides having similar K_ds. Although these annual liquid releases for Categories 1 and 3 were derived from fundamental data (e.g., Cummins, 1991 [4]), they are consistent with the Phase II report.

C.5.2 Comparison of Phase III Releases with Phase II Screening Assumptions

Because of the approach adopted for Phase III of the SRS Dose Reconstruction Project, the releases to streams, seepage basins, and containment basins were compiled by radionuclide as point-of-release estimates. Two desirable checks place the Phase III analysis in context: (1) comparison of the point-of-release estimates used in Phase III to the screening values used in Phase II, and (2) comparison of the extrapolated releases used in Phase III to the screening assessment values used in Phase II. Table C-24 makes these comparisons.

Table C-24 Comparison of Phase III Releases with Phase II Screening Assumptions

Releases from Phase II Water-Step 1 Screening		Sum of 36-year Releases from Cummins Data - Basis for Phase III Point-of-Release Estimates		Sum of 36-year Phase III Releases to Savannah River		
Radionuclide	**Surface Water Release from SRS (Ci/36 yr)**	**Cat. 1+Cat. 3 Unless Otherwise Noted (Ci/36 yr)**	**Ratio, Screening to Phase III Basis**	**Eval.**	**Phase III Release to River (Ci/36 yr)**	**Ratio, Phase III River Release to Screening**
^{141,144}Ce	$7.00 \times 10^{+02}$	$7.08 \times 10^{+02}$	0.99		$4.58 \times 10^{+02}$	6.54×10^{-01}
^{134}Cs	$1.35 \times 10^{+01}$	$1.35 \times 10^{+01}$	1.00		2.87	2.13×10^{-01}
^{137}Cs	$1.95 \times 10^{+03}$	$1.95 \times 10^{+03}$	1.00		$2.57 \times 10^{+02}$	1.32×10^{-01}
^{60}Co	$8.40 \times 10^{+01}$	$8.42 \times 10^{+01}$	1.00		$5.40 \times 10^{+01}$	6.43×10^{-01}
^{3}H	$1.50 \times 10^{+06}$	$1.53 \times 10^{+06}$	0.98	*	$1.73 \times 10^{+06}$	1.16
^{131}I	$3.03 \times 10^{+02}$	$3.02 \times 10^{+02}$	1.00	*	$2.88 \times 10^{+02}$	9.50×10^{-01}
^{129}I	1.20	3.00	see note	*	2.71	2.26
^{32}P	$1.96 \times 10^{+02}$	$1.96 \times 10^{+02}$	1.00		$1.29 \times 10^{+02}$	6.60×10^{-01}
^{239,240}Pu	8.00	7.9	1.01		2.95	3.69×10^{-01}
^{238}Pu	4.00	4.0	0.98		7.08×10^{-01}	1.77×10^{-01}
^{103,106}Ru	$1.80 \times 10^{+03}$	$1.80 \times 10^{+03}$	1.00		$1.30 \times 10^{+03}$	7.25×10^{-01}
^{89,90}Sr	$6.20 \times 10^{+02}$	$7.11 \times 10^{+02}$	0.87	*	$4.60 \times 10^{+02}$	7.42×10^{-01}
^{35}S	$1.75 \times 10^{+03}$	$1.75 \times 10^{+03}$	1.00		$1.53 \times 10^{+03}$	8.77×10^{-01}
^{99}Tc	$5.30 \times 10^{+01}$	$5.30 \times 10^{+01}$	1.00		$5.47 \times 10^{+01}$	1.03
^{235,238}U	$4.20 \times 10^{+01}$	$4.15 \times 10^{+01}$	1.01		$1.19 \times 10^{+01}$	2.83×10^{-01}
^{65}Zn	$1.50 \times 10^{+02}$	$1.50 \times 10^{+02}$	1.00		$9.64 \times 10^{+01}$	6.43×10^{-01}
^{95}Zr, ^{95}Nb	$1.45 \times 10^{+02}$	$9.64 \times 10^{+02}$	0.15	*	$8.23 \times 10^{+02}$	5.67
						Average Ratio

Releases from Phase II Water-Step 1 Screening		Sum of 36-year Releases from Cummins Data - Basis for Phase III Point-of-Release Estimates		Sum of 36-year Phase III Releases to Savannah River		
Radionuclide	**Surface Water Release from SRS (Ci/36 yr)**	**Cat. 1+Cat. 3 Unless Otherwise Noted (Ci/36 yr)**	**Ratio, Screening to Phase III Basis**	**Eval.**	**Phase III Release to River (Ci/36 yr)**	**Ratio, Phase III River Release to Screening**
^{3}H Group: ^{129}I, ^{131}I, ^{99}Tc, ^{35}S						1.28E+00
Strontium Group: $^{103, 106}$Ru, ^{60}Co, ^{89,90}Sr, ^{95}Nb, ^{95}Zr, ^{32}P, ^{65}Zn, $^{141, 144}$Ce, U						6.21E-01
Cesium Group: $^{134, 137}$Cs, Pu						2.23E-01

C.5.2.1 Comparison of the Phase III Point-of-Release Estimates to Phase II Screening Values

The Table C-24 column headed "Eval." compares the unadjusted Phase III values to the Phase II screening values. A star notation indicates that an explanation is warranted.

^{3}H

For ^{3}H, the Phase II study states that both stream and seepage basins were included as the source of releases to the surface water pathway in the screening assessment (3). It appears from the data presented in the Phase II report that seepage basin data for ^{3}H (and ^{131}I) were not included in the screening assessment. This is indicated by the good agreement between the stream-only source terms. (The Phase III point-of-release estimates releases to streams, seepage basins, and containment basins.)

^{131}I

The entry from the Phase II screening assessment is Category 1 release only (i.e., release to streams). This appears to be appropriate because of the eight-day half-life of ^{131}I. Any substantial holdup duration would have caused the seepage basin inventory to decay away. The Phase III point-of-release data file only includes releases to streams and not to seepage basins for this isotope.

^{129}I

In the Phase II report, the 1.2 Ci entry for ^{129}I in the table for the screening calculation was obtained by assuming that 3 Ci entered the seepage basin and 40 percent of that inventory was released from the basin to the stream (3 Ci * 0.4 = 1.2 Ci) (3). Because Phase III modifies all of the other radionuclide inventories using an adjustment factor, the 3-Ci assumption was used.

^{89,90}Sr

Although the Phase II screening value and the Phase III base value are different by about 15 percent, this appears to be due to an addition error in the Phase II report. The screening spreadsheet value should have been about 720 Ci based on the note in the spreadsheet indicating how the entry was obtained. However, this difference is not important. When ^{89,90}Sr releases are applied in the dose reconstruction, unidentified beta-gamma releases were added to the ^{90}Sr inventory in the amount of 218.88 Ci (before multiplication by the adjustment factor for ^{90}Sr), which dwarfs any differences between the Phase III basis and screening values.

^{95}Zr, ^{95}Nb

The Phase II report stated that all estimates of reported releases of ^{95}Zr, ^{95}Nb, and ^{95}Zr, ^{95}Nb were combined to ensure a conservative approach. However, the value used in the Phase II screening seems to match only the total of ^{95}Zr and ^{95}Nb.

C.5.2.2 Comparison of Phase III Savannah River Releases to Screening Values

The adjustment factors, applied on the basis of K_d, are reflected in the ratios of the Savannah River releases (Phase III) to the screening assessment releases (Phase II). Table C-24 presents the average ratios for the three groups of radionuclides (^{3}H, ^{90}Sr, and ^{137}Cs groups).

The radionuclides scaled to ^{3}H have, on average, increased values compared with the screening assessment inventories (+28 percent). The strontium-scaled nuclides have, on average, 62.1 percent of the screening value. The cesium-scaled nuclides have, on average, about 20 percent of the screening values. This is due to hold-up in the environment based on use of different K_d values. These values compare, in general, with the adjustment factor values for each scaling group averaged over all the years, which are, respectively, 0.749, 0.711, and 0.232. Because the ratio for each nuclide depends on applying the annual adjustment factor for the group to the annual releases for the radionuclide, the sum of the products depends upon the release history of the radionuclide. This accounts for the variability of the ratios within each group.

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APPENDIX D TRANSPORT, PATHWAY, AND DOSE ASSESSMENT

The primary purpose of this appendix is to summarize the mathematical relationships used in Version 2 of GENII to model the transport of radionuclides through the air from a release point to an exposure location, the exposure of humans to radionuclides existing at that exposure location, and the annual radiation dose and cancer risk resulting from that exposure. Exposure of humans to radionuclides is assessed through 18 exposure pathways – 13 pathways associated with radionuclides released to the air, and 5 pathways associated with radionuclides released to surface water. Each pathway may cause radiation exposure either through external exposure to radiation, through ingestion of radionuclides, or through inhalation of radionuclides.

The movement of radionuclides by air to an exposure location was assessed in a different manner than the movement of radionuclides by surface water to an exposure location. For air transport, the Gaussian plume model contained in the GENII code was used. This Gaussian plume model is described in Section D.2. Radionuclide concentrations in air at an exposure location, as calculated using this Gaussian plume model, were used along with GENII-calculated radionuclide deposition rates as source terms for the subsequent GENII assessments of the 13 exposure pathways considered for radionuclides released to the air.

For water transport, a procedure independent of the GENII code was used. Radionuclide holdup in surface water sediments, as well as dilution by surface water bodies, was considered as part of a procedure discussed in Appendix C and Chapter 7. This procedure was used to develop radionuclide concentrations that were used as source terms for the subsequent GENII assessments of the 5 exposure pathways considered for radionuclides released to surface water.

The mathematical relationships presented in this appendix have been obtained from the GENII model (1). These mathematical relationships were included to enable the reader to relate the results of the analyses to their mathematical bases. The preparers of this report were concerned that the lack of this information would have detracted from the report's discussion of important variables that influenced the calculated doses and risks, and believed that many readers would not possess a copy of the [GENII SDD]. To enable easier referencing by the reader, the same terminology and notation as those used in the GENII SDD was generally used. This enabled easier referencing by the reader.

In addition, the mathematical relations described in Sections D.2 through D.4 are each composed of a set of parameters, each requiring a numerical value. To avoid a voluminous and complicated appendix, we generally defer a discussion of the assumed values for parameters that are used in the base-case GENII calculations to other appendices.

D.1 Overview of Transport, Pathway Exposure, and Dose and Risk Assessment

This section consists of two principal subsections. Subsection D.1.1 addresses some considerations that guided decisions about the transport and exposure pathways to be addressed for this phase of the SRS Dose Reconstruction Project. Subsection D.1.2 describes how the perparers envisioned the assessment as a linked set of calculation modules, and points the reader toward those parts of the report that address each calculational module.

D.1.1 Selection of Transport and Exposure Pathways

D.1.1.1 Background

This report provides a plausible, yet bounding, assessment of the radiological impacts that may have resulted from release of radioactive material to the environment from 39 years of SRS operation. The report was prepared for the Center of Disease Control and Prevention (CDC), and builds on the work performed by the Risk Assessment Company (RAC) to characterize the principal sources of radionuclide release to the environment. In [Phase II] (2), RAC provided estimates of radionuclides and chemicals discharged over 39 years into the air and into onsite surface waters.

As charged by CDC, the analysis was performed in terms of exposure scenarios representing hypothetical families performing plausible activities. The goal of reconstructing possible doses and risks from past SRS operations dictated somewhat different considerations in selecting pathways for analysis than would be the case if the goal was to perform preoperational evaluation for comparison to a regulatory requirement. Analyses performed for comparison against regulatory limits are typically performed in a very conservative manner to assure that doses or risks would not be underestimated even under unusual circumstances. But this level of conservatism would have been unwarranted for the SRS Dose Reconstruction Project. Rather, it was preferable to conduct an assessment that more closely examined plausible rather than extreme activities and pathways. Such an assessment would be more reflective of the mass of the persons in the vicinity of SRS and potentially exposed from site operations.

In addition, by the same logic that guided use of a screening process to identify those radionuclides that contributed the great majority of the possible health effects from site operations, it was desirable to focus on the exposure pathways leading to the largest doses and risks. In practice, the relative significance of different pathways was not initially clear, which prompted a bias for completeness in the initial stages of the analysis.

D.1.1.2 Pathways Considered

The Phase II report identified two principal sources of release of radionuclides into the environment from SRS: release into the air, and release into surface water (2). The Phase II report identified and quantified the principal radionuclides that were released.[1] To assess the environmental consequences of these releases, an existing state-of-the-art computer code was used, Version 2[2] of the GENII family of codes.[3] The process for selecting this code over other computer codes and options is summarized in Appendix H.

Of the exposure pathways addressed in GENII, those considered appropriate for this report are shown in Table D-1. Exposure pathways consist of those associated with release of radionuclides into the air (*air pathways)*, and those associated with release of radionuclides into surface water (*water pathways*). Doses and risks experienced by the receptors may have resulted from three exposure routes: external exposure, ingestion, and inhalation. Exposures from each exposure route represent the sum of exposures from all applicable exposure pathways.

An overview of the air and water exposure pathways considered for this report is provided in Section D.1.1.2.1. Section D.1.1.2.2 addresses the approach for addressing radiological impacts from ingestion of

[1] The estimates of release were reviewed from the Phase II report, and, using site-specific data, adjusted the Phase II estimates as needed to perform the analyses for this report (see Chapter 5 and Appendix B).
[2] In the rest of this appendix, references to GENII mean Version 2 of GENII.
[3] The original version of GENII was developed in the late 1980s for use at DOE's Hanford Reservation, although the codes were designed with the flexibility to accommodate input parameters for a wide variety of sites. GENII Version 2 incorporates improved transport models, exposure options, dose and risk estimates, and user interfaces.

meat from game animals. Both the CDC and the SRS Health Effects Subcommittee identified the need to consider radiological impacts from ingestion of meat from game animals (see Appendix E).

Table D-1 Exposure Routes and Pathways for Air and Water Pathways

Exposure Route & Pathway	Air Pathways	Water Pathways	All Pathways
External Radiation:			
• Immersion in a Plume of Air	X		X
• Exposure to Contaminated Soil	X		X
• Exposure to a Contaminated Shoreline		X	X
• Exposure to Contaminated Water While Swimming		X	X
• Exposure to Contaminated Water While Boating		X	X
Ingestion:			
• Leafy Vegetable Consumption	X		X
• Root Vegetable Consumption	X		X
• Fruit Consumption	X		X
• Grain Consumption	X		X
• Beef Consumption	X		X
• Poultry Consumption	X		X
• Milk Consumption	X		X
• Egg Consumption	X		X
• Inadvertent Soil Consumption	X		X
• Fish Consumption		X	X
• Inadvertent Ingestion of Water While Swimming		X	X
Inhalation:			
• Inhalation of Contamination in the Air	X		X
• Inhalation of Contamination Resuspended from Soil	X		X

D.1.1.2.1 Pathways Associated with Release of Radionuclides into the Air and Water

Radionuclides discharged from SRS release points were transported to various receptor locations, leading to receptor exposures from external radiation and inhalation pathways. Radionuclides were also deposited on the ground at receptor locations. Contaminated soil exposed receptors to radiation through several pathways. Exposure pathways considered in this report resulting from deposition of contamination on the ground were:

- External radiation exposure to the contaminated soil.
- Inhalation of resuspended soil.
- Inadvertent ingestion of soil from working or playing in soil.
- Consumption of food crops, where the crops were contaminated through root uptake of radionuclides in soil, direct deposition of radionuclides on plant surfaces, or deposition on plant surfaces from radionuclides resuspended from contaminated soil.

Consumption of food products from animals that had consumed forage crops grown in contaminated soil. Forage crops ingested by animals were contaminated through root uptake of radionuclides in soil, direct

deposition of radionuclides on plant surfaces, and deposition on plant surfaces from radionuclides resuspended from contaminated soil.

Surface water exposure pathways considered in this study were:

- Ingestion of aquatic animals (e.g., fish) obtained from Savannah River and Lower Three Runs Creek access locations.
- External radiation exposure to radionuclides building up in sediment alongside Savannah River and Lower Three Runs Creek.
- Exposures from swimming in contaminated water, including external exposure to water and accidental ingestion of water.
- External exposures from boating on contaminated water.

Exposures from possible ingestion or inhalation of resuspended sediment were not analyzed. Considering that sediment is normally saturated, resuspension of sediment would have been less likely than resuspension of dryer soil, particularly soil used for growing food and crops that were abraded and dispersed by farm implements. Therefore, it was concluded that this pathway was likely much smaller than other possible pathways from contaminated surface water. It is also not considered in GENII.

Radiation exposures caused by use of contaminated river or creek water were not assessed for irrigation, drinking or cooking, or showering.

Two studies have considered the potential use of the Savannah River for irrigation. The first study, published in 1991, was performed by the Westinghouse Savannah River Company (WSRC), the primary contractor at SRS. It summarized land and water use characteristics around SRS that could be incorporated as site-specific information in dose models (3). The author contacted the Georgia Department of Natural Resources and the Clemson University Extension Cooperative. These organizations "provided information regarding irrigation practices along the Savannah River from Clark's Hill reservoir to the Atlantic Ocean." They found that "the only known use of Savannah River water for irrigation is by a dairy farmer in Edgefield [County], upstream of the SRS" (3). This statement implied that the Savannah River was not used as a source of irrigation water downstream of SRS, at least as of the late 1980s and early 1990s. The author recommended that irrigation not be considered as a pathway for ingestion of radionuclides in dose models used for SRS (3).

The second study, issued in 2002 by the South Carolina Department of Health and Environmental Control (SCDHEC), was a critical pathway assessment of SRS to be used to help assess the environmental monitoring program at SRS (4). The author surveyed state employees. This report states: "The state county extension offices report no knowledge of any irrigation system originating from the Savannah River downstream of the SRS. Pine plantations bordering the Savannah River in Allendale and Jasper counties are used by deer hunters." In Georgia, "due to the high elevation of the Georgia river bank, irrigation from the Savannah River is not practical. Irrigation water, therefore, comes from other sources such as groundwater or ponds" (4).

An extension engineer in Georgia was contacted who verified that, to his knowledge, the Savannah River was not used for irrigation and that irrigation water in Georgia was primarily from ponds and groundwater (5). The SCDHEC author of the second assessment was contacted and the author stated that the extension agents he contacted based their information on their 20 to 30 years of experience (6). It was concluded that the Savannah River most likely had not been used for irrigation since at least the early 1970s.

In any event, this study considered two farming-family scenarios. The closest to the SRS lived near Girard, Georgia. It would have been unreasonable to assume that this family used the Savannah River as a source of irrigation water. The family farm was about three miles from the river, an unfeasible distance for piping Savannah River water to a farm. Groundwater levels are normally less than 100 feet below the surface in this part of South Carolina and Georgia, making groundwater more easily available and cost effective to use for irrigation. Using ponds that are commonly found on farms in the southeast U.S. is also more cost-effective than pumping water from a river.

With respect to drinking and showering water, the only scenario involving a dwelling located reasonably near a source of contaminated surface water was the Family Near the River. It was assumed that the family in this scenario lived in or near Martin, SC, which is near Lower Three Runs Creek. There was no evidence that persons living in or near Martin used Lower Three Runs Creek as a source of drinking water.

Considering this, it was concluded that incorporating use of water from Lower Three Runs Creek into the scenario would have been unreasonable.

D.1.1.2.2 Game Animals

Background. Humans could have become exposed to radionuclides by ingesting meat from game animals that had taken up radionuclides. It was determined that these game animals could be represented by deer and wild fowl.

[ERDA-1537] (7) documents that the deer herd before SRS was officially closed to the public in December 1952 constituted about 20 animals. The population as of the mid 1970s had grown to 5,000 to 8,000. The greatest population densities occurred on the southern and northeastern portions of SRS. Controlled public hunts began in 1965. From that time to the mid 1970s, about 10,000 deer were taken in public hunts, and about 500 were killed for research programs (7). In addition, several domestic hogs, abandoned in 1952, had reverted to the semi-wild state. SRS began a control program for hog removal, and since 1969, about 125 wild hogs had been killed as of the mid 1970s (7).

Therefore, deer were selected to represent all wild mammals assumed to be taken for consumption. Deer was routinely taken by hunters between 1954 and 1992. Although wild hogs were also taken, the numbers killed by hunters were apparently small in comparison to deer. From the mid 1960s to the mid 1970s, the number of wild hogs taken by hunters was only about 1% the number of deer.

With respect to wild fowl, there was no evidence that the consumption of wild fowl constituted a major source of human intake of radionuclides during the SRS operational period. Nonetheless, it was recognized that waterfowl were present on the SRS, mainly during winter migrations. In addition, other game birds such as quail and dove were abundant. [ERDA-1537] (7) observed that the population of quail and dove in the SRS vicinity did not initially decrease when the SRS land was removed from agriculture, but probably reached a record high in the early 1960s. Wild turkeys are also on the site, resulting from use of SRS as a breeding ground.

Hence, it was felt plausible that hunters either onsite or in the vicinity of SRS would have taken wild fowl during the period of SRS operations, and that wild fowl represented a possible source of ingestion exposures to some receptors.

Analyzing exposures from contaminated game. Development of exposure pathways for game animals was difficult. For example:

- It was not clear that such pathways were reasonable for game taken on the SRS. Persons would have done so voluntarily with knowledge that the game may have contained radionuclide contamination. This would arguably not have been the case for deer or other game animals taken off the SRS site.
- Unlike animals used for food products such as beef or pork, game animals are generally not confined to a definable location. Game animals may have wandered from one widely separated location to another, consuming grass or other plant products as well as water from SRS streams.
- There was a lack of basic information such as transfer coefficients for deer except for a few isotopes, as well as other computational difficulties (see below).
- It was unclear whether exposures that may result from taking deer on or near SRS were significantly different from exposures elsewhere (see below).

Options for modeling doses from consumption of contaminated wild game were considered as discussed in [ATL white paper on venison] (8). It was determined that with respect to deer, transfer factors for most isotopes of concern were not available. (A transfer coefficient value for ^{137}Cs to deer was available from [IAEA 1994] (9).) It was also determined that for most years, data about the concentrations of radionuclides in venison were available for one or a few nuclides (^{137}Cs and ^{90}Sr) from SRS annual environmental reports. As discussed in Chapter 11 of the Phase II report, there was a substantial body of information about the concentrations of cesium in meat from deer killed on the SRS and elsewhere in the region. "In general, ^{137}Cs is the radionuclide of greatest concern because of its relatively long half-life (30 years) and its tendency to accumulate in edible (muscle) tissues" (2). Nonetheless, concentration data for other radionuclides and for missing years would have had to be derived or estimated.

Perhaps more significantly, the Phase II report notes, "Concentrations measured in deer collected from offsite locations give no indication that mean ^{137}Cs burdens in SRS deer are elevated above the expected background concentrations." The Phase II authors described comparisons between SRS deer and deer taken from other locations in South Carolina and Georgia, and discussed potassium levels in soils as the most likely reason that the mean ^{137}Cs concentrations in the SRS deer were consistently lower. They discussed a study designed to use the fact that the ^{134}Cs/^{137}Cs ratio from SRS releases differed from that in fallout: the cesium ratios in deer in that study "were consistent with global fallout and were comparable to those calculated for offsite deer" (2).

In a 1999 report available on the web site of the University of Georgia's Savannah River Ecology Laboratory, Dr. Michael Smith of the University of Georgia and Peter Fledderman of Westinghouse Savannah River Company provided additional information comparing levels of ^{137}Cs found in deer at SRS with those at Fort Jackson, SC, Fort Stewart, Georgia, Cedar Knoll Plantation, SC and Webb Wildlife Center, SC. These authors provided data showing higher average concentrations of ^{137}Cs in deer at the two military bases than at SRS. They described the soils at the military bases as similar to those at SRS. Deer from the other two locations had much lower concentrations of ^{137}Cs, but the authors maintained that fertilizers with potassium were used at these locations and that this probably reduced the ^{137}Cs levels in the deer (10).

The Phase II authors suggested how the deer pathway might be further explored in "future phases of the SRS Dose Reconstruction Project." However, there was a lack of usable data that would have enabled the perparers to confidently quantify human exposures via deer consumption from radionuclides released by the SRS. As noted, information was lacking about transfer coefficients for elements other than cesium. A more difficult issue was the lack of data that showed that radionuclide concentrations in venison from SRS were "above background"— i.e, larger than the concentrations in other deer. It was not possible to discern a significant difference in the isotopic ratios between the cesium in the SRS deer and the cesium

from atmospheric fallout.[4] Furthermore, "radioiodine concentrations measured in deer thyroids have consistently corresponded to periods of weapons testing" (2).

Therefore, the wild game consumption pathway was modeled as a form of beef and poultry consumption.

D.1.2 Dose and Risk Assessment

D.1.2.1 Assessment Modules

Although the calculational procedure for determining dose and risk from long-term operation of SRS is complex, the overall governing relationship between the stages of the calculational procedure is straightforward. For each year that SRS operated between 1954 and 1992, the dose and risk to an individual can be mathematically envisioned for each radionuclide as a set of separate calculational modules. The outputs of each calculational module are multiplied in turn by the next module. For each year and radionuclide, therefore, the annual dose to an individual is:

$$D_i = RE_i \; TR_i \; PA_i \; DF_i$$

And the annual risk to an individual is:

$$R_i = RE_i \; TR_i \; PA_i \; RF_i$$

Where D_i = Annual dose in Sieverts (Sv) for radionuclide i.

R_i = Annual risk for radionuclide i.

RE_i = *Release Module*. Quantity of radionuclide i released to the air (as from a stack) or to a surface water body (Bq)

TR_i = *Air and Surface Water Transport Module.* Mathematical relationships that model the transport of a radionuclide through air or surface water to an exposure location – i.e., a location occupied by a receptor or a location where a receptor obtains foods such as vegetables, beef, or fish. The calculational result of this module is the concentration of the air or water containing that radionuclide at that exposure location -- i.e., m^{-3} of air or L^{-1} of surface water. Note that RE_i x TR_i = Bq/m^3 or Bq/L.

PA_i = *Pathway Assessment Module.* Mathematical relationships (pathway assessments) that model the movement of a radionuclide through each of the exposure pathways listed in Table D-1. The calculational result of this module is the concentration or quantity of a radionuclide that the receptor is exposed to, inhales, or ingests. The units associated with this module depend on the pathway being considered (see below).

DF_i = *Dose and Risk Module*. Dose conversion factor, a relationship that gives the dose to a receptor for radionuclide i for the particular exposure pathway of interest (e.g., Sv per annual exposure to a concentration of 1 Bq per m^3 of air, Sv per Bq ingested from food, water, or other sources of contamination).

RF = *Dose and Risk Module*. Risk conversion factor, a relationship that gives risk of cancer to a receptor for radionuclide i for the particular exposure pathway of interest (e.g., risk per annual exposure to a concentration of 1 Bq per m^3 of air, risk per Bq ingested from food, water, or other sources of contamination), given as an annual probability of cancer incidence or fatality.

[4] If either the concentrations of ^{137}Cs in SRS venison were notably larger than venison from other areas, or the cesium isotopic ratios in SRS venison were notably different that that from venison in other areas, it could have been possible to calculated doses from venison consumed in different scenarios. But such differences cannot be discerned, based on available literature.

Each of these modules is briefly addressed below.

Release Module. The release of radionuclides into the air and surface water is addressed in Appendices A and B. Appendix A addresses the determination of airborne release points for the assessment. Appendix B lists the quantities of radionuclides annually released into the air and water from each source considered in this study, as well as the bases for these listed quantities. From the information in these appendices, a series of data files was created that list the quantities of radionuclides released into the air as a function of major SRS facility and year, and the quantities of radionuclides released into surface water as a function of year. The files were input to GENII using the pre-processor, a program was created to facilitate entry of data into GENII.

Air and Surface Water Transport Module. Different mathematical procedures were used to model movement of radionuclides to exposure locations, depending on whether the radionuclide release was to air or to water. For release of radionuclides to air, a sector-averaged Gaussian model was contained in the GENII code as described in Section D.2. For release of radionuclides to surface water, simple dilution models were considered that differed depending on whether the exposure location being considered was Lower Three Runs Creek or was the Savannah River (Appendix C). For Lower Three Runs Creek, radionuclide concentration data considered as measured in this creek are reported in SRS documents such as annual environmental reports. For the Savannah River, a simple dilution model was considered. The annual quantities of radionuclides that were discharged into the Savannah River were first estimated from all major surface water systems (including Lower Three Runs Creek), and then diluted this annual discharge by a volume of water equal to the annual river flow rate. The outcome of this module was a set of files containing radionuclide concentrations in water. These files were input into GENII for the pathway assessment.

Pathway Assessment Module. This portion of the assessment was performed using the GENII code. For radionuclides released through the air pathway, the starting point of the pathway assessment was the concentration of radionuclides in air at an exposure location. Radioactive exposures were then assessed for each of the 13 air pathways listed in Table D-1, in accordance with the mathematical procedures summarized in Section D.3. While the radionuclides were in the air, they caused exposures to humans by the following pathways:

1. Inhalation exposures from immersion in air containing radionuclides (Section D.3.3.1).
2. External exposures from immersion in air containing radionuclides (Section D.3.2).

Radionuclides also fell to earth through depositional processes. This deposition resulted in a concentration of radionuclides in the top part of the soil. Radionuclides in this top part of the soil then caused radionuclides through additional pathways. Three pathways caused by ground contamination at an exposure location are:

1. External exposures from proximity to contaminated soil (Section D.3.3.2).
2. Inhalation exposures from breathing radionuclides that had been resuspended from contaminated soil (Section D.3.3.3).
3. Ingestion exposures from inadvertently ingesting contaminated soil (Section D.3.3.4).

In addition, radionuclides may be transported through the food chain to humans. This transport mechanism has historically been a very important mechanism for human exposure to radionuclides released to the environment. In GENII, radionuclide transport through food chain pathways are considered in two ways. First, GENII considers foods that take up radionuclides from soil (or have radionuclides deposited on food surfaces) and are directly eaten by humans. The four pathways considered in this manner are:

1. Ingestion exposures from eating leafy vegetables (Section D.3.4.1).
2. Ingestion exposures from eating root vegetables (Section D.3.4.1).
3. Ingestion exposures from eating fruit (Section D.3.4.1).
4. Ingestion exposures from eating grain (Section D.3.4.1).

Second, GENII considers animal products that are eaten by humans and have previously consumed contaminated grass or forage. The four pathways considered in this manner are:

1. Ingestion exposures from eating beef (Section D.3.4.2).
2. Ingestion exposures from eating poultry (Section D.3.4.2).
3. Ingestion exposures from drinking milk (Section D.3.4.2).
4. Ingestion exposures from eating eggs (Section D.3.4.2).

For radionuclides released into surface water, the starting point of the pathway assessment was the concentration of radionuclides in water at an exposure location. Radioactive exposures were then assessed for each of the 5 water pathways listed in Table D-1, in accordance with the mathematical procedures summarized in Section D.3. While the radionuclides were in contained within the water, they could they caused exposures to humans by the following pathways:

5. Ingestion exposures from eating fish (Section D.3.4.3).
6. External exposures from swimming in water (Section D.3.6.1).
7. Ingestion exposures from inadvertently drinking water while swimming (Section D.3.6.2).
8. External exposures from boating in water (Section D.3.6.3).

Note that eating fish is another very important mechanism for food-chain transport of radionuclides to humans.

Finally, radionuclides may be deposited from the water onto river or creek sediment. Persons standing or performing other activities along a shoreline may receive external exposures from the radionuclides in these sediments – i.e.:

1. External exposures from a contaminated shoreline (Section D.3.5).

Dose and Risk Module. This portion of the assessment was basically calculated using the GENII code, although certain dose and risk calculations were also performed using the post-processor. This module calculated equivalent dose for 23 organs, effective dose, and cancer risk as a function of radionuclide and year for each receptor. Almost all dose and risk conversion factors used for this report were those obtained from EPA's April 2002 update to its Federal Guidance Report No. 13 [FGR-13U] (11). Section D.4 contains a discussion of radiation dose and risk concepts, and summaries the basic equations used by GENII to calculate dose and risk from exposure to radioactive material.

D.1.2.2 Approach for Presenting Mathematical Relationships used in GENII

The remaining three sections of this appendix present the mathematical relationships used in the GENII code to:

- Model transport of radionuclides through air to an exposure location (Section D.2).
- Perform pathway assessments, include food-chain transport assessments, of radionuclides through air and surface water pathways (Section D.3).
- Assess human radiation doses and cancer risks from external exposure to radionuclides, inhalation of radionuclides, and ingestion of radionuclides (Section D.4).

It was recognized that a rigorous description of the mathematical relationships set forth in GENII would be lengthy and would largely repeat the information in the GENII SDD. Yet it was also recognized that if the mathematical relationships were not presented in some detail, most readers would be unable to easily relate the results of the analyses to their mathematical bases. (It was believed that many readers would not have access to a copy of the GENII SDD.) This would have detracted from the report's discussion of important variables that influenced the calculated doses and risks. Hence, the mathematical relationships used in GENII are briefly summarized, hoping that this summary would be sufficient for most persons interested in the technical details of the analysis.

The preparers of this document used the same terminology and notation as those used in the GENII SDD. This enabled easier referencing by the reader. Also where appropriate, the equations cited in this section were related to their application in GENII using the FRAMES software system. In some cases the terminology for particular parameters is somewhat different in the GENII SDD than in the FRAMES interface.[5]

In addition, the mathematical relations described in Sections D.2 through D.4 are each composed of a set of parameters, each requiring a numerical value. To avoid a voluminous and complicated appendix, we generally defer a discussion of the assumed values for parameters that are used in the base-case GENII calculations to other appendices. Some parameters pertain to site-specific considerations such as the density of soil (see Appendix F). Others pertain to human activities that influence the uptake or exposure to radionuclides (e.g., time spent in an exposure location) and are determined in Appendix E.

D.2 Transport Through Air

D.2.1 Fundamentals of Air Dispersion

Radioactive materials in the form of gases and particulates may be released into the atmosphere and may result in radiation exposure to humans from both external and internal pathways. External exposures may result from immersion in contaminated air or from proximity to radionuclides deposited on the ground, while internal exposures may result from inhalation and ingestion of radionuclides. The magnitude of exposure depends on the concentrations of radionuclides in contaminated media contacted by, or in proximity to, a human receptor. In turn, radionuclide concentrations in contaminated media depend on atmospheric diffusion and deposition processes that affect the transport of radionuclides from the point of release to the location of the receptor.

Figure D-1 and Figure D-2 depict many of the atmospheric processes that affect airborne release and transport [from Till & Meyer, IAEA SS-19] (12), (13). These include plume rise, dispersion, wind speed and direction, depletion, release height, building effects, and topography and geographic features.

[5] Documentation for use of FRAMES is available on the Internet at the FRAMES Version 1.3 website (http://mepas.pnl.gov/FRAMESV1/index.html) [FRAMES 1.3] (14).

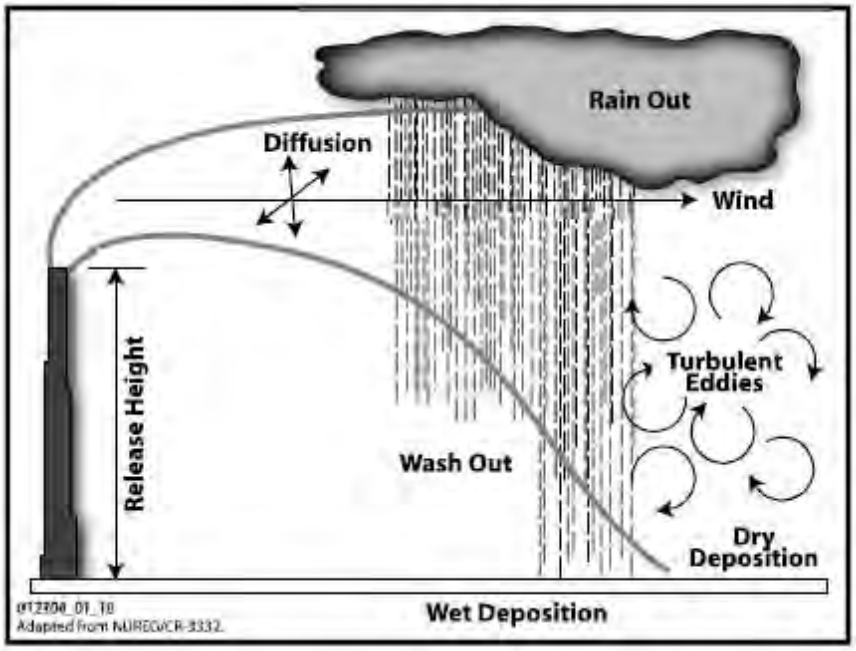

Figure D-1 Atmospheric Dispersion and Removal Processes
Adapted from [IAEA SS-19] (13).

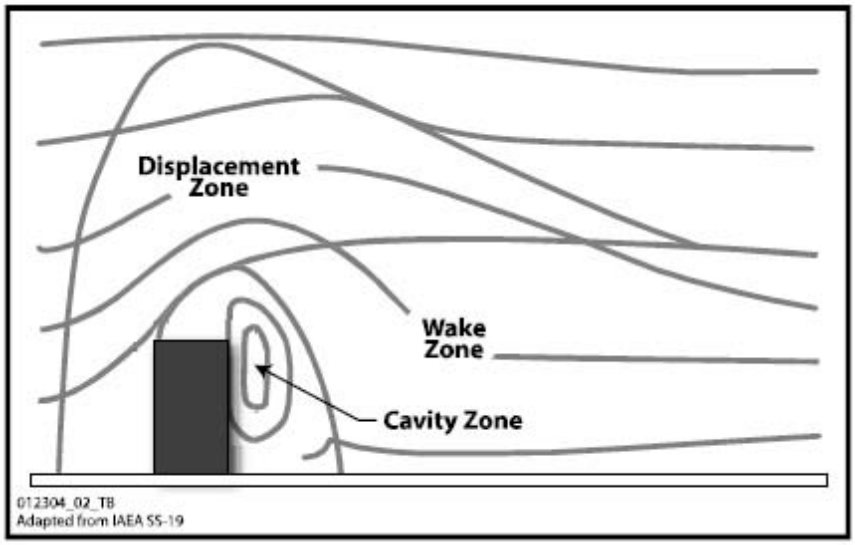

Figure D-2 Air Flow Around a Building
Adapted from [IAEA SS-19] (13).

D.2.1.1 Plume Rise

As a plume of air containing gaseous and particulate materials (effluent) is released from a source such as a tall stack, the effluent may initially rise. Some of the factors influencing plume rise include the temperature of the effluent and the ambient air, the velocity of the effluent leaving the stack, the inside radius of the stack, the wind speed at the release height, and the atmospheric stability (see below). Plume rise affects the "effective stack height" of the release point. Plume rise may significant increase the effective stack height, which in turn may significantly reduce near-field ground-level concentrations (12).

D.2.1.2 Dispersion

As the effluent plume is transported from the source by wind, turbulent eddies in the atmosphere diffuse the effluent. Consistent with Fick's Law, a concentration gradient exists in the effluent, so that the effluent concentrations in the center of the plume are larger than those toward the plume edges. The combined influences of diffusion and transport are called dispersion.

As the plume moves with the wind, diffusion continues in the vertical direction until certain "boundaries" are reached. Of course, vertical diffusion from the depicted stack (Figure D-1) cannot continue below the surface of the earth. In the other direction, the plume continues to diffuse up to the mixing height, which generally ranges from about 200 m to about 2,000 m above the surface of the earth.[6] Within this atmospheric "mixing layer", friction caused by ground surface roughness and heating combine to generate turbulence that efficiently mixes the effluent. But the top of the mixing layer is marked by a decrease in turbulence brought about by stable atmospheric conditions above. Above this "boundary," further diffusion in the vertical direction is significantly reduced, and the vertical concentration distribution becomes more uniform. The thickness of the mixing layer changes with atmospheric conditions. The mixing layer is generally thickest during the day and during periods having high wind speeds, and it is thinnest at night during periods having low wind speeds. It also tends to be thickest on summer afternoons and thinnest on autumn mornings. Thicknesses also vary considerably by geographic location. In either case, the mixing layer depth tends to increase with surface roughness (12).

The stability of the atmosphere within the mixing layer largely determines the intensity of turbulence within the mixing layer and therefore the diffusion of effluent within it. Essentially, conditions within the mixing layer are said to be stable, neutral, or unstable depending on variations of temperature and air density. These variations affect the movement of air particles from one location to another. If the variations tend to retard movement of particles, then the atmospheric conditions are said to be stable; if the variations have no effect on the movement of the particles, then atmospheric conditions are said to be neutral; and if the atmospheric conditions tend to promote the movement of the particles, then atmospheric conditions are said to be unstable. Clearly, unstable conditions promote dispersion of particles within air, while stable conditions retard it.

A common method for describing stability conditions is to differentiate meteorological conditions into stability classes. One of the original classification systems was developed in 1962 by Pasquill, who distinguished six stability classes ranging from Class A (highly unstable) to Class F (highly stable). Pasquill's original classification is reproduced here as Table D-2, and it considers the relationship of wind speed, amount of incoming solar radiation, and cloudiness. Since this classification system was developed, it has been modified by various researchers and regulatory agencies, and other, similar, classification systems have been developed (12). The choice of a particular classification system, which affects the analyses performed to numerically describe effluent diffusion in air, is somewhat subjective.

[6] Another name for the mixing layer is the planetary boundary layer (12).

Table D-2 Pasquill Stability Categories

A. Extremely Unstable Conditions	*D. Neutral Conditions**
B. Moderately Unstable Conditions	*E. Slightly Stable Conditions*
C. Slightly Unstable Conditions	*F. Moderately Stable Conditions*

Surface Wind Speed at 10 m (m/s)	Daytime Insolation			Nightime Conditions	
	Strong	Moderate	Slight	Thin Overcast or > 3/8 Cloudiness†	≤ 3/8 Cloudiness
<2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

*Applicable to heavy overcast day or night.
†The degree of cloudiness is the fraction of the sky above the local apparent horizon that is covered by clouds.

D.2.1.3 Wind Speed and Direction

Clearly, wind speed affects the airborne dispersion of effluent. Higher wind speeds promote dispersion, while lower wind speeds retard it. Wind speeds frequently fluctuate both temporally and with height, as does wind direction.

D.2.1.4 Depletion

Removal mechanisms reduce effluent concentrations within the plume, and include wet and dry deposition, radioactive decay, and chemical change.

Wet deposition processes include rainout and washout. Rainout refers to the interaction of gaseous and particulate effluents with precipitation formation processes within clouds. Effluents are subsequently removed by the precipitation. Washout refers to the removal of gaseous or particulate matter below the cloud layer from contact by falling precipitation. Dry deposition processes include removal of effluent through gravitational settling, or through contact with the ground, vegetation, or other ground cover such as buildings. Although dry deposition is continuous, compared to wet deposition that only occurs during periods of precipitation, dry removal of effluent from air is a less efficient process than wet removal.

Radioactive isotopes decay during transport. The significance of this removal process for exposure to a downwind receptor depends on the radionuclide half-life and the transport time. Chemicals may degrade or otherwise change during transport.

D.2.1.5 Release Height

Generally speaking, the higher the effluent release point, the farther the effluent travels from the release point before significant effluent concentrations reach ground level. NRC notes that for a facility such as a nuclear power plant, gaseous effluents released from tall stacks generally produce peak ground-level air concentrations near the site boundary, while near-ground-level releases usually produce concentrations that monotonically decrease from the release point to all locations downwind (15). Till and Meyer suggest that a common approach is to assume an elevated release when the release point is 2.5 times the height of nearby structures, and to assume a ground-level release when the release point is below the height of the structures (see below) (12) .

D.2.1.6 Building Effects

The flow of air and effluent from a release point can be disturbed by surrounding structures. Figure D-2 [from IAEA SS-19] illustrates idealized flow around a single building. The three main zones of airflow around this building are (13):

1. The upwind displacement zone, where the approaching air is deflected around the building.
2. The relatively isolated cavity zone immediately on the leeward side of the building.
3. The highly disturbed wake zone further downwind from the building. The exact distance of the downwind wake zone depends on the source configuration and meteorological conditions.

The prevailing dispersion pattern will depend on both the release height and the building geometry. If the release height is greater than about 2.5 times the building height, then building effects on dispersion are relatively small. Dispersion characteristics are similar to those in the displacement zone. If the release height is less than about 2.5 times the building height, the transition between the downwind cavity zone and the wake zone occurs downwind of the release point at a distance of about 2.5 times the square root of the surface area of the largest wall of the building. Variations in dispersion patterns caused by buildings can be considered through modifications of basic atmospheric dispersion models such as the Gaussian plume model.

D.2.1.7 Topographic and Geographic Features

Geographic features such as hills, valleys, and large bodies of water influence dispersion and airflow patterns. For example, effluent released in a well-defined river valley will likely follow the confines of the valley rather than remain in a straight-line trajectory. Surface roughness, including vegetative cover, affects the degree of turbulent mixing. Sites having similar topographical and climatological features can have similar dispersion and airflow patterns. Detailed dispersion patterns, however, are usually unique for each site (12), (15).

D.2.2 Gaussian Plume Model

One of the most widely used models for numerically describing the movement and dispersion of effluent from a release point is the Gaussian plume model. In theory, notes the IAEA, the Gaussian plume model is limited to rather simple dispersion situations (13):

- Dispersion over flat, non-complex terrain.
- Short range transport (about 100 m to 20 km downwind).
- Steady state meteorological conditions.
- No elevated temperature inversions.
- Quasi-continuous releases.
- Transport and mixing in the lee of isolated point sources.
- Non-depositing materials, such as noble gases.

But in practice, the Gaussian plume model has been successfully applied to a wide variety of dispersion problems. This is possible because the model is firmly supported by extensive experimental data, as well as being one of the most widely validated of the general dispersion models (13).

D.2.2.1 Basic Model

The basic model used for chronic release of effluent from a source is provided below (1). It describes dispersion of effluent from a single point source assuming that wind always flows in a single, straight-line

direction. Modifications to this model to address the release from multiple sources, and the flow of wind from multiple directions, are described in the next section.

A point source model was used for this report, rather than an area source model, because a point source model best described the release of most of the radioactive material into the air at SRS.[7] Furthermore, no attempt is made to consider plume rise or building effects. Regarding plume rise, offgas from SRS stacks was not particularly elevated in temperature. Therefore, plume rise from SRS stacks should have been comparatively small. In any event, neglecting plume rise was conservative because the assumption of no plume rise deposited more radionuclides on the ground closer to the release point. Regarding building effects, most release of radioactive material occurred from stacks that were considerably taller than nearby buildings. In addition, most receptor locations were several miles from release points, minimizing the local effects of buildings. Finally, it was determined that the calculational complications associated with consideration of building effects was unwarranted considering the limited availability of long-term meteorological data for SRS (see below).

Therefore, the complete straight-line Gaussian plume model used in this study is, from [GENII SDD] (1):

$$\frac{\chi\left(x,y,z,H,h_{eff}\right)}{Q'(x)} = \frac{1}{2\pi U\left(h_s\right)\sigma_y\sigma_z}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)G(z)$$

$X(x,y,z,H,h_{eff})$	=	the concentration at distance x, crosswind position y, and height z, in a plume with axis at height h_{eff} (Ci/m^3)[8]
$Q'(x)$	=	the release rate, corrected for deposition and decay as appropriate (Ci/s)
$U(h_s)$	=	the wind speed at release height, h_s (m/s)
σ_y	=	the horizontal diffusion coefficient (m)
σ_z	=	the vertical diffusion coefficient (m)
$G(z)$	=	the vertical dispersion factor.

The vertical dispersion factor includes plume reflection off the ground and off the top of the mixing layer. It is given by (1):

$$G(z) = \sum_{n=-\infty}^{\infty}\exp\left[-\frac{\left(2nH+\left(h_{eff}-z\right)\right)^2}{2\sigma_z^2}\right]+\exp\left[-\frac{\left(2nH-\left(h_{eff}+z\right)\right)^2}{2\sigma_z^2}\right]$$

Where h_{eff}	=	the effective release height (h_s + plume rise) (m)
H	=	the mixing layer thickness (m).

[7] The great majority of airborne releases were from tall stacks from the reactor and separations areas. Relatively small quantities of radionuclides were released into the air (primarily tritium as evaporated water vapor) from seepage basins and other area sources.

[8] In the GENII SDD, radionuclide activity is described in units of curies (Ci) as well as Becquerals (Bq), where 1 Ci = 3.7E+10 Bq.

In GENII, the limits of summation in the second equation are truncated between (-2 < n < 2), a simplification that should not significantly affect the accuracy of the equations. The receptor height (z) is assumed to be one meter.

If the distance from the source is sufficiently large, the value of the vertical diffusion coefficient (in meters) approaches the thickness of the mixing layer (H). Under this condition, the effluent is uniformly mixed in the vertical direction, and the straight-line Gaussian plume model is simplified to (1):

$$\frac{\chi(x,y,z)}{Q'(x)} = \frac{1}{\sqrt{2\pi}\,U(h_s)H_u\sigma_y}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

Where H_u = the height of the mixing layer, or the effective release height, whichever is higher.

In GENII, the effluent is considered to be uniformly mixed in the vertical direction when the vertical diffusion coefficient is at least 1.2 times the uniform depth (as defined above) (1).

Horizontal and vertical diffusion coefficients in the above equations (i.e., σ_y and σ_z) may be calculated using a variety of methods that incorporate consideration of stability classes. Horizontal and vertical diffusion coefficients are automatically calculated in GENII when meteorological data is entered using the joint frequency distribution approach. The joint frequency distribution approach is used for this report.

D.2.2.2 Sector Average Model

Wind normally does not blow from the same direction for prolonged periods. So for chronic or long-duration releases, the basic Gaussian plume model is modified using a sector-average approximation. One first draws an imaginary circle around the release point, and divides the circle into a series of arcs. Historically, the circumference around the release point has been divided into 16 sectors corresponding to the 16-major compass directions: N, NE, NNE, E, and so forth. Each sector is a pie-shaped wedge describing a 22.5^o arc (360° /16 sectors). (Since 1965, however, directions have been recorded in 10-degree sectors, leading to 36 sectors.) One then estimates the dispersion of effluent in each horizontal direction around the release point. One considers the concentrations produced by each wind direction, wind speed, and stability class, weighted by the frequency with which these conditions occur (the joint frequency distribution), and obtains an average effluent concentration within each sector as a function of distance from the release point.

Although the straight-line Gaussian plume model discussed above is given in Cartesian coordinates, the model when adjusted for sector averaging is normally converted to cylindrical coordinates. The sector average model as used in GENII is (1):

$$\frac{\chi(\theta,r,z)}{Q'(r)} = \frac{1}{\sqrt{2\pi}U\sigma_z\theta_w}G(z)$$

$X(\theta_i,r,z)$ = the concentration at distance r, in sector θ_i, at height z (Ci/m^3)

$Q'(r)$ = the total mass of material released, corrected for deposition and decay

θ_w = the sector width, which is the larger of the arc length in a 22.5^o sector, or 4 times σ_y

U = wind speed (m/s)

σ_z = vertical diffusion coefficient for distance r (or time t = x/U)

G(z) = vertical factor given by the above equation.

At long distances, the model further simplifies, because of uniform mixing in the vertical direction, to (1):

$$\frac{\chi(\theta,r,z)}{Q'(r)} = \frac{1}{U H_u \theta_w}$$

In GENII, it is again assumed that the plume is uniformly mixed in the vertical direction when the vertical diffusion program is 1.2 times the uniform depth.

D.2.2.3 Joint Frequency Distribution (JFD)

The joint frequency distribution, P_{pjk}, is a function of wind direction sector, p, stability category, j, and wind speed class, k. The joint frequency distribution is computed by compiling meteorological data, usually determined and recorded for each hour, over an appropriate time interval and computing the frequency of occurrence of each joint frequency category. Each joint frequency category represents a band of wind speeds, directions, and stability conditions.

D.2.2.4 Multiple Sources and Receptor Locations

The above discussions regarding the Gaussian plume model, and modifications to account for sector averaging, are for a single source emitting radionuclides into the air. But there are multiple SRS sources as well as multiple receptors. A single receptor may receive radiation exposures from all sources. Even if the release rate from each source was the same, the exposure received by a receptor would differ for each source because of distance and sector-averaging considerations.

The GENII code determines the total exposure received by each receptor as summed over the contribution from all sources. (See Section 5.1.5 of the GENII SDD.) It establishes the location of each receptor and source on a polar grid, and then for each receptor determining the distance and bearing from each source. For each radionuclide, the contribution from each source is summed, leading to a total concentration in air at the receptor's location. This average concentration is then used for further exposure and pathway analyses as addressed in Section D.3.

D.2.2.5 Depletion Processes

As radionuclides transit from a source to a receptor, several processes deplete the quantities of radionuclides in air. These processes include dry and wet deposition and radioactive decay.

D.2.2.5.1 Dry Deposition

Dry deposition is modeled in accordance with an assumption that the flux of material reaching the ground in is proportional to the concentration of the material in the air near the ground (1):

$\omega_{1ij}(t) = v_{dd} \; X_{ij}(t)$

Where $\omega_{1ij}(t)$ = the dry deposition rate at position i,j at time t (g/(s m^2)

v_{dd} = the dry deposition velocity (m/s), which is a function of the height at which the concentration is measured or calculated (assumed to be one meter for GENII).

$X_{ij}(t)$ = the concentration at a height of one meter above the ground at position i,j at time t.

Dry deposition velocities may be estimated using an analogy to electrical resistance, in that particles resist falling to the ground surface depending on their physical and chemical characteristics and atmospheric conditions. (Because noble gases are inert, the deposition velocity for noble gases is assumed to be zero.) For *small* particles, the dry deposition velocity is given by:

v_{dd} = $(r_a + r_s + r_t)^{-1}$

Where r_a = aerodynamic resistance (s/m)

r_s = surface resistance (s/m)

r_t = transfer resistance (s/m).

Aerodynamic resistance is a parameter characteristic of the turbulence in the lowest layer of the atmosphere, and can be calculated from the wind speed as:

r_a = $U(z) / u^2$

Where z = the height at which the concentration is estimated

u = the characteristic turbulence velocity, called the friction velocity

U(z) = the wind speed at height z.

The surface resistance is a function of the friction velocity, where:

r_s = $2.6 / (0.4\ u) = 6.5/u$

where 2.6 is a dimensionless empirical constant and 0.4 is von Karman's constant.

The transfer resistance is a mathematical device to establish an upper limit on the deposition velocity. As a default, the transfer resistance is assumed to be 10 s/m for iodine and 100 s/m for particles.

For *large* particles, the gravitational settling velocity of the particles must be considered, and the deposition velocity becomes:

$$V_{dd} = \left(r_a + r_s + r_t + r_a r_s v_s\right)^{-1} + v_s$$

Where v_s is the gravitational settling velocity, a function of particle size and density. GENII uses the same settling velocity as that used in the EPA ISC3 model, or [GENII SDD]:

$$v_s = \frac{\left(\rho - \rho_{AIR}\right) g d_p^2 c_2 S_{CF}}{18\mu}$$

Where ρ = the particle density (g/cm^3)

ρ_{AIR} = the air density (assumed to be 1.2E-3 g/cm^3)

d_p = the particle diameter (μm)

μ = the absolute viscosity of air (assumed to be 1.81E-4 g/cm/s)

c_2 = air units conversion constant (assumed to be 1E-8 $cm^2/\mu m^2$)

S_{CF} = the slip correction factor, which is computed as (1):

$$S_{CF} = 1 + \frac{2x_2\left(a_1 + a_2 \exp\left(-\frac{a_3 d_p}{x_2}\right)\right)}{10^{-4} d_p}$$

Where x_2, a_1, a_2, and a_3 are constants with values of 6.5E-6, 1.257, 0.4, and 0.55E-4, respectively.

D.2.2.5.2 Wet Deposition

Wet deposition of gases is modeled under an assumption that the exchange of gas between air and precipitation is sufficient to maintain equilibrium between the concentrations in the air and in the precipitation. The flux of gas to the ground surface is therefore proportional to the concentration of gas in air at ground level, the precipitation rate, and a solubility constant related to the Henry's Law constant for the gas. The wet deposition rate is given by (1):

$\omega_{2ij}(t)$ = v_{dw} $X_{ij}(t)$.

Where $\omega_{2ij}(t)$ = the wet deposition rate for gas at position i,j at time t (g/(s m^2)).

v_{dw} = the wet deposition velocity (m/s).

$X_{ij}(t)$ = the concentration at a one-meter height above ground surface at position i,j at time t.

And v_{dw} = c S P_r

Where S = the solubility coefficient (dimensionless).

P_r = the precipitation rate in mm/hr.

c = a conversion factor to convert P_r to m/s.

For gases, it is assumed for GENII that the gases are dissolved rapidly by precipitation. The wet deposition model for snow is assumed to be zero if the temperature is less than –3°C. (If temperature data are not available, the wet deposition velocity is zero for all forms of frozen precipitation.) This assumption is made because unless the precipitation is liquid, or has a liquid exterior, the rate of exchange of gases between air and ice is negligible.

For particulates, wet deposition is given by the following model, assuming that the particles are irreversibly collected by impaction as the precipitation falls through the plume (1):

$$\omega 3_{ij}(t) = \Lambda \int_o^\infty \chi_{ij}(z,t)dz$$

Where Λ is the washout coefficient, a function of the type of precipitation (liquid or frozen), the precipitation rate, and the precipitation collection efficiency.

This integral can be approximated as follows for sector-averaged point sources (1):

$$\omega_3 = \frac{\Lambda Q'}{U\theta_w}$$

Where Q' is the release rate corrected for depletion and decay.

For rain and drizzle, GENII uses the following expression to calculate the washout coefficient (1):

$$\Lambda_r = \frac{C E P_r}{0.35 P_n^{1/4}}$$

Where Λ_r = the washout coefficient for rain ($hr^{-1)}$

C = empirical constant with a value of 0.5

E = the average collection efficiency, assumed to be unity

P_r = precipitation rate in mm/hr

P_n = normalized precipitation rate (P_r/1 mm/hr)

During periods of hail, snow, and other frozen precipitation, GENII calculates the washout coefficient as (1):

$$\Lambda_r = 0.2 P_r$$

Where Λ_s = the washout coefficient for snow (hr^{-1})

0.2 = empirical constant with units of mm^{-1}

P_s = precipitation rate in mm/hr, liquid water equivalent

D.2.2.5.3 Total Deposition

Given the above formulas for wet and dry deposition, the surface contamination that accumulated at any point during any short period is given as (1):

$$D(x,y,T) = \sum_{o}^{T} \left[\omega 1_{ij}(t) + \omega 2_{ij}(t) + \omega 3_{ij}(t)\right]\Delta t$$

Where D(x,y,T) is the total surface contamination (Ci/m^2) at position (x,y) and for time period T. ω_{1ij}, ω_{2ij}, and ω_{3ij} are the deposition rates for dry deposition, rain deposition, and snow deposition, respectively. The total deposition rate, which is calculated for the GENII chronic models, is (1):

$$D'(x,y,T) = \frac{1}{T} D(x,y,T)$$

D.2.2.5.4 Radioactive Decay

Radionuclide decay is considered as radionuclides transit between the source and the receptor. For most radionuclides of interest, the decay is negligible, as is the buildup of daughter products. The algorithm for describing radionuclide decay during plume transit is given in Section 5.3.6 and Appendix C of the GENII SDD. The general procedure described in Appendix C for calculating decay chains includes branching as addressed in [Kennedy and Strenge] (16), and in [Strenge 1997] (17). Appendix C of the GENII SDD also references [Lederer and Shirley] (18) and the International Commission on Radiation Protection in ICRP Publication 38 [ICRP-38] (19) for data on radionuclide half-lives, decay chains, and

fractional branching within chains. Half-lives for the radionuclides considered in this report (including daughter products) are listed, in units of days, in Table D-3. They were obtained from Appendix E of [Kennedy and Strenge] (16). Half-lives are given as the relationship, $\log_e(2)/\lambda_i$, where λ_i is the radionuclide decay constant in units (in this case) of days^{-1}.

Table D-3 Half-Lives (days) for Radionuclides Considered in This Report

Isotope	Half-Life	Isotope	Half-Life	Isotope	Half-Life
^{3}H	4.51E+3	^{95}Nb	3.52E+1	^{231}Th	1.06E+0
^{14}C	2.09E+6	^{95}mNb	3.61E+0	^{234}Th	2.41E+1
^{32}P	1.43E+1	^{99}Tc	7.78E+7	^{234}U	8.93E+7
^{35}S	8.74E+1	^{103}Ru	3.93E+1	^{235}U	2.57E+11
^{41}Ar	7.63E-2*	^{106}Ru	3.68E+2	^{236}U	8.55E+9
^{60}Co	1.93E+3	^{129}I	5.73E+9	^{238}U	1.63E+12
^{65}Zn	2.44E+2	^{131}I	8.04E+0	^{238}Pu	3.20E+4
^{89}Sr	5.05E+1	^{134}Cs	7.53E+2	^{239}Pu	8.79E+6
^{90}Sr	1.06E+4	^{137}Cs	1.10E+4	^{240}Pu	2.39E+6
^{90}Y	2.67E+0	^{141}Ce	3.25E+1	^{241}Am	1.58E+5
^{95}Zr	6.40E+1	^{144}Ce	2.84E+2		

*From [FGR-13] (20).

D.2.2.5.5 Correction of Release Rate

To determine the concentrations of radionuclides at the point of interest, one must subtract those radionuclides that are lost through deposition and decay before reaching the point of interest. This is done for the basic Gaussian plume model by correcting the radionuclide release rate. For a given distance, x, from the source, one calculates an effective release rate, Q'(t), in units of Ci/s or Bq/s, which is equal to the actual release rate from which one subtracts the loss up to point x from deposition and decay. This assessment is done in GENII through consideration of conservation of mass. For plume models, the depletion of the source term per unit distance is given as (1):

$$\frac{dQ'}{dx} = -\int_{-\infty}^{\infty} \omega(x,y)\,dy = -\int_{-\infty}^{\infty} d_v \chi^{dy}$$

This integral can be solved to give a second integral which is approximated in GENII using a trapezoidal rule. Because the calculational procedure breaks down very close to the source, no depletion is assumed to occur within 100 meters of the source. (See Chapter 5 of [GENII SDD].)

D.2.2.6 Calms

The straight line Gaussian plume model cannot be derived for zero wind speeds. In GENII, a minimum wind speed (1 m/s) is assumed for calm conditions, and a randomly-selected direction. Unless the user of GENII supplies a distribution of low wind speed directions, all wind directions are assumed for GENII to be equally likely (1).

D.2.3 Application of Air Transport Models to SRS

Fifteen major sources of radionuclide release to air were identified. These 15 sources were then collapsed to four virtual sources of which three are represented by a release point of 61 meters above ground level (AGL) and one of 10 meters AGL (Appendix A).

To estimate transport from these virtual sources to exposure locations, the preparers had to develop a set of meteorological data that reflected the meteorological conditions that existed between 1954 and 1992. The principal need for the meteorological data was to establish the joint frequency distributions for input to the GENII computer code.

It would have been desirable to use SRS-specific meteorological data that spanned the entire 39-year period of operations. Unfortunately, the SRS meteorological program was only established in the early 1970's, leaving a gap of about 20 years in SRS-specific meteorological data.

Data from nearby weather stations. To approximate meteorological data for the entire 39 years of operation, data from nearby locations was considered. Yet this approach would have contained pitfalls as illustrated in [Weber 2001] (21).

[Weber 2001] documented the results of a study performed by Westinghouse Savannah River Company and Oregon State University to create a meteorological database for SRS for the years 1955 through 1961 (21). The authors of this study projected 1992-1996 data from reasonably close National Weather Service (NWS) stations to the 1955-1961 time period at SRS.

The two sets of NWS data used for the study were obtained from NWS sites near the Columbia, South Carolina, airport (CAE) and Bush Field near Augusta, Georgia (AGS). Figure D-3 [from Weber 2001] and Table D-4 [from Weber 2001] respectively illustrate the locations of these two airports relative to SRS and summarizes the differences in measurement parameters relative to SRS.

Columbia, South Carolina, and Augusta, Georgia, lie about 90 km apart from one another in the South Carolina Piedmont, a primarily agricultural area broken by forests, streams, and small communities. The Augusta NWS station is about 30 km west-northwest of the SRS meteorological station, while the Columbia NWS station is about 80 km northeast of the SRS meteorological station. The terrain surrounding the Columbia NWS station more closely resembles SRS than that surrounding the Augusta NWS station, which is located near swampy terrain in the Savannah River drainage basin. Fog and calm wind conditions occur much more frequently at Augusta than at Columbia or SRS. Also, the wind direction at the Augusta NWS is influenced by "channeling" caused by the presence of the Savannah River.

Unlike the meteorological data for SRS, which are obtained from a 61-meter tower (the same height as the stacks at SRS that are primarily responsible for airborne radionuclide release), the data at the Augusta and Columbia NWS stations were obtained from a 10-meter tower. The instrumentation at Augusta and Columbia was less sensitive than that at SRS, so that low wind speeds at Augusta and Columbia were more likely to be recorded as "zeros" (calms) than as actual measurements of speed and direction. In addition, the meteorological data at the Augusta and Columbia NWSs were 2-minute averages at the top of each hour (or 1/30 of the weather conditions over each hour). The SRS data, however, are averaged continuously over one-hour intervals.

To illustrate the variability in meteorological conditions that can occur between locations that are nominally close, wind roses for the years 1992 to 1996 are provided in Figure D-4 [from Weber 2001] for Augusta, Columbia, and SRS. These wind rose plots depict the frequency of the direction from which the

wind is blowing along with the wind speeds. As shown, the Columbia wind rose shows more frequently northerly winds than does that for SRS, although in both cases winds seem to predominately blow from either the north-through-east sectors or the south-through-west sectors. SRS winds blow more frequently from the southeast than do Columbia winds. The Augusta wind rose is more nearly symmetrical than that for either SRS or Columbia.

The authors [Weber 2001] also compared long-term average data for Augusta and Columbia NWSs. They determined that the 1948-1995 wind rose for Columbia was similar to the 1992-1996 SRS wind rose, and that the 1948-1995 wind rose for Columbia was more similar to a 1955-1961 Columbia wind rose than to the 1992-1996 Columbia wind rose. "In spite of the fact that the 1992-96 time period (as evidenced by the CAE wind rose) is not representative of the longer-term trends, it was nevertheless used to provide the basis for representing the wind direction at SRS" (21).

Hence, the authors projected SRS meteorological conditions at a 61-meter level for the years 1955 through 1961using recorded data at a 10-meter level for the 1992-1996 time period from the Columbia NWS station. They used three different statistical techniques: (1) a linear regression method, (2) a similarity theory approach, and (3) a statistical differences method. They judged the last method to give the "best" [quotes in original] statistical distribution because of its superior distribution function and lack of appreciable bias (21).

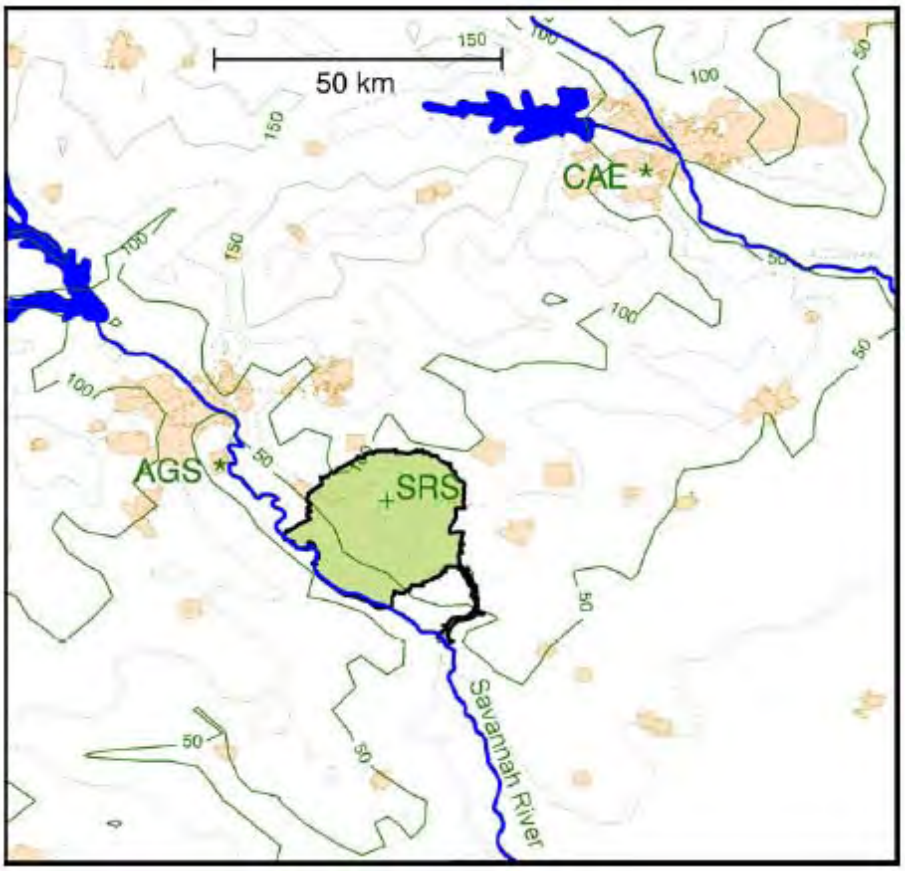

Figure D-3 Map of SRS Showing the Locations of Augusta and Columbia National Weather Service Stations[9]

[9]Adapted from [Weber 2001] (21). Topographic contours are 25-meter intervals above sea level, with highlighted 50- and 100-meter intervals. Lightly-shaded filled areas denote locations of cities and towns.

Table D-4 Differences Between Measurement Parameters for Augusta and Columbia National Weather Stations and for SRS

Difference	Savannah River Site	Columbia, SC NWS (CAE)	Augusta, GA NWS (AGS)
Height of Sensors	61 meters.	10 meters.	10 meters.
Instrument Sensitivity	High sensitivity.	Robust instrumentation but low sensitivity.	Robust instrumentation but low sensitivity.
Averaging Time	One hour (continuous).	Two minute "snapshots".	Two minute "snapshots".
Topographical Influences	Pine tree forest. Mostly flat within 2 km of the tower. Modest terrain changes beyond.	Airport location. Lies near partially developed suburban landscape.	Airport location. Lies at the edge of the Savannah River drainage basin.

Source: [Weber 2001] (21).

Decision to use twenty-year averages. The preparers might have used the projected metrological conditions determined in [Weber 2001] for this report. The preparers did not do so, however, because it only covered the years 1955 through 1961, leaving a meteorological data gap about a decade long. The scope of this study did not include preparation of this projected data. In addition, it was not apparent that use of the information from [Weber 2001] would have added add appreciably, if at all, to the accuracy of the doses calculated for this study.

Therefore, it was decided to use SRS-specific data from the SRS meteorological station to represent the entire 39 years of operation. Because joint frequency distribution data from the SRS meteorological station was available only as five-year averages, the prepareres averaged four five-year averages to arrive at a twenty-year average.

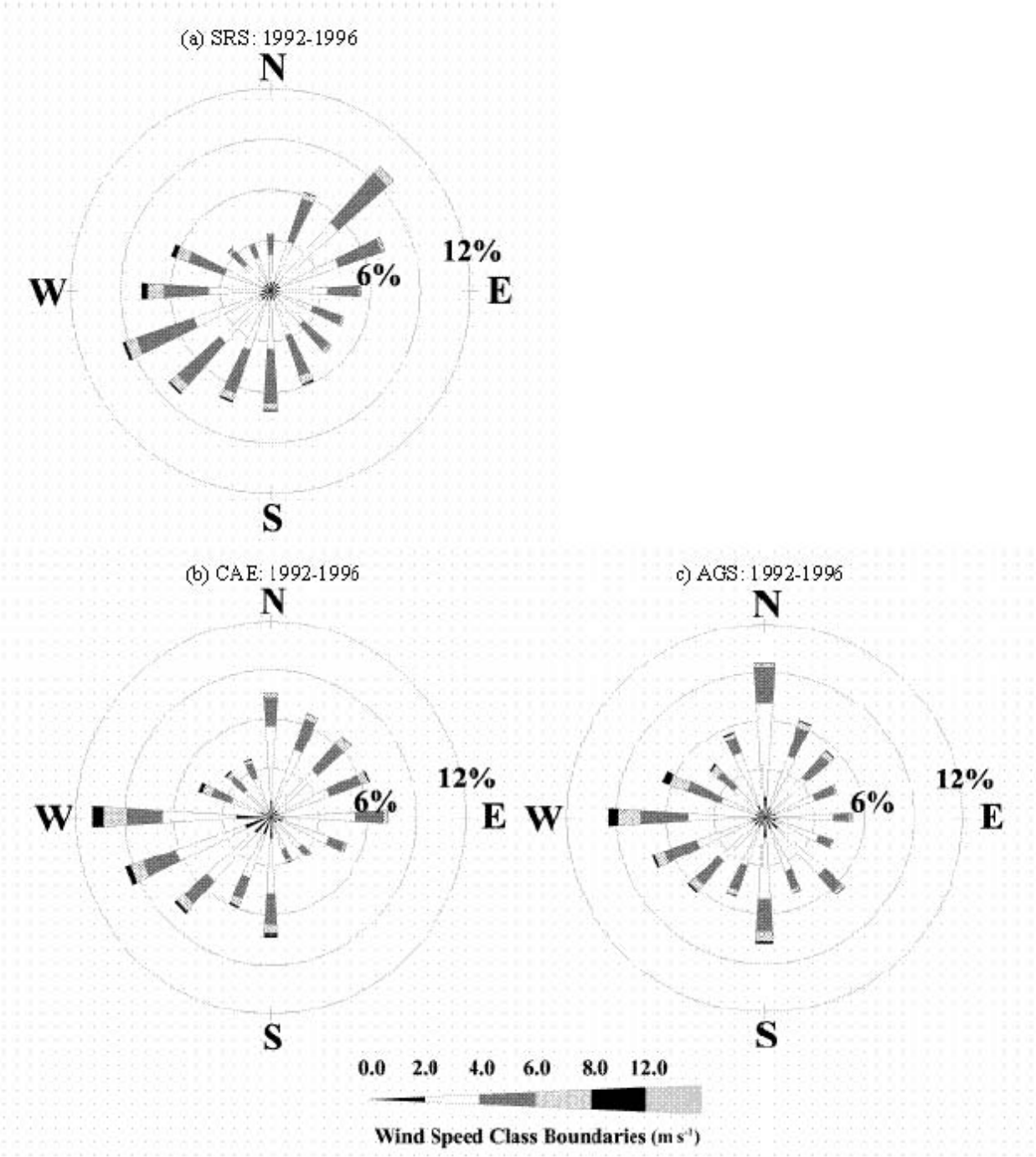

Figure D-4 1992-1996 Wind Rose Plots for SRS and the Columbia and Augusta National Weather Service Stations[10]

[10]Adapted from [Weber 2001] (21).

D.3 Transfer and Exposure Pathways

This section presents the mathematical relationships used in GENII to model the transfer of radionuclides through air and water exposure pathways. The mathematical relationships are from Chapters 9 and 10 of the GENII SDD. This section summarizes the equations used for most radionuclides as well as those used for the behavior of tritium and ^{14}C in environmental pathways.

The general form of the equations in this section can be depicted as Figure D.5.

Given a concentration of a radionuclide in air (Ci/m^3 or Bq/m^3) or water (Ci/L or Bq/L) at an exposure location, the mathematical relationships model the movement of radionuclides through each pathway. Each relationship is composed of a set of parameters, each requiring a numerical value. To avoid a voluminous and complicated appendix, we generally defer a discussion of the assumed values for parameters that are used in the base-case GENII calculations to other appendices. Some parameters pertain to site-specific considerations such as the density of soil (see Appendix F). Others, called Usage Factors in Figure D.5, pertain to human activities that influence the uptake or exposure to radionuclides (e.g., time spent in an exposure location) and are determined in Appendix E in accordance with the exposure scenarios discussed in Appendix E.

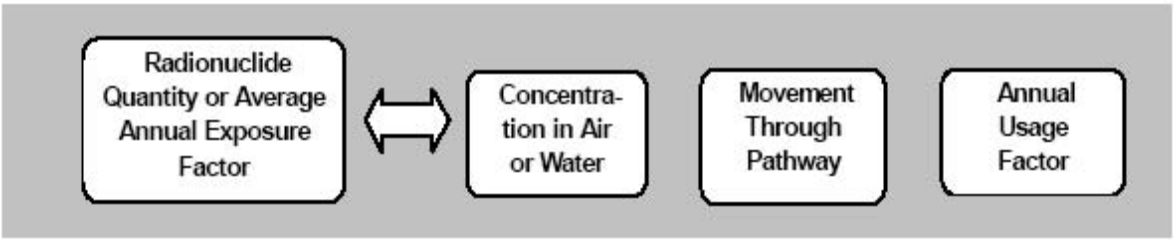

Figure D-5 Illustration of General Form of Equations in Section D.3

The GENII mathematical relationships first determine the following information:

- Annual radionuclide activity ingested (Bq in a year) for ingestion exposure pathways
- Annual radionuclide activity inhaled (Bq in a year) for inhalation exposure pathways
- Annual average exposure factor for external radiation exposure pathways. Units depend on whether exposure results from immersion in air (Bq/m^3) or water (Bq/L), or from proximity to soil or sediment (Bq/kg) or water (Bq/L).

GENII then multiplies this information by dose and risk relationships that are described in [GENII SDD] and summarized in Section D.4.

Not all exposure pathways that are considered in this report may be appropriate for a specific receptor.

D.3.1 Inhalation of Contaminated Air

Section D.2.1 addresses models describing the movement of radionuclides through the air pathway. The output of the model is the radionuclide concentration (Bq/m^3) at the receptor location, assuming a receptor height of 1 meter, as a function of time (e.g., average concentration over a year).

Exposure as a function of location and time is modeled as an average concentration of radionuclides in air that is inhaled over the time period of concern. The amount that is inhaled is a function of the average breathing rate, which depends on the age of the receptor.

The total amount of radioactive material that is inhaled is given as (1):

$$I_{aaig}(T) = C_{aag}\ U_{aag}\ T_{aag}\ ED_{aag}$$

Where $I_{aaig}(T)$ = total intake of radionuclide i from air inhalation over the period T at air usage location a for individuals in age group g (Bq)

C_{aag} = average air concentration for radionuclide i at air usage location a over time period T (Bq/m^3)

U_{aag} = inhalation rate at air usage location a for individuals in age group g (m^3/d)

T_{aag} = annual intake factor giving days per year that air inhalation occurs at air usage location a for individuals in age group g (d/y)

ED_{aag} = exposure duration for the air inhalation pathway at air usage location a for individuals in age group g (y).

Assumed parameter values for exposure times per individual, and average breathing rates as a function of age group, are provided in Appendix E.

Table D-5 Transport, Transfer, and Exposure Matrix

Transport Mechanism	Transfer Pathway or Activity	Exposure Route	Section	Rural Family One	Rural Family Two	Urban Family	Delivery Person Family	Outdoors Person Family	Family Living Near River	Migrant Family
Air (Sections D.3.1 & 3.3.2)	Plume Inhalation	Inhalation	D.3.3.1	X	X	X	X	X	X	X
	Plume Immersion	External	D.3.2	X	X	X	X	X	X	X
	Ground Contamination	External Exposure	D.3.3.2	X	X	X	X	X	X	X
		Inhalation	D.3.3.3	X	X	X	X	X	X	X
		Ingestion Soil	D.3.3.4							
	Plant and Food Concentration	Ingestion: Vegetables Fruit Grains	D.3.4.1	X	X	X	X	X	X	X
	Animal Product Concentration	Ingestion: Beef Poultry Milk Eggs	D.3.4.2	X	X	X	X	X	X	X
Surface Water (Section D.2.3)	Aquatic Accumulation	Ingestion	D.3.4.3				X	X	X	
	Concentration in Sediment	External Exposure	D.3.5				X	X	X	
	Recreational Swimming	External Exposure	D.3.6.1				X		X	
		Ingestion	D.3.6.2				X		X	
	Recreational Boating	External Exposure	D.3.6.3				X		X	

D.3.2 Immersion in Plume of Contaminated Air

External exposures from immersion in a plume of contaminated air is given as (1):

$I_{eaig}(T) = C_{eai}(T)\ U_{eag}\ TC_p$

$I_{eaig}(T)$ = average exposure factor over the period T for external plume immersion exposure for radionuclide i for an individual in age group g (Bq/m^3)

$C_{eai}(T)$ = average air concentration over the period T at the location of the exposed individual for radionuclide i (Bq/m^3)

U_{eag} = daily exposure factor (daily plume immersion exposure time) giving hours of plume immersion exposure per day for individuals in age group g (h/d)

TC_p = time correction set to T_{eag}/(8760 h/y) for chronic releases

T_{eag} = annual exposure factor (yearly plume exposure time) giving the number of days in a year of external plume immersion for individuals in age group g (d in a y).

Parameter values for calculating external doses from immersion in contaminated air are provided in Appendix F. Important considerations are the age of the receptor, and the duration of exposure.

D.3.3 Ground Contamination Pathways

Exposures and resulting doses arising from ground contamination pathways are addressed here and include external radiation exposures from contaminated soil, inhalation of resuspended soil, and ingestion of contaminated soil.

D.3.3.1 Contamination Buildup and Loss in Soil

To assess doses resulting from ground contamination pathways, one must first consider processes for buildup and loss of radionuclides in soil. Radionuclides accumulate in soil by wet and dry deposition from the air, and from deposition via irrigation. (However, irrigation was not considered a reasonable pathway for the scenarios defined for this report.) Radionuclides are lost by leaching from the surface soil zone, by harvesting vegetation that has taken up radionuclides from the soil, and by radioactive decay. The general model for expressing the buildup and loss of radionuclides from soil is a differential equation of the form (1):

$dA_i(t)/dt = (R_{bi} + R_{ai}) - (\lambda_{Li} + \lambda_i)\ A_i$

Where A_i = amount of radionuclide i in the surface soil zone at time t (atoms)[11]

R_{ai} = rate of input from atmospheric depletion (wet and dry deposition) (atoms/y)

R_{bi} = rate of input from irrigation water (atoms/y)

λ_i = radioactive decay constant for radionuclide i (y^{-1})

λ_{Li} = rate constant for leaching radionuclide from the surface soil zone (y^{-1}).

This model is solved in GENII by an integrator that considers radionuclide decay chains. For chronic releases, the initial activity of radionuclide in the soil is assumed to be zero.

[11] As indicated, the basic equation as presented in the GENII SDD is given in units of atoms. The quantity of a radionuclide in soil can be converted from radioactive atoms to activity (Bq) by multiplying by the decay constant, λ_i.

Losses from harvest are handled outside this differential equation because they occur as isolated events during the year rather than as a continuous process. Losses from harvest are subtracted from the calculated radionuclide amount via a step function at the time of harvest.

Below we discuss the deposition of radionuclides from the air, leaching from the soil zone, and loss by harvest.

D.3.3.1.1 Deposition from the Air

Accumulation from deposition from the air is determined using the calculational relationships for airborne deposition as presented in Chapter 5 of the GENII SDD and summarized in Section D.2.1.6 of this report. For chronic and essentially uniform release of radionuclides over the course of multiple years (see next paragraph), initial radionuclide concentrations in the upper surface of the soil zone are set equal to zero. In each subsequent year the soil concentrations at the end of the year are evaluated based on the concentrations present at the beginning of the year as modified by activity deposited during the year, and by activity lost considering decay and other processes. The average concentration from past years' contributions is represented by the term $C_{si}(T_{yr})$, with units of Bq/m^2. Decay evaluations are made using the GENII decay processor, which considers branching and ingrowth of radioactive chains as needed.

As implied by the above paragraph, the system used in GENII to calculate buildup over the course of several years was designed under the assumption that releases to air (and surface water), and deposition over time, are essentially constant per year. This assumption would be consistent with use of the GENII code for preoperational evaluation of a nuclear facility. In addition, the system for calculating doses and risks using GENII was designed under the assumption that the same dose and risk conversion factors would be used for each year (i.e., one assumes a constant receptor age over the time period of concern).

But GENII is being used for this project for reconstructing past doses and risks rather than evaluating the doses and risks that may result from operation of a new or existing nuclear facility. Different radionuclide release rates were considered for each of the 39 years of operation, and also doses and risks to receptors as they grow up in the area were considered, meaning that over 39 years several sets of age-specific dose and risk conversion factors may be used for each receptor as that receptor grows from an infant to an adult. To address these calculational needs, GENII was linked to a custom-designed pre- and post-processor. Doses and risks are calculated for each receptor according to the receptor's age group, and summed over all operational years.

To do this, separate GENII computations had to be made for each year of operation. Each time this was done, the radionuclide concentrations in the upper surface of the soil zone were set equal to zero as discussed in the first paragraph of this section. Hence, although buildup in soil, and loss through leaching from the surface soil zone, are considered over the course of a year, buildup and loss that may have taken place over all 39 years of SRS operation are not considered directly in GENII. The implications of this calculational limitation on the results of the study are addressed elsewhere.

D.3.3.1.2 Leaching from the Surface Soil Zone

Removal from surface soils through leaching into deeper soils may be addressed in GENII in three optional ways:

1. Calculate leaching using GENII default leach rates.
2. Calculate leaching using a soil removal formula.
3. Calculate leaching using user-provided leach rate constants.

For this report, leaching from the surface soil zone was calculated using the second option: a soil removal rate constant, λ_{si}. This constant is calculated in GENII according to a general formula developed by Baes and Sharp (22):

$$\lambda_{si} = \frac{10^{-2}(P + 1 - E)}{d_s \theta_s \left[1 + \frac{10^3 10^{-6} \rho_s}{\theta_s} Kd_{si} \right]}$$

Where λ_{si}	=	removal rate constant for activity of radionuclide i in the surface soil layer (y^{-1})
P	=	total annual precipitation (cm/y)
I	=	total irrigation rate (cm/y)
E	=	total evapotranspiration rate (cm/y)
d_s	=	surface soil thickness (cm)
ρ_s	=	surface soil bulk density (kg/m^3)
Θ_s	=	surface soil volumetric water content (mL/cm^3)[12]
Kd_{si}	=	surface soil distribution coefficient for radionuclide i (mL/g)
10^{-2}	=	units correction factor (m/cm)
10^3	=	units correction factor (g/kg)
10^{-6}	=	units correction factor (m^3/ml).

In the above equation, the surface soil thickness is the average thickness of the surface soil. If the surface soil is agricultural land, the thickness should be set to represent the plow layer. And where, for this report,

The total infiltration rate is evaluated in GENII as the sum of the total annual precipitation plus the irrigation rate minus the evapotranspiration rate. It represents the quantity, (P + I – E), in the numerator of the above equation. Note that for this report, the total irrigation rate, I, is assumed to equal zero based on the scenarios defined for this report.

D.3.3.1.3 Loss by Harvest

Loss of radionuclides from the surface soil zone is modeled in GENII as a step function applied at the end of each year. The model accounts for plant concentrations at harvest, the annual plant yield, and the soil concentrations at harvest (1):

$C_{si}(t_+)$	=	$C_{si}(t_-)\ [\ (C_{si} - C_{ci}(Th_c)\ Y_c) / C_{si}\ ]$
Where $C_{si}(t_+)$	=	surface soil concentration at soil location s for radionuclide i after correction for harvest removal at time t (Bq/m^2)
C_{si}	=	average (over the year) value of surface soil concentration at soil location s for radionuclide i (Bq/m^2)
$C_{si}(t_-)$	=	surface soil concentration at soil location s for radionuclide i before correction for harvest removal at time t (Bq/m^2)

[12] This unit sited in the [GENII SDD] is functionally dimensionless.

$C_{ci}(Th_c)$ = Concentration of radionuclide i in crop c at time of harvest (Bq/kg)

Y_c = annual harvested yield of crop c (kg/m^2).

In the above equation, the term on the right, within the square brackets, represents the average (over a year) ratio of the contaminant in soil to that in crops. This term is used rather than a simple subtraction of amount harvested because, for short-lived radionuclides, the amount harvested over the year might be larger than the amount remaining in the soil at the end of the year.

In addition, the radionuclide concentration in each food crop considered in GENII ($C_{ci}(Th_c)$) is calculated using the relationships described in Section D.3.4.1 for ingestion of radionuclides through food crops. However, for purposes of the ground contamination pathways, the radionuclides that are ingrown into harvested food crops would be removed from the analysis. (Radionuclides ingrown into food crops are, of course, considered in the food crop ingestion analysis considered in Section D.3.4.1.) Note that GENII allows the user to consider, for purposes of harvesting, a different set of food crop growth parameters (e.g., interception fractions, standing biomass) from those considered for food crop ingestion (see Section F.4.2.1). In any event, for this study, loss through harvesting is conservatively not considered. This conservatism maximizes the concentrations of radionuclides assumed to be concentrated in the top surface of the soil.

D.3.3.2 External Radiation Exposures from Contaminated Soil

To determine exposures one must first calculate, over the year of exposure considered, average soil concentration in units of Bq/m^2. This value is then divided by the soil areal density (units of kg/m^2) to obtain an average concentration in units of Bq/kg. The general form of the equation to calculate average soil concentrations is (1):

$$C_{esi}\left(T_{yr}\right) = \left[C_{si}\left(T_{yr}\right) + \left[R_{ait} + R_{wit}\right] \frac{1}{\lambda_i T_{yr}} \left[T_{yr} - \frac{1 - e^{-\lambda_i T_{yr}}}{\lambda_i} \right] \right] / \left(d_s \rho_s\right)$$

Where $C_{esi}(T_{yr})$ = average surface soil concentration (including deposition) at soil location s for radionuclide i including deposition during the year (Bq/kg)

$C_{si}(T_{yr})$ = average surface soil concentration at soil location s for radionuclide i at the start of the current year (Bq/m^2)

R_{ait} = constant deposition rate of radionuclide i from air for year t (Bq/(m^{2}y))

R_{wit} = constant deposition rate of radionuclide i from irrigation water for year t (Bq/(m^{2}y))

d_s = thickness of soil containing radionuclide contamination (m)[13]

ρ_s = density of soil (kg/m^3)

T_{yr} = one year integration period (y).

The term on the right side of the equation, following the [R_{ait} + R_{wit}] term, represents the evaluation of the time-integral from deposition onto soil at a constant rate. Accumulation occurs over a one-year period. Division by the one-year period provides the average soil concentration during the year.

[13] For purposes of modeling for these and other exposure pathways considering deposition of radionuclides onto soil or sediment, one assumes that the radionuclides are uniformly concentrated throughout a narrow band of soil near the earth's surface (e.g., a thickness of about 15 cm (6 in), which is about the depth that a plow would penetrate soil).

The deposition rate for atmospheric (wet and dry) deposition is described in Section D.2.1.6. Deposition from irrigation is not considered (R_{wit} = 0.)

Once average soil concentrations (Bq/kg) are determined, the average exposure factor for exposure to surface-contaminated ground is calculated as (1):

$$I_{esig}(T) = C_{esi}(T)\, U_{esg} \left[SH_h\, FT_{hg} + SH_o\, FT_{og} \right] T_{esg}$$

Where $I_{esig}(T)$ = average exposure factor over time period T for external exposure to contaminated ground for radionuclide i for individuals in age group g (Bq/kg)

$C_{esi}(T)$ = average soil concentration at the location of individual exposure for radionuclide i for time period T (Bq/kg)

U_{esg} = daily exposure factor (daily external ground exposure time) giving hours of exposure to contaminated ground per day for individuals in age group g (h/d)

SH_h = shield factor (indoor shielding factor) for exposure to soil while inside a home (dimensionless)

FT_{hg} = fraction of time spent inside a home (indoors) for individuals in age group g (dimensionless)

SH_o = shield factor (outdoor shielding factor) for exposure to soil while outside (dimensionless)

FT_{og} = fraction of time spent outside (outdoors) for individuals in age group g (dimensionless)

T_{esg} = annual exposure factor (yearly external ground exposure time) giving external ground exposure for individuals in age group g (d).

Assumed values for U_{esg}, SH_h, FT_{hg}, SH_o, FT_{og}, and T_{esg} are provided as a function of receptor in Appendix E.

D.3.3.3 Inhalation of Resuspended Soil

GENII uses a model for inhalation exposure from resuspended radionuclides that incorporates a parameter called the resuspension factor, a factor relating the soil concentration (per unit area) to the air concentration (per unit volume), and is in units of m^{-1}. The mathematical equation for the model is (1):

$$C_{esi}\left(T_{yr}\right) = RF_a \left[C_{si}\left(T_{yr}\right) + \frac{R_{ait} + R_{wit}}{\lambda_i T_{yr}} \left[T_{yr} - \frac{1 - e^{-\lambda_i T_{yr}}}{\lambda_i} \right] \right]$$

Where $C_{sai}(T_{yr})$ = air concentration of radionuclide i at soil resuspension exposure location a for a one-year period (Bq/m^3)

RF_a = resuspension factor for soil exposure location s (m^{-1})

$C_{si}(T_{yr})$ = average surface soil concentration over the current year at the soil exposure location s from material deposited in earlier years (Bq/m^2).

Other terms are as defined previously.

The resuspension factor may be estimated in more than one way. GENII offers three optional methods for doing so (1). The method used for this report was to input an assumed resuspension factor in units of m^{-1}.

The resuspension factor had a different value depending on the location where soil resuspension occurs. As addressed in Section F.3.1, a larger resuspension factor was assumed for locations where there was likely to be farming.

Once air concentrations are calculated, the total intake of contamination over the period of concern is given as (1):

$I_{saig}(T)$ = $C_{sai}(T)\ U_{sag}\ F_{sag}\ T_{sag}\ ED_{sag}$

Where $I_{saig}(T)$ = total intake of radionuclide i from resuspension inhalation over the time period T at soil usage location a for individuals in age group g (Bq)

$C_{sai}(T)$ = average concentration of radionuclide i in soil over time period T at soil usage location s (Bq/m^2)

U_{sag} = inhalation rate of air for the resuspension pathway at soil location s for individuals in age group g (m^3/d)

F_{sag} = fraction of a day that resuspension inhalation exposure occurs at soil usage location s for individuals in age group g (dimensionless)

T_{sag} = annual intake factor (resuspended soil inhalation period) giving days per year that resuspension inhalation occurs at soil usage location s for individuals in age group g (d/y)

ED_{sag} = exposure duration for the resuspension inhalation at soil usage location s for individuals in age group g (y).

The exposure duration (ED_{sag}) accounts for possible multiple years of exposure from deposition of radionuclides onto the ground during these years at a constant rate. As addressed in Section D.3.3.1, this period is set at one year because deposition is not constant from year to year, and because multiple age-specific sets of risk and dose conversion factors must be considered. Otherwise, assumed values for U_{sag}, F_{sag}, and T_{sag} are provided in Appendix E.

D.3.3.4 Inadvertent Ingestion of Soil

Inadvertent ingestion of soil is evaluated in the following manner (1):

$$C_{dsi}(T_{yr}) = \frac{10^3}{10^4 \rho_s d_s}\left[C_{si}(T_{yr}) + \frac{R_{ait} + R_{wit}}{\lambda_i T_{yr}}\left(T_{yr} - \frac{1 - e^{-\lambda_i T_{yr}}}{\lambda}\right)\right]$$

Where $C_{dsi}(T_{yr})$ = average concentration at soil location s for radionuclide i in soil consumed during the current year (Bq/kg)

$C_{si}(T_{yr})$ = average surface soil concentration at soil location s for radionuclide i during the current year (Bq/m^2)

ρ_s = density of surface soil (g/cm^3)

d_s = thickness of contaminated surface soil layer (cm)

10^4 = units conversion factor ($cm^2/m^{2)}$

10^3 = units conversion factor (g/kg).

Other terms are as previously defined.

The total intake is then calculated from the average soil concentration ($C_{dsi}(T_{yr})$) as follows (1):

$$I_{dsig}(T) = 10^{-6}\ C_{dsi}(T)\ U_{dsg}\ T_{dsg}\ ED_{ds}$$

Where $I_{dsig}(T)$ = total intake of radionuclide i from inadvertent soil ingestion over time period T at soil usage location s for individuals in age group g (Bq)

$C_{dsi}(T)$ = average soil concentration for radionuclide i at soil usage location s for time period T (Bq/m^2)

U_{dsg} = ingestion rate for soil location s for individuals in age group g (mg/d)

T_{dsg} = annual intake factor (soil contact days) giving days per year that ingestion occurs at soil usage location s for individuals in age group g (d/y)

ED_{ds} = exposure duration for the soil ingestion pathway at soil usage location s for individuals in age group g (y)

10^{-6} = units conversion factor (mg/kg).

As above, the exposure duration (ED_{ds}) accounts for possible multiple years of exposure from deposition of radionuclides onto the ground during these years at a constant rate. As addressed in Section D.3.3.1, this period is set at one year because deposition is not constant from year to year, and because multiple age-specific sets of risk and dose conversion factors must be considered. Otherwise, assumed values for U_{dsg}, and T_{dsg} are provided in Appendix E.

D.3.4 Food-Chain Transport and Exposure

This section covers the following exposure pathways:

Section	Section Description
D.3.4.1	Ingestion of food crops contaminated with radionuclides, including deposition (surface) contamination as well as root uptake.
D.3.4.2	Ingestion of animals (e.g., livestock) and animal products (e.g., eggs) that have taken up radionuclides through consumption of contaminated forage (from deposition) or consumption of contaminated surface water.
D.3.4.3	Ingestion of contaminated aquatic foods (fish, shellfish, etc.)

These three exposure pathways model transfer of radionuclides through food pathways. The calculations are normally performed using variables generally called transfer factors that describe the ratio (at equilibrium) between contamination levels in two types of media (or environmental compartments). Some variables are partition coefficients — for example, the ratio of contamination levels in soil and in a plant that grows in soil. Other variables describe the steady state ratio between contamination levels in plant matter and contamination levels in animal products (meat, eggs, or milk) that is produced from an animal that consumes the plant matter at a unit intake rate. Still other variables characterize bioaccumulation processes, such as those for fish and shellfish..

Although a substantial body of literature exists for various transfer values, there is considerable uncertainty in any single value assigned to a transfer factor. For this reason, we discuss the selection of values for transfer factor parameters in detail, mainly in Appendix F.

D.3.4.1 Ingestion of Food Crops

This section addresses direct ingestion of crops and plants grown in contaminated soil or dusted with deposited and resuspended soil. These crops and plants include leafy vegetables, other vegetables, cereal grains, and fruit. Special models for calculation of uptake of tritium and ^{14}C in food products are also described. Similar models are used to calculate uptake by animals that are then used as food products by humans. Human ingestion of animal products, including cow's milk, beef and meat, poultry, and eggs from poultry, is considered in Section D.3.4.2.

D.3.4.1.1 Radionuclide Concentration in Soil

Deposition considered for the terrestrial food pathways is the deposition that is modeled to exist at the location where the farm product is produced. This deposition is considered as an average value obtained from the output of the atmospheric transport model addressed in Section D.2. The annual average deposition is evaluated as the time integral of the deposited activity for deposition at a constant rate.

Deposition, accumulation, and loss is modeled as a differential equation of the following form (1):

$$\frac{d\,C_{ai}(t)}{d\,t} = R_{ait} - \lambda_i C_{ai}(t)$$

Where $C_{ai}(t)$ = areal concentration from deposition from air to soil or plants at location a for radionuclide i as a function of time (Bq/m^2).

R_{ait} = constant deposition rate of radionuclide i from air at location a (Bq/m^2 y).

λ_i = radiological decay constant for radionuclide i (y^{-1}).

The atmospheric deposition rate is the sum of the dry and wet deposition rates.

The soil concentration is used when estimating root uptake to plants, as well as the resuspension and re-deposition of activity onto plant surfaces. The concentration during the year is calculated as the sum of the surface soil concentration from the soil model, $C_{si}(T_{yr})$, discussed previously. The soil concentration is addressed as follows, where the amount deposited is calculated as the time-integral of deposition over the particular annual period considered (1):

$$C_{ci}(T_{yr}) = C_{si}(T_{yr}) + \frac{R_{ait} + R_{wit}}{\lambda_i\,T_{yr}}\left[T_{yr} - \frac{1-e^{-\lambda_i T_{yr}}}{\lambda_i}\right]$$

Where$C_{ci}(T_{yr})$ = average concentration of radionuclide i in farmland soil for crop type c during the year considered (Bq/m^2).

$C_{si}(T_{yr})$ = the average concentration during the current year of radionuclide i in surface soil in location s (where crop c is grown) for deposition from earlier years (Bq/m^2).

Other terms are as previously defined.

D.3.4.1.2 Radionuclide Concentration in Food Crops

The concentration in plants at the time of harvest is calculated as the sum of contributions from deposition onto plant surfaces, plus uptake through roots. Deposition onto plant surfaces includes deposition directly onto plant surfaces, as well as deposition from material resuspended from soil. The general form of the model is given as (1):

$$C_{dci}(T_{yr}) = \left[R_{aitd}\, r_{dc} + R_{aitw}\, r_{we} + 3.15E7 C_{ci}(T_{yr}) RF_c Vd_i\, r_{dc} + R_{wit} \frac{12 r_{ic}}{M_c} \right] \frac{T_{Vc}}{B_c} \left[\frac{1 - e^{-\lambda_{wi} Tg_c\, 2.74E-3}}{\lambda_{ei}} \right]$$

Where $C_{dci}(T_{yr})$ = concentration of radionuclide i on plant type c at harvest from deposition processes for a one-year period (Bq/kg wet weight)

T_{yr} = one-year exposure period (y)

r_{dc} = interception fraction from airborne dry deposition for plant type c (dimensionless)

r_{wc} = interception fraction for airborne wet deposition to plant type c (dimensionless)

$C_{ci}(T_{yr})$ = average concentration of radionuclide i in farmland soil for crop type c for the current one-year period (Bq/m^2)

RF_c = resuspension factor for crop soil (m^{-1})

Vd_i = deposition velocity of radionuclide i (m/s)[14]

12 = months per year

r_{ic} = interception fraction for irrigation deposition to plant type c (dimensionless), and assumed to be generally equivalent to r_{wc}

M_c = irrigation period for plant type c (month)

T_{Vc} = translocation factor for plant type c (dimensionless)

B_c = total standing biomass for plant type c (kg wet weight/m^2)

λ_e = λ_{wi} + λ_i

λ_{wi} = weathering rate constant for crops for radionuclide i (y^{-1})[15]

Tg_c = crop growing period for plant type c (d)

3.15E+7 = units conversion factor (sec/y)

2.74E-3 = units conversion factor (y/d).

And where irrigation is assumed not to occur for scenarios defined for this report.

The plant concentration at harvest from root uptake is given as (1):

[14] In fact, however, the deposition velocity as actually used in the GENII coding is not radionuclide-specific. A value for deposition velocity must be assumed that is the same for all radionuclides.

[15] Note that the value actually input when using GENII is the weathering half-life, in days, as calculated from the relation ln2/ $\lambda_{wi.}$ The GENII coding performs the needed conversion to λ_{wi} and corrects from d^{-1} to y^{-1}. In addition, the weathering rate as used in GENII is actually constant for all radionuclides.

$$C_{rci}(T_{yr}) = \frac{C_{ci}(T_{yr}) RP_{sc}\, Bv_{ci}\, f_c}{P_3}$$

Where $C_{rci}(T_{yr})$ = concentration of radionuclide i in crop type c from root uptake pathways for a one-year period (Bq/kg wet weight)

Bv_{ci} = concentration ratio for root uptake of radionuclide i in crop type c (Bq/kg dry plant per Bq/kg dry soil)

f_c = dry-to-wet ratio for plant type c (kg dry plant/kg wet plant)

P_3 = areal soil density of farmland soil (kg/m^2)

RP_3 = fraction of plant type c having roots in surface soil zone (dimensionless).

The total concentration in the plant at the time of harvest is the sum of the contribution from the deposition and root uptake pathways, or:

$$C_{hci}(T_{yr}) = C_{dci}(T_{yr}) + C_{rci}(T_{yr})$$

Where $C_{hci}(T_{yr})$ is the concentration in plant type c at harvest for a one-year period (Bq/kg wet weight). Other variables have already been defined.

D.3.4.1.3 Radioactive Decay

GENII has the capability of evaluating radionuclide decay between harvest of food crops and consumption of the crops by humans. The decay calculation is performed in GENII, considering decay chains and branching, using the decay processor described in Section D.2.1.6 of this report. For most radionuclides (those for which decay chains and branching is not a factor), the decay calculation is calculated as follows (1):

$$C_{csi}(T_{yr}) = C_{hei}(T_{yr})\, e^{-\lambda i\, Thc\, 2.74E-3}$$

Where $C_{csi}(T_{yr})$ = concentration of radionuclide i in crop type c at location s at the time of consumption over a one-year period (Bq/kg wet weight)

Th_c = holdup delay time between harvest and consumption for crop type c (d)

λ_i = radiological decay constant for radionuclide i(y-1)

2.74E-3 = Conversion factor, years per day (1 year /365 days).

D.3.4.1.4 Interception Factor and Dry-to-Wet Ratio

This factor (also called interception fraction, or retention fraction) accounts for the fact that not all material deposited from the air lands on plant surfaces. A fraction deposited from the air lands on plant surfaces, while the remaining fraction misses plant surfaces and lands on soil. GENII provides two optional methods for performing calculations using the interception fraction (1). These calculations were performed using user-defined values for wet and dry interception (dimensionless). The assumptions for the wet and dry interception factors, and for dry-to-wet ratios, are presented in Section F.4.2.1.

D.3.4.1.5 Resuspension Factor

The resuspension factor for crop soil (RFc) in the above equation is essentially the same resuspension factor as that described in Section D.3.3.3. RFc is in units of m^{-1} and is the ratio of the radionuclide concentration in air (Bq/m^3) to the areal concentration of radionuclides in the top soil layer (Bq/m^2). For this report, a larger resuspension factor is assumed for locations where farming is assumed to occur than for residential areas.

D.3.4.1.6 Translocation Factor and Weathering

Material deposited on plant surfaces may be absorbed into the plant or may be removed from the plant because of wind, rain, or other weathering processes. The translocation factor (T_{Vc}) is the fraction of the total deposition on plant surfaces that is incorporated into the edible parts of the plant. As a GENII default, a value of 0.1 is assumed for all vegetation except for leafy vegetables and forage crops, for which a value of unity is assumed. (The GENII user may input different assumed parameter values, however.)

Weathering is accounted for by a rate constant, λ_{wi}, in units of $days^{-1}$, and the GENII default value for this parameter is 14 d^{-1}.

D.3.4.1.7 Tritium and ^{14}C Calculations

Concentrations of tritium and ^{14}C in soil and plants are assumed to be related to the specific activity of these radionuclides in the air or water media. *Need better words.* The fractional content of hydrogen or carbon in a plant or animal product is used to calculate the concentration of tritium or ^{14}C in the product.

Tritium. The hydrogen content in the aqueous (HTO) and dryer portions of the food products is considered when calculating tritium concentration. Also addressed is the creation of organically-bound tritium (OBT) in plant (and animal) products.

Models for tritium are different depending on whether the tritium exists as tritiated water (HTO) or as elemental hydrogen gas (HT).

The general equation for calculating concentrations of tritium as HTO in plant products (Bq per kg of fresh matter) is (1):

$$C_{pp_HTO} = RF_{pp}\ C_{am}\ F_{fw_pp}$$

Where C_{pp_HTO} = the concentration of HTO in the "wet" (fresh matter (fm)) portion of plant products (Bq/kg fm).

RF_{pp} = a reduction factor that accounts for low soil concentrations relative to concentrations in air moisture (varies by vegetable type) (see below)

C_{am} = the concentration of tritium as HTO in air moisture (Bq/L), which is determined by dividing the tritium concentration in air (Bq/m^3) by the absolute humidity in units of (kg or L per m^3)

F_{fw_pp} = the fresh weight fraction (the fraction of the plant having a high aqueous content), which is dimensionless and varies by plant type.

For GENII, it is assumed that the concentration of HTO in plant water equals $0.9C_{am}$ for leafy vegetables and pasture and $0.8C_{am}$ for fruit, root crops and other vegetables, and grain. (That is, RF_{pp} = 0.9 for leafy

vegetables and pasture, and RF_{pp} = 0.8 for fruit, root crops and other vegetables, and grain.) These reduction factors account for dilution from soil water, which has a lower tritium concentration than does air moisture and which affects fruit and root crops more than leaves.

The general equation for calculating concentrations of tritium as OBT in plant products (Bq per kg of fresh matter) is (1):

$$C_{pp_OBT} = RF_1 \; ID_{pp} \; C_{am} \; F_{dm_pp} \; W_{eq_pp}$$

Where C_{pp_OBT} = Tritium concentration existing as OBT in plant products (Bq/kg fw)

RF_1 = Reduction factor for plant leaves (0.9)

ID_{pp} = isotopic discrimination factor for plant products (0.9)

F_{dm_pp} = the dry weight fraction (the fraction of the plant have a very low aqueous content), which is dimensionless and varies by plant type.

W_{eq_pp} = water equivalent factor (dimensionless), which varies by plant type.

OBT concentrations are estimated assuming a plant water concentration of $0.9C_{am}$ for all types of plants (i.e., RF_1 = 0.9.) OBT is assumed to form exclusively in the leaves and be translocated to other parts of the plant. Isotopic discrimination occurring in the formation of OBT is conservatively assumed to result in an OBT concentration that is 0.9 times the concentration in plant water (ID_{pp} = 0.9.)

Parameter values for calculating HTO and OBT concentrations in plant products (RF_{pp}, RF_1, ID_{pp}, F_{fw_pp}, F_{dm_pp}, W_{eq_pp}) are "hard-wired" in GENII and are listed in Table D-6.

Table D-6 Parameter Values for Calculating HTO and OBT Concentrations in Plant Products

Parameter Values	Leafy Vegetables	Fruit	Root & Other Vegetables	Grain	Pasture
Reduction Factor (RF_{pp})	0.9	0.8	0.8	0.8	0.9
Reduction Factor for Leaves (RF_1)	0.9	0.9	0.9	0.9	0.9
Isotopic Discrimination Factor (ID_{pp})	0.9	0.9	0.9	0.9	0.9
Fresh Matter Fraction (F_{fw_pp})	0.906	0.853	0.824	0.117	0.8
Dry Matter Fraction (F_{dm_pp})	0.094	0.147	0.176	0.883	0.2
Water Equivalent Factor (W_{eq_pp})	0.6	0.59	0.58	0.577	0.616

Source: (1).

Calculation of tritium as elemental gas (HT) is performed in GENII as an empirical relationship. Although elemental hydrogen is not readily taken up into vegetation, HT is slowly oxidized into tritiated water by microbes in soil. The GENII SDD references work by Peterson and Davis who determined, after numerous observations, that the ratio of HTO in air moisture to HT in air was about 8 (Bq/L)/(Bq/m^3). This led to a modification for GENII of the above model for uptake of HTO in plants, where most terms remain the same but C_{caH} is approximated as $8C_{caHT}$ H, where H in this case is the absolute humidity. Peterson and Davis also recommend that, for HT releases, the isotopic discrimination factor ID_{pp} be set to 1.0, and the reduction factor for HTO, RF_{pp}, be replaced with a supplemental factor numerically equal to 1.5 (23). This results in the following equation for uptake of tritium as HT in plants:

C_{pp_HT} = $1.5\ (8C_{caHT})\ F_{fw_pp}$

= $12\ C_{caHT}\ F_{fw_pp}$

And the uptake of tritium as HT in plants as OBT is given as:

C_{pp_OBT} = $RF_1\ (8C_{caHT})\ F_{dm_pp}\ W_{eq_pp}$

= $8\ RF_1\ C_{caHT}\ F_{dm_pp}\ W_{eq_pp}$

Where: $C_{pp_OBT,HT}$ = Tritium concentration existing as OBT in plant products from HT (Bq/kg fw)

RF_1 = Reduction factor for plant leaves (0.9)

F_{dm_pp} = the dry weight fraction (the fraction of the plant have a very low aqueous content), which is dimensionless and varies by plant type.

W_{eq_pp} = water equivalent factor, which is dimensionless and varies by plant type.

Carbon-14. It is assumed that plants obtain all carbon from airborne CO_2 and that animals obtain all carbon from ingestion of plants. Because plants acquire most of their carbon from the air, transfer through the root pathway is negligible. Models for ^{14}C are similar to those for tritium. The concentration of ^{14}C in crops from atmospheric contamination is (1):

$$C_{hcaC}(T_{yr}) = \frac{C_{aaC}(T_{yr})F_{Cc}}{P_C}$$

Where $C_{hcaC}(T_{yr})$ = concentration of ^{14}C in crop type c at harvest from atmospheric deposition at year t (Bq/kg wet weight)

$C_{aaC}(T_{yr})$ = annual average air concentration of ^{14}C at usage location a (Bq/m^3)

F_{Cc} = fraction of carbon in crop type c (dimensionless)

P_C = concentration of carbon in the air (kg/m^3).

The concentration of ^{14}C in crops from contamination in the surface soil from initial or previous depositions is calculated from the average annual soil concentration for ^{14}C, or $C_{cC}(T_{yr})$ (1):

$$C_{hcsC}(T_{yr}) = \frac{0.1F_{Cc}C_{sC}(T_{yr})}{0.01\,P_3}$$

Where $C_{hcsC}(T_{yr})$ = concentration of ^{14}C in crop type c at harvest from soil root uptake for one year (Bq/kg wet weight)

$C_{sC}(T_{yr})$ = average surface soil concentration at soil location s for ^{14}C during the current year from material present at the start of the year (Bq/m^2)

F_{Cc} = fraction of carbon in crop type c (kg carbon/kg plant)

P_3 = areal soil density of farmland soil (kg/m^2)

0.1 = assumed uptake of 10% of plant carbon from soil (dimensionless)

0.01 = average fraction of soil that is carbon (kg carbon/kg soil).

The total concentration in food crops is evaluated as the sum of the contributions from air, water, and soil, or:

$C_{hcC}(T_{yr}) = C_{hcaC}(T_{yr}) + C_{hewC}(T_{yr}) + C_{hcsC}(T_{yr})$

Where $C_{hcC}(T_{yr})$ = concentration of ^{14}C in crop type c at harvest for one year (Bq/kg wet weight).

$C_{hewC}(T_{yr})$ = concentration of ^{14}C in crop type c at harvest from irrigation for one year (Bq/kg/wet weight) (assumed to be zero).

Other terms are defined above. No decay is considered between harvest and consumption of crops containing ^{14}C because the radiological half-life of ^{14}C is long.

D.3.4.1.8 Ingestion of Radioactive Material

Ingestion of radioactive material is considered in GENII for leafy vegetables, other vegetables, cereal grains, and fruit. Given an average radionuclide concentration ($C_{csi}(T)$) in food products, the quantity of a given radionuclide ingested over a given time period is calculated as (1):

$I_{csig}(T) = C_{csi}(T)\ U_{csg}\ T_{csg}\ ED_{csg}$

Where $I_{csig}(T)$ = total intake of radionuclide i in food crop c over the period T from ingestion at agricultural location s for individuals in age group g (Bq)

$C_{csi}(T)$ = average concentration in food crop c at agricultural location s for radionuclide i (Bq/kg)

U_{csg} = ingestion rate (food crop consumption rate) of food crop c at agricultural location s by an individual in age group g (kg/d)

T_{csg} = annual intake factor (food crop consumption period) giving the days per year that food crop c is eaten (at the average rate) at agricultural location s by individuals in age group g (d/y)

ED_{csg} = exposure duration for consumption of food crop c at agricultural location s for individuals in age group g (y).

The exposure duration (ED_{csg}) is the number of years that exposure occurs, which for this study is assumed to be one year. [16] Assumed parameter values for the ingestion rate and annual intake factor are provided in Appendix E.

D.3.4.2 Ingestion of Animals and Animal Products

Pathways describing the transfer of radionuclides to humans from animals and animal products generally start with calculations such as those described in Section D.3.4.1, except that transfer factors for forage crops are used, as well as consumption rates and other parameters that are appropriate for the animal. Then, animal-to-human transfer is considered assuming animal products that are characteristic of the area as well as typical rates of consumption.

D.3.4.2.1 Radionuclide Concentration in Animals and Animal Products

Basic equation. The basic radionuclide concentration in a given animal product as determined at the time of harvest (slaughter, milking, egg collection) is (1):

[16] Because the annual quantity of each radionuclide ingested may be different from year to year, radionuclide ingestion is recalculated for each year for each receptor rather than assuming ingestion of a uniform radionuclide quantity over several years.

$$C_{hai}(T_{yr}) = Fa_i \left[C_{wi}(T_{yr}) d_{aw} U_{ae} + C_{ai}(T_{yr}) d_{as} U_{as} + \sum_{f-1}^{N_{af}} C_{cfi}(T_{yr}) d_{af} U_{af} \right]$$

$C_{hai}(T_{yr})$	=	concentration of radionuclide i in animal product a at harvest of the animal product for a one-year period (Bq/kg)
T_{yr}	=	one-year exposure period (y)
Fa_i	=	transfer coefficient that relates daily intake rate by an animal to the concentration in an edible animal product a (Bq/L milk per Bq/d for milk, and Bq/kg meat per Bq/d for meat)
$C_{wi}(T_{yr})$	=	average concentration of radionuclide i in water consumed by animals for a year (Bq/L)
$C_{ai}(T_{yr})$	=	average concentration of radionuclide i in soil consumed by animals for a year (Bq/kg dry soil)
$C_{cfi}(Tyr)$	=	concentration of radionuclide i in animal feed type f at the time of consumption for a one-year period (Bq/kg wet weight)
d_{aw}	=	fraction of animal type a water intake that is contaminated (dimensionless)
U_{aw}	=	daily water intake rate for animal type a (L/d)
d_{as}	=	fraction of animal type a soil intake that is contaminated (dimensionless)
U_{as}	=	daily soil intake rate for animal type a (kg/d)[17]
N_{af}	=	number of feed types, f, fed to animal type a
d_{af}	=	fraction of animal type a feed type f intake that is contaminated (dimensionless)
U_{af}	=	daily feed intake rate for animal type a of feed type f (kg/d).

Where animal uptake of contaminated water is not considered for the scenarios defined for this report. Other terms have been already defined.

D.3.4.2.2 Radioactive Decay

GENII has the capability of considering two periods of radioactive decay for human ingestion of animals and animal products: (1) radioactive decay between harvesting and animal consumption of animal feed and forage, and (2) radioactive decay between animal or animal product harvest (e.g., animal slaughter, collection of eggs) and consumption of the animal or animal product by humans.

The first period of radioactive decay is addressed in GENII as explained in Section D.3.4.1.3, except that the calculation is performed for animal feed and forage rather than food crops. Note that different holdup (delay) times may be appropriate for animal feed and forage than would be the case for food crops.

The second period of radioactive decay is again addressed in GENII using the GENII decay processor. For most radionuclides (those for which decay chains and branching is not a factor), the decay calculation is calculated as follows (1):

[17] Inadvertent soil ingestion by animals is not at this time considered in GENII. Although the equation is coded into GENII including the inadvertent soil ingestion pathway, the user interface does not request input of any values for the animal soil ingestion rate, and the GENII variable (SLCONA) for this parameter is set to zero [Napier 2003e].

$C_{asi}(T_{yr}) = C_{hai}(T_{yr})\, e^{-\lambda i\, Tha\, 2.74E-3}$

Where $C_{asi}(T_{yr})$ = concentration of radionuclide i in animal product a at usage location s at the time of consumption over a one-year period (Bq/kg wet weight)

Th_a = holdup delay time between harvest and consumption for animal product a (d)

λ_i = radiological decay constant for radionuclide i (y^{-1})

2.74E-3 = Conversion factor, years per day (1 year /365 days).

D.3.4.2.3 Tritium and ^{14}C Calculations

Tritium. HTO concentrations in animals are assumed to equal the average weighted tritium concentration of ingested water based on the fraction of water supplied by each source, including skin absorption, inhalation, drinking water, and food (from plant water and digested organically bound molecules).

Concentrations of tritium as HTO in animal products are calculated as (1):

$$C_{HTOap}(T_{yr}) = F_{Wa} \frac{C_{wH}(T_{yr}) U_{wa}\, d_{aw} + \sum_{f=1}^{N_{fa}} C_{cfH}(T_{yr}) U_{af}\, d_{af}}{U_{wa} + \sum_{f=1}^{N_{fa}} F_{fw_pp} RF_{pp} U_{af}}$$

Where:

$C_{HTOap}(T_{yr})$ = concentration of tritiated water in animal product a at time of consumption by humans over a one-year period (Bq/kg)

F_{Wa} = fraction of water in animal product a (dimensionless)

$C_{wH}(T_{yr})$ = average concentration of tritium in water consumed by animal type a over a one-year period (Bq/L)

U_{aw} = daily water intake rate for animal type a (L/d)

d_{aw} = fraction of animal type a water intake that is contaminated (dimensionless)

$C_{cfH}(T_{yr})$ = concentration of tritium, calculated as the sum of the water and organic portions (see above), in animal feed type f at the time of consumption for a one-year period (Bq/kg wet weight)

U_{af} = daily intake rate for animal type a of feed type f (kg/d)

d_{af} = fraction of animal type a feed type f intake that is contaminated (dimensionless)

N_{fa} = number of feed crops eaten by animal type a.

Other constants are previously defined. Tritium (as HTO) concentrations in animal feed is evaluated using the above equations with values defined for the animal feed crops.

Regarding tritium as OBT, the relationship used to calculate concentrations in animal products was created under the assumption that the specific activity in organic material equals the specific activity in the aqueous phase apart from a discrimination factor. It is given, after the derivation of Peterson and Davis (23) as:

$$C_{ap_OBT} = C_{ap_HTO} F_{dm_ap} / F_{fw_ap} W_{eq_ap}$$

Default values for the parameters needed for the above equations (9.30a and 9.30b) are listed in Table D-7.

Table D-7 Parameter Values for Calculating HTO and OBT Concentrations in Animal Products

Parameter Values	Eggs	Milk	Beef	Pork	Poultry
Fresh Weight Fraction (F_{fw_ap})	0.74	0.897	0.668	0.50	0.67
Dry Matter Fraction (F_{dm_ap})	0.26	0.103	0.332	0.50	0.33
Water Equivalent Factor (W_{eq_ap})	0.835	0.669	0.795	0.904	0.796

Source: (1).

Carbon-14. GENII calculates the concentration of ^{14}C in animal products as (1):

$$C_{caC}(t) = F_{Ca} \frac{\sum_{f=1}^{N_{fi}} C_{efC} U_{af} d_{af}}{\sum_{f=1}^{N_{fi}} F_{Ca} U_{af}}$$

Where $C_{caC}(T_{yr})$ = concentration of ^{14}C in animal product a at time of consumption by humans (Bq/kg)

F_{Ca} = fraction of carbon in animal product a (dimensionless)

$C_{efC}(T_{yr})$ = concentration of ^{14}C in animal feed type f at time of consumption for a year (Bq/kg wet weight)

U_{af} = daily feed intake rate for animal type a of feed type f (kg/d)

d_{af} = fraction of animal type a feed type f intake that is contaminated (dimensionless)

F_{Cf} = fraction of carbon in animal feed type f (dimensionless)

N_{fa} = number of feed crops eaten by animal type a.

D.3.4.2.4 Ingestion of radioactive Material

Once average concentrations of radionuclides in animal products are determined, the quantity of radioactive material ingested over a given period of time is (1):

$I_{asig}(T)$ = $C_{asi}(T)$ U_{asg} T_{asg} ED_{asg}

Where $I_{asig}(T)$ = total intake of radionuclide i in animal product a over the period T from ingestion at agricultural location s for individuals in age group g (Bq)

$C_{asi}(T)$ = average concentration in animal product a at agricultural location s for radionuclide i (Bq/kg)

U_{asg} = ingestion rate (animal product consumption rate) of animal product a at agricultural location s by an individual in age group g (kg per day on the days that the food is eaten)

T_{asg} = annual intake factor (animal product consumption period) giving the number of days

per year that animal product a is eaten (at the average rate) at agricultural location s by individuals in age group g (d/y)

ED_{asg} = exposure duration for consumption of animal product a at agricultural location s for individuals in age group g (y).

As for ingestion of food crops, the exposure duration (ED_{asg}) is assumed to be one year. Assumed values for the ingestion rate and annual intake factor are provided for each receptor in Appendix E.

D.3.4.3 Aquatic Food Ingestion

Fish, crustaceans, mollusks, and other possible aquatic food products may become contaminated with radionuclides and cause radiation doses to humans when food products are consumed.

D.3.4.3.1 Radionuclide Concentration in Aquatic Foods

The radionuclide concentration in a particular type of aquatic food is given as the radionuclide concentration in water multiplied by a bioaccumulation factor. The basic equation to describe accumulation is (1):

$$C_{hqi}(T_{yr}) = C_{wi}(T_{yr})\ B_{qi}$$

Where $C_{hqi}(T_{yr})$ = concentration of radionuclide i in aquatic food type q at the time of harvest (Bq/kg).

$C_{wi}(T_{yr})$ = average concentration of radionuclide i in water over the year.

B_{qi} = bioaccumulation factor for radionuclide i in aquatic food type q (Bq/kg in wet fish per Bq/L of water).

D.3.4.3.2 Radioactive Decay

Radionuclide concentrations in aquatic food products may be reduced by means of radioactive decay between food product harvesting and food product consumption. Radioactive decay is accounted for using the GENII decay processor in a similar manner as that for food crops and animal products. For most radionuclides (those without decay chains or branching), radioactive decay is considered in the following manner (1):

$$C_{fwi}(T_{yr}) = C_{hqi}(T_{yr})\ e^{-\lambda i\ Tha\ 2.74E-3}$$

Where $C_{fwi}(T_{yr})$ = concentration of radionuclide i in aquatic food type q at water location w at the time of consumption over a one-year period (Bq/kg wet weight)

Th_a = holdup delay time between harvest and consumption of aquatic food type q (d)

λ_i = radiological decay constant for radionuclide i (y^{-1})

2.74E-3 = Conversion factor, years per day (1 year /365 days).

D.3.4.3.3 Ingestion of Radioactive Material

Once the concentration of a radionuclide in aquatic food products are calculated (fish, mollusks, invertebrates, and water plants), the radionuclide quantity (Bq) ingested is calculated as (1):

$$I_{fwig}(T) = C_{fwi}(T)\ U_{fwg}\ T_{fwg}\ ED_{fwg}$$

Where $I_{fwig}(T)$ = total intake of radionuclide i from ingestion of aquatic food f over the period T at aquatic food location w for individuals in age group g (Bq)

$C_{fwi}(T)$ = average concentration in aquatic food f at aquatic food location w for radionuclide i (Bq/kg)

U_{fwg} = ingestion rate (aquatic food product consumption rate) of aquatic food f at aquatic food location w by an individual in age group g (kg per day on the days that the food is eaten)

T_{fwg} = annual intake factor (aquatic food product consumption period) giving the days per year that aquatic food f is eaten (at the average rate) at aquatic food location w by individuals in age group g (d/y)

ED_{fwg} = exposure duration for consumption of aquatic food f at aquatic food location w for individuals in age group g (y).

The exposure duration (ED_{fwg}) in this equation is assumed in this report to be one year. Assumed values for the ingestion rate and annual intake factor are provided as a function of receptor in Appendix E.

D.3.5 Sedimentation Pathways

Individuals involved in sun bathing, fishing, or other recreational shoreline activities along contaminated surface water may be exposed to radiation from radionuclides that have built up over the years in sediment. The build up over time is evaluated as an integral that considers the deposition of radionuclides from the water. The concentration in sediment built up over a single year is (1):

$$C_{sri}\left(T_{yr}\right) = \frac{TC\, C_{ri}\left(T_{yr}\right)\left(1 - e^{-\lambda_i T_{yr}}\right)}{\lambda_i}$$

Where $C_{sri}(T_{yr})$ = concentration of radionuclide i in sediment after one year of accumulation from deposition on the shoreline at recreational water usage location r (Bq/m^2)

TC = transfer rate constant from water to sediment ($L/m^2/y$)

$C_{ri}(T_{yr})$ = average (constant) annual water concentration for radionuclide i at recreational water usage location r (Bq/L)

T_{yr} = one-year integrating period for deposition to sediments (y).

The concentration over several years would be determined by integrating over the appropriate time period (say five years), considering the average concentration in the water over that time period.

In the above equation, the transfer rate constant (TC) is a parameter that describes the transfer of radionuclides to sediment (Bq/m^2) from water (Bq/L) during a year ($L/m^2/y$). In GENII, a transfer rate constant of 35,400 $L/m^2/y$ is used, a value chosen from consideration of data obtained for several radionuclides that compared concentrations in river water and sediment. River and sediment samples were obtained from the Columbia River between Richland, Washington, and the river mouth, and from Tillamock Bay, Oregon, 75 km south of the river mouth (1).

The exposure to an individual in any year is the time-integral of the shoreline sediment concentration during that year, considering the amount of time spent on the shoreline. The average concentration (Bq per kg of sediment) is determined using a model of the following form (1):

$$C_{sri}(T_{yr}) = \int_0^{T_{yr}} C_{sri}(t)dt / (T_{yr}\, d_{ed}\, \rho_{sed})$$

Where $C_{sri}(T_{yr})$ = shoreline sediment time integral of exposure for radionuclide i evaluated at the recreational usage location r (Bq/kg)

d_{ed} = thickness of shoreline sediments (m)

ρ_{sed} = density of shoreline sediments (kg/m^3)

T_{yr} = one-year exposure period (y).

In this case, the concentration within the integral is integrated over a one-year period starting from the total concentration in sediment at the beginning of the year. For example, if one wishes to evaluate the exposure during the 6th year of operations for a given radionuclide, one would calculate the total average radionuclide concentration over the year considering the concentration that had built up over the previous five years, as well as the concentration as enhanced in sediment over the course of the 6th year.

In addition, neither D_{sed} nor ρ_{sed} is input into the GENII calculations. Rather, to use GENII one inputs the shoreline areal density, in units of kg/m^2, which is the product of D_{sed} with ρ_{sed} (see Section F.5).

Recreational shoreline exposures are then calculated using the average radionuclide concentration in shoreline sediment as (1):

$I_{srig}(T)$ = $C_{sri}(T)\ SW_r\ FE_{srg}\ TE_{srg}\ T_{srg}$

$I_{srig}(T)$ = average exposure factor over the period T for radionuclide i from shoreline exposure at recreational shoreline location r for individuals in age group g (Bq/kg)

C_{sri} = average shoreline sediment concentration of radionuclide i at recreational shoreline location r (Bq/kg)

SW_r = shoreline width factor for recreational shoreline location r (dimensionless)

FE_{srg} = shoreline use event frequency (frequency of shoreline use) at recreational shoreline location r for individuals in age group g (events/d)

TE_{srg} = duration of each shoreline exposure event at recreational shoreline location r for individuals in age group g (h/event)

T_{srg} = annual exposure factor (shoreline days) for shoreline exposure at recreational shoreline location r for individuals in age group g (number of days in a year that the shoreline exposure location is visited).

The annual exposure factor for shoreline exposure, T_{srg}, is assumed to be 365 days for chronic exposures, which is the situation considered for this report. The daily exposure factor is the product of the event frequency, FE_{srg}, and the event duration, TE_{srg}. Assumed values for these parameters, and for T_{srg}, are provided as a function of receptor in Appendix E. The shoreline width factor (SW_r) is assumed to be 0.2 for the base case evaluation (see Section F.5).

D.3.6 Recreational Exposures from Surface Water Pathways

Recreational exposures to contaminated water are considered for two cases: swimming and boating. Exposure pathways considered for swimming include immersion in a contaminated plume of water, and inadvertent ingestion of small quantities of water. The exposure pathway considered for boating is

external exposure to a volume-contaminated source. The starting point for all pathways is the concentrations of radionuclides in water, given as Bq/L.

D.3.6.1 External Exposure From Immersion in Water (Swimming)

Recreational swimming exposures are calculated in GENII as (1):

$I_{wrig}(T)$ = $C_{wri}(T)$ FE_{wrg} TE_{wrg} T_{Cs}

$I_{wrig}(T)$ = average exposure factor over time period T for radionuclide i from swimming at recreational swimming location r for individuals in age group g (Bq/L)

$C_{wri}(T)$ = average water concentration over time period T for radionuclide i in surface water at recreational swimming location r (Bq/L)

FE_{wrg} = frequency of swimming events at recreational swimming location r for individuals in age group g (events per day on the days when swimming occurs)

Tc_s = time correction set to T_{wrg}/8760 h/y for chronic releases

TE_{wrg} = duration of an average swimming event at recreational swimming location r for individuals in age group g (h/event)

T_{wrg} = annual exposure factor (swimming days) for swimming at recreational swimming location r for individuals in age group g (number of days in a year that swimming occurs).[18]

Here, the daily exposure factor is the product of the event frequency, FE_{wrg}, and the event duration, TE_{wrg}. Assumed parameter values for FE_{wrg}, TE_{wrg}, and T_{wrg} are provided in Appendix E as a function of receptor.

D.3.6.2 Ingestion of Surface Water While Swimming

Inadvertent consumption of surface water while swimming is calculated as (1):

$I_{wwig}(T)$ = $C_{wri}(T)$ FE_{wrg} TE_{wrg} T_{Cs} U_{swg}

$I_{wwig}(T)$ = average exposure factor over time period T for radionuclide i from ingestion at swimming location w for individuals in age group g (Bq)

$C_{wri}(T)$ = average water concentration over time period T for radionuclide I in surface water at the recreational swimming location r (Bq/L)

FE_{wrg} = frequency of swimming events at water use location r for individuals in age group g (events/d

TE_{wrg} = duration of an average swimming event at water use location r for individuals in age group g (h/event)

T_{Cs} = time correction, set equal to T_{wrg}/8760 h/y for chronic releases

T_{wrg} = annual exposure factor (swimming days) for swimming at water use location r for individuals in age group g (number of days in a year that swimming occurs)

U_{wwg} = uptake rate of water while swimming (ingestion rate of water while swimming) for age group g (L during an hour of swimming).[19]

[18] On each of the days it is assumed for purposes of the GENII calculations that the individual swims the number of times specified by the frequency of swimming event and for the duration of swimming event for each of these events.

Here, the daily exposure factor is the product of the event frequency, FE_{wrg}, and the event duration, TE_{wrg}, in units of h/d. The ingestion rate of water while swimming (U_{wwg}) is provided in Appendix E as a function of receptor. Otherwise, one assumes the same usage factors (FE_{wrg}, TE_{wrg}, and T_{wrg}) as those used to calculate direct radiation exposure while swimming (Section D.3.6.2).

D.3.6.3 External Exposure While Boating

Exposure of humans during recreational boating may be calculated as (1):

$$I_{brig}(T) = C_{bri}(T)\ SB\ FE_{brg}\ TE_{brg}\ T_{Cb}$$

$I_{brig}(T)$ = average exposure factor over time period T for radionuclide I from boating at recreational boating location r for individuals in age group g (Bq/L)

$C_{bri}(T)$ = average water concentration of radionuclide i at recreational boating location r (Bq/L)

SB = shielding factor for boating exposures (dimensionless)[20]

FE_{brg} = average frequency of daily boating events at recreational boating location r for individuals in age group g (events/d)

TE_{brg} = duration of an average boating event at recreational boating location r for individuals in age group g (h/event)

T_{Cb} = time correction set equal to T_{brg}/8760 h/y for chronic releases

T_{brg} = annual exposure factor (boating days) for boating at recreational boating location r for individuals in age group g (number of days in a year that boating occurs).[21]

Here, the daily exposure factor is the product of the event frequency, FE_{brg}, and the event duration TE_{bgr}, in units of h/d. Assumed values for SB, Fe_{brg}, Te_{brg}, and T_{brg} are provided as a function of receptor in Appendix E. The shielding factor for boating exposures (SB) is assumed to be 0.5 as addressed in Section F.6.

D.4 Dose and Risk Principles

Additional information about radiation assessment and protection principles, and terminology, can be obtained from Internet sites on radiation established by EPA (http://www.epa.gov/radiation) and the University of Michigan (http://www.umich.edu/~nradinfo).

D.4.1 Types of Radiation

Decaying radionuclides such as those considered for this portion of the SRS Dose Reconstruction Study can each emit up to three basic types of ionizing radiation:

- *Alpha particles*: These particles are essentially the nuclei of helium atoms. Each particle contains two protons and two neutrons. Because of their relatively large size, alpha particles lose energy quickly as

[19] Despite the terminology used by the GENII SDD and the documentation for the FRAMES interface, this parameter is used as a quantity rather than a rate.

[20] The shielding factor for boating accounts for the shielding to direct radiation that may be provided by the structure of the boat. It is different from the geometry factor, which accounts for the location of the receptor above the surface of the water (rather than being immersed in the water). The geometry factor is assumed by the GENII authors to be a factor of 2 reduction, and is incorporated into the dose and risk equations for boating exposures that are addressed in Section D.4.3.

[21] During each of the boating days, the individual is assumed for purposes of the GENII calculations to be involved in the number of events given by the frequency of boating events with each event lasting for the duration of boating events hours.

they collide with matter. They will not penetrate human skin. Therefore, human skin can be impacted by alpha particles (i.e., the human receives an *external exposure* to alpha particles) without harm. However, alpha particles can damage cells within the human body if they are taken into the body by breathing or by swallowing. In this case, a human receives *internal exposure* to alpha particles.

- *Beta particles*: These particles are electrons identical to those that surround the nuclei of atoms. They are much smaller than alpha particles and can penetrate up to a few centimeters of water or human flesh. Therefore, both external and internal exposure to beta particles can damage human cells.
- *Gamma rays and X-rays*: These rays are forms of electromagnetic energy. (Ordinary light is another form of electromagnetic energy, as are microwaves and radio waves). Gamma rays and X-rays are virtually identical except that gamma rays tend to have more energy and are emitted by atomic nuclei, while X-rays tend to have less energy and are emitted from the electrons surrounding atomic nuclei. Gamma rays and X-rays have considerable penetrating power. Both external and internal exposure to gamma rays and X-rays can damage human cells.

Ionizing radiation damages cells by imparting energy to the cells. Energy absorbed by the cells can break chemical bonds, among other impacts.

D.4.2 Radiation Dose

To estimate the effects of radiation on human (or other) tissue, one must estimate the *dose* that the human receives. A radiation dose is a measure of the amount of energy imparted to tissue (absorbed) by the radiation. However, a strict calculation of the *absorbed dose* —e.g., in units of joules of energy absorbed by a kilogram of tissue (J/kg)—is insufficient. Different particles of radiation —alpha, beta, gamma— impart energy to tissue in different ways. One accounts for these differences through the concept of an *equivalent dose*,[22] which may be considered as:

$$H = D\ W_R$$

Where H = equivalent dose (Sievert)

D = absorbed dose (Gray)[23]

W_R = weighting factor (dimensionless)

The unit of equivalent dose, called the *Sievert* (Sv), is therefore defined as:

1 Sievert = 1 J/kg = 100 rem, and

1 milliSievert (mSv) = 1/1000 Sv = 100 millirem (mrem)

Where a "*rem*," or "Roentgen equivalent man," is a dose unit commonly used in the United States, and, as indicated, is one one-hundredth of a Sievert. A *millirem* (mrem) is one one-thousandth of a rem.

The weighting factor[24] accounts for differences in how energy is imparted to tissue by different types of radiation. X-rays, gamma rays, and beta particles are generally assigned weighting factors of one, while alpha particles are generally assigned weighting factors of twenty.

One difficulty of estimating radiation doses to humans is that human bodies are variable. To achieve agreement on standards for radiation protection, and to help comparisons of different radiation dose assessments, a concept was developed called a *standard man*, a surrogate human having organs of both

[22] Except where noted, ICRP-60 terminology is used in this chapter.
[23] A *Gray* is a unit of absorbed dose equal to 1 Joule/kilogram (1 J/kg).
[24] In ICRP-60 and other ICRP recommendations preceding ICRP-60, a weighting factor was called a quality factor.

sexes of reference radii and masses. Risk assessments are commonly performed using these standard physiological assumptions.

Doses from internal exposures, such as those from inhalation or ingestion of radioactive material, are determined using models describing the movement and retention of the material in the body. Some radionuclides may build up in the body as a person inhales or ingests the radionuclides year after year. A radionuclide retained in the body will impart a dose to a person not only for the first year of intake, but in following years until the radionuclide decays or is eliminated. This phenomenon causes a *committed dose*. It may be considered as:

$$H_C = \int H(t)\, dt$$

Where H_C = committed equivalent dose (Sv)

$H(t)$ = equivalent dose rate (Sv/y)

And the integral is evaluated over a specified period of time.[25]

At one time, the usual practice was to calculate doses to individual bodily organs or tissues. But in 1977, the ICRP recommended in ICRP-26 the concept of a weighted mean whole-body dose (24). It provides a measure of the dose across multiple organs or tissues, and is determined by multiplying the dose received by each organ or tissue by a weighting factor, and then adding all of these weighted doses to arrive at a single representative dose. ICRP originally called this dose an *effective dose equivalent* (24). In a more recent recommendation [ICRP-60, issued in 1991] (25), ICRP called this dose an *effective dose*. It may be considered as:

$$H_E = \sum_T W_T H_T$$

Where H_E = effective dose (Sv)

W_T = a weighting factor representing the ratio of the stochastic risk from irradiation of tissue T to that for the whole body when irradiated uniformly.

H_T = equivalent dose in tissue T.

Values for tissue weighting factors recommended by ICRP in 1977 (24) and 1991 [ICRP-60] (25) are listed in Table D-8. The weighting factors recommended in ICRP-60 are different from those recommended in ICRP-26.[26]

The concept of effective dose is used for doses resulting from both external and internal exposures. To calculate committed effective dose from internal exposures, ICRP in ICRP-60 recommended using an integration time of 50 years following intake for assessments of occupational dose, and 70 years for members of the public.

[25] ICRP-26 recommended a 50-year time period for members of the public as well as radiation workers. ICRP-60 recommends a 70-year time period for members of the public and a 50-year time period for radiation workers.

[26] These weighting factors were calculated under somewhat different assumptions. ICRP-26 weighting factors are based on the risk of fatal cancers and hereditary defects in the first two generations. ICRP-60 weighting factors are based on risks for both fatal and non-fatal cancers, the risk of hereditary defects over all future generations, and the relative loss of live expectancy given a fatal cancer or a severe generic disorder.

Table D-8 ICRP-26 and ICRP-60 Tissue Weighting Factors

Organ or Tissue	ICRP-26 Weighting Factors	ICRP-60 Weighting Factors
Gonads	0.25	0.20
Breast	0.15	0.05
Colon		0.12
Red bond Marrow	0.12	0.12
Lungs	0.12	0.12
Stomach		0.12
Urinary Bladder		0.05
Liver		0.05
Esophagus		0.05
Thyroid	0.03	0.05
Bone Surface	0.03	0.01
Skin		0.01
Remainder	0.30*	0.05[†,‡]

*The value 0.30 is applied to the average dose among the five remaining organs or tissues receiving the entire dose, excluding the skin, lens of the eye, and the extremities.
[†]The reminder consists of: adrenals, brain, small intestine, upper large intestine, kidney, muscle, pancreas, spleen, thymus, and uterus.
[‡]The value 0.05 is applied to the average dose to the remainder tissue group. However, if a member of the remainder receives a dose exceeding the highest dose in any of the 12 organs for which weighting factors are specified, a weighting factor of 0.025 is applied to that organ and weighting factor of 0.025 is applied to the average dose to the rest of the remainder.

D.4.3 Risk from Radiation Exposure

Ionizing radiation was first discovered and used in the last years of the 19th Century. The most urgent need was to avoid exposures causing immediate or near-term effects on the health of individuals. These health effects were seen after individuals had received very large exposures above a *threshold* of received radiation. Below the threshold the health effects did not occur, and above it the severity of the health effects increased. These *nonstochastic* effects were avoided by limiting exposures to levels below the threshold.[27]

Scientists and health providers later observed that exposure to radiation might lead to delayed health effects, either to exposed individuals (called *somatic* effects) or to descendents (called *genetic* effects). These effects are called *stochastic* effects, because they occur with given frequencies in populations receiving radiation exposures rather than predictably to an exposed individual. The severity of stochastic effects, including cancer and hereditary effects, is not related to the level of exposure.

From these observations came the development of procedures for estimating the risks of negative health effects that may occur from exposure to ionizing radiation. One way to express risks is the probability of cancer *fatality* (*mortality*) occurring over a lifetime from exposure to radioactive material. Fatality (mortality) is the risk of dying of cancer. Another way to express risks is the probability of cancer

[27] Radiation exposures that members of the public may have received from SRS operations are several orders of magnitude below those levels that could result in nonstochastic effects.

incidence (morbidity) occurring over a lifetime from exposure to radioactive material. Incidence (morbidity) is the risk of radiogenic cancer whether or not the cancer is fatal.

Modern estimates of risk have, particularly for low-LET ionizing radiation,[28] been largely based on information about Hiroshima and Nagasaki atomic bomb survivors as documented in the Radiation Effects Research Foundation's Life Span Study. The Study cohort was a large, relatively healthy population at the time of exposure. The cohort was exposed to a wide range of reasonably established doses to individuals, and there exists a large, well-matched control group (people who received only small doses of radiation but were present at the time the bombs exploded). Additional information used for estimating radiation risks has come from sources such as: (1) persons who have had large intakes of radium into the body from occupational contamination or supposedly therapeutic administration, (2) persons who have had large intakes of a thorium preparation known as Throtrast as part of diagnostic procedures, and (3) workers in uranium mines and other mines resulting in exposure to radon gas.

Application of the various studies to estimations of risks from low levels of radiation exposure is subject to considerable uncertainty, for a variety of reasons, including:

- Sampling uncertainties
- Latency of health effects such as cancer following radiation
- Transferability of risks from one population to another
- Dose and dose rate dependence (e.g., although risk relationships have been developed based on observation of doses that have tended to be acute and much larger than doses at background levels, they have been primarily applied to assessment of risks from chronic doses at levels in the range of background).

There are also various ways to express risks, such as risks of disease or adverse genetic change, the number of days of life shortening from a given dose, and so forth. A common way to express risks, however, is the probability of a radiogenic cancer fatality (mortality) occurring over a lifetime from exposure to radioactive material. As used here, cancer *fatality (mortality)* refers to the risk of dying of cancer. Another way to express risks is the probability of radiogenic cancer incidence (morbidity) occurring over a lifetime from exposure to radioactive material. Cancer *incidence (morbidity)* refers to the risk of experiencing radiogenic cancer whether or not the cancer is fatal.

In any event, to estimate the consequences of radiation exposures to individuals and populations, and to regulate use of radioactive materials, it is normally assumed that the probability of occurrence of late stochastic effects is proportional to the radiation exposure that is received and that there is no threshold for the probability of health effects. This assumption is commonly known as the *linear no-threshold* assumption. For roughly 50 years it has formed the basis for international recommendations for protection of the public from radiation. As summarized by the IAEA in Publication No. 26 [ICRP-26] in 1977 (24):

- No practice shall be adopted unless it introduction produces a positive net benefit.
- All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account.
- The dose equivalent limits to individuals shall not exceed the limits recommended for the appropriate circumstances by the [ICRP].

[28] LET stands for "linear effective track." Low-LET radiation refers to radiation such as gamma rays and beta particles. High-LET radiation refers to more massive radiation particles such as alpha particles.

D.4.4 Dose and Risk Coefficients

To calculate doses to individuals from exposure to radioactive materials, most risk assessors normally use standard tables that relate human doses or risks to the quantity of individual radioactive material ingested, inhaled, or exposed to. These tables of *dose coefficients* and *risk coefficients* are based on complicated models of physical and human physiological factors. This avoids the need to repeatedly perform these complicated calculations, and it is easier to compare different assessments.

For this report, the most up-to-date dose and risk coefficients provided in GENII were used. These dose and risk coefficients are almost all based on EPA's April 2002[29] Update [FGR-13U] (11) to Federal Guidance Report No.13 [FGR-13] (20).

For exposures of persons from inhaling or ingesting radionuclides, the following coefficients were used:

- Age-dependent dose coefficients for 23 organs and bodily tissues, plus effective dose based on ICRP-60 weighting factors (see Table D-8).
- Age-dependent cancer risk coefficients (fatality and incidence) for 15 cancer sites, plus the sum of cancers across all cancer sites.

Table D-9 lists the organs and bodily tissues considered in the dose coefficients, and the cancer sites considered in the risk coefficients. Table D-10 lists the age categories considered for the dose and risk coefficients. (Note that the age categories are different for the dose and risk coefficients.)

Table D-9 Organs, Tissues, and Lung-Compartments, and Cancer Sites, Addressed in Dose and Risk Conversion Factors in the FGR-13 Update

Organs, Tissues and Lung-Compartments Addressed in Dose Conversion Factors			Cancer Sites Addressed in Risk Conversion Factors	
Adrenals	Kidneys	Skin	Esophagus	Breast
Bone Surface	Liver	Spleen	Stomach	Ovary
Brain	ET-Region*	Testes	Colon	Bladder
Breast	Lung	Thymus	Liver	Kidneys
Stomach Wall	Muscle	Thyroid	Lung	Thyroid
SI Wall*	Ovaries	Uterus	Bone	Leukemia
ULI Wall*	Pancreas	UB Wall*	Skin	Residual†
LLI Wall*	Red Bone Marrow	Effective*		Total

*SI: small intestine; ULI: upper lower intestine; LLI: lower lower intestine; ET: extra-thoracic; UB: urinary bladder; effective: effective dose.
†Residual cancer sites.

[29] A supplement was first issued in 2000, but this supplement contained errors in the viewer and was replaced by the April 2002 version.

Table D-10 Age Categories Addressed in Dose and Risk Conversion Factors Presented in the FGR-13 Update

Dose Conversion Factors	Risk Conversion Factors
Infant	0-5 Years
1-Year Old	5-15 Years
5-Year Old	15-25 Years
10-year Old	25-70 Years
15-Year Old	0-110 Years
Adult	

For doses and risks from inhalation, specify dose and risk coefficients had to be consistent with assumptions about the physical and chemical form of each inhaled radionuclide. This was done because a radionuclide's chemical and physical form affected the rate that it could be absorbed into blood. It was assumed most radionuclides were particulates assigned to one of three absorption types:

- Type F: Fast dissolution and a high level of absorption to blood.
- Type M: Intermediate rates of dissolution and levels of absorption to blood.
- Type S: Slow dissolution and a low level of absorption to blood.

It was assumed some radionuclides existed as a gas or vapor. The assumptions for the lung absorption types used in this report are listed in Table D-11.

For Table D-11, a value of G was selected for carbon assuming that the carbon was released as CO_2. Carbon dioxide was considered the most expected form of carbon that would have been inhaled because it is the most chemically stable of the oxidized forms of carbon. For iodine, a value of G for an organic gas was selected because it provides dose and risk results that are intermediate between particulate and elemental iodine. For ruthenium, a value of M was selected based on EPA's recommended value for particulates. It is also an intermediate value. For sulfur, a value of V was selected, which is EPA's recommended value for sulfur dioxide. Limited data on the chemical form suggested that an oxide would be more likely than the other choice of chemical form, carbon disulfide (26), at least from reactor areas.

For external exposures resulting from (1) immersion in a "cloud" of radionuclides in air, and (2) proximity to a contaminated ground surface, the following coefficients were used:

- Adult dose coefficients for 23 organs and bodily tissues, plus effective dose based on ICRP-60 weighting factors (see Table D-8).
- Age-specific cancer risk coefficients (fatality and incidence) for 15 cancer sites, plus the sum of cancers across all cancer sites.

GENII (and FGR-13U) provide only adult dose conversion factors for these types of external exposures. The authors of FGR-13 believe that use of adult external dose coefficients for all age groups should normally result in small errors (usually <30%). The FGR-13 authors believe that these errors are likely to be negligible compared to the errors associated with the simplified exposure scenarios assumed to calculate the dose conversion factors (e.g., the phantoms were in constant position in relation to the radiation source, and shielding was not considered) (20).

Table D-11 Assumptions for Lung Absorption Classes by Element

Element	Absorption Class*	Comments†
Americium (Am)	M	Default absorption type recommended in ICRP-72 (27).
Argon (Ar)	NA	No absorption occurs for noble gases.
Carbon (C)	G	Type G was assumed because it was recommended in FGR-13 for CO_2.
Cesium (Cs)	F	Default absorption type recommended in ICRP-72 (27).
Hydrogen (^3H)	HT: G HTO: V OBT‡: V	Type G was assumed for tritium released as a gas (HT) in accordance with FGR-13. Type G is also appropriate for tritium released as an organic. Type V is assumed for tritium released as water vapor (HTO) in accordance with FGR-13.
Iodine (I)	G	Iodine was released in several forms. Type G was assumed because it resulted in dose and risk conversion factors between those for a particulate and elemental I.
Plutonium (Pu)	M	Default absorption type recommended in ICRP-72 (27).
Sulfur (S)	V	FGR-13 recommends Type V for sulfur dioxide. (Note that if S is released as a particulate, ICRP-72 (27) recommends Type M.)
Strontium (Sr)	M	Default absorption type recommended in ICRP-72 (27).
Thorium (Th)	S	Default absorption type recommended in ICRP-72 (27).
Uranium (U)	M	Default absorption type recommended in ICRP-72 (27)
Xenon (Xe)	NA	No absorption occurs for noble gases.

*F: fast; M: medium; S: slow; G: gas; V: vapor; NA: not applicable.
†Lung absorption classes are not listed for radioactive isotopes of elements released only into surface waters. Although GENII requires that lung absorption class assumptions be input for these isotopes, the assumed values are not used in the dose and risk calculations because inhalation exposure is not assessed for the surface water pathways considered in this report.
‡OBT: organic bound tritium.

The ages considered in the risk coefficients for these types of external exposures are the same as those listed in Table D-10.

For external exposures while swimming in water or while boating, dose and risk coefficients are not available from the update to FGR-13. Dose coefficients for water immersion and boating from [FGR-12] were used (28). These (adult) dose coefficients are provided for fewer organs than those in the FGR-13 update, and the weighting factors used to calculate effective dose equivalent are from ICRP-26 rather than ICRP-60 (see Table D-8). Risk was estimated by multiplying the calculated doses for water immersion and boating by the following health effects conversion factors:

- Fatality: 0.05 Sv^{-1}
- Incidence: 0.06 Sv^{-1}

Finally, the dose and risk coefficients were grouped into four age groups: 0 to 5 years, 5 to 15 years, 15 to 25 years, and 25 to 70 years. This assumption allowed for better correlation between the doses and risks calculated as a function of age group. Dose and risk conversion factors for these calculations were determined by interpolating between appropriate dose and risk conversion factors obtained from the

update to FGR-13 and from FGR-12. The three combined age groups are summarized in Table D-12. Also presented is the assumed duration of exposure for each age group.

Table D-12 Exposure Groupings and Corresponding Combined Dose and Risk Factor Age Groups

Age / Gender	Exposure Group (Duration [years])	Dose and Risk Factor Age Group
<1 male	Infant (male only) [1]	0 – 5
1 – 4 male	Preschool (male only) [4]	0 – 5
5 – 11 male	Schoolage (male only) [7]	5 – 15
12 – 17 male	Teenage (male only) [6]	15 - 25
18 – 70 male	Adult male [varies] *	25 – 70
18 – 70 female	Adult female [varies] *	25 – 70

*The exposure duration of the adult age groups depends on the year that the individual reaches age 18. Exposure duration lasts from the year of the 18th birthday until the end of 1992, when one child would be 38 and the other 29.

D.4.5 Calculation of Dose and Risk

Annual doses, and doses summed over all years of exposure, are calculated for each member of the exposure scenario families described in Appendix E. In addition, for each year of exposure, the lifetime risk resulting from that exposure is calculated, as well as the total lifetime risk caused by all years of exposure. Total annual doses and risks are the sum of doses and risks from each pathway. The pathways considered for each family member, and other factors important for calculating doses and risks (e.g., food consumption rates) may differ depending on the scenario and family member.

Section D.3 addressed the calculational procedures used by GENII to model each of the exposure pathways considered for this report. The output of these calculations is a set of annual exposure factors as summarized in Table D-13. Each exposure factor is calculated over a period of time, T, which is one year for the scenarios in this report.

Some exposure factors may be calculated several times for each receptor, and the individual calculations summed, to arrive at a total exposure factor for that receptor. This would be the case, for example, for exposure factors involving food crop ingestion, where the exposure factor calculated from consumption of each food product is summed to arrive at a total exposure factor for food crop ingestion.

The exposure factors for each pathway are then used in set of calculational procedures involving multiplication by appropriate dose or risk conversion factors as needed to determine the annual doses and lifetime risks that would result from each of exposure.

Three sets of calculational procedures are used to address effective dose, equivalent dose to various organs, and lifetime risks. Because the calculational procedures are repetitive, they have been summarized in tables. The equations used to calculate effective dose are listed in Table D-14, while definitions for the various parameters listed in these equations are summarized in Table D-15. Similarly, the equations used to calculate equivalent dose are listed in Table D-16, while the definitions for the various parameters used in these equations are summarized in Table D-17. Finally, the equations used to calculate risk are listed in Table D-18, while the definitions for the various parameters used in these equations are summarized in

Table D-19. For these tables, the assumed values for the surface soil bulk density (ρ_s) and the thickness of the contaminated surface soil layer (d_s) are provided in Section F.7.

Table D-13 Summary of Exposure Factors

Exposure Route	Pathway	Exposure Factor	Definition
External	Plume	$I_{eaig}(T)$	Exposure factor for plume immersion exposure for radionuclide i for an individual in age group g (Bq/m^3) (Sec. D.3.2)
	Ground	$I_{esig}(T)$	Exposure factor for exposure to contaminated ground for radionuclide i for individuals in age group g (Bq/kg) (Sec. D.3.3.2)
	Swim-ming	$I_{wrig}(T)$	Exposure factor for radionuclide i from swimming at recreational swimming location r for individuals in age group g (Bq/L) (Sec. D.3.6.1)
	Boating	$I_{brig}(T)$	Exposure factor for radionuclide i from boating at recreational boating location r for individuals in age group g (Bq/L) (Sec. D.3.6.3)
	Shoreline	$I_{srig}(T)$	Exposure factor for radionuclide i from shoreline exposure at recreational shoreline location r for individuals in age group g (Bq/kg) (Sec. D.3.5)
Ingestion	Farm Crops	$I_{csig}(T)$	Intake of radionuclide i in food crop c from ingestion of agriculture location s for individuals in age group g (Bq) (Sec. D.3.4.1)
	Animal Products	$I_{asig}(T)$	Intake of radionuclide i in animal product a from ingestion at agricultural location s for individuals in age group g (Bq) (Sec. D.3.4.2)
	Aquatic Foods	$I_{fwig}(T)$	Intake of radionuclide i from ingestion of aquatic food f at aquatic food location w for individuals in age group g (Bq) (Sec. D.3.4.3)
	Inadver-tent Soil	$I_{dsig}(T)$	Intake of radionuclide i from inadvertent soil ingestion at soil usage location s for individuals in age group g (Bq) (Sec. D.3.3.4)
	Inadver-tent Swim	$I_{wwig}(T)$	Intake of radionuclide i from inadvertent water ingestion at swimming location w for individuals in age group g (Bq) (Sec. D.3.6.2)
Inhalation	Air	$I_{aaig}(T)$	Intake of radionuclide i from air inhalation at air usage location a for individuals in age group g (Bq) (Sec. D.3.1)
	Resus-pended Soil	$I_{saig}(T)$	Intake of radionuclide i from resuspension inhalation at soil usage location a for individuals in age group g (Bq) (Sec. D.3.3.3)

Table D-14 Equations for Calculation of Effective Dose

Exposure Route	Exposure Pathway	Dose Parameter	How Calculated
External	Plume	$IE_{eaig}(T)$	$I_{eaig}(T)$ EC_{iaa} T_{yr} 3.15E+7
	Ground	IEesig(T)	$I_{esig}(T)$ ECiag Tyr 3.15E+7 / (ρ_s d_s)
	Swimming	$IE_{wrig}(T)$	10^{-3} $I_{wrig}(T)$ $EC_{ia}w$ T_{yr} 3.15E+7
	Boating	$IE_{brig}(T)$	10^{-3} $I_{brig}(T)$ EC_{iaw} T_{yr} 3.15E+7 / 2*
	Shoreline	$IE_{srig}(T)$	$I_{srig}(T)$ EC_{iag} T_{yr} 3.15E+7 / (ρ_s d_s)
Ingestion	Farm Crops	$IE_{csig}(T)$	$I_{csig}(T)$ EC_{igoc}
	Animal Products	$IE_{asig}(T)$	$I_{asig}(T)$ EC_{igoc}
	Aquatic Foods	$IE_{fwig}(T)$	$I_{fwig}(T)$ EC_{igoc}
	Inadvertent Soil	$IE_{dsig}(T)$	$I_{dsig}(T)$ EC_{igoc}
	Inadvertent Swim	$IE_{wwig}(T)$	$I_{wwig}(T)$ EC_{igoc}
Inhalation	Air	$IE_{aaig}(T)$	$I_{aaig}(T)$ EC_{igrc}
	Resuspended Soil	$IE_{saig}(T)$	$I_{saig}(T)$ EC_{igrc}

*The factor of two devisor reflects the different geometry of the exposure situation for swimming vs. boating. The swimming pathway entails immersion in the radioactive source, while the boating pathway entails being in proximity to it.

Table D-15 Definitions for Calculation of Effective Dose

Parameter	Definition
$IE_{eaig}(T)$	Effective dose from external exposure to radionuclide i from plume immersion at air usage location a for an individual in age group g (Sv)
$IE_{esig}(T)$	Effective dose from external exposure to radionuclide i in contaminated soil at soil usage location s for an individual in age group g for exposure over time period (T)
$IE_{wrig}(T)$	Effective dose from external exposure to radionuclide i in contaminated water at recreational water usage location r for an individual in age group g (Sv)
$IE_{brig}(T)$	Effective dose from external exposure to radionuclide i from boating in contaminated water at recreational water usage location r for an individual in age group g (Sv)
$IE_{srig}(T)$	Effective dose from external exposure to radionuclide i in shoreline sediment at recreational water usage location r for an individual in age group g (Sv)
$IE_{csig}(T)$	Effective dose from ingestion intake of radionuclide i in food crop c at soil usage location s for an individual in age group g for exposure over time period T (Sv)
$IE_{asig}(T)$	Effective dose from ingestion intake of radionuclide i in animal product a at soil usage location s for an individual in age group g for exposure over time period T (Sv)
$IE_{fwig}(T)$	Effective dose from ingestion intake of radionuclide i in aquatic food f at water usage location w for an individual in age group g for exposure over time period T (Sv)
$IE_{dsig}(T)$	Effective dose from ingestion intake of radionuclide i in soil at soil usage location s for an individual in age group g for exposure over time period T (Sv)
$IE_{wwig}(T)$	Effective dose from ingestion intake of radionuclide i in swimming water at water usage location w for an individual in age group g for exposure over time period T (Sv)

$IE_{aaig}(T)$	Effective dose from inhalation intake of radionuclide i in air at air usage location a for an individual in age group g for exposure over time period T (Sv)
$IE_{saig}(T)$	Effective dose from inhalation intake of radionuclide i in resuspended soil at air usage location a for an individual in age group g for exposure over time period T (Sv)
EC_{iaa}	Effective dose coefficient for external exposure from plume immersion for radionuclide i for an adult (Sv m^3 per Bq s)
EC_{iag}	Effective dose equivalent factor for external exposure from ground exposure for radionuclide i for an adult (Sv m^2 per Bq s)
EC_{iaw}	Effective dose equivalent factor for external exposure from water immersion for radionuclide i for an adult (Sv L per Bq s)
EC_{igoc}	Effective dose coefficient for ingestion intake of radionuclide i of class c for an individual in age group g (Sv/Bq)
EC_{igrc}	Effective dose coefficient for ingestion intake of radionuclide i for an individual in age group g (Sv/Bq)
T_{yr}	Time of exposure, one year.
3.15E+7	Factor for correction of units (seconds per year)
10^{-3}	Factor for correction of units (m^3 per liter)
ρ_s	Surface soil bulk density (kg/m^3)
d_s	Thickness of surface soil layer (m)

Table D-16 Equations for Calculation of Equivalent Dose

Exposure Route	Exposure Pathway	Dose Parameter	How Calculated
External	Plume	$IE_{eaig}T(T)$	$I_{eaig}(T)\ HC_{iaa}T\ T_{yr}\ 3.15E+7$
	Ground	$IE_{esig}T(T)$	$I_{esig}(T)\ HC_{iag}T\ T_{yr}\ 3.15E+7 / (\rho_s\ d_s)$
	Swimming	$IE_{wrig}T(T)$	$10^{-3}\ I_{wrig}(T)\ HC_{iaw}T\ T_{yr}\ 3.15E+7$
	Boating	$IE_{brig}T(T)$	$10^{-3}\ I_{brig}(T)\ HC_{iaw}T\ T_{yr}\ 3.15E+7 / 2$*
	Shoreline	$IE_{srig}T(T)$	$I_{srig}(T)\ HC_{iag}T\ T_{yr}\ 3.15E+7 / (\rho_s\ d_s)$
Ingestion	Farm Crops	$IE_{csig}T(T)$	$I_{csig}(T)\ HC_{igoc}T$
	Animal Products	$IE_{asig}T(T)$	$I_{asig}(T)\ HC_{igoc}T$
	Aquatic Foods	$IE_{fwig}T(T)$	$I_{fwig}(T)\ HC_{igoc}T$
	Inadvertent Soil	$IE_{dsig}T(T)$	$I_{dsig}(T)\ HC_{igoc}T$
	Inadvertent Swim	$IE_{wwig}T(T)$	$I_{wwig}(T)\ HC_{igoc}T$
Inhalation	Air	$IE_{aaig}T(T)$	$I_{aaig}(T)\ HC_{igrc}T$
	Resuspended Soil	$IE_{saig}T(T)$	$I_{saig}(T)\ HC_{igrc}T$

*The factor of two devisor reflects the different geometry of the exposure situation for swimming vs. boating. The swimming pathway entails immersion in the radioactive source, while the boating pathway entails being in proximity to it.

Table D-17 Definitions for Calculation of Equivalent Dose

Parameter	Definition
$IE_{eaig}T(T)$	Equivalent dose to organ or tissue T from external exposure to radionuclide i from plume immersion at air location a for an individual in age group g (Sv)
$IE_{esig}T(T)$	Equivalent dose to organ T from external exposure to radionuclide i from plume immersion at soil usage location s for an individual in age group g for exposure over time period T (Sv)
$IE_{wrig}T(T)$	Equivalent dose to organ T from external exposure to radionuclide i while swimming at recreational water usage location r for an individual in age group g for exposure over time period T (Sv)
$IE_{brig}T(T)$	Equivalent dose to organ T from external exposure to radionuclide i while boating at recreational water usage location r for an individual in age group g for exposure over time period T (Sv)
$IE_{srig}T(T)$	Equivalent dose to organ T from external exposure to radionuclide i from shoreline sediment at recreational water usage location r for an individual in age group g over time period T (Sv)
$IE_{csig}T(T)$	Equivalent dose to organ T from ingestion intake of radionuclide i in food crop c at soil usage location s for an individual in age group g for exposure over time period T (Sv)
$IE_{asig}T(T)$	Equivalent dose to organ T from ingestion intake of radionuclide i in animal product a at soil location s for an individual in age group g for exposure over time period T (Sv)
$IE_{fwig}T(T)$	Equivalent dose to organ T from ingestion intake of radionuclide i in aquatic food f at water usage location w for an individual in age group g for exposure over time period T (Sv)
$IE_{dsig}T(T)$	Equivalent dose to organ T from ingestion intake of radionuclide i in soil at soil usage location s for an individual in age group g for exposure over time period T (Sv)
$IE_{wwig}T(T)$	Equivalent dose to organ T from ingestion intake of radionuclide i in water at water usage location w for an individual in age group g for exposure over time period T (Sv)
$IE_{aaig}T(T)$	Equivalent dose to organ T from inhalation intake of radionuclide i in air at air usage location a for an individual in age group g for exposure over time period T (Sv)
$IE_{saig}T(T)$	Equivalent dose to organ T from inhalation intake of radionuclide i in resuspended soil at air usage location a for an individual in age group g for exposure over time period T (Sv)
$HC_{iaa}T$	Equivalent dose coefficient for air immersion to an organ T, radionuclide i, for an adult (Sv m^3 per Bq s)
$HC_{iag}T$	Equivalent dose coefficient to organ T for external exposure to ground for radionuclide i for an adult (Sv per Bq s)
$HC_{iaw}T$	Equivalent dose coefficient to organ T for external exposure from water immersion for radionuclide I for an adult (Sv L per Bq s)
$HC_{igoc}T$	Equivalent dose coefficient to organ T for ingestion intake of radionuclide c of class c for an individual in age group g (Sv/Bq)
$HC_{igrc}T$	Equivalent dose coefficient to organ T for inhalation intake of radionuclide i of class c for an individual in age group g (Sv/Bq)

Parameter	Definition
EC_{igrc}	Effective dose coefficient for ingestion intake of radionuclide i for an individual in age group g (Sv/Bq)
T_{yr}	Time of exposure, one year.
3.15E+7	Factor for correction of units (seconds per year)
10^{-3}	Factor for correction of units (m^3 per liter)
ρ_s	Surface soil bulk density (kg/m^3)
d_s	Thickness of surface soil layer (m)

Table D-18 Equations for Calculation of Cancer Risk

Exposure Route	Exposure Pathway	Risk Parameter	How Calculated
External	Plume	$IR_{eaig}T(T)$	$I_{eaig}(T)\ RC_{iga}T\ T_{yr}\ 3.15E+7$
	Ground Contam.	$IR_{esig}T(T)$	$I_{esig}(T)\ RC_{igg}T\ T_{yr}\ 3.15E+7 / (\rho_s\ d_s)$
	Swimming	$IR_{wrig}T(T)$	$10^{-3}\ I_{wrig}(T)\ HC_{iaw}T\ HC_{gh}\ T_{yr}\ 3.15E+7$
	Boating	$IR_{brig}T(T)$	$10^{-3}\ I_{brig}(T)\ HC_{iaw}T\ HC_{gh}\ T_{yr}\ 3.15E+7 / 2$*
	Shoreline	$RH_{srig}T(T)$	$I_{srig}(T)\ RC_{iag}T\ T_{yr}\ 3.15E+7 / (\rho_s\ d_s)$
Ingestion	Farm Crops	$RH_{csig}T(T)$	$I_{csig}(T)\ RC_{igoc}T$
	Animal Products	$RH_{asig}T(T)$	$I_{asig}(T)\ EC_{igoc}T$
	Aquatic Foods	$RH_{fwig}T(T)$	$I_{fwig}(T)\ RC_{igoc}T$
	Inadvertent Soil	$RH_{dsig}T(T)$	$I_{dsig}(T)\ RC_{igoc}T$
	Inadvertent Swim	$RH_{wwig}T(T)$	$I_{wwig}(T)\ RC_{igoc}T$
Inhalation	Air	$RH_{aaig}T(T)$	$I_{aaig}(T)\ RC_{igrc}T$
	Resuspended Soil	$RH_{saig}T(T)$	$I_{saig}(T)\ RC_{igrc}T$

*The factor of two devisor reflects the different geometry of the exposure situation for swimming vs. boating. The swimming pathway entails immersion in the radioactive source, while the boating pathway entails being in proximity to it.

Table D-19 Definitions for Calculation of Cancer Risk

Parameter	Definition
$IR_{eaig}T(T)$	Risk to organ or tissue T from external exposure to radionuclide i from plume immersion at air location a for an individual in age group g (risk)
$IR_{esig}T(T)$	Risk to organ T from external exposure to radionuclide i from plume immersion at soil usage location s for an individual in age group g for exposure over time period T (risk)
$IR_{wrig}T(T)$	Risk to organ T from external exposure to radionuclide i while swimming at recreational water usage location r for an individual in age group g for exposure over time period T (risk)
$IR_{brig}T(T)$	Risk to organ T from external exposure to radionuclide i while boating at recreational water usage location r for an individual in age group g for exposure over time period T (risk)
$RH_{srig}T(T)$	Risk to organ T from external exposure to radionuclide i from shoreline sediment at recreational water usage location r for an individual in age group g over time period T (risk)
$RH_{csig}T(T)$	Risk to organ T from ingestion intake of radionuclide i in food crop c at soil usage location s for an individual in age group g for exposure over time period T (risk)
$RH_{asig}T(T)$	Risk to organ T from ingestion intake of radionuclide i in animal product a at soil location s for an individual in age group g for exposure over time period T (risk)
$RH_{fwig}T(T)$	Risk to organ T from ingestion intake of radionuclide i in aquatic food f at water usage location w for an individual in age group g for exposure over time period T (risk)
$RH_{dsig}T(T)$	Risk to organ T from ingestion intake of radionuclide i in soil at soil usage location s for an individual in age group g for exposure over time period T (risk)
$RH_{wwig}T(T)$	Risk to organ T from ingestion intake of radionuclide i in water at water usage location w for an individual in age group g for exposure over time period T (risk)
$RH_{aaig}T(T)$	Risk to organ T from inhalation intake of radionuclide i in air at air usage location a for an individual in age group g for exposure over time period T (risk)
$RH_{saig}T(T)$	Risk to organ T from inhalation intake of radionuclide i in resuspended soil at air usage location a for an individual in age groupg g for exposure over time period T (risk)
$RC_{iga}T$	Risk coefficient for air immersion to an organ T, radionuclide i, for an individual in age group g (m^3 per Bq s)
$RC_{igg}T$	Risk coefficient to organ T for external exposure to ground for radionuclide i for an adult (m^2 per Bq s)
$HC_{iaw}T$	Equivalent dose coefficient to organ T for external exposure from water immersion for radionuclide I for an adult (Sv L per Bq s)
HC_{gh}	Health effects conversion factor for effect h and an individual in age group g (risk/Sv)
$RC_{iag}T$	Risk coefficient to organ T for external exposure to ground (the soil surface factor is used for sediment as well) for radionuclide i for an adult (m^3 per Bq s)
$RC_{igoc}T$	Risk coefficient to organ T for ingestion intake of radionuclide c of class c for an individual in age group g (Bq^{-1})

Parameter	Definition
$RC_{igrc}T$	Risk coefficient to organ T for inhalation intake of radionuclide i of class c for an individual in age group g (Bq^{-1})
$RC_{igrc}T$	Risk coefficient for inhalation of radionuclide i for an individual in age group g (Sv/Bq)
T_{yr}	Time of exposure, one year
3.15E+7	Factor for correction of units (seconds per year)
10^{-3}	Factor for correction of units (m^3 per liter)
ρ_s	Surface soil bulk density (kg/m^3)
d_s	Thickness of surface soil layer (m)

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APPENDIX E RECEPTOR ACTIVITIES AND USAGE RATES

This appendix presents the seven exposure scenarios assumed for Phase III of the Savannah River Site (SRS) Dose Reconstruction Project, along with the derivation of base case values for those radiological assessment parameters that depend on the behaviors of the human receptors comprising the exposure scenarios. Seven human receptors were modeled using the GENII[1] computer code for each exposure scenario (28 receptors total). Assumptions about the behavior of each receptor were used to develop values for many of the parameters comprising the mathematical relationships used in GENII for radiological assessment (see Appendix D). These parameters address human-oriented behavior such as the assumed breathing rates of the four receptors associated with each scenario, their food consumption rates, and the times spent in various exposure locations.

The assessments that were performed were complex. Radiation doses and risks were determined for each receptor for each of years of nuclear material production at the SRS. The behavior of each receptor, as well as the receptor's age, changed over time. Therefore, the radiation exposure calculations were made using GENII and assuming "unit" quantities for receptor-specific parameters such as food consumption rates. This output from GENII was then modified in the post-processor (software created for this Phase III study) to arrive at the proper doses and risks for each receptor. These modifications were performed using a set of receptor- and pathway-specific *exposure* and *adjustment factors*.

To link the exposure scenarios, the computational procedures outlined in Appendix D, the receptor-specific parameters and their values input to GENII, and the exposure and adjustment factors used to modify the output from GENII, this appendix is organized in the following manner:

- Section E.1: Scenarios proposed by the Centers for Disease Control and Prevention (CDC) and considered by the Savannah River Site Health Effects Subcommittee (SRSHES).
- : Additional assumptions about scenarios.
- Section E.3: Overview of final exposure scenarios.
- Section E.4: Linkage of GENII variables to exposure and adjustment factors.
- Section E.5: Exposure and adjustment factors for each exposure pathway.

Except for radiation dosimetry assumptions, other GENII parameter values that are not clearly receptor-specific (such as food crop production rates, soil density, etc.) are presented in Appendix F. Radiation dosimetry assumptions are presented in Section D.4 of Appendix D.

E.1 Scenarios Proposed by CDC and Considered by the SRSHES

The exposure scenarios considered for this report evolved over time. Originally, CDC proposed the following six scenarios (1):

- A rural family just downwind of the site boundary.
- An urban/suburban family just downwind of the site boundary.
- A delivery person scenario.
- An outdoors person (hunting, fishing, camping, etc.).
- A family living near the river.
- A migrant worker family living mostly outdoors.

[1] All references to the GENII code in this chapter refer to Version 2 of GENII.

These scenarios were meant to represent hypothetical families that might have lived in the SRS vicinity and engaged in activities that were typical for the area. The activities postulated for these scenarios were intended to represent a broad range of lifestyles.

CDC presented proposed assumptions about these six scenarios to the SRSHES at a meeting of the SRSHES held in January 2002 in Charleston, South Carolina. Shortly thereafter, these assumptions were somewhat modified, and the SRSHES formed a work group to consider the proposed scenarios. On September 6, 2002, a SRSHES meeting was held, and J. Lockridge, the chair of the SRSHES Scenario Work Group, presented comments on the proposed scenarios to the CDC and the preparers of this report (1). Table E-1 summarizes the CDC proposed scenarios (as modified) and the SRSHES Work Group comments on the proposed scenarios. The SRSHES also made suggestions about further modifying the scenarios, and Table E-2 summarizes these suggested modifications (1).

The preparers of this report discussed the proposed scenarios with CDC staff in early 2003. Two key references that address these discussions are memoranda from the preparers of this report to CDC (2,3). These discussions principally addressed overall decisions about the number of exposure scenarios to be considered and where the hypothetical families comprising the exposure scenarios would live, work, attend church and school, obtain food, and recreate.

Table E-1 Summary of CDC Proposed Scenarios and SRSHES Comments

Proposed Scenario	Scenario Description	SRSHES Work Group Comments (1)
Rural	• Use the closest downwind location where there could have been farms in 1955. • Consider an adult, an infant born in 1955, and an infant born in 1964 (year of largest iodine release). Use default consumption values. • Assume a lot of time outdoors working in soil. • Assume they drank milk from a backyard cow. • Assume the crops were irrigated from Savannah River. • Assumption of "working in soil" also included resuspension of soil contaminants in the breathing zone. • In addition to two infants, consider the mother nursing at least one of the infants.	• Farm in rural Burke County, GA. Girard, GA - 3 miles west of Savannah River, SW from SRS. Population about 200 in 1950s. Located in SRS plume path. • In 1950's, a family of two parents, five children. In 1960's, a family of two parents, three children. • Schools: Girard Elementary, Waynesboro High School. • Cash crops: peanuts, corn, cotton. Vegetables grown for family consumption. • Religion: Methodist. • In 1950's, 50% of meat & vegetables grown on farm. In 1960s, 25% grown on farm; most milk from one of two dairies in Girard. Family had a few dairy cows. • Some swimming, but minimal camping. No recreational boating. • Lots of fishing from Briar Creek, 2 miles east of Girard. Significant hunting for deer, quail and dove. Limited trapping.
Urban/ Suburban	• Use the closest downwind location where urban or suburban families could have lived in 1955. • Consider an adult, an infant born in 1955, and an infant born in • 1964 (year of largest iodine release).	• Family resided in Augusta, GA (region of Broad and Greene Streets). • In 1950's, a family of two parents, two children of varying ages. In 1960's, a family of two parents, three children. • Schools: Augusta neighborhood schools.

Proposed Scenario	Scenario Description	SRSHES Work Group Comments (1)
	• Use default consumption values. • Assume the adult worked at the nearest industrial location downwind in 1955. • Assume milk drunk from nearest dairy or rural neighbor. • Assume the adult worked onsite at SRS in lieu of the "nearest industrial location." • Assume the onsite work location was associated with higher radiological exposures (e.g., SRS Canyons).	• Assume father to have worked in the SRS F-Area Canyon Building from 1955 to 1992. • Assume the mother to have stayed home to raise the children. Mother worked onsite until well into her pregnancy. • Attended local church in Augusta, GA. • Food and milk were obtained from local grocery stores in Augusta, GA. Milk was supplied to local stores from dairies in the Aiken and Augusta area. • Occasional swimming and boating in Clark's Hill Lake. • No hunting, but fishing in Clark's Hill Reservoir. Fishing two weekends per month.
Delivery	• Same as Urban/Suburban Family. • Use the closest downwind location where urban or suburban families could have lived in 1955. • Consider an adult, an infant born in 1955, and an infant born in 1964 (year of largest iodine release). • Use default consumption values. • Assume the adult worked at the nearest industrial location downwind in 1955. • Assume they drank milk from the nearest dairy or rural neighbor. • Assume that the person spent 8 hours per week onsite.	• Family resided in Barnwell, SC. Father provided weekly beverage deliveries to SRS. • In 1950's, family of two parents, two children of varying ages. In 1960's, a family of two parents, three children. • Schools: Barnwell, SC, school system. • Assume the delivery person worked at the Allendale Coca Cola Bottling Plant in Allendale, SC, and made routine deliveries to SRS (various locations) spending 8 hours per week onsite. • Attended Mount Hope Baptist Church, Martin, SC. • Food Sources: Barnwell, SC, grocery stores, and Furses' Grocery Store, Martin, SC. • Swimming in Lower Three Runs Creek outside Martin, SC. Boating and camping at Little Hell Landing on Savannah River (south boundary of SRS). • Hunting at Lower Three Runs Creek area (known for poaching). Fishing at Lower Three Runs Creek, and Savannah River's Smith Lake. • Family drank lots of carbonated beverages (including beer).
Outdoor	• Assume camping at the nearest downwind location that would make sense with the season (hunting, fishing, etc.). • Assume that the person was always outdoors. • Use default consumption values.	• Family resided in Jackson, SC. • In 1950's, a family of two parents, two children of varying ages. In 1960's, a family of two parents, three children. • Schools: (1950) Jackson Elementary (29,831). (1986) Redcliff Elementary (29,803). Jackson High School.

Proposed Scenario	Scenario Description	SRSHES Work Group Comments (1)
	• Assume the person spent 8 hours per day on the Savannah River in the summer. • Assume the person spent 8 hours per week on site hunting or fishing (in season). • Assume the person obtained fish and meat (deer, game birds, turtles) from hunting and fishing onsite (some authorized, some not—a "poacher" assumption.)	• Worked as a hunter/trapper subcontractor to the primary SRS Contractor (DuPont, WSRC, etc.) or the U.S. Forest Service. • Religion: First Baptist Church, Jackson, SC. • 50% of vegetables locally grown and irrigated from a surface creek. 75% of meat obtained from SRS. Fish obtained from Savannah River. Water obtained from well on home property. • Boating in Savannah River from Jackson, SC, boat ramp. • Obtained deer, hogs from work at SRS trapping. Fished in Savannah River.
Near River	• Use the nearest docking location downwind where people could have lived on the house boats in 1955. • Consider an adult, an infant born in 1955 and an infant born in 1964 (year of largest iodine release). • Use default consumption values. • Assume always outdoors in contact with Savannah River. • Assume they obtained their food from the nearest local farm or grocery store. • Validate with the Citizens Advisory Board that the boat scenario is plausible, and if so, define a location. • If not plausible, replace the boat scenario with a new scenario of a site construction worker living in a trailer.	• Scenario location: Consider Martin-Millet area • Family: To be developed (TBD). • Schools: TBD. • Work: TBD. • Religion: TBD. • Food sources: Shell fishing, shrimping, crabbing. • Swimming, boating, camping, hunting, & fishing: TBD.
Migrant Worker	• Use the closest downwind location. • Consider an adult, an infant born in 1955 and an infant born in 1964 (year of largest iodine release). • Use default consumption values. • Assume always outdoors in contact with the soil. • Assume that crops were irrigated by the Savannah River. • Assume they obtained their food from the nearest local farm or grocery store.	• Scenario location: TBD. • In 1950's, a family of two parents, two children of varying ages. In 1960's, a family of two parents, three children. • Schools: TBD. • Work: TBD. • Religion: TBD. • Food sources: TBD. • Swimming, boating, camping, hunting, & fishing: TBD.

Table E-2 SRSHES Work Group Suggested Modifications to CDC Proposed Scenarios

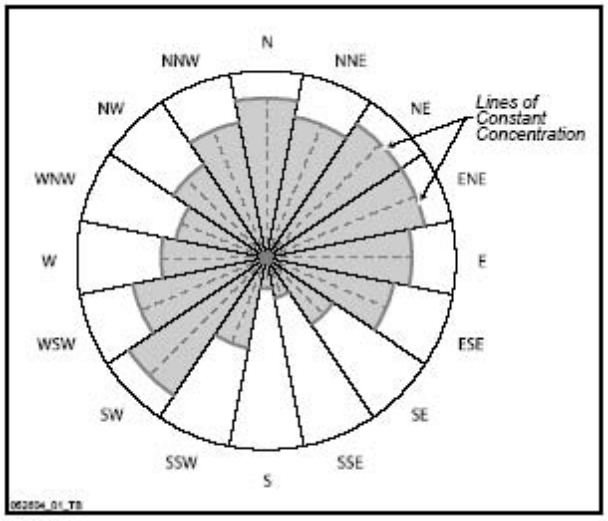
Proposed Scenario	SRSHES Work Group Suggested Modifications to Scenarios
Rural	• Milk source was most likely the local dairies near Girard, but not to the exclusion of the backyard cow. • Assume the family had dogs for pets. • Assume the family had chickens.
Urban/ Suburban	• Milk was obtained from a local grocery in Augusta, and not the "nearest dairy or a rural neighbor." Backyard cow is also included for the purpose of dose modeling. • Add that the mother also worked at the site during the early months of her first pregnancy (actual anecdotal). Stayed home after birth of her first child. • Include a family pet.
Delivery	• No dosimetry issued for this person. • Consider backyard chickens and/or rabbits at residence.
Outdoor	• Scenario also includes the hypothetical poacher. • Hunting dogs were also family pets. • Some potential onsite exposure from trapping activities, streams, ponds, etc.
Near River	• Scenario modifications to be developed.
Migrant Worker	• Scenario modifications to be developed.

Source: Lockridge, 2002 (1).

E.1.1 Exposure Scenarios and Locations

As discussed in Chapter 6, releases to the air from any SRS source were modeled as being transported in each of 16 sectors defined by the 16 major compass directions, consistent with the meteorological data obtained for the SRS. Figure E-1 shows that, in any sector, at a given distance from a source, concentrations were modeled as being the same along all points of an arc defined by the radial distance from the source. It shows the relative radionuclide concentration from a unit source at a distance of 10 miles from the source. In each sector, the relative concentration is constant across the sector width.

The meaning of this modeling simplification is that at a given distance from a source, the same concentrations will be determined anywhere is a sector.



Radionuclide Concentration at 10 Miles from a Unit SRS Source

Thus, two hypothetical exposure locations that are fairly close together will generally not differ significantly in modeled concentrations.

E.1.1.1 Exposure Scenarios and Locations Considered for Phase III

In addition to the six exposure scenarios originally proposed by CDC, a seventh was added. When the scenario locations were plotted on a map of the area surrounding the SRS, it was noted that approximately 90° out of 360°—generally towards the northeast—was without an exposure scenario. Therefore, a seventh—identified as Rural Family Two—was added with concurrence from CDC and the SRSHES.

Each of the seven exposure scenarios consisted of a family living at a designated location. In each scenario, exposure locations were identified to represent where family members lived, worked, attended school, and engaged in recreational activities; where their food was grown; and where other activities were located. For all 7 scenarios, a total of 10 exposure locations were considered for radionuclides that had been transported through the air, while 2 exposure locations were considered for radionuclides that had been transported through surface water.

Figure E-2 shows the exposure locations assumed for the seven exposure scenarios.

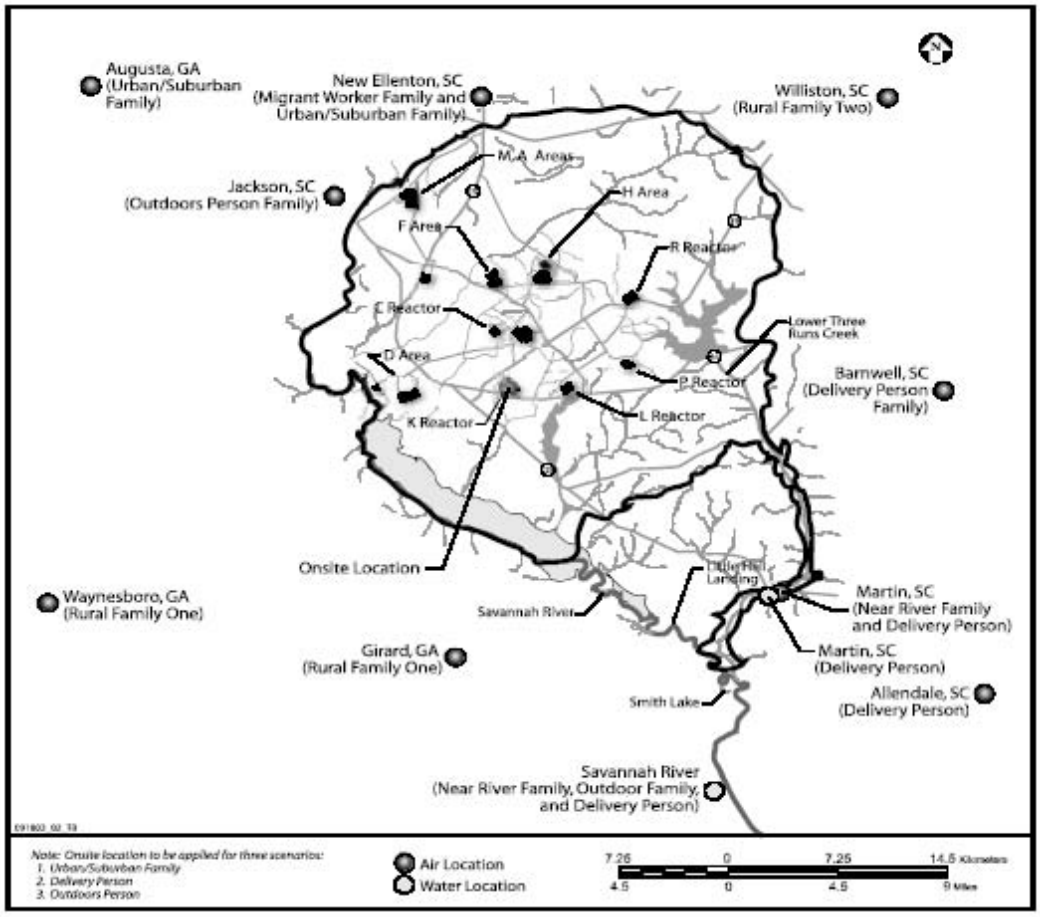


Figure E-2 Exposure Locations for Exposure Scenarios

Tables E-3 and E-4 summarize the exposure locations for contamination released into the air, while Tables E-5 and E-6 summarize the exposure locations for contamination released to surface water. The Lower Three Runs Creek exposure location is in the vicinity of Martin, South Carolina. The downstream Savannah River exposure location is representative of multiple possible locations downstream from the site.

Table E-3 Summary of Exposure Locations for SRS Air Releases

CDC Scenario	Activity	Exposure Location									
		Girard	Waynesboro	Martin	Augusta	Williston	SRS Onsite	Barnwell	Allendale	Jackson	New Ellenton
Rural Family One	All except high school	X									
	High school		X								
Rural Family Two	All activities					X					
Urban/Suburban Family	All except employment				X						
	Employment						X				
Delivery Person	All except noted below							X			
	Employment						X		X		
	Church, hunting. Partial grocery, swimming, fishing			X							
Outdoors Person	All except employment									X	
	Employment						X				
Near River Family	All activities			X							
Migrant Family	All activities										X

The scenarios and exposure locations are:

- Rural Family One. This family lived on a farm near Girard, Georgia. The Girard exposure location was where the family hunted, fished, and grew or produced much of their food. Although the adults always stayed near the farm, the children attended high school in Waynesboro, Georgia.
- Rural Family Two. This family lived on a farm near Williston, South Carolina. The Williston exposure location was where the family hunted, fished, and grew or produced much of their food. All family members lived at the Williston exposure location for all 39 years, including grade and high school for the children.
- Urban/Suburban Family. This family lived near the intersection of Broad and Greene Streets in Augusta, Georgia. The Augusta exposure location was assumed for most family activities including swimming, boating, and fishing. It was the exposure location where much of the family's food was grown or produced, including half of their milk. The other half of their milk came from cows located

Table E-4 Exposure Locations for Air Releases by Scenario and Pathway

Scenario	Individual	Pathway												
		External Exposure		Inhalation		Ingestion								
		Air	Soil	Air	Resus-pended Soil	Beef	Poultry	Milk	Eggs	Leafy Veg	Root Veg	Fruit	Grain	Soil
Rural Family One	Adult Male	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
	Adult Female	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
	Child Born 1955	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
	Child Born 1964	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
Rural Family Two	Adult Male	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
	Adult Female	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
	Child Born 1955	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
	Child Born 1964	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
Urban/ Suburb Family	Adult Male	Augusta, Onsite SRS	Augusta, Onsite SRS	Augusta, Onsite SRS	Augusta, Onsite SRS	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
	Adult Female	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
	Child Born 1955	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
	Child Born 1964	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
Delivery Person	Adult Male	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin
	Adult Female	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin
	Child Born 1955	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin
	Child Born 1964	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin

Scenario	Individual	Pathway												
		External Exposure		Inhalation		Ingestion								
		Air	Soil	Air	Resus-pended Soil	Beef	Poultry	Milk	Eggs	Leafy Veg	Root Veg	Fruit	Grain	Soil
Outdoors Person	Adult Male	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
	Adult Female	Jackson	Jackson	Jackson	Jackson	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
	Child Born 1955	Jackson	Jackson	Jackson	Jackson	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
	Child Born 1964	Jackson	Jackson	Jackson	Jackson	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
Near River Family	Adult Male	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
	Adult Female	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
	Child Born 1955	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
	Child Born 1964	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
Migrant Worker Family	Adult Male	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton
	Adult Female	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton
	Child Born 1955	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton
	Child Born 1964	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton

Table E-5 Exposure Locations for Water Releases by Scenario and Pathway

	Family Member	External Exposure			Ingestion	
		Shoreline	Swimming	Boating	Fish	Swimming
Rural Family One	Adult Male Adult Female Child Born 1955 Child Born 1964	This family was assumed to do no boating in accordance with Lockridge 2002 (1).				
Rural Family Two	Adult Male Adult Female Child Born 1955 Child Born 1964	This family was assumed to do no boating in accordance with Lockridge 2002 (1).				
Urban/ Suburb Family	Adult Male Adult Female Child Born 1955 Child Born 1964	Activities were unaffected by radionuclides released to surface waters.				
Delivery Person	Adult Male Adult Female Child Born 1955 Child Born 1964	LTRC & SR*	LTRC	Savannah River	LTRC & SR*	LTRC
Outdoors† Person	Adult Male† Adult Female Child Born 1955 Child Born 1964	Savannah River†	Savannah River†	Savannah River†	Savannah River†	Savannah River†
Near River Family	Adult Male Adult Female Child Born 1955 Child Born 1964	Savannah River, all pathways				
Migrant Worker Family	Adult Male Adult Female Child Born 1955 Child Born 1964	Activities were unaffected by radionuclides released to surface waters.				

*LTRC – Lower Three Runs Creek; SR — Savannah River.
†The Adult Male and grown children received external shoreline exposures. The Adult Female did not. Family members received exposures from boating and from eating fish, but not from swimming.

Table E-6 Summary of Exposure Locations for SRS Water Releases

Scenario	Activities / Pathways	Downstream Savannah River	Lower Three Runs Creek	No Exposure to Affected Water*
Rural Family One	All activities†			X
Rural Family Two	All activities†			X
Urban/Suburban Family	All activities†			X
Delivery Person	Fishing, swimming, shoreline		X	
	Boating (and fishing)	X		
Outdoors Person	Fishing, shoreline, boating	X‡		
	Swimming			X§
Near River Family	All activities†	X		
Migrant Worker Family	All activities†			X

*Either the activity occurred in unaffected water or the activity did not occur.
†"All activities" included fishing, boating, swimming, and shoreline.
‡Only the adult male and grown children received shoreline exposures, while working at SRS.
§For entire family while recreating on the Savannah River.

in New Ellenton, South Carolina. The father worked onsite at the SRS. (The children also worked onsite at the SRS when they grew up.) A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location.

- Migrant Worker Family. This family lived in New Ellenton, South Carolina, for half of any year. The New Ellenton exposure location was assumed for all exposures and activities (home, schools, church, work, recreation, and the source for locally grown vegetables, milk, and meat).
- Delivery Person Family. This family lived in Barnwell, South Carolina, and attended church in Martin, South Carolina. Some of the food eaten by this family was obtained from Barnwell and some from Martin. The father worked in Allendale, South Carolina, and onsite at the SRS. (The children also worked onsite when they grew up.) A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location. The father hunted deer and wild fowl near Martin. The family engaged in recreation on the shore of Lower Three Runs Creek (at Martin) and on the shore of the Savannah River below its confluence with Lower Three Runs Creek. The family boated on, and ate fish from, the Savannah River at this same exposure location. The family also ate fish caught in Lower Three Runs Creek.
- Outdoors Person Family. This family lived in Jackson, South Carolina, where the family also attended church and the children went to grade and high school. Much of the food eaten by the family was grown in Jackson. The father worked and hunted on the SRS site (as did the children when they grew up). The same location on the SRS site, near the K-Reactor, was assumed for the work exposure location and the hunting exposure location. The father boated on the Savannah River while working and with his family for recreation. The family swam and spent time along the shoreline at the Jackson

Boat Ramp, which is upstream of the SRS discharge to the Savannah River. All family members ate fish that were caught in the Savannah River below its confluence with Lower Three Runs Creek.

- Near River Family. This family lived in Martin, South Carolina.[2] The Martin exposure location was assumed for all activities (home, schools, church, work, recreation, source of milk, and the source of locally grown vegetables). In addition, the family boated in, and ate fish from, the Savannah River below its confluence with Lower Three Runs Creek.

Discussion of Assumptions About Exposure Scenarios and Locations

The following discussion provides additional information about the selection of exposure scenarios and the locations:

- Two rural farming families—Rural Family One and Rural Family Two—were assumed rather than one. Rural Family Two was added to the area near Williston, South Carolina. CDC staff had suggested adding an exposure scenario to the northeast of the SRS to assure that possible radiation exposures in that direction would be considered (3). It was decided that this exposure scenario would be a rural family similar to the farming family located near Girard, Georgia (Rural Family One).
- New Ellenton, South Carolina, was chosen as the exposure location for the Migrant Worker Family. Although a migrant worker scenario had been proposed by CDC, the location where the scenario would be sited was undetermined. (The SRSHES Work Group did not recommend a location [1].) The Migrant Worker Scenario was located in New Ellenton to assure that exposures from radionuclides released to the north from the SRS would be considered and because migrant farm families were probably present in the New Ellenton area during much of the period of interest (2). In addition, the New Ellenton area was chosen as the location of a dairy patronized by the Urban/Suburban Family (2).
- The Urban/Suburban Family was assumed to fish, swim, and boat at the Augusta exposure location. The SRSHES Scenarios Work Group had proposed using Clark's Hill Lake (now called the Strom Thurmond Reservoir) for these activities (1). The Augusta location was chosen as an alternative to help limit the number of exposure locations that had to be modeled. Because both Clark's Hill Lake and Augusta are well above any point of surface water discharge from the SRS, no receptors at either location would have experienced radiological exposures from radionuclides released by the SRS to surface water. The only potential exposures would have been from radionuclides released into the air. Because Augusta is closer to the SRS than Clark's Hill Lake and both locations are northeast of the SRS, Augusta was a more conservative choice than Clark's Hill Lake.
- Any person exposed on the SRS site was assumed not to have been a radiological worker whose radiation exposures would have been routinely measured. This person would have had access to the site but not to areas controlled for purposes of radiation protection. Two candidate locations were identified: (1) near K-Reactor, and (2) the F- and H-Areas. Although hunting was probably more likely near K-Reactor, more people were employed in the F- and H-Areas. The K-Reactor vicinity was chosen to represent the exposure location for all onsite receptors, whether working or hunting.
- For all scenarios, all hypothetical family members stayed in the SRS area over the entire 39-year period. Children born and raised in the area always remained at home except for participating in specified activities such as school and recreation. After finishing high school, the children lived in their home communities. Each child adopted the same occupation and recreational activities as the adult male in their family from age 18 on.
- All radiation exposures associated with the Savannah River (boating, swimming, shoreline, and fishing) were assumed to occur at a location below the confluence of the Savannah River with Lower

[2] Note that Martin, South Carolina, is not directly on the river.

Three Runs Creek. Below the confluence, the Savannah River contained radionuclides that were discharged into the river through the Savannah River Swamp as well as radionuclides that were discharged into the river from Lower Three Runs Creek. The flow rate was not significantly larger than further upstream. For purposes of calculating air exposures while recreating on the Savannah River (e.g., immersion and inhalation doses), the Martin location was assumed as representative. Martin, Smith Lake, and Little Hell Landing are all within a few miles of one another.

E.1.2 Additional Refinements to Proposed Exposure Scenarios

In addition to the overall decisions described above, the following several refinements were made to the specifics of the exposure scenarios proposed by CDC and addressed by the SRSHES:

- Consumption of locally acquired milk. It was assumed for all scenarios that family members drank milk from cows located in the SRS vicinity, meaning that all milk contained radionuclides that had been released into the air from the SRS. This assumption met the intent of the SRSHES Work Group's suggestion that the urban/suburban and rural families should drink milk from family cows (1).
- Consumption of poultry. It was assumed that much of the poultry eaten by all members of all scenarios was produced in the SRS vicinity. This assumption largely met the intent of the SRSHES Work Group's suggestion to include family chickens in some scenarios (1).
- Hunting and similar outdoors activities. It was assumed for several scenarios that the adult male performed outdoor activities such as hunting, trapping, and fishing. Radiation exposures received through consumption of game animals was modeled for the two rural families (i.e., the Delivery Person and Outdoors Person Families) by assuming that meat from game animals could be represented as either a form of beef or poultry (see Section E.2.2 of this appendix and Section D.1.1.2 of Appendix D.) Radiation exposures received through consumption of fish was modeled for the Delivery Person, Outdoor Person, and Near River Families (see Section E.5.2.3).
- Consumption of crustaceans. All radiation exposures from eating aquatic animals were assumed to come from eating fish. The SRSHES Work Group had suggested that shell fishing, shrimping, and crabbing should be considered as food sources for the Near River Family scenario (1). However, the level of contamination at brackish downriver water locations is small and unlikely to add to radiation exposures in the vicinity of the SRS.
- Irrigation. Irrigation with water contaminated with radionuclides from the SRS was not modeled as an exposure pathway. Although the proposed CDC scenario had envisioned that the rural family and migrant families would irrigate crops with water taken from the Savannah River (1), it was determined that such a pathway would be unrealistic for the SRS area.
- Houseboating. The Near River Family was assumed to live in Martin, South Carolina, an exposure location that was consistent with the recommendations of the SRSHES Work Group (1). CDC had proposed that the family living near the river should live on a houseboat (1). Yet there was no evidence that persons lived on houseboats in the SRS area.
- Family composition. Each exposure scenario consists of two adults and two children. The SRSHES Work Group had suggested that five children be assumed for the rural family and three for the delivery person family (1). However, it was determined that this additional information would only confirm the assumptions of the proposed CDC scenarios. Each scenario proposed by CDC included two children who were born during years that SRS released large quantities of radionuclides into the air (1).
- Religion. It was assumed that all family members attended religious services for a few hours each week. This assumption was consistent with the SRSHES Work Group's suggestions (1). For most

scenarios, it was assumed that the place of worship was near the family residence. The scope of the study did not support making distinctions between the specific locations of the structures within a small geographical area.

- Pets. Pets were not modeled as a separate exposure pathway. The SRSHES Work Group suggested that persons living in the SRS vicinity would probably have had pets such as hunting dogs (1). These pets may have brought radionuclides into a house from dust or dirt caught in their fur. However, the Phase III radiological assessment made no distinction between radionuclide concentrations indoors or outdoors, either in the air or deposited on the ground.
- Nursing mothers. The rural family scenario as proposed by CDC called for a mother nursing at least one of the children (1). Separate exposures through this pathway were not modeled because a standard approach could not be used to simulate this pathway. However, the Phase III radiological assessment did consider the consumption of contaminated foodstuffs by infants, including cow's milk.
- *In utero* exposures. It was assumed that the Adult Female for the Urban/Suburban Family scenario always worked at home. The SRSHES Work Group had suggested that the mother of the urban/suburban family be assumed to work onsite until well into her pregnancy (1). It was recognized that the Work Group's proposed assumption was directed at assessing *in utero* exposure to an unborn child. However, neither the modeling approach used nor the dose and risk coefficients that were used as principal components of the analysis address such exposures.[3]

E.2 Additional Assumptions About Scenarios

To perform the Phase III radiological assessments, it was necessary to add several additional assumptions to those provided by CDC and the SRSHES to address specific features of the exposure scenarios. These assumptions are addressed in detail in Appendix E and summarized here.

E.2.1 Composition of Exposure Scenario Families

It was assumed that each of the seven hypothetical families had the same composition:

- A male who was an adult (over age 18) in 1954.
- A female who was an adult (over age 18) in 1954.
- A male child born in 1955.
- A male child born in 1964.

This family composition was chosen to model infant exposures during 1955 and 1964 when releases of radionuclides to the environment were relatively large. Male children were modeled because males receive slightly larger radiation exposures for some pathways than females (e.g., males eat more than females) and therefore provide more conservative estimates of doses and risks. It was desirable to make both children the same sex to allow direct observation of the effect of being born at different times.

Figure E-3 presents the age and gender of each receptor for each year of exposure. A 39-year period was modeled starting at the beginning of 1954 and finishing at the end of 1992. Information about the age and gender of each member of the scenario families was used to determine the ingestion rates of certain foods (Section E.2.2), the times spent performing different activities (Section E.2.3), and other activities. In

[3]The dose and risk coefficients used are up-to-date coefficients issued by the Environmental Protection Agency in their 1992 update to Federal Guidance Report 13, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides" (4).

addition, information about each individual's age and gender was used to convert exposure levels to lifetime radiation dose and cancer risk as discussed in Chapter 10 and Appendix D.

As the children grew from infants to adults, assumptions about parameter values were made that were appropriate for their age. Each child was assumed to grow from a male infant (his first year), to a preschooler (3 years from ages 2-4), to a grade-school aged child (7 years from ages 5-11), to a teenager (6 years from ages 12-17) years), to an adult age (all remaining years from age 18 on). After each child reached age 18, parameter values appropriate for an adult were maintained for the rest of the study period. The Child Born in 1955 became an adult in 1973; the Child Born in 1964 became an adult in 1982.

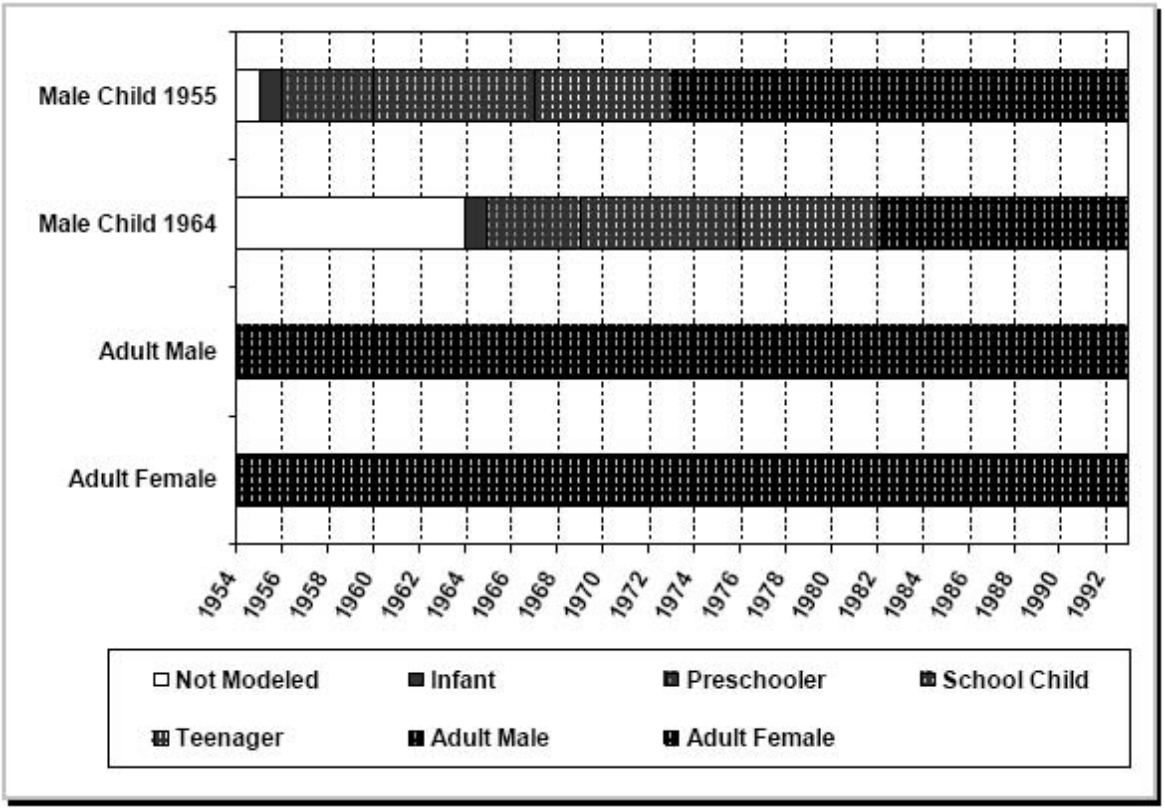


Figure E-3 Age and Gender Categories of Modeled Receptors by Year

E.2.2 Overview of Food Product Consumption

To address radiation exposures through consumption of food and animal products, quantities of each food product eaten by each receptor were estimated as well as the fraction of each food product that had been contaminated with radionuclides released by the SRS. Assumptions were made for each family member about the consumption rates of the food products listed below. The primary data source for these assumptions was EPA's "Exposure Factors Handbook" (5):

- Leafy vegetables
- Root vegetables
- Fruit
- Grain
- Beef
- Poultry
- Milk
- Eggs
- Fish

The quantity of each food product consumed annually depended on the age of the receptor. Adults living in the SRS vicinity at the start of SRS operations in 1954 ate a constant annual quantity of each food product over the 39 years of the study. Adult females generally ate less food than did the adult males. The children ate different quantities of each food product depending on their age. After each child reached age 18, they ate each food product in annual quantities appropriate for an adult male.

Assumptions about food product contamination depended on the food product and scenario. If the food product was grown or produced locally (e.g., from local farms or dairies), then it was assumed that all was contaminated. If the food product was from a local store, then it was assumed that some (generally half) was obtained locally (and therefore contaminated) and the remainder was obtained from sources external to the SRS vicinity.

Radiation exposure from eating game animals taken near the SRS site was modeled by assuming that meat from all game animals could be represented as forms of beef (e.g., venison) or poultry (e.g., wild fowl). Members of Rural Family One and Two, the Delivery Person Family, and the Outdoors Person Family were assumed to eat game animal meat. The total quantities of beef and poultry that these members ate were the same as that eaten by comparable members of the other three scenarios. However, larger fractions of this meat were assumed to be locally produced for these four scenarios compared to the other three scenarios.

E.2.3 Scenario Exposure Time Assumptions

To perform the exposure assessments outlined in Section E.5, it is necessary to document the time spent by each family member performing each of their assumed activities. Each family member was assigned a time spent at home, at work (for the adult male and for the children after they became adults), at church, and while performing other activities including hunting, fishing, swimming, and boating. Times spent performing these activities were determined from Lockridge (1), the 1997 EPA "Exposure Factors Handbook" (5), and Hamby (6). Appendix Q includes a matrix showing the times performing each activity by each member of each family exposure scenario.

Except for the Migrant Worker Family, the total time spent by each family member performing all activities added to 8,760 hours each year (24 hours/day x 365 days/year). This reflects the conservative assumption that no family member was ever away from the SRS vicinity. The total time spent by each member of the Migrant Worker Family was only 4,380 hours/year, reflecting their presence in New Ellenton for only half of any year.

A distinction is made between hours spent indoors vs. hours spent outdoors because the information is used to help determine external radiation exposures from contaminated soil (Section E.5.1.2). For each exposure scenario, the split between indoor and outdoors hours changed for the two children as they grew from infant to adult; however, it was assumed to be constant for the two adults. This assumption was made to reduce modeling complexity despite the expectation that an infant and an Adult Female would have the same number of outside hours. But because each of the children were infants for only a single year, it was determined that adjusting the outside hours of the Adult Female to closely correspond to that of the children as they grew up was not warranted.

The hours spent indoors and outdoors were determined principally based on (1) the definition of the exposure pathways and (2) data from Lockridge (1) and EPA, 1997 (5). For some exposure pathways, the time spent indoors and outdoors was contained within the definition of a receptor's actions. For example, it was assumed that swimming, boating, or walking a river shoreline were all outdoor activities. When indoor and outdoor hours were not defined under the scenario specifications, assumptions about the split between indoor and outdoor hours were made as addressed below.

- Church. Except for the Migrant Worker Family, all members of all exposure scenarios spent 104 hours per year in church (52 weeks/year x 2 hours/week). All members of the Migrant Worker Family spent 52 hours per year in church. All hours in church were spent indoors.

- School. Except for the Migrant Worker Family, for all exposure scenarios, the school-aged and teenaged children all spent 1,260 hours per year in school (180 days/year x 7 hours/day). (The school-aged children attended grade school and the teenagers attended high school.) Of these 1,260 hours per year, 900 hours were spent indoors and 360 hours were spent outdoors [(5 hours indoors/day, 2 hours outdoors/day) x 180 days/year]. The school-aged and teenaged children of the Migrant Worker Family spent 630 hours per year in school (90 days/year x 7 hours/day). Of these 630 hours/year; 450 hours were spent indoors and 180 hours were spent outdoors [(5 hours indoors/day, 2 hours outdoors/day) x 90 days/year].

- Work. Except for the Migrant Worker Family, the Adult Male of all exposure scenarios spent 2,000 per year at work (40 hours/week x 50 weeks/year).[4] The Adult Male of the Migrant Worker Scenario spent 1,000 hours per year at work. The split between indoors and outdoors hours depended on the nature of the work. The Adult Males of Rural Family One, Rural Family Two, and Migrant Worker Family were farmers, spending one working hour per day indoors, and seven working hours per day outdoors. The Adult Males of the Urban/Suburban Family and Near River Family mainly worked within buildings, spending seven working hours per day indoors, and one working hour per day outdoors. The Adult Male of the Delivery Person Family worked 400 hours per year making deliveries to the SRS and the remaining 1,600 hours per year in Allendale. Of the annual 400 hours working onsite at the SRS, 200 hours were indoors and 200 hours were outdoors. At Allendale, the remaining annual 1,600 hours were divided into 1,350 hours indoors and 250 hours outdoors (1 hr/day for 250 days/year spent outdoors). The Adult Male of the Outdoors Person Family spent all of his 2,000 working hours at the SRS outside. Of these working hours, 260 hours/year were spent along the SRS shoreline (where he was exposed to radionuclides deposited from the Savannah River on the shoreline), and 260 hours/year were spent boating in the Savannah River. The exposures from these working activities were in addition to recreational shoreline and boating activities addressed below. Thus, the following are the annual working hours for the Adult Males of each exposure scenario:

  -- Rural Family One: 250 hours indoors, 1,750 hours outdoors.

  -- Rural Family Two: 250 hours indoors, 1,750 hours outdoors.

  -- Urban/Suburban Family: 1,750 hours indoors, 250 hours outdoors.

  -- Migrant Worker Family: 125 hours indoors, 875 hours outdoors.

  -- Delivery Person Family: Allendale – 1,350 hours indoors, 250 hours outdoors; SRS – 200 hours indoors, 200 hours outdoors.

  -- Outdoors Person Family: 2,000 hours outdoors, including 260 hours on the shoreline and 260 hours boating.

  -- Near River Family: 1,750 hours indoors, 250 hours outdoors.

  Note that all children of all exposure scenarios adopted the same work habits (and annual times spent indoors and outdoors) as did the Adult Male of the exposure scenario when each of the children reached age 18.

- Hunting and fishing. For all receptors, hunting and fishing were outside activities. Except for the Adult Male of the Outdoors Person Scenario, the time spent hunting and fishing was included with

[4] All two-week vacations from work were spent at home.

the residential outside hours (see below). For the Adult Male of the Outdoors Person Scenario, time spent outdoors hunting and fishing was included with his work hours. This assumption also applied to the two children of the Outdoors Person Scenario when they reached age 18 and began working on the SRS site.

- Recreational swimming, shoreline, and boating. Except for members of the Migrant Worker and Near River Family, members of all exposure scenarios (including all members of the Outdoors Person Scenario) spent 21 hours/year swimming and 85 hours/year along a river or creek shoreline. Members of the Migrant Worker Family swam for 11 hours per year and spent 43 hours along a shoreline. Members of the Near River Family swam for 91 hours per year and spent 365 hours per year along a shoreline. (See Section E.5.1.4 for the derivation of the swimming hours, and Section E.5.1.3 for the derivation of shoreline hours.)

  Members of Rural Family One, Rural Family Two, and the Migrant Worker Family did no boating. Members of the Urban/Suburban Family, Delivery Person Family, and Outdoors Person Family recreationally boated for 96 hours per year, while members of the Near River Family boated for 192 hours per year. (See Section E.5.1.5 for the derivation of the boating hours.) All swimming, shoreline, and boating hours were spent outside.

- Home. Times spent at home were determined for each member of each exposure scenario by adding all hours spent while at church, work, and school, and while swimming, boating, and spending time along a shoreline. These summed hours were subtracted from the total hours spent in the SRS vicinity each year (generally 8,760 hours). The remaining hours were distributed between indoors and outdoors hours using data from the EPA "Exposure Factors Handbook" (5) as summarized in Table E-7. This table summarizes data from the EPA "Exposure Factors Handbook" (5) that presents mean values for the times spent indoors and outdoors for various age and gender categories (first column). Table E-7 also shows the corresponding grouping of age and gender categories that were modeled for this study (second column).

Table E-7 Time Spent Outdoors – EPA 1997 Age and Gender Categories and Rate Data, and Corresponding Modeled Age and Gender Categories and Calculated Rates

EPA Age and Gender Categories	Corresponding Modeled Age and Gender Categories	Time Spent Outdoors (minutes/ day)	Calculated Time Spent Outdoors (hours/year)	Time Spent Indoors (minutes/day)	Calculated Time Spent Indoors (hours/year)
1 – 4	Infant (<1)	196	1,190	1,212	7,371
1 – 4	Pre-School (1-7)	196	1,190	1,212	7,371
5 – 11	Child (<7 – 12)	188	1,141	1,005	6,115
12 – 17	Teenager (<12 – 17)	135	823	970	5,898
18 – 64	Adult Male (>17)	144	877	948	5,766
18 – 64	Adult Female (>17)	144	877	948	5,766

Source: Table 15-132 (mean values) from EPA, 1997 (5).

As an example, the Infant of Rural Family One annually spent 104 hours in church, 21 hours swimming, and 85 hours along a shoreline. This leaves (8,760 – 104 – 21 – 85 = 8,550 hours. Using Table 3-7, the hours spent indoors were calculated as 8,550 x 7371/(1190 + 7371) = 7,362 hours. The hours spent outdoors were calculated as 8,850 x 1190/(1190 + 7371) = 1,188 hours.

Hours for the remaining members of the exposure scenarios were calculated in a similar manner and are listed in Appendix Q.

E.3 Overview of Final Exposure Scenarios

The seven scenarios and the assumed home locations for each of the hypothetical families making up these scenarios are described in detail in the following sections.

E.3.1 Rural Family One

This hypothetical family lived in Girard, Georgia. All family members spent much of their work, home activities, and recreation time outdoors. The Adult Male was a farmer, and the Adult Female worked at home. The family hunted, fished, and swam in the Girard area and in the nearby area of Briar Creek. The family did no boating. The children stayed at home until they reached school age; then they attended grade schools in Girard and high school in Waynesboro, Georgia. When not attending school, the children remained in the Girard area. When the children grew to adulthood, they became farmers and fished, hunted, and engaged in recreational activities in the Girard area. All family members remained permanently in the Girard area. Figure E-4 shows the exposure locations of Rural Family One.

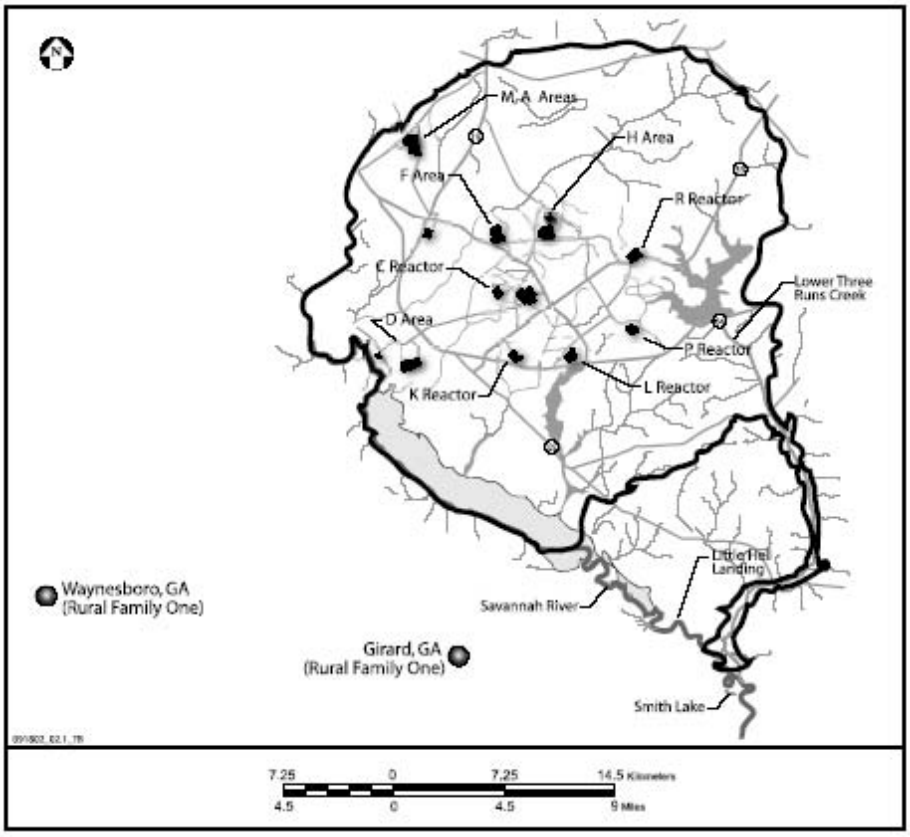


Figure E-4 Exposure Locations of Rural Family One

All the family's milk and eggs came from cows and hens located in Girard. The fish eaten by the family was caught in Briar Creek or other nearby locations. Because Briar Creek is not located hydrologically downstream from the SRS, none of the fish consumed by the family was affected by SRS release of radionuclides to surface water. During the 1950's, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remainder came from other sources such as stores in Girard. Half of this remaining food was locally grown or produced. Beginning in 1960, only 25 percent of their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75 percent came from sources such as stores. Half of this remaining food was grown or produced in Girard, and half came from sources outside the SRS. It was assumed that all of the locally grown grain eaten by the family was corn.[5] Drinking water and water used to irrigate the food grown and eaten by the family came from local ground water or surface water sources that were unaffected by SRS releases.

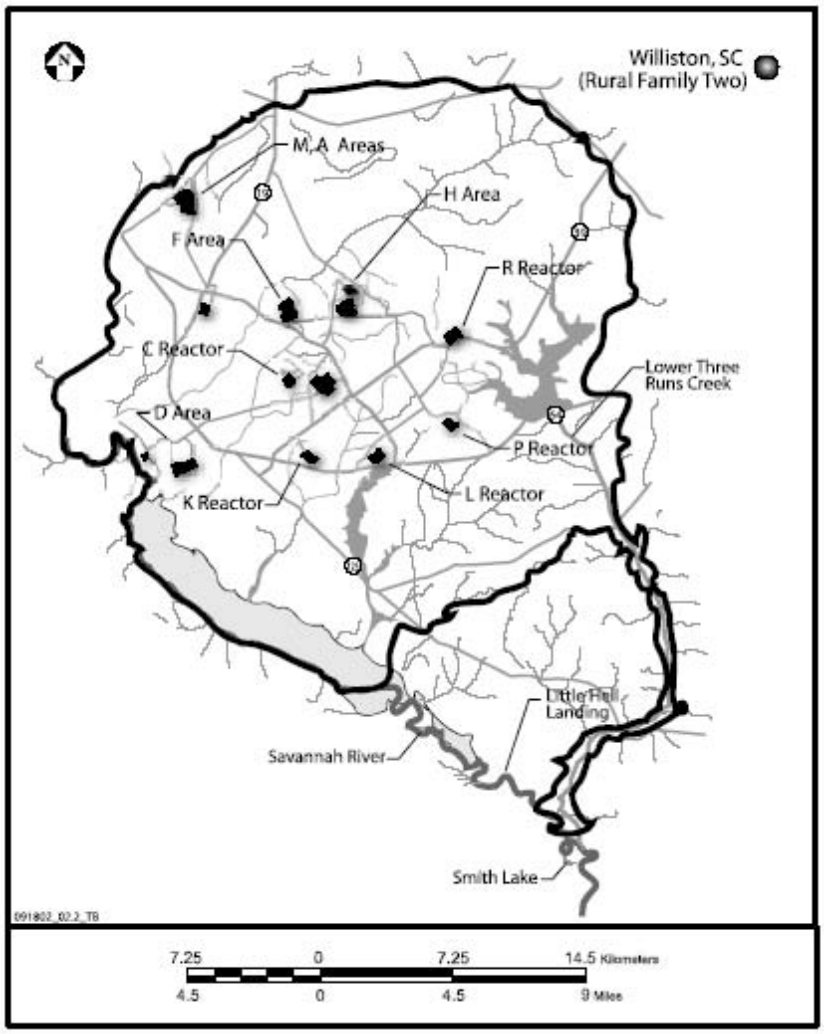


Figure E-5 Exposure Location of Rural Family Two

E.3.2 Rural Family Two

Rural Family Two was a hypothetical family substantially similar to Rural Family One, except that the family lived and spent all their time in Williston, South Carolina. Figure E-5 shows the exposure location of Rural Family Two.

All family members spent much of their work, home activities, and recreation time outdoors. The adult male was a farmer, and the adult female worked at home. The family hunted, fished, and swam in the Williston area. Like Rural Family One, this family did no boating. The children stayed at home until they reached school age, and then they attended schools in Williston. When not attending school, the children

[5] This assumption was made for all receptors and scenarios. Individuals in the SRS vicinity would have consumed grain products such as breads, pasta, or flours; however, most of these grain products were likely grown or produced out of the SRS vicinity and therefore were not contaminated by SRS operations. But it is plausible to assume that individuals in the SRS vicinity consume locally grown corn. Such consumption could occur for those persons living in a suburban as well as a rural environment. Therefore, corn was treated as a grain for purposes of this study and as a grain surrogate for purposes of the assessments.

remained in the Williston area. When the children grew to adulthood, they became farmers. The family always lived, engaged in recreational activities, and worked in and around the Williston area.

All of the family's milk and eggs came from cows and hens located in Williston (on the family farm or nearby). All of the fish eaten by the family were caught in streams or ponds in or near Williston. Because these streams and ponds are not hydrologically downstream from the SRS, none of the fish eaten by the family was affected by SRS releases of radioactive material to surface water.

During the 1950's, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remaining half came from other sources such as stores in Williston. Half of this remaining food (i.e., food not grown or raised on the family farm) was grown or produced in Williston and the other half came from outside the SRS area. Beginning in 1960, only 25 percent of their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75 percent was obtained from other sources such as stores in Williston. Half of this remaining food was locally grown or produced, and half came from outside the SRS area.

All locally grown grain eaten by the family was corn. Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases

E.3.3 Urban/Suburban Family

This hypothetical family lived in Augusta, Georgia, and all family members were present there for most activities including school and church. The Adult Male worked onsite at the SRS for the duration of the study period (39 years). The children worked onsite at the SRS beginning in 1973 for the Child Born in 1955 and 1982 for the Child Born in 1964. All family members swam, boated, and fished in the Savannah River flowing through the Augusta area, a location well upstream of any point of radionuclide discharge to surface water from the SRS. Figure E-6 shows the exposure locations of the Urban/Suburban Family.

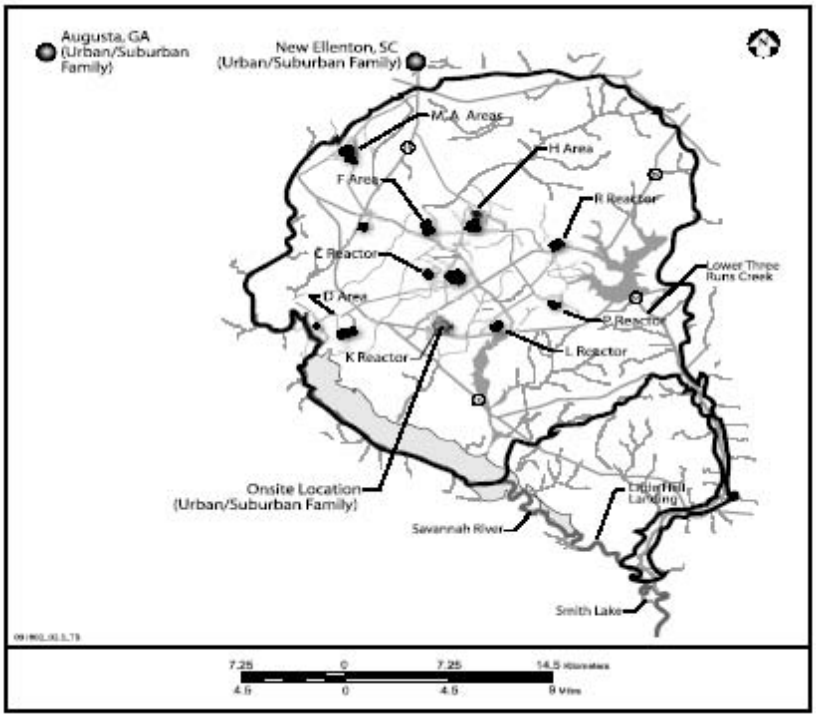


Figure E-6 Exposure Locations of Urban/Suburban Family

Half the family's milk came from cows in the Augusta area and half from cows in the New Ellenton area. All eggs came from hens located in the Augusta area. Half of their beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in the Augusta area, and half came from unaffected nonlocal sources. All locally grown grain eaten by the family was corn. Fish came from sources unaffected by liquid releases from the SRS (e.g., from the nearby Savannah River). Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases

E.3.4 Migrant Worker Family

All family members spent much of their work, home activities, and recreation time outdoors in New Ellenton, South Carolina. Figure E-7 shows the exposure location of the Migrant Worker Family. Because the Adult Male and Adult Female worked as migrant farm workers, the family lived in New Ellenton for only half of any year. While living in New Ellenton, the family participated in hunting, trapping, and other outdoor activities. The family did no boating but did participate in other water sports such as fishing and swimming in local pools, ponds, and creeks. The children stayed at home until they reached school age and attended schools in New Ellenton. When the children grew to adulthood, they became migrant farmers spending half the year in New Ellenton and half the year away from the SRS vicinity.

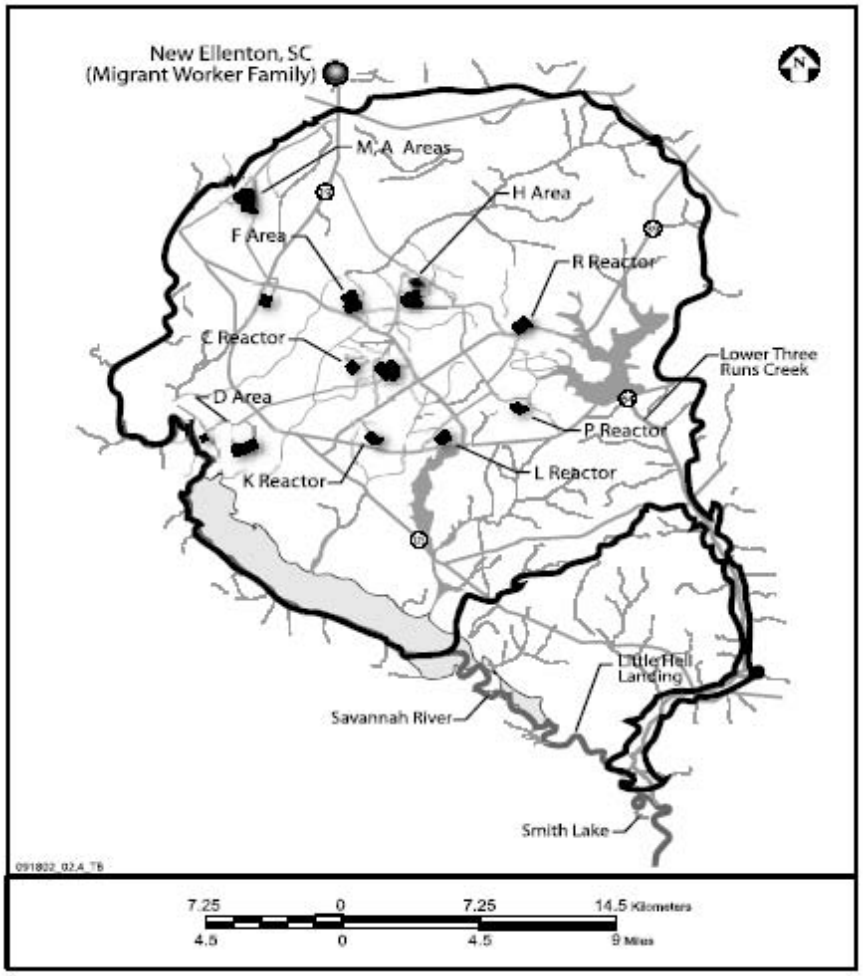


Figure E-7 Exposure Location of Migrant Worker Family

During the six months of each year that the family lived in New Ellenton, all of their milk and eggs were produced or collected in or near New Ellenton. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in the New Ellenton area and half came from sources outside the SRS vicinity. All of their corn was grown in the New Ellenton area. Because ponds and creeks in the vicinity of New Ellenton are not hydrologically downstream from the SRS, none of the fish eaten by the family was affected by SRS releases. Drinking water and water used to irrigate foods eaten by the family came from ground water or surface water sources unaffected by SRS liquid releases.

E.3.5 Delivery Person Family

This hypothetical family lived in Barnwell, South Carolina, where the children attended grade and high school. Because the Adult Male worked as a delivery driver for a bottling plant located in Allendale, South Carolina, he spent portions of his time in Allendale and portions onsite at the SRS where he made periodic deliveries. (When the children reached 18, they lived in Barnwell and became delivery drivers like the Adult Male.) All family members attended religious services in Martin, South Carolina, for two hours each week. All family members swam, fished, and spent time along the shoreline at Lower Three Runs Creek near Martin. The adult male hunted for deer and fowl in the Martin vicinity. Figure E-8 shows the exposure locations of the Delivery Person Family.

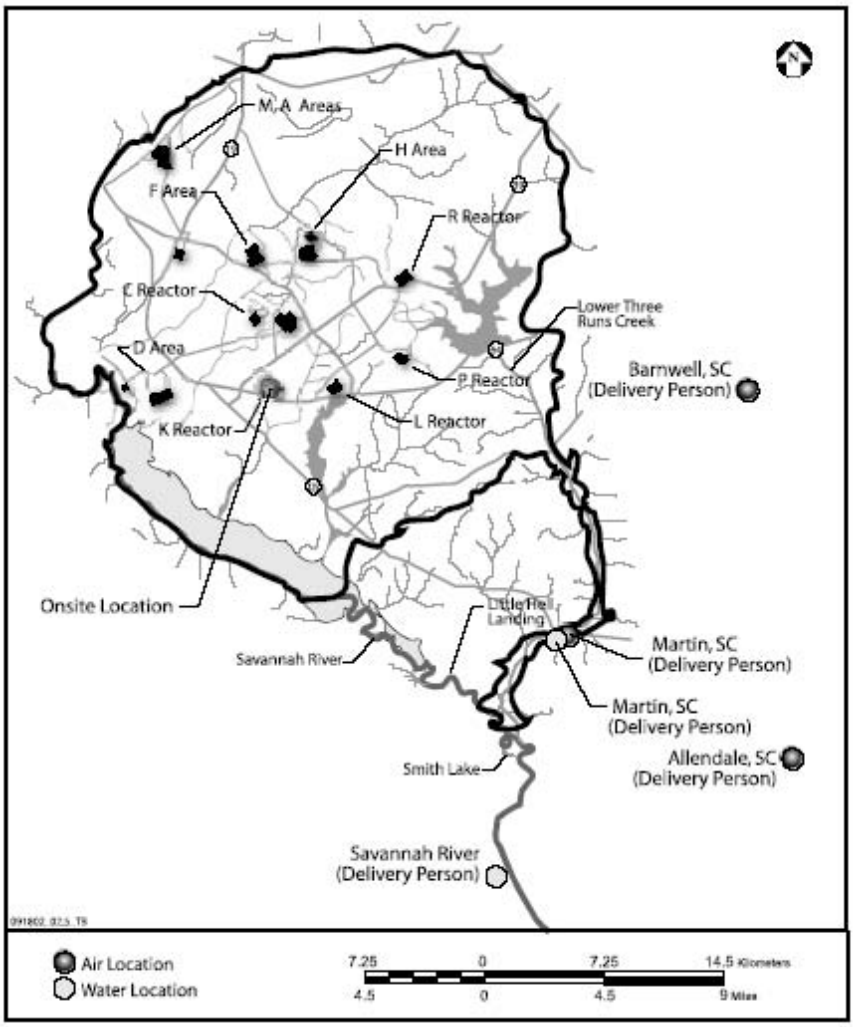


Figure E-8 Exposure Locations of Delivery Person Family

The family boated on the Savannah River using the boat ramp at Little Hell Landing, which is upstream of the confluence of the Savannah River with Lower Three Runs Creek. The family then moved the boat to the Smith Lake area for fishing and activities along the Savannah River shoreline. Smith Lake is located just below the confluence of the Savannah River with Lower Three Runs Creek. The family did not swim in the Savannah River.

Half of the family's milk and eggs came from cows and hens in the Barnwell area and half came from cows and hens in the Martin area. In addition, half the family's beef and poultry came from Barnwell and half from Martin. Half of the beef and poultry from Barnwell was actually produced in the Barnwell area, and half was acquired from sources away from the SRS area. Of the beef and poultry from Martin, 25 percent consisted of meat from hunting deer and wild fowl. That is, 25 percent of the beef from Martin consisted of locally hunted venison while 25 percent of the poultry from Martin consisted of locally hunted wild fowl. Of the remaining 75 percent of the beef and poultry from Martin, half was produced in the Martin area and half was acquired (e.g., by stores) from sources well away from the SRS.

Half the leafy vegetables, root vegetables, and fruit came from Barnwell, and half came from Martin. Half of the produce obtained in the Barnwell area was grown in areas away from the SRS vicinity and half of the produce obtained in the Martin area was grown in areas away from the SRS vicinity. Half of the corn eaten by the family was grown in Barnwell and half in Martin.

Half of the fish eaten by the family was caught in Lower Three Runs Creek at Martin and half was caught in the Savannah River.

E.3.6 Outdoors Person Family

This hypothetical family lived in Jackson, South Carolina, and all family members were present there for most activities including school and religious services. When the children grew to adulthood, they continued to live in Jackson. Family members were not present in Jackson during employment for the Adult Male and employment for the children when they each reached age 18. The Adult Male worked onsite at the SRS as a hunter, as did the children when they grew up. During the time the Adult Male spent onsite at the SRS annually, he took game animals in the form of deer and birds, and caught fish from the Savannah River. His job required him to spend 260 hours per year along on the Savannah River shoreline as well as 260 hours per the year boating on the Savannah River. Figure E-9 shows the exposure locations of the Outdoors Person Family.

All family members (including the Adult Male) engaged in recreational swimming in the Savannah River and spent time along the Savannah River shoreline near the Jackson boat ramp (upstream of sources of SRS radionuclide release to the Savannah River). All family members boated in the Savannah River downstream of the SRS.[6]

All milk and eggs came from cows and hens located in Jackson. Half the leafy and root vegetables and fruit were grown in Jackson, and half came from sources away from the SRS area. All of the family corn was grown in Jackson.

Three-quarters of the family's beef and poultry consisted of venison and wild fowl that was hunted by the Adult Male on the SRS site. Their remaining beef and poultry came from other sources such as stores. Of this, half was produced in Jackson and half came from sources away from the SRS area. All fish taken from the Savannah River contained radionuclides from SRS operations.

[6] After putting the boat in the water at the Jackson boat ramp, the family moved the boat to an area downstream of the confluence of the Savannah River with Lower Three Runs Creek. Therefore, the Adult Male received radiation exposures while recreationally boating as well as while working at the SRS.

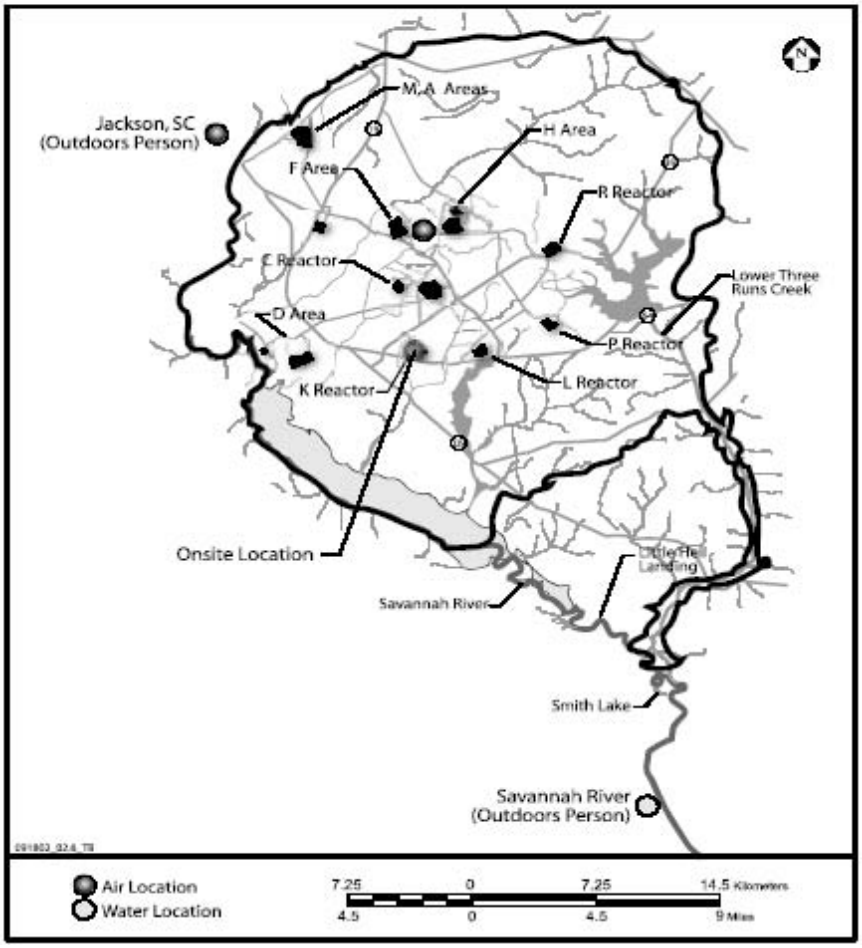


Figure E-9 Exposure Locations of Outdoors Person Family

E.3.7 Near River Family

This hypothetical family lived in Martin, South Carolina. All members spent much of their work, home activities, and recreation time outdoors. The family lived, worked, and went to school and church in Martin, and participated in outdoor activities such as hunting, fishing, and boating. Figure 3-10 shows the exposure locations for the Near River Family.

This family spent twice as much time boating (in the Savannah River) as did other families. Each family member spent an average of an hour per day of each year on the Savannah River shoreline and an average of an hour a day swimming during the summer in the Savannah River. When the children grew up, they continued to live in Martin. The family's milk and eggs all came from cows and hens located in Martin. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in Martin and half came from sources outside the SRS vicinity. All of the corn eaten by the family was grown in Martin. All of the fish eaten by the family was caught in the Savannah River below its confluence with Lower Three Runs Creek. Drinking water and any irrigation used to produce the food eaten by the family came from sources unaffected by SRS releases.

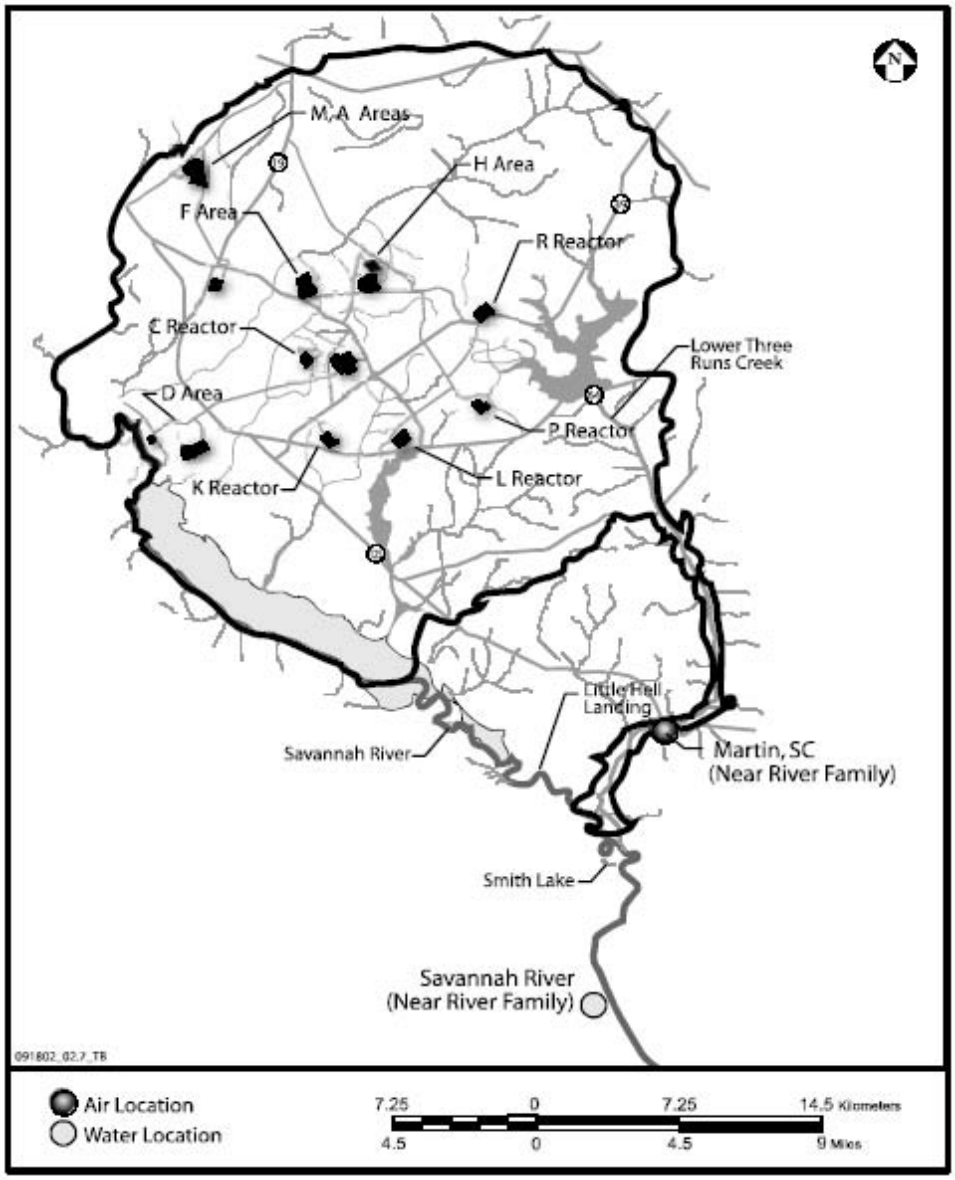


Figure E-10 Exposure Locations for Near River Family

E.4 Linkage of GENII Variables to Exposure and Adjustment Factors

Because of the size and complexity of the computational requirements, radiological assessment calculations were performed using the GENII code assuming "unit" quantities for receptor-specific usage factors such as food consumption rates. The output from the GENII code was then modified in the post-processor (software specially created for this Phase III study) to arrive at the proper doses and risks as a function of year for each receptor. These adjustments were performed using a series of receptor- and pathway-specific *exposure* and *adjustment factors* that were multiplied by the GENII output. Mathematically, the use of the exposure and adjustment factors to calculate annual dose may be envisioned as follows:

$$D_{PPrp} = D_{Grp}\ EF_{rp}\ AF_{rp}$$

Where D_{PPrp} = The dose (Sv) calculated from the post-processor for each receptor and for each pathway.

D_{Grp} = The dose (Sv) calculated from GENII for each receptor and for each pathway, assuming unit quantities for usage factors.

EF_{rp} = A receptor- and pathway-specific exposure factor.

AF_{rp} = A receptor- and pathway-specific adjustment factor.

A similar relationship may be envisioned to calculate the use of exposure and adjustment factors to link risks calculated from GENII runs and those calculated using the post-processor.

Exposure and adjustment factors are discussed in Sections E.4.1 and E.4.2, respectively.

E.4.1 Creation of Exposure Factors

An *exposure factor* was created for each pathway by multiplication of two or more GENII variables used to describe receptor-specific usage factors. The creation of an exposure factor may be illustrated using the example provided below.

The mathematical relationship used in the GENII code to calculate radiation exposures received by a receptor from inhaling air containing radionuclides is presented in the GENII Software Design Document (Napier, 2002) and summarized in Section D.3.1 of Appendix D. The total amount of radioactive material inhaled over a period of time (in this case one year) is given as follows (7):

$$I_{aaig}(T) = C_{aag} \; U_{aag} \; T_{aag} \; ED_{aag}$$

Where $I_{aaig}(T)$ = total intake of radionuclide i from air inhalation over the period T at air usage location a for individuals in age group g (Bq)

C_{aag} = average air concentration for radionuclide i at air usage location a over time period T (Bq/m^3)

U_{aag} = inhalation rate at air usage location a for individuals in age group g (m^3/d)

T_{aag} = annual intake factor giving days per year that air inhalation occurs at air usage location a for individuals in age group g (d/y)

ED_{aag} = exposure duration for the air inhalation pathway at air usage location a for individuals in age group g (y).

The total intake of radionuclide i, or $I_{aaig}(T)$, was then input to the dose and risk computational module described in Section D.4, and doses and risks were calculated for each receptor for each year of SRS operation. To calculate $I_{aaig}(T)$, C_{aag}, U_{aag}, T_{aag}, and ED_{aag} had to be numerically specified. The exposure duration (ED_{aag}) was one year in all cases. The average concentration (C_{aag}) was determined for each year and receptor location using the Gaussian plume air dispersion model described in Section D.2.

The remaining parameters, U_{aag} and T_{aag}, had to be input to GENII for each code run using the FRAMES interface. The GENII variable names for these parameters are UINH and TINH, respectively (7). Under

normal circumstances, assuming year-round presence of an adult male at the location of interest, one would have input a value for UNIH of 15.2 m^3/ day, which is the average daily breathing rate of an adult male according to EPA data in its 1997 Exposure Factors Handbook (5). One would have also input 365 days per year for TINH. (The product of UINH and TINH is 15.2 x 365 = 5,548 m^3/year.)

But to address computational needs as discussed above, GENII was run (determining values for $I_{aaig}(T)$) assuming that UINH and TINH both equaled unity (i.e., UINH = TINH = 1). After completing the GENII computer runs, the output from GENII was fed into the postprocessor, and the GENII calculations were adjusted using appropriate exposure factors. For this example, the exposure factor was calculated as the product of the above example values for UINH and TINH. For an adult male, the exposure factor would have been 5,548 m^3/year. The exposure factor for another person (say, an infant or an adult female) would have been different because that person would have had a different average daily breathing rate.

Similar procedures were performed for each of the pathways. Table E-8 lists, for each pathway, the GENII variables that were input as unit values to the GENII calculations. This table also identifies the computational parameter that the GENII variable represents, as well as that section in Appendix D where the use of the parameter in the mathematical expressions codified in GENII can be found.

Table E-8 GENII Variables Input as Unit Values and Adjusted in Post-Processor

Trans-port	Transfer Process or Activity	Exposure Pathway (Section)	Param-eter	GENII Variable Name and Description
Air	Plume Immersion	External Exposure (Section D.3.2.1)	U_{eag} T_{eag}	UEXAIR – Daily exposure factor (h/d) TEXAIR – Annual exposure factor (d/y)
Air	Ground Contamination	External Exposure (Section D.3.2.2)	SH_h SH_o U_{esg} T_{esg} FT_{hg} FT_{og}	SHIN – Indoor shielding factor (dimensionless)* SHOUT – Outdoor shielding factor (dimensionless)* UEXGRD – Daily external exposure time (h/d) TEXGRD – Yearly external exposure time (d/y) FTIN – Fraction of time indoors (dimensionless)* FTOUT – Fraction of time outdoors (dimensionless)*
Surface Water	Concentration in Sediment	External Exposure (Section D.3.2.3)	FE_{srg} TE_{srg} T_{srg}	EVSHOR – Frequency of shoreline use (event/d) TESHOR – Duration of shoreline use (h/event) TSHOR – Shoreline days (d/y)
Surface Water	Recreational Swimming	External Exposure (Section D.3.2.4)	FE_{wrg} TE_{wrg} T_{wrg}	EVSWIM – Frequency of swimming (event/d) TESWIM – Duration of swimming event (h/event) TSWIM – Swimming days (d/y)
Surface Water	Recreational Boating	External Exposure (Section D.3.2.5)	FE_{brg} TE_{brg} T_{brg}	EVBOAT – Frequency of boating event (event/d) TEBOAT – Duration of boating event (h/event) TBOAT – Boating days (d/y)
Air	Food Crop Concentration	Leafy Veg. Ingest. (Section D.3.3.1)	U_{csg} T_{csg}	UCRP 1 – Leafy vegetable consumption rate (kg/y) TCRP 1 – Leafy vegetable consumption period (d/y)

Trans-port	Transfer Process or Activity	Exposure Pathway (Section)	Param-eter	GENII Variable Name and Description
		Root Veg. Ingest. (Section D.3.3.1)	U_{csg} T_{csg}	UCRP 2 – Root vegetable consumption rate (kg/y) TCRP 2 – Root vegetable consumption period (d/y)
		Fruit Ingestion (Section D.3.3.1)	U_{csg} T_{csg}	UCRP 3 – Fruit consumption rate (kg/y) TCRP 3 – Fruit consumption period (d/y)
		Grain Ingestion (Section D.3.3.1)	U_{csg} T_{csg}	UCRP 4 – Grain consumption rate (kg/y) TCRP 4 – Grain consumption period (d/y)
Air	Animal Product Concentration	Beef Ingestion (Section D.3.3.2)	U_{asg} T_{asg}	UNAM 1 – Beef consumption rate (kg/y) TANM 1 – Beef consumption period (d/y)
		Poultry Ingestion (Section D.3.3.2)	U_{asg} T_{asg}	UNAM 2 – Poultry consumption rate (kg/y) TANM 2 – Poultry consumption period (d/y)
		Milk Ingestion (Section D.3.3.2)	U_{asg} T_{asg}	UNAM 3 – Milk consumption rate (kg/y) TANM 3 – Milk consumption period (d/y)
		Egg Ingestion (Section D.3.3.2)	U_{asg} T_{asg}	UNAM 4 – Egg consumption rate (kg/y) TANM 4 – Egg consumption period (d/y)
Surface Water	Aquatic Accumulation	Fish Ingestion (Section D.3.3.3)	U_{fwg} T_{fwg}	UAQU 1 – Fish consumption rate (kg/y) TAQU 1 – Fish consumption period (d/y)
Air	Ground Contamination	Soil Ingestion (Section D.3.3.4)	U_{dsg} T_{dsg}	USOIL – Daily soil consumption rate (mg/d) TSOIL – Days of ingestion in a year (d/y)
Surface Water	Recreational Swimming	Ingestion (Section D.3.3.5)	FE_{wrg} TE_{wrg} T_{wrg} U_{wwg}	EVSWIM – Frequency of swimming (event/d) TESWIM – Duration of swimming event (h/event) TSWIM – Swimming days (d/y) USWIM – Ingestion rate while swimming (L/h)
Air	Contaminated Plume	Inhalation (Section D.3.4.1)	U_{aag} T_{aag}	UINH – Air inhalation rate (m^3/d) TINH – Intake factor (d/y)
Air	Ground Contamination	Inhalation (Section D.3.4.2)	U_{sag} T_{sag} F_{sag}	UINHR – Resuspended soil inhalation rate (m^3/d) TINHR – Resuspended soil inhalation period (d/y) FRINHR – Fraction of day resuspended inhalation occurs

* SHIN and FTIN were both set equal to zero. SHOUT and FTOUT were both set equal to unity (see Section E.5.1.2).
Source: Napier, 2002 (7).

The exposure factors that were used in the post-processor to modify the GENII output from the calculations performed assuming unit quantities for these GENII variables are presented for each pathway in Section E.5.

E.4.2 Creation of Adjustment Factors

Adjustment factors were created as needed for certain pathways and receptors. The adjustment factors were created when the use of a single factor to modify GENII exposures using the post-processor was insufficient for computational needs. Therefore, an adjustment factor supplements an exposure factor.

Adjustment factors were most commonly used to correct for the consumption of foods that were grown or produced outside the vicinity of the SRS and therefore could not be contaminated by SRS operations. GENII does not include any direct mechanism to address this situation except for reducing the amounts of certain foods consumed during the year. This approach was not taken, however, because it would have been more difficult to compare assumptions taken for Phase III with those for other studies. It was clearer to separate the two considerations: (1) food quantities consumed and (2) the fraction of the consumed food that was contaminated. Each consideration could then be considered separately, and compared to other studies separately.

Section E.5 addresses the derivation of adjustment factors for each receptor and pathway.

E.5 Exposure and Adjustment Factors for Each Exposure Pathway

Exposure and adjustment factors are presented for each exposure pathway in the same order as the pathways summarized in Table E-8. That is, they are organized by exposure route:

- Section E.5.1: External Exposure Route
  - E.5.1.1 Immersion in a Plume of Contaminated Air
  - E.5.1.2 Exposure to Contaminated Soil
  - E.5.1.3 Exposure to a Contaminated Shoreline
  - E.5.1.4 Exposure to Contaminated Water While Swimming
  - E.5.1.5 Exposure to Contaminated Water While Boating
- Section E.5.2: Ingestion Exposure Route
  - E.5.2.1 Ingestion of Food Crops
  - E.5.2.2 Ingestion of Animals and Animal Products
  - E.5.2.3 Aquatic Food Ingestion
  - E.5.2.4 Inadvertent Soil Consumption
  - E.5.2.5 Inadvertent Ingestion of Water While Swimming
- Section E.5.3: Inhalation Exposure Route
  - E.5.3.1 Inhalation of a Contaminated Plume of Air
  - E.5.3.2 Inhalation of Resuspended Soil

E.5.1 External Radiation Exposure Route

E.5.1.1 Immersion in a Plume of Contaminated Air

This exposure pathway accounts for external radiation exposure from immersion in a plume of contaminated air. The following are GENII variables for this exposure pathway:

- UEXAIR: Daily plume immersion exposure time (hours/day).
- TEXAIR: Yearly plume immersion exposure time (days/year).

The combination of these two variables resulted in an exposure factor in units of hours/year. It was assumed that each receptor spent 8,760 hours out of the year in the SRS vicinity at one or more exposure locations (i.e., 365 days/year x 24 hours/day = 8,760 hours/year). Similar to that for inhalation of

contaminated air (Section E.5.3.1), no adjustments in exposure factors were assumed for receptors being indoors for a portion of each day. That is, indoor air concentrations were equal to outdoor air concentrations. Because indoor air concentrations would likely contain lower concentrations of airborne radioactivity, this assumption contributed to conservative (i.e., increased) estimates of dose and risk.

The exposure factors for the teenagers of Rural Family One were split between Girard and Waynesboro, where the teenagers attended high school. Assuming a total of 1,260 hours per year spent in high school, out of a total 8,760 hours in a year, the teenagers' exposure factors were 1,260 hours/year for the time spent in high school, and 7,500 hours/year for the remaining time spent in Girard. For the remaining family members, exposure factors were calculated assuming that they spent the entire year in Girard.

The split in exposure factors between Girard and Waynesboro for the teenagers was applied for the entire time they were teenagers (i.e., for the six years comprising 1967 through 1972 for the Child Born in 1955 and the six years comprising 1976 through 1981 for the Child Born in 1964). Thus, these teenagers spent six years partially in the Waynesboro area rather than four.[7]

Exposure factors for the Adult Male of the Urban/Suburban Family were split between Augusta and his job onsite at the SRS. The adult male exposure factors were 2,000 hours/year for the time spent at work and 6,760 hour/year for the remaining time spent in Augusta. Exposure factors for the Adult Female of this family were calculated assuming that she spent all her time in Augusta. The two children spent all their time in Augusta until they each age 18, and then they each worked onsite for 2,000 hours per year.

For the Delivery Person Family, the Adult Male worked in Allendale (1,600 hours/year) and also occasionally came onsite at the SRS for deliveries (400 hours/year). The remainder of his time was spent between Barnwell, where he lived with his family, and Martin, where he and his family recreated and attended church.

For the Outdoors Person Family, exposure factors for the adult male were split between Jackson and his job onsite at the SRS. Exposure factors for the Adult Female of this family were calculated assuming that she spent all her time in Jackson. The two children were assumed to spend all their time in Jackson until they each reached age 18, and then they each worked onsite for 2,000 hours per year.

Exposure factors for all members of the Near River Family were calculated assuming that each member spent all their time in Martin. The exposure factors for the members of the Migrant Worker Family were calculated assuming that each member spent all their time in New Ellenton, and that they were only in the SRS vicinity for half of any year.

Table E-9 lists the calculated exposure factors for Rural Family One, and Table E-10 lists the calculated exposure factors for all other exposure scenarios. While the children were teenagers, each spent six years in the Waynesboro area. For the remaining years, they stayed in Girard.

Adjustment factors were assumed to be unity for all receptors.

[7] This was assumed to reduce the complexity of the computational procedures.

Table E-9 Exposure Factors (hours/year) for Air Immersion Pathway for Rural Family One

Individual	Girard	Waynesboro
Adult M	8,760	0
Adult F	8,760	0
Child Born in 1955	7,500 for 1967-72; 8,760 for other years	1,260 for 1967-72; 0 for other years
Child Born in 1964	7,500 for 1976-81; 8,760 for other years	1,260 for 1976-81; 0 for other years

Table E-10 Exposure Factors (hours/year) for Air Immersion Pathway for Remaining Scenarios

Individual	Rural Family Two	Urban/Suburban Family		Delivery Family		
	Williston	Augusta	Onsite SRS	Martin	Onsite SRS	Allendale
Adult Male	8,760	6,760	2,000	306	400	1,600
Adult Female	8,760	8,760	0	306	0	0
Child Born in 1955:						
Thru 1972	8,760	8,760	0	306	0	0
Starting 1973	8,760	6,760	2,000	306	400	1,600
Child Born in 1964:						
Thru 1981	8,760	8,760	0	306	0	0
Starting 1982	8,760	6,760	2,000	306	400	1,600

Individual	Delivery Family (continued)	Outdoors Person Family		Near River Family	Migrant Worker Family
	Barnwell	Onsite SRS	Jackson	Martin	New Ellenton
Adult Male	6,454	2,000	6,760	8,760	4,380
Adult Female	8,454	0	8,760	8,760	4,380
Child Born in 1955:					
Thru 1972	8,454	0	8,760	8,760	4,380
Starting 1973	6,454	2,000	6,760	8,760	4,380
Child Born in 1964:					
Thru 1981	8,454	0	8,760	8,760	4,360
Starting 1982	6,454	2,000	6,760	8,760	4,380

E.5.1.2 Exposure to Contaminated Soil

This exposure pathway accounts for external radiation exposure resulting from standing on the ground at a specified exposure location contaminated by the deposition of radionuclides from the air. Exposures may occur either indoors or outdoors. The following are GENII variables for this exposure pathway:

- UEXGRD (U_{esg}): Daily external ground exposure time (hours/day).
- TEXGRD (T_{esg}): Yearly external ground exposure time (days/year).
- SHIN (SH_h): Indoor shielding factor (unitless).
- SHOU (SH_o): Outdoor shielding factor (unitless).
- FTIN (FT_{hg}): Fraction of time spent indoors (unitless).
- FTOUT (FT_{og}): Fraction of time spent outdoors (unitless).

For each exposure location, exposure and adjustment factors were calculated as follows:

$$\text{Exposure Factor} = U_{esg}\, T_{esg} \quad \text{(hours/year)}$$

$$\text{Adjustment Factor} = [(SH_h\ FT_{hg}) + (SH_o\ FT_{og})] \quad \text{(units are dimensionless)}$$

Exposure factors represented the total hours spent out of the year by each receptor at each location where the receptor may have been exposed. The amount of time that receptors spent at each location exposed to external radiation from contaminated ground surfaces was similar, but not equal, to the amount of time that the receptors spent at those locations exposed to external radiation from immersion in a plume of contaminated air. External radiation exposures from surface-contaminated soil did not occur when the receptor was either swimming or boating. A matrix by which exposure factors were determined for each scenario and receptor in accordance with these considerations is presented in Appendix Q. Table E-11 summarizes these exposure factors for Rural Family One, and Table E-12 summarizes the exposure factors for the remaining scenarios.

To determine adjustment factors, because structures provide shielding against ionizing radiation, the fraction of a year that each receptor spent inside and outside had to be determined. That is, values had to be determined for FT_{hg} and FT_{og} , where $FT_{hg} + FT_{og} = 1$.

Appendix Q provides a matrix that lists the hours spent indoors and outdoors for each receptor and exposure location. This matrix also provides the indoor and outdoor fractions calculated from these hours as well as the total hours spent "out of the water" (total hours out of the year excluding swimming and boating times). The following example illustrates the calculation of indoors and outdoors fractions.

The infant for Rural Family One was exposed to ground contamination at Girard for 8,739 hours out of the year (8,760 total hours in a year – 21 hours swimming minus – hours boating = 8,739 hours). These 8,739 hours were distributed as listed in Table E-13.

The fraction of the time spent indoors was 7,466/8,739 = 0.85. The fraction of the time spent outdoors was 1,273/8,739 = 0.15.

All church hours were spent indoors. To determine the hours spent indoors and outdoors while at home, the total time spent at home was distributed between indoor and outdoor hours using information from Table E-12. In this case, the infant spent 8,550 hours at home (8,760 hours/yr – 85 hours at the shore – 21 hours swimming – 104 hours at church = 8,550 hours/year at home). Inside hours were taken to be 8,550 x 1190 / (1190 + 7371) = 1188 hours. Outside hours were taken to be 8,550 x 7371 / (1190 + 7371) = 7362 hours.

Table E-11 Exposure Factors (hours/year) for Ground Contamination External Exposure Pathway for Rural Family One

Individual	Girard	Waynesboro
Adult M	8,739	0
Adult F	8,739	0
Child Born in 1955	7,479 for 1967-72;* 8,739 for other years	1,260 for 1967-72;* 0 for other years
Child Born in 1964	7,479 for 1976-81;* 8,739 for other years	1,260 for 1976-81;* 0 for other years

*****During the indicated years (1969-1972 for the Child Born in 1955 and 1978-81 for the Child Born in 1964), the children born in 1955 and 1964 are classed as teenagers.

Table E-12 Exposure Factors (hours/year) for Ground Contamination External Exposure Pathway for Remaining Scenarios

Individual	Rural Family Two	Urban/Suburban Family		Delivery Family		
	Williston	Augusta	Onsite SRS	Martin	Onsite SRS	Allendale
Adult M	8,739	6,643	2,000	189	400	1,600
Adult F	8,739	8,643	0	189	0	0
Child Born in 1955:						
Thru 1972	8,739	8,643	0	189	0	0
Starting 1973	8,739	6,643	2,000	189	400	1,600
Child Born in 1964:						
Thru 1981	8,739	8,643	0	189	0	0
Starting 1982	8,739	6,643	2,000	189	400	1,600

Individual	Delivery Family (continued)	Outdoors Person Family		Near River Family	Migrant Worker Family
	Barnwell	Onsite SRS	Jackson	Martin	New Ellenton
Adult M	6,454	1,740	6,643	8,447	4,370
Adult F	8,454	0	8,643	8,447	4,370
Child Born in 1955:					
Thru 1972	8,454	0	8,643	8,447	4,370
Starting 1973	6,454	1,740	6,643	8,447	4,370
Child Born in 1964:					
Thru 1981	8,454	0	8,643	8,447	4,370
Starting 1982	6,454	1,740	6,643	8,447	4,370

Table E-13 Indoor and Outdoor Hours for Infant of Rural Family One

Activity	Hours Indoor	Hours Outdoor
At home	7,362	1,188
At work	0	0
On the shoreline	0	85
At school	0	0
At Church	104	0
Total:	7,466	1,273

This accounting was performed for all receptors as addressed in Appendix Q. Appendix Q presents the total indoor and outdoor hours calculated for each receptor as well as the corresponding overall indoor (FT_{hg}) and outdoor (FT_{og}) fractions. Table E-14 summarizes the indoor and outdoor fractions for each receptor calculated from Appendix Q. (Note that $FT_{hg} + FT_{og} = 1$.)

These fractions were used with the indoor and outdoor shielding factors to create receptor-specific adjustment factors according to the equation listed above. The outdoor shielding factor (SH_o) was set equal to 1.0 for all scenarios, exposure locations, individuals, and years. The value assumed for the indoor shielding factor (SH_h) was conservatively taken to be 0.7.

The authors of this report found occasions where values for the indoor shielding factor of 0.4, 0.5, 0.7, and 0.8 had been used or recommended. Values of 0.5 and 0.7 have been used for modeling population doses resulting from SRS activities (8-10). EPA had at one time recommended using a shielding factor of 0.8, but in 1996 recommended a shielding factor of 0.4 (11). For this recommendation, EPA had reviewed a 1981 EPA report (12) that performed a review of experimentally measured reduction factors from fallout. The authors concluded that "reduction factors of 0.4 to 0.2 are recommended as representative values for above-ground lightly constructed (wood frame) and heavily constructed (block and brick) homes, respectively" (12). From this review, EPA suggested that a default gamma shielding factor of 0.4 based solely on the contribution of terrestrial radiation might be more appropriate for use at sites having soil contaminated with radionuclides than the previous default value of 0.8. This previous default value included the effects of cosmic radiation and the radioactivity inherent in structural materials (11).

But it was assumed that doors and windows of structures tended to remain open (see Section E.5.3.1), which meant that interior surfaces of structures may have been more likely to be contaminated than the situation assumed by EPA. Therefore, a larger value (0.7) was used for the indoor shielding factor than the default value recommended by EPA (0.4), resulting in somewhat larger exposures than would have been the case using the EPA default value.

Adjustment factors calculated from these considerations are presented in Table E-15.

Table E-14 Indoor and Outdoor Fractions for Ground Contamination Pathway

Scenario	Member*	Location†	Out. Frac.	In. Frac.
Rural Family One	Inf.	Girard	0.15	0.85
	Presch	Girard	0.15	0.85
	School	Girard	0.18	0.82
	Teen	Girard	0.13	0.87
	Teen	Wayne	0.29	0.71
	Ad. M	Girard	0.31	0.69
	Ad. F	Girard	0.14	0.86
Rural Family Two	Inf.	Will	0.15	0.85
	Presch	Will	0.15	0.85
	School	Will	0.18	0.82
	Teen	Will	0.15	0.85
	Ad. M	Will	0.31	0.69
	Ad. F	Will	0.14	0.86
Urban/ Suburb. Family	Inf.	Aug	0.14	0.86
	Presch	Aug	0.14	0.86
	School	Aug	0.17	0.83
	Teen	Aug	0.14	0.86
	Ad. M	Aug	0.13	0.87
	Ad. M	SRS	0.13	0.87
	Ad. F	Aug	0.13	0.87
Delivery Person Family	Inf.	Martin	0.45	0.55
	Inf.	Barn	0.14	0.86
	Presch	Martin	0.45	0.55
	Presch	Barn	0.14	0.86
	School	Martin	0.45	0.55
	School	Barn	0.18	0.82
Delivery Person Family (cont.)	Teen	Martin	0.45	0.55
	Teen	Barn	0.15	0.85
	Ad. M	Martin	0.45	0.55
	Ad. M	Barn	0.13	0.87
	Ad. M	SRS	0.50	0.50
	Ad. M	Allen	0.16	0.84
	Ad. F	Martin	0.45	0.55
	Ad. F	Barn	0.13	0.87
Outdoor Person	Inf.	Jack	0.15	0.85
	Presch	Jack	0.15	0.85
	School	Jack	0.18	0.82
	Teen	Jack	0.15	0.85
	Ad. M	Jack	0.14	0.86
	Ad. M	SRS	1.0	0
	Ad. F	Jack	0.14	0.86
Near River Family	Inf.	Martin	0.14	0.86
	Presch	Martin	0.14	0.86
	School	Martin	0.18	0.82
	Teen	Martin	0.15	0.85
	Ad. M	Martin	0.13	0.87
	Ad. F	Martin	0.13	0.87
Migrant Worker Family	Inf.	N E	0.15	0.85
	Presch	N E	0.15	0.85
	School	N E	0.18	0.82
	Teen	N E	0.15	0.85
	Ad. M	N E	0.31	0.69
	Ad. F	N E	0.14	0.86

*Inf - infant; Presch - preschooler; School - school child; Ad M - Adult Male; Ad F - adult female.
†Wayne - Waynesboro; Will -Williston; Aug - Augusta; Barn - Barnwell; Allen - Allendale; Jack - Jackson; N E - New Ellenton.

Table E-15 Adjustment Factors for Ground Contamination External Exposure Pathway

Individual	Years	Rural Family One		Rural Family Two	Urban/Suburban Family		Delivery Person Family	
		Girard	Waynes-boro	Willi-ston	Augusta	Onsite SRS	Martin	Onsite SRS
Adult M	All	0.7927	0	0.7927	0.7386	0.7375	0.8349	0.8500
Adult F	All	0.7417	0	0.7417	0.7388	0	0.8349	0
Children Born in 1955 and 1964	Infant	0.7437	0	0.7437	0.7409	0	0.8349	0
	Preschool	0.7437	0	0.7437	0.7409	0	0.8349	0
	Schoolchild	0.7546	0	0.7546	0.7519	0	0.8349	0
	Teen	0.7392	0.7857	0.7459	0.7431	0	0.8349	0
	Adult	0.7927	0	0.7927	0.7386	0.7375	0.8349	0

Individual	Years	Delivery Person Family (continued)		Outdoors Person Family		Near River Family	Migrant Family
		Allendale	Barnwell	Onsite SRS	Jackson	Martin	New Ellenton
Adult M	All	0.7469	0.7396	1.0	0.7423	0.7391	0.7927
Adult F	All	0	0.7396	0	0.7417	0.7396	0.7417
Child Born in 1955	Infant	0	0.7417	0	0.7437	0.7417	0.7437
	Preschool	0	0.7417	0	0.7437	0.7417	0.7437
	Schoolchild	0	0.7529	0	0.7547	0.7528	0.7547
	Teen	0	0.7440	0	0.7460	0.7440	0.7460
	Adult	0.7469	0.7396	0	0.7423	0.7391	0.7927

E.5.1.3 Exposure to a Contaminated Shoreline

This exposure pathway accounts for external radiation exposure resulting from standing on the shoreline containing radioactive material deposited by contaminated water. The following are GENII variables for this exposure pathway:

- EVSHOR - Frequency of shoreline use (event/day).
- TESHOR - Duration of shoreline use events (hours/event).
- TSHOR - Shoreline days (days/year).

Exposure factors were calculated by multiplying age- and location-specific values for these variables, resulting in a set of exposure factors in units of hours of exposure per year. Exposure factors thus developed are summarized in Table E-16 in accordance with the assumptions described in Sections E.5.1.3.1 through E.5.1.3.3.

Table E-16 Exposure Factors for Shoreline External Exposure Pathway

Scenario	Shoreline External Pathway	Exposure Factors
Rural Family One	No shoreline external exposure. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.	Exposure Factors (hours/year) = 0 (all years and individuals)
Rural Family Two	No shoreline external exposure. Exposure locations (Savannah River upstream of the SRS and farm ponds around Williston) are not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)
Urban/Suburban Family	No shoreline external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)
Delivery Person	**Lower Three Runs Creek (LTRC) at Martin (50%) and the Savannah River down stream of the LTRC confluence (50%).** All individuals exposed for 85 hours/year for all years, combined from both locations.	Exposure Factors (hours/year) **Receptor** / **LTRC-Martin** / **Savannah River** Adult M: 42.5 / 42.5 Adult F: 42.5 / 42.5 Child 1955: 42.5 / 42.5 Child 1964: 42.5 / 42.5
Outdoors Person	**Savannah River upstream of the SRS:** No shoreline external exposure for the adult female and children. The exposure location is not hydrologically downgradient from release points. **Savannah River Downstream of the SRS:** The adult male is exposed for 260 hours/year for all years.	Exposure Factors (hours/year) **Receptor** / **Savannah River** Adult M: 260 Adult F: 0 Child 1955: 0 Child 1964: 0
Near River Family	**Savannah River Downstream of SRS:** All individuals are exposed for 365 hours/year for all years.	Exposure Factors (hours/year) **Receptor** / **Savannah River** Adult M: 365 Adult F: 365 Child 1955: 365 Child 1964: 365
Migrant Worker Family	No shoreline external exposure. Exposure locations (Savannah River upstream of the SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)

E.5.1.3.1 Exposure Factors for the Delivery Person Family

Shoreline exposure rates were estimated using the following factors based on South Carolina recreational patterns as cited on pages 6 and 24 of Hamby (6):

- Average number of shoreline usage events/year – 19.15.
- Average hours/shoreline usage event – 4.44.

This resulted in an exposure rate of 85 hours/year which was applied to all members of the Delivery Person Family. The Hamby (6) values are based on Ledbetter (13). The numbers apply to all age groups and represent warm-water fishing activity. This exposure value is larger than default values cited in the Nuclear Regulatory Commission's (NRC) Regulatory Guide 1.109 (14) for a maximum exposed individual (MEI). NRC MEI exposure values for adults, teens, and children are 12, 67, and 14 hours/year, respectively (14). Hamby (6) calculated MEI values for population doses in the area around the SRS using local data and assumptions. The Hamby (6) MEI numbers for adults, teens, and children are 23, 128, and 27 hours/year, respectively.

E.5.1.3.2 Exposure Factors for the Outdoors Person Family

The only family members that were exposed to contaminated shorelines were the Adult Male and the two children when they became adults at age 18. It was assumed the Adult Male was present in shoreline areas along the Savannah River onsite at the SRS as part of his job. This time included time spent fishing and hunting. It was assumed the Adult Male was "on the river" 8 hours/day (40 hours/week) during the summer (13 weeks), as cited in Lockridge (1). It was further assumed that half the time spent "on the river" was spent on the shoreline, and the other half was spent on a boat. This resulted in an exposure factor of 260 hours/year on the shoreline for the Adult Male. The Adult Female always spent time along the shoreline at the Jackson, South Carolina, boat ramp, which is upstream from site discharges. Until they each reached age 18, the two children also spent their shoreline time at the Jackson boat ramp. After reaching age 18, they each spent the same time along the shoreline while working at the SRS as did the Adult Male (260 hours/year).

E.5.1.3.3 Exposure Factors for the Near River Family

For these receptors, Lockridge (1) states, "Assume they were always outdoors in contact with the Savannah River." It was assumed that the shoreline exposure rate would have been well above average values. An average daily exposure level of 1 hour/day (365 hours/year) was assumed for each receptor.

E.5.1.4 Exposure to Contaminated Water While Swimming

This exposure pathway accounts for external radiation exposure resulting from swimming in contaminated water. The following are GENII variables for this exposure pathway:

- EVSWIM - Frequency of swimming use (event/day).
- TESWIM - Duration of swimming events (hours/event).
- TSWIM - Swimming days (days/year).

Exposure factors were calculated taking into account these three variables which, when multiplied, result in receptor- and location-specific exposure factors in units of hours per year. Swimming exposures were determined only for members of the Delivery Person Family, who swam on Lower Three Runs Creek near Martin, South Carolina, and the Near River Family, who swam on the Savannah River downstream of the SRS.

For the Delivery Person Family, swimming water exposure rates were estimated using the following factors based on South Carolina recreational patterns cited on pages 6 and 24 of Hamby (6). The Hamby values are based on Ledbetter (13). The following values apply to all age groups and represent warm-water fishing activity:

- Average number of lake swimming events per year – 8.12 events/y.
- Average time of lake swimming event – 2.61 h/event.

These data resulted in exposure factors of 21.2 hours/year for each member of the Delivery Person Family.

For the Near River Family, it is stated in Lockridge (1) to "Assume they were always outdoors in contact with the Savannah River." A swimming rate was assumed during the summer months of 1 hour/day, leading to an exposure rate of 91 hrs/yr for each receptor. Table E-17 summarizes swimming water exposure factors.

Table E-17 Exposure Factors for Swimming External Exposure Pathway

Scenario	Swimming Water External Pathway	Exposure Factors
Rural Family One	No swimming water external exposure. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)
Rural Family Two	No swimming water external exposure. Exposure locations (farm ponds around Williston) are not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)
Urban/Suburban Family	No swimming water external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)
Delivery Person	**Lower Three Runs Creek (LTRC) at Martin:** All individuals exposed for 21.2 hours/year for all years.	Exposure Factors (hours/year) **Receptor** / **LTRC-Martin** Adult M 21.2 Adult F 21.2 Child 1955 21.2 Child 1964 21.2
Outdoors Person	No swimming water external exposure. Exposure location (Savannah River upstream of the SRS) is not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)
Near River Family	**Savannah River Downstream of the SRS:** All individuals exposed for 91 hours/year for all years.	Exposure Factors (hours/year) **Receptor** / **Savannah River** Adult M 91 Adult F 91 Child 1955 91 Child 1964 91

Scenario	Swimming Water External Pathway	Exposure Factors
Migrant Worker Family	No swimming water external exposure. Exposure locations (Savannah River upstream of the SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)

E.5.1.5 Exposure to Contaminated Water While Boating

This exposure pathway accounts for external radiation exposures received while boating in contaminated water. The following are GENII variables for this exposure pathway:

- EVBOAT – Frequency of boating event (event/d).
- TEBOAT – Duration of boating event (h/event).
- TBOAT – Boating days (d/y).

Exposure factors determined when multiplying these variables resulted in exposure factors in units of hours/year. Boating exposure factors were calculated for members of the Delivery Person Family, the Outdoors Person Family, and the Near River Family. The rationale for these exposure factors, summarized in Table E-18, is presented in Subsections E.5.1.5.1 through E.6.1.5.3.

Table E-18 Exposure Factors for Boating External Exposure Pathway

Scenario	Boating External Pathway	Exposure Factors
Rural Family One	No boating external exposure. No boating performed by receptor.	Exposure Factors = 0 (all years and individuals)
Rural Family Two	No boating external exposure. No boating performed by receptor.	Exposure Factors = 0 (all years and individuals)
Urban/Suburban Family	No boating external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.	Exposure Factors = 0 (all years and individuals)
Delivery Person	**Savannah River Downstream of the SRS:** All individuals exposed for 96 hours/year for all years.	Exposure Factors (hours/year) **Receptor** / **Savannah River** Adult M 96 Adult F 96 Child 1955 96 Child 1964 96
Outdoors Person	**Savannah River Downstream of the SRS:** The adult male is exposed 356 hours/year for all years, including 260 hours for work and 96 hours for recreation. Boating exposure for all other individuals is 96 hours/year for all years.	Exposure Factors (hours/year) **Individual** / **Savannah River** Adult M 356 Adult F 96 Child 1955 96 Child 1964 96
Near River Family	**Savannah River Downstream of the SRS:** All individuals exposed for 192 hours/year for all years.	Exposure Factors (hours/year) **Receptor** / **Savannah River** Adult M 192

Scenario	Boating External Pathway	Exposure Factors
		Adult F 192 Child 1955 192 Child 1964 192
Migrant Worker Family	No boating external exposure. No boating performed by receptor.	Exposure Factors (hours/year) = 0 (all years and individuals)

E.5.1.5.1 Delivery Person Family

Boating exposure rates were estimated considering South Carolina recreational patterns as cited on pages 6 and 24 of Hamby (6), and summarized in Table E-19. These values are based on Ledbetter (13). The values apply to all age groups and include two categories: canoeing and boating/sailing.

Table E-19 South Carolina Boating Usage Rates (adapted from Hamby [6])

Boating Usage	Canoe Trails	Boating / Sailing
Events / Year (average)	6.13	18.77
Hours / Event (average)	2.25	4.38
Hours / Year	13.8	82.2
Total	96 hours/year	

An exposure factor of 96 hours/year was assumed for all members of the Delivery Person Family.

E.5.1.5.2 Outdoors Person

The Adult Male was exposed to radiation to a greater extent than other family members. The exposure factor for the Adult Male includes two components: one for work and one for recreation. For work, the Adult Male was calculated to boat for 260 hours/year, or half the time spent "on the river" as cited in Lockridge (1). Because the time spent "on the river" was cited (1) as 8 hours/day (i.e., 40 hours/week) during the summer (i.e., 13 weeks), it assumed that the Adult Male boated while at work for 0.5 x 40 x 130 = 260 hours/year. For recreational boating, the same rate (i.e., 96 hours/year adapted from Hamby [6]) was applied to all members of the family, including the Adult Male.

E.5.1.5.3 Near River Family

For these receptors, Lockridge (1) states, "Assume they were always in contact with the Savannah River." An exposure factor was calculated assuming that these receptors went boating for twice the average rates cited in Hamby (6). An exposure factor of 192 hours/year was assumed for each receptor.

E.5.2 Ingestion Exposure Route

E.5.2.1 Ingestion of Food Crops

Exposures from ingestion of food crops include exposures from ingestion of leafy vegetables, root and other vegetables, fruit, and grain. The following are GENII variables for these exposure pathways:

- UCRP 1 – Leafy vegetable daily consumption rate on days that consumption occurs (kg/d).
- TCRP 1 – Leafy vegetable consumption period: days per year that consumption occurs (d/y).

- UCRP 2 – Root vegetable daily consumption rate on days that consumption occurs (kg/d).
- TCRP 2 – Root vegetable consumption period: days per year that consumption occurs (d/y).
- UCRP 3 – Fruit daily consumption rate on days that consumption occurs (kg/d).
- TCRP 3 – Fruit consumption period: in days out of the year that consumption occurs (d/y).
- UCRP 4– Grain daily consumption rate on days that consumption occurs (kg/d).
- TCRP 4 – Grain consumption period: in days out of the year that consumption occurs (d/y).

Four sets of exposure factors were calculated that were linked to these GENII variables and given in units of kilograms per year for leafy vegetables, root vegetables, fruit, and grain. Section E.5.2.1.1 presents exposure factors for leafy and root vegetables and fruit. Section E.5.2.1.2 presents exposure factors for grain.

E.5.2.1.1 Exposure and Adjustment Factors for Leafy and Root Vegetables and Fruit

Background

Consumption rate data for produce (leafy vegetables, root and other vegetables, and fruit) was assessed from EPA, 1997 (5); Hamby (6); and NRC (14). The first two of these references are secondary sources citing data from U.S. Department of Agriculture (USDA) studies, including National Food Consumption Surveys (NFCS) and the Continuing Surveys of Food Intakes by Individuals (CSFII). Consumption rates are specified in these references for specific age and gender categories, and for produce categories, as shown in Table E-20 (EPA [5]; Hamby [6]; NRC [14]). Data sets listed in Table E-20 consisted of:

- 1989-91 CSFII (EPA [5]).
- 1977-78 NFCS (Data Set No. 1) (EPA [5]).
- 1977-78 NFCS (Data Set No. 2) (EPA [5]).
- 1987-88 NFCS (EPA [5]).
- 1994-95 CFSII (EPA [5]).
- Hamby (6) regional estimates.
- NRC defaults from Regulatory Guide 1.109 (NRC [5]).

EPA, 1997 (5) also presents consumption rates based on other factors including geographic region, urbanization, season, and race (see Table E-20). But because age and gender differentiations are not specified for these factors, they were not used to create exposure factors. Although data distinguishing between geographic regions were not reported in EPA, 1997 (5) as a function of age or gender categories, the data do indicate that regional differences in consumption rates are small (i.e., <10%). EPA, 1997 (5) also compared consumption rates over time as illustrated in Table E-21. The data indicate that fruit consumption has gradually increased over time, and that vegetable consumption has fluctuated over time but overall has decreased.

Table E-20 Categories of Produce Consumption Data

Study [rate units]	Age and Gender Categories	Produce Categories*	Other Categories†
1989-91 CSFII (EPA [5]) [g / kg-d]	<5 6 – 11 male / female 12 – 19 male / female >20 male / female All individuals	Total fruits and vegetables Individual fruits and vegetables (28 types) Exposed and protected fruits Exposed and protected vegetables Root vegetables	Geographic region (northeast, midwest, south, west) Urban (city, suburban, nonmetro) Season (spring, summer, fall, winter) Race (White, Black, Asian, Native American, other)
1977-78 NFCS (EPA [5]) [g / d] Data Set #1	<1, 1-2, 3-5, 6-8 9 – 11 male / female 12 – 14 male / female 15 – 18 male / female 19 – 22 male / female 23 – 34 male / female 35 – 50 male / female 51 – 64 male / female 65 – 74 male / female >75 male / female All individuals	Total fruits Total vegetables Total produce	Geographic region (northeast, north central, south, west)
1977-78 NFCS (EPA [5]) [g / d] Data Set #2	<1 1 – 4 5 – 9 10 – 14 15 – 19 20 – 24 25 – 29 30 – 39 40 – 59 >60	Leafy produce Exposed produce Protected produce Other produce	Geographic region (northeast, north central, south, west)
1987-88 NFCS (EPA [5]) [g / d]	<6 6 – 11 male / female 12 – 19 male / female >19 male / female All individuals	Total fruits Total vegetables	None reported
1994-95 CSFII (EPA [5]) [g / d]	<6 6 – 11 male / female 12 – 19 male / female >19 male / female All individuals	Total fruits Total vegetables	None reported
Hamby (6) Regional estimates [kg / yr]	Infant Child Teen Adult	Leafy vegetables Other vegetables	None reported

Study [rate units]	Age and Gender Categories	Produce Categories*	Other Categories†
NRC Defaults (Hamby [6]) [kg / yr]	Infant Child Teen Adult	Other vegetables	None reported

*Data for the listed produce categories are reported by age and gender categories.
†Data for these other categories are not reported by age and gender categories.
Sources: EPA, 1997 (5); Hamby, 1991 (6); NRC, 1977 (14).

Table E-21 Comparison of Produce Consumption Rates Over Time

Produce Category	1977-78 NFCS	1987-88 NFCS	1989-91 CSFII	1995 CSFII
Fruits	142	142	156	173
Vegetables	201	182	179	188

Source: Tables 9-12 of EPA, 1997 (5).

Selection of data sets

The two data sets from the 1977-78 NFCS in EPA, 1997 (5) were chosen as the bases for the produce consumption rates. The following provided the rationale for this selection:

- The time period covered by this data set (1977-1978) was closer to the midpoint of the 1954-1992 period being modeled than the other data sets, which occur near or after 1992.
- This data set provided numerous age and gender categories that could be more easily aligned with the CDC and GENII age and gender categories.
- This data set was expressed in units that more easily converted to units required by GENII (g/day to kg/year). Additional conversions considering consumption rate variations by body weight were not needed.

Consumption rates

Consumption rates for the three different produce categories (leafy vegetables, root vegetables, and fruit) and the six different age and gender-specific categories modeled in GENII were derived from the NFCS data in the following manner:

- Leafy Vegetables. Age- and gender-specific consumption rates were calculated by averaging the NFCS age-specific categories for leafy vegetables in NFCS Data Set #2 using an approach similar to that used for meat consumption (see Section E.5.2.2.1). The data did not distinguish between male and female consumption of leafy vegetables.
- Root Vegetables. Age- and gender-specific consumption rates for root vegetables were determined using a two-step calculation. First, age- and gender-specific rates were calculated by averaging the NFCS age and gender categories for total vegetables in the NFCS Data Set #1, using an approach similar to that used for meat ingestion (see Section E.5.2.2.1). Second, the calculated leafy vegetable rates were subtracted from the total vegetable rates to yield age- and gender-specific consumption rates for root vegetables.
- Fruit. Age- and gender-specific consumption rates for fruit were calculated by averaging the NFCS age and gender categories for fruit in the NFCS Data Set #1 using an approach similar to that used for meat consumption.

For all three cases, the calculated rates were converted from g/day to kg/yr. Table E-22 presents the results of these calculations and the categories that were used for averaging.

Table E-22 GENII-Modeled Age and Gender Categories for Leafy and Root Vegetables and Fruit, Corresponding EPA 1997 (5) Age and Gender Categories, and Calculated Rates

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged		Calculated Value – Average Consumption (kg/year)			
	Data Set #1 (used for total vegetables and fruit)	Data Set #2 (used for leafy vegetables)	Leafy Vegetables	Total Vegetables	Root Vegetables*	Fruit
Infant (<1)	<1	<1	1.2	27.7	26.6	61.7
Pre-School (1 – 4)	1 – 2 3 – 5	1 – 4	4.1	35.2	31.1	50.7
Child (5 – 11)	6 – 8 9 – 11 male	5 – 9 10 – 14	8.1	50.0	41.9	52.0
Teenager (12 – 17)	12 – 14 male 15 – 18 male	15 – 19	10.6	73.8	63.2	49.4
Adult Male (>18)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	20 – 24 25 – 29 30 – 34 40 – 59 >=60	16.7	95.9	79.21	55.2
Adult Female (>18)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	20 – 24 25 – 29 30 – 34 40 – 59 >=60	16.7	73.9	57.2	56.6

*Root vegetables are calculated by difference (total vegetables – leafy vegetables = root vegetables).
Source: Data adapted from Tables 9-14. 9-16, and 9-22 of EPA, 1997 (5).

Information from this table was used to calculate exposure and adjustment factors for consumption of leafy vegetables, root vegetables, and fruit. For many receptors, some of the consumed vegetables and fruit were obtained from sources external to the SRS vicinity and therefore did not contain radionuclides from SRS operations.

Table E-23 lists exposure factors. Exposure factors reflect the assumptions that (1) half the leafy vegetables, root vegetables, and fruit consumed by the Delivery Person Family were obtained from the Barnwell area and half from the Martin area, and (2) the Migrant Worker Family was in the SRS vicinity for only half of any year.

Table E-24 lists adjustment factors. For Rural Families One and Two, during the 1950s, half of the vegetables and fruit was grown on the farm, and all of this farm-grown produce had the potential for contamination. The remaining vegetables and fruit were obtained from local stores. Of this produce, it

was assumed that half was grown locally and half was grown outside the SRS vicinity. But beginning in 1960, only 25 percent of their vegetables and fruit was grown on the farm. Of this produce, all had the potential for contamination. The remaining 75 percent was obtained from local groceries. It was assumed that half of this store-bought produce was grown locally, and half was obtained from outside the SRS vicinity.

Table E-23 Exposure Factors (kg/yr) for Three Produce Ingestion Pathways

Individual	Rural Families One and Two, Urban/Suburban Family, Outdoors Person Family, Near River Family			Delivery Person Family (Barnwell/Martin)†			Migrant Worker Family		
	LV*	RV*	F*	LV	RV	F	LV	RV	F
Adult Male	16.7	79.2	55.2	8.35/ 8.35	39.6/ 39.6	27.6/ 27.6	8.35	39.6	27.6
Adult Female	16.7	57.2	56.6	8.35/ 8.35	28.6/ 28.6	28.3/ 28.3	8.35	28.6	28.3
Children Born in 1955 and 1964:									
Infant	1.2	26.6	61.7	0.6/ 0.6	13.3/ 13.3	30.85/ 30.85	0.6	13.3	30.85
Preschool	4.1	31.1	50.7	2.05/ 2.05	15.55/ 15.55	25.35/ 25.35	2.1	15.55	25.35
School	8.1	41.9	52.0	4.05/ 4.05	20.95/ 20.95	26.0/ 26.0	4.05	20.95	26.0
Teen	10.6	63.2	49.4	5.3/ 5.3	31.6/ 31.6	24.7/ 24.7	5.3	31.6	24.7
Adult	16.7	79.2	55.2	8.35/ 8.35	39.6/ 39.6	27.6/ 27.6	8.35	39.6	27.6

*LV: Leafy Vegetables; RV: Root Vegetables; F: Fruit.
†The Delivery Person Family obtained half its produce from Martin and half from Barnwell.

The fraction of vegetables and fruit that may have originated locally and been consumed by receptors was difficult to estimate, particularly over the 39 years considered in this assessment. One could expect, however, that the locally grown fraction had decreased over the years as marketing networks built up in the SRS vicinity. Lockridge (1) had recommended that for the rural family, the study should assume that 50 percent of the vegetables and meat originated from the farm during the 1950's, and only 25 percent thereafter. This recommendation was followed for Rural Families One and Two for all vegetables and fruit. It was reasoned that fruit was about as likely as vegetables to be grown locally or imported from outside the SRS vicinity.

For all other scenarios, it was assumed that half of the receptors' vegetables and fruit was imported from outside the SRS vicinity. The authors of this report considered this assumption to be conservative in that it corresponded to the recommendation made in Lockridge (1) for the 1950's, but was applied to all years. Note that the same adjustment factors were assumed, for the Delivery Person Family, for vegetables and fruit obtained respectively from Martin and Barnwell.

Table E-24 Adjustment Factors (kg/y) for Leafy Vegetable, Root Vegetable, and Fruit Ingestion Exposure Pathways

Individual	Rural Families One And Two	Urban/Suburban Family, Delivery Person Family, Outdoors Person Family, Near River Family, Migrant Worker Family
Adult Male:		
Thru 1959	0.75	0.50
1960 & on	0.625	0.50
Adult Female:		
Thru 1959	0.75	0.50
1960 & on	0.625	0.50
1955 Child:		
Infant 1955	0.75	0.50
Preschool 1956-59	0.75	0.50
School 1960-66	0.625	0.50
Teen 1967-73	0.625	0.50
Adult 1974-92	0.625	0.50
1964 Child:		
All ages (1964 to 1992)	0.625	0.50

E.5.2.1.2 Exposure and Adjustment Factors for Grain

No data regarding grain consumption were identified for the SRS vicinity. Therefore, the authors of this report used data on per-capita intake of corn from EPA, 1997 (5) to generate exposure factors for grain consumption. It was assumed that although individuals in the SRS vicinity would likely have consumed grain products such as breads, pastas, or flours that would not have been derived from locally grown grains, individuals in the SRS vicinity could plausibly have consumed a considerable amount of locally grown corn. In this case, corn was considered to be a grain rather than as a vegetable. Table E-25 shows that consumption rates were combined and averaged for specific age- and gender-categories.

These calculated rates for grain ingestion were used to determine exposure factors for each receptor as summarized in Table E-26.

Exposure factors for the Delivery Person Family reflect the situation that half the grain was obtained half from Barnwell and half from Martin. Exposure factors for the Migrant Worker Family reflect the situation that the family was only in the area for half of the year.

For all receptors and scenarios, adjustment factors were assumed to be unity (i.e., all of the grain [corn] was obtained from the SRS vicinity). It was assumed that because corn was commonly grown in the vicinity, it could have been easily acquired by all receptors, rural or urban.

Table E-25 GENII-Modeled Age and Gender Categories for Grains, Corresponding EPA 1997 Age and Gender Categories, and Calculated Consumption Rates

Modeled Age Categories	Corresponding Averaged EPA 1997 Categories	Average Consumption (kg/year)
Infant (<1)	<1	1.2
Pre-School (1 – 4)	1 – 2 3 – 5	2.9
Child (5 – 11)	6 – 8 9 – 11 male	4.0
Teenager (12 – 17)	12 – 14 male 15 – 18 male	3.6
Adult Male (>18)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	4.1
Adult Female (>18)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	3.4

Table E-26 Exposure Factors (kg/y) for Grain Ingestion Exposure Pathway

Individual	Rural Families One and Two, Urban/Suburban Family, Outdoors Person Family, and Near River Family	Delivery Person Family		Migrant Worker Family
		Barnwell	Martin	
Adult Male	4.1	2.05	2.05	2.05
Adult Female	3.4	1.7	1.7	1.7
1955 Child:				
Infant 1955	1.2	0.6	0.6	0.6
Preschool 1956-59	2.9	1.45	1.45	1.45
School 1960-66	4.0	2.0	2.0	2.0
Teen 1967-73	3.6	1.8	1.8	1.8
Adult 1974-92	4.1	2.05	2.05	2.05
1964 Child:				
Infant 1964	1.2	0.6	0.6	0.6
Preschool 1965-68	2.9	1.45	1.45	1.45
School 1969-75	4.0	2.0	2.0	2.0
Teen 1976-82	3.6	1.8	1.8	1.8
Adult 1983-92	4.1	2.05	2.05	2.05

E.5.2.2 Ingestion of Animals and Animal Products

Exposures from ingestion of animals and animal products include exposures from ingestion of beef, poultry, milk, and eggs. The following are GENII variables for these exposure pathways:

- UNAM 1 – Beef daily consumption rate on days that consumption occurs (kg/d).
- TANM 1 – Beef consumption period: days out of the year that consumption occurs (d/y).
- UNAM 2 – Poultry daily consumption rate on days that consumption occurs (kg/d).
- TANM 2 – Poultry consumption period: days out of the year that consumption occurs (d/y).
- UNAM 3 – Milk daily consumption rate on days that consumption occurs (kg/d).
- TANM 3 – Milk period: days out of the year that consumption occurs (d/y).
- UNAM 4 – Eggs daily consumption rate on days that consumption occurs (kg/d).
- TANM 4 – Eggs consumption period: days out of the year that consumption occurs (d/y).

Four sets of exposure factors were determined, linked to these GENII variables, in units of kilograms per year. Exposure factors for beef are presented in Section E.5.2.2.1. Exposure factors for poultry are presented in Section E.5.2.2.2. Exposure factors for milk and eggs are presented in Section E.5.2.2.3.

E.5.2.2.1 Exposure and Adjustment Factors for Beef

The beef pathway was used to represent all non-poultry and non-fish meat that was potentially affected by SRS releases. This pathway includes beef, but serves as a surrogate for wild game, pork, and other non-poultry meats. Several sets of data were evaluated to develop values for meat consumption. The principal source was EPA, 1997 (5), which provides national averages for adult and child meat and beef consumption. Another reference for beef consumption was Hamby (6). Neither of these sources provides values that align exactly with the report scenarios or the age group categories of GENII. Additionally, neither source is based on local (e.g., county- or State-level) data. Therefore, the authors of this report made some adjustments of the raw data to develop values that better corresponded with the scenarios and GENII specifications. EPA, 1997 (5) was selected as a better source than Hamby (6) because it provided separate categories for adult males and females and multiple categories identifying different meat types. Tables E-27 and E-28 present the categories of data included in each of the sources.

Table E-27 Ingestion Categories Presented in EPA 1997 Meat Consumption Data

1987-88 NFCS and 1994/1995 CSFII		1977-78 NFCS	
Age and Gender Categories	**Meat Categories**	**Age and Gender Categories**	**Meat Categories**
<5	Total Meat, Poultry and Fish	<1	Total Meat, Poultry and Fish
6 – 11 male / female	Beef	1 – 2	Beef
12 – 19 male / female	Pork	3 – 5	Pork
>20 male / female	Lamb, Veal, Game	6 – 8	Lamb, Veal, Game
All individuals	Frankfurters, sausages, luncheon meats	9 – 11 male / female	Frankfurters, sausages, luncheon meats
	Total Poultry	12 – 14 male / female	Total Poultry
	Chicken Only	15 – 18 male / female	Chicken Only
	Meat Mixtures	19 – 22 male / female	Meat Mixtures
		23 – 34 male / female	
		35 – 50 male / female	
		51 – 64 male / female	
		65 – 74 male / female	
		>75 male / female	
		All individuals	

Source: EPA, 1997 (5).

Table E-28 Ingestion Categories in Hamby 1991 Meat Consumption Data*

Age and Gender Categories Considered	Meat Categories Considered
Infant, Child, Teen, and Adult	Beef (households in the south only) All meat (nationwide only)

*Hamby, 1991 (6) provides two sets of data: NFCS 1977-78 data for southern households, and NRC defaults.

The meat consumption assumptions used for this report were derived primarily from EPA, 1997 (5) data derived from the 1977-78 NFCS. The 1977-78 NFCS data set was selected for four reasons:

1. This data set included values for a broad range of individual meat categories.
2. The time period covered by this data set (1977-1978) was closer to the midpoint of the 1954-1992 period being modeled than the other data sets, which occur near or after 1992.
3. This data set provides numerous age and gender categories that were more easily aligned with the age and gender categories used for this report.
4. This data set was expressed in units that more easily convert to units required by this report (g/day to kg/year). Additional conversions considering consumption rate variations by body weight were not needed.

To calculate consumption rates for the beef pathway (i.e., meat that is not poultry and not fish), the authors of this report added values from EPA, 1997 (5) for intake of beef, pork, lamb/veal/game, meat mixtures, and processed meats (frankfurters, sausages, luncheon meats, spreads). For non-adult age and gender categories, male and female values were averaged. Table E-29 shows the modeled age and gender categories, the corresponding age and gender categories from EPA, 1997 (5) that were averaged to calculate a comparable input value, and the calculated value that was converted to units of kg consumed per year (or liters per year in the case of milk).

These calculated ingestion rates were used to determine receptor and location-specific exposure factors as summarized in Table E-30. These exposure factors reflected the assumption that (1) the Delivery Person Family consumed beef obtained from both Martin and Barnwell areas, (2) the Migrant Worker Family is in the SRS vicinity for only half the year, and (3) three-quarters of the beef consumed by the Outdoors Person Family originated from the SRS site as venison and one-quarter (not venison) originated from the Jackson area.

Adjustment factors took into account the following assumptions:

- For Rural Families One and Two, it was assumed that up through the end of 1959, half the beef was grown on the farm and therefore contaminated. The other half came from local grocery stores, of which 50 percent was contaminated. Starting in 1960, 25 percent of the beef was grown on the farm. All this beef contained radionuclides from the SRS. The other 75 percent of the beef came from local grocery stores, of which half was contaminated. These assumptions are consistent with Lockridge (1) and reflect the assumption that half the beef acquired from local grocery stores came from local farms, and half came from sources outside the SRS vicinity.
- For the Urban/Suburban Family, Near River Family, and the Migrant Worker Family, it was assumed that half the consumed beef came from sources local to the SRS, and half did not. (This assumption is equivalent to the assumption that all the beef came from local grocery stores, and that the grocery stores obtained only half their beef locally.) This assumption is conservative, in that it essentially assumed that 1950's conditions for meat consumption, as recommended in Lockridge (1), were applicable for all years for these families. This assumption is consistent with those made for vegetables and fruit for these families (see Section E.5.2.1.1).

- For the Delivery Person Family, half the beef came from the Martin area and half came from the Barnwell area. Of the beef obtained from the Martin area, it was assumed that 25 percent was obtained from hunting deer, and all of this venison contained radionuclides from the SRS. The remaining beef obtained from the Martin area was acquired from stores, of which 50 percent was not contaminated because it was obtained from outside the SRS vicinity. Of the beef obtained from the Barnwell area, half came from sources local to the SRS, and half did not. Combining the venison obtained from hunting with other beef obtained in Martin, it was assumed that 62.5 percent of all beef obtained from Martin potentially contained radionuclides from the SRS.
- For the Outdoors person family, half the beef obtained from stores in the Jackson area came from sources local to Jackson, and half came from sources outside the SRS vicinity. However, it was assumed that all the beef obtained onsite from the SRS was venison and all had the potential for contamination.

Adjustment factors determined according to these assumptions are listed in Table E-31 for Rural Families One and Two. Adjustment factors for the remaining families are listed in Table E-32.

Table E-29 GENII-Modeled Age/Gender Categories for Beef, Poultry, Milk, and Eggs, Corresponding EPA 1997 Age/Gender Categories, and Calculated Consumption Rates

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged	Calculated Value – Average Consumption (kg/year or L/yr)			
		Beef	Poultry	Milk	Eggs
Infant (<1)	<1	25.2	1.5	131.8	1.8
Pre-School (1 – 4)	1 – 2 3 – 5	31.4	6.5	130.2	7.7
Child (5 – 11)	6 – 8 9 – 11 male	50.6	8.0	146.5	8.0
Teenager (12 – 17)	12 – 14 male 15 – 18 male	75.6	11.9	169.5	10.8
Adult Male (>18)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	78.1	11.3	73.7	13.9
Adult Female (>18)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	49.7	9.1	55.5	8.4

Source: EPA, 1997 (5).

Table E-30 Exposure Factors (kg/y) for Beef Ingestion Exposure Pathway

Individual	Rural Families One and Two, Urban/ Suburban Family, Near River Family	Delivery Person Family		Outdoors Person Family		Migrant Worker Family
		Martin	Barn-well	Jackson	SRS Onsite	
Adult Male	78.1	39.05	39.05	19.52	58.58	39.05
Adult Female	49.7	24.85	24.85	12.42	37.28	24.85
Children Born in 1955 and 1964:						
Infant	25.2	12.6	12.6	6.3	18.9	12.6
Preschool	31.4	15.7	15.7	7.85	23.55	15.7
School	50.6	25.3	25.3	12.65	37.95	25.3
Teen	75.6	37.8	37.8	18.9	56.7	37.8
Adult	78.1	39.05	39.05	19.52	58.58	39.05

Table E-31 Adjustment Factors for Beef Exposure Pathway, Rural Families One and Two

Individual		Adjustment Factors
Adult Male	Through 1959	0.75
	1960 and on	0.625
Adult Female	Through 1959	0.75
	1960 and on	0.625
1955 Child:	Infant (In 1955)	0.75
	Preschooler (1956 to 1959)	0.75
	School child (1960 to 1966)	0.625
	Teen (1967 to 1973)	0.625
	Adult (1974 to 1992)	0.625
1964 Child:	All ages (1964 to 1992)	0.625

Table E-32 Adjustment Factors for Beef Exposure Pathway, Remaining Scenarios

Individual	Urban/Suburban, Near River, & Migrant Worker Families	Delivery Person Family		Outdoors Person Family	
		Martin	Barnwell	Jackson	SRS Onsite
Adult Male	0.5	0.625	0.5	0.5	1.0
Adult Female	0.5	0.625	0.5	0.5	1.0
1955 Child	0.5	0.625	0.5	0.5	1.0
1964 Child	0.5	0.625	0.5	0.5	1.0

E.5.2.2.2 Exposure and Adjustment Factors for Poultry

For the poultry ingestion exposure pathway, the authors of this report adapted consumption rates from Table 11-10 of EPA, 1997 (5) (citing the 1977-78 NFCS), using the same approach as that for beef (Section E.5.2.2.1). Consumption rates for poultry have been presented in Table E-29. These consumption rates were used to develop exposure factors for poultry ingestion as listed in Table E-33.

Table E-33 Exposure Factors (kg/y) for Poultry Ingestion Exposure Pathway

Individual	Rural Families One and Two, Urban/ Suburban Family, and Near River Family	Delivery Person Family		Outdoors Person Family		Migrant Worker Family
		Martin	Barn-well	Jackson	SRS Onsite	
Adult Male:	11.3	5.65	5.65	2.825	8.475	5.65
Adult Female:	9.1	4.55	4.55	2.275	6.825	4.55
Children Born in 1955 and 1964:						
Infant	1.5	0.75	0.75	0.375	1.125	0.75
Preschool	6.5	3.25	3.25	1.625	4.875	3.25
School	8.0	4.0	4.0	2.0	6.0	4.0
Teen	11.9	5.95	5.95	2.975	8.925	5.95
Adult	11.3	5.65	5.65	2.825	8.475	5.65

Adjustment factors for poultry ingestion were determined in a similar manner as that for beef. It was assumed that both the Outdoors Person Family and the Delivery Person Family obtained some of their poultry as hunted fowl. That is:

- For Rural Families One and Two, it was assumed that up through the end of 1959, half the poultry was grown on the farm. All of this poultry contained radionuclides from the SRS. The other half came from local grocery stores, of which 50 percent was contaminated. Starting in 1960, 25 percent of the poultry was grown on the farm and contained radionuclides from the SRS. The other 75 percent of the poultry came from local grocery stores, of which half was contaminated. These assumptions are consistent with Lockridge (1) in that poultry was assumed to be a form of meat. Table E-34 lists the adjustment factors for Rural Families One and Two.
- For the Urban/Suburban Family, the Near River Family, and the Migrant Worker Family, it was assumed that half the poultry came from sources local to the SRS and half did not. This assumption is conservative: 1950's conditions for poultry consumption, as recommended in Lockridge (1), were assumed to be applicable to all years for these families (Table E-35). This assumption is consistent with those made for vegetables and fruit for these families (see Section E.5.2.1.1).
- For the Delivery Person Family, half the poultry came from the Martin area and half came from the Barnwell area. Of the poultry obtained from the Martin area, 25 percent was obtained from hunting wild fowl, and all of this poultry contained radionuclides from the SRS. The remaining poultry from the Martin area was acquired from stores, of which 50 percent was not contaminated because it was obtained from outside the SRS vicinity. Of the poultry obtained from the Barnwell area, half came from sources local to the SRS and half did not. Combining the wild fowl obtained from hunting with

other poultry obtained in Martin, it was assumed that 62.5 percent of poultry (including wild fowl) obtained from Martin potentially contained radionuclides from the SRS (Table E-35).

- For the Outdoors person family, it was assumed that half the poultry came from sources local to Jackson, and half the poultry came from sources outside the SRS vicinity. However, assumed that all the poultry obtained onsite from the SRS was hunted fowl (e.g., ducks), and all such fowl had the potential for contamination (Table E-35).

Table E-34 Adjustment Factors (kg/y) for Poultry Exposure Pathway, Rural Families One and Two

Individual		Adjustment Factor
Adult Male:	Through 1959	
	1960 and on	0.75
Adult Female:	Through 1959	
	1960 and on	0.75
1955 Child:	Infant (In 1955)	
	Preschooler (1956 to 1959)	0.75
	School child (1960 to 1966)	0.75
	Teen (1967 to 1973)	0.625
	Adult (1974 to 1992)	0.625
1964 Child:	All ages (1964 to 1992)	

Table E-35 Adjustment Factors (kg/y) for Poultry Pathway — Remaining Scenarios

Individual	Urban/ Suburban Family	Delivery Person Family		Outdoors Person Family		Near River Family	Migrant Worker Family
		Martin	Barn-well	Jackson	SRS Onsite		
Adult Male	0.5	0.625	0.5	0.5	1.0	0.5	0.5
Adult Female	0.5	0.625	0.5	0.5	1.0	0.5	0.5
1955 Child	0.5	0.625	0.5	0.5	1.0	0.5	0.5
1964 Child	0.5	0.625	0.5	0.5	1.0	0.5	0.5

E.5.2.2.3 Exposure and Adjustment Factors for Milk and Eggs

For the milk and egg ingestion exposure pathways, the authors of this report adapted consumption rates from Table 11.12 of EPA, 1997 (5), which cited the 1977-78 NFCS. These rates were adapted to the age and gender categories used in this report, using the same approach as that for beef and poultry. Table E-29 presents the consumption rates for milk and eggs (in units of L/y for milk, and kg/y for eggs). Table E-36 summarizes the exposure factors for milk and egg ingestion.

It was assumed that all milk and eggs were obtained from sources local to the SRS. Therefore, the adjustment factors for the milk and egg ingestion pathways were assumed to be unity for all scenarios and receptors.

Table E-36 Exposure Factors (kg/y) for Milk and Egg Ingestion Exposure Pathways

Individual	Rural Family One		Rural Family Two		Urban/Suburban*		Delivery Person	
	Milk	Eggs	Milk	Eggs	Milk	Eggs	Milk	Eggs
Adult Male	73.7	13.9	73.7	13.9	36.85/36.85	13.9	36.85	6.95
Adult Female	55.5	8.4	55.5	8.4	27.75/27.75	8.4	27.75	4.2
Children Born in 1955 and 1964:								
Infant	131.8	1.8	131.8	1.8	65.9/65.9	1.8	65.9	0.9
Preschool	130.2	7.7	130.2	7.7	65.1/65.1	7.7	65.1	3.85
School	146.5	8.0	146.5	8.0	73.25/73.25	8.0	73.25	4.0
Teen	169.5	10.8	169.5	10.8	84.75/84/75	10.8	84.75	5.4
Adult	73.7	13.9	73.7	13.9	36.85/36.85	13.9	36.85	6.95
Individual	**Delivery Person**		**Outdoors Person**		**Near River Family**		**Migrant Worker**	
	Milk	Eggs	Milk	Eggs	Milk	Eggs	Milk	Eggs
Adult Male	36.85	6.95	73.7	13.9	73.7	13.9	36.85	6.95
Adult Female	27.8	4.2	55.5	8.4	55.5	8.4	27.75	4.2
Children Born in 1955 and 1964:								
Infant	65.9	0.9	131.8	1.8	131.8	1.8	65.9	0.9
Preschool	65.1	3.85	130.2	7.7	130.2	7.7	65.1	3.85
School	73.3	4.0	146.5	8.0	146.5	8.0	73.25	4.0
Teen	84.8	5.4	169.5	10.8	169.5	10.8	84.75	5.4
Adult	36.9	6.95	73.7	13.9	73.7	13.9	36.85	6.95

*Although the Urban/Suburban family obtained all of its eggs from the Augusta area, it obtained half its milk from the Augusta area and half from the New Ellenton area. Hence (for example), the adult male annually consumed 36.85 kg of milk from Augusta, 36.85 kg of milk from New Ellenton, and 13.9 kg of eggs from Augusta.

E.5.2.3 Aquatic Food Ingestion

Exposures from ingestion of aquatic food products include exposures from ingestion of fish, mollusks, crustacea, and aquatic plants. The following are GENII variables for these exposure pathways:

- UAQU 1 – Fish daily consumption rate on days that consumption occurs (kg/d).
- TAQU 1 – Fish consumption period: days out of the year that consumption occurs (d/y).
- UAQU 2 – Mollusk daily consumption rate on days that consumption occurs (kg/d).
- TAQU 2 – Mollusk consumption period: days out of the year that consumption occurs (d/y).
- UAQU 3 – Crustacea daily consumption rate on days that consumption occurs (kg/d).
- TAQU 3 – Crustacea consumption period: days out of the year that consumption occurs (d/y).
- UAQU 4– Aquatic plant daily consumption rate on days that consumption occurs (kg/d).
- TAQU 4 – Aquatic plant consumption period: days out of the year that consumption occurs (d/y).

Radiation exposure through the aquatic food consumption pathway was modeled as occurring entirely from eating fish. Therefore, an exposure factor was calculated for fish consumption, in units of kg of fish consumed per year, in a manner linked to the UAQU 1 and TAQI2 GENII variables. Exposure factors for

mollusk, crustacea, and aquatic plant consumption were set equal to zero (UAQU 2 = UAQU 3 = UAQU 4 = 0).

The authors of this report considered fish consumption rate data from several references including EPA, 1997 (5); Hamby (6); EPA, 1991 (11); EPA, 1994 (15); and EPA, 2002 (16). These sources are mainly secondary references citing data from several studies, including the USDA, NFCS, and CSFII studies and several State-level studies. No studies, however, were local to South Carolina and Georgia. EPA, 1997 (5) values were used.

Table E-37 summarizes age- and gender-specific fish consumption rates.

Table E-37 GENII-Modeled Age and Gender Categories and Calculated Consumption Rates for Fish

Modeled Age Categories	Fish Consumption Rate (kg/yr)
Infant (<1)	4.2
Pre-School (1 – 4)	4.2
Child (5 – 11)	5.0
Teenager (12 – 17)	4.5
Adult Male (>18)	9.9
Adult Female (>18)	9.9

Table E-38 summarizes the exposure factors determined using these consumption rates.

Table E-38 Exposure Factors (kg/yr) for Fish Ingestion Exposure Pathway

Individual	Rural Family One	Rural Family Two	Urban/ Suburban Family	Delivery Person Family		Outdoors Person Family	Near River Family	Migrant Worker Family
	Briar Creek	Creeks, ponds near Williston	Savannah River near Augusta	Lower Three Runs Creek	Savannah River (Smith Lake)	Savannah River (various locations)	Savannah River (various locations)	Creeks, etc. near New Ellenton
Adult Male	9.9	9.9	9.9	4.95	4.95	9.9	9.9	4.95
Adult Female	9.9	9.9	9.9	4.95	4.95	9.9	9.9	4.95
Children Born in 1955 and 1964:								
Infant	4.2	4.2	4.2	2.1	2.1	4.2	4.2	2.1
Preschool	4.2	4.2	4.2	2.1	2.1	4.2	4.2	2.1
School	5.0	5.0	5.0	2.5	2.5	5.0	5.0	2.5
Teen	4.5	4.5	4.5	2.25	2.25	4.5	4.5	2.25
Adult	9.9	9.9	9.9	4.95	4.95	9.9	9.9	4.95

All fish eaten by Rural Families One and Two, the Urban/Suburban Family, and the Migrant Worker Family came from sources that are not hydrologically downgradient of any release by the SRS to surface water. For this reason, the adjustment factors for all members of these families were set to zero. However,

it was assumed that all of the fish annually consumed by the members of the Delivery Person Family, the Outdoors Person Family, and the Near River Family had the potential for radionuclide contamination caused by SRS activities. Hence, the adjustment factors for all these receptors were set to unity. Table E-39 summarizes adjustment factors according to these assumptions for the fish ingestion pathway.

Table E-39 Adjustment Factors (dimensionless) for Fish Ingestion Exposure Pathway

Individual	Rural Family One	Rural Family Two	Urban/ Suburban Family	Delivery Person Family		Outdoors Person Family	Near River Family	Migrant Worker Family
	Briar Creek	Creeks, ponds near Williston	Savannah River near Augusta	Lower Three Runs Creek	Savannah River (Smith Lake)	Savannah River (various locations)	Savannah River (various locations)	Creeks, ponds near New Ellenton
Adult Male	0	0	0	1.0	1.0	1.0	1.0	0
Adult Female	0	0	0	1.0	1.0	1.0	1.0	0
Children Born in 1955 and 1964:								
Infant	0	0	0	1.0	1.0	1.0	1.0	0
Preschool	0	0	0	1.0	1.0	1.0	1.0	0
School	0	0	0	1.0	1.0	1.0	1.0	0
Teen	0	0	0	1.0	1.0	1.0	1.0	0
Adult	0	0	0	1.0	1.0	1.0	1.0	0

E.5.2.4 Inadvertent Soil Consumption

This exposure pathway considers exposures from inadvertent ingestion of contaminated soil. The following are GENII variables for this exposure pathway:

- USOIL – Daily soil ingestion rates (milligrams/d), when consumption occurs.
- TSOIL – Soil contact days (days out of the year that soil is consumed).

Exposure factors for this exposure pathway represented the total mass of contaminated soil eaten during each year. They were calculated for each receptor and exposure location by multiplying the daily soil ingestion rate appropriate for that receptor by the days out of the year that the receptor stayed in any exposure location. The results were exposure factors in units of kg/y.

Soil ingestion rates were based on Table 4-23 of EPA, 1997 (5). Daily rates of 100 milligrams per day for children, and 50 milligrams per day for adults, were converted to annual rates (in units of kg/y) as summarized in Table E-40.

Table E-41 summarizes the exposure factors. They were calculated in the same manner as that used to determine exposure factors for the air inhalation exposure pathway (Section E.5.3.1). For example, the Adult Male of the Urban/Suburban family spent 2000 hours out of the year (8,760 hours) working onsite at the SRS. The exposure factor for the time spent at work was 0.0183 x (2000/8,760) = 0.00418 kg/year.

Adjustment factors were unity for all receptors and locations.

Table E-40 GENII-Modeled Age and Gender Categories and Calculated Rates for Soil Ingestion

Modeled Age Categories	Soil Ingestion (g/yr)
Infant (<1)	0.0365
Pre-School (1 – 4)	0.0365
Child (5 – 11)	0.0365
Teenager (12 – 17)	0.0365
Adult Male (>18)	0.0183
Adult Female (>18)	0.0183

Table E-41 Exposure Factors (kg/year) for Soil Ingestion Pathway

Individual	Years	Rural Family One		Rural Family Two	Urban/Suburban Family		Delivery Person Family	
		Girard	Waynes-boro	Willi-ston	Augusta	Onsite SRS	Martin	Onsite SRS
Adult M	All	0.0183	0	0.0183	0.0141	0.00418	0.000693	0.000836
Adult F	All	0.0183	0	0.0183	0.0183	0	0.000393	0
Children Born in 1955 and 1964	Infant	0.0365	0	0.0365	0.0365	0	0.001275	
	Preschool	0.0365	0	0.0365	0.0365	0	0.001275	0
	Schoolchild	0.0365	0	0.0365	0.0365	0	0.001275	0
	Teen	0.03125	0.00525	0.0365	0.0365	0	0.001275	0
	Adult M	0.0183	0	0.0183	0.0141	0.00418	0.00693	0.000836

Individual	Years	Delivery Person Family (continued)		Outdoors Person Family		Near River Family	Migrant Worker Family
		Allendale	Barnwell	Onsite SRS	Jackson	Martin	New Ellenton
Adult M	All	0.00334	0.0135	0.00418	0.0141	0.0183	0.009125
Adult F	All	0	0.0177	0	0.0183	0.0183	0.009125
Children Born in 1955 and 1964	Infant	0	0.0352	0	0.0365	0.0365	0.01825
	Preschool	0	0.0352	0	0.0365	0.0365	0.01825
	Schoolchild	0	0.0352	0	0.0365	0.0365	0.01825
	Teen	0	0.0352	0	0.0365	0.0365	0.01825
	Adult M	0.0034	0.0135	0.00418	0.0141	0.0183	0.009125

E.5.2.5 Inadvertent Ingestion of Surface Water While Swimming

This exposure pathway accounts for ingestion of contaminated water that occurs when an individual swims in contaminated water. The following are GENII variables for this exposure pathway:

- EVSWIM - Frequency of swimming use (event/day).
- TESWIM - Duration of swimming events (hours/event).
- TSWIM - Swimming days (days/year).
- USWIM – Ingestion rate of water while swimming (L/h).

Exposure factors determined in consideration of these variables are in units of L/y.

Swimming water ingestion rates were zero for Rural Families One and Two, the Migrant Worker Family, the Urban/Suburban Family, and the Outdoors Person Family because no swimming occurred in water that was hydrologically downgradient from the site. For the Delivery Person and the Near River Families, swimming water ingestion rates were estimated based on the time spent swimming and the ingestion rates while swimming. The swimming times were 21.2 hours/year for the Delivery Person Family, and 91 hours per year for the Near River Family (see Section E.5.1.4). The ingestion rate while swimming was 0.05 L/hr. This value was equal to EPA's default rate of water ingestion while swimming (5).

Table E-42 summarizes the exposure factors for the swimming water ingestion exposure pathway.

Table E-42 Exposure Factors (L/yr) for Swimming Water Ingestion Exposure Pathway

Individual	Rural Family One	Rural Family Two	Urban/ Suburban Family	Delivery Person Family	Outdoors Person Family	Near River Family	Migrant Worker Family
	Briar Creek	Savannah River	Savannah River	Lower Three Runs Creek	Savannah River	Savannah River	Savannah River
Adult Male	0	0	0	1.06	0	4.6	0
Adult Female	0	0	0	1.06	0	4.6	0
Children Born in 1955 and 1964:							
Infant	0	0	0	1.06	0	4.6	0
Preschool	0	0	0	1.06	0	4.6	0
School	0	0	0	1.06	0	4.6	0
Teen	0	0	0	1.06	0	4.6	0
Adult	0	0	0	1.06	0	4.6	0

E.5.3 Inhalation Exposure Route

E.5.3.1 Inhalation of Contaminated Air

This exposure pathway accounts for radiation exposure resulting from inhalation of airborne contaminants. The following are GENII variables for this exposure pathway:

- UINH: Air inhalation rate (m^3/day).
- TINH: Air inhalation period (days/year).

Exposure factors were created for each receptor by assuming a constant daily inhalation rate that was appropriate for the age and gender of the receptor, and by multiplying it by the number of days in a year that the receptor was at a specified exposure location. The total time that the receptor occupied all specified exposure locations was 365 days. The result was an average air inhalation rate in units of m^3 per year.

The authors of this report conservatively did not consider any differences in radiation exposure based on whether the receptor was inside or outside of a building. This was equivalent to assuming that indoor concentrations for constituents such as fine particulate matter and gasses were roughly equal to the outdoor concentrations. This situation could have existed if the receptors routinely left windows open or spent their time in structures that were not completely sealed.

Exposure factors for each receptor and exposure location were determined using the exposure rates recommended by EPA on Table 5.26 of EPA, 1997 (5), and the assumed days out of the year spent by each receptor at each exposure location. EPA, 1997 (5) provides recommended inhalation values for a more detailed distribution of ages and genders than was assumed for this study. Therefore, the EPA data were grouped into the age and gender categories that were considered in this report, and the EPA data in each group were averaged to align with the modeled categories. Table E-43 specifies the categories and data from this reference and the corresponding modeled categories and rates. Because both the modeled children were male, average exposure rates were calculated for the child (5-11) and teenage (12-17) years assuming male breathing rates (when specified by EPA). (The average annual air inhalation rate for the child was determined by averaging the three 6-8 years with the three 9-11 male years. The average annual air inhalation rate for the teenager was determined by averaging the three 12-14 male years with the four 15-18 male years.)

Table E-43 Air Inhalation Age/Gender Categories and Rates, and Corresponding GENII-Modeled Air Inhalation Age/Gender Categories and Calculated Rates

EPA 1997 Data (Table 5-26)		Corresponding Modeled Exposure Rate Values	
Age/Gender Categories	**Air Inhalation (m^3/day)**	**Modeled Age/Gender Categories**	**Air Inhalation (m^3/year)**
Infants (<1)	4.5	Infant (<1)	1,643
1 – 2 3 – 5	6.8 8.3	Pre-School (1 – 4)	2.,811
6 – 8 9 – 11 Male 9 – 11 Female	10 14 13	Child (5 – 11)	4,380*
12 – 14 Male 12 – 14 Female 15 – 18 Male 15 – 18 Female	15 12 17 12	Teenager (12 – 17)	5,892†
Adult Male 19 – 65+	15.2	Adult Male (>18)	5,548
Adult Female 19 – 65+	11.3	Adult Female (>18)	4,125

*Averaged using the three 6-8 years plus the three 9-11 male years.
†Averaged using the three 12-14 male years and the four 15-18 male years.
Source: EPA, 1997 (5).

Table E-44 lists the exposure factors calculated from the Table E-43 data, and from the assumed location times for each receptor.

The exposure factors for the teenagers of Rural Family One were split between Girard and Waynesboro, where the teenagers attended high school. Assuming a total of 1,260 hours per year spent in high school,

out of a total 8,760 hours in a year, the teenagers' exposure factors were 1260/8760 (5,892) = 847.5 m^3 per year (rounded to 848 m^3 per year) for the time spent in high school, and 5,892 – 847.5 = 5,044.5 m^3 per year (rounded to 5,045 m^3 per year) for the remaining time spent in Girard. For the remaining family members, exposure factors were calculated assuming that they spent the entire year in Girard.

Table E-44 Table E-44 Exposure Factors (m3/y) for Inhalation Exposure Pathway

Individual	Years			Rural Family Two	Urban/Suburban Family		Delivery Person Family	
		Girard	Waynes-boro	Williston	Augusta	Onsite SRS	Martin	Onsite SRS
Adult M	All	5,548	0	5,548	4,281	1,267	194	253
Adult F	All	4,125	0	4,125	4,125	0	144	0
Children Born in 1955 and 1964	Infant	1,643	0	1,643	1,643	0	57	0
	Preschool	2,811	0	2,811	2,811	0	98	0
	Schoolchild	4,380	0	4,380	4,380	0	153	0
	Teen	5,045	848	5,892	5,892	0	206	0
	Adult M	5,548	0	5,548	5,281	1,267	194	128

Individual	Years	Delivery Person Family (continued)		Outdoors Person Family		Near River Family	Migrant Worker Family
		Allendale	Barnwell	Onsite SRS	Jackson	Martin	New Ellenton
Adult M	All	1,013	4,088	1,267	4,281	5,548	2,774
Adult F	All	0	3,980	0	4,125	4,125	2,062
Children Born in 1955 and 1964	Infant	0	1,585	0	1,643	1,643	821
	Preschool	0	2,712	0	2,811	2,811	1,405
	Schoolchild	0	4,227	0	4,380	4,380	2,190
	Teen	0	5,686	0	5,892	5,892	2,946
	Adult M	1,013	4088	1,267	4,281	5,548	2,774

As addressed in Section E.5.1.1, the split in exposure factors between Girard and Waynesboro for the teenagers was applied for the entire time they were teenagers: for the six years comprising 1967 through 1972 for the Child Born in 1955, and the six years comprising 1976 through 1981 for the Child Born in 1964.

The exposure factors for the Adult Male of the Urban/Suburban Family were split between Augusta and his job onsite at the SRS. Assuming a total of 2,000 hours per year spent at work, again out of a total 8,760 hours in a year, the adult male exposure factors were 2000/8760 (5,548) = 1,267 m^3 per year for the time spent at work, and 5,548 – 1,267 = 4,281 m^3 per year for the remaining time spent in Augusta. Exposure factors for the Adult Female of this family were calculated assuming that she spent all her time was spent in Augusta. The two children spent all their time in Augusta until the each reached 18. Both then worked 2,000 hours per year onsite.

For the Delivery Person Family, the Adult Male worked in Allendale and also occasionally came onsite at the SRS for deliveries. The remainder of his time was spent between Barnwell, where he lived with his family, and Martin, where he and his family recreated and attended church. Table E-45 lists the total hours spent at each location for each family member.

Table E-45 Hours Spent by Each Member of the Delivery Person Family at Four Different Exposure Locations

Family Member	Martin	Onsite SRS	Allendale	Barnwell
Adult Male	306	400	1,600	6,454
Adult Female	306	0	0	8,454
Child Born in 1955	306	0	0	8,454
Child Born in 1964	306	0	0	8,454

For the Outdoors Person Family, exposure factors for the Adult Male were split between Jackson and his job onsite at the SRS. The adult male exposure factors were 2,000/8,760 x 5,548 = 1,267 m^3 per year for the time spent at work, and 5,548 – 1,267 = 4,281 m^3 per year for the time spent in Jackson. Exposure factors for the Adult Female of this family were calculated assuming that she spent all her time in Jackson. The two children were assumed to spend all their time in Jackson until they each reached age 18, after which they each worked onsite for 2,000 hours per year.

Exposure factors for all members of the Near River Family were calculated assuming that each member spent all their time in Martin.

The exposure factors for the members of the Migrant Worker Family were calculated assuming that each member spent all their time in New Ellenton, and that they were only in the SRS vicinity for half of any year.

Adjustment factors equaled unity for each receptor and location.

E.5.3.2 Inhalation of Resuspended Soil

This exposure pathway addresses inhalation of resuspended contaminated soil. The following are GENII variables for this exposure pathway:

- UINHR - Resuspended soil inhalation rate (m^3/day).
- TINHR - Resuspended soil inhalation period (days/year).
- FRINHR - Fraction of a day inhalation of resuspended soil occurs (unitless).

Exposure factors were calculated for each receptor and location based on an assumed daily inhalation rate for each receptor, and an assumed time spent at each location. It was assumed that resuspended contamination was breathed for 24 hours out of the day (FRINHR = 1). Therefore, the exposure factors for this exposure pathway were the same as those for inhalation of contaminated air that are listed in Table E-44.

Adjustment factors were assumed to be unity for all receptors and locations.

As discussed previously, no adjustments were made to account for any differences in air concentrations between indoor and outdoor exposures. The indoor and outdoor air concentrations were assumed to be the

same. (This is equivalent to the assumption that individuals left windows and doors of living or working structures open for ventilation, or that the structures were not perfectly sealed.)

E.6 References

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APPENDIX F SITE SPECIFIC PARAMETER VALUES USED FOR BASE CASE

This appendix presents values for nearly all parameters used in the GENII code[1] that do not depend on the behavior of the hypothetical receptors (exposure scenario family members) that were modeled for Phase III of the Savannah River Site (SRS) Dose Reconstruction Project. The appendix is in three sections:

- Section F.1: Food Chain Transfer Factors.
- Section F.2: Food Chain Variables.
- Section F.3: Additional Parameter Values.

The discussion refers to those GENII variables that were used for those assessment models and exposure pathways that were considered in Phase III. The GENII Software Design Document may be consulted for a complete list of variables considered in all assessment models and exposure pathways.

Values for parameters needed for human radiation dosimetry assessments (e.g., radionuclide-specific lung clearance classes) are provided in Section D.4 of Appendix D.

F.1 Food Chain Transfer Factors

Transfer factors are needed to model several food-chain pathways. Transfer factors for partitioning between radionuclide concentrations in soil to those in plants are used in the equations set forth in Section D.3.3.1. Transfer factors used to assess the uptake of radionuclides by animals, and the uptake of radionuclides by humans consuming the animals or the animal products, are used in the equations set forth in Section D.3.3.2. Transfer factors that address bioaccumulation of radionuclides in fresh-water fish are used in Section D.3.3 to assess uptake of radionuclides by humans consuming aquatic foods.

F.1.1 Introduction

The three sets of transfer factors used for this report are presented in Table F-1 along with units and GENII variable names. The three sets of transfer factors correspond to the following parameters:

- Bv_{ci}: Concentration ratio for root uptake of radionuclide i in crop type c (Section D.3.3.1).
- Fa_i: Transfer coefficient that relates daily intake rate by an animal to concentration in an edible animal product a (Section D.3.3.2).
- B_{qi}: Bioaccumulation factor for radionuclide i in aquatic food type q (Section D.3.3.3).

Table F-1 shows two sets of units. The first set comprises those units specified for the GENII software and has been simplified from the complete units by eliminating units that cancel each other. For example, the units for the soil-to-plant concentration ratio for animal forage (kg soil/kg dry) are actually a reduction of the ratio [Bq/kg dry forage] / [Bq/kg soil]. The second set comprises the complete units of the factor. These transfer factors are all element-specific (i.e., a single value for each transfer factor identified for a given element or isotope is used for all isotopes of that element). This is a common assumption made in environmental studies involving radionuclides because the chemical behavior in the environment depends on the atomic number rather than the atomic weight.

[1] All references to GENII in this chapter refer to Version 2 of the GENII code.

Table F-1 GENII Transfer Factors in Used in SRS Food Chain Modeling

Category	Variable	GENII Variable Name	GENII Units	Complete Units
Soil-to-Plant Concentration Ratios	Soil to Animal Forage	CLBVAF	kg soil/kg dry	(Bq/kg dry plant matter) / (Bq/kg soil)
	Soil to Grain	CLBVAG		
	Soil to Hay	CLBVAH		
	Soil to Cereal	CLBVCL		
	Soil to Fruit	CLBVFR		
	Soil to Leafy Vegetables	CLBVLV		
	Soil to Other Vegetables	CLBVOV		
	Soil to Root Vegetables	CLBVRV		
Animal-Intake-to-Animal-Product Transfer Factor Ratios	Feed to Egg	CLFEG	d/kg	(Bq/kg eggs) / (Bq/day intake)
	Feed to Animal Milk	CLFMK	d/L	(Bq/L milk) / (Bq/day intake)
	Feed to Animal Meat	CLFMT	d/kg	(Bq/kg meat) / (Bq/day intake)
	Feed to Poultry	CLFPL	d/kg	
Water-to-Aquatic-Food Bioaccumulation Factors (Freshwater)	Bioaccumulation in Freshwater Fish	CLBFF	L/kg	(Bq/kg fish) / (Bq/L water)

Table F-2 summarizes the isotopes and corresponding elements considered in the food-chain assessments.

Table F-2 Elements and Modeled Isotopes Requiring Transfer Factor Values

Atmospheric Release		Liquid Release	
C	(^{14}C)	P	(^{32}P)
Sr	(^{89}Sr, ^{90}Sr)	S	(^{35}S)
Y	(^{90}Y)	Co	(^{60}Co)
Ru	(^{103}Ru, ^{106}Ru)	Zn	(^{65}Zn)
I	(^{129}I, ^{131}I) (both elemental and organic)	Sr	(^{89}Sr, ^{90}Sr)
Cs	(^{137}Cs)	Y	(^{90}Y) *
Th	(^{231}Th, ^{234}Th) *	Nb	(^{95}Nb, ^{95m}Nb)
U	(^{234}U, ^{235}U, ^{236}U, ^{238}U)	Zr	(^{95}Zr)
Pu	(^{238}Pu, ^{239}Pu)	Tc	(^{99}Tc)
Am	(^{241}Am)	Ru	(^{103}Ru, ^{106}Ru)
		I	(^{129}I, ^{131}I)
		Cs	(^{134}Cs, ^{137}Cs)
		Ce	(^{141}Ce, ^{144}Ce)
		Th	(^{231}Th, ^{234}Th)*
		U	(^{234}U, ^{235}U, ^{236}U, ^{238}U)
		Pu	(^{238}Pu, ^{239}Pu)

*Transfer factors were needed for these radionuclides because they are decay products of other radionuclides released into air and water pathways from SRS operations.

No transfer factors were selected for tritium, carbon, and noble gases such as argon. For tritium and carbon, GENII determines transfer between compartments and media using special models as summarized in Sections D.3.4.1.7 and D.3.4.2.3. For argon and other noble gases, which do not interact chemically except in unusual circumstances not found in the environment, transfer through the food chain does not occur. Hence, no transfer factors were assumed for noble gasses.

F.1.2 Limitations and Uncertainties in Selecting Transfer Factor Values

In selecting values for transfer factor factors for this study, two limitations became apparent: (1) the use of the same transfer factor in multiple pathways, and (2) limitations in the availability of site-specific transfer factor values.

F.1.2.1 Use of Transfer Factors for Different Pathways

A limitation on selecting values for transfer factors was that GENII requires that certain transfer factors be used for multiple pathways (1). For example, GENII applies the variable used for the soil-to-leafy-vegetable transfer factors (CLBVLV) to four different transport pathways (see Table F-3).[2]

Table F-3 Transfer Factors used in GENII for Multiple Pathways

GENII Transfer Factor	Pathways Covered in GENII
Soil-to-leafy-vegetables (CLBVLV)	• Soil-to-leafy-vegetables (for leafy vegetables that are subsequently consumed by humans, CLBVLV) • Soil-to-beef-cattle-forage (for pasture grass that is subsequently consumed by beef cattle, CLBVAF) • Soil-to-milk-cow-forage (for pasture grass that is subsequently consumed by milk cows, CLBVAF) • Soil-to-milk-cow-feed (for hay that is subsequently consumed by milk cows, CLBVAH)
Soil-to-cereal (CLBVCL)	• Soil-to-cereal (for cereal that is subsequently consumed by humans, CLBVCL) • Soil-to-beef-cattle-feed (for grain that is subsequently consumed by beef cattle, CLBVAG) • Soil-to-poultry-feed (for grain that is subsequently consumed by poultry, CLBVAG) • Soil-to-egg-animal-feed (for grain that is subsequently consumed by egg-producing chickens, CLBVAG)
Soil-to-other-vegetable (CLBVOV)	• Soil-to-other-vegetables (for other vegetables that are subsequently consumed by humans, CLBVOV) • Soil-to-root-vegetables (for root vegetables that are subsequently consumed by humans, CLBVRV)

[2] In this case, the FRAMES software that forms the user interface for GENII lets the user input values for three different transfer factors (CLBVLV, CLBVAF, and CLBVAH). But only CLGVLV is actually read by GENII and it is used for two different pathways. GENII ignores the values input for the other variables.

Because of GENII's calculational simplification, values for the transfer factors listed on the left side of Table F-3 had to be selected based on its understanding of the type of crop or food product represented in each segment of the food chain involving that transfer factor. For soil-to-plant transfer factors, Table F-4 lists the crops or food products to which the transfer factors were applied. Figure F-1 illustrates how the transfer factor variables are used in the food-chain pathways modeled by GENII.

Table F-4 Crops or Food Products represented by GENII Transfer Factors in SRS Exposure Scenarios

GENII Variable Used in Calculations	Pathway and GENII Variable	Crop or Food Product
CLBVLV	Soil-to-Leafy Vegetables (CLBVLV)	Locally-produced leafy vegetables
	Soil-to-Animal Forage (CLBVAF)	Locally-grown Bermuda grass used as pasture for beef cattle and milk cows as well as stored Bermuda grass green chop consumed by beef cattle
	Soil-to-Hay (CLBVAH)	Locally-produced corn silage used as feed for milk cows
CLBVCL	Soil-to-grain (CLBVAG)	Locally-produced corn grain used as feed for beef cattle, poultry, and egg animals (chickens)
	Soil-to-cereal (CLBVCL)	Locally-produced corn grain consumed by humans
CLBVFR	Soil-to-Fruit (CLBVFR)	Locally-produced fruit
CLBVOV	Soil-to-Other Vegetables (CLBVOV)	Locally-produced non-leafy vegetables
	Soil-to-Root Vegetables (CLBVRV)	Locally-produced non-leafy vegetables

For the CLBVLV transfer factor, three different crops were considered when assigning a value for each element listed in Table F-3. The preparers selected values generally considering the most conservative (i.e., largest) values of those available in the literature for the transfer factor as applied to the three pathways. Although this approach may have overestimated the exposure through the different pathways covered by the CLBVLV transfer factor, implementing this approach was relatively straightforward. Otherwise, extensive calculations would have been required to determine the pathways that were the most dominant or representative of the total exposure to human receptors. Determining the soil-to-plant transfer

(soil-to- leafy-vegetable, soil-to-beef-animal-forage, soil-to-milk-animal-forage, and soil-to-milk-animal-feed) that were most representative would have involved calculating the total dose summed up over all soil-to-plant transfer pathways, which would have been calculated using a different transfer factor value for each soil-to-plant transfer pathway.

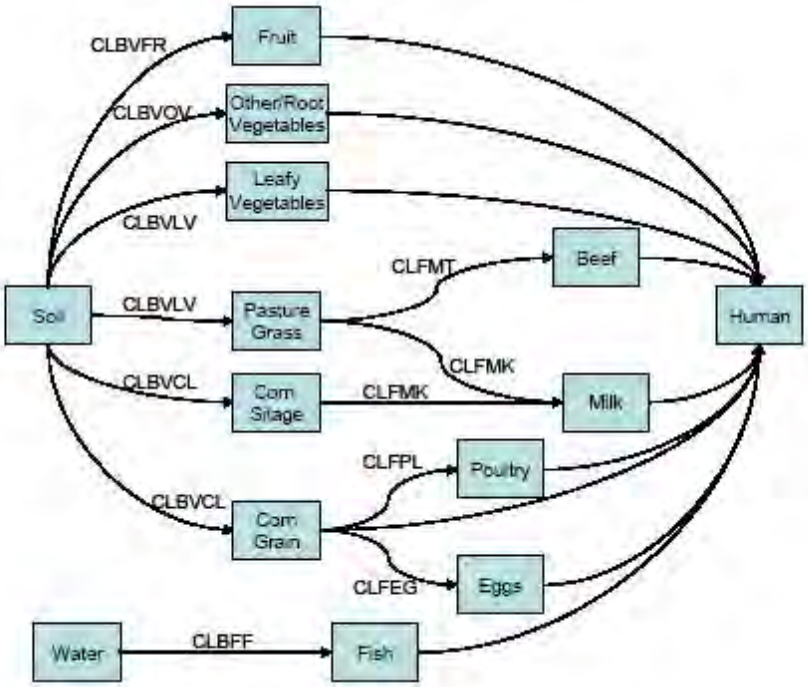

Figure F-1 Exposure Pathways of the Food Chain and Corresponding Transfer Factor Variables Used by GENII

Although the exposure through human consumption of leafy vegetables would have been relatively easy to determine, the exposure through the other pathways would have been more complex to model. It would have required calculations involving the amount of contaminated plant food intake by milk and meat producing animals, the amount of milk and meat consumed by each receptor at each exposure location (including the different amounts consumed by the different age groups), and the values of the other transfer factors that formed the food chain (the animal-intake-to-milk and animal-intake-to-meat factors).

Similar considerations guided the selection of values for the soil-to-cereal transfer factor, CLBVCL, a parameter representing corn consumed by humans, poultry, and egg animals, and corn silage consumed by milk cows. The largest values were again selected from the literature.

F.1.2.2 Limitations in Site-Specific Values for Transfer Factors

A substantial body of literature exists for various transfer factors. This literature includes numerous studies that examine radionuclide transport through the food chain. These studies provide experimental results for specific environmental conditions. For example, soil-to-plant factors are typically specified for individual plant species, soil conditions, and growing conditions. Because transfer factor values cited in the literature often range over several orders of magnitude, there is considerable uncertainty in selecting any single value assigned to a given transfer factor.

A three-step process—illustrated in Figure F-2—was used to select transfer factor values for this report. The first step in determining values was to consider data for local or site-specific conditions. Where local data were not available, default values were used. The first reference source used for default values was *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments*, Technical Reports Series No. 364 (2). For cases where the handbook (2) did not contain a default value, the GENII default was used. Site-specific data and default values were compared where possible. Where site-specific values were selected, the corresponding value from the handbook (2) is provided for information. Where the selected values are considerably different from the handbook (2) values, the 95-percent confidence range, if cited in the handbook (2), is also provided for information.

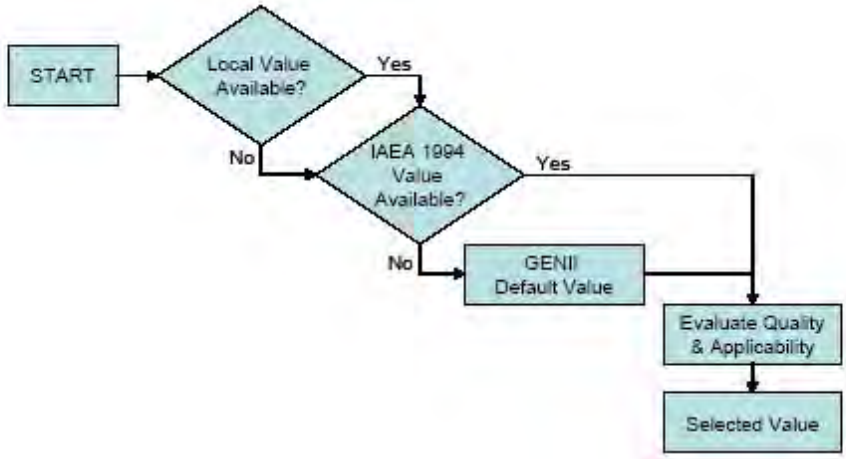

Figure F-2 Process for Selecting Transfer Factor Values

F.1.2.2.1 Site-specific Values

Site-specific data were used to identify values for several transfer factors for four elements being modeled—strontium, cesium, plutonium, and americium. Using data from Friday et al.(3) and, in some cases, a combination of data from Friday et al. (3) and the International Atomic Energy Agency's (IAEA) *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments* (2), the selected values and the rationale for their determination are described in Table F-5. In general, site-specific values were used without modification if they were within two orders of magnitude of generic values; if the differences were larger, then a geometric mean of the site specific and generic value was usually selected.

In selecting values for some variables, the preparers took into account the GENII use of the same values for some transfer factors. In particular, for the soil-to-leafy-vegetable transfer factor (which is also used for beef cattle forage, milk cow forage, and milk cow feed), where the approach was to select the largest values, only a few SRS-specific values were available from the literature. In no case were values cited for more than one plant species for a given radionuclide. For the soil-to-cereal transfer factors, the values selected corresponded to corn grain. Corn was selected over other crops (wheat, rice, etc.) because corn is grown in the region (4) and could have been consumed by humans as well as poultry.

Table F-5 Site-Specific Transfer Factor Values Calculated Using Data from Friday 1996

Pathway	Value and Rationale
Strontium	
Water-to-Freshwater-Fish	Value = 450 (Strontium) Friday et al. (3) presents two values for piscivores (3,400) and benthic invertebrate and fish feeders (610). The average value is ~2,000. This value is higher than the IAEA (2) default value (60) by a factor of ~33 and is outside the range of measured values (1 – 1,000) cited in the IAEA report. Because the values from Friday et al. (3) are so high and represent only two data points, the geometric mean (450) of the site-specific average value (2,000) and the generic value (60) was used.
Soil-to-Cereal	Value = 0.15 (Strontium) Friday et al. (3) provides a single value for corn grain of 0.15. Corn grain is consumed by humans and by poultry. This value is smaller than the IAEA (2) default value (0.21) by a factor of ~1.4.
Cesium	
Water-to-Freshwater-Fish	Value = 4,700 (Cesium) Friday et al. (3) presents values for different types of fish muscle. An average of three mean values was taken for surface and midwater insectivores (7,009), insect and bottom invertebrate feeders (911), and piscivores (10,980). The average value (6,300) is larger than the value used by the SRS (3,000) in the Savannah River Site Environmental Report for 2001(5) by a factor of ~2 and the IAEA (2) expected value (2,000) by a factor of ~. It is above the 95 percent confidence range (30 – 3,000) cited by IAEA (2). The value selected (4,700) was the geometric average of the average of the site-specific values and the IAEA expected value. Friday et al. (3) states "...the relatively high bioconcentration factors of ^{137}Cs in fish flesh can be largely explained by the low concentrations of potassium in the water" (p.14). Other SRS studies (5,6) have recommended a value of 3000 kg/L.
Soil-to-Leafy-Vegetables	Value = 5.31 (Cesium) Friday et al. (3) provides a mean value for Bahia Grass of 5.31. Bahia grass is the primary forage for cattle, and the soil-to-leafy vegetable factor is used for soil-to-cattle-forage in GENII. This value is larger than the IAEA (2) default value (0.46) by a factor of ~12. Friday et al. (3) states, "The site-specific bioconcentration factors determined for plants and grasses are higher than values reported in the literature and are probably due to the local clay content of the soils at the SRS" (p.18).
Soil-to-Cereal	Value = 0.02 (Cesium) Friday et al. (3) provides a single value for corn grain of 0.01. Corn grain is consumed by humans and by poultry. This value is smaller than the IAEA (2) default value (0.026) by a factor of ~3. However, it is within the 95 percent confidence range (0.0026 – 0.26) cited by IAEA (2). The selected value, 0.02, is the geometric mean of the site-specific and IAEA default values.
Soil-to-Other-Vegetables	Value = 0.9 (Cesium) Friday et al. (3) provides a single value for fresh vegetables of 0.9. This value is higher than the IAEA (2) default value (0.46) by a factor of ~2.

Pathway	Value and Rationale
Plutonium	
Water-to-Freshwater-Fish	Value = 4,700 (Plutonium) Friday et al. (3) provides three values for fish muscle, including two values for piscivores (2,600 and 5,600) and one value for benthic invertebrate and fish feeders (12,000). The average value is ~6,700; the geometric average is 5,600. This value is higher than the IAEA (2) expected value (30) by a factor of ~190 and is higher than the 95 percent confidence range (4 – 300) cited by IAEA (2). The value selected (4,700) was the geometric average of the average of the site-specific values and the IAEA expected value. Friday et al. (3) states, "Transuranic elements are known to be fixed by clay minerals and complexed by organic matter which may decrease their availability. Zooplankton and benthic insect larvae have high surface to volume ratios. This allows their surfaces as well as their guts to carry sediment and sestonic particles, which adsorb transuranic particles; thus resulting in higher bioconcentration factors... " (p.27). Additionally, for general population dose calculations, the SRS has used a value of 3,000 (5,6).
Soil-to-Cereal	Value = 6E-5 (Plutonium) Friday et al. (3) provides a single value for corn grain of $6x10^{-5}$. This value is larger than the IAEA (2) default value ($8.6x10^{-6}$) by a factor of ~7.
Soil-to-Leafy-Vegetables	Value = 0.0022 (Plutonium) Friday et al. (3) provides maximum and minimum values for Bahia grass of $4.4x10^{-3}$ and $8.9x10^{-5}$. The average of these two values is ~$2.2x10^{-3}$ (the geometric average is $6.3x10^{-4}$). The average value is larger than the IAEA (2) default value ($3.4x10^{-4}$) by a factor of ~6.5; the geometric average is larger by a factor of ~1.8. Both values are within the 95 percent confidence range ($5x10^{-5}$ – 0.65) cited by IAEA (2). The selected value is the average of the site-specific values.
Americium	
Water-to-Freshwater-Fish	Value = 2,400 (Americium) Friday et al. (3) provides two values for fish muscle, including one value for piscivores (2,500) and one value for benthic invertebrate and fish feeders (4,200). The average value is ~3,400; the geometric mean is 3,200. The average value is larger than the IAEA (2) expected value (30) by a factor of ~140, and the geometric mean is larger by a factor of ~110. Both values are larger than the 95 percent confidence range (30 – 300) cited by IAEA (2). The value selected (2,400) was the geometric average of the average of the site-specific values and the IAEA expected value. The explanation for the higher site-value for Americium is same as that for plutonium (Friday et al. [3]).
Soil-to-Leafy-Vegetables	Value = 0.067 (Americium) Friday et al. (3) provides a mean value for Bahai grass of 0.067. This value is larger than the IAEA (2) default value ($1.2x10^{-3}$) by a factor of ~56.

F.1.2.2.2 IAEA Default Values

Default values from IAEA were found for most radionuclides and pathways (See Table F-6). In general, only a single value was provided for each animal-intake-to-milk, meat, poultry, and egg pathways. However, for soil-to-plant transfer factors, IAEA (2) listed multiple values for different plant species and soil conditions. The following different approaches were used to select from among different plant species:

- For the soil-to-leafy-vegetable transfer factor, different values were considered for both leafy vegetables and grass forage. The available values in each group were averaged, and the highest calculated average value was used. In some cases, only a single value was available, and in other cases multiple values were considered.
- For the soil-to-cereal transfer factor, values for corn grain were preferred over other values. But in cases where no value was available for corn grain, other values for grains and corn fodder were averaged.
- For the soil-to-other vegetable transfer factor, available values were averaged.

In addition, transfer factor values were frequently specified for different soil conditions. In these cases, "sand, pH5" was selected because this condition was judged most similar to the soils surrounding the SRS. Other soil conditions (clay, peat) were not considered when data for sandy soil were available. For instances where IAEA (2) cited multiple values, Table F-6 lists the values considered and calculated.

F.1.2.2.3 GENII Default Values

IAEA (2) did not recommend values for some radionuclides and pathways. For these cases, the default values specified by GENII were used. The GENII default values are generally specified in both the constituent library included in the GENII software and in Appendix D of the GENII Software Design Document (7). A few of the values were only documented in the constituent library. The GENII default values are not specific to plant species, soil types, or growing conditions.

F.1.2.2.4 References Cited in IAEA (2) and PNNL (7)

For each of the default values taken from IAEA (2), Table F-7 identifies the previous reference (generally the primary reference) cited by IAEA (2). With a few exceptions, Table F-7—for each GENII default value taken from PNNL (7)—also identifies the previous reference (generally the primary reference) cited by PNNL (7). These reference citations are provided for information only. The selection of transfer factor values was based on information and recommendations in IAEA (2) and PNNL (7). The references cited by these documents generally were not researched.

F.1.3 Transfer Factor Values Used in Report

Table F-8 lists the transfer factor values used and selected using the process outlined above. The entry "Not Specified" in Table F-8 indicates that the exact species of plant, on which the transfer factor was based, was not provided by the source. The citations in the footnotes of Table F-8 refer to the references listed in Table F-7.

Table F-6 Default Transfer Factor Values Calculated from IAEA 1994

Nuclide and Pathway	Selected Value	Values Cited	
Cobalt – Leafy Vegetables	0.20 (average of cabbage, lettuce, and spinach)	Grass	$5.4x10^{-02}$
		Cabbage	$4.4x10^{-02}$
		Lettuce	$2.8x10^{-01}$
		Spinach	$2.9x10^{-01}$
Cobalt – Other/Root Vegetables	0.11 (average of cited values)	Bean pods	$3.0x10^{-02}$
		Carrot roots	$1.3x10^{-01}$
		Radish roots	$1.2x10^{-01}$
		Potato tubers	$6.0x10^{-02}$
		Mixed green vegetables	$2.x10^{-01}$
Zinc – Cereals	1.0 (average of cited values)	Barley grain	$8.8x10^{-01}$
		Wheat grain	1.6
		Maize fodder	$5.6x10^{-01}$
Zinc – Leafy Vegetables	3.3 (highest value)	Grass	$9.9x10^{-01}$
		Spinach	3.3
Zinc – Other/Root Vegetables	12 (average of cited values)	Bean pod	$7.1x10^{-01}$
		Potato tuber	$3.5x10^{+01}$
		Broccoli	$8.2x10^{-01}$
Strontium – Leafy Vegetables	1.7 (grass in sand pH5)	Grass in sand pH5	1.7
		Grass in peat pH4	$3.4x10^{-01}$
Strontium – Other/Root Vegetables	1.7 (average of values in sand pH5)	Pea/bean pod in clay loam pH6	1.3
		Pea/bean pod in sand pH5	2.2
		Root crops in clay loam pH6	1.1
		Root crops in sand pH5	1.4
		Potato tubers in clay loam pH6	$1.5x10^{-01}$
		Potato tubers in sand pH5	$2.6x10^{-01}$
		Potato tubers in peat pH4	$2.0x10^{-02}$
		Green veg exc. spinach in clay loam pH6	2.7
		Green veg exc. spinach in sand pH5	3.0
		Green veg exc. spinach in peat pH4	$2.6x10^{-01}$
Technetium – Leafy Vegetables	940 (average of cabbage, lettuce, and spinach)	Grass	$7.6x10^{+01}$
		Cabbage	$1.2x10^{+01}$
		Lettuce	$2.0x10^{+02}$
		Spinach	$2.6x10^{+03}$
Technetium – Other/Root Vegetables	28 (average of cited values)	Pea/bean pod	4.3
		Turnip root	$7.9x10^{+01}$
		Potato tuber	$2.4x10^{-01}$
Thorium – Other/Root Vegetables	$6.9x10^{-03}$ (average of cited values)	Bean pod	$1.2x10^{-04}$
		Carrot root	$3.0x10^{-04}$
		Radish root	$3.9x10^{-02}$
		Potato tuber	$5.6x10^{-05}$
		Sweet potato tuber	$2.9x10^{-05}$
		Mixed green vegetables	$1.8x10^{-03}$
Uranium – Other/Root Vegetables	0.011 (average of cited values)	Mixed roots	$1.4x10^{-02}$
		Potato tuber	$1.1x10^{-02}$
		Mixed green vegetables	$8.3x10^{-03}$

Nuclide and Pathway	Selected Value	Values Cited	
Plutonium – Other/Root Vegetables	$8.2x10^{-04}$ (average of cited values)	Bean pod	$6.1x10^{-05}$
		Carrot root	$4.4x10^{-03}$
		Radish root	$7.7x10^{-04}$
		Onion root	$8.7x10^{-05}$
		Mixed roots	$9.1x10^{-04}$
		Potato tuber, swede	$1.5x10^{-04}$
		Cucumber	$9.0x10^{-05}$
		Mixed green vegetables	$7.3x10^{-05}$
Americium – Other/Root Vegetables	$8.4x10^{-04}$ (average of cited values)	Bean pod	$3.9x10^{-04}$
		Carrot root	$2.2x10^{-03}$
		Radish root	$1.4x10^{-03}$
		Onion root	$1.6x10^{-04}$
		Potato tuber flesh	$2.0x10^{-04}$
		Mixed green vegetables	$6.6x10^{-04}$

Table F-7 Previous and Primary References Cited in [IAEA 1994] and [PNNL 2002]

Citation	Reference	Application
Baes 1984 (8)	Baes CF, Sharp RD, Sjoreen AL, Shor RW. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture. ORNL-5786. Oak Ridge National Laboratory, TN. 1984.	Feed-to-Milk
Bishop 1989 (9)	Bishop GP, Beetham CJ, Cuff YS. Review of Literature for Chlorine, Technetium, Iodine and Neptunium, Nirex Radioactive Waste Disposal Safety Studies. Rep. NSS/R193, UK Nirex Ltd. Harwell. 1989.	Feed-to-Beef
CEC 1987 (10)	Commission of the European Communities. 1987. Radionuclide Transfer Factors for Animal Feedingstuffs and Animal Products. Doc. 7682/87. Luxembourg.	Feed-to-Milk
Coughtrey 1983 (11)	Coughtrey PJ, Thorne MC. 1983. Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems, A Critical Review of Data, Vols. 1 – 6. A.A. Balkema, Rotterdam.	Soil-to-Plant
Coughtrey 1990 (12)	Coughtrey, PJ. Radioactivity Transfer to Animal Products. Rep EUR 12608 EN, Commission of the European Communities, Luxembourg. 1990.	Feed-to-Milk, Beef, Poultry, Egg
Cramp 1990 (13)	Cramp TJ, Cuff YS, Davis A, Morgan JE. Review of Data for Uranium, Nickel, and Cobalt. Rep 2150-RI. Associated Nuclear Services Ltd, Epsom. 1990.	Feed-to-Beef
Ennis 1988a (14)	Ennis ME Jr, Ward GM, Johnson JE, Boamah KN. Transfer Coefficients of Selected Radionuclides to Animal Products. II Hen Eggs and Meat, Health Physics 54. pp. 167-170. 1988.	Feed-to-Poultry, Egg
Ennis 1988b (15)	Ennis ME, Johnson JE, Ward GM, Voigt GM. A Specific Activity Effect in the Metabolism of Technetium. Health Physics 54. pp. 157-160. 1988.	Feed-to-Poultry

Citation	Reference	Application
Frissel 1989 (16)	Frissel MJ, van Bergeijk KE. Mean Transfer Values Derived by Simple Statistical Regression Analysis, Sixth Report of IUR Working Group on Soil-to-Plant Transfer Factors, RIVM Bilthoven. 1989.	Soil-to-Plant
Frissel 1992 (17)	Frissel, MJ. An Update of the Recommended Soil-to-Plant Transfer Factors, Eighth Report of the IUR Working Group on Soil-to-Plant Transfer, IUR, Balen, Belgium. 1992.	Soil-to-Plant
Gerzabek 1993 (18)	Gerzabek MH, Horak O, Mohamad S, Muck K. Gefabversuche zum Radionuclidtransfer Boden-Pfanze, Fusionsreaktor – Erste Wand, Rep. OEFZS A-2531, Osterreichisches Forschungszentrum Seibersdorf, 22-31. 1993.	Soil-to-Plant
Handl 1989 (19)	Handl J, Pfau A.. Long-Term Transfer of ^{129}I into the Food Chain, Sci. Total Environ. 85. 245-252. 1989.	Feed-to-Beef
Hoffman 1988 (20)	Hoffman FO, Amaral E, Mohrbacher DA, Deming E. The Comparison of Generic Model Predictions with Chernobyl Fallout Data on the Transfer of Radioiodine Over the Air-Pasture-Cow-Milk Pathway, J. Environmental Radioactivity 8. 53-71. 1988.	Feed-to-Milk
Johnson 1988 (21)	Johnson JE, Ward GM, Ennis ME Jr, Boamah KN. Transfer Coefficients of Selected Radionuclides to Animal Products. 1. Comparison of Milk and Meat from Dairy Cows and Goats, Health Physics 54, 161-166. 1988.	Feed-to-Milk, Beef
Kennedy 1992 (22)	Kennedy WE Jr, Strenge DL. Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent. Pacific Northwest Laboratory, NUREG/CR-5512. Richland, WA. 1992.	Soil-to-Plant
Morgan 1990 (23)	Morgan JE, Beetham CJ. Review of Literature for Radium, Protactinium, Tin, and Carbon, Nirex Radioactive Waste Disposal Studies, UK Nirex Ltd, Harwell. 1990	Feed-to-Milk
Napier 1988 (24)	Napier BA, Peloquin RA, Strenge DL, Ramsdell JV. GENII – The Hanford Environmental Radiation Dosimetry Software System. Pacific Northwest Laboratory. PNL-6584. Richland, WA. 1988.	Soil-to-Plant
Ng 1977 (25)	Ng YC, Colsher CS, Quinn DJ, Tompson SE. Transfer Coefficients for the Prediction of the Dose to Man via the Forage-Cow-Milk Pathway from Radionuclides Released to the Biosphere. UCRL-51939. Lawrence Livermore National Laboratory, California. 1977.	Feed-to-Milk
Ng 1982a (26)	Ng, YC, Colsher CS, Thompson, SE. Soil-to-Plant Concentration Factors for Radiological Assessments, Rep. NUREG/CR-2975 UCID-19463, Lawrence Livermore National Laboratory, CA. 1982.	Soil-to-Plant
Ng 1982b (27)	Ng, YC. A Review of Transfer Factors for Assessing the Dose from Radionuclides in Agricultural Products, Nucl. Saf. 23. 57-71. 1982.	Feed-to-Milk
Ng 1982c (28)	Ng, YC, Colsher CS, Thompson, SE. Transfer Coefficients for Assessing the Dose from Radionuclides in Meat and Eggs, Final Rep. to USNRC NUREG/CR-2976 UCID-19464 Lawrence Livermore National Laboratory, CA. 1982.	Feed-to-Beef, Poultry, Egg

Table F-8 Selected Values for Transfer, Bioconcentration, and Bioaccumulation Factors

Nuclide	Soil-to-Plant Factors (dry kg/dry kg) [ad]				Animal-Intake-to-Animal Product Factors				
	Cereal and Grain (CLBVCL, CLBVAG)	Leafy Vegetables, Animal Forage, and Hay (CLBVLV, CLBVAF, CLBVAH)	Other Vegetables and Root Vegetables (CLBVOV, CLBVRV)	Fruit (CLBVFR)	Animal Milk (CLFMK) (kg/L)	Animal Meat (CLFMT) (beef) (kg/kg)	Poultry (CLFPL) (kg/kg)	Egg (CLFEG) (kg/kg)	Freshwater Fish (CLBFF) Edible Portions (L/kg)
Phosphorus	3.5 [b]	3.5 [b]	3.5 [y]	3.5 [y]	$1.6x10^{-02}$ [j]	$5x10^{-02}$ [k]	0.19 [a]	1.0 [a]	$5x10^{+04}$ [i]
Sulfur	1.5 [b]	1.5 [b]	1.5 [y]	1.5 [y]	$1.6x10^{-02}$ [j]	$2x10^{-01}$ [l]	2.3 [m]	7.0 [m]	800 [i]
Cobalt	Cereal grain $3.7x10^{-03}$ [c]	Average of 3 values 0.20 [c]	Average of 5 values 0.11 [c]	7 e-03 [y]	Organic cobalt $3xx10^{-04}$ [n]	Organic cobalt $1x10^{-02}$ [k]	2 [k]	0.1 [k]	300 [i]
Zinc	Wheat grain 1.6 [c]	Spinach 3.3 [c]	Average of 3 values 12 [c]	0.9 [y]	0.01 [p]	0.1 [k]	7 [k]	3 [k]	1,000 [i]
Strontium	Site-specific corn grain 0.15 [d]	Grass in sand pH5 1.7 [e]	Average of 4 values 1.7 [e]	Fruit in sand pH5 0.2 [e]	$2.8x10^{-03}$ [o]	$8x10^{-03}$ [o]	0.08 [o]	0.2 [o]	450 [d]
Yttrium	Not specified 0.01 [f]	Not specified 0.01 [f]	Not specified 0.01 [f]	Not specified 0.01 [f]	$2x10^{-05}$ [p]	$1x10^{-03}$ [k]	$1x10^{-02}$ [k]	$2x10^{-03}$ [k]	30 [i]
Niobium	$2.5x10^{-2}$ [g]	$2.5x10^{-2}$ [g]	Bean pod $1.7x10^{-02}$ [h]	$2.5x10^{-02}$ [g]	$4.1x10^{-07}$ [q]	$3x10^{-07}$ [q]	$3x10^{-04}$ [r]	$1x10^{-03}$ [r]	300 [i]
Zirconium	Not specified $1x10^{-03}$ [f]	Not specified $1x10^{-03}$ [f]	Not specified $1x10^{-03}$ [f]	Not specified $1x10^{-03}$ [f]	$5.5x10^{-07}$ [q]	$1x10^{-06}$ [q]	$6x10^{-05}$ [r]	$2x10^{-04}$ [r]	300 [i]
Technetium	Cereals grain 0.73 [c]	Average of 3 values 940 [c]	Average of 3 values 28 [c]	1.5 [y]	$2.3x10^{-05}$ [q]	$1x10^{-04}$ [aa]	0.03 [s]	3 [r]	20 [i]

Nuclide	Soil-to-Plant Factors (dry kg/dry kg) [ad]				Animal-Intake-to-Animal Product Factors				
	Cereal and Grain (CLBVCL, CLBVAG)	Leafy Vegetables, Animal Forage, and Hay (CLBVLV, CLBVAF, CLBVAH)	Other Vegetables and Root Vegetables (CLBVOV, CLBVRV)	Fruit (CLBVFR)	Animal Milk (CLFMK) (kg/L)	Animal Meat (CLFMT) (beef) (kg/kg)	Poultry (CLFPL) (kg/kg)	Egg (CLFEG) (kg/kg)	Freshwater Fish (CLBFF) Edible Portions (L/kg)
Ruthenium	Wheat grain $5x10^{-03}$ [c]	Cabbage 0.2 [c]	Not specified 0.04 [f]	Not specified 0.04 [f]	$3.3\ x10^{-06}$ [o]	0.05 [o]	8 [o]	$5x10^{-03}$ [o]	10 [i]
Iodine	Not specified $2x10^{-02}$ [f]	Grass $3.4x10^{-03}$ [c]	Not specified 0.02 [f]	Not specified 0.02 [f]	0.01 [t]	0.04 [u]	0.01 [r]	3 [r]	40 [i]
Cesium	Corn grain 0.02 [d]	Site-specific Bahai grass 5.31 [d]	Site-specific value 0.9 [d]	Tomato fruit 0.22 [c]	$7.9x10^{-03}$ [o]	0.05 [o]	10 [o]	0.4 [o]	4,700 [d]
Cerium	Not specified $3x10^{-02}$ [f]	Not specified $3x10^{-02}$ [f]	Not specified $3x10^{-02}$ [f]	Not specified $3x10^{-02}$ [f]	$3x10^{-05}$ [v]	$2x10^{-05}$ [v]	$3x10^{-03}$ [w]	$6.5x10^{-05}$ [w]	30 [i]
Thorium	Maize grain $3.4x10^{-05}$ [c]	Grass $1.1x10^{-02}$ [c]	Average of 6 values $6.9x10^{-03}$ [c]	$2.5x10^{-04}$ [y]	$5x10^{-06}$ [p]	$4x10^{-05}$ [x]	$6x10^{-03}$ [x]	$4x10^{-03}$ [ac]	100 [i]
Uranium	Cereals grain $1.3x10^{-03}$ [c]	Grass $2.3x10^{-02}$ [c]	Average of 3 values 0.011 [c]	$4\ x10^{-03}$ [y]	$4x10^{-04}$ [z]	$3x10^{-04}$ [ab]	1 [k]	1 [k]	10 [i]
Plutonium	Site-specific corn grain $6x10^{-05}$ [d]	Site-specific Bahai grass $2.2x10^{-03}$ [d]	Average of 8 values $8.2x10^{-04}$ [e]	$4.5x10^{-05}$ [y]	$1.1x10^{-06}$ [o]	$1x10^{-05}$ [o]	$3x10^{-03}$ [o]	$5x10^{-04}$ [k]	4,700 [d]
Americium	Cereals grain $2.2x10^{-05}$ [e]	Site-specific Bahai grass 0.067 [d]	Average of 6 values $8.4x10^{-04}$ [e]	$2.5x10^{-04}$ [y]	$1.5x10^{-06}$ [o]	$4x10^{-05}$ [o]	$6x10^{-03}$ [o]	$4x10^{-03}$ [k]	2,400 [d]

[a] GENII default value, PNNL 2002 (7), Appx D, which cites a previous reference of Napier 1988 (24).
[b] GENII default value, PNNL 2002 (7), Appx D, which cites a previous reference of Kennedy 1992 (22).
[c] IAEA default value, IAEA 1994 (2), Table VI, p.17-25, which cites a previous reference of Frissel 1989 (16).
[d] Selected value calculated from data in Friday 1996 (3), or from a combination of data taken from Friday 1996 (3) and IAEA 1994 (2).
[e] IAEA default value, IAEA 1994 (2), Table VI, p.17-25, which cites a previous reference of Frissel 1992 (17).
[f] IAEA default value, IAEA 1994 (2), Table VI, p.17-25, which cites a previous reference of Ng 1982a (26).
[g] GENII default value, PNNL 2002 (7), Appx D; which cites a previous reference of Coughtrey 1983 (11).
[h] IAEA default value, IAEA 1994 (2), Table VI, p.17-25, which cites a previous reference of Gerzabek 1993 (18).
[i] IAEA default value, IAEA 1994 (2), p.45, which cites a several previous references.
[j] IAEA default value, IAEA 1994 (2), p.35, which cites a previous reference of Ng 1982b (27).
[k] IAEA default value, IAEA 1994 (2), pp.37, 40, and 41, which cites a previous reference of Ng 1982c (28).
[l] GENII default value, PNNL 2002 (7), Appendix D, which cites a previous reference of IAEA 1987.
[m] GENII default value, GENII V.2 constituent database, unattributed.
[n] IAEA default value, IAEA 1994 (2), p.35, which cites a previous reference of Baes 1984 (8).
[o] IAEA default value, IAEA 1994 (2), pp.35, 37, 40, and 41, which cites a previous reference of Coughtrey 1990 (12).
[p] GENII default value, PNNL 2002 (7), Appx D, which cites a previous reference of Ng 1977 (25).
[q] IAEA default value, IAEA 1994 (2), pp.35 and 37, which cites a previous reference of Johnson 1988 (21).
[r] IAEA default value, IAEA 1994 (2), pp.40 and 41, which cites a previous reference of Ennis 1988a (14).
[s] IAEA default value, IAEA 1994 (2), pp.40 and 41, which cites a previous reference of Ennis 1988b (15).
[t] IAEA default value, IAEA 1994 (2), p.35, which cites a previous reference of Hoffman 1988 (20).
[u] IAEA default value, IAEA 1994 (2), p.37, which cites a previous reference of Handl 1989 (19).
[v] IAEA default value, IAEA 1994 (2), pp.35 and 37, which cites a previous reference of CEC 1987 (10).
[w] IAEA default value, IAEA 1994 (2), pp. 40 and 41, which cites a previous reference of CEC 1987 (10), average of two values for ^{141}Ce and ^{144}Ce.
[x] GENII default value, PNNL 2002 (7), Appx D, which cites a previous reference of Coughtrey 1990 (12).
[y] GENII default value, PNNL 2002 (7), Appx D, which cites a previous reference of Baes 1984 (8).
[z] IAEA default value, IAEA 1994 (2), p.35, which cites a previous reference of Morgan 1990 (23).
[aa] IAEA default value, IAEA 1994 (2), p. 37, which cites a previous reference of Bishop 1989 (9).
[ab] IAEA default value, IAEA 1994 (2), p. 37, which cites a previous reference of Cramp 1990 (13).
[ac] GENII default value, PNNL 2002 (7), Appx D, which cites a previous reference of Ng 1982c (28).
[ad] GENII requires some of the soil-to-plant bioaccumulation factor variables to have the same value. The values entered for the soil-to-cereal transfer factor (CLBVCL) are also used by GENII for three other soil-to-grain pathways covered by the CLBVAG variable, including soil-to-beef-cattle-feed, soil-to-poultry-feed, and soil-to-egg-animal-feed. Similarly, the values entered for the soil-to-leafy-vegetable transfer factor variable (CLBVLV) are also used by GENII for three other soil-to-plant pathways covered by the CLBVAF and CLBVAH variables, including soil-to-beef-cattle-forage, soil-to-milk-cow-forage, and soil-to-milk-cow-feed (hay). Finally, the values entered for the soil-to-other-vegetable transfer factor variable (CLBVOV) are also used by GENII for the soil-to-root-vegetable transfer factor variable (CLBVRV).

F.2 Food Chain Variables

This section provides assumed values for GENII parameters used for the base-case assessment and needed to assess radiation exposures from ingestion of food (leafy vegetables, root vegetables, fruit, grain) and animal products (beef, poultry, milk, eggs). Table F-9 lists parameter values.

Note that the parameters listed in Table F-9 only address those parameters needed to determine annual ingestion rates of radionuclides. Parameters needed to determine radiation dosimetry from ingestion of radionuclides (e.g., gastro-intestinal absorption fractions) are addressed in Section D.4 (Dose and Risk Assessment) of Appendix D.

Table F-9 Food Chain Variables Other than Transfer Factors

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed – Biomass	Animal feed standing biomass (wet) – Beef animal feed	BIOMA2	kg/m^2	1, By exposure location	Value = 1.6 kg/m^2 This pathway is not being modeled. The selected value is the GENII default value (7). The value assigned to this variable should not affect the model calculations because the amount of beef cattle feed consumed is set at Zero (see CONSUM for beef cattle feed).
Exposure – Agriculture – Animal Feed – Biomass	Animal feed standing biomass (wet) – Poultry feed	BIOMA2	kg/m^2	2, By exposure location	Value = 2.4 kg/m^2 Standing biomass for poultry feed is assumed to be locally grown corn consumed by backyard chickens. USDA 1992 Census of Agriculture data for Aiken County, South Carolina, (page 329, Table 28) includes data on corn silage production, which is presumed to include the entire corn plant (all biomass). The published USDA report includes data for both 1987 and 1992 (4): 1987: 4,330 tons / 464 acres = 2.1 kg/m^2 1992: 4,284 tons / 362 acres = 2.6 kg/m^2 The average of these two years (2.4 kg/m^2) was taken as the input value. (conversion factors: 4,047 m^2/acre and 907 kg/ton)
Exposure – Agriculture – Animal Feed – Biomass	Animal feed standing biomass (wet) – Milk animal feed	BIOMA2	kg/m^2	3, By exposure location	Value = 2.4 kg/m^2 The selected value is equal to the value used for poultry feed biomass. It is assumed that milk cattle feed is locally produced corn silage, based on Hamby 1991 (29) (see CONSUM for milk cattle feed).
Exposure – Agriculture – Animal Feed – Biomass	Animal feed standing biomass (wet) – Egg animal feed	BIOMA2	kg/m^2	4, By exposure location	Value = 2.4 kg/m^2 Standing biomass for egg animal feed is assumed to be locally grown corn consumed by backyard chickens (the same as for poultry feed. The selected value is equal to the value used for poultry feed biomass.

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed – Biomass	Animal feed standing biomass (wet) – Beef animal forage	BIOMA2	kg/m^2	5, By exposure location	Value = 0.3 kg/m^2 The standing biomass represents the amount of biomass present in the field (e.g., foliage) on which airborne contamination is deposited (see PNNL 2002 [7], pp. 149-154). While different values can be assigned to different exposure locations, all locations are assumed to have the same value. According to Hamby 1991 (29), p.3: "Bermudagrass is the best hay plant for South Carolina and with adequate fertilization and frequent cuttings, yields of up to 8 tons per acre (1.8 kg/m^2) are common." This is based on a Clemson University report on use of Bermudagrass (30). The Hamby value represents total yield and includes multiple cuttings. Hamby 1991 (29) states, "Bermudagrass that is not consumed is cut and bailed every 30 days..." For the Base Case, it is assumed that the 30-day value is a shorter-than-average period between cuttings (spring and summer) and there are 6 cuttings/year. Assuming 6 cuttings/year, the standing biomass value is 1.8 kg/m^2 / 6 = 0.3 kg/m^2.
Exposure – Agriculture – Animal Feed – Biomass	Animal feed standing biomass (wet) – Milk animal forage	BIOMA2	kg/m^2	6, By exposure location	Value = 0.3 kg/m^2 The selected value for milk animal forage biomass is equal to the value used for beef animal forage biomass. Standing biomass for milk animal forage is assumed to be Bermudagrass.
Exposure – Agriculture – Food Crop – Biomass	Standing biomass (wet) – Leafy vegetables	BIOMAS	kg/m^2	1, By exposure location	Value = 0.7 kg/m^2 This value is based on a recommendation in Hamby 1991 (29), p. 4. See explanation for leafy vegetable yield.
Exposure – Agriculture – Food Crop – Biomass	Standing biomass (wet) – Root vegetables	BIOMAS	kg/m^2	2, By exposure location	Value = 0.7 kg/m^2 This value is based on a recommendation in Hamby 1991 (29), p. 4. See explanation for leafy vegetable yield.
Exposure – Agriculture – Food Crop – Biomass	Standing biomass (wet) – Fruits	BIOMAS	kg/m^2	3, By exposure location	Value = 0.7 kg/m^2 This value is based on a recommendation in Hamby 1991 (29), p. 4. See explanation for fruit yield.
Exposure – Agriculture – Food Crop – Biomass	Standing biomass (wet) – Grains	BIOMAS	kg/m^2	4, By exposure location	Value = 0.7 kg/m^2 This value is based on a recommendation in Hamby 1991 (29), p. 4. See explanation for fruit yield.

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Animal feed consumption rate – Beef animal feed	CONSUM	kg/d	1, By exposure location	Value = 0 kg/day This pathway is not being modeled. According to Hamby 1991 (29) (p.3), "...Farmers in the south rely on year-round grazing of fresh coastal bermudagrass (30)." "The diets of beef cattle in the region generally consist of about 75 percent pasture grass and 25 percent stored grass with total forage consumption averaging 36 kg/day (29)." In the Base Case scenario, the entire beef cattle diet, including both stored and fresh forage, is modeled through the beef animal forage pathway with the beef cattle feed pathway set at zero. Use of the "feed" pathway is eliminated because this pathway is established in GENII using a transfer factor for cereal (i.e., grain) consumption by cattle. The forage pathway is established in GENII to use a transfer factor for leafy vegetable (i.e., grass) consumption by cattle and is therefore more appropriate for beef cattle at the SRS.
Exposure – Agriculture – Animal Feed	Animal feed consumption rate – Poultry feed	CONSUM	kg/d	2, By exposure location	Value = 0.12 kg/day Assume GENII Default Average
Exposure – Agriculture – Animal Feed	Animal feed consumption rate – Milk animal feed	CONSUM	kg/d	3, By exposure location	Value = 13 kg/day According to Hamby 1991 (29): "...Farmers in the south rely on year-round grazing of fresh coastal bermudagrass (30)." "Dairy cattle consume approximately 52 kg/day of which 56 percent is pasture grass, 25 percent is silage, and 19 percent is commercial grain." Milk animal feed for the Base Case is based on the Hamby 1991 (29) figure for silage of 25 percent of 52 kg/day (=13 kg/day (wet)). The commercial grain cited by Hamby is assumed to come from outside the SRS region.
Exposure – Agriculture – Animal Feed	Animal feed consumption rate – Egg animal feed	CONSUM	kg/d	4, By exposure location	Value = 0.12 kg/day Assume GENII Default Average [PNNL 2002].

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Animal feed consumption rate – Beef animal forage	CONSUM	kg/d	5, By exposure location	Value = 36 kg/day According to Hamby 1991(29), "…Farmers in the south rely on year-round grazing of fresh coastal bermudagrass." (30) "The diets of beef cattle in the region generally consist of about 75 percent pasture grass and 25 percent stored grass with total forage consumption averaging 36 kg/day." The default value from NRC 1971 as cited by Hamby 1991 (29) for beef animal forage consumption is 50 kg/day (wet). Beef animal forage for the Base Case is based on the Hamby 1991 (29) figure including both grazing and stored grass. Both portions of the diet are included in the forage pathway because that pathway uses a transfer factor for leafy vegetables and grass. None of the diet is modeled using the beef feed pathway because that pathway uses a transfer factor for cereal and grain, and the local diet does not include cereal or grain. Including the stored grass portion of the diet in the beef forage pathway has the effect of increasing the dose because the pathway does not include a storage period during which radionuclides would decay.
Exposure – Agriculture – Animal Feed	Animal feed consumption rate – Milk animal forage	CONSUM	kg/d	6, By exposure location	Value = 29 kg/day According to Hamby 1991 (29): "...Farmers in the south rely on year-round grazing of fresh coastal bermudagrass." (30) "Dairy cattle consume approximately 52 kg/day of which 56 percent is pasture grass, 25 percent is silage, and 19 percent is commercial grain." The default value from NRC 1971 as cited by Hamby 1991 (29) for milk animal forage consumption is 50 kg/day (wet). Milk animal feed for the Base Case is based on the Hamby 1991 (29) figure for silage of 56 percent of 52 kg/day (=29 kg/day (wet)). This approach assumes that 1) the silage is locally grown corn silage, and 2) the commercial grain portion of the diet is not locally grown.

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Fraction of diet that is contaminated – Beef animal feed	DIETFR	fraction	1, By exposure location	Value = 1.0 This pathway is not being modeled. In the Base Case, no portion of the beef animal diet is modeled through the beef animal feed pathway. The value assigned to this variable should not affect the model calculations because the amount of beef cattle feed consumed is set at Zero (see CONSUM for beef cattle feed).
Exposure – Agriculture – Animal Feed	Fraction of diet that is contaminated – Poultry animal feed	DIETFR	fraction	2, By exposure location	Value 0.5 According to Hamby 1991 (29): "...Chickens are housed in covered shelters and eat feed provided by the parent companies responsible for marketing the final product." This indicates a value of Zero for the contaminated fraction of poultry feed and thereby eliminates the poultry and egg pathways. However, because at least one CDC scenario posits "backyard chickens" and because agricultural practices may have changed over the time period of the study, a higher value (contaminated fraction =0.5) is assumed for the exposure scenarios.
Exposure – Agriculture – Animal Feed	Fraction of diet that is contaminated – Milk animal feed	DIETFR	fraction	3, By exposure location	Value = 1.0 In the Base Case, milk animal feed is modeled to represent silage that is locally grown, as described in Hamby 1991 (29). As a result, 100 percent of this portion of the milk animal diet is assumed to be contaminated. (Input value =1)
Exposure – Agriculture – Animal Feed	Fraction of diet that is contaminated – Egg animal feed	DIETFR	fraction	4, By exposure location	Value = 0.5 The value for poultry feed (0.5) is assumed to equal the value for egg animal feed.
Exposure – Agriculture – Animal Feed	Fraction of diet that is contaminated – Beef animal forage	DIETFR	fraction	5, By exposure location	Value = 1.0 In the Base Case, beef animal forage is modeled to represent pasture grass and stored grass, both local, as described in Hamby 1991 (29). As a result, 100 percent of this portion of the beef animal diet is assumed to be contaminated. (Input value =1)
Exposure – Agriculture – Animal Feed	Fraction of diet that is contaminated – Milk animal forage	DIETFR	fraction	6, By exposure location	Value = 1.0 In the Base Case, milk animal forage is modeled to represent pasture grass, as described in Hamby 1991 (29). As a result, 100 percent of this portion of the milk animal diet is assumed to be contaminated. (Input value =1)

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Animal feed dry/wet ratio – Beef animal feed	DRYFA2	fraction	1, By exposure location	This pathway is not being modeled. The value assigned to this variable should not affect the model calculations because the amount of beef cattle feed consumed is set at Zero (see CONSUM for beef cattle feed).
Exposure – Agriculture – Animal Feed	Animal feed dry/wet ratio – Poultry feed	DRYFA2	fraction	2, By exposure location	Value = 0.91 Assume value for grain (0.91) (adapted from Till 1983 [31])
Exposure – Agriculture – Animal Feed	Animal feed dry/wet ratio – Milk animal feed	DRYFA2	fraction	3, By exposure location	Value = 0.22 Assume value for beef forage (0.22) (adapted from Till 1983 [31])
Exposure – Agriculture – Animal Feed	Animal feed dry/wet ratio – Egg animal feed	DRYFA2	fraction	4, By exposure location	Value = 0.91 Assume value for grain (0.91) (adapted from Till 1983 [31])
Exposure – Agriculture – Animal Feed	Animal feed dry/wet ratio – Beef animal forage	DRYFA2	fraction	5, By exposure location	Value = 0.22 The selected value is based on Till 1983 [31] which cites a fresh-to-dry ratio for fresh forage of 4.5. The dry/wet ratio is the reciprocal of the fresh-to-dry ratio. (1 / 4.5) = 0.22. Hamby 1991 (29) recommends using the NRC Regulatory Guide 1.109 value of 0.25 (NRC 1977 [32]).
Exposure – Agriculture – Animal Feed	Animal feed dry/wet ratio – Milk animal forage	DRYFA2	fraction	6, By exposure location	Assume value for beef forage (0.22) (adapted from Till 1983 [31]).
Exposure – Agriculture – Food Crop	Dry/wet ratio – Leafy vegetables	DRYFAC	fraction	1, By exposure location	Value = 0.10 The selected value is based on Till 1983 (31), which cites two fresh-to-dry ratios for leafy vegetables of 12.6 and 8.5. The dry/wet ratio is the reciprocal of the fresh-to-dry ratio. The selected value was determined by averaging the reciprocals of the cited values. ((1 / 12.6) + (1 / 8.5)) / 2 = 0.10
Exposure – Agriculture – Food Crop	Dry/wet ratio – Root vegetables	DRYFAC	fraction	2, By exposure location	Value = 0.15 The selected value is based on Till 1983 (31), which cites three fresh-to-dry ratios for root vegetables of 4, 8.2, and 13. The dry/wet ratio is the reciprocal of the fresh-to-dry ratio. The selected value was determined by averaging the reciprocals of the cited values. ((1 / 4) + (1 / 8.2) + (1 / 13)) / 3 = 0.15

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Food Crop	Dry/wet ratio – Fruits	DRYFAC	fraction	3, By exposure location	Value = 0.15 The selected value is based on Till 1983 (31), which cites three fresh-to-dry ratios for fruits of 5.7, 15, and 8.3. The dry/wet ratio is the reciprocal of the fresh-to-dry ratio. The selected value was determined by averaging the reciprocals of the cited values. ((1 / 5.7) + (1 / 15) + (1 / 8.3)) / 3 = 0.12
Exposure – Agriculture – Food Crop	Dry/wet ratio – Grains	DRYFAC	fraction	4, By exposure location	Value = 0.91 The selected value is based on Till 1983 (31), which cites a fresh-to-dry ratio for grain of 1.1. The dry/wet ratio is the reciprocal of the fresh-to-dry ratio. The selected value was determined by taking the reciprocal of the cited value. (1 / 1.1) = 0.91
Exposure – Water – Animal Water	Intake rate of water – Beef animal	DWATER	L/d	1, By exposure location	Value = 50 L/day This value is the default from Table E-3 of NRC 1977 (32). IAEA 1994 (2) cites a value of 20 to 60 L/d for a 500 kg beef cattle. (References cited in IAEA 1994 [2] are Coughtrey 1990 [12] and Ng 1982 [33].) Note that the quantity of contaminated water is further adjusted by the DWFACA variable, so the water quantity specified by DWATER represents total water intake, not just contaminated water intake.
Exposure – Water – Animal Water	Intake rate of water – Poultry	DWATER	L/d	2, By exposure location	Value = 0.3 L/day This value is the GENII default. IAEA 1994 (2) cites a value of 0.1 to 0.3 L/d for chickens and laying hens. (References cited in IAEA 1994 [2] are Coughtrey 1990 [12] and Ng 1982 [33].)
Exposure – Water – Animal Water	Intake rate of water – Milk animal	DWATER	L/d	3, By exposure location	Value = 60 L/day This value is the default from Table E-3 of NRC 1977 (32). IAEA 1994 (2) cites a value of 50 to 100 L/d for a dairy cow. (References cited in IAEA 1994 [2] are Coughtrey 1990 [12] and Ng 1982 [33].)
Exposure – Water – Animal Water	Intake rate of water – Egg animal	DWATER	L/d	4, By exposure location	Value = 0.3 L/day This value is the GENII default. IAEA 1994 (2) cites a value of 0.1 to 0.3 L/d for chickens and laying hens. (References cited in IAEA 1994 [2] are Coughtrey 1990 [12] and Ng 1982 [33].)

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Water – Animal Water	Animal water contaminated fraction – Beef animal	DWFACA	fraction	1, By exposure location	Value = 0 for all exposure locations. These values are based on the exposure scenarios. None of the food chain animals consume contaminated water from the Savannah River or Lower Three Runs Creek .
Exposure – Water – Animal Water	Animal water contaminated fraction – Poultry animal	DWFACA	fraction	2, By exposure location	Value = 0 for all exposure locations.
Exposure – Water – Animal Water	Animal water contaminated fraction – Milk animal	DWFACA	fraction	3, By exposure location	Value = 0 for all exposure locations.
Exposure – Water – Animal Water	Animal water contaminated fraction – Egg animal	DWFACA	fraction	4, By exposure location	Value = 0 for all exposure locations.
Exposure – Agriculture – Food Crop	Growing period – Leafy vegetables	GRWP	day	1, By exposure location	Value = 70 days The growing period is the time period over which the food crop is exposed to contamination. For leafy vegetables, the value for the growing period is based on the value cited for unspecified vegetables by Hamby 1991 (29) which states, "The average growing time, or time of exposure, for above-ground vegetables in South Carolina is approximately 70 days." This information is from a 1990 U.S. Department of Agriculture circular (34). This value is longer than the NRC default value (32) of 60 days.
Exposure – Agriculture – Food Crop	Growing period – Root vegetables	GRWP	day	2, By exposure location	Value = 70 days The growing period for root vegetables is based on Hamby 1991 (p.4) (See above discussion for the leafy vegetable growing period.)
Exposure – Agriculture – Food Crop	Growing period – Fruit	GRWP	day	3, By exposure location	Value = 70 days The growing period for fruit is based on Hamby 1991 (29) (See above discussion for the leafy vegetable growing period.)

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Food Crop	Growing period – Grains	GRWP	day	4, By exposure location	Value = 145 days The growing period for grains is based on the growing period for corn in South Carolina, as cited in a 1997 US Department of Agriculture handbook (35). The difference between the peak planting and harvesting dates is ~145 to 150 days. The difference between the earliest planting and harvesting dates is 135 days. The difference between the latest planting and harvesting dates is 145 days.
Exposure – Agriculture – Animal Feed	Growing period for animal feed – Beef animal feed	GRWPA	day	1, By exposure location	This pathway is not being modeled. The value assigned to this variable should not affect the model calculations because the amount of beef cattle feed consumed is set at Zero (see CONSUM for beef cattle feed).
Exposure – Agriculture – Animal Feed	Growing period for animal feed – Poultry feed	GRWPA	day	2, By exposure location	Value = 145 days The growing period for poultry feed is based on the growing period for corn cited in USDA 1997 (35). (See above discussion for the grain growing period.)
Exposure – Agriculture – Animal Feed	Growing period for animal feed – Milk animal feed	GRWPA	day	3, By exposure location	Value = 145 days The growing period for milk animal feed is based on the growing period for corn cited in USDA 1997 (35). (See above discussion for the grain growing period.)
Exposure – Agriculture – Animal Feed	Growing period for animal feed – Egg animal feed	GRWPA	day	4, By exposure location	Value = 145 days The growing period for egg animal feed is based on the growing period for corn cited in USDA 1997 (35). (See above discussion for the grain growing period.)
Exposure – Agriculture – Animal Feed	Growing period for animal feed – Beef animal forage	GRWPA	day	5, By exposure location	Value = 30 days The growing period for beef animal forage is based on Bermudagrass consumption discussed in Hamby 1991 (29), which notes that "Bermudagrass that is not consumed is cut and bailed every 30 days..."

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Growing period for animal feed – Milk animal forage	GRWPA	day	6, By exposure location	Value = 30 days The growing period for milk animal forage is based on Bermudagrass consumption discussed in Hamby 1991 (29), which notes that "Bermudagrass that is not consumed is cut and bailed every 30 days..."
Exposure – Agriculture – Intake Delays	Time from harvest to ingestion – Leafy vegetables	HLDUP	day	1, By exposure location	Value = 1 day (for Rural Family One and Two, Outdoor Person Family, Migrant Family, and Near River Family). Value = 7 days (for Urban Family and Delivery Person Family) This corresponds to the assigned value for each exposure location: **Location** / **Value (days)** 1. Girard: 1 2. Waynesboro: NA 3. Augusta: 7 4. Jackson: 1 5. New Ellenton: 1 6. Barnwell: 7 7. Martin: 1 8. Allendale: NA 9. Williston: 1 10. Onsite: NA NA - No leafy vegetable production occurs at these locations The selected values are based on scenario-specific conditions. For families consuming vegetables from their own gardens, the value is set at 1 day. For families consuming vegetables from local markets, the value is set at 7 days. NRC recommends a default value of 14 days for both leafy and root vegetables (32) for the general population and 1 day for the maximum exposed individual. The GENII default value is 14 days (7).

<table>
<tr><th>GENII Module – Submodule</th><th>Variable Description</th><th>Variable Name</th><th>Units</th><th>Indices</th><th>Value and Discussion</th></tr>
<tr><td>Exposure – Agriculture – Intake Delays</td><td>Time from harvest to ingestion – Root vegetables</td><td>HLDUP</td><td>day</td><td>2, By exposure location</td><td>Value = 14 days
A 14-day time period is recommended in Hamby 1991 (29). NRC recommends a default value of 14 days for root vegetables (32) for the general population. The GENII default value is 14 days (7).</td></tr>
<tr><td>Exposure – Agriculture – Intake Delays</td><td>Time from harvest to ingestion – Fruits</td><td>HLDUP</td><td>day</td><td>3, By exposure location</td><td>Value = 1 day (for Rural Family One and Two, Outdoor Person Family, Migrant Family, and Near River Family)
Value = 7 days (for Urban Family and Delivery Person Family)
This corresponds to the assigned value for each exposure location:
<table>
<tr><th>Location</th><th>Value (days)</th></tr>
<tr><td>1. Girard</td><td>1</td></tr>
<tr><td>2. Waynesboro</td><td>NA</td></tr>
<tr><td>3. Augusta</td><td>7</td></tr>
<tr><td>4. Jackson</td><td>1</td></tr>
<tr><td>5. New Ellenton</td><td>1</td></tr>
<tr><td>6. Barnwell</td><td>7</td></tr>
<tr><td>7. Martin</td><td>1</td></tr>
<tr><td>8. Allendale</td><td>NA</td></tr>
<tr><td>9. Williston</td><td>1</td></tr>
<tr><td>10. Onsite</td><td>NA</td></tr>
<tr><td colspan="2">NA - No fruit production occurs at these locations.</td></tr>
</table>
The selected values are based on scenario-specific conditions. For families consuming vegetables from their own gardens, the value is set at one day. For families consuming vegetables from local markets, the value is set at seven days. NRC recommends a default value of 60 days for produce (32) for the maximum exposed individual. The GENII default value is 14 days (7).</td></tr>
</table>

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Intake Delays	Time from harvest to ingestion – Grains	HLDUP	day	4, By exposure location	Value = 1 day (for Rural Family One and Two, Outdoor Person Family, Migrant Family, and Near River Family) Value = 7 days (for Urban Family and Delivery Person Family) This corresponds to the assigned value for each exposure location: **Location** / **Value (days)** 1. Girard: 1 2. Waynesboro: NA 3. Augusta: 7 4. Jackson: 1 5. New Ellenton: 1 6. Barnwell: 7 7. Martin: 1 8. Allendale: NA 9. Williston: 1 10. Onsite: NA NA - No grain production occurs at these locations. The selected values are based on scenario-specific conditions and consider consumption of only locally produced corn. For families consuming corn from their own gardens, the value is set at one day. For families consuming corn from local markets, the value is set at seven days. NRC recommends a default value of 60 days for produce (32) for the maximum exposed individual. The GENII default value is 180 days (7).
Exposure – Agriculture – Intake Delays	Time from harvest to ingestion – Fish	HLDUP2	day	1, By exposure location	Value = 1 day The selected value is based on the GENII default average (7). The NRC default average is seven days for sport fish (32).

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Intake Delays	Time from harvest to ingestion – Slaughter to Beef ingestion	HLDUPA	day	1, By exposure location	Value = 6 days The selected value is based on Hamby 1991 (29), which states, "The commercial slaughtering of beef cattle is generally a six-day process. Cattle are slaughtered the first day, processed and packed the next, and shipped on the sixth day. The beef is cured for the four days between packing and shipping." [Hamby to Mathis, personal communication, Nov. 12, 1990] In the Base Case scenarios, consumption of locally grown beef is assumed, and the six-day slaughter-to-ingestion period is assumed for all receptor scenarios. The NRC default value for this parameter for all meat is 20 days (32) and the GENII default value is 34 days (7). A shorter period is appropriate for the CDC receptors because the ingested beef is locally produced with less time required for long distance transport.
Exposure – Agriculture – Intake Delays	Time from harvest to ingestion – Slaughter to poultry ingestion	HLDUPA	day	2, By exposure location	Value = 6 days The selected value is based on the corresponding value for beef. The NRC default value for this parameter for all meat is 20 days (32) and the GENII default value is 18 days (7). A shorter period is appropriate for the CDC receptors because the ingested poultry is locally produced with less time required for long distance transport.
Exposure – Agriculture – Intake Delays	Time from harvest to ingestion – Harvest to milk ingestion	HLDUPA	day	3, By exposure location	Value = 3 days The selected value is based on Hamby 1991 (29) which states, "Generally, milk is collected every other day from local dairies and shipped to one of several processing plants in the Southeast. The process of homogenizing, pasteurizing, and packing the milk can be completed in about 36 hours. Accordingly, it is assumed that milk is collected and delivered on day one, processed on day two, and shipped, ready for consumption on day three." This is based on a personal communication between Hamby and J. Bailes, Flav-O-Rich, Florence, SC, January 8, 1991, and J. Dawson, Borden, Macon GA, January 7, 1991. The NRC and GENII default values are both four days (32,7).

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Intake Delays	Time from harvest to ingestion – Harvest to egg ingestion	HLDUPA	day	4, By exposure location	Value = 1 day (for Rural Family One and Two, Outdoor Person Family, Migrant Family, and Near River Family) Value = 7 days (for Urban Family and Delivery Person Family) This corresponds to the assigned value for each exposure location: **Location** / **Value (days)** 1. Girard: 1 2. Waynesboro: NA 3. Augusta: 7 4. Jackson: 1 5. New Ellenton: 1 6. Barnwell: 7 7. Martin: 1 8. Allendale: NA 9. Williston: 1 10. Onsite: NA NA - No egg production occurs at these locations. The selected values are based on scenario-specific conditions. For families raising their own chickens, the value is set at one day. For families consuming eggs from local markets, the value is set at seven days. The GENII default value is 34 days (7).
Exposure – Agriculture – Animal Feed	Storage time – Beef animal feed	STORTM	day	1, By exposure location	This pathway is not being modeled. The value assigned to this variable should not affect the model calculations because the amount of beef cattle feed consumed is set at Zero (see CONSUM for beef cattle feed).
Exposure – Agriculture – Animal Feed	Storage time – Poultry feed	STORTM	day	2, By exposure location	Value = 180 days The selected value is based on the GENII default average (180 days [7])

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Storage time – Milk animal feed	STORTM	day	3, By exposure location	Value = 90 days The value is based on milk cow consumption of corn silage. The value corresponds to the value for beef animal feed (stored grass) cited in Hamby 1991 (29). The GENII default average is 100 days (7).
Exposure – Agriculture – Animal Feed	Storage time – Egg animal feed	STORTM	day	4, By exposure location	Value = 180 days. The value applies to locally produced corn grain that is consumed by egg animals. The selected value is base on the GENII default average of 180 days (7).
Exposure – Agriculture – Animal Feed	Storage time – Beef animal forage	STORTM	day	5, By exposure location	Value = 0 days The value is based on Hamby 1991 (29) which states, "Farmers in the south rely on year-round grazing for fresh, coastal bermudagrass." (Hamby reference is personal communication with T. Mathis, November 12, 1990.)
Exposure – Agriculture – Animal Feed	Storage time – Milk animal forage	STORTM	day	6, By exposure location	Value = 0 days The selected value is based on the corresponding value for beef animal forage (29).
Exposure – Agriculture – Food Crop	Translocation factor – Leafy vegetables	TRANS	fraction	1, By exposure location	Value = 1.0 The translocation factor for food crops is the ratio of the nuclide concentration in the edible portion of the plant and the portion exposed to air-deposited contamination. The selected value is based on Food Chain Models for Risk Assessment, Appendix F. Oak Ridge Risk Assessment Information System, at http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml, which cites a translocation factor for leafy vegetables of 1.0 as the default in NCRP 1984 (36). The GENII default average for leafy vegetables also equals 1.0 (7).
Exposure – Agriculture – Food Crop	Translocation factor – Root vegetables	TRANS	fraction	2, By exposure location	Value = 0.1 The selected value is based on the NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The GENII default average for root vegetables also = 0.1 (7).

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Food Crop	Translocation factor – Fruits	TRANS	fraction	3, By exposure location	Value = 0.1 The selected value is based on NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The cited value for nonleafy vegetables is 0.1 and is applied to fruit. The GENII default average for fruit equals 0.1 (7).
Exposure – Agriculture – Food Crop	Translocation factor – Grains	TRANS	fraction	4, By exposure location	Value = 0.1 The selected value is based on NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The cited value for nonleafy vegetables is 0.1 and is applied to grains. The GENII default average for grains equals 0.1 (7).
Exposure – Agriculture – Animal Feed	Translocation factor for animal feed – Beef animal feed	TRANSA	fraction	1, By exposure location	This pathway is not being modeled. The value assigned to this variable should not affect the model calculations because the amount of beef cattle feed consumed is set at Zero (see CONSUM for beef cattle feed). The translocation factor for animal diet is the ratio of the nuclide concentration in the portion of the plant consumed by the animal and the portion exposed to contamination.
Exposure – Agriculture – Animal Feed	Translocation factor for animal feed – Poultry feed	TRANSA	fraction	2, By exposure location	Value = 0.1 The selected value is based on NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The cited value for nonleafy vegetables is 0.1 and is applied to poultry feed (corn grain). The GENII default average for poultry feed = 0.1 (7).
Exposure – Agriculture – Animal Feed	Translocation factor for animal feed – Milk animal feed	TRANSA	fraction	3, By exposure location	Value = 0.1 The selected value is based on NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The cited value for nonleafy vegetables is 0.1 and is applied to milk animal feed (corn silage). The GENII default average for milk animal feed = 0.1 (7).
Exposure – Agriculture – Animal Feed	Translocation factor for animal feed – Egg animal feed	TRANSA	fraction	4, By exposure location	Value = 0.1 The selected value is based on NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The cited value for nonleafy vegetables is 0.1 and is applied to egg animal feed (corn grain). The GENII default average for egg animal feed = 0.1 (7).

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Translocation factor for animal feed – Beef animal forage	TRANSA	fraction	5, By exposure location	Value = 1.0 The selected value is based on NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The cited value for pasture is 1.0 and is applied to beef animal forage (bahai grass). The GENII default average for beef animal forage = 1.0 (7).
Exposure – Agriculture – Animal Feed	Translocation factor for animal feed – Milk animal forage	TRANSA	fraction	6, By exposure location	Value = 1.0 The selected value is based on NCRP 1984 (36) as cited in http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. The cited value for pasture is 1.0 and is applied to milk animal forage (bahai grass). The GENII default average for milk animal forage = 1.0 (7).
Exposure – Agriculture – Food Crop	Yield – Leafy vegetables	YELD	kg/m^2	1, By exposure location	Value = 0.7 kg/m^2 According to Hamby 1991 (29) for garden productivity, the average response in a survey of county extension agents was a value of 0.2 kg/m^2. This value is one-tenth the NRC default value (32) and, therefore, would result in higher doses than the default value. Therefore, Hamby 1991 (29) recommends using a value of 0.7 kg/m^2, which corresponds to survey responses for average agricultural productivity.
Exposure – Agriculture – Food Crop	Yield – Root vegetables	YELD	kg/m^2	2, By exposure location	Value = 0.7 kg/m^2 The value is based on Hamby 1991 (29). See YELD for leafy vegetables.
Exposure – Agriculture – Food Crop	Yield – Fruits	YELD	kg/m^2	3, By exposure location	Value = 0.7 kg/m^2 The value for agricultural productivity (0.7 kg/m^2) cited by Hamby 1991 (29) was used in the Base Case for fruits. This is the same as the default value for agricultural productivity for produce or leafy vegetables ingested by man in NRC 1977 (32).
Exposure – Agriculture – Food Crop	Yield – Grains	YELD	kg/m^2	4, By exposure location	Value = 0.7 kg/m^2 The value for agricultural productivity (0.7 kg/m^2) cited by Hamby 1991 (29) was used in the Base Case for grains. This is the same as the default value for agricultural productivity for produce or leafy vegetables ingested by man in NRC 1977 (32).

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Agriculture – Animal Feed	Yield for animal feed – Beef animal feed	YELDA	kg/m^2	1, By exposure location	This pathway is not being modeled. The value assigned to this variable should not affect the model calculations because the amount of beef cattle feed consumed is set at Zero (see CONSUM for beef cattle feed).
Exposure – Agriculture – Animal Feed	Yield for animal feed – Poultry feed	YELDA	kg/m^2	2, By exposure location	Value = 2.4 kg/m^2 The selected value is based on the corresponding value for poultry feed standing biomass calculated from USDA 1992 data (4).
Exposure – Agriculture – Animal Feed	Yield for animal feed – Milk animal feed	YELDA	kg/m^2	3, By exposure location	Value = 2.4 kg/m^2 The selected value is based on the corresponding value for milk animal feed (corn silage) standing biomass calculated from USDA 1992 data (4).
Exposure – Agriculture – Animal Feed	Yield for animal feed – Egg animal feed	YELDA	kg/m^2	4, By exposure location	Value = 2.4 kg/m^2 The selected value is based on the corresponding value for poultry feed standing biomass calculated from USDA 1992 data (4).
Exposure – Agriculture – Animal Feed	Yield for animal feed – Beef animal forage	YELDA	kg/m^2	5, By exposure location	Value = 1.8 kg/m^2 The selected value is based on Hamby 1991 (29) which states, "Bermudagrass is the best hay plant for South Carolina and with adequate fertilization and frequent cuttings, yields of up to 8 tons per acre (1.8 kg/m^2) are common." This is based on Clemson 1988 (30).
Exposure – Agriculture – Animal Feed	Yield for animal feed – Milk animal forage	YELDA	kg/m^2	6, By exposure location	Value = 1.8 kg/m^2 The selected value is based on the corresponding yield value for beef animal forage.
Exposure – Controls	Fraction of plant roots in surface soil	RF1	fraction	0, By exposure location	Value = 1.0 The selected value is based on the GENII default average (7)
Exposure – Water	Animal feed irrigation time – Beef animal feed	IRTIMA	mon/yr	1, By exposure location	This variable is not used because the irrigation pathways are not being modeled. Several references indicate that no irrigation occurs in the exposure locations of interest downstream from the SRS, including Hamby 1991 (29) and Moore 2002 (37).

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Water	Animal feed irrigation time – Poultry feed	IRTIMA	mon/yr	2, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation time – Milk animal feed	IRTIMA	mon/yr	3, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation time – Egg animal feed	IRTIMA	mon/yr	4, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation time – Beef animal forage	IRTIMA	mon/yr	5, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation time – Milk animal forage	IRTIMA	mon/yr	6, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation time for residential land	IRTIMR	mon/yr	0, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation time – Leafy vegetables	IRTIMT	mon/yr	1, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation time – Root vegetables	IRTIMT	mon/yr	2, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation time – Fruits	IRTIMT	mon/yr	3, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation time – Grains	IRTIMT	mon/yr	4, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation rate – Leafy vegetables	RIRR	in/yr	1, By exposure location	This variable is not used because the irrigation pathways are not being modeled.

GENII Module – Submodule	Variable Description	Variable Name	Units	Indices	Value and Discussion
Exposure – Water	Irrigation rate – Root vegetables	RIRR	in/yr	2, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation rate – Fruits	RIRR	in/yr	3, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Irrigation rate – Grains	RIRR	in/yr	4, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation rate – Beef animal feed	RIRRA	in/yr	1, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation rate – Poultry feed	RIRRA	in/yr	2, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation rate – Milk animal feed	RIRRA	in/yr	3, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation rate – Egg animal feed	RIRRA	in/yr	4, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation rate – Beef animal forage	RIRRA	in/yr	5, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water	Animal feed irrigation rate – Milk animal forage	RIRRA	in/yr	6, By exposure location	This variable is not used because the irrigation pathways are not being modeled.
Exposure – Water – General	Irrigation rate for residential land	RIRRR	in/yr	0, By exposure location	This variable is not used because the irrigation pathways are not being modeled.

F.3 Additional Parameter Values

This appendix identifies the source, transport, and exposure variables used in the SRS Base Case GENII model runs, indicates the GENII module and the section and subsection of FRAMES where the variable is used (this corresponds to the dialog boxes contained in the FRAMES user interface), states the units and input value(s) of each variable, and describes how each value was determined. Supporting references are also identified.

In addition to the variables addressed herein, another set of variables—receptor factors—is discussed in Appendix E. For the Base Case analysis, the receptor factors are input into a custom post-processor unit rather than input into GENII using the FRAMES interface.

The variables discussed here are organized according to the GENII modules and FRAMES sections and subsections listed in Table F-10.

F-10 GENII Modules and FRAMES Sections and Subsections

GENII Module	FRAMES Section and Subsection
Source	Atmospheric Flux Atmospheric Flux – Flux Types
Air	Model Information – Meteorological Files Model Information – Default Parameters Model Information – Model Parameters Model Information – Radial Grid Definition
Constituent Database	Partitioning Toxicity Parameters – Exposure Factors
Exposure	Agriculture – General Controls Soil – Leaching Soil – Resuspension Soil – Surface Soil
Water	General
River	Surface Water

The following notes apply to the discussions of variables and input values in this document.

Significant Figures. Generally, for any numerical value documented, only the first two digits should be considered significant. Some values reported here are shown with more significant digits than are appropriate given the lack of precision in data and models. In these cases, the additional significant digits are included to reduce the round-off error in the subsequent computer calculations and to help readers and reviewers trace these values to the original data sources. For example, the value used for relative humidity—0.01125 kg/m^3—is a 42-year average with a standard deviation of 0.00053 kg/m^3. This clearly implies the last two digits in the cited value are in doubt, but they are included so the value may be more easily traced through the computer calculation.

Stochastic Analysis. A list of the variables selected for stochastic analysis is provided in Chapter 12.

Parameters pertaining to human radiation dosimetry. The GENII Health Impacts submodule and the FRAMES Constituent Parameter section require that the code use input values for some parameters addressing human dosimetry (e.g., lung clearance classes for determination of dose and risk from

inhalation, soil depth, and density for determination of dose and risk from external exposure to contaminated soil). Assumed values for these parameters are provided in Section D.4 of Appendix D.

References. Table F-11 summarizes the references used to support the variables addressed in this appendix. Parameter values and their bases are listed in Table F-12.

Table F-11 References Used to Support Variables Addressed in Section A.3

Citation	Reference	Variables Supported
ATL 2003a (38)	Advanced Technologies and Laboratories International, Inc. Combining sources of air releases for the SRS dose reconstruction. June 5, 2003.	Flux type, Two, ARRADVAL
ATL 2003b (39)	Source Term Analysis (under preparation)	CFLUX
ATL 2003c (40)	Distribution Coefficients for Radionuclides Considered in the Dose Reconstruction of Savannah River Site. ATL June xx, 2003.	CLKD, SOILKD
Chaki 2000 (41)	Chaki S, Parks B. CAP88-PC Version 2.1 Updated Users Guide (Beta Version), Ch.12, p.8. September 2000.	ABSHUM
DOE 2002 (42)	Savannah River Site High-Level Waste Tank Closure Final Environmental Impact Statement. U.S. Department of Energy. DOE/EIS-0303. May 2002.	SLDN, BULKD, SSLDN
EPA 2000 (43)	EPA Soil Screening Guidance for Radionuclides, Users Guide. EPA/540-R-00-007. October 2000.	MOISTC
EPA 2001 (44)	Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments), Final. U.S. Environmental Protection Agency. Publication 9285.7-47. December 2001.	SHOUT
EPA 2003 (45)	Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors, (Federal Guidance Report No.13, Morbidity Risk Coefficients, in Units of Picocuries). U.S. Environmental Protection Agency. http://www.epa.gov/radiation/heast/docs/heast2_table_4-d2_0401.pdf . 2003.	SOLUBIL
Cook 2002a (46)	JR Cook, MA Phifer, EL Wilhite, KE Young. Closure Plant for the E-Area Low-Level Waste Facility, Rev. 2. WSRC-RP-2000-00425. WSRC, SRS, September 2, 2002.	VLEACH
Cook 2002b (47)	JR Cook and EL Wilhite. Analysis of Disposal of Lead in the E-Area Low-Level Waste Facility. WSRC-TR-2002-00101. WSRC, SRS. February 20, 2002.	VLEACH
Hamby 1991 (29)	Hamby DM. Land and Water Use Characteristics in the Vicinity of the Savannah River Site. WSRC-RP-91-17. Westinghouse Savannah River Company, Aiken, SC. March 1, 1991.	VLEACH

Citation	Reference	Variables Supported
Hamby 1993 (48)	Hamby DM. A Probabilistic Estimation of Atmospheric Tritium Dose. Health Physics; 65(1):33-40. July 1993.	ABSHUM
Hubbard 1987 (49)	Hubbard JE and Engelhardt M. Calculation of Groundwater Recharge at the Old SRP Burial Ground Using the CREAMS Model (1961-1986). Memorandum. July 31, 1987	RAIN, VLEACH
Johnson 1962 (50)	Johnson JE. ^{35}S Releases from Reactor Areas. Dupont Interoffice Memorandum to CM Patterson. Savannah River Plant. RAC reference no. SKR1994020129. July 19, 1962.	SOLUBIL
Kennedy 1992 (22)	WE Kennedy and DL Strenge. Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Final Report. NUREG/CR-5512, PNL-7994. October 1992.	LEAFRS, RESFAC
Moore 2002 (37)	Moore MS. Critical Pathway Assessment of the Savannah River Site, Aiken, South Carolina. South Carolina Department of Health and Environmental Control. May 2002.	VLEACH
Napier 2003a (51)	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. March 4, 2003.	Radius, Density
Napier 2003b (52)	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. June 9, 2003.	Density
Napier 2003c (53)	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. March 31, 2003.	DEPFR1, DEPFR2
Napier 2003d (54)	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. February 12, 2003.	ANDKR
NCDC 2003 (55)	2002 Local Climatological Data (LCD) Annual Summary with Comparative Data, Augusta, GA. ISSN 0198-1587. National Oceanic and Atmospheric Administration. National Climactic Data Center. 2003.	RAIN
NRC 1977 (32)	Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I. Revision 1. U.S. Nuclear Regulatory Commission. October 1977.	WTIM, SLDN, SEDDN, SOILT
ORNL 2002 (56)	Food Chain Models for Risk Assessment, Appendix F. Risk Assessment Information System. Oak Ridge National Laboratory. http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. July 1, 2002.	DEPFR1, DPVRES
Phifer 2003 (57)	M.A Phifer and L.B. Collard. Unreviewed Disposal Question Evaluation: Backfill Soil Compaction Requirements. WSRC-TR-2003-00081. WSRC, SRS. February 6, 2003.	VLEACH
PNNL 2002 (7)	Napier, BA, Strenge DL, Ramsdell JV, Eslinger PW, and Fosmire C. GENII Version 2 Software Design Document. Pacific Northwest National Laboratory (PNNL). November 2002.	[numerous]

Citation	Reference	Variables Supported
Simpkins 2002 (6)	Ali A. Simpkins. Estimating Derived Response Levels at the Savannah River Site for Use with Emergency Response Models. WSRC-MS-2002-00596. Westinghouse Savannah River Company. 2002.	SLDN, SEDDN
Till 1983 (31)	Till JE, Meyer HR, Peterson, HT. Radiological Assessment, A Textbook on Environmental Dose Analysis. NUREG/CR-3332, ORNL-5968. September 1983.	WTIM, LEAFRS, DPVRES, RESFAC
Till 2001 (58)	Till JE. FINAL REPORT, Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released from the Savannah River Site. Risk Assessment Corporation, Neeses, SC. April 30, 2001.	Radius, Density
Wild 2003 (59)	Wild EW, Brigmon RL, Berry CJ, Altman DJ, Rossabi J, Looney BB, and Harris SP. D-Area Drip Irrigation-Phytoremediation Project: SRTC Final Report. WSRC-TR-2002-00080. Westinghouse Savannah River Company, Aiken, SC. January 2003.	VLEACH
WSRC 1991 (60)	Savannah River Site Environmental Report for 1990. WSRC-IM-91-28. Westinghouse Savannah River Company, Aiken, SC. 1991.	SHIN, SWFAC
WSRC 1992 (61)	Savannah River Site Environmental Report for 1991. Westinghouse Savannah River Company, Aiken, SC. 1992.	SHIN, SWFAC
WSRC 1993 (62)	Savannah River Site Environmental Report for 1992. WSRC-TR-93-075 and -077. Westinghouse Savannah River Company, Aiken, SC. 1993.	SHIN, SWFAC

Table F-12 Values for Variables and their Bases

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Source	Atmospheric Flux	Flux Type	(none)	By source	Value = Point source (for offsite exposure locations) For air releases, all sources will be defined as point sources (as opposed to area sources). The rationale is as follows: The four defined model sources are virtual sources representing several (~2 to ~5) actual sources. Most of the nuclide releases come from elevated sources (typically 61 meters). GENII can only model an elevated source if it is a point source; area sources cannot be elevated. The selection of point or area has an effect on air concentrations very close to the release location, but would not have a substantive effect on concentrations that are far (several miles) from the release location (7,38). In this study, the offsite exposure locations are far enough away from the sources that using the simpler point source flux type is not expected to substantively affect the results.
Source	Atmospheric Flux	Exit height of source (m)	Two (m)	By media type (3=Air)	Value = [see table below] This variable is established for each of four distinct "virtual sources," each of which represents several actual sources. Each virtual source represents the combined releases from several physical sources such as stacks or evaporation from basins. The exit height for each virtual source is based on the heights of the individual physical sources that it represents. The process under which these sources are defined is described in Appendix A. The source heights are specified as follows:

Virtual Source Group	Height (m)	Actual Sources Represented
1	10	A Area, M Area, SRL
2	61	F Canyon, H Canyon, H Area Tritium Stack (includes stacks and basin evaporation)
3	61	C, K, and L Reactors (includes stacks and basin evaporation)
4	61	P and R Reactors (includes stacks and basin evaporation)

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Source	Atmospheric Flux	Release Rate	CFLUX (pCi, , pCi/ml)	By Media Type and Isotope	Value = [see Appendix B]. The release rate is the Base Case source term data. For air releases, the release rate is entered in the GID file (and the FRAMES interface) in units of pCi for each nuclide over a 1-year period (corresponding to pCi/year) for each of the four virtual release points. For water releases, the release is in terms of radionuclide concentrations in Savannah River or Lower Three Runs Creek (pCi/ml). .
Source	Atmospheric Flux – Flux Types	Particle radius (um)	Radius (um)	By flux type	Value = 0.5 um Particle radius is used to characterize the source release for the air pathway. The particle radius value is used in the model to determine the rate of deposition (7). The user can specify multiple flux types, including up to three particle types (defined by their radii and density) and a gas fraction for each nuclide. For this analysis, all nuclides except the following were modeled as particles. The following nuclides were modeled as gases, based on their physical properties: H-3 (both as HT or HTO), ^{41}Ar, ^{129}I, ^{131}I (51). Part of the iodine source terms will also be modeled as a particulate release. Limited data on particle size is available (58), and an analysis of this data did not yield a meaningful single value or range of values to be used for particle diameter. The limited available data focused on stack measurements of particle size. However, as used in the model, particle size after the time of release (i.e., at the time of deposition) is more relevant. The stack measurements do not account for the particle agglomeration and other physiochemical changes that would be expected to occur after the particles are released. A radius value of 0.5 micron (i.e., 1.0 micron diameter) was selected to model particle deposition. At this size, depletion of the air concentration by gravitational deposition should be minimal, resulting in conservative (high) air concentrations at the exposure locations. In the absence of applicable data and with many factors causing variation over time, choice of a standard value is justified.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Source	Atmospheric Flux – Flux Types	Particle density (g/cm^3)	Density (g/cm^3)	By Particle Size	Value = 2.0 g/cm^3 Particle density is used with particle radius in the model to determine the rate of dry deposition (7). Previous SRS studies identified in the RAC Phase II report (58) have assumed particle densities of 1 and 2 g/cm^3. However, there are no available data that characterize particle density for SRS air releases. Since the emissions at the SRS may be particulates as well as dehydrated solutions, a density between water (1.0) and soil (~2.5) has some appeal.
Source	Atmospheric Flux – Flux Types	Nonreactive fraction if gas	Density (fraction)	None	Value = 0.5 (Iodine isotopes) This variable is used when a nuclide source term air release is specified as a gas rather than a particle. The nonreactive fraction represents the proportion of the release quantity that is not reduced through degradation, except for iodine, which uses a special model (the reactive fraction is converted to a particle), forms of tritium, and noble gases. For forms of tritium and noble gases, GENII automatically assigns a nonreactive gas fraction of 1.0. For other gaseous nuclides, GENII allows a single nonreactive gas fraction to be specified. For iodine, a value of 0.5 is assumed, based on the assumption that the release will eventually reach equilibrium at 40% particle, 30% reactive gas, and 30% nonreactive gas (51,52).
Air	Model Information – Meteorological Files	Name of met file	ARMETFILE (met file name)	None	The name of the file containing met data to be read into GENII is determined according to the pre-processor design document (see Appendix G).
Air	Model Information – Default Parameters	Transfer resistance for Iodine	ARTRANSRESIST (s/m)	None	Value = 10 s/m Transfer resistance is used in the GENII air deposition model as a mathematical device to establish an upper limit on the deposition velocity of contaminants depositing on the soil and foliage. The deposition velocity is the factor relating the concentration of contaminants in the air and the flux rate of the contamination depositing on the ground. High transfer resistance reduces the deposition velocity and the amount of contamination deposited. As transfer resistance is decreased, deposition velocities and contaminant fluxes increase until transfer resistance becomes small in comparison to aerodynamic and surface resistances (which are calculated from near surface wind data), at which point these other resistances dominate dry deposition velocity. The GENII default for gases (iodine) is 10 s/m (7). The Base Case analysis adopted the GENII default value (10 s/m).

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Air	Model Information – Default Parameters	Transfer resistance for particulates	ARTRANSRESIST (s/m)	None	Value = 100 s/m The transfer resistance for particulates is used in the GENII air deposition model in the same manner as the transfer resistance for iodine. The Base Case analysis adopted the GENII default value of 100 s/m (7).
Air	Model Information – Model Parameters	Sigma Paramaterization Usage	ARSIGPARM (none)	None	Value = Pasquill-Gifford (NRC) This variable is used in the GENII air dispersion module chronic plume model. This variable is used to specify the approach to calculate plume diffusion coefficients which are used to describe the spread of effluents in plumes. These coefficients are related to atmospheric turbulence and the time since release. Most of the schemes used to estimate diffusion coefficients are based on atmospheric stability classes and distance from the source (see PNNL 2002, p. 59-67 [7]). The following five options available in GENII: Brigg's Open Country (Default) Pasquill-Gifford (ISC3) Pasquill-Gifford (NRC) Brigg's Urban Condition, and Turbulence Statistics. Note: For each option, it is possible to select a user-supplied calm wind distribution, which includes the fraction of time the wind blows in each given direction during calm periods. (See GENII FRAMES User Interface, air dispersion module, Model Parameters tab.) The Pasquill-Gifford (NRC) was selected because it is consistent with how SRS meteorological data is collected and stability classes determined.

<table>
<tr><th>GENII Module</th><th>Module Section-Subsection</th><th>Variable</th><th>Variable Name (Units)</th><th>Indices</th><th>Value and Basis</th></tr>
<tr><td>Air</td><td>Model Information – Radial Grid Definition</td><td>Ring Distance</td><td>ARRADVAL (m)</td><td>By Ring Index</td><td>Value = [see below].
This variable is the radii of the rings used in the sector-based air dispersion analysis. When GENII determines air concentrations at various locations, the locations are moved to the closest calculation point on a grid formed by user-defined ring distances and 16 established compass headings. The ring diameters will be set so as to minimize the distance a exposure location must be moved to get to a grid point. The radii value of each ring is set so that it coincides with the distance between the source and exposure locations.

A separate set of ring distances is calculated for each source. Since there are 4 sources and up to 10 distances can be calculated for each source, (4 x 10) 40 ring distances are calculated. The distances are listed below in units of meters (m):
<table>
<tr><th colspan="2">A-Area, M-Area, SRL</th><th colspan="2">F- and H-Area</th><th colspan="2">C-, K-, & L-Reactors, D-Area, CMX-TNX</th><th colspan="2">P- & R-Reactors</th></tr>
<tr><th>Distance</th><th>Exposure Location</th><th>Distance</th><th>Exposure Location</th><th>Distance</th><th>Exposure Location</th><th>Distance</th><th>Exposure Location</th></tr>
<tr><td>4,824</td><td>Jackson</td><td>8,666</td><td>On site</td><td>1,889</td><td>On site</td><td>8,881</td><td>On site</td></tr>
<tr><td>9,266</td><td>New Ellenton</td><td>12,392</td><td>Jackson</td><td>16,582</td><td>Jackson</td><td>20,648</td><td>Barnwell</td></tr>
<tr><td>16,226</td><td>On site</td><td>14,205</td><td>New Ellenton</td><td>21,092</td><td>New Ellenton</td><td>20,666</td><td>New Ellenton</td></tr>
<tr><td>24,196</td><td>Augusta</td><td>25,657</td><td>Williston</td><td>23,149</td><td>Girard</td><td>20,961</td><td>Jackson</td></tr>
<tr><td>30,065</td><td>Williston</td><td>28,585</td><td>Barnwell</td><td>23,629</td><td>Martin</td><td>21,880</td><td>Martin</td></tr>
<tr><td>36,789</td><td>Barnwell</td><td>29,293</td><td>Martin</td><td>27,743</td><td>Barnwell</td><td>22,354</td><td>Williston</td></tr>
<tr><td>37,477</td><td>Girard</td><td>30,033</td><td>Girard</td><td>29,256</td><td>Williston</td><td>25,800</td><td>Girard</td></tr>
<tr><td>38,309</td><td>Martin</td><td>33,397</td><td>Augusta</td><td>36,775</td><td>Waynesboro</td><td>36,775</td><td>Allendale</td></tr>
<tr><td>38,710</td><td>Waynesboro</td><td>39,858</td><td>Waynesboro</td><td>38,318</td><td>Augusta</td><td>41,940</td><td>Augusta</td></tr>
<tr><td>54,256</td><td>Allendale</td><td>45,038</td><td>Allendale</td><td>40,178</td><td>Allendale</td><td>44,286</td><td>Waynesboro</td></tr>
</table>
</td></tr>
<tr><td>Constit Database</td><td>Partitioning</td><td>Soil-water Partition Coefficient</td><td>CLKD (ml/g)</td><td>By Isotope and Daughter</td><td>This is the same as the soil adsorption coefficient (SOILKD), which is addressed in the Exposure-Soil-Leaching GENII module.</td></tr>
<tr><td>Constit Database</td><td>Toxicity Parameters – Exposure Factors</td><td>Water Purification Factor</td><td>CLWPF (none)</td><td>By isotope and daughters</td><td>Value = 0.0
This variable is used in drinking water/showering pathways. In the SRS Base Case, no families use the contaminated water for indoor uses. Usage of this variable is documented in PNNL 2002, p. 156 (7).</td></tr>
</table>

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Agriculture – General	Weathering rate constant from plants	WTIM (days)	None	Value = 14 days This variable is the weathering half-life of nuclides that have been deposited on plant surfaces. It used in calculations of contaminant levels on foliage that is consumed by humans or by animals that are subsequently consumed by humans (7). NRC 1977, p.69 (32), recommends a value of 14 days (this is also the GENII default value). Till 1983 (31) includes a range of values (4 days to 300 days) and recognizes how the value can be affected by different seasons and different plant species. Most cited values are in the 10- to 30-day range (Till 1983, p. 5-33 to 5-38 [31]). The default value (14 days) is therefore reasonable.
Exposure	Agriculture – General	Dry deposition retention fraction to plants	DEPFR1 (fraction)	None	Value = 0.25 This variable represents the fraction of dry-deposited contamination that is retained on plant surfaces. It is also considered the interception fraction (see Napier 2003c [53]). The GENII default value is 0.20. The selected value of 0.25 is considered a reasonable value based on the following analysis cited by Oak Ridge 2002 (56) (http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml): "...The interception fraction accounts for the proportion of aerial deposition that is intercepted by plant surfaces. The interception fraction varies with plant type and density of vegetation. NRC (1977) and NCRP (1984) use a default value of 0.25 for pasture grasses and 0.2 for vegetable crops. NCRP (1989) used 0.25 as the default for both vegetables and pasture. However, Miller (1980) reviewed a number of studies and reported a range of 0.02-0.82 for various grasses. The midpoint of this range (0.42) is suggested as the default value for use in the pasture plant models in this report. Interception fractions for vegetable crops ranged from 0.06-1.2 (Miller 1980), but 10 of 13 values were less than 0.49. The value of 0.42 used for pasture grasses is also suggested as the default for vegetable crops. Breshears et al. (1992) examined a number of values and determined that the geometric mean for the interception fraction was 0.39. The reader should note that there is considerable variability in the interception fraction values. Iodines exhibit a greater tendency to be retained on vegetation. The default iodine value of 1.0 from NRC (1977) is recommended in this white paper for both pasture and vegetable crops. The recommended value for interception of particles deposited by spray irrigation is 0.25; this is the default value used by NRC (1977) and is within the range reported by Miller (1980)."

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Agriculture – General	Wet deposition retention fraction to plant surfaces	DEPFR2 (fraction)	None	Value = 0.25 This variable represents the fraction of wet-deposited contamination that is retained on plant surfaces. It is also considered the interception fraction. [see Napier 2003c] The GENII default value is 0.25. The rationale for selecting 0.25 is the same as described above for DEPFR1.
Exposure	Agriculture – General	Resuspension factor from soil to plant surfaces	LEAFRS (1/m)	None	Value = 10^{-5} & 10^{-7} (depending on location) The values used for this variable are the same as those used for soil resuspension for use in the soil inhalation pathway (see RESFAC, below). These values are 10^{-5} m^{-1} for the Girard (1), New Ellenton (5), and Williston (9) exposure locations, and 10^{-7} m^{-1} for all other exposure locations.
Exposure	Agriculture – General	Deposition velocity from soil to plant surfaces	DPVRES (m/s)	None	Value = 0.001 m/s. The selected value of 0.001 m/s is based on a review of Till 1983, p.5-16 through 5-21 [31]. Limited data are available, most of it for iodine deposition. Values tend to cover a range between 0.01 and 0.00001 m/s. The GENII Default = 0.001 m/s, and NCRP 1989 (as cited in ORNL 2002 [56]) recommends a value of 1000 m/d (roughly equal to 0.01 m/s). GENII requires a single value be used for all nuclides.
Exposure	Agriculture – General	Radionuclide removal due to harvesting	HARVST (on/off)	None	Value = FALSE (OFF) This variable is an on/off switch used to account for reductions in soil contamination levels resulting when contaminated plants are harvested and removed from the area (7). To be conservative, the switch will be OFF in the Base Case scenario. OFF means that the soil contamination levels will not be automatically reduced to account for contamination removed from the field when crops are harvested.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Controls	Absolute humidity, used only for tritium model	ABSHUM (kg/m^3)	None	Value = 0.01125 kg/m^3 The absolute humidity parameter is used only in the tritium model of the GENII exposure module (7). Only a single value is needed to model the Base Case scenario. The following two candidate values were identified: The value selected for the Base Case scenario is a site-specific value (0.01125 kg/m^3). According to Hamby 1993 [48], weekly averages at the SRS over a two-year period ranged from 0.0032 to 0.0244 kg/m^3 (Hamby and Jumper 1990, cited in Hamby 1993, p. 34 [48]). Annual averages, however, are less variable. A database of average daily temperature and average daily wet-bulb temperature from the Columbia, SC, National Weather Service station were analyzed to generate a distribution of annual average absolute humidity values for the SRS. The database includes the 42-year period from 1949 to 1990 and provides the basis for the selected value of the absolute humidity parameter. The mean value of the distribution of the 42 data points is 0.01125 kg/m^3, with a standard deviation of 0.00053 kg/m^3 (48). An alternative, non-site-specific default value (not used) of 0.008 kg/m^3 is proposed in the documentation for EPA's CAP88-PC computer model for estimating dose and risk for radionuclide emissions to air. The 0.008 kg/m^3 value is proposed for use with the CAP-88 tritium module (Chaki 2000 [41]). The GENII default value = 0.008.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Controls	Average daily rain rate	RAIN (mm/d)	None	Value = 11.4mm/d This is the average daily rain rate, when it is raining. It is used in the calculation of wet deposition (7). A value of 11.4 mm/d was calculated using data from two references (55,49). Hubbard 1987 [49] presents annual rainfall data for F-Area at the SRS for the 1961-1986 period and calculates an average value of 48.51 inches. This value is slightly higher than the "normal" annual rainfall reported for Augusta on NCDC 2003, p. 3 (55) (44.66 inches/year). NCDC 2003, p. 3, (55) also reports 108.2 days/year with precipitation of at least 0.01 inches (normal long-term average). Using this data, the average daily rain rate is calculated as follows: (48.51 in/yr) * (25.4 mm/in) / (108.2 d/yr) = 11.4 mm/d

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Soil – Leaching	Surface soil moisture content	MOISTC (fraction)	None	Value = 0.22 This variable is used in the GENII leach rate calculations. GENII offers 3 options for leach rates: Use GENII Default leach rates (Not Used) Use leach rates calculated from user input. For this option, the user must specify the following variables: Surface Soil Thickness Surf. Soil Moisture Content (fraction) Surf. Soil Bulk Density Total Infiltration Rate Soil Adsorption Coefficient (Kd), which is specific for each nuclide Use User-provided leach rate constants. (Not Used) In this study, leach rates are determined using option (2), above. See formulas in PNNL 2002, p.101, 104, and 143 (7). Using the formulas and values in EPA 2000, pp. A-5 and A-6 (43), the following soil moisture values can be calculated using the local 40 cm/year infiltration rate and the following formula: Soil Moisture (unitless fraction) = $n * (I / K_s)^e$, where: n = total soil porosity (unitless fraction) [value = 0.4 (see below)] I = infiltration rate (m/yr) [local value =0.373 m/yr] K_s = saturated hydraulic conductivity (m/yr) e = soil-specific exponential parameter (unitless) Values for K_s and e are provided by EPA 2000 (43) for different soil types (below). For total soil porosity (n), n = (1 – (dry soil bulk density / soil particle density)) Using EPA's recommended soil particle density value of 2.65 g/cm^3 and the local soil bulk density of 1.59 g/cm^3, n = 0.4:

Soil Type	I (m/yr)	K_s (m/yr)	E	(I/Ks)e	BulkSoil Porosity	Soil Moist
Sand	0.373	1830	0.09	0.47	0.4	0.19
Loamy Sand	0.373	540	0.085	0.54	0.4	0.22
Sandy Loam	0.373	230	0.08	0.60	0.4	0.24
Silt Loam	0.373	120	0.074	0.66	0.4	0.26
Loam	0.373	60	0.073	0.69	0.4	0.28
Sandy Clay Loam	0.373	40	0.058	0.77	0.4	0.30
Silt Clay Loam	0.373	13	0.054	0.83	0.4	0.33
Clay Loam	0.373	20	0.05	0.82	0.4	0.33
Sandy Clay	0.373	10	0.042	0.87	0.4	0.35
Silt Clay	0.373	8	0.042	0.88	0.4	0.35
Clay	0.373	5	0.039	0.90	0.4	0.36

The soil type at the SRS was taken to be loamy sand, and a soil moisture value of 0.22 was selected.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Soil - Leaching	Surface soil thickness	THICK (cm)	None	GENII Default = 15 cm. Used in direct exposure and leach rate calculations - See PNNL 2002, p. 186 (7). (same as SURCM). This is a standard value widely used.
Exposure	Soil – Leaching	Total infiltration rate	VLEACH (cm/yr)	None	Value = 37.3 cm/yr This value is based on a study conducted at the SRS (49) which calculated ground-water recharge rates at the SRS in the vicinity of the Old SRP Burial Ground from 1961 to 1986. Several other SRS and local studies have cited a local value of about 40 cm/yr. Phifer 2003, p. 5 (57), cites an infiltration rate of 40 cm/year based on "past infiltration studies conducted at SRS." Other references citing a 40 cm/yr infiltration rate (46,47). Wild 2003, p.17 (59), cites an infiltration rate of "1/6th to 1/3 of rainfall" which, when combined with the 1961-86 average precipitation rate at F-Area (48.51 inches/year [49]) yields an infiltration rate of 20 to 41 cm/year. These studies use values that do not consider additional infiltration resulting from irrigation. In this analysis, irrigation is assumed to be zero (see Moore 2002, pp. 17-18 [37], and Hamby 1991 [29]).

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Soil – Leaching	Soil adsorption coefficient	SOILKD (ml/g)	By Isotope Index	This variable is also known the Kd or distribution coefficient. The Kd is used in the soil model to calculate leaching of contaminants from the surface soil to deeper soil (PNNL 2002, pp. 105 & 143 [7]). Higher Kds result in the contaminant remaining in the surface soil longer and resulting in higher availability of the contaminant to transfer to the air (resuspension) or to plants (for ingestion). An analysis of available Kd data from several sources for the purpose of this model is presented in ATL 2003c (40). The Kd values resulting from the analysis are as follows:

Nuc.	Value		Nuc.	Value
Am	2000		Pu	4100
Ar	Not Applic		Ru	55
C	Not Applic		S	7.5
Ce	490		Sr	3041
Co	60		Tc	2.49
Cs	59		Th	3000
H3	0		U	1000
I	1.55		Y	510
Nb	160		Zn	200
P	173		Zr	600

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Soil – Resuspension	Resuspension factor	RESFAC (1/m)	None	Value = 10^{-5} m^{-1} and 10^{-7} m^{-1}, depending on location GENII offers 3 different ways to calculate a soil resuspension factor (1/m), which is multiplied by the areal soil concentration (Bq/m^2) to calculate an air concentration (Bq/m^3) (PNNL 2002, p. 159 [7]): Mass loading model. This method requires a Mass Loading Factor [GENII Default = 5.00×10^{-5} g/m3] to calculate a resuspension factor (1/m). [Not Used] Anspaugh model. This is a time-dependent approach that is independent of soil characteristics. It calculates a resuspension factor that is exponential with time. It requires a top soil depth [GENII Default = 1 cm]. [Not Used] User input of resuspension factor, GENII default = 1.0×10^{-9} m^{-1}. The third option, which allows the user to input a resuspension factor, was selected for this analysis. Two values are selected for this variable. A higher value (10^{-5}/m) is assigned to exposure locations around agricultural areas where there is a relatively higher level of soil disturbance. A lower value (10^{-7}/m) is assigned to exposure locations in areas where there is comparatively less soil disturbance. In each case, the available literature does not identify a single preferred value for this variable. However, recommended values occur over a range (see Kennedy 1992, Table 6-4 [22], and Till 1983, Sect 5.2.2.6 (p.5-30) and Table 5.8 [31]). Exposure Locations, CDC Scenarios, (Location Index Numbers), and Assigned Values for Resuspension Factor 1×10^{-5} m^{-1} (More Disturbed Exposure Locations): Girard – Rural Family One (1); New Ellenton – Migrant Family (5); Williston – Rural Family Two (9) 10×10^{-7} m^{-1} (Less Disturbed Exposure Locations): Waynesboro – Rural Family One (2); Augusta – Urban Family (3); Jackson – Outdoors Family(4); Barnwell – Delivery Person (6); Martin/LTRC – Near River Family, Delivery Family (7 and 21); Allendale – Delivery Family (8); Onsite Location – Urban Family, Delivery Family, Outdoors Family (10); Savannah River Downstream (22)

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Soil – Surface Soil	Surface soil areal density	SLDN (kg/m^2)	None	Value = 240 kg/m^2 This variable is used in calculating soil concentrations for use in food chain pathways. It represents the bulk mass of soil into which air-deposited contamination is mixed. The selected value of is consistent with a soil thickness of 15 cm and the site-specific soil density of 1,600 kg/m^3. This value is also equal to the default value (240 kg/m^3) recommended by the NRC (32). The SRS adopted the same NRC default value in a dose modeling study (6). The 240 kg/m^2 value is also the GENII default value (7). The basis for the soil thickness and density values cited above is explained below.
Exposure	Soil – Surface Soil	GENII soil layer thickness used for density	SURCM (cm)	None	Value = 15 cm This variable is used in calculating direct exposure from contaminated soil (PNNL 2002, p. 186 [7]). GENII Default = 15 cm (7).
Exposure	Soil – Surface Soil	Surface soil bulk density	BULKD (g/cm^3)	None	Value 1.60 g/cm^3 This variable is used in connection with SURCM in the calculation of the direct exposure pathway (7). The selected value of 1.60 g/cm^3 is based on the bulk density of soil of the vadose zone at H and F areas used in DOE 2002, p.C-22 (42) (the value was rounded from 1.59 g/cm^3).
Exposure	Water - General	Delay time in water distribution system	HOLDDW (days)	None	Value = 0 days This variable is the drinking water and shower inhalation pathways. For the base case, because no member of any exposure scenario is assumed to use contaminated water for drinking or showering, the assumption of a value has no effect on the base case assessment. It would be otherwise reasonable to assume that any river water used by a scenario family would have minimal holdup time between when it is removed from the river and used in the household. Therefore, a value of zero (0) is assumed for input to GENII.
Exposure	Water – General	Shoreline sediment density	SEDDN (kg/m^2)	None	Value = 240 kg/m^2 This variable is used in determining the direct exposure rate resulting from contaminant deposition along the shoreline. Neither default nor site-specific data for sediment density was found. The selected value is based on the value selected for the surface soil areal density (SLDN).

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
	Water - General	Indoor volatilization factor for radionuclides	ANDKR (l/m^3)	None	Value = 0.0 This variable is used in determining the amount of nuclides in water that volatilize into indoor breathing air. This exposure pathway is not considered in the base case assessment. Nonetheless, because the variable is not contaminant specific, and because most radionuclides that were discharged to surface water from SRS are nonvolatile, this variable should always be set to 0 (54).
Receptor	External Ground Exposure	Indoor shielding factor	SHIN (none)	None	Value = 0.7 A value of 0.7 is assumed. Values of 0.5, 0.7 and 0.8 were found in the literature. EPA recommends a value of 0.8 for Reasonable Maximum Exposure in an example screening scenario (EPA 2001, Example Scenario 11, Table 4.3 [44]). Values 0.7 and 0.5 are used by the SRS in population dose modeling (WSRC 1991, p. A-48 [60]; WSRC 1992, p. 115 [61]; WSRC 1993, p. 133 [62]).
Receptor	External Ground Exposure	Outdoor shielding factor	SHOUT (none)	None	Value = 1.0 A value of 1.0 is assumed. The GENII default value = 1.0 (PNNL 2002, p. 300 [7]). No shielding would be expected in outdoor situations. A value of 1.0 is specified by EPA for Reasonable Maximum Exposure (44).
Receptor	External Exposure to Shoreline	Shoreline width factor	SWFAC (none)	None	Value = 0.2 The shore width factor is a factor for reduction of the external dose rate factor for exposure to the shoreline. The external dose rate factors are based on exposure to an infinite flat plane of contamination. Because most shorelines do not represent an infinite plane, a reduction is allowed to address this difference in geometry. A value of 0.2 was selected based on its use in SRS analyses and use as a GENII default value (PNNL 2002, p.300 [7], WSRC 1991, p.A-56 [60], WSRC 1992, p. 123 [61], WSRC 1992, p. 138 [61]). A value of 0.2 accounts for the shoreline being a narrow strip rather than an infinite plane.
River	Surface Water	Concentration	CVAL	pCi/ml	This variable represents the concentration of each contaminant at a specified exposure location. The values for this variable differ based on the year of release, the nuclide of interest, and the specified exposure location. Values for this variable are determined through a separate analysis of releases, water flowrates, and holdup/loss between the release and exposure locations.

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APPENDIX G SYSTEM IMPLEMENTATION

G.1 Introduction

This appendix describes how the GENII-V2 computer was implemented to create an integrated system for the Dose Reconstruction Project at the Savannah River Site. The first step in the implementation was the understanding how GENII-V2 could be used to implement the requirements for this project. An analysis of the scope of the problem identified the following: 1) upwards of 40 unique locations for exposure, 2) approximately 17 releases points, 3) 39 years of release data, 4) approximately 25 isotopes released, 5) both atmospheric and liquid releases, 6) six different age groups for most exposure locations, and 7) each receptor's dose output was needed by isotope and pathway. In addition there could be up to 100 uncertainty/sensitivity runs for each of the above runs.

Several tasks were identified to reduce the scope of the calculations. These included reducing the number of locations to 10 and combining the release point to 4. Through understanding the GENII-V2 methodology, it was concluded that based on assuming that GENII-V3 calculated doses for a receptor was of known age and known usage rates/ exposure times, additional doses/risks could be produced for a receptor of any age and any usage rate/ exposure times. It was also found that doses could be generated for receptors at 10 different exposure locations within a given GENII-V2 computer run. At this point a single GENII-V2 input file (GID file) consisted of over 8,000 lines of data in a text format. Manually setting up and verifying the input for these runs and ensuring that the input is successfully activating GENII-V2 would require a significant labor commitment and risk creating input errors. A single output file consisted of over 2 megabytes of data in a comma delimited text format. Reading and analyzing the output would also require a significant labor commitment and also incur potential errors.

It was concluded that the process of generating, running and analyzing a GENII-V2 analysis would require automation. It was decided that two separate programs would be generated: a preprocessor to generate input files and a postprocessor to "read" the output and prepare output suitable for further analysis. Automating the input activities using a customized pre-processor interface to GENII-V2 would result in faster and less labor-intensive modeling efforts, and reduce the likelihood of data input errors. In addition, a post-processor would read and extract GENII-V2 output (HIF) files based on the user's requirements.

The System Architecture is discussed in Chapter G.2. Details of the computer programs are presented in Chapter G.3, Pre-Processor, and Chapter G.4, Post-Processor. Testing of the computer programs is discussed in Chapter G.5.

G.2 System Architecture

The pre-processor and post-processor modules were both written in Microsoft Visual Basic and use Microsoft Access database table structure and calculations. Due to the limitation and no thread capability of the Access database, any database file stored in Access can not be larger than 2GB of data. Thus, the SRSDR system was designed by using dual database files, one was for application and parameter tables, and the other was for temporary and processing data tables. This method provides the capability to compact and optimize the temporary database files without interrupting the processing of data. Also, since the program requires a large amount of disk space and time to run, the data for each facility will be run independently. Both the pre- and post-processor run on distributed client systems, with the required input files for both modules located on each client system. The output for the post-processor is written to the Access database for the appropriate receptor family located on a shared network drive.

The overall scheme for generating a series of GID files consists of a series of loops. All process operations are table driven within the database. Once the user specifies the facility, the type of release, the years desired, whether uncertainty is to be run, and file names, the pre-processor will loop over the isotopes within the release file and loop over the number of runs to be created, generating a GID file for each completion of a loop over the number of runs. These output files are stored in the local hard drive to be used by GENII-V2 for calculation. At the same time when generating the GID files, each file name and its location path is written to a batch file to be executed by the integrated GENII-V2 system, and a list of the file information is written to the QC file for quality assurance purpose.

The post-processor takes in a set of GENII-V2 output (HIF) files for a given facility and prepares a set of dose/risk results for the receptors designated in the scenario requirements for that facility. It will then combine the facility based results to form results for the entire site once all the facility results are available. The post-processor has the capability of providing various levels of results depending on the user input. The post-processor output is written to the Access database for the appropriate receptor family located on a shared network drive.

Figure G-1 illustrates these system modules, and briefly describes the input flow for each module.

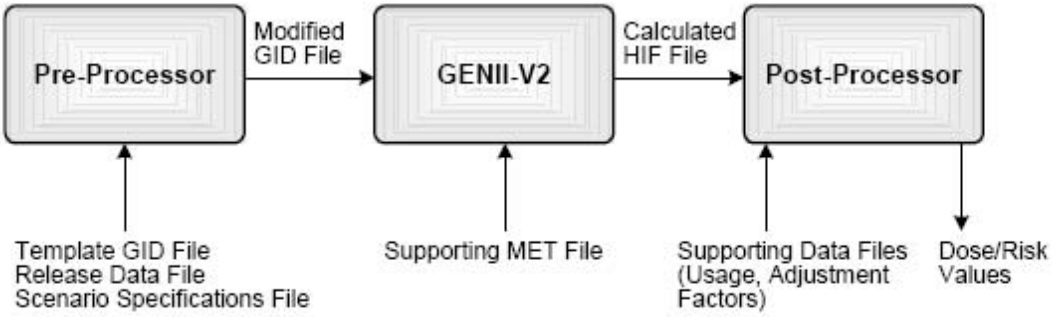

Figure G-1 System Module Input Flow

G.3 The Pre-Processor

The pre-processor will take a standardized GENII-V2 input file (GID file) and make changes in the standardized GID to account for varying facilities releases by isotope, year of operation and receptor combination. In addition, for each facility, year, and receptor combination, there could be up to 101 GID files generated as required by the uncertainty analysis (one for the point estimate data and 100 for the uncertainty data).

The overall processing was designed to proceed in the following fashion.

- Read user-specified input.
- Read template (standardized) GID file(s) as required.
- For a user specified facility and release type (atmospheric or liquid).
- Read the isotope description data file.
- Read the uncertainty data files (both the source term and parameters) to determine the point estimate and the set of uncertainty values for each parameter in the file.
- Cycle over the available standardized GID files.

- Modify the standardized GID data for changes required only once.
- Cycle over the years of operation.
- Cycle over the number of uncertainty runs (There will always be one run to evaluate the point estimate data.).
- Prepare the release data by isotope.
- Prepare the values for the parameters in the uncertainty file.
- Generate an input file for execution by GENII-V2.

G.3.1 The Pre-Processor User Interface

The user selects the pre-processor module from the SRS Dose Reconstruction System (SRSDRS) main menu screen, as shown in Figure G-2.

Figure G-2 SRSDRS Menu Screen

The user then enters the following information:

- Facility name and ID,
- The type of release (atmospheric and liquid), and
- The year or range of years for processing the source terms,

The Pre-Processor user interface screen is shown in Figure G-3. Table G-1 describes the type of information that should be entered into the screen.

Based on the information entered into this screen, the user is presented with a list of facility release data files that comply with the above requirements. The list of files is composed of files with names having the format of ABCDEFX.XLS where

- A is the type of release (A for atmospheric, and L for liquid),
- B is the facility ID,
- CD is the last two digits of the first year of releases,
- EF is the last two digits of the last year of releases, and
- X is the version.

NOTE: *The year or range of years required by the user must be contained between the years specified by CD and EF. The user will be asked to select the file name containing the appropriate release data.*

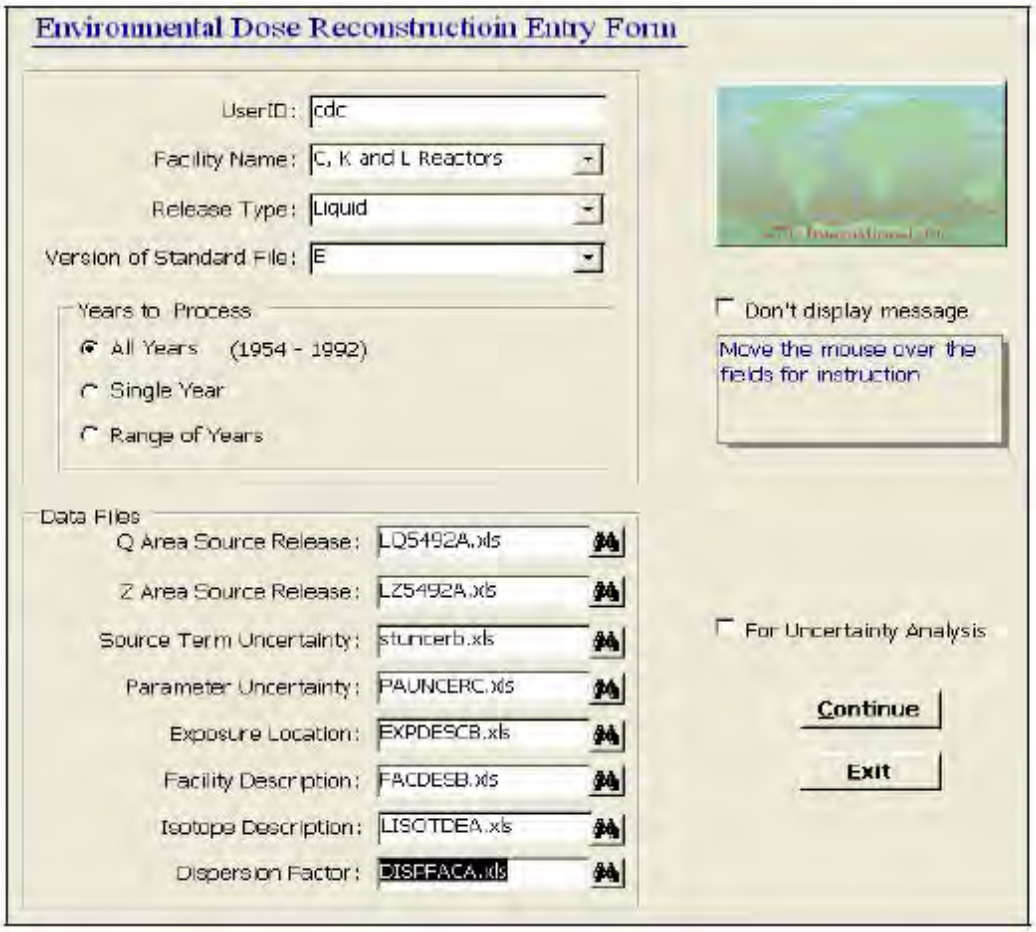

Figure G-3 Pre-processor User Interface Screen

Table G-1 Data Entry for the Pre-processor User Interface Screen

Field Name	Description
User ID	Enter the user ID to identify the person who runs the program.
Facility Name	Select the facility name from the dropdown menu. Available facility names include A M & SRL, H&F Area, C K & L Reactors, P&R Reactors, and All Site Liquid Release
Release Type	Select the release type from the dropdown menu. Available release types include Atmospheric and Liquid.
Version of Standard File	The identification code to the modified version of the standard template file.
Years to Process	Select the radio button corresponding to the appropriate year or range of years. Valid selections include 1954 - 1992, Single Year (enter the single year of your choice), and Range of Years (enter the year range of your choice).

Field Name	Description
Data Files	For each Data File type, select a data file from the dropdown menus. The dropdown menus that will be visible and the files that will be available for selection will depend upon the facility selected. These data files are described in more detail in the following paragraphs.

There are nine additional data files that the preprocessor needs to read. All of these files are EXCEL files and are located in the C:\CDC\Preprocessor\Input directory.

The user is prompted to select a file for the source term uncertainty file from a list of available files. The list is composed of files having names with a format of STUNCERx.XLS.

The user is then prompted to select a file for the parameter uncertainty file from a list of available files. The list is composed of files having names with a format of PAUNCERx.XLS.

The user is then presented with a list of exposure location description files available. The list is composed of files having names with a format of EXPDESx.XLS. The user is asked to select a file name.

The user is then presented with a list of facility description files available. The list is composed of files having names with a format of FACDESx.XLS. The user is asked to select a file name.

The user is then presented with a list of isotope description files available. The list is composed of files having names with a format of ISOTDESx.XLS. The user is asked to select a file name.

The user is then presented with a list of dispersion parameter files available. The list is composed of files having names with a format of DISPDECx.XLS. The user is asked to select a file name.

The user is then prompted to determine whether an uncertainty analysis is needed. If the user replies by checking the Uncertainty Run option, then the number of runs is needed to be selected, and that number of GID files will be prepared for each standardized GID file read. Otherwise, only the point estimate file will be prepared for each standardized GID file read.

NOTE: *If the user specifies an input that results in an incorrect value, such as a facility not contained in the facility description file, a facility without a release file, or year not within the range of years in existing release files, a message will be written to the message file and the pre-processor will abort.*

When data entry is complete, the *Continue* button will take the user to the pre-processor confirmation screen shown in Figure G-4.

Click the *Create GID* button on the Pre-processor Confirmation screen to generate the GID input file for GENII-V2. A message will be displayed that the GID has been successfully created.

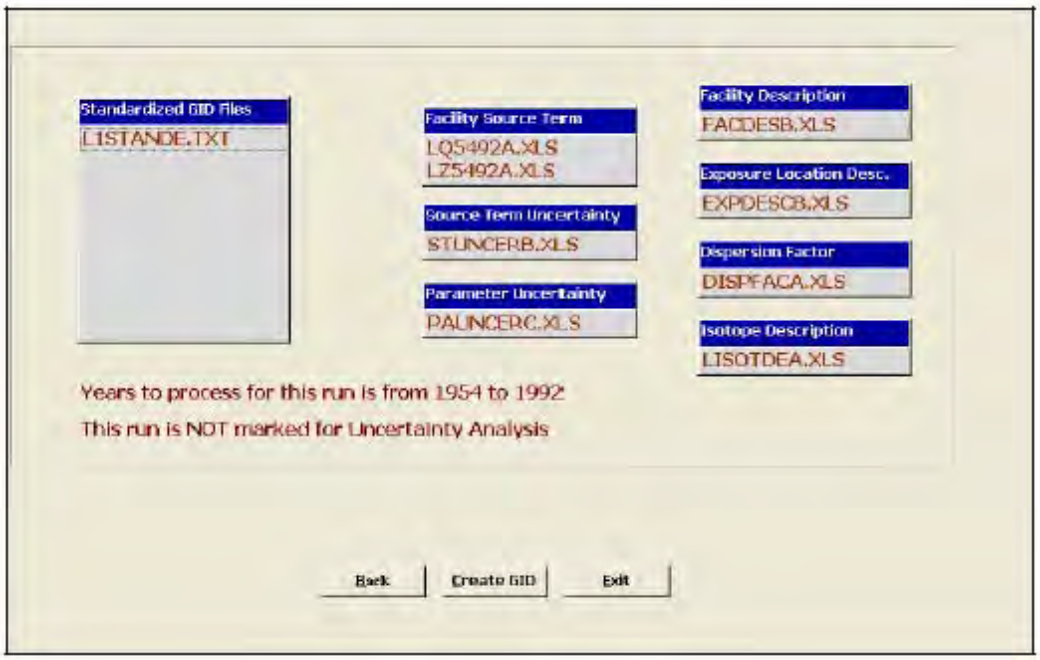

Figure G-4 Pre-processor Confirmation Screen

G.3.2 Standardized GID Files (Template Files)

The template files are located in the C:\CDC\Preprocessor\Input directory, they must have the TXT file extension. Their names have the following format: xySTANDz.TXT where

- x = A, L or S (A – Atmospheric, L – liquid)
- y = 1,2,3, or 4 is the number of depending on the total number of exposure locations, each template GID file can have up to 10 exposure locations
- z = A, B, C, etc depending on the total number of revisions that have been made to the template files

When the user has responded, the pre-processor must cycle through the appropriate number of template files with the release type and revision number specified by the user. For example, if the user has specified an atmospheric release and there are three atmospheric template files (that means more than 30 exposure locations in this scenario) , the file names will be A1STANDA.TXT, A2STANDA.TXT and A3STANDA.TXT assuming version “A” of the template file was specified. Therefore the pre-processor needs to read these three files.

The template GID files are ASCII files containing prepared input files suitable for execution by GENII-V2. These files contain data which will be modified by processing; however, the format (the number of lines, format of each line, etc) will not be changed. In general, each line within the GID file has the following format:

Variable Name
Seven index values
Two string values
A value in either an integer or string format.

There are many sections within a GID file, each section has a module ID, and the number of lines of data that follow for that module.

If there is an error in reading any of the template files, a message will be written to the message file and the pre-processor will abort. The message should contain the file name and the contents of the last line of data read. If possible, the line causing the error should also be written if possible.

G.3.3 Generating GID Files -- Processing Overview

The overall scheme for generating a series of GID files consists of a series of loops. Once the users has specified the facility, the type of release, the years desired, whether or not uncertainty is to be run, and file names, the pre-processor will loop over the number of years, loop over the isotopes within the release file and loop over the number of runs to be created, generating a GID file for each completion of the loop over the number of runs.

Some processing will need to be done only once and it will apply to all runs for a given facility, type of release and receptor combination (for a given template file). For atmospheric releases, one variable may have to be changed based on the release year. Some processing will need to be done for all runs. The processing requirements will be divided into atmospheric releases, and liquid releases. Presently, only the atmospheric processing requirements will be addressed. Some processing will refer to a section within the GID file such as “src” or “exp.” It should be noted that the label for a section is three characters followed by a number (such as src5 or exp21.) For some sections (exp, rcp and hei), the number is the exposure location index; for other sections (src, air, con), the number is just a number generated when the template file was created.

G.3.3.1 Atmospheric Release Processing -- Required only Once

G.3.3.1.1 Source Term Data

Two changes in the “src” section will need to apply for all runs (for all years and for both the point estimate and the uncertainty runs.) These include the variables “two” and “three.”

"two",3,0,0,0,0,0,0,"m","m",0
"three",3,0,0,0,0,0,0,"m","m",0

The value for two is the release height obtained from the facility description file. The value for three is the height of adjacent building obtained from the facility description file.

G.3.3.1.2 Air Dispersion Data

The ten “ARRADVAL” variables need to be read and adjusted to reflect the distances between the release facility and each exposure location. The ten values need to be put into increasing order. For some template files, there may not be 10 exposure locations or 10 different distances. In this case, the unused values can be filled with the smaller distances from the file.

In the “air” section the 10 values in the following variables need to be changed. These variables and values represent the standardized spacing between the 10 annular distances used by GENII-V2. The following presents a fragment from a GID containing these variables and values.

"ARRADVAL",1,1,1,0,0,0,0,"m","m", 805
"ARRADVAL",1,1,2,0,0,0,0,"m","m", 2414

```
"ARRADVAL",1,1,3,0,0,0,0,"m","m", 4023
"ARRADVAL",1,1,4,0,0,0,0,"m","m", 5632
"ARRADVAL",1,1,5,0,0,0,0,"m","m", 7241
"ARRADVAL",1,1,6,0,0,0,0,"m","m", 12069
"ARRADVAL",1,1,7,0,0,0,0,"m","m", 24135
"ARRADVAL",1,1,8,0,0,0,0,"m","m", 40255
"ARRADVAL",1,1,9,0,0,0,0,"m","m", 56315
"ARRADVAL",1,1,10,0,0,0,0,"m","m", 72405
```

As can be seen from the fragment, the first two indices are always 1. The third index is the ring number varying from 1 to 10 (the number of rings allowed by GENII-V2.) The values need to be changed to reflect more closely the distances from the release facility to each exposure location within the standardized GID file.

The 10 values are stored in a temporary matrix. The distances from the releasing facility to the each receptor are calculated within the template file. The data for each receptor is contained in the exposure location description file. The exposure location index from this file is the same as contained in the “expx” line of each “exp” section of the GID file. The facility X-UTM (Universal Transverse Mercator) and Y-UTM measurements are obtained from the Facility Description File associated with the facility ID requested by the user. The distance is calculated by the following formula:

Distance = square root $[(\text{Delta X-UTM})^2 + (\text{Delta Y-UTM})^2]$
Where Delta X-UTM = Facility X-UTM – Receptor X-UTM and
Delta Y-UTM = Facility Y-UTM – Receptor Y-UTM

The distances are inserted into the temporary matrix. The distances are then ordered from the smallest to largest distance.

If there are less than 10 exposure locations in the template file, the remaining unused values are not changed in the temporary matrix.

G.3.3.1.3 Exposure Location Data

The next item to be performed is the identification of the correct section of the GID file in which the exposure location name and easting and northing values are placed. The exposure location index (for example 1) will be combined with the string “exp” to form a new string of the form “exp1”. This string will be used to search the GID file for the variable expName with that value (see the following fragment from a GID file.) The second index will be collected. The value for the expLabel (with the correct second index) will be changed if different than that contained in the exposure description file. The expX and expY (with the correct second index) for the location will be changed to the easting and northing values.

```
"expName",1,1,0,0,0,0,0,"N/A","N/A","exp1"
"expLabel",1,1,0,0,0,0,0,"N/A","N/A","Rural Family-Gaird,GA"
"expModel",1,1,0,0,0,0,0,"N/A","N/A","GENII V.2 Chronic Exposure Module"
"expDesPath",1,1,0,0,0,0,0,"N/A","N/A","\FRAMES\Gen_Exp.des"
"expX",1,1,0,0,0,0,0,"N/A","N/A",10
"expY",1,1,0,0,0,0,0,"N/A","N/A",10
```

To calculate the easting and northing, the following steps are performed:

The offset from the exposure location file is converted into radians by multiplying the offset in degrees by PI/180.

The angle "alpha" which is an angle in the UTM coordinate system is calculated by:

Alpha = inverse tan (DeltaY-UTM/DeltaX-UTM)

The magnitude of the distance easting in kilometers = Distance * cos(Alpha – offset) / 1000
The magnitude of the distance northing in kilometer = Distance * sin(Alpha – offset)/ 1000

If Delta Y-UTM is negative then the distance northing is negative. Similarly if Delta X-UTM is negative then the distance easting is negative.

G.3.3.2 Miscellaneous Processing

The site name is read from the template file. The year of the release and facility is added to the SiteName and a new site name is written.

For each "xxxModelStat" variable (such as "rcpModelStat") the value is 1 except for the "conModelStat" which should be set to 2.

For each "ModState" variable, the value is 1.

G.3.3.3 Processing Over Release Years

The meteorological file name, obtained from the Dispersion File, is inserted into the value for the variable ARMETFILE.

"ARMETFILE",1,1,0,0,0,0,0,"N/A","N/A","C:\FRAMES\SRS7579.5YR"

G.3.3.4 Processing Over Uncertainty Runs

Once the above changes have been made, the pre-processor cycles over the number of required years processing the release data, the uncertainty data for the source term, and the parameters for each year desired. The description of the processing is divided into processing the source term data and processing the parameters in the parameter uncertainty file. Once the processing over a given uncertainty run, a GID file is created.

G.3.3.5 Source Term Processing

For each isotope, the lines in Example G-1 need to be read from the template file, processed, and modified as necessary and written. There are always at least these lines for every isotope with the initial release quantities. A "casid" line will be followed by two sets of "ctime" lines. Within each set of "ctime" lines there will be one or more "cflux" lines. The number of "cflux" lines per "ctime" line pairs will be dependent on the number of flux types for each type of release (at least two flux types for atmospheric releases and one flux type for liquid release).

The following is a partial example of an atmospheric release with two flux types (CO60 was the first isotope in this example).

Example G-1

```
"casid",3,1,0,0,0,0,0,"yr","pCi/yr","CO60"
"ctime",3,1,0,1,0,0,0,"yr","yr",0
"cflux",3,1,0,1,1,0,0,"pCi/yr","pCi/yr",0
"cflux",3,1,0,1,2,0,0,"pCi/yr","pCi/yr",10
"ctime",3,1,0,2,0,0,0,"yr","yr",100
"cflux",3,1,0,2,1,0,0,"pCi/yr","pCi/yr",0
"cflux",3,1,0,2,2,0,0,"pCi/yr","pCi/yr",10
```

Table G-2 contains the meaning of each of the seven indices used within the source term data section.

Table G-2 Index Values for Source Term Data

Index Position	Value	Meaning
	Cflux	
1	0	Not Used
	1	Not Used
	2	Liquid Release
	3	Atmospheric Release
	4	Not Used
2		Isotope Index
3		Daughter Index
4	1	First Time Period
	2	Second Time Period
5		Flux Type
6 and 7		Not Used

For some isotopes, there may be a “casid” line with the third index as 1. These lines are not changes. These are daughters of the isotope. The amounts of these daughters will have initial releases of zero (no cflux lines).

The processing of the isotope data begins with a “casid” line containing the isotope name and isotope index. There will be two “ctime” lines each followed two or more “cflux” lines. Each “ctime” line starts the release data for a given time. Each “cflux” line contains the release data. The pre-processor will read the facility release file for the quantity of isotopes released by year. From the Atmospheric Isotope Description file, the pre-processor will obtain the isotope index and flux type associated with the isotope name. From the Source Term Uncertainty file, the preprocessor will obtain a set of scaling factors for the point estimate and uncertainty runs. The preprocessor will cycle over the required years. For each year, the pre-processor will cycle over the point estimate values and the 100 uncertainty files (if desired), by isotope, changing the values contained in the GID file as necessary. For a given isotope, the released value is the quantity released, from the Source Term File, multiplied by the quantity of $1x10^{12}$, multiplied by the appropriate factor in the Source Term Uncertainty File. The resulting value is entered in both “ctime” groups. Only one “cflux” line within each “ctime” group will be changed (the “cflux” line with the correct isotope index and the flux type.) The remaining “cflux” lines will remain with a zero release.

In summary, only the values in two lines for each isotope are changed. These are the “cflux” values for the correct “cflux” type, one in each “ctime” group.

If there are isotopes contained in the template file for which the release is not changed, the values should be changed to zero. A message will be written to the message file.

G.3.3.6 Parameter Uncertainty Data

The processing for the parameter uncertainty data is driven by the data within the Parameter Uncertainty File. This file contains a list of parameters for which a point estimate and 100 uncertainty data values are provided. Each parameter is identified by a variable name, isotope name (if applicable) and a series of three indices. An additional index is also provided to allow a parameter to be changed from exposure location to exposure location. Since the list of parameters is provided by tabular input, specific sections within a GID file cannot be identified. The pre-processor will search the template file for a match with a variable name and its three indices. If the exposure location index is zero, then all occurrences of the variable name and its three indices are changed. If the exposure location index is not zero, the variable for the specified exposure location is changed.

If any parameter contained in the Parameter Uncertainty file is not used, a message will be written in the message file.

G.3.3.7 Creating a GID File

Once the processing is completed for a given point estimate or uncertainty run, a GID file can be generated. The GID file will be comprised of all the lines in the template file with the appropriate values changed as describe above. The output GID file will be written to a folder in C:\CDC\GENIIV2\Input with a name as specified as follows:

ABCDEFGH.GID

where:

- A is for atmospheric release,
- B is the second character of the standardized GID file,
- C is the facility ID,
- DE is the last two digits of the year of the release, and
- FGH is a number that varies from 000 (the point estimate) to 100 (the number of the uncertainty runs).

G.3.4 Generating Other Output Files

There are three output files other than the GID files used for input into the GENII-V2 calculation. These are: a QCQA file, a batch file and a message file.

Each file name will have the following format:

ABCDEFG.xxx

Where

- A is the type of releases,
- B is the facility,

- CD is the last two digits of the first year of releases processed,
- EF is the last two digits of the last year releases processed,
- G is the version of the standardized GID file processed, and
- xxx is QA for the QCQA file, BAT for the batch file and MES for the message file.

The contents of each file are described below.

G.3.4.1 QC/QA File

This file contains information related to the documentation of the creation of the GID files. Included in this file are:

- The date of the pre-processor run,
- The version of the pre-processor run,
- The list of all the user inputs (user name, facility selected, type of release, the year or range of years chosen, files selected and date of the run),
- The list of GID files generated,
- The name of the batch file generated, and
- The name of the message file generated.

G.3.4.2 Batch File

This file contains the command line information for the execution of GENII-V2 of the GID files created. The file should also contain commands to delete all files created by GENII-V2 except for the GID file used as input and the "HIF" file once GENII-V2 has completed processing a GID file. The commands move each processed "GID" file and "HIF" file to a folder of completed runs..

G.3.4.3 Message File

This file contains all messages generated by the pre-processor. Messages could consist of two types. The first type are messages generated to document such items as parameter variables that are not processed, such as a parameter variable in the Parameter Uncertainty File. These are merely information messages and not errors. This situation could arise during the pre-processing when a parameter included in the file is not appropriate for the type of release calculated (such as a parameter which relates to a liquid release and the type of release being processed is an atmospheric release.) The second type of message results from an error having occurred during the processing. Error messages could be generated from any of a number of reasons. These include:

- An isotope contained in the facility release data that is not found in the Isotope Description file,
- An isotope release quantity set to zero when its data is not included in the Facility Release File,
- A facility ID contained in the facility release data that is not found in the Facility Description file
- A receptor found in the standardized GID that is not contained in the Exposure Location Description file.
- A Mismatch in the number of uncertainty values in the source term and parameter uncertainty files, and
- A file missing or misread.

If an error message is generated, the pre-processor will immediately write the message to both the message file and to the screen. Then the pre-processor will abort.

G.4 The Post-Processor

Briefly, the post-processor will read a calculated GENII-V2 output file (HIF file) for a given facility, and will also read user-defined report parameters (Pathway file), and prepare a set of dose/risk results for the receptors designated in the scenario requirements for the facility. It will then combine the facility-based results to generate results for the entire site once all the facility results are available. The post-processor has the capability of providing various levels of detail depending on the user input. The primary level of detail will be the Total Effective Dose Estimate (TEDE) and the effective cancer incidence and cancer fatalities by scenario receptor. The most detail will consist of the dose and risk numbers by organ, year, exposure pathway, isotope, and facility.

For the first stage, the post-processor "reads" a set of HIF file(s). The set of HIF files could consist of up to 3939 output files for a given facility (39 years of releases times up to 101 runs per year.) The post-processor also reads two files containing the scenario receptor description and behavior. One file contains the year of birth of each receptor. The second file contains data where each receptor is located and what they consume, the consumption rates, and duration that they are at the location. The post-processor also reads a file of dose conversion and risk conversion factors. The post-processor uses this data to adjust the GENII-V2 output results to account for each receptor's behavior and age. As an intermediate result, the post-processor will produce a table of results for each scenario receptor that includes the dose/risk results specified by the user for up to 101 runs by release year. Once all facilities have been processed, a final table of results is produced combining all of the intermediate results by facility into the doses/risks on a site basis.

For the second stage, the post-processor reads each facility's results and combines them into the results for the site.

The following briefly describes the flow of information processing, as shown in Figure G-5:

- The user-specified input data is read: Facility ID, Release Type (Air or Liquid), Pathway File, and Year(s)
    - The Facility IDs available for selection depend upon the Release Type.
      If *Atmospheric* is selected for Release Type, then:
      Facility IDs will include the following:
      A, M and SRL; C, K, and L Reactors; H and F Area; and P and R Reactors
      If Liquid is selected for release type, then:
      Facility IDs include the following: AllSiteLiquidRelease
    - The years desired (from 1954 to 1992).
    - Number of uncertainty runs (from 0 to 100).
    - The level of detail:
      Total Effective Dose/Risk of cancer incidents and cancer fatalities.
      Dose/Risk values by organ, exposure pathway, isotope and years.
    - The Receptor names.
- The specified Pathway file is loaded to the database table.
    - The pathway file contains the usage factors for each exposure location corresponding to the receptor(s) under study.

- The Risk and Dose factor file is loaded to the database table.
  - The Risk Factor file contains the risk factor value for each body organ by isotope by pathway by age.
  - The Dose Factor file contains the dose factor value for each body organ by isotope by pathway by age.
- The GENII-V2 generated HIF file is read. Each HIF file contains sets of dose and risk value for each body organ by exposure location.
  - Exposure location (for example, hei1) is read.
  - Under each exposure location, the data for each isotope is read.
  - For each isotope, the data for every possible pathway is read.
  - For each pathway, read the dose and risk data for each organ is read.
    The Risk and dose factors based on age of the user-specified receptor(s) are applied.
    The Usage or Exposure Factor based on the age of the user-specified receptor(s) are applied.
- Is this the last exposure location?
- If yes, then report is generated.
- If no, then the next exposure location is read.
- Cycle through all exposure locations, isotopes, and associated pathways and organ dose data, as described above.
- A report is generated.

The calculations performed by the post-processor involve the following:

- Determination of the age of the receptor (the difference between the year of birth and current year processed).
- Based on the receptor's age, the correct dose factors, risk factors are obtained and usage/exposure factors by pathway, isotope and organ.
- Multiply the values for the doses/risks in the HIF File by the dose and risk factor for the correct age of the selected recipient(s).
- Divide the adjusted doses by the dose factor for the adult receptor (used in GENII-V2) year period.
- Divide the adjusted risks by the risk factor for the 0-110 age receptor.
- Multiply the results of the above calculation by the receptors usage/exposure factor.
- Perform summations as indicated by the user input choices, such as summation over isotopes for a given pathway/route, summation over isotopes and pathway/routes, etc.

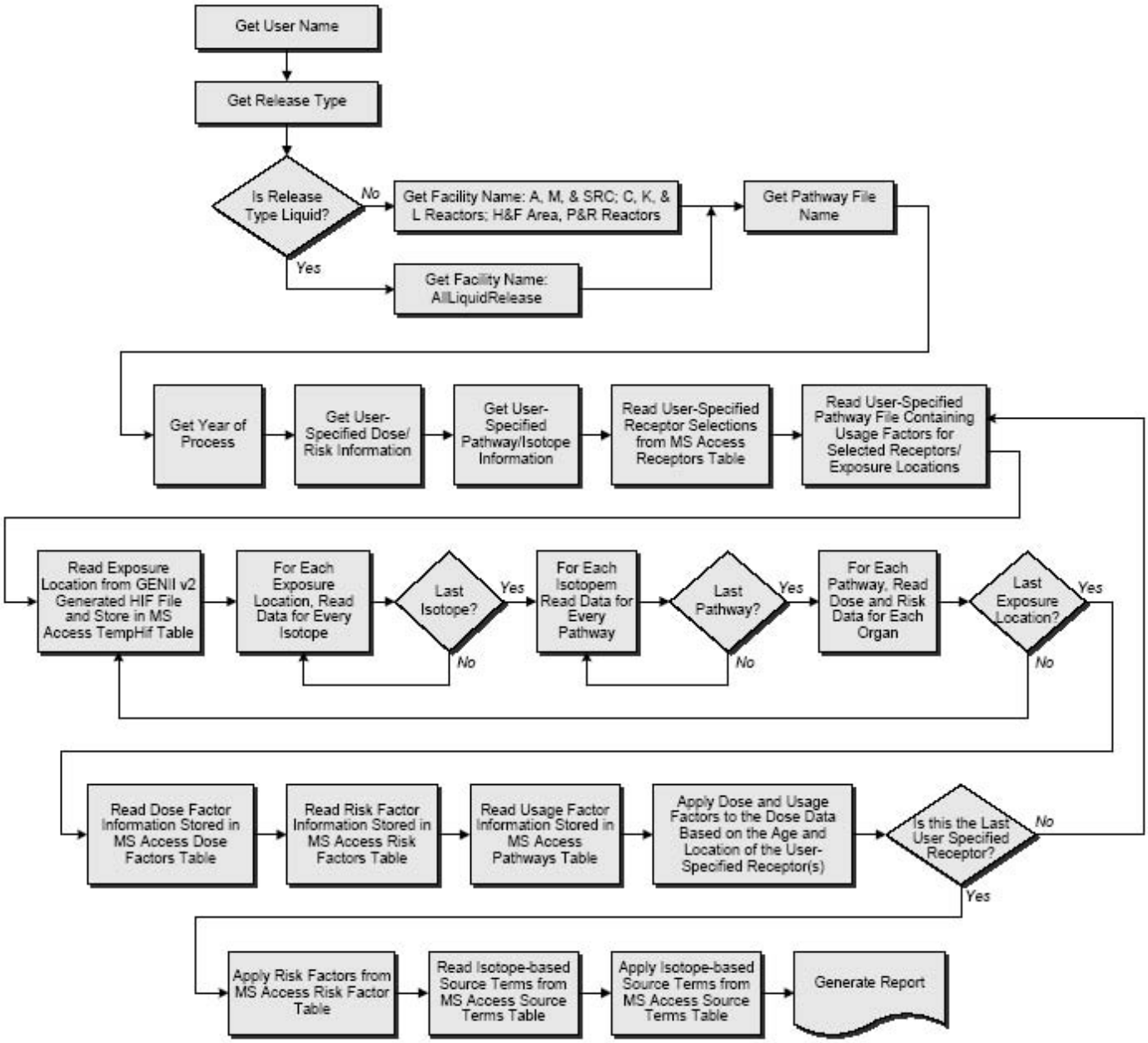

Figure G-5 High-level Post-Processor Process Flow

G.4.1 The Post-Processor User Interface

The post-processor user interface is composed of the following tabs. Information entered into each of these tabs determines the content of the post-processor output report.

G.4.1.1 The General Information Tab

In the General Information tab, as shown in Figure G-6, the user inputs the *User Name*, and selects the *Release Type* and *Facility Name* from dropdown menus. *Release Type* includes *Atmospheric* and *Liquid*, and *Facility Names.* Facility Names will be provided based on the selected release type. For atmospheric the available facility types are "A, M and SRL", "F and H Area", "C, K and L Reactors", and "P and R Reactors". For liquid releases, only one facility name will be provided: "All Site Liquid Release". The user specifies the *Pathway Data File*, which is an Excel spreadsheet containing data about the selected pathway type. This value may either be keyed directly, or the user must browse to locate a file. *Years to Process* may include *All Years (1954 – 1992)*, *Single Year*, or *Range of Years*. The user enters the desired range if this option is selected. All values of dropdown menus are stored in Access lookup tables. The post-processor uses the information entered by the user on this screen to determine the exposure location, release type, and which pathway table to read. The dose and risk factors that will be applied during the calculation of the effective dose over time will be determined by these values. Table G-3 provides descriptions of the General Information fields.

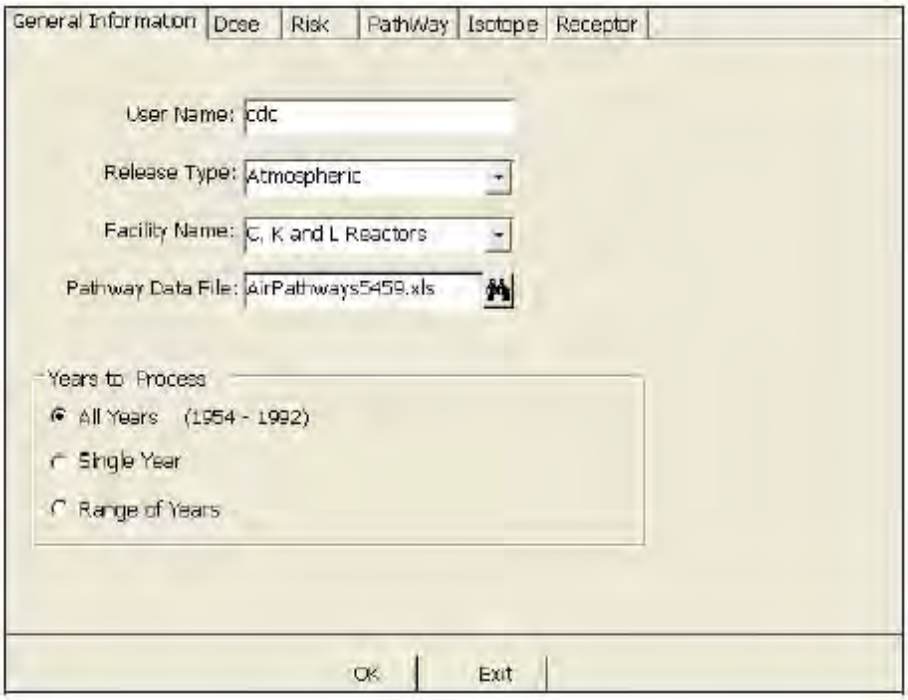

Figure G-6 General Information Tab

Table G-3 Field Descriptions for the General Information Tab

Field Name	Description
User Name	Enter a user name to identify the person who creates the reports.
Release Type	Atmospheric or Liquid.
Facility Name	Based on the release type a list of available facilities is displayed in a drop down box. The user can then choose any one facility from the list.
Pathway Data File	Brows to select a data file. The files that will be visible to you will depend upon the selections made for Facility Name and Release Type.
Years to Process	Select the radio button corresponding to the appropriate year or range of years. Valid selections are based on the range of years determined in the source term files available for use based on the above user selections.

G.4.1.2 The Dose Tab

The user selects *Total Effective Dose Estimate (TEDE)* or *By Organs* to control the amount of dose information presented in the results report. If *By Organs* is selected, the user must select which organs are to be included in the report. Selected organs are then stored in an Access temporary table to be referenced during Post-processor calculations.

Figure G-7 shows the Dose Tab, with "By Organs" selected. Figure G-8 shows the Dose Tab with TEDE selected.

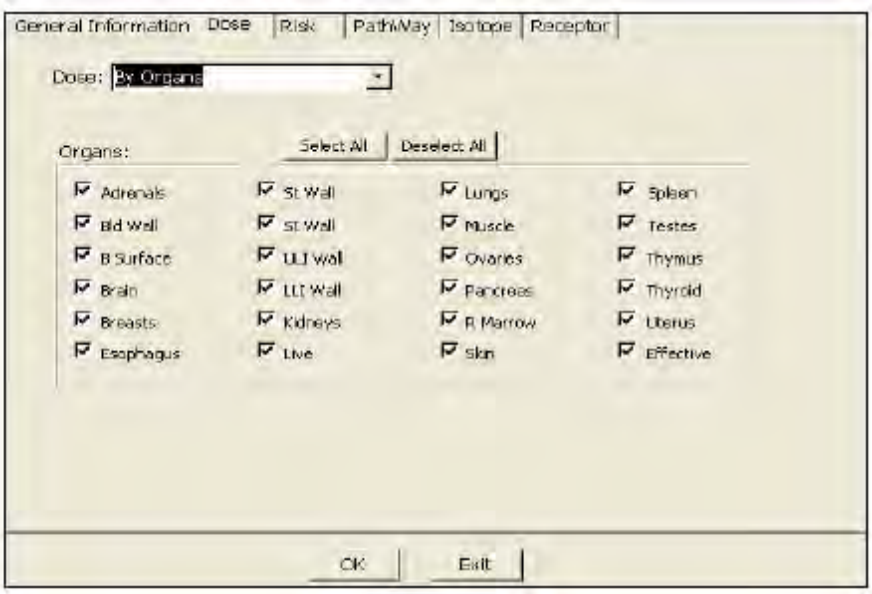

Figure G-7 The Dose Tab, "By Organs" Selected

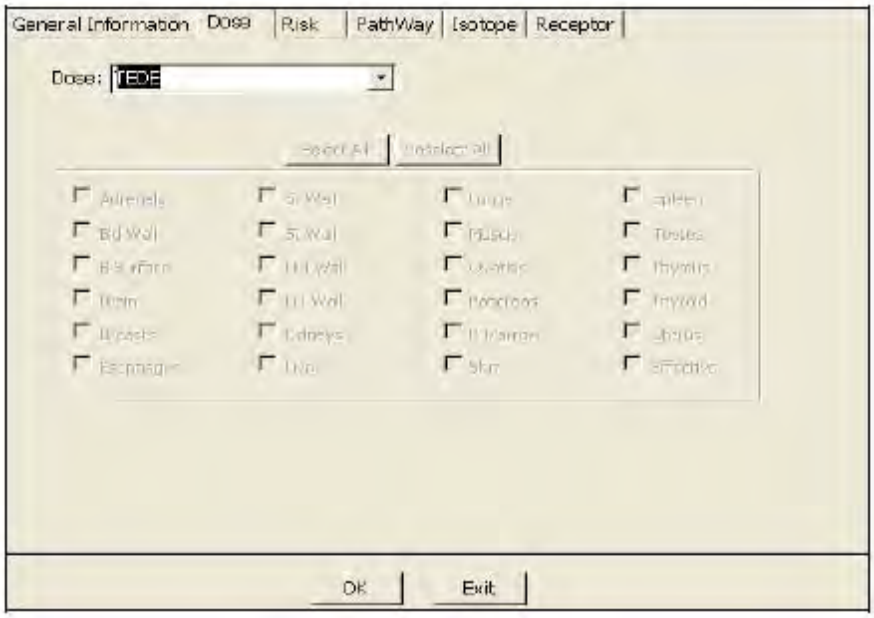

Figure G-8 The Dose Tab, "TEDE" Selected

G.4.1.3 The Risk Tab

This tab is used to calculate the cancer risks. The user elects whether to create the results report with or without cancer results. If the user chooses *With Cancer Results*, two selections become available, *Cancer Incidents*, and *Cancer Fatalities*. When the user selects one or both of these options, a list of organs becomes available. The user may select all, or select specific organs to be included in the report.

Figure G-9 shows the Risk Tab with "No Cancer Results" selected. Figure G-10 shows the Risk Tab with cancer results.

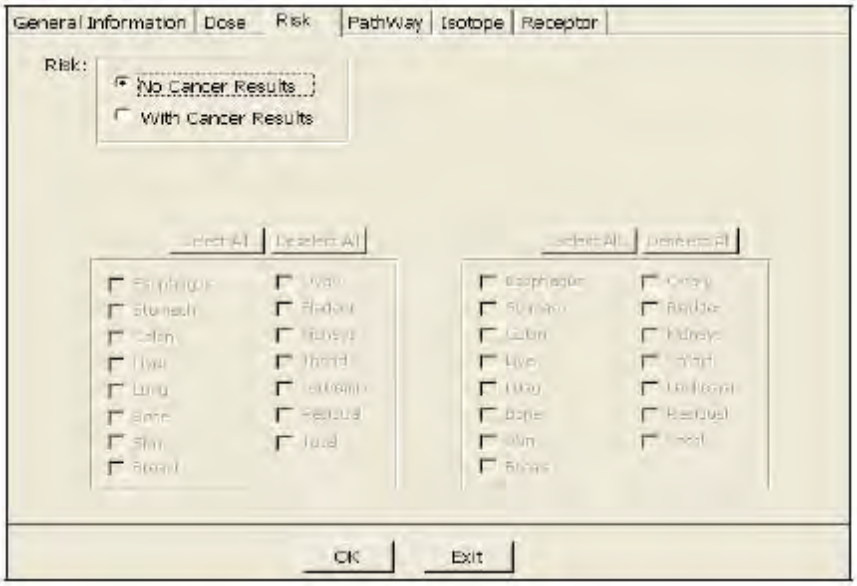

Figure G-9 The Risk Tab, "No Cancer Results" Selected

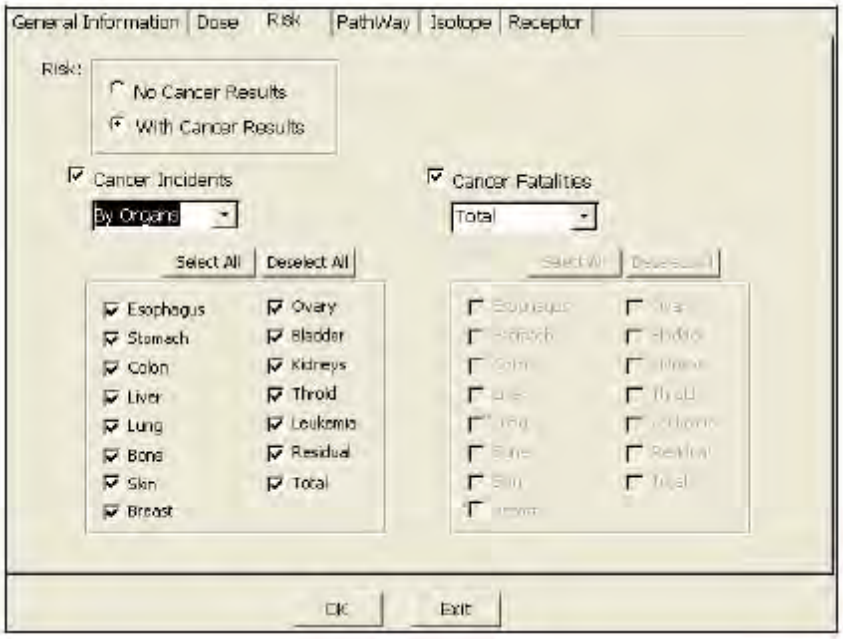

Figure G-10 The Risk Tab, "Cancer Results" Selected

G.4.1.4 The Pathway Tab

This tab controls how the results are displayed for the various pathways (*Summed Over All Pathways*, or *By Pathway)*. If *By Pathway* is selected, a listing of pathways becomes available. The user may select all, or select specific pathways. Doses and/or risks will be presented for the selected pathways. Depending upon the selections the user makes on this tab, information on this tab is used to build the query for the results report. If pathways are selected that are not included in the GENII-V2 HIF file, they will not be included in the report file. Figure G-11 shows the Pathway tab, with *By Exposure Pathways* selected.

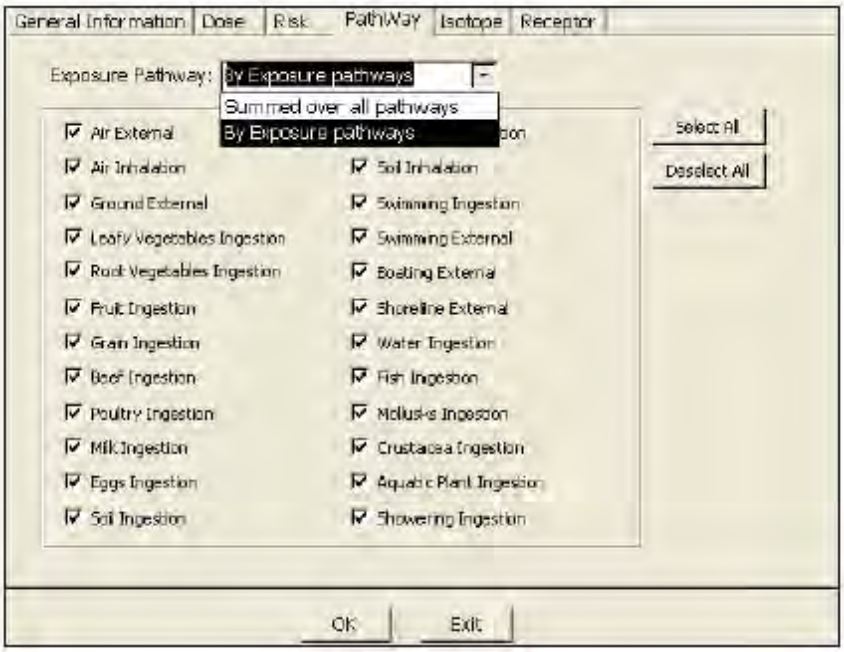

Figure G-11 The Pathway Tab, "By Exposure Pathways" Selected

G.4.1.5 The Isotope Tab

This tab is used to control the display of results as a function of isotopes (*Summed Over All Isotopes*, or *By Isotope.)* If *By Isotope* is selected, a listing of isotopes becomes available. The user may select all, or select specific isotopes. Results will be displayed for the selected isotopes only. Isotope names are stored in an Access lookup table. Information selected on this tab is used to build the query for the results report. If isotopes are selected that are not included in the GENII-V2 HIF file, they will not be included in the report file.

Figure G-12 shows the Isotope Tab with "Summed Over All Isotopes" selected. Figure G-13 shows the Isotope Tab with "By Isotope" selected.

Figure G-12 Isotope Tab, "Summed Over All Isotopes" Selected

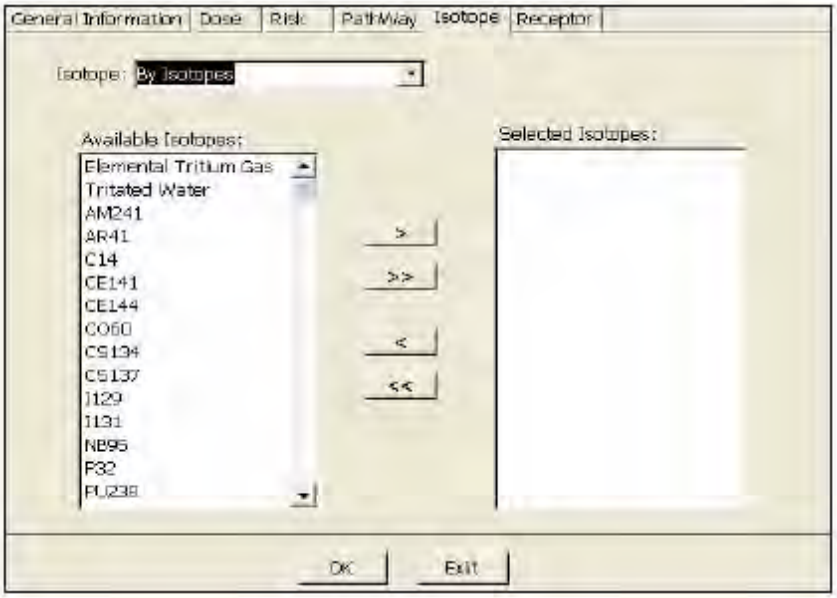

Figure G-13 Isotope Tab, "By Isotope" Selected

G.4.1.6 The Year Tab

The user selects *Summed over all years* or *By year* to control the detail of dose information presented in the results report. If *Summed over all years* is selected, the output result will be the total of the range of years. If *By year* is selected, the output result will be grouped by each year.

Figure G-14 shows the Year Tab with the "Summed over all years" or "By year" selections visible in the dropdown menu.

Figure G-14 Year Tab with "Summed over all Years" or "By Year" Selections Visible

G.4.1.7 The Receptor Tab

The user selects one or more possible recipients for which doses/risks will be calculated. User choices include: *All Family, Rural Family #1, Rural Family #2, Urban Family, Delivery Family, etc.* Information selected on this tab is read from the Access Receptor table, which contains fixed values.

At least one receptor must be selected to generate a report.

The post-processor will generated a dose/risk report for each selected receptor from the list based on the above user input information. Figure G-15 shows the Receptor Tab.

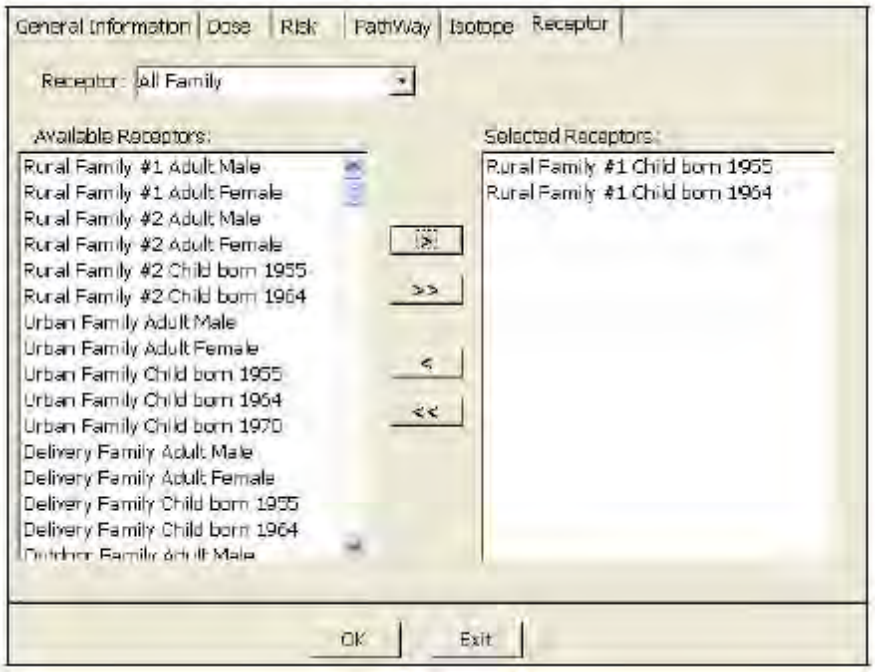

Figure G-15 The Receptor Tab

G.4.2 The Post-Processor Input File Requirements

There are three file types required for any given post-processor run. These include: 1) GENII-V2 output data contained in the GENII-V2 files with the HIF extension, 2) pathways behavior file (Usage factor), isotope description file, Dose adjustment file (Dose factor), and Risk adjustment file (Risk factor), and 3) data selected by the user from the post-processor user interface by facility, which will be used as input for developing site doses and risk numbers.

There are a total of seven input files required by the Post-processor:

- One HIF file, which will be determined by the system based on the user-input information
- One user-specified input file (Pathways)
- Five other supporting tables which are already loaded to the database during the system development cycle:
  - DoseFactor – contains adjustment values from the Federal Guidance Report 13 (1) for all isotopes, all pathways, all routes, all lung-classes, and all organs at all ages.
  - RiskFactor – contains adjustment values from the Federal Guidance Report 13 (1) for all isotopes, all pathways, all routes, all lung-classes, and all organs at all ages.
  - IsotopeNames – contain names of all radionuclides for both atmospheric and liquid releases.
  - IsotopeList – contains descriptions of isotopes such as isotope index number, daughter index if any, and its lung-class value.
  - Receptors – information of receptor's name, family name, and the birth year.

G.4.2.1 The GENII-V2 HIF File

GENII-V2 produces several output files during the execution of a given computer run. These files contain doses, cancer incidents, and cancer fatalities by exposure location, by isotope, by pathway, and organ. Due to the strict naming convention established in the pre-processor requirements, the post-processor can identify GENII-V2 results by type of release, facility, year of release, and uncertainty run ID. The filename has the standard format for GENIIV2 output, for example, ABCDE000.HIF:

Where

- A = A (atmospheric) or L (Liquid),
- B is the second character of the template file,
- C is the facility ID,
- DE is the last two digits of the year of the release, and
- FGH is a number that varies from 000 (the point estimate) to 100 (the number of the uncertainty runs).

The HIF files are ASCII files containing the generic values which were calculated by GENII-V2. These values are for each organ by all pathways by all isotopes. In general, each HIF file has ten sections, each section has a section header following by the number of lines in that section. A section header is three characters, “hei”, plus the exposure location number.

Within each “hei” section, there will two lines with organ names, one is the header for risk organs, and the other one is the header for dose organs, followed by a section for each isotope. Within each isotope section, there will be three lines for each pathway, the first two lines list the generic values for each risk organ, and the third line contains the values for the dose organs. Figure G-16 shows the contents of an HIF file:

```
"hei1",2069
  4,
 This GLYPH has data for  1 RECEPTOR sources.
 GENII VER 2.0 B1
Run on: 02-21-2004  at 11:57:17
  1,"chronic",
  1,
"chronic","expl","Air",  1, 1, 18, 15, 24,
"Esophagus","Stomach","Colon","Liver",……,"Thyroid","Leukemia","Residual","Total",
"Adrenals","Bld Wall","B Surface",……,"Testes","Thymus","Thyroid","Uterus","Effective",
     11.1,"km",    -35.8,"km",
   0.,  70.,"yr",
"AM241","AM241", 0,   1,
     0.00,"yr",     1.000,"yr", 42,
       1.,"Air","external","risk","cancer incidence",
 3.20E-10, 3.10E-10, 2.40E-10, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 5.20E-08,
       1.,"Air","external","risk","cancer fatalities",
 3.10E-10, 3.40E-10, 2.40E-10, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 6.20E-08,
       1.,"Air","external","Sv","radiation dose",
 3.20E-10, 3.10E-10, 2.40E-10, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 7.20E-08,
…
…
"AR41","AR41", 0,   1,
     0.00,"yr",     1.000,"yr", 42,
       1.,"Air","external","risk","cancer incidence",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
       1.,"Air","external","risk","cancer fatalities",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
       1.,"Air","external","Sv","radiation dose",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
…
...
"hei2",2069
"Esophagus","Stomach","Colon","Liver",……,"Thyroid","Leukemia","Residual","Total",
"Adrenals","Bld Wall","B Surface",……,"Testes","Thymus","Thyroid","Uterus","Effective",
     11.1,"km",    -35.8,"km",
   0.,  70.,"yr",
"AM241","AM241", 0,   1,
     0.00,"yr",     1.000,"yr", 42,
       1.,"Air","external","risk","cancer incidence",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
       1.,"Air","external","risk","cancer fatalities",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
       1.,"Air","external","Sv","radiation dose",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
…
"AR41","AR41", 0,   1,
     0.00,"yr",     1.000,"yr", 42,
       1.,"Air","external","risk","cancer incidence",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
       1.,"Air","external","risk","cancer fatalities",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
       1.,"Air","external","Sv","radiation dose",
 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00, ......, 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00,
…
```

Figure G-16 HIF File

G.4.2.2 The User-Specified Excel Pathways File (User Supplied)

The user-specified Pathways matrices contain information about the means by which the radioactivity was transmitted (Air, Liquid). These matrices are in Excel spreadsheet format. The post-processor reads the information in this file and loads it into the Access Pathways table for use by the system. The columns of this matrix are shown in Table G-4.

Table G-4 Pathways Matrix Column Heading Descriptions

Matrix Column Heading	Definition
Receptor Location	The location of the recipient at the time of exposure
Receptor Age	The age of the recipient at the time of exposure
Medium	The medium or substance by which the radiation was transmitted
Route	The means by which the radiation traveled. Values include *external*, *inhalation*, and *ingestion.*
Exposure Location 1	A code indicating the location of the recipient at the time of exposure.
Usage Factor 1	A value indicating the extent of usage of the medium that transmitted the radiation. For example, if the medium is air, then this value would be the number of hours the air was breathed by the recipient.
Adjustment Factor 1	A factor by which the dose calculation will be adjusted to allow for the fact that the recipient may not have been exposed 100% of the time. For example, if the recipient was estimated to have eaten 100 kg of vegetables per year, but half of these vegetables were purchased at a location that carried non-local food, then the adjustment factor would be 0.5.
Exposure Location 2	A code indicating a second location of the recipient at the time of exposure.
Usage Factor 2	The usage factor applied to exposure location 2.
Adjustment factor 2	The adjustment factor applied to exposure location 2
Exposure Location 3	A code indicating a third location of the recipient at the time of exposure.
Usage Factor 3	The usage factor applied to exposure location 3.
Adjustment factor 3	The adjustment factor applied to exposure location 3
Exposure Location 4	A code indicating a fourth location of the recipient at the time of exposure.
Usage Factor 4	The usage factor applied to exposure location 4.
Adjustment factor 4	The adjustment factor applied to exposure location 4

G.4.2.3 Other Supporting Files (pre-loaded)

This section will describe the contents of additional files that need to be read by the post-processor, and the relationship that exists between various files. There are seven additional Excel files that the post-

processor needs to read. These Excel files are pre-loaded to the database during the system development cycle.

G.4.2.3.1 The Dose Factor Table

The Dose Factors Table contains a set of dose factors for various age groups, lung classes, selected pathways, routes, and isotopes by organ. The entries for this file are extracted out of the Federal Guidance Report 13 (1).

The columns of the Dose Factors table are shown in Table G-5.

Table G-5 Dose Factors Table Column Heading Descriptions

Table Field	Definition
Isotope	Abbreviations of all isotopes relevant to the exposure
Pathway	The pathway by which the exposure was received by the recipient (Air, Liquid)
Route	The route by which the dose was received (inhalation, ingestion, external)
Lung_class	Values include F, M, S, V, and G. The lung class determine the solubility from Federal Guide Report 13
Age	Age group for the dose factor (Infant, 1 yr old, 5 yr old, 10 yr old, 15 yr old and adult)
Twenty two columns of dose factor by organ	Dose factor for a given organ by pathway, route, lung class and age.
Adrenals	Dose factor for the adrenal glands by pathway, route, lung class, and age.
UB Wall	Dose factor for the UB wall by pathway, route, lung class, and age
B_Surface	Dose factor for the B Surface by pathway, route, lung class, and age
Brain	Dose factor for the brain by pathway, route, lung class, and age
Breast	Dose factor for the breast by pathway, route, lung class, and age
ET_Region	Dose factor for the esophagus-trachea Region by pathway, route, lung class, and age
St_Wall	Dose factor for the stomach wall by pathway, route, lung class, and age
SI_Wall	Dose factor for the small intestine wall by pathway, route, lung class, and age
ULI Wall	Dose factor for the upper large intestine wall by pathway, route, lung class, and age
LLI Wall	Dose factor for the lower large Intestine wall by pathway, route, lung class, and age
Kidneys	Dose factor for the Kidneys by pathway, route, lung class, and age
Liver	Dose factor for the Liver by pathway, route, lung class, and age
Lung	Dose factor for the Lung by pathway, route, lung class, and age
Muscle	Dose factor for the muscle tissue by pathway, route, lung class, and age
Ovaries	Dose factor for the ovaries by pathway, route, lung class, and age
Pancreas	Dose factor for the pancreas by pathway, route, lung class, and age
R_Marrow	Dose factor for the red marrow by pathway, route, lung class, and age

Table Field	Definition
Skin	Dose factor for the skin by pathway, route, lung class, and age
Spleen	Dose factor for the spleen by pathway, route, lung class, and age
Testes	Dose factor for the testes by pathway, route, lung class, and age
Thymus	Dose factor for the thymus by pathway, route, lung class, and age
Thyroid	Dose factor for the thyroid by pathway, route, lung class, and age
Uterus	Dose factor for the uterus by pathway, route, lung class, and age
E_50	Equivalent dose factor by pathway, route, lung class and age

G.4.2.3.2 The RiskFactor Table

The Risk Factors Table contains information about the calculated cancer risks factors. The entries for this file are extracted out of the Federal Guidance Report 13 (1).

Table G-6 describes the columns of the Risk Factors Table.

Table G-6 Risk Factors Table Column Heading Descriptions

Table Fields	Definition
Isotope	The Abbreviations of all isotopes relevant to SRS exposures.
Pathway	The pathway by which the exposure was transmitted. Values include Air, D Water (drinking water), Dietary, Ground, or Swimming
Route	External, Inhalation, or Ingestion.
Lung_Class	Values include F, M, S, V, and G. The lung class determines the solubility from Federal Guide Report 13
Age	Age group for the risk factors (0-5 yr, 5-15yr, 15-25yr, 25- 70yr and 0-110 yr)
Thirty columns of risk factors by organ	The risk factors are grouped first by risk of cancer incidence and by risk of cancer fatalities...
Esophagus	Cancer Fatality Risk Factor for the esophagus by pathway, route, lung class, and age.
CFStomach	Cancer Fatality Risk Factor for the stomach by pathway, route, lung class, and age
CFColon	Cancer Fatality Risk Factor for the colon by pathway, route, lung class, and age
CFLiver	Cancer Fatality Risk Factor for the liver by pathway, route, lung class, and age
CFLung	Cancer Fatality Risk Factor for the lung by pathway, route, lung class, and age
CFBone	Cancer Fatality Risk Factor for the bone by pathway, route, lung class, and age
CFSkin	Cancer Fatality Risk Factor for the skin by pathway, route, lung class, and age
CFBreast	Cancer Fatality Risk Factor for the breast by pathway, route, lung class, and age
CFOvary	Cancer Fatality Risk Factor for the ovary by pathway, route, lung class, and age

Table Fields	Definition
CFBladder	Cancer Fatality Risk Factor for the bladder by pathway, route, lung class, and age
CFKidney	Cancer Fatality Risk Factor for the kidney by pathway, route, lung class, and age
CFThyroid	Cancer Fatality Risk Factor for the thyroid by pathway, route, lung class, and age
CFLeukemia	Cancer Fatality Risk Factor for Leukemia by pathway, route, lung class, and age
CFResidual	Cancer Fatality Risk Factor for the residual organs by pathway, route, lung class, and age
CFTotal	Total Cancer Fatality Risk Factor by pathway, route, lung class, and age
CIEsophagus	Cancer Incidence Risk Factor for the esophagus by pathway, route, lung class, and age.
CIStomach	Cancer Incidence Risk Factor for the stomach by pathway, route, lung class, and age
CIColon	Cancer Incidence Risk Factor for the colon by pathway, route, lung class, and age
CILiver	Cancer Incidence Risk Factor for the liver by pathway, route, lung class, and age
CILung	Cancer Incidence Risk Factor for the lung by pathway, route, lung class, and age
CIBone	Cancer Incidence Risk Factor for the bone by pathway, route, lung class, and age
CISkin	Cancer Incidence Risk Factor for the skin by pathway, route, lung class, and age
CIBreast	Cancer Incidence Risk Factor for the breast by pathway, route, lung class, and age
CIOvary	Cancer Incidence Risk Factor for the ovary by pathway, route, lung class, and age
CIBladder	Cancer Incidence Risk Factor for the bladder by pathway, route, lung class, and age
CIKidney	Cancer Incidence Risk Factor for the kidney by pathway, route, lung class, and age
CIThyroid	Cancer Incidence Risk Factor for the thyroid by pathway, route, lung class, and age
CILeukemia	Cancer Incidence Risk Factor for the Leukemia by pathway, route, lung class, and age
CIResidual	Cancer Incidence Risk Factor for the residual organs by pathway, route, lung class, and age
CITotal	Total Cancer Incidence Risk Factor by pathway, route, lung class, and age

G.4.2.3.3 The Isotope Names Table

The Isotope Names Table lists the name of each isotope to be displayed in the isotope list box for atmospheric or liquid pathways. Column headings of the Isotope Names Table are described in Table G-7.

Table G-7 Isotope Names Table Column Heading Descriptions

Table Fields	Definition
Isotope	The names of all relevant isotopes involved in the exposure.
Selected (true or false)	Specifies whether or not the user selected the isotope for use in the dose calculations.
AtmosphericRelease	Specifies whether or not the dose was received by atmospheric release.
LiquidReleases	Specifies whether or not the dose was received by liquid release.

G.4.2.3.4 Isotope List Table

The IsotopeList table lists the correct isotope number, the isotope abbreviations, the index of any daughter isotope, and the lung-class, which determines the solubility of the contaminant according to Federal Guide Report 13 (1). The column headings of the IsotopeList table are described in Table G-8.

Table G-8 Isotope List Table Column Heading Descriptions

Table Fields	Definition
Isotope	The abbreviations of all relevant isotopes involved in the exposure.
IsotopeNum	The index of an isotope.
DaugIndex	The index of any daughter isotopes that the parent isotopes yield due to radioactive decay.
Lung_Class	The lung class determines the solubility from Federal Guide Report 13. Values include F, M, S, G, and V.

G.4.2.3.5 The Receptors Table (User Supplied)

The Receptors Table contains the location, age at the time of exposure, age range over the duration of the exposure, and birth year of all receptors. Users select specific receptors through the post-processor user interface, and their selections are recorded in the *Selected* field. The column headings of the Receptors table are described in Table G-9.

Table G-9 The Receptors Table Column Heading Descriptions

Table Fields	Definitions
Name	Type of receptor, for example, Rural Family #1 Adult Male.
Location	The location of the receptor, for example, Rural Family #2.
Receptor	The age range of the receptor, for example, Adult Male.
YearBorn	The birth year of a given receptor type.
Selected	A yes/no field indicating that the user has selected an option.

G.4.3 Detailed Processing Required to Generate the Final Post-processor Report

The post-processor will read the files described in G.4.2.3. The post-processor will then obtain the user's choices. Then, based on the user's choices, the post-processor will read the appropriate GENII-V2 HIF files. As the post-processor reads each HIF file, the computer code will adjust the results according to the information in the behavior file and by the dose conversion/risk factors. The results will then be accumulated into the correct cells of the DoseRisk Table depending on the user's choices.

This section describes the logic that the post-processor will use during the calculations. The logic flow begins after the post-processor has obtained the user choices and read the supplemental files. Briefly, for a given exposure location, the post-processor will read doses/risk results by isotope and pathway. The post-processor will adjust the dose/risk numbers for a given receptor to account for that receptor's behavior contained in the behavior file and birth year files. The adjustments will include an adjustment of the

dose/risk to change the results from age independent to age dependent dose/risk factors and age dependent location behavior.

For example, look at the Rural Family #1 Child born in 1955 with the external air pathway and a release year of 1969. The receptor is now a teenager who resides at his house for 7500 hours per year (exposure location 1) and goes to school for 1260 hours per year (exposure location 2.) The post-processor will adjust GENII-V2 dose/risk results for each isotope and organ. For exposure location 1, the dose/risk results would be multiplied by a factor of 6760 and multiplied by the teenager air external dose conversion factor by isotope and organ divided by the adult air external dose factor by isotope and organ. The resulting dose/risk will be stored and summed as required by the user.

G.4.3.1 The Dose Reconstruction Report

The logic flow begins after the post-processor has obtained the user choices and read the supplemental files. For a given exposure location, the post-processor will read the doses/risk results by isotope and pathway. The post-processor will adjust the dose/risk numbers for a given receptor to account for that receptor's behavior, as described in the behavior file and birth year files. The adjustments will include an adjustment of the dose/risk to change the results from age independent to age dependent dose/risk factors and age dependent location behavior.

For example, look at a child born in 1954 with the external air pathway and a release year of 1969. The receptor is now a teenager who resides at his house for 7375 hours per year (exposure location 1) and goes to school for 1295 hours per year (exposure location 2.) The post-processor will adjust GENII-V2 dose/risk results for each isotope and organ. For exposure location 1, the dose/risk results would be multiplied by a factor of 6760 and multiplied by the teenager air external dose conversion factor by isotope and organ divided by the adult air external dose factor by isotope and organ. The resulting dose/risk will be stored and summed as required by the user.

The post-processor collects information from the user input window, based on the release type, facility ID, and the year of process, then loops through the GENII-V2 output files and checks to see if this run is valid for Uncertainty or just for Point-Estimate. For a given release type, facility ID and year of processing, if there are 101 GID files, the system will assign 100 to the MaxRun variable. Otherwise, it will set MaxRun equals 0). Once this process has completed, the post-processor will load the user-specified Pathway file into the Pathways table in the database.

For each receptor in the selected list, the receptor’s name is assigned to the RecpName variable. Based on the RecpName value, the Location, Receptor, and YearBorn are obtained from the Receptor table.

For each year of the specified processing years (the user specifies the starting year and the ending year of the process), the current processing year is assigned to the intYear variable (intYear is used to determine which HIF file should be loaded and the current age of the receptor).

As the processing year goes up, the receptor’s age is also changing. All age group variables must be reassigned with a proper value based on the receptor’s current age at that processing year. (See Age Group Assignment Table for detail)

There are four varying age group variables:

RecepAge = 1900 + intYear – YearBorn

RiskAge = Risk factor age based on the RecepAge

DoseAge = Dose factor age based on the RecepAge

USFAge = Usage factor age based on the RecepAge

For RunNum from 0 to MaxRun

Clean up the HIFData and TempHIF tables

Load HIF file based on RunNum to HIFData table

Read each record from the HIFData table, arrange require fields and write to TempHIF table

Select all records from the Pathways table based on the known Location and USFAge values

For each record read above

Assign the first set of values from the Pathways table to the variables of ExpLoc, Pathway, Route, UsageFactor, and AdjFactor

Read all records from TempHIF table based on the known ExpLoc, UsageFactor, and AdjFactor

For each record read from the TempHIF table, assign the Isotope value to the Isotope variable

Read the Isotope Table based on the Isotope value to get the lung-class

Get DoseFactor for each organ and store in a 1 by 24 temporary array called DoseFactor(24)

The DoseFactor for each organ is equal to the current age Dose AdjFactor divides by the adult age Dose AdjFactor

The current age Dose AdjFactor is read from the DoseFactor table based on the Isoto, Route, Pathway, Lung-class, and DoseAge

The adult age Dose AdjFactor is read from the DoseFactor table based on the Isoto, Route, Pathway, Lung-class, and DoseGroup, which equals “Adult”

Certain rules may apply to the DoseFactor:

The DoseFactor table does not have values for a Route equals “Inhalation” and the Pathway equals “Indoor Air”. In this case, the Pathway will be assumed to “Air”.

If Route equals “External” the DoseFactor value will 1.

Get RiskFactor for each organ and store in a 1 by 30 temporary array Call RiskFactor (30)

The RiskFactor for each organ is equal to the current age Risk AdjFactor divides by the adult age Risk AdjFactor

The current age Risk AdjFactor is read from the RiskFactor table based on the Isoto, Route, Pathway, Lung-class, and RiskAge

The adult age Risk AdjFactor is read from the RiskFactor table based on the Isoto, Route, Pathway, Lung-class, and RiskGroup which equals “0-110 y”

Certain rules may apply to the RiskFactor:

The DoseFactor table does not have values for a Route equals “Inhalation” and the Pathway equals or “Indoor Air”. In this case, the Pathway will be assumed to “Air”.

If Route equals “Ingestion” and Pathway equals “Swimming”, or “Showering”, or “Water” then the Pathway will be set to “D Water” when reading the RiskFactor table.

If the Pathway equals “Fish” then the Pathway will be set to “Dietary” when reading the RiskFactor table.

Apply the UsageFactor and each of the RiskFactor (30) to the first 30 organs from the TempHIF record.

Apply the UsageFactor and each of the DoseFactor (24) to the last 24 organs from the TempHIF record.

Write TempHIF record to DoseRisk table.

Read next TempHIF record

Read next Pathway record

Process next RunNum through

Process next intYear through the end

Export DoseRisk table to C:\CDC\Postprocessor\Completed for the current receptor in an Excel format.

Process next Receptor from selection list.

G.4.3.2 Other Output Files

Two Post-processor output files are generated in addition to the calculated Excel Dose/Risk Report. These are a QA file and a message (MES) file.

Each file name will have the following format:

ABCDEFG.xxx

Where

- A is the type of releases (A, S, L)
- B is the facility
- CD is the last two digits of the first year of releases processed
- EF is the last two digits of the last year releases processed
- G is the version of the standardized GID file processed. and
- xxx is QA for the QA file and MES for the message file

G.4.3.3 QA File

This file contains referencing information related to the processing of the post-processor during the creation of the report files. Included in this file are:

- The post-processor start date and time.
- The user who created the post-processor run
- The Facility Name
- Pathway Usage Factors excel file used
- The list of output files generated
- A message describing if the post-processor run completed successfully and the date and time of completion.

G.4.3.4 MES File

The Message (EMS) file documents any errors that occurred during the post-processor run. The program generates an error message for the EMS file and displays it to the user if any unexpected condition arises. Several conditions that could arise are:

- Missing of GENII-V2 output file
- An exposure location that is not in an output file.
- An isotope name is not found.
- An error occurred when reading input file.

G.5 Testing

The Quality Assurance Application Test Plan for the Pre- and Post-Processors to GENII-V2, contains the detailed test plan. The following sections briefly describe testing approaches for the pre- and post-processor.

G.5.1 Pre-Processor

G.5.1.1 Input Data Creation

The test data for the Pre-Processor is set up to address specific test scenarios and is contained in a combination of standard GID templates for given exposure location sets and facility specific source term data files. Reference data is contained in pre-defined isotope description files, dispersion factor files, exposure description files, facility description files, parameter uncertainty files and source term uncertainty files. The appropriate combination of input files is set up for each execution run as they pertain to the test scenarios within that particular run. Many input reference files remain constant across test scenarios and will be re-used by multiple test runs as necessary. Any variation of input files is documented and kept for reference.

G.5.1.2 Expected Results Calculation

Expected results for each test scenario are determined through both manual calculations and other tool-assisted methods. In the most basic scenario, the application obtains data directly from a source term file for a given media and facility, then multiplies by a unit conversion factor and places the data in a specific row within the GID output file based on corresponding variable names and row indices for a given isotope or exposure location. These calculations are relatively simple, self-explanatory and do not require additional explanation beyond referencing the detailed design requirement. Distance calculations are slightly more complex and a separate tool was developed using Excel to determine values for expected results. Since user interface requirements typically affect all test runs and only occur during execution setup, they have no particular test scenarios and no specific expected results to compare. Visual verification will suffice to confirm application functionality for most user interface requirements.

G.5.1.3 Error Messages Confirmation

Error message functionality is confirmed by setting up various error scenarios within the input files and capturing output text within message files. Since the same message output filename may be used for several error scenarios, the message output files will be re-named after each error run to include the corresponding scenario for easy traceability.

G.5.1.4 Output Data Comparison Analysis

Once each test execution run has completed successfully, the output files for each run will be captured and analyzed using a text editor or Excel to assist in the analysis.

For each test scenario within the corresponding GID output file, the specific field name and index values are matched to find the actual quantity, distance or setup values. The row number is noted and the entire row of data is captured and the actual values are placed in the traceability matrix for comparison with the expected values.

If the actual value matches expected results within acceptable tolerances, the scenario is marked as passed in the verification column. If the value does not match the expected results, the scenario is marked as failed in the verification column and placed in the failed history. Failed scenarios must be retested as fixes are made available.

G.5.2 Post-Processor

G.5.2.1 Input Data Creation

The test data for the post-processor needs to be generated by the GEN-II V2 dose calculation software and will be contained in a combination of HIF files based on selected media, facility, year range and uncertainty criteria. Reference data is contained in pre-defined receptor description files, isotope description files, risk factor files, dose factor files and behavior pathway usage files. The appropriate combination of input files will be set up for each execution run as they pertain to the test scenarios within that particular run.

G.5.2.2 Expected Results Calculation

Expected results for each test scenario are determined through both manual calculations and other tool-assisted methods. In the most basic scenario, the application obtains data directly from an HIF file for a given media, exposure set, facility, year and uncertainty, then multiplies by a series of risk, dose and usage factors and places the data by organ and total in a specific row within the XLS output file based on corresponding row indices for a given location, receptor, year, uncertainty, pathway and isotope. These calculations are relatively simple, self-explanatory and do not require additional explanation beyond referencing the detailed design requirement. A tool was be developed using Excel to determine risk and dose values for expected results.

G.5.2.3 Output Data Comparison Analysis

Once each test execution run has completed successfully, the output files for each run are captured and analyzed using a text editor or Excel to assist in the analysis.

For each test scenario within the corresponding XLS output file, the index values are matched to find the actual risk and dose values for specific organ name or total. The row number is noted and the index portion of the row of data is captured including the organ name or total and the actual risk or dose values are placed in the traceability matrix for comparison with the expected values.

If the actual value matches expected results within acceptable tolerances, the scenario is marked as passed in the verification column. If the value does not match the expected results, the scenario is marked as failed in the verification column and placed in the failed history. Failed scenarios must be retested as fixes are made available.

G.6 References

1. U.S. Environmental Protection Agency. Federal guidance report 13. "Cancer Risk Coefficients for Environmental Exposure to Radionuclides": CD supplement. EPA 402-C-99-001, Rev. 1. Oak Ridge National Laboratory and United States Environmental Protection Agency. April 2002.

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APPENDIX H SELECTION OF GENII, VERSION II, FOR ASSESSMENT OF DOSES AND RISKS FOR THE SRS DOSE RECONSTRUCTION PROJECT

H.1 Introduction

As part of its work to complete the revised Phase III effort for the Dose Reconstruction Project for the Savannah River Site (SRS), a project overseen by the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), Advanced Technologies and Laboratories International, Inc. (ATL) had to select a software program to estimate human doses and risks caused by past SRS operations. ATL's selection of Version 2 of GENII, a product of the Pacific Northwest National Laboratory (PNNL) is documented in ATL's *Software Selection Decision for the Savannah River Site Dose Reconstruction Software Program* [ATL, 2003] (1). The software decision document was based on the requirements for the software that ATL documented in its *Software Requirements Document for the Savannah River Site Dose Reconstruction Software Program* [ATL, 2002] (2).

This appendix summarizes ATL's selection of GENII Version 2, drawing information from [ATL, 2003] and [ATL, 2002].

H.2 Identification of Computational Requirements

When initiating the revised Phase III effort, ATL recognized a critical need to develop a software program to perform the detailed mathematical modeling computations that would be required. ATL envisioned a dose assessment program that could be represented conceptually as having three components: a pre-processor, a dose calculation component, and a post-processor (Figure H-1). The preprocessor would compile input data and prepare it for use by the modeling program. The dose calculation component would perform the transport and exposure pathway computations that estimate the movement, dilution, buildup, and concentration of radionuclide contaminants in the environment and the human intake of and exposure to the contaminants, and the resulting human health risks. The postprocessor would extract results from output files and compile them in a readily useable format.

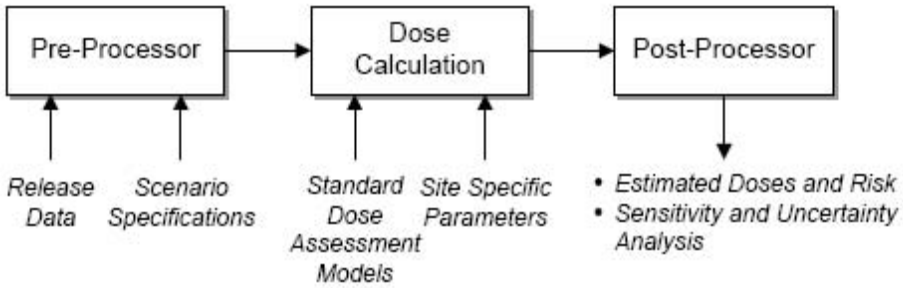

Figure H-1 Conceptual Configuration of SRS Dose Assessment Program

For the dose calculation component of the program, ATL considered two potential approaches: (1) use an existing code, or (2) custom-develop a code. Under either approach, the dose calculation component performing the modeling computations would be mated to the pre-processor and post-processor components.

Although a custom-developed modeling code could have been produced that met all applicable project requirements, it would have required an extensive effort. Therefore, ATL determined that an existing modeling program would be preferable if one could be found that met the minimum requirements.

ATL reviewed the modeling requirements for the dose reconstruction efforts against the environmental transfer and exposure pathways that needed to be considered (ATL, 2002). ATL then organized the requirements into three high-level groupings:

1. **Mandatory.** Requirements that had to be incorporated in the modeling code to meet project objectives. Although in some cases, the pre- or post-processor could have been used to meet a mandatory requirement, it was preferable that the modeling code meet these requirements.
2. **Highly Desirable.** Requirements that were not mandatory, but would greatly facilitate use of the software and enhance its ability to meet project objectives.
3. **Discretionary.** Requirements that would help the project, but were not necessary. However, if multiple modeling programs were found that met higher level requirements, these requirements could be used to differentiate between the programs.

The requirements were categorized as follows:

- Transport
  General
  Surface Water
  Air
  Food Chain
- Exposure
- Dose and Risk
- Data Input and Output
- Other

Altogether, ATL identified 18 mandatory requirements and 15 non-mandatory (i.e., highly desirable or discretionary) requirements. The requirements are summarized below.

H.2.1 Mandatory Requirements

H.2.1.1 Transport–General

Annual Releases. Must be able to model annual releases of contaminants.

Site-Specific Transport Parameters. Must be able to use site-specific transport parameters in place of default values.

Chronic Releases. Must be able to model long-term contaminant releases.

Linked Compartments. For the various transport and exposure pathways, the code must be able to link and sequence the computations so that the calculated concentration values produced as output from each module (compartment) is automatically fed as data input to all appropriate downstream modules.

H.2.1.2 Transport-Surface Water

Simple Dilution Model. Must use a simple dilution model to simulate surface water contaminant transport.

Annual Flow. Must be able to use variable annual flow data.

Sediment Transfer. Must include a module to simulate the transfer of contam-ination from water to sediment, the subsequent transfer of this contamination to other media, and the external exposure of individuals from sediment.

H.2.1.3 Transport-Air

Sector Averaging Model. Must use a sector-averaging model to simulation the transport and dilution of contamination in air.

Deposition. Must include a module to calculate the transfer of contamination from air to soil by dry and wet deposition.

H.2.1.4 Transport-Food Chain

Established Models. Must use established formulations to model the transfer and accumulation of contamination in the food chain.

Site-Specific Transfer Factors. Must allow for use of site-specific values (rather than default values) in calculating the transfer (uptake and usage) and accumulation of contamination in the food chain.

H.2.1.5 Exposure

Food Categories Specified. For the modeling of contamination transfer and accumulation within the food chain, the code must allow for the multiple different food categories (e.g., grain, meat, milk, leafy vegetables, fish), each with different uptake and usage factors, to be modeled simultaneously.

Five Exposure Pathways. The code must include modules to account for the five different exposure pathways represented in the CDC exposure scenarios (inhalation, ingestion, submersion, ground plane, sediment).

H.2.1.6 Dose/Risk

There were no mandatory requirements in this category/subcategory.

H.2.1.7 Data Input/Output

Disaggregate Doses. Must allow the computation of results in a disaggregate form according to radionuclide, transport pathway, exposure pathway, and year.

QA Transparency. Must produce output that is easy to review and verify/validate.

H.2.1.8 Other

Special Models for C-14 and H-3. Must include special models for carbon-14 and tritium since the behavior of these contaminants in the environment is different that of other contaminants.

RN Chains. Must include calculations to account for decay of radionuclides, including ingrowth, that occurs during contaminant transport.

Availability. Must be available to ATL for use on this project.

H.2.2 Highly Desirable Requirements

H.2.2.1 Transport-General

There were no requirements in this subcategory.

H.2.2.2 Transport-Surface Water

Additional Compartments. Within the surface water transport model, the code should include additional compartments to simulate different contaminant transport behaviors that could affect surface water. For example, an additional compartment may be needed to simulate operation of the seepage basins.

H.2.2.3 Transport-Air

Annual Meteorological Data. Within the air transport model, the code should include the capability to use annual meteorological data.

H.2.2.4 Transport-Food Chain

Resuspension Factor. Within the food chain transport model, the code should include a soil resuspension compartment to address resuspension of contaminated soil that subsequently deposits on food chain crops.

Soil Build-up. Within the food chain transport model, the code should include the capability to model the build-up over time of contamination in the soil resulting from long-term (>1 year) deposition.

H.2.2.5 Exposure

Variable Exposure Parameters. The code should have the capability to accommodate user-assigned values for exposure parameters.

H.2.2.6 Dose/Risk

FGR-13. The code should use the values for dose conversion factors (DCFs) set forth in U.S. Environmental Protection Agency Federal Guidance Report No. 13 (EPA 402-R-99-001, September 1999).

Age Dependent DCFs. The code should be able to calculate doses using age-specific dose conversion factors.

H.2.2.7 Data Input/Output

Easy to Automate. The code should easily accommodate approaches to automate modeling runs. This project will probably require hundreds or thousands of individual modeling runs. Therefore, it is desirable to avoid manual data entry and processing.

Intermediate Results. The code should produce intermediate results between modules so that intermediate results can be reviewed. For example, intermediate results would include the number of curies passing through a specific transport pathway.

H.2.2.8 Other

Chemicals. The code should accommodate the modeling of nonradioactive chemicals, including noncarcinogenic health effects and biodegredation.

Multiple years with Varying Releases. The code should allow for modeling multi-year releases with rates that vary by year.

*Cos*t. The cost of the code should be reasonable and not have a significant effect on the task budget.

QA Status. The code should be verified and validated and in a final product form.

Stochastic Capability. The code should accommodate sensitivity and uncertainty analyses using stochastic variable distributions.

H.2.3 Discretionary Requirements.

Only one discretionary requirement was identified.

H.2.3.1 Transport-General

Acute Releases. The code should be capable of modeling the environmental transport and subsequent human exposure and health consequences resulting short duration pulse releases of a few hours or days.

H.3 Assessment of Candidate Codes

ATL conducted the software assessment in phases. In the first phase, ATL identified available modeling codes. The codes were then screened. In the second phase, the screened codes were evaluated against identified software requirements to identify the most suitable (ATL, 2002).

In its survey, ATL identified 66 codes based on their general classification as tools for environmental transport, exposure, dose and risk modeling. (These codes perform various combinations of contaminant transport and exposure computations to determine exposure levels, doses, and risks to humans.) The criteria used in the screening included the following:

- Compatible and consistent with transport and exposure formulations in IAEA Safety Reports Series No. 19.
- Capable of calculating dose and risk for individuals (as identified in CDC exposure scenarios).
- Capable of modeling long-term non-constant release levels from industrial facilities such as the sources identified for SRS.
- Available in a personal computer (Windows or DOS) version.
- Not obsolete by a more recent version.

From this screening process, ATL further evaluated 17 candidate codes to determine their suitability for the SRS Dose Reconstruction Project. This evaluation eliminated codes that only addressed a limited number of pathways and exposure scenarios

ATL identified two suitable codes: Hanford Environmental Dosimetry System, Generation II, Version 2 (GENII-V2), and Multimedia Environmental Pollutant Assessment System (MEPAS).

The GENII computer code was developed at PNNL to support radiological exposure and risk assessment for the U.S. Environmental Protection Agency's (EPA's) Office of Indoor Air and Radiation. The GENII code was developed to provide a state-of-the-art, technically peer-reviewed, documented set of programs for calculating radiation doses from radionuclides released to the environment. It was designed with the flexibility to accommodate input parameters for a variety of generic sites, and includes capabilities for calculating radiation doses following chronic and acute releases. Radionuclide transport via air, water, or biological activity may be considered.

The MEPAS code was also developed by PNNL and is a risk analysis software tool to estimate environmental concentrations and chronic public health impacts from radioactive and hazardous materials. It uses standard EPA mathematical models to predict the potential for release and transport of contaminants into the environment as well as the impact to the surrounding environment, individuals, and populations. MEPAS addresses major exposure routes resulting in either carcinogenic or non-carcinogenic impacts.

ATL subjected GENII-V2 and MEPAS to one final evaluation against the specific software requirements (ATL, 2002). To assist this evaluation, ATL collected additional relevant information about the two codes by obtaining and reviewing available literature and copies of these codes and discussing various code characteristics with PNNL representatives who were responsible for developing and validating the codes. ATL then critically compared these codes for each of the mandatory, desirable, and discretionary requirements (ATL, 2003). This evaluation resulted in the selection of GENII-V2.

H.4 Selection of GENII, Version 2

Mandatory Requirements. GENII-V2 met all mandatory requirements. MEPAS met all but one of the mandatory requirements. MEPAS did not meet requirement for special models for C-14 and H-3. By itself, this distinction was enough to determine GENII-V2 as the preferable software code for this project. However, for completeness, a discussion of the desirable and discretionary requirements follows.

Desirable Requirements. GENII-V2 met all except three desirable requirements:

- Soil Buildup,
- Chemicals, and
- Multiple Years with Varying Releases.

In addition, ATL determined that GENII-V2 would be easy to automate, with only limited certainty (a more precise understanding of the automated functions was needed to address this requirement with greater certainty). In comparison, MEPAS met all but three desirable requirements, and had limited certainty in meeting a fourth. The three desirable requirements that MEPAS did not meet were:

- Soil Buildup (same as for GENII-V2)
- FGR-13, and
- Multiple Years with Varying Releases (same as for GENII-V2).

In addition, ATL determined that MEPAS would be easy to automate, with only limited certainty (same as for GENII-V2).

Discretionary Requirements. GENII-V2 met the only discretionary requirement. MEPAS did not.

Conclusion. ATL determined that GENII-V2 would be the best choice among those available to perform pathway and exposure calculations for the Phase III effort.

H.5 References for Appendix H

1. ATL, 2003. ATL International, Inc. Software Selection Decision for the Savannah River Site Dose Reconstruction Program. (Internal ATL document.) January 13, 2003.

2. ATL, 2002. ATL International, Inc. Software Requirements Document for the Savannah River Site Dose Reconstruction Project. (Internal unpublished draft document.) December 9, 2002.

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APPENDIX I TABLES OF DOSES AND RISKS BY YEAR FOR EACH SCENARIO

This appendix presents the calculated Effective Dose, Total Cancer Incident Risk, and Total Cancer Fatality Risk by year for each hypothetical individual in each scenario. Reports for Effective Dose, Total Cancer Incident Risk, and Total Cancer Fatality Risk are listed in separate tables grouped by different release pathways when applicable.

Tables are presented electronically via the following links for each scenario.

Delivery Family Scenario

Urban Family Scenario

Migrant Family Scenario

Near Water Family Scenario

Outdoor Family Scenario

Rural Family One Scenario

Rural Family Two Scenario

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Table 6.C Effective Dose By Year For Delivery Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	6.0E-07	0.2	6.0E-07	0.1	--	--	--	--
1955	2.6E-05	6.7	3.5E-05	6.1	7.8E-05	3.6	--	--
1956	1.8E-04	46.0	2.6E-04	45.5	1.5E-03	71.2	--	--
1957	4.1E-05	10.4	5.9E-05	10.4	1.9E-04	8.7	--	--
1958	1.0E-05	2.5	1.4E-05	2.5	2.4E-05	1.1	--	--
1959	2.7E-05	6.7	3.9E-05	6.8	1.1E-04	5.1	--	--
1960	7.0E-06	1.8	1.1E-05	1.9	1.6E-05	0.8	--	--
1961	1.6E-05	4.1	2.4E-05	4.2	7.9E-05	3.7	--	--
1962	7.4E-06	1.9	1.1E-05	1.9	1.2E-05	0.5	--	--
1963	7.1E-06	1.8	1.1E-05	1.9	1.0E-05	0.5	--	--
1964	7.1E-06	1.8	1.1E-05	1.8	1.0E-05	0.5	1.7E-05	14.6
1965	4.5E-06	1.1	7.5E-06	1.3	6.5E-06	0.3	1.0E-05	8.4
1966	4.3E-06	1.1	7.2E-06	1.3	6.3E-06	0.3	6.9E-06	5.8
1967	4.6E-06	1.2	7.8E-06	1.4	6.3E-06	0.3	7.1E-06	6.0
1968	4.1E-06	1.0	6.4E-06	1.1	5.9E-06	0.3	6.8E-06	5.7
1969	5.5E-06	1.4	7.8E-06	1.4	7.9E-06	0.4	1.0E-05	8.4
1970	2.6E-06	0.7	4.0E-06	0.7	4.0E-06	0.2	5.9E-06	4.9
1971	3.0E-06	0.8	4.5E-06	0.8	4.4E-06	0.2	4.6E-06	3.9
1972	3.4E-06	0.9	5.3E-06	0.9	4.9E-06	0.2	5.1E-06	4.2
1973	3.2E-06	0.8	5.0E-06	0.9	5.0E-06	0.2	4.5E-06	3.8
1974	2.6E-06	0.7	3.7E-06	0.7	3.7E-06	0.2	3.9E-06	3.3
1975	1.6E-06	0.4	2.4E-06	0.4	2.4E-06	0.1	2.5E-06	2.1
1976	1.6E-06	0.4	2.5E-06	0.4	2.5E-06	0.1	2.2E-06	1.8
1977	1.5E-06	0.4	2.4E-06	0.4	2.4E-06	0.1	2.3E-06	1.9
1978	1.6E-06	0.4	2.4E-06	0.4	2.4E-06	0.1	2.4E-06	2.0
1979	1.4E-06	0.3	2.1E-06	0.4	2.1E-06	0.1	2.0E-06	1.7
1980	1.5E-06	0.4	2.3E-06	0.4	2.3E-06	0.1	2.1E-06	1.8
1981	1.5E-06	0.4	2.3E-06	0.4	2.3E-06	0.1	2.3E-06	1.9
1982	1.6E-06	0.4	2.4E-06	0.4	2.4E-06	0.1	2.4E-06	2.0
1983	1.8E-06	0.5	2.5E-06	0.4	2.5E-06	0.1	2.5E-06	2.1
1984	2.3E-06	0.6	3.1E-06	0.5	3.1E-06	0.1	3.1E-06	2.6
1985	2.2E-06	0.6	3.0E-06	0.5	3.0E-06	0.1	3.0E-06	2.6
1986	1.9E-06	0.5	2.6E-06	0.4	2.6E-06	0.1	2.6E-06	2.2
1987	1.9E-06	0.5	2.7E-06	0.5	2.7E-06	0.1	2.7E-06	2.3
1988	1.3E-06	0.3	1.8E-06	0.3	1.8E-06	0.1	1.8E-06	1.5
1989	8.5E-07	0.2	1.1E-06	0.2	1.1E-06	0.1	1.1E-06	0.9
1990	6.0E-07	0.2	8.2E-07	0.1	8.2E-07	0.0	8.2E-07	0.7
1991	4.8E-07	0.1	6.5E-07	0.1	6.5E-07	0.0	6.5E-07	0.5
1992	3.5E-07	0.1	4.7E-07	0.1	4.7E-07	0.0	4.7E-07	0.4
Total	4.0E-04	100.0	5.7E-04	100.0	2.1E-03	100.0	1.2E-04	100.0

Table 6.C Effective Dose By Year For Delivery Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	3.9E-05	0.7	3.9E-05	0.7	--	--	--	--
1955	8.0E-05	1.4	8.0E-05	1.4	9.4E-05	3.1	--	--
1956	1.1E-04	1.8	1.1E-04	1.8	5.4E-05	1.8	--	--
1957	5.8E-04	10.1	5.8E-04	10.1	2.1E-04	7.0	--	--
1958	1.0E-03	17.5	1.0E-03	17.5	3.6E-04	11.9	--	--
1959	2.4E-04	4.3	2.4E-04	4.3	8.8E-05	2.9	--	--
1960	1.5E-04	2.7	1.5E-04	2.7	7.1E-05	2.3	--	--
1961	1.2E-04	2.1	1.2E-04	2.1	5.6E-05	1.8	--	--
1962	1.8E-04	3.2	1.8E-04	3.2	9.3E-05	3.0	--	--
1963	4.8E-04	8.5	4.8E-04	8.5	2.1E-04	6.9	--	--
1964	5.7E-04	9.9	5.7E-04	9.9	2.5E-04	8.2	5.3E-04	26.9
1965	2.9E-04	5.1	2.9E-04	5.1	1.6E-04	5.2	2.6E-04	13.1
1966	4.1E-04	7.1	4.1E-04	7.1	3.1E-04	10.2	4.0E-04	20.2
1967	2.6E-04	4.5	2.6E-04	4.5	1.5E-04	4.9	1.3E-04	6.5
1968	1.7E-04	2.9	1.7E-04	2.9	8.6E-05	2.8	6.6E-05	3.4
1969	1.1E-04	1.9	1.1E-04	1.9	5.7E-05	1.9	4.9E-05	2.5
1970	1.2E-04	2.1	1.2E-04	2.1	6.4E-05	2.1	5.8E-05	2.9
1971	1.1E-04	1.9	1.1E-04	1.9	5.9E-05	1.9	5.3E-05	2.7
1972	5.5E-05	1.0	5.5E-05	1.0	2.9E-05	0.9	2.5E-05	1.3
1973	4.3E-05	0.7	4.3E-05	0.7	4.3E-05	1.4	2.5E-05	1.3
1974	6.3E-05	1.1	6.3E-05	1.1	6.3E-05	2.1	3.0E-05	1.5
1975	1.1E-04	1.9	1.1E-04	1.9	1.1E-04	3.5	4.3E-05	2.2
1976	3.8E-05	0.7	3.8E-05	0.7	3.8E-05	1.2	2.1E-05	1.1
1977	4.7E-05	0.8	4.7E-05	0.8	4.7E-05	1.5	2.2E-05	1.1
1978	6.0E-05	1.1	6.0E-05	1.1	6.0E-05	2.0	2.8E-05	1.4
1979	6.5E-05	1.1	6.5E-05	1.1	6.5E-05	2.1	3.0E-05	1.5
1980	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.6	1.1E-05	0.6
1981	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.6	1.0E-05	0.5
1982	1.3E-05	0.2	1.3E-05	0.2	1.3E-05	0.4	1.3E-05	0.7
1983	2.0E-05	0.4	2.0E-05	0.4	2.0E-05	0.7	2.0E-05	1.0
1984	1.3E-05	0.2	1.3E-05	0.2	1.3E-05	0.4	1.3E-05	0.7
1985	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.6	1.8E-05	0.9
1986	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.6	1.8E-05	0.9
1987	1.7E-05	0.3	1.7E-05	0.3	1.7E-05	0.6	1.7E-05	0.9
1988	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.6	1.8E-05	0.9
1989	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.6	1.8E-05	0.9
1990	1.7E-05	0.3	1.7E-05	0.3	1.7E-05	0.6	1.7E-05	0.9
1991	1.7E-05	0.3	1.7E-05	0.3	1.7E-05	0.5	1.7E-05	0.8
1992	1.6E-05	0.3	1.6E-05	0.3	1.6E-05	0.5	1.6E-05	0.8
Total	5.7E-03	100.0	5.7E-03	100.0	3.1E-03	100.0	2.0E-03	100.0

Table 6.C Effective Dose By Year For Delivery Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	4.0E-05	0.6	4.0E-05	0.6	--	--	--	--
1955	1.1E-04	1.7	1.2E-04	1.8	1.7E-04	3.3	--	--
1956	2.9E-04	4.7	3.7E-04	5.8	1.6E-03	30.4	--	--
1957	6.2E-04	10.2	6.4E-04	10.2	4.0E-04	7.7	--	--
1958	1.0E-03	16.5	1.0E-03	16.1	3.9E-04	7.5	--	--
1959	2.7E-04	4.4	2.8E-04	4.5	2.0E-04	3.8	--	--
1960	1.6E-04	2.6	1.6E-04	2.6	8.8E-05	1.7	--	--
1961	1.4E-04	2.3	1.5E-04	2.3	1.3E-04	2.6	--	--
1962	1.9E-04	3.1	1.9E-04	3.1	1.0E-04	2.0	--	--
1963	4.9E-04	8.0	5.0E-04	7.9	2.2E-04	4.3	--	--
1964	5.7E-04	9.4	5.8E-04	9.2	2.6E-04	5.0	5.5E-04	26.2
1965	3.0E-04	4.9	3.0E-04	4.8	1.7E-04	3.2	2.7E-04	12.9
1966	4.1E-04	6.7	4.1E-04	6.6	3.2E-04	6.1	4.0E-04	19.3
1967	2.6E-04	4.3	2.7E-04	4.3	1.6E-04	3.0	1.4E-04	6.5
1968	1.7E-04	2.8	1.7E-04	2.8	9.2E-05	1.8	7.3E-05	3.5
1969	1.1E-04	1.8	1.1E-04	1.8	6.5E-05	1.2	6.0E-05	2.8
1970	1.2E-04	2.0	1.2E-04	2.0	6.8E-05	1.3	6.4E-05	3.0
1971	1.1E-04	1.8	1.1E-04	1.8	6.3E-05	1.2	5.7E-05	2.7
1972	5.9E-05	1.0	6.0E-05	1.0	3.4E-05	0.6	3.0E-05	1.5
1973	4.6E-05	0.8	4.8E-05	0.8	4.8E-05	0.9	2.9E-05	1.4
1974	6.6E-05	1.1	6.7E-05	1.1	6.7E-05	1.3	3.4E-05	1.6
1975	1.1E-04	1.8	1.1E-04	1.7	1.1E-04	2.1	4.6E-05	2.2
1976	4.0E-05	0.7	4.1E-05	0.6	4.1E-05	0.8	2.3E-05	1.1
1977	4.9E-05	0.8	5.0E-05	0.8	5.0E-05	1.0	2.4E-05	1.2
1978	6.2E-05	1.0	6.3E-05	1.0	6.3E-05	1.2	3.0E-05	1.4
1979	6.7E-05	1.1	6.7E-05	1.1	6.7E-05	1.3	3.2E-05	1.5
1980	2.0E-05	0.3	2.1E-05	0.3	2.1E-05	0.4	1.3E-05	0.6
1981	2.0E-05	0.3	2.1E-05	0.3	2.1E-05	0.4	1.3E-05	0.6
1982	1.5E-05	0.2	1.5E-05	0.2	1.5E-05	0.3	1.5E-05	0.7
1983	2.2E-05	0.4	2.3E-05	0.4	2.3E-05	0.4	2.3E-05	1.1
1984	1.6E-05	0.3	1.6E-05	0.3	1.6E-05	0.3	1.6E-05	0.8
1985	2.0E-05	0.3	2.1E-05	0.3	2.1E-05	0.4	2.1E-05	1.0
1986	2.0E-05	0.3	2.0E-05	0.3	2.0E-05	0.4	2.0E-05	1.0
1987	1.9E-05	0.3	2.0E-05	0.3	2.0E-05	0.4	2.0E-05	0.9
1988	1.9E-05	0.3	2.0E-05	0.3	2.0E-05	0.4	2.0E-05	0.9
1989	1.8E-05	0.3	1.9E-05	0.3	1.9E-05	0.4	1.9E-05	0.9
1990	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.3	1.8E-05	0.9
1991	1.7E-05	0.3	1.7E-05	0.3	1.7E-05	0.3	1.7E-05	0.8
1992	1.7E-05	0.3	1.7E-05	0.3	1.7E-05	0.3	1.7E-05	0.8
Total	6.1E-03	100.0	6.3E-03	100.0	5.2E-03	100.0	2.1E-03	100.0

Table 6.C Total Cancer Incident Risk By Year For Delivery Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	2.9E-08	0.2	2.9E-08	0.2	--	--	--	--
1955	4.8E-07	4.1	6.6E-07	3.9	6.2E-06	2.9	--	--
1956	4.2E-06	36.0	6.0E-06	35.0	1.4E-04	62.7	--	--
1957	1.1E-06	9.0	1.5E-06	8.9	2.9E-05	13.3	--	--
1958	4.1E-07	3.5	6.0E-07	3.5	4.5E-06	2.1	--	--
1959	7.6E-07	6.5	1.1E-06	6.5	1.7E-05	8.0	--	--
1960	3.1E-07	2.6	4.7E-07	2.7	1.8E-06	0.8	--	--
1961	5.2E-07	4.4	7.7E-07	4.5	5.1E-06	2.4	--	--
1962	3.3E-07	2.8	5.0E-07	2.9	1.9E-06	0.9	--	--
1963	3.3E-07	2.8	5.1E-07	3.0	1.7E-06	0.8	--	--
1964	3.4E-07	2.9	5.1E-07	2.9	1.8E-06	0.8	2.2E-06	11.8
1965	2.1E-07	1.8	3.5E-07	2.0	1.1E-06	0.5	1.5E-06	8.0
1966	2.0E-07	1.7	3.4E-07	2.0	1.1E-06	0.5	1.4E-06	7.8
1967	2.2E-07	1.8	3.7E-07	2.1	1.3E-06	0.6	1.5E-06	7.9
1968	1.9E-07	1.6	3.0E-07	1.8	1.3E-06	0.6	1.5E-06	8.2
1969	1.7E-07	1.4	2.5E-07	1.5	1.1E-06	0.5	9.3E-07	5.1
1970	1.2E-07	1.0	1.8E-07	1.0	4.7E-07	0.2	6.9E-07	3.8
1971	1.4E-07	1.2	2.1E-07	1.2	5.4E-07	0.3	7.9E-07	4.4
1972	1.6E-07	1.4	2.5E-07	1.5	6.4E-07	0.3	9.1E-07	5.0
1973	1.5E-07	1.3	2.4E-07	1.4	6.5E-07	0.3	8.1E-07	4.4
1974	1.2E-07	1.1	1.8E-07	1.0	4.9E-07	0.2	6.9E-07	3.8
1975	7.8E-08	0.7	1.2E-07	0.7	3.2E-07	0.1	4.4E-07	2.4
1976	7.5E-08	0.6	1.2E-07	0.7	3.2E-07	0.1	4.7E-07	2.6
1977	7.4E-08	0.6	1.1E-07	0.7	3.1E-07	0.1	5.0E-07	2.7
1978	7.6E-08	0.7	1.1E-07	0.7	3.4E-07	0.2	6.8E-07	3.7
1979	6.5E-08	0.6	9.9E-08	0.6	2.7E-07	0.1	2.6E-07	1.4
1980	7.1E-08	0.6	1.1E-07	0.6	1.1E-07	0.1	2.8E-07	1.5
1981	7.4E-08	0.6	1.1E-07	0.6	1.1E-07	0.1	2.9E-07	1.6
1982	7.9E-08	0.7	1.2E-07	0.7	1.2E-07	0.1	3.1E-07	1.7
1983	8.9E-08	0.8	1.2E-07	0.7	1.2E-07	0.1	3.3E-07	1.8
1984	1.1E-07	0.9	1.5E-07	0.9	1.5E-07	0.1	4.1E-07	2.2
1985	1.1E-07	0.9	1.5E-07	0.9	1.5E-07	0.1	4.0E-07	2.2
1986	9.2E-08	0.8	1.2E-07	0.7	1.2E-07	0.1	3.4E-07	1.9
1987	9.1E-08	0.8	1.3E-07	0.8	1.3E-07	0.1	3.6E-07	2.0
1988	6.3E-08	0.5	8.5E-08	0.5	8.5E-08	0.0	2.3E-07	1.3
1989	4.1E-08	0.3	5.4E-08	0.3	5.4E-08	0.0	5.4E-08	0.3
1990	2.9E-08	0.2	3.9E-08	0.2	3.9E-08	0.0	3.9E-08	0.2
1991	2.3E-08	0.2	3.2E-08	0.2	3.2E-08	0.0	3.2E-08	0.2
1992	1.7E-08	0.1	2.3E-08	0.1	2.3E-08	0.0	2.3E-08	0.1
Total	1.2E-05	100.0	1.7E-05	100.0	2.2E-04	100.0	1.8E-05	100.0

Table 6.C Total Cancer Incident Risk By Year For Delivery Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.9E-06	0.7	1.9E-06	0.7	--	--	--	--
1955	3.8E-06	1.4	3.8E-06	1.4	6.4E-06	1.3	--	--
1956	4.7E-06	1.7	4.7E-06	1.7	8.1E-06	1.7	--	--
1957	2.8E-05	10.2	2.8E-05	10.2	4.7E-05	9.6	--	--
1958	4.8E-05	17.6	4.8E-05	17.6	8.0E-05	16.5	--	--
1959	1.2E-05	4.3	1.2E-05	4.3	1.9E-05	4.0	--	--
1960	7.2E-06	2.7	7.2E-06	2.7	1.2E-05	2.5	--	--
1961	5.7E-06	2.1	5.7E-06	2.1	9.6E-06	2.0	--	--
1962	8.6E-06	3.2	8.6E-06	3.2	1.5E-05	3.1	--	--
1963	2.3E-05	8.6	2.3E-05	8.6	3.8E-05	7.8	--	--
1964	2.7E-05	10.1	2.7E-05	10.1	4.5E-05	9.2	4.5E-05	14.5
1965	1.4E-05	5.2	1.4E-05	5.2	2.8E-05	5.8	3.9E-05	12.3
1966	1.9E-05	7.2	1.9E-05	7.2	5.6E-05	11.7	1.0E-04	33.4
1967	1.2E-05	4.4	1.2E-05	4.4	2.0E-05	4.2	2.9E-05	9.3
1968	7.7E-06	2.8	7.7E-06	2.8	1.2E-05	2.5	1.5E-05	4.7
1969	4.7E-06	1.7	4.7E-06	1.7	7.1E-06	1.5	7.9E-06	2.5
1970	5.3E-06	1.9	5.3E-06	1.9	6.4E-06	1.3	9.0E-06	2.9
1971	4.9E-06	1.8	4.9E-06	1.8	6.0E-06	1.2	8.5E-06	2.7
1972	2.6E-06	1.0	2.6E-06	1.0	3.2E-06	0.7	4.4E-06	1.4
1973	2.0E-06	0.7	2.0E-06	0.7	5.2E-06	1.1	3.5E-06	1.1
1974	3.0E-06	1.1	3.0E-06	1.1	8.0E-06	1.7	5.1E-06	1.6
1975	5.2E-06	1.9	5.2E-06	1.9	1.4E-05	2.8	8.3E-06	2.6
1976	1.8E-06	0.7	1.8E-06	0.7	4.8E-06	1.0	2.8E-06	0.9
1977	2.3E-06	0.8	2.3E-06	0.8	6.1E-06	1.3	3.3E-06	1.1
1978	2.9E-06	1.1	2.9E-06	1.1	7.8E-06	1.6	4.2E-06	1.3
1979	3.2E-06	1.2	3.2E-06	1.2	8.4E-06	1.7	3.8E-06	1.2
1980	8.6E-07	0.3	8.6E-07	0.3	8.6E-07	0.2	1.1E-06	0.3
1981	8.7E-07	0.3	8.7E-07	0.3	8.7E-07	0.2	1.1E-06	0.3
1982	6.2E-07	0.2	6.2E-07	0.2	6.2E-07	0.1	1.7E-06	0.5
1983	9.8E-07	0.4	9.8E-07	0.4	9.8E-07	0.2	2.6E-06	0.8
1984	6.3E-07	0.2	6.3E-07	0.2	6.3E-07	0.1	1.7E-06	0.5
1985	8.6E-07	0.3	8.6E-07	0.3	8.6E-07	0.2	2.3E-06	0.7
1986	8.3E-07	0.3	8.3E-07	0.3	8.3E-07	0.2	2.2E-06	0.7
1987	8.1E-07	0.3	8.1E-07	0.3	8.1E-07	0.2	2.1E-06	0.7
1988	8.5E-07	0.3	8.5E-07	0.3	8.5E-07	0.2	2.3E-06	0.7
1989	8.3E-07	0.3	8.3E-07	0.3	8.3E-07	0.2	8.3E-07	0.3
1990	8.0E-07	0.3	8.0E-07	0.3	8.0E-07	0.2	8.0E-07	0.3
1991	7.9E-07	0.3	7.9E-07	0.3	7.9E-07	0.2	7.9E-07	0.3
1992	7.7E-07	0.3	7.7E-07	0.3	7.7E-07	0.2	7.7E-07	0.2
Total	2.7E-04	100.0	2.7E-04	100.0	4.8E-04	100.0	3.1E-04	100.0

Table 6.C Total Cancer Incident Risk By Year For Delivery Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.9E-06	0.7	1.9E-06	0.7	--	--	--	--
1955	4.3E-06	1.5	4.4E-06	1.5	1.3E-05	1.8	--	--
1956	8.9E-06	3.2	1.1E-05	3.7	1.4E-04	20.5	--	--
1957	2.9E-05	10.2	2.9E-05	10.1	7.5E-05	10.8	--	--
1958	4.8E-05	17.0	4.8E-05	16.8	8.4E-05	12.0	--	--
1959	1.2E-05	4.4	1.3E-05	4.4	3.6E-05	5.2	--	--
1960	7.5E-06	2.7	7.7E-06	2.7	1.4E-05	2.0	--	--
1961	6.2E-06	2.2	6.5E-06	2.2	1.5E-05	2.1	--	--
1962	8.9E-06	3.2	9.1E-06	3.2	1.7E-05	2.4	--	--
1963	2.4E-05	8.4	2.4E-05	8.3	4.0E-05	5.7	--	--
1964	2.8E-05	9.8	2.8E-05	9.6	4.6E-05	6.6	4.8E-05	14.4
1965	1.4E-05	5.0	1.4E-05	5.0	2.9E-05	4.2	4.0E-05	12.1
1966	2.0E-05	6.9	2.0E-05	6.9	5.7E-05	8.2	1.1E-04	31.9
1967	1.2E-05	4.3	1.2E-05	4.3	2.2E-05	3.1	3.0E-05	9.2
1968	7.9E-06	2.8	8.0E-06	2.8	1.3E-05	1.9	1.6E-05	4.9
1969	4.8E-06	1.7	4.9E-06	1.7	8.2E-06	1.2	8.8E-06	2.6
1970	5.4E-06	1.9	5.4E-06	1.9	6.9E-06	1.0	9.7E-06	2.9
1971	5.0E-06	1.8	5.1E-06	1.8	6.5E-06	0.9	9.3E-06	2.8
1972	2.8E-06	1.0	2.9E-06	1.0	3.8E-06	0.6	5.4E-06	1.6
1973	2.1E-06	0.8	2.2E-06	0.8	5.9E-06	0.8	4.3E-06	1.3
1974	3.1E-06	1.1	3.2E-06	1.1	8.5E-06	1.2	5.8E-06	1.8
1975	5.3E-06	1.9	5.3E-06	1.8	1.4E-05	2.0	8.7E-06	2.6
1976	1.9E-06	0.7	1.9E-06	0.7	5.2E-06	0.7	3.2E-06	1.0
1977	2.4E-06	0.8	2.4E-06	0.8	6.4E-06	0.9	3.8E-06	1.2
1978	3.0E-06	1.1	3.1E-06	1.1	8.2E-06	1.2	4.9E-06	1.5
1979	3.2E-06	1.1	3.3E-06	1.1	8.7E-06	1.2	4.1E-06	1.2
1980	9.3E-07	0.3	9.7E-07	0.3	9.7E-07	0.1	1.4E-06	0.4
1981	9.4E-07	0.3	9.8E-07	0.3	9.8E-07	0.1	1.4E-06	0.4
1982	7.0E-07	0.2	7.4E-07	0.3	7.4E-07	0.1	2.0E-06	0.6
1983	1.1E-06	0.4	1.1E-06	0.4	1.1E-06	0.2	2.9E-06	0.9
1984	7.4E-07	0.3	7.8E-07	0.3	7.8E-07	0.1	2.1E-06	0.6
1985	9.7E-07	0.3	1.0E-06	0.4	1.0E-06	0.1	2.7E-06	0.8
1986	9.3E-07	0.3	9.6E-07	0.3	9.6E-07	0.1	2.6E-06	0.8
1987	9.0E-07	0.3	9.4E-07	0.3	9.4E-07	0.1	2.5E-06	0.8
1988	9.1E-07	0.3	9.3E-07	0.3	9.3E-07	0.1	2.5E-06	0.7
1989	8.7E-07	0.3	8.8E-07	0.3	8.8E-07	0.1	8.8E-07	0.3
1990	8.3E-07	0.3	8.4E-07	0.3	8.4E-07	0.1	8.4E-07	0.3
1991	8.1E-07	0.3	8.2E-07	0.3	8.2E-07	0.1	8.2E-07	0.2
1992	7.9E-07	0.3	8.0E-07	0.3	8.0E-07	0.1	8.0E-07	0.2
Total	2.8E-04	100.0	2.9E-04	100.0	7.0E-04	100.0	3.3E-04	100.0

Table 6.C Total Cancer Fatality Risk By Year For Delivery Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	2.1E-08	0.4	2.0E-08	0.3	--	--	--	--
1955	2.9E-07	5.8	3.8E-07	5.2	1.4E-06	3.6	--	--
1956	6.5E-07	13.0	9.0E-07	12.2	1.5E-05	39.6	--	--
1957	2.8E-07	5.5	4.0E-07	5.4	3.9E-06	10.3	--	--
1958	2.6E-07	5.2	3.8E-07	5.1	1.8E-06	4.8	--	--
1959	2.7E-07	5.5	4.1E-07	5.5	2.8E-06	7.4	--	--
1960	2.0E-07	4.1	3.1E-07	4.3	9.5E-07	2.5	--	--
1961	2.3E-07	4.6	3.5E-07	4.7	1.3E-06	3.4	--	--
1962	2.2E-07	4.5	3.4E-07	4.6	1.0E-06	2.7	--	--
1963	2.3E-07	4.6	3.6E-07	4.8	1.0E-06	2.8	--	--
1964	2.4E-07	4.8	3.6E-07	4.9	1.2E-06	3.1	1.4E-06	11.8
1965	1.5E-07	3.0	2.5E-07	3.4	7.0E-07	1.9	8.9E-07	7.8
1966	1.4E-07	2.9	2.4E-07	3.2	6.7E-07	1.8	8.4E-07	7.3
1967	1.5E-07	3.1	2.6E-07	3.5	7.9E-07	2.1	8.6E-07	7.5
1968	1.3E-07	2.7	2.1E-07	2.9	8.1E-07	2.1	8.8E-07	7.7
1969	1.2E-07	2.4	1.8E-07	2.5	7.0E-07	1.9	5.7E-07	5.0
1970	8.1E-08	1.6	1.2E-07	1.7	3.0E-07	0.8	4.1E-07	3.6
1971	9.9E-08	2.0	1.5E-07	2.0	3.5E-07	0.9	4.9E-07	4.3
1972	1.2E-07	2.4	1.8E-07	2.4	4.3E-07	1.1	5.9E-07	5.1
1973	1.1E-07	2.2	1.7E-07	2.3	4.4E-07	1.2	5.2E-07	4.6
1974	8.9E-08	1.8	1.3E-07	1.7	3.3E-07	0.9	4.5E-07	3.9
1975	5.6E-08	1.1	8.3E-08	1.1	2.1E-07	0.6	2.9E-07	2.5
1976	5.4E-08	1.1	8.4E-08	1.1	2.1E-07	0.6	3.1E-07	2.7
1977	5.3E-08	1.1	8.2E-08	1.1	2.1E-07	0.6	3.2E-07	2.8
1978	5.4E-08	1.1	8.0E-08	1.1	2.2E-07	0.6	4.3E-07	3.7
1979	4.7E-08	0.9	7.1E-08	1.0	1.8E-07	0.5	1.8E-07	1.5
1980	5.1E-08	1.0	7.8E-08	1.1	7.8E-08	0.2	1.9E-07	1.6
1981	5.3E-08	1.1	7.9E-08	1.1	7.9E-08	0.2	2.0E-07	1.7
1982	5.6E-08	1.1	8.3E-08	1.1	8.3E-08	0.2	2.1E-07	1.8
1983	6.4E-08	1.3	8.7E-08	1.2	8.7E-08	0.2	2.2E-07	1.9
1984	8.0E-08	1.6	1.1E-07	1.5	1.1E-07	0.3	2.7E-07	2.4
1985	7.7E-08	1.5	1.1E-07	1.4	1.1E-07	0.3	2.7E-07	2.3
1986	6.6E-08	1.3	8.8E-08	1.2	8.8E-08	0.2	2.3E-07	2.0
1987	6.5E-08	1.3	9.4E-08	1.3	9.4E-08	0.2	2.4E-07	2.1
1988	4.5E-08	0.9	6.1E-08	0.8	6.1E-08	0.2	1.5E-07	1.3
1989	2.9E-08	0.6	3.9E-08	0.5	3.9E-08	0.1	3.9E-08	0.3
1990	2.1E-08	0.4	2.8E-08	0.4	2.8E-08	0.1	2.8E-08	0.2
1991	1.7E-08	0.3	2.3E-08	0.3	2.3E-08	0.1	2.3E-08	0.2
1992	1.2E-08	0.2	1.6E-08	0.2	1.6E-08	0.0	1.6E-08	0.1
Total	5.0E-06	100.0	7.4E-06	100.0	3.8E-05	100.0	1.1E-05	100.0

Table 6.C Total Cancer Fatality Risk By Year For Delivery Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.4E-06	0.7	1.4E-06	0.7	--	--	--	--
1955	2.8E-06	1.4	2.8E-06	1.4	4.1E-06	1.3	--	--
1956	3.5E-06	1.8	3.5E-06	1.8	5.3E-06	1.7	--	--
1957	2.0E-05	10.2	2.0E-05	10.2	3.0E-05	9.4	--	--
1958	3.5E-05	17.7	3.5E-05	17.7	5.2E-05	16.3	--	--
1959	8.5E-06	4.3	8.5E-06	4.3	1.3E-05	3.9	--	--
1960	5.3E-06	2.7	5.3E-06	2.7	8.1E-06	2.5	--	--
1961	4.2E-06	2.1	4.2E-06	2.1	6.3E-06	2.0	--	--
1962	6.3E-06	3.2	6.3E-06	3.2	9.7E-06	3.0	--	--
1963	1.7E-05	8.5	1.7E-05	8.5	2.5E-05	7.8	--	--
1964	2.0E-05	10.0	2.0E-05	10.0	2.9E-05	9.2	2.9E-05	14.2
1965	1.0E-05	5.2	1.0E-05	5.2	1.8E-05	5.8	2.5E-05	12.2
1966	1.5E-05	7.3	1.5E-05	7.3	3.6E-05	11.4	6.8E-05	33.3
1967	8.9E-06	4.5	8.9E-06	4.5	1.3E-05	4.2	1.9E-05	9.2
1968	5.6E-06	2.8	5.6E-06	2.8	7.9E-06	2.5	9.4E-06	4.6
1969	3.4E-06	1.7	3.4E-06	1.7	4.7E-06	1.5	5.2E-06	2.5
1970	3.9E-06	1.9	3.9E-06	1.9	4.5E-06	1.4	5.9E-06	2.9
1971	3.6E-06	1.8	3.6E-06	1.8	4.2E-06	1.3	5.6E-06	2.7
1972	1.9E-06	1.0	1.9E-06	1.0	2.2E-06	0.7	2.9E-06	1.4
1973	1.5E-06	0.7	1.5E-06	0.7	3.7E-06	1.2	2.3E-06	1.1
1974	2.2E-06	1.1	2.2E-06	1.1	5.5E-06	1.7	3.4E-06	1.6
1975	3.7E-06	1.9	3.7E-06	1.9	9.4E-06	2.9	5.4E-06	2.6
1976	1.3E-06	0.7	1.3E-06	0.7	3.4E-06	1.1	1.8E-06	0.9
1977	1.6E-06	0.8	1.6E-06	0.8	4.1E-06	1.3	2.2E-06	1.1
1978	2.1E-06	1.1	2.1E-06	1.1	5.3E-06	1.7	2.7E-06	1.3
1979	2.3E-06	1.1	2.3E-06	1.1	5.7E-06	1.8	2.6E-06	1.3
1980	6.4E-07	0.3	6.4E-07	0.3	6.4E-07	0.2	7.7E-07	0.4
1981	6.4E-07	0.3	6.4E-07	0.3	6.4E-07	0.2	7.4E-07	0.4
1982	4.5E-07	0.2	4.5E-07	0.2	4.5E-07	0.1	1.1E-06	0.6
1983	7.1E-07	0.4	7.1E-07	0.4	7.1E-07	0.2	1.8E-06	0.9
1984	4.6E-07	0.2	4.6E-07	0.2	4.6E-07	0.1	1.2E-06	0.6
1985	6.2E-07	0.3	6.2E-07	0.3	6.2E-07	0.2	1.6E-06	0.8
1986	6.1E-07	0.3	6.1E-07	0.3	6.1E-07	0.2	1.5E-06	0.7
1987	5.8E-07	0.3	5.8E-07	0.3	5.8E-07	0.2	1.5E-06	0.7
1988	6.2E-07	0.3	6.2E-07	0.3	6.2E-07	0.2	1.6E-06	0.8
1989	6.0E-07	0.3	6.0E-07	0.3	6.0E-07	0.2	6.0E-07	0.3
1990	5.8E-07	0.3	5.8E-07	0.3	5.8E-07	0.2	5.8E-07	0.3
1991	5.7E-07	0.3	5.7E-07	0.3	5.7E-07	0.2	5.7E-07	0.3
1992	5.6E-07	0.3	5.6E-07	0.3	5.6E-07	0.2	5.6E-07	0.3
Total	2.0E-04	100.0	2.0E-04	100.0	3.2E-04	100.0	2.1E-04	100.0

Table 6.C Total Cancer Fatality Risk By Year For Delivery Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.4E-06	0.7	1.4E-06	0.7	--	--	--	--
1955	3.1E-06	1.5	3.2E-06	1.5	5.5E-06	1.5	--	--
1956	4.2E-06	2.0	4.4E-06	2.1	2.0E-05	5.7	--	--
1957	2.1E-05	10.1	2.1E-05	10.1	3.4E-05	9.5	--	--
1958	3.6E-05	17.4	3.6E-05	17.2	5.4E-05	15.1	--	--
1959	8.8E-06	4.3	8.9E-06	4.3	1.5E-05	4.3	--	--
1960	5.6E-06	2.7	5.7E-06	2.7	9.0E-06	2.5	--	--
1961	4.4E-06	2.2	4.6E-06	2.2	7.6E-06	2.1	--	--
1962	6.6E-06	3.2	6.7E-06	3.2	1.1E-05	3.0	--	--
1963	1.7E-05	8.4	1.7E-05	8.4	2.6E-05	7.3	--	--
1964	2.0E-05	9.8	2.0E-05	9.8	3.0E-05	8.6	3.1E-05	14.1
1965	1.0E-05	5.1	1.1E-05	5.1	1.9E-05	5.4	2.6E-05	12.0
1966	1.5E-05	7.2	1.5E-05	7.2	3.7E-05	10.4	6.9E-05	32.0
1967	9.1E-06	4.4	9.2E-06	4.4	1.4E-05	4.0	2.0E-05	9.1
1968	5.8E-06	2.8	5.8E-06	2.8	8.7E-06	2.4	1.0E-05	4.8
1969	3.6E-06	1.7	3.6E-06	1.7	5.4E-06	1.5	5.7E-06	2.7
1970	4.0E-06	1.9	4.0E-06	1.9	4.8E-06	1.3	6.3E-06	2.9
1971	3.7E-06	1.8	3.8E-06	1.8	4.5E-06	1.3	6.1E-06	2.8
1972	2.0E-06	1.0	2.1E-06	1.0	2.6E-06	0.7	3.5E-06	1.6
1973	1.6E-06	0.8	1.7E-06	0.8	4.2E-06	1.2	2.9E-06	1.3
1974	2.3E-06	1.1	2.3E-06	1.1	5.8E-06	1.6	3.8E-06	1.8
1975	3.8E-06	1.9	3.8E-06	1.8	9.6E-06	2.7	5.7E-06	2.6
1976	1.4E-06	0.7	1.4E-06	0.7	3.6E-06	1.0	2.1E-06	1.0
1977	1.7E-06	0.8	1.7E-06	0.8	4.4E-06	1.2	2.5E-06	1.2
1978	2.2E-06	1.1	2.2E-06	1.1	5.5E-06	1.6	3.2E-06	1.5
1979	2.3E-06	1.1	2.3E-06	1.1	5.9E-06	1.7	2.8E-06	1.3
1980	6.9E-07	0.3	7.2E-07	0.3	7.2E-07	0.2	9.5E-07	0.4
1981	6.9E-07	0.3	7.2E-07	0.3	7.2E-07	0.2	9.4E-07	0.4
1982	5.1E-07	0.2	5.3E-07	0.3	5.3E-07	0.1	1.3E-06	0.6
1983	7.7E-07	0.4	8.0E-07	0.4	8.0E-07	0.2	2.0E-06	0.9
1984	5.4E-07	0.3	5.6E-07	0.3	5.6E-07	0.2	1.4E-06	0.7
1985	7.0E-07	0.3	7.3E-07	0.4	7.3E-07	0.2	1.8E-06	0.9
1986	6.7E-07	0.3	6.9E-07	0.3	6.9E-07	0.2	1.8E-06	0.8
1987	6.5E-07	0.3	6.8E-07	0.3	6.8E-07	0.2	1.7E-06	0.8
1988	6.6E-07	0.3	6.8E-07	0.3	6.8E-07	0.2	1.7E-06	0.8
1989	6.3E-07	0.3	6.4E-07	0.3	6.4E-07	0.2	6.4E-07	0.3
1990	6.1E-07	0.3	6.1E-07	0.3	6.1E-07	0.2	6.1E-07	0.3
1991	5.9E-07	0.3	5.9E-07	0.3	5.9E-07	0.2	5.9E-07	0.3
1992	5.7E-07	0.3	5.7E-07	0.3	5.7E-07	0.2	5.7E-07	0.3
Total	2.0E-04	100.0	2.1E-04	100.0	3.6E-04	100.0	2.2E-04	100.0

Table 6.C Effective Dose By Year for Urban Family

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	1.2E-07	0.0	6.7E-07	0.1	--	--	--	--
1955	1.9E-05	5.9	3.9E-05	5.4	8.8E-05	3.3	--	--
1956	1.7E-04	52.6	2.6E-04	36.0	2.0E-03	73.2	--	--
1957	3.8E-05	11.4	6.6E-05	9.0	2.4E-04	8.8	--	--
1958	7.4E-06	2.3	2.3E-05	3.1	2.6E-05	1.0	--	--
1959	2.3E-05	6.9	4.9E-05	6.7	1.4E-04	5.0	--	--
1960	4.0E-06	1.2	2.1E-05	2.8	1.4E-05	0.5	--	--
1961	1.3E-05	3.9	3.4E-05	4.6	8.9E-05	3.3	--	--
1962	3.8E-06	1.2	2.1E-05	2.8	7.6E-06	0.3	--	--
1963	3.7E-06	1.1	2.2E-05	3.0	6.9E-06	0.3	--	--
1964	4.2E-06	1.3	2.0E-05	2.7	7.8E-06	0.3	1.4E-05	13.4
1965	2.6E-06	0.8	1.6E-05	2.2	4.8E-06	0.2	8.5E-06	8.0
1966	2.5E-06	0.8	1.6E-05	2.2	4.7E-06	0.2	5.5E-06	5.2
1967	2.5E-06	0.8	1.8E-05	2.4	4.3E-06	0.2	5.4E-06	5.0
1968	2.5E-06	0.7	1.3E-05	1.7	4.4E-06	0.2	5.6E-06	5.2
1969	3.5E-06	1.1	1.2E-05	1.6	5.7E-06	0.2	7.9E-06	7.4
1970	1.7E-06	0.5	7.0E-06	1.0	3.2E-06	0.1	5.2E-06	4.8
1971	1.9E-06	0.6	7.9E-06	1.1	3.4E-06	0.1	3.7E-06	3.4
1972	2.2E-06	0.7	9.9E-06	1.4	3.7E-06	0.1	4.0E-06	3.7
1973	1.8E-06	0.5	9.8E-06	1.3	9.8E-06	0.4	3.2E-06	3.0
1974	1.6E-06	0.5	6.1E-06	0.8	6.1E-06	0.2	3.0E-06	2.8
1975	1.0E-06	0.3	4.1E-06	0.6	4.1E-06	0.2	1.9E-06	1.8
1976	9.1E-07	0.3	4.8E-06	0.7	4.8E-06	0.2	1.5E-06	1.4
1977	9.9E-07	0.3	4.3E-06	0.6	4.3E-06	0.2	1.7E-06	1.6
1978	1.0E-06	0.3	3.8E-06	0.5	3.8E-06	0.1	1.8E-06	1.7
1979	8.6E-07	0.3	3.6E-06	0.5	3.6E-06	0.1	1.5E-06	1.4
1980	9.0E-07	0.3	4.3E-06	0.6	4.3E-06	0.2	1.6E-06	1.5
1981	1.0E-06	0.3	4.1E-06	0.6	4.1E-06	0.2	1.8E-06	1.7
1982	1.1E-06	0.3	4.0E-06	0.5	4.0E-06	0.1	4.0E-06	3.7
1983	1.3E-06	0.4	3.3E-06	0.5	3.3E-06	0.1	3.3E-06	3.1
1984	1.7E-06	0.5	3.7E-06	0.5	3.7E-06	0.1	3.7E-06	3.5
1985	1.5E-06	0.5	4.1E-06	0.6	4.1E-06	0.2	4.1E-06	3.8
1986	1.1E-06	0.3	3.9E-06	0.5	3.9E-06	0.1	3.9E-06	3.6
1987	1.2E-06	0.4	4.7E-06	0.6	4.7E-06	0.2	4.7E-06	4.4
1988	9.3E-07	0.3	2.2E-06	0.3	2.2E-06	0.1	2.2E-06	2.1
1989	6.4E-07	0.2	1.0E-06	0.1	1.0E-06	0.0	1.0E-06	0.9
1990	5.1E-07	0.2	8.7E-07	0.1	8.7E-07	0.0	8.7E-07	0.8
1991	3.9E-07	0.1	7.0E-07	0.1	7.0E-07	0.0	7.0E-07	0.7
1992	3.0E-07	0.1	5.4E-07	0.1	5.4E-07	0.0	5.4E-07	0.5
Total	3.3E-04	100.0	7.3E-04	100.0	2.7E-03	100.0	1.1E-04	100.0

Table 6.C Total Cancer Incident Risk By Year For Urban Family

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	5.6E-09	0.1	3.2E-08	0.1	--	--	--	--
1955	3.5E-07	3.9	8.3E-07	3.3	7.1E-06	2.7	--	--
1956	4.0E-06	43.7	6.2E-06	25.0	1.7E-04	65.4	--	--
1957	9.2E-07	10.2	1.8E-06	7.4	3.6E-05	13.7	--	--
1958	3.0E-07	3.3	1.0E-06	4.0	4.8E-06	1.8	--	--
1959	5.9E-07	6.6	1.6E-06	6.5	2.1E-05	7.9	--	--
1960	1.7E-07	1.9	9.5E-07	3.8	1.3E-06	0.5	--	--
1961	3.7E-07	4.1	1.2E-06	5.0	5.3E-06	2.0	--	--
1962	1.7E-07	1.9	9.8E-07	3.9	1.2E-06	0.5	--	--
1963	1.7E-07	1.9	1.0E-06	4.2	1.2E-06	0.4	--	--
1964	2.0E-07	2.2	9.5E-07	3.8	1.4E-06	0.5	1.6E-06	10.4
1965	1.2E-07	1.3	7.7E-07	3.1	8.1E-07	0.3	1.2E-06	7.4
1966	1.1E-07	1.3	7.6E-07	3.0	7.8E-07	0.3	1.2E-06	7.3
1967	1.2E-07	1.3	8.5E-07	3.4	9.1E-07	0.3	1.1E-06	7.1
1968	1.1E-07	1.3	6.1E-07	2.4	1.0E-06	0.4	1.2E-06	7.8
1969	1.0E-07	1.1	4.5E-07	1.8	8.8E-07	0.3	7.1E-07	4.5
1970	7.4E-08	0.8	3.3E-07	1.3	3.5E-07	0.1	5.6E-07	3.5
1971	8.5E-08	0.9	3.8E-07	1.5	4.0E-07	0.2	6.2E-07	3.9
1972	1.0E-07	1.1	4.8E-07	1.9	4.9E-07	0.2	7.1E-07	4.5
1973	8.6E-08	1.0	4.7E-07	1.9	1.3E-06	0.5	5.7E-07	3.6
1974	7.6E-08	0.8	2.9E-07	1.2	8.1E-07	0.3	5.3E-07	3.4
1975	4.9E-08	0.5	2.0E-07	0.8	5.5E-07	0.2	3.4E-07	2.2
1976	4.3E-08	0.5	2.3E-07	0.9	6.3E-07	0.2	3.4E-07	2.1
1977	4.7E-08	0.5	2.1E-07	0.8	5.8E-07	0.2	3.9E-07	2.5
1978	4.9E-08	0.5	1.8E-07	0.7	5.2E-07	0.2	5.1E-07	3.2
1979	4.1E-08	0.5	1.7E-07	0.7	4.7E-07	0.2	2.0E-07	1.2
1980	4.3E-08	0.5	2.1E-07	0.8	2.1E-07	0.1	2.0E-07	1.3
1981	4.9E-08	0.5	2.0E-07	0.8	2.0E-07	0.1	2.4E-07	1.5
1982	5.2E-08	0.6	1.9E-07	0.8	1.9E-07	0.1	5.3E-07	3.3
1983	6.4E-08	0.7	1.6E-07	0.6	1.6E-07	0.1	4.4E-07	2.8
1984	8.4E-08	0.9	1.8E-07	0.7	1.8E-07	0.1	4.9E-07	3.1
1985	7.4E-08	0.8	2.0E-07	0.8	2.0E-07	0.1	5.4E-07	3.4
1986	5.3E-08	0.6	1.9E-07	0.7	1.9E-07	0.1	5.1E-07	3.3
1987	5.7E-08	0.6	2.3E-07	0.9	2.3E-07	0.1	6.3E-07	4.0
1988	4.5E-08	0.5	1.1E-07	0.4	1.1E-07	0.0	2.9E-07	1.9
1989	3.1E-08	0.3	4.9E-08	0.2	4.9E-08	0.0	4.9E-08	0.3
1990	2.5E-08	0.3	4.2E-08	0.2	4.2E-08	0.0	4.2E-08	0.3
1991	1.9E-08	0.2	3.4E-08	0.1	3.4E-08	0.0	3.4E-08	0.2
1992	1.4E-08	0.2	2.6E-08	0.1	2.6E-08	0.0	2.6E-08	0.2

Total	9.0E-06	100.0	2.5E-05	100.0	2.7E-04	100.0	1.6E-05	100.0

Table 6.C Total Cancer Fatality Risk By Year For Urban Family

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	4.0E-09	0.1	2.3E-08	0.2	--	--	--	--
1955	1.8E-07	5.7	5.0E-07	3.9	1.2E-06	3.0	--	--
1956	5.3E-07	16.8	1.1E-06	8.5	1.9E-05	45.4	--	--
1957	2.0E-07	6.2	6.4E-07	4.9	4.5E-06	11.0	--	--
1958	1.8E-07	5.7	6.7E-07	5.1	1.8E-06	4.5	--	--
1959	1.6E-07	5.2	7.8E-07	6.0	2.9E-06	7.1	--	--
1960	1.1E-07	3.4	6.6E-07	5.1	6.5E-07	1.6	--	--
1961	1.3E-07	4.0	6.9E-07	5.3	1.0E-06	2.5	--	--
1962	1.2E-07	3.6	6.9E-07	5.3	6.8E-07	1.6	--	--
1963	1.2E-07	3.8	7.4E-07	5.7	7.0E-07	1.7	--	--
1964	1.4E-07	4.4	6.8E-07	5.2	8.6E-07	2.1	1.0E-06	10.4
1965	8.5E-08	2.7	5.5E-07	4.2	5.0E-07	1.2	6.9E-07	7.0
1966	8.0E-08	2.5	5.4E-07	4.1	4.6E-07	1.1	6.5E-07	6.6
1967	8.2E-08	2.6	6.0E-07	4.6	5.4E-07	1.3	6.4E-07	6.5
1968	7.9E-08	2.5	4.3E-07	3.3	6.0E-07	1.5	7.0E-07	7.2
1969	7.4E-08	2.3	3.3E-07	2.5	5.2E-07	1.3	4.2E-07	4.2
1970	5.0E-08	1.6	2.3E-07	1.8	2.2E-07	0.5	3.1E-07	3.2
1971	5.9E-08	1.9	2.7E-07	2.0	2.6E-07	0.6	3.7E-07	3.8
1972	7.4E-08	2.3	3.4E-07	2.6	3.3E-07	0.8	4.6E-07	4.7
1973	6.2E-08	1.9	3.4E-07	2.6	8.7E-07	2.1	3.7E-07	3.8
1974	5.5E-08	1.7	2.1E-07	1.6	5.4E-07	1.3	3.5E-07	3.5
1975	3.5E-08	1.1	1.4E-07	1.1	3.7E-07	0.9	2.2E-07	2.3
1976	3.1E-08	1.0	1.6E-07	1.3	4.2E-07	1.0	2.2E-07	2.2
1977	3.4E-08	1.1	1.5E-07	1.1	3.9E-07	0.9	2.5E-07	2.6
1978	3.4E-08	1.1	1.3E-07	1.0	3.5E-07	0.8	3.2E-07	3.3
1979	3.0E-08	0.9	1.2E-07	0.9	3.2E-07	0.8	1.3E-07	1.3
1980	3.1E-08	1.0	1.5E-07	1.1	1.5E-07	0.4	1.4E-07	1.4
1981	3.5E-08	1.1	1.4E-07	1.1	1.4E-07	0.3	1.6E-07	1.6
1982	3.7E-08	1.2	1.4E-07	1.0	1.4E-07	0.3	3.5E-07	3.6
1983	4.6E-08	1.4	1.1E-07	0.9	1.1E-07	0.3	2.9E-07	3.0
1984	6.0E-08	1.9	1.3E-07	1.0	1.3E-07	0.3	3.3E-07	3.4
1985	5.3E-08	1.7	1.4E-07	1.1	1.4E-07	0.3	3.6E-07	3.7
1986	3.8E-08	1.2	1.3E-07	1.0	1.3E-07	0.3	3.4E-07	3.5
1987	4.1E-08	1.3	1.6E-07	1.3	1.6E-07	0.4	4.2E-07	4.3
1988	3.2E-08	1.0	7.7E-08	0.6	7.7E-08	0.2	2.0E-07	2.0
1989	2.2E-08	0.7	3.5E-08	0.3	3.5E-08	0.1	3.5E-08	0.4
1990	1.8E-08	0.6	3.0E-08	0.2	3.0E-08	0.1	3.0E-08	0.3
1991	1.4E-08	0.4	2.4E-08	0.2	2.4E-08	0.1	2.4E-08	0.2
1992	1.0E-08	0.3	1.9E-08	0.1	1.9E-08	0.0	1.9E-08	0.2

Total	3.2E-06	100.0	1.3E-05	100.0	4.1E-05	100.0	9.8E-06	100.0

Table 6.C Effective Dose By Year for Migrant Family

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	2.9E-07	0.1	2.9E-07	0.0	--	--	--	--
1955	3.6E-05	8.0	4.9E-05	7.8	8.4E-05	3.8	--	--
1956	2.3E-04	52.2	3.4E-04	54.3	1.6E-03	73.1	--	--
1957	5.0E-05	11.3	7.2E-05	11.6	1.9E-04	8.8	--	--
1958	9.0E-06	2.0	1.2E-05	1.9	2.1E-05	1.0	--	--
1959	3.1E-05	6.9	4.3E-05	6.9	1.1E-04	5.1	--	--
1960	5.6E-06	1.3	6.8E-06	1.1	1.3E-05	0.6	--	--
1961	1.8E-05	4.0	2.4E-05	3.9	8.2E-05	3.8	--	--
1962	5.1E-06	1.1	6.0E-06	1.0	7.2E-06	0.3	--	--
1963	5.0E-06	1.1	5.8E-06	0.9	6.7E-06	0.3	--	--
1964	5.1E-06	1.1	6.0E-06	1.0	6.9E-06	0.3	1.1E-05	13.2
1965	3.5E-06	0.8	4.1E-06	0.7	4.6E-06	0.2	6.8E-06	8.2
1966	3.4E-06	0.8	3.9E-06	0.6	4.6E-06	0.2	5.0E-06	6.0
1967	3.5E-06	0.8	4.0E-06	0.6	4.5E-06	0.2	4.9E-06	5.9
1968	3.2E-06	0.7	3.8E-06	0.6	4.4E-06	0.2	4.9E-06	5.9
1969	6.0E-06	1.3	7.8E-06	1.3	8.4E-06	0.4	1.0E-05	12.1
1970	2.0E-06	0.4	2.5E-06	0.4	3.0E-06	0.1	4.4E-06	5.2
1971	2.3E-06	0.5	2.8E-06	0.4	3.2E-06	0.1	3.3E-06	4.0
1972	2.6E-06	0.6	3.1E-06	0.5	3.4E-06	0.2	3.5E-06	4.2
1973	2.3E-06	0.5	2.7E-06	0.4	2.7E-06	0.1	3.0E-06	3.6
1974	1.8E-06	0.4	2.1E-06	0.3	2.1E-06	0.1	2.4E-06	2.9
1975	1.1E-06	0.2	1.4E-06	0.2	1.4E-06	0.1	1.5E-06	1.8
1976	1.1E-06	0.2	1.3E-06	0.2	1.3E-06	0.1	1.4E-06	1.7
1977	1.1E-06	0.2	1.3E-06	0.2	1.3E-06	0.1	1.5E-06	1.7
1978	1.4E-06	0.3	1.7E-06	0.3	1.7E-06	0.1	1.9E-06	2.3
1979	9.3E-07	0.2	1.1E-06	0.2	1.1E-06	0.1	1.2E-06	1.5
1980	1.0E-06	0.2	1.2E-06	0.2	1.2E-06	0.1	1.4E-06	1.6
1981	1.1E-06	0.3	1.4E-06	0.2	1.4E-06	0.1	1.5E-06	1.8
1982	1.2E-06	0.3	1.4E-06	0.2	1.4E-06	0.1	1.4E-06	1.7
1983	1.3E-06	0.3	1.6E-06	0.3	1.6E-06	0.1	1.6E-06	2.0
1984	1.6E-06	0.4	2.1E-06	0.3	2.1E-06	0.1	2.1E-06	2.5
1985	1.5E-06	0.3	1.9E-06	0.3	1.9E-06	0.1	1.9E-06	2.3
1986	1.3E-06	0.3	1.5E-06	0.2	1.5E-06	0.1	1.5E-06	1.8
1987	1.4E-06	0.3	1.7E-06	0.3	1.7E-06	0.1	1.7E-06	2.0
1988	9.2E-07	0.2	1.2E-06	0.2	1.2E-06	0.1	1.2E-06	1.4
1989	5.5E-07	0.1	7.2E-07	0.1	7.2E-07	0.0	7.2E-07	0.9
1990	4.5E-07	0.1	5.9E-07	0.1	5.9E-07	0.0	5.9E-07	0.7
1991	3.3E-07	0.1	4.4E-07	0.1	4.4E-07	0.0	4.4E-07	0.5
1992	2.6E-07	0.1	3.4E-07	0.1	3.4E-07	0.0	3.4E-07	0.4
Total	4.5E-04	100.0	6.2E-04	100.0	2.2E-03	100.0	8.3E-05	100.0

Table 6.C Total Cancer Incident Risk By Year For Migrant Family

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.4E-08	0.1	1.4E-08	0.1	--	--	--	--
1955	6.2E-07	5.2	8.4E-07	5.2	6.4E-06	3.0	--	--
1956	5.4E-06	44.7	7.7E-06	47.6	1.4E-04	65.4	--	--
1957	1.2E-06	10.3	1.7E-06	10.7	2.9E-05	13.6	--	--
1958	3.5E-07	2.9	4.4E-07	2.7	3.7E-06	1.7	--	--
1959	8.1E-07	6.8	1.1E-06	6.8	1.7E-05	8.0	--	--
1960	2.3E-07	1.9	2.7E-07	1.7	1.3E-06	0.6	--	--
1961	5.1E-07	4.2	6.7E-07	4.1	5.1E-06	2.4	--	--
1962	2.3E-07	1.9	2.7E-07	1.6	1.2E-06	0.5	--	--
1963	2.3E-07	2.0	2.7E-07	1.7	1.1E-06	0.5	--	--
1964	2.4E-07	2.0	2.8E-07	1.7	1.2E-06	0.6	1.4E-06	11.0
1965	1.6E-07	1.3	1.8E-07	1.1	7.7E-07	0.4	9.8E-07	7.8
1966	1.5E-07	1.3	1.8E-07	1.1	7.8E-07	0.4	1.0E-06	8.0
1967	1.6E-07	1.3	1.8E-07	1.1	8.8E-07	0.4	9.6E-07	7.6
1968	1.5E-07	1.2	1.8E-07	1.1	1.1E-06	0.5	1.2E-06	9.1
1969	1.5E-07	1.3	1.9E-07	1.2	1.0E-06	0.5	8.2E-07	6.5
1970	8.6E-08	0.7	1.0E-07	0.6	3.2E-07	0.1	4.8E-07	3.8
1971	1.0E-07	0.9	1.2E-07	0.8	3.8E-07	0.2	5.6E-07	4.5
1972	1.2E-07	1.0	1.5E-07	0.9	4.4E-07	0.2	6.4E-07	5.1
1973	1.1E-07	0.9	1.3E-07	0.8	3.5E-07	0.2	5.3E-07	4.2
1974	8.4E-08	0.7	1.0E-07	0.6	2.8E-07	0.1	4.2E-07	3.4
1975	5.3E-08	0.4	6.5E-08	0.4	1.8E-07	0.1	2.7E-07	2.1
1976	5.2E-08	0.4	6.1E-08	0.4	1.7E-07	0.1	2.9E-07	2.3
1977	5.2E-08	0.4	6.2E-08	0.4	1.7E-07	0.1	3.1E-07	2.5
1978	6.3E-08	0.5	8.1E-08	0.5	2.7E-07	0.1	6.7E-07	5.4
1979	4.4E-08	0.4	5.4E-08	0.3	1.5E-07	0.1	1.6E-07	1.3
1980	4.9E-08	0.4	5.9E-08	0.4	5.9E-08	0.0	1.8E-07	1.4
1981	5.4E-08	0.5	6.6E-08	0.4	6.6E-08	0.0	2.0E-07	1.6
1982	5.6E-08	0.5	6.8E-08	0.4	6.8E-08	0.0	1.8E-07	1.5
1983	6.2E-08	0.5	7.9E-08	0.5	7.9E-08	0.0	2.1E-07	1.7
1984	7.9E-08	0.7	1.0E-07	0.6	1.0E-07	0.0	2.7E-07	2.2
1985	7.2E-08	0.6	9.1E-08	0.6	9.1E-08	0.0	2.4E-07	1.9
1986	6.1E-08	0.5	7.3E-08	0.4	7.3E-08	0.0	2.0E-07	1.6
1987	6.6E-08	0.6	8.0E-08	0.5	8.0E-08	0.0	2.2E-07	1.7
1988	4.4E-08	0.4	5.6E-08	0.3	5.6E-08	0.0	1.5E-07	1.2
1989	2.6E-08	0.2	3.5E-08	0.2	3.5E-08	0.0	3.5E-08	0.3
1990	2.1E-08	0.2	2.8E-08	0.2	2.8E-08	0.0	2.8E-08	0.2
1991	1.6E-08	0.1	2.1E-08	0.1	2.1E-08	0.0	2.1E-08	0.2
1992	1.2E-08	0.1	1.6E-08	0.1	1.6E-08	0.0	1.6E-08	0.1

Total	1.2E-05	100.0	1.6E-05	100.0	2.2E-04	100.0	1.3E-05	100.0

Table 6.C Total Cancer Fatality Risk By Year For Migrant Family

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.0E-08	0.2	1.0E-08	0.2	--	--	--	--
1955	3.7E-07	8.8	4.9E-07	9.4	1.6E-06	4.7	--	--
1956	7.7E-07	18.3	1.0E-06	20.1	1.6E-05	46.1	--	--
1957	2.7E-07	6.3	3.4E-07	6.6	3.7E-06	11.1	--	--
1958	2.1E-07	5.0	2.6E-07	4.9	1.4E-06	4.1	--	--
1959	2.3E-07	5.6	2.9E-07	5.5	2.5E-06	7.5	--	--
1960	1.5E-07	3.6	1.7E-07	3.3	6.8E-07	2.0	--	--
1961	1.8E-07	4.3	2.2E-07	4.1	1.1E-06	3.1	--	--
1962	1.6E-07	3.7	1.8E-07	3.4	6.8E-07	2.0	--	--
1963	1.6E-07	3.9	1.9E-07	3.6	7.0E-07	2.1	--	--
1964	1.7E-07	4.0	2.0E-07	3.8	7.6E-07	2.2	8.6E-07	11.0
1965	1.1E-07	2.6	1.3E-07	2.4	4.7E-07	1.4	5.8E-07	7.5
1966	1.1E-07	2.5	1.2E-07	2.3	4.6E-07	1.4	5.7E-07	7.3
1967	1.1E-07	2.6	1.3E-07	2.4	5.3E-07	1.6	5.6E-07	7.2
1968	1.0E-07	2.4	1.2E-07	2.3	6.2E-07	1.8	6.6E-07	8.5
1969	1.1E-07	2.7	1.4E-07	2.7	6.5E-07	1.9	5.1E-07	6.6
1970	5.8E-08	1.4	6.9E-08	1.3	1.9E-07	0.6	2.7E-07	3.4
1971	7.1E-08	1.7	8.4E-08	1.6	2.4E-07	0.7	3.4E-07	4.3
1972	8.7E-08	2.1	1.0E-07	2.0	3.0E-07	0.9	4.1E-07	5.3
1973	7.8E-08	1.8	9.0E-08	1.7	2.3E-07	0.7	3.4E-07	4.4
1974	6.0E-08	1.4	7.2E-08	1.4	1.8E-07	0.5	2.7E-07	3.5
1975	3.8E-08	0.9	4.6E-08	0.9	1.2E-07	0.3	1.8E-07	2.3
1976	3.7E-08	0.9	4.3E-08	0.8	1.1E-07	0.3	1.9E-07	2.4
1977	3.7E-08	0.9	4.5E-08	0.9	1.1E-07	0.3	2.0E-07	2.6
1978	4.4E-08	1.0	5.5E-08	1.1	1.7E-07	0.5	4.1E-07	5.3
1979	3.2E-08	0.8	3.8E-08	0.7	9.8E-08	0.3	1.1E-07	1.4
1980	3.5E-08	0.8	4.2E-08	0.8	4.2E-08	0.1	1.2E-07	1.5
1981	3.9E-08	0.9	4.7E-08	0.9	4.7E-08	0.1	1.3E-07	1.7
1982	4.0E-08	0.9	4.9E-08	0.9	4.9E-08	0.1	1.2E-07	1.6
1983	4.5E-08	1.1	5.6E-08	1.1	5.6E-08	0.2	1.4E-07	1.8
1984	5.6E-08	1.3	7.2E-08	1.4	7.2E-08	0.2	1.8E-07	2.4
1985	5.2E-08	1.2	6.5E-08	1.2	6.5E-08	0.2	1.6E-07	2.1
1986	4.4E-08	1.0	5.2E-08	1.0	5.2E-08	0.2	1.3E-07	1.7
1987	4.8E-08	1.1	5.7E-08	1.1	5.7E-08	0.2	1.5E-07	1.9
1988	3.2E-08	0.8	4.0E-08	0.8	4.0E-08	0.1	1.0E-07	1.3
1989	1.9E-08	0.4	2.5E-08	0.5	2.5E-08	0.1	2.5E-08	0.3
1990	1.5E-08	0.4	2.0E-08	0.4	2.0E-08	0.1	2.0E-08	0.3
1991	1.2E-08	0.3	1.5E-08	0.3	1.5E-08	0.0	1.5E-08	0.2
1992	8.9E-09	0.2	1.2E-08	0.2	1.2E-08	0.0	1.2E-08	0.2

Total	4.2E-06	100.0	5.2E-06	100.0	3.4E-05	100.0	7.8E-06	100.0

Table 6.C Effective Dose By Year For Near Water Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	2.6E-07	0.1	2.6E-07	0.1	--	--	--	--
1955	1.9E-05	6.1	2.5E-05	6.0	6.0E-05	3.5	--	--
1956	1.5E-04	48.4	2.1E-04	50.7	1.2E-03	72.0	--	--
1957	3.3E-05	10.8	4.7E-05	11.1	1.5E-04	8.8	--	--
1958	7.3E-06	2.4	9.3E-06	2.2	1.9E-05	1.1	--	--
1959	2.1E-05	6.8	2.9E-05	6.9	8.8E-05	5.1	--	--
1960	4.9E-06	1.6	5.9E-06	1.4	1.2E-05	0.7	--	--
1961	1.3E-05	4.1	1.7E-05	4.0	6.3E-05	3.7	--	--
1962	5.0E-06	1.6	6.0E-06	1.4	8.2E-06	0.5	--	--
1963	4.9E-06	1.6	5.8E-06	1.4	7.4E-06	0.4	--	--
1964	5.0E-06	1.6	5.9E-06	1.4	7.4E-06	0.4	1.3E-05	15.0
1965	3.4E-06	1.1	4.0E-06	1.0	5.0E-06	0.3	7.9E-06	9.0
1966	3.3E-06	1.1	3.8E-06	0.9	4.8E-06	0.3	5.3E-06	6.1
1967	3.5E-06	1.1	4.0E-06	1.0	4.8E-06	0.3	5.6E-06	6.3
1968	3.0E-06	1.0	3.6E-06	0.9	4.5E-06	0.3	5.2E-06	6.0
1969	3.9E-06	1.3	4.9E-06	1.2	5.7E-06	0.3	7.4E-06	8.5
1970	1.9E-06	0.6	2.4E-06	0.6	3.0E-06	0.2	4.5E-06	5.1
1971	2.1E-06	0.7	2.6E-06	0.6	3.2E-06	0.2	3.4E-06	3.9
1972	2.5E-06	0.8	3.0E-06	0.7	3.6E-06	0.2	3.7E-06	4.3
1973	2.3E-06	0.7	2.7E-06	0.6	2.7E-06	0.2	3.3E-06	3.7
1974	1.8E-06	0.6	2.2E-06	0.5	2.2E-06	0.1	2.8E-06	3.2
1975	1.2E-06	0.4	1.4E-06	0.3	1.4E-06	0.1	1.8E-06	2.1
1976	1.1E-06	0.4	1.4E-06	0.3	1.4E-06	0.1	1.6E-06	1.8
1977	1.1E-06	0.4	1.4E-06	0.3	1.4E-06	0.1	1.7E-06	1.9
1978	1.2E-06	0.4	1.5E-06	0.4	1.5E-06	0.1	1.8E-06	2.1
1979	9.9E-07	0.3	1.2E-06	0.3	1.2E-06	0.1	1.5E-06	1.7
1980	1.1E-06	0.3	1.3E-06	0.3	1.3E-06	0.1	1.6E-06	1.8
1981	1.1E-06	0.4	1.4E-06	0.3	1.4E-06	0.1	1.7E-06	1.9
1982	1.2E-06	0.4	1.5E-06	0.3	1.5E-06	0.1	1.5E-06	1.7
1983	1.3E-06	0.4	1.7E-06	0.4	1.7E-06	0.1	1.7E-06	1.9
1984	1.6E-06	0.5	2.1E-06	0.5	2.1E-06	0.1	2.1E-06	2.4
1985	1.6E-06	0.5	2.0E-06	0.5	2.0E-06	0.1	2.0E-06	2.3
1986	1.2E-06	0.4	1.5E-06	0.4	1.5E-06	0.1	1.5E-06	1.7
1987	1.3E-06	0.4	1.6E-06	0.4	1.6E-06	0.1	1.6E-06	1.8
1988	9.0E-07	0.3	1.1E-06	0.3	1.1E-06	0.1	1.1E-06	1.3
1989	6.0E-07	0.2	8.0E-07	0.2	8.0E-07	0.0	8.0E-07	0.9
1990	4.5E-07	0.1	6.0E-07	0.1	6.0E-07	0.0	6.0E-07	0.7
1991	3.6E-07	0.1	4.8E-07	0.1	4.8E-07	0.0	4.8E-07	0.5
1992	2.7E-07	0.1	3.5E-07	0.1	3.5E-07	0.0	3.5E-07	0.4
Total	3.1E-04	100.0	4.2E-04	100.0	1.7E-03	100.0	8.8E-05	100.0

Table 6.C Effective Dose By Year For Near Water Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	8.8E-07	0.0	8.8E-07	0.0	--	--	--	--
1955	5.1E-06	0.3	5.1E-06	0.3	2.4E-05	1.7	--	--
1956	2.2E-05	1.3	2.2E-05	1.3	1.5E-05	1.0	--	--
1957	8.1E-06	0.5	8.1E-06	0.5	8.0E-06	0.6	--	--
1958	2.8E-05	1.5	2.8E-05	1.5	1.1E-05	0.8	--	--
1959	1.6E-05	0.9	1.6E-05	0.9	7.7E-06	0.5	--	--
1960	5.9E-05	3.3	5.9E-05	3.3	5.1E-05	3.5	--	--
1961	4.7E-05	2.6	4.7E-05	2.6	3.2E-05	2.2	--	--
1962	9.4E-05	5.3	9.4E-05	5.3	6.3E-05	4.4	--	--
1963	7.5E-05	4.2	7.5E-05	4.2	5.0E-05	3.5	--	--
1964	1.1E-04	6.1	1.1E-04	6.1	6.8E-05	4.8	1.5E-04	8.8
1965	1.7E-04	9.3	1.7E-04	9.3	1.4E-04	9.8	3.3E-04	20.0
1966	5.0E-04	28.3	5.0E-04	28.3	5.1E-04	35.3	7.0E-04	42.1
1967	2.4E-04	13.3	2.4E-04	13.3	1.7E-04	11.6	1.8E-04	10.6
1968	1.1E-04	6.0	1.1E-04	6.0	6.3E-05	4.4	6.6E-05	3.9
1969	5.8E-05	3.2	5.8E-05	3.2	3.1E-05	2.2	3.7E-05	2.2
1970	7.9E-05	4.4	7.9E-05	4.4	4.5E-05	3.1	5.2E-05	3.1
1971	3.8E-05	2.1	3.8E-05	2.1	2.7E-05	1.9	3.1E-05	1.8
1972	1.6E-05	0.9	1.6E-05	0.9	1.3E-05	0.9	1.4E-05	0.8
1973	1.7E-05	0.9	1.7E-05	0.9	1.7E-05	1.2	1.6E-05	1.0
1974	2.2E-05	1.2	2.2E-05	1.2	2.2E-05	1.5	2.1E-05	1.2
1975	3.5E-06	0.2	3.5E-06	0.2	3.5E-06	0.2	3.0E-06	0.2
1976	7.6E-06	0.4	7.6E-06	0.4	7.6E-06	0.5	7.3E-06	0.4
1977	4.6E-06	0.3	4.6E-06	0.3	4.6E-06	0.3	4.2E-06	0.3
1978	1.7E-06	0.1	1.7E-06	0.1	1.7E-06	0.1	1.6E-06	0.1
1979	1.5E-06	0.1	1.5E-06	0.1	1.5E-06	0.1	1.4E-06	0.1
1980	9.4E-06	0.5	9.4E-06	0.5	9.4E-06	0.7	9.4E-06	0.6
1981	4.4E-06	0.2	4.4E-06	0.2	4.4E-06	0.3	4.0E-06	0.2
1982	3.1E-06	0.2	3.1E-06	0.2	3.1E-06	0.2	3.1E-06	0.2
1983	2.6E-06	0.1	2.6E-06	0.1	2.6E-06	0.2	2.6E-06	0.2
1984	8.4E-06	0.5	8.4E-06	0.5	8.4E-06	0.6	8.4E-06	0.5
1985	7.7E-06	0.4	7.7E-06	0.4	7.7E-06	0.5	7.7E-06	0.5
1986	7.2E-06	0.4	7.2E-06	0.4	7.2E-06	0.5	7.2E-06	0.4
1987	3.2E-06	0.2	3.2E-06	0.2	3.2E-06	0.2	3.2E-06	0.2
1988	2.9E-06	0.2	2.9E-06	0.2	2.9E-06	0.2	2.9E-06	0.2
1989	2.8E-06	0.2	2.8E-06	0.2	2.8E-06	0.2	2.8E-06	0.2
1990	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1
1991	9.6E-07	0.1	9.6E-07	0.1	9.6E-07	0.1	9.6E-07	0.1
1992	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1
Total	1.8E-03	100.0	1.8E-03	100.0	1.4E-03	100.0	1.7E-03	100.0

Table 6.C Effective Dose By Year For Near Water Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	1.1E-06	0.1	1.1E-06	0.1	--	--	--	--
1955	2.4E-05	1.1	3.1E-05	1.4	8.4E-05	2.7	--	--
1956	1.7E-04	8.2	2.4E-04	10.7	1.2E-03	39.6	--	--
1957	4.1E-05	2.0	5.5E-05	2.5	1.6E-04	5.0	--	--
1958	3.5E-05	1.7	3.7E-05	1.7	3.0E-05	0.9	--	--
1959	3.7E-05	1.8	4.5E-05	2.0	9.5E-05	3.0	--	--
1960	6.4E-05	3.1	6.5E-05	3.0	6.3E-05	2.0	--	--
1961	6.0E-05	2.8	6.4E-05	2.9	9.5E-05	3.0	--	--
1962	9.9E-05	4.7	1.0E-04	4.5	7.1E-05	2.3	--	--
1963	8.0E-05	3.8	8.1E-05	3.7	5.7E-05	1.8	--	--
1964	1.1E-04	5.4	1.1E-04	5.2	7.6E-05	2.4	1.6E-04	9.1
1965	1.7E-04	8.1	1.7E-04	7.7	1.5E-04	4.6	3.4E-04	19.5
1966	5.1E-04	24.3	5.1E-04	23.0	5.1E-04	16.3	7.1E-04	40.3
1967	2.4E-04	11.5	2.4E-04	11.0	1.7E-04	5.5	1.8E-04	10.4
1968	1.1E-04	5.2	1.1E-04	5.0	6.7E-05	2.1	7.1E-05	4.0
1969	6.1E-05	2.9	6.3E-05	2.8	3.7E-05	1.2	4.4E-05	2.5
1970	8.0E-05	3.8	8.1E-05	3.7	4.8E-05	1.5	5.7E-05	3.2
1971	4.0E-05	1.9	4.1E-05	1.8	3.1E-05	1.0	3.4E-05	1.9
1972	1.8E-05	0.9	1.9E-05	0.9	1.7E-05	0.5	1.8E-05	1.0
1973	1.9E-05	0.9	1.9E-05	0.9	1.9E-05	0.6	1.9E-05	1.1
1974	2.4E-05	1.1	2.4E-05	1.1	2.4E-05	0.8	2.4E-05	1.3
1975	4.7E-06	0.2	4.9E-06	0.2	4.9E-06	0.2	4.8E-06	0.3
1976	8.7E-06	0.4	8.9E-06	0.4	8.9E-06	0.3	8.9E-06	0.5
1977	5.8E-06	0.3	6.0E-06	0.3	6.0E-06	0.2	5.9E-06	0.3
1978	2.9E-06	0.1	3.2E-06	0.1	3.2E-06	0.1	3.4E-06	0.2
1979	2.5E-06	0.1	2.7E-06	0.1	2.7E-06	0.1	2.9E-06	0.2
1980	1.0E-05	0.5	1.1E-05	0.5	1.1E-05	0.3	1.1E-05	0.6
1981	5.5E-06	0.3	5.8E-06	0.3	5.8E-06	0.2	5.7E-06	0.3
1982	4.3E-06	0.2	4.6E-06	0.2	4.6E-06	0.1	4.6E-06	0.3
1983	3.9E-06	0.2	4.3E-06	0.2	4.3E-06	0.1	4.3E-06	0.2
1984	1.0E-05	0.5	1.1E-05	0.5	1.1E-05	0.3	1.1E-05	0.6
1985	9.3E-06	0.4	9.7E-06	0.4	9.7E-06	0.3	9.7E-06	0.6
1986	8.4E-06	0.4	8.7E-06	0.4	8.7E-06	0.3	8.7E-06	0.5
1987	4.5E-06	0.2	4.8E-06	0.2	4.8E-06	0.2	4.8E-06	0.3
1988	3.8E-06	0.2	4.0E-06	0.2	4.0E-06	0.1	4.0E-06	0.2
1989	3.4E-06	0.2	3.6E-06	0.2	3.6E-06	0.1	3.6E-06	0.2
1990	1.7E-06	0.1	1.8E-06	0.1	1.8E-06	0.1	1.8E-06	0.1
1991	1.3E-06	0.1	1.4E-06	0.1	1.4E-06	0.0	1.4E-06	0.1
1992	1.5E-06	0.1	1.6E-06	0.1	1.6E-06	0.0	1.6E-06	0.1
Total	2.1E-03	100.0	2.2E-03	100.0	3.1E-03	100.0	1.8E-03	100.0

Table 6.C Total Cancer Incident Risk By Year For Near Water Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.3E-08	0.1	1.3E-08	0.1	--	--	--	--
1955	3.5E-07	3.9	4.7E-07	4.0	4.9E-06	2.9	--	--
1956	3.4E-06	38.5	4.9E-06	41.4	1.1E-04	63.6	--	--
1957	8.4E-07	9.4	1.2E-06	9.8	2.3E-05	13.5	--	--
1958	2.9E-07	3.3	3.7E-07	3.1	3.4E-06	2.0	--	--
1959	5.8E-07	6.5	7.8E-07	6.6	1.4E-05	8.0	--	--
1960	2.1E-07	2.4	2.5E-07	2.1	1.3E-06	0.8	--	--
1961	3.8E-07	4.3	4.9E-07	4.2	4.0E-06	2.3	--	--
1962	2.2E-07	2.5	2.6E-07	2.2	1.3E-06	0.8	--	--
1963	2.3E-07	2.6	2.6E-07	2.2	1.2E-06	0.7	--	--
1964	2.4E-07	2.6	2.8E-07	2.4	1.3E-06	0.8	1.6E-06	11.9
1965	1.6E-07	1.8	1.9E-07	1.6	8.6E-07	0.5	1.1E-06	8.4
1966	1.5E-07	1.7	1.8E-07	1.5	8.2E-07	0.5	1.1E-06	8.2
1967	1.6E-07	1.8	1.9E-07	1.6	9.9E-07	0.6	1.1E-06	8.4
1968	1.4E-07	1.6	1.7E-07	1.4	1.0E-06	0.6	1.2E-06	8.6
1969	1.2E-07	1.3	1.5E-07	1.3	8.6E-07	0.5	7.0E-07	5.2
1970	8.6E-08	1.0	1.1E-07	0.9	3.5E-07	0.2	5.2E-07	3.9
1971	9.9E-08	1.1	1.2E-07	1.0	3.9E-07	0.2	5.8E-07	4.3
1972	1.2E-07	1.3	1.4E-07	1.2	4.7E-07	0.3	6.8E-07	5.0
1973	1.1E-07	1.2	1.3E-07	1.1	3.5E-07	0.2	5.8E-07	4.3
1974	8.7E-08	1.0	1.1E-07	0.9	2.9E-07	0.2	4.9E-07	3.7
1975	5.6E-08	0.6	6.9E-08	0.6	1.9E-07	0.1	3.2E-07	2.4
1976	5.4E-08	0.6	6.5E-08	0.5	1.8E-07	0.1	3.4E-07	2.6
1977	5.5E-08	0.6	6.8E-08	0.6	1.8E-07	0.1	3.7E-07	2.8
1978	5.6E-08	0.6	7.1E-08	0.6	2.2E-07	0.1	5.2E-07	3.9
1979	4.8E-08	0.5	5.9E-08	0.5	1.6E-07	0.1	1.9E-07	1.4
1980	5.2E-08	0.6	6.3E-08	0.5	6.3E-08	0.0	2.1E-07	1.5
1981	5.4E-08	0.6	6.6E-08	0.6	6.6E-08	0.0	2.2E-07	1.6
1982	5.7E-08	0.6	7.0E-08	0.6	7.0E-08	0.0	1.9E-07	1.4
1983	6.3E-08	0.7	8.1E-08	0.7	8.1E-08	0.0	2.2E-07	1.6
1984	7.9E-08	0.9	1.0E-07	0.9	1.0E-07	0.1	2.8E-07	2.1
1985	7.7E-08	0.9	9.7E-08	0.8	9.7E-08	0.1	2.6E-07	2.0
1986	6.0E-08	0.7	7.3E-08	0.6	7.3E-08	0.0	2.0E-07	1.5
1987	6.2E-08	0.7	7.5E-08	0.6	7.5E-08	0.0	2.0E-07	1.5
1988	4.3E-08	0.5	5.5E-08	0.5	5.5E-08	0.0	1.5E-07	1.1
1989	2.9E-08	0.3	3.8E-08	0.3	3.8E-08	0.0	3.8E-08	0.3
1990	2.2E-08	0.2	2.9E-08	0.2	2.9E-08	0.0	2.9E-08	0.2
1991	1.8E-08	0.2	2.3E-08	0.2	2.3E-08	0.0	2.3E-08	0.2
1992	1.3E-08	0.1	1.7E-08	0.1	1.7E-08	0.0	1.7E-08	0.1
Total	8.9E-06	100.0	1.2E-05	100.0	1.7E-04	100.0	1.3E-05	100.0

Table 6.C Total Cancer Incident Risk By Year For Near Water Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	3.7E-08	0.0	3.7E-08	0.0	--	--	--	--
1955	1.2E-07	0.2	1.2E-07	0.2	3.4E-07	0.2	--	--
1956	4.4E-07	0.6	4.4E-07	0.6	1.2E-06	0.6	--	--
1957	3.1E-07	0.4	3.1E-07	0.4	1.3E-06	0.6	--	--
1958	1.3E-06	1.6	1.3E-06	1.6	2.2E-06	1.0	--	--
1959	6.4E-07	0.8	6.4E-07	0.8	1.3E-06	0.6	--	--
1960	2.4E-06	3.2	2.4E-06	3.2	6.9E-06	3.2	--	--
1961	2.0E-06	2.6	2.0E-06	2.6	4.7E-06	2.2	--	--
1962	4.1E-06	5.4	4.1E-06	5.4	1.0E-05	4.7	--	--
1963	3.3E-06	4.3	3.3E-06	4.3	7.9E-06	3.7	--	--
1964	4.9E-06	6.5	4.9E-06	6.5	1.2E-05	5.5	1.4E-05	4.3
1965	7.6E-06	10.0	7.6E-06	10.0	2.5E-05	11.6	4.6E-05	14.0
1966	2.4E-05	31.3	2.4E-05	31.3	9.0E-05	42.2	1.9E-04	57.1
1967	1.0E-05	13.2	1.0E-05	13.2	2.2E-05	10.4	3.8E-05	11.6
1968	4.3E-06	5.7	4.3E-06	5.7	9.4E-06	4.4	1.3E-05	4.0
1969	1.9E-06	2.5	1.9E-06	2.5	3.8E-06	1.8	4.1E-06	1.3
1970	2.6E-06	3.5	2.6E-06	3.5	3.8E-06	1.8	6.0E-06	1.8
1971	1.3E-06	1.7	1.3E-06	1.7	2.4E-06	1.1	4.1E-06	1.3
1972	5.8E-07	0.8	5.8E-07	0.8	1.2E-06	0.6	2.0E-06	0.6
1973	6.2E-07	0.8	6.2E-07	0.8	1.7E-06	0.8	2.2E-06	0.7
1974	8.4E-07	1.1	8.4E-07	1.1	2.4E-06	1.1	3.0E-06	0.9
1975	1.4E-07	0.2	1.4E-07	0.2	3.8E-07	0.2	4.0E-07	0.1
1976	3.0E-07	0.4	3.0E-07	0.4	8.6E-07	0.4	1.1E-06	0.3
1977	1.9E-07	0.2	1.9E-07	0.2	5.2E-07	0.2	6.0E-07	0.2
1978	6.5E-08	0.1	6.5E-08	0.1	1.8E-07	0.1	1.8E-07	0.1
1979	5.6E-08	0.1	5.6E-08	0.1	1.5E-07	0.1	1.1E-07	0.0
1980	3.4E-07	0.5	3.4E-07	0.5	3.4E-07	0.2	8.6E-07	0.3
1981	1.6E-07	0.2	1.6E-07	0.2	1.6E-07	0.1	3.5E-07	0.1
1982	1.2E-07	0.2	1.2E-07	0.2	1.2E-07	0.1	3.5E-07	0.1
1983	1.1E-07	0.1	1.1E-07	0.1	1.1E-07	0.1	3.1E-07	0.1
1984	3.8E-07	0.5	3.8E-07	0.5	3.8E-07	0.2	1.1E-06	0.3
1985	3.3E-07	0.4	3.3E-07	0.4	3.3E-07	0.2	9.3E-07	0.3
1986	2.5E-07	0.3	2.5E-07	0.3	2.5E-07	0.1	7.0E-07	0.2
1987	1.3E-07	0.2	1.3E-07	0.2	1.3E-07	0.1	3.4E-07	0.1
1988	1.2E-07	0.2	1.2E-07	0.2	1.2E-07	0.1	3.1E-07	0.1
1989	9.0E-08	0.1	9.0E-08	0.1	9.0E-08	0.0	9.0E-08	0.0
1990	2.6E-08	0.0	2.6E-08	0.0	2.6E-08	0.0	2.6E-08	0.0
1991	1.5E-08	0.0	1.5E-08	0.0	1.5E-08	0.0	1.5E-08	0.0
1992	3.3E-08	0.0	3.3E-08	0.0	3.3E-08	0.0	3.3E-08	0.0
Total	7.6E-05	100.0	7.6E-05	100.0	2.1E-04	100.0	3.3E-04	100.0

Table 6.C Total Cancer Incident Risk By Year For Near Water Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	4.9E-08	0.1	4.9E-08	0.1	--	--	--	--
1955	4.7E-07	0.6	5.9E-07	0.7	5.2E-06	1.4	--	--
1956	3.9E-06	4.6	5.3E-06	6.1	1.1E-04	28.5	--	--
1957	1.2E-06	1.4	1.5E-06	1.7	2.4E-05	6.3	--	--
1958	1.5E-06	1.8	1.6E-06	1.8	5.6E-06	1.5	--	--
1959	1.2E-06	1.4	1.4E-06	1.6	1.5E-05	3.9	--	--
1960	2.6E-06	3.1	2.6E-06	3.0	8.2E-06	2.1	--	--
1961	2.4E-06	2.8	2.5E-06	2.8	8.7E-06	2.3	--	--
1962	4.3E-06	5.1	4.3E-06	4.9	1.1E-05	3.0	--	--
1963	3.5E-06	4.1	3.5E-06	4.0	9.2E-06	2.4	--	--
1964	5.1E-06	6.1	5.2E-06	5.9	1.3E-05	3.4	1.6E-05	4.6
1965	7.7E-06	9.1	7.8E-06	8.8	2.6E-05	6.7	4.7E-05	13.8
1966	2.4E-05	28.2	2.4E-05	27.3	9.1E-05	23.7	1.9E-04	55.2
1967	1.0E-05	12.0	1.0E-05	11.7	2.3E-05	6.0	3.9E-05	11.5
1968	4.5E-06	5.3	4.5E-06	5.1	1.0E-05	2.7	1.4E-05	4.2
1969	2.0E-06	2.4	2.1E-06	2.3	4.7E-06	1.2	4.8E-06	1.4
1970	2.7E-06	3.2	2.8E-06	3.1	4.2E-06	1.1	6.5E-06	1.9
1971	1.4E-06	1.6	1.4E-06	1.6	2.8E-06	0.7	4.7E-06	1.4
1972	7.0E-07	0.8	7.2E-07	0.8	1.6E-06	0.4	2.6E-06	0.8
1973	7.3E-07	0.9	7.5E-07	0.9	2.1E-06	0.5	2.8E-06	0.8
1974	9.3E-07	1.1	9.5E-07	1.1	2.7E-06	0.7	3.5E-06	1.0
1975	1.9E-07	0.2	2.1E-07	0.2	5.6E-07	0.1	7.2E-07	0.2
1976	3.6E-07	0.4	3.7E-07	0.4	1.0E-06	0.3	1.4E-06	0.4
1977	2.4E-07	0.3	2.6E-07	0.3	7.1E-07	0.2	9.7E-07	0.3
1978	1.2E-07	0.1	1.4E-07	0.2	3.9E-07	0.1	7.0E-07	0.2
1979	1.0E-07	0.1	1.1E-07	0.1	3.1E-07	0.1	3.0E-07	0.1
1980	4.0E-07	0.5	4.1E-07	0.5	4.1E-07	0.1	1.1E-06	0.3
1981	2.1E-07	0.3	2.2E-07	0.3	2.2E-07	0.1	5.7E-07	0.2
1982	1.8E-07	0.2	1.9E-07	0.2	1.9E-07	0.1	5.4E-07	0.2
1983	1.7E-07	0.2	1.9E-07	0.2	1.9E-07	0.0	5.3E-07	0.2
1984	4.5E-07	0.5	4.8E-07	0.5	4.8E-07	0.1	1.3E-06	0.4
1985	4.0E-07	0.5	4.2E-07	0.5	4.2E-07	0.1	1.2E-06	0.3
1986	3.1E-07	0.4	3.2E-07	0.4	3.2E-07	0.1	9.0E-07	0.3
1987	1.9E-07	0.2	2.0E-07	0.2	2.0E-07	0.1	5.4E-07	0.2
1988	1.6E-07	0.2	1.7E-07	0.2	1.7E-07	0.0	4.6E-07	0.1
1989	1.2E-07	0.1	1.3E-07	0.1	1.3E-07	0.0	1.3E-07	0.0
1990	4.8E-08	0.1	5.5E-08	0.1	5.5E-08	0.0	5.5E-08	0.0
1991	3.3E-08	0.0	3.9E-08	0.0	3.9E-08	0.0	3.9E-08	0.0
1992	4.6E-08	0.1	5.0E-08	0.1	5.0E-08	0.0	5.0E-08	0.0
Total	8.5E-05	100.0	8.8E-05	100.0	3.8E-04	100.0	3.4E-04	100.0

Table 6.C Total Cancer Fatality Risk By Year For Near Water Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	9.0E-09	0.3	9.0E-09	0.2	--	--	--	--
1955	1.9E-07	5.4	2.5E-07	5.7	1.0E-06	3.5	--	--
1956	5.0E-07	14.0	6.6E-07	15.2	1.2E-05	41.7	--	--
1957	2.0E-07	5.6	2.5E-07	5.8	3.0E-06	10.7	--	--
1958	1.8E-07	5.1	2.2E-07	5.0	1.3E-06	4.7	--	--
1959	1.9E-07	5.4	2.3E-07	5.3	2.1E-06	7.5	--	--
1960	1.4E-07	3.9	1.6E-07	3.7	6.7E-07	2.4	--	--
1961	1.6E-07	4.4	1.9E-07	4.2	9.3E-07	3.3	--	--
1962	1.5E-07	4.2	1.7E-07	4.0	7.1E-07	2.5	--	--
1963	1.6E-07	4.4	1.8E-07	4.2	7.4E-07	2.6	--	--
1964	1.7E-07	4.7	2.0E-07	4.6	8.3E-07	2.9	1.0E-06	12.0
1965	1.1E-07	3.1	1.3E-07	3.0	5.4E-07	1.9	6.9E-07	8.2
1966	1.1E-07	3.0	1.2E-07	2.8	5.1E-07	1.8	6.5E-07	7.7
1967	1.1E-07	3.2	1.3E-07	3.0	6.0E-07	2.1	6.7E-07	7.9
1968	9.8E-08	2.7	1.2E-07	2.7	6.1E-07	2.1	6.7E-07	8.0
1969	8.6E-08	2.4	1.1E-07	2.4	5.2E-07	1.8	4.2E-07	5.0
1970	5.9E-08	1.7	7.2E-08	1.6	2.2E-07	0.8	3.1E-07	3.6
1971	6.9E-08	1.9	8.3E-08	1.9	2.6E-07	0.9	3.6E-07	4.2
1972	8.5E-08	2.4	1.0E-07	2.4	3.2E-07	1.1	4.4E-07	5.2
1973	7.8E-08	2.2	9.2E-08	2.1	2.4E-07	0.8	3.8E-07	4.5
1974	6.2E-08	1.7	7.6E-08	1.7	1.9E-07	0.7	3.2E-07	3.8
1975	4.0E-08	1.1	4.9E-08	1.1	1.3E-07	0.4	2.1E-07	2.5
1976	3.9E-08	1.1	4.6E-08	1.1	1.2E-07	0.4	2.3E-07	2.7
1977	3.9E-08	1.1	4.8E-08	1.1	1.2E-07	0.4	2.4E-07	2.9
1978	3.9E-08	1.1	5.0E-08	1.1	1.4E-07	0.5	3.2E-07	3.8
1979	3.4E-08	1.0	4.2E-08	1.0	1.1E-07	0.4	1.3E-07	1.6
1980	3.7E-08	1.0	4.5E-08	1.0	4.5E-08	0.2	1.4E-07	1.6
1981	3.8E-08	1.1	4.7E-08	1.1	4.7E-08	0.2	1.5E-07	1.7
1982	4.1E-08	1.1	5.0E-08	1.2	5.0E-08	0.2	1.3E-07	1.5
1983	4.5E-08	1.3	5.8E-08	1.3	5.8E-08	0.2	1.5E-07	1.7
1984	5.7E-08	1.6	7.4E-08	1.7	7.4E-08	0.3	1.9E-07	2.2
1985	5.5E-08	1.5	7.0E-08	1.6	7.0E-08	0.2	1.8E-07	2.1
1986	4.3E-08	1.2	5.2E-08	1.2	5.2E-08	0.2	1.3E-07	1.6
1987	4.5E-08	1.3	5.4E-08	1.2	5.4E-08	0.2	1.4E-07	1.6
1988	3.1E-08	0.9	4.0E-08	0.9	4.0E-08	0.1	1.0E-07	1.2
1989	2.1E-08	0.6	2.8E-08	0.6	2.8E-08	0.1	2.8E-08	0.3
1990	1.6E-08	0.4	2.1E-08	0.5	2.1E-08	0.1	2.1E-08	0.2
1991	1.3E-08	0.4	1.7E-08	0.4	1.7E-08	0.1	1.7E-08	0.2
1992	9.2E-09	0.3	1.2E-08	0.3	1.2E-08	0.0	1.2E-08	0.1
Total	3.6E-06	100.0	4.4E-06	100.0	2.8E-05	100.0	8.4E-06	100.0

Table 6.C Total Cancer Fatality Risk By Year For Near Water Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	2.7E-08	0.0	2.7E-08	0.0	--	--	--	--
1955	9.2E-08	0.2	9.2E-08	0.2	2.3E-07	0.2	--	--
1956	3.4E-07	0.6	3.4E-07	0.6	7.9E-07	0.6	--	--
1957	2.0E-07	0.3	2.0E-07	0.3	4.4E-07	0.3	--	--
1958	9.0E-07	1.6	9.0E-07	1.6	1.4E-06	1.0	--	--
1959	4.7E-07	0.8	4.7E-07	0.8	8.7E-07	0.6	--	--
1960	1.8E-06	3.1	1.8E-06	3.1	4.5E-06	3.3	--	--
1961	1.4E-06	2.5	1.4E-06	2.5	3.0E-06	2.2	--	--
1962	2.9E-06	5.1	2.9E-06	5.1	6.4E-06	4.6	--	--
1963	2.4E-06	4.2	2.4E-06	4.2	5.1E-06	3.7	--	--
1964	3.6E-06	6.2	3.6E-06	6.2	7.6E-06	5.5	9.0E-06	4.2
1965	5.7E-06	10.0	5.7E-06	10.0	1.6E-05	11.5	3.0E-05	14.0
1966	1.8E-05	32.2	1.8E-05	32.2	5.8E-05	41.8	1.2E-04	57.1
1967	7.8E-06	13.6	7.8E-06	13.6	1.5E-05	10.6	2.5E-05	11.7
1968	3.2E-06	5.5	3.2E-06	5.5	6.1E-06	4.4	8.5E-06	4.0
1969	1.4E-06	2.5	1.4E-06	2.5	2.5E-06	1.8	2.7E-06	1.3
1970	2.0E-06	3.4	2.0E-06	3.4	2.6E-06	1.9	3.9E-06	1.8
1971	9.8E-07	1.7	9.8E-07	1.7	1.6E-06	1.2	2.7E-06	1.3
1972	4.3E-07	0.8	4.3E-07	0.8	8.1E-07	0.6	1.3E-06	0.6
1973	4.6E-07	0.8	4.6E-07	0.8	1.2E-06	0.9	1.5E-06	0.7
1974	6.2E-07	1.1	6.2E-07	1.1	1.6E-06	1.2	1.9E-06	0.9
1975	1.0E-07	0.2	1.0E-07	0.2	2.7E-07	0.2	2.7E-07	0.1
1976	2.3E-07	0.4	2.3E-07	0.4	5.9E-07	0.4	7.0E-07	0.3
1977	1.4E-07	0.2	1.4E-07	0.2	3.6E-07	0.3	4.0E-07	0.2
1978	5.0E-08	0.1	5.0E-08	0.1	1.3E-07	0.1	1.2E-07	0.1
1979	4.3E-08	0.1	4.3E-08	0.1	1.1E-07	0.1	7.6E-08	0.0
1980	2.6E-07	0.4	2.6E-07	0.4	2.6E-07	0.2	5.9E-07	0.3
1981	1.2E-07	0.2	1.2E-07	0.2	1.2E-07	0.1	2.4E-07	0.1
1982	9.2E-08	0.2	9.2E-08	0.2	9.2E-08	0.1	2.4E-07	0.1
1983	8.2E-08	0.1	8.2E-08	0.1	8.2E-08	0.1	2.1E-07	0.1
1984	2.8E-07	0.5	2.8E-07	0.5	2.8E-07	0.2	7.3E-07	0.3
1985	2.4E-07	0.4	2.4E-07	0.4	2.4E-07	0.2	6.4E-07	0.3
1986	1.9E-07	0.3	1.9E-07	0.3	1.9E-07	0.1	4.9E-07	0.2
1987	1.0E-07	0.2	1.0E-07	0.2	1.0E-07	0.1	2.5E-07	0.1
1988	8.7E-08	0.2	8.7E-08	0.2	8.7E-08	0.1	2.2E-07	0.1
1989	7.0E-08	0.1	7.0E-08	0.1	7.0E-08	0.1	7.0E-08	0.0
1990	2.2E-08	0.0	2.2E-08	0.0	2.2E-08	0.0	2.2E-08	0.0
1991	1.2E-08	0.0	1.2E-08	0.0	1.2E-08	0.0	1.2E-08	0.0
1992	2.8E-08	0.0	2.8E-08	0.0	2.8E-08	0.0	2.8E-08	0.0
Total	5.7E-05	100.0	5.7E-05	100.0	1.4E-04	100.0	2.1E-04	100.0

Table 6.C Total Cancer Fatality Risk By Year For Near Water Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	3.6E-08	0.1	3.6E-08	0.1	--	--	--	--
1955	2.9E-07	0.5	3.4E-07	0.6	1.2E-06	0.7	--	--
1956	8.4E-07	1.4	1.0E-06	1.6	1.3E-05	7.6	--	--
1957	4.0E-07	0.7	4.5E-07	0.7	3.5E-06	2.1	--	--
1958	1.1E-06	1.8	1.1E-06	1.8	2.7E-06	1.6	--	--
1959	6.6E-07	1.1	7.0E-07	1.1	3.0E-06	1.8	--	--
1960	1.9E-06	3.2	2.0E-06	3.2	5.2E-06	3.1	--	--
1961	1.6E-06	2.6	1.6E-06	2.6	4.0E-06	2.4	--	--
1962	3.1E-06	5.0	3.1E-06	5.0	7.1E-06	4.3	--	--
1963	2.5E-06	4.2	2.6E-06	4.2	5.8E-06	3.5	--	--
1964	3.7E-06	6.1	3.8E-06	6.1	8.4E-06	5.0	1.0E-05	4.5
1965	5.8E-06	9.6	5.9E-06	9.5	1.6E-05	9.9	3.1E-05	13.8
1966	1.9E-05	30.5	1.9E-05	30.1	5.8E-05	35.0	1.2E-04	55.3
1967	7.9E-06	13.0	7.9E-06	12.9	1.5E-05	9.2	2.6E-05	11.5
1968	3.3E-06	5.4	3.3E-06	5.3	6.7E-06	4.0	9.2E-06	4.1
1969	1.5E-06	2.5	1.5E-06	2.5	3.0E-06	1.8	3.1E-06	1.4
1970	2.0E-06	3.3	2.0E-06	3.3	2.9E-06	1.7	4.2E-06	1.9
1971	1.1E-06	1.7	1.1E-06	1.7	1.9E-06	1.1	3.1E-06	1.4
1972	5.2E-07	0.9	5.4E-07	0.9	1.1E-06	0.7	1.7E-06	0.8
1973	5.4E-07	0.9	5.5E-07	0.9	1.4E-06	0.9	1.9E-06	0.8
1974	6.8E-07	1.1	6.9E-07	1.1	1.8E-06	1.1	2.3E-06	1.0
1975	1.4E-07	0.2	1.5E-07	0.2	3.9E-07	0.2	4.8E-07	0.2
1976	2.6E-07	0.4	2.7E-07	0.4	7.1E-07	0.4	9.3E-07	0.4
1977	1.8E-07	0.3	1.9E-07	0.3	4.9E-07	0.3	6.4E-07	0.3
1978	9.0E-08	0.1	1.0E-07	0.2	2.7E-07	0.2	4.4E-07	0.2
1979	7.7E-08	0.1	8.5E-08	0.1	2.2E-07	0.1	2.1E-07	0.1
1980	2.9E-07	0.5	3.0E-07	0.5	3.0E-07	0.2	7.3E-07	0.3
1981	1.6E-07	0.3	1.7E-07	0.3	1.7E-07	0.1	3.9E-07	0.2
1982	1.3E-07	0.2	1.4E-07	0.2	1.4E-07	0.1	3.7E-07	0.2
1983	1.3E-07	0.2	1.4E-07	0.2	1.4E-07	0.1	3.6E-07	0.2
1984	3.3E-07	0.5	3.5E-07	0.6	3.5E-07	0.2	9.2E-07	0.4
1985	2.9E-07	0.5	3.1E-07	0.5	3.1E-07	0.2	8.1E-07	0.4
1986	2.3E-07	0.4	2.4E-07	0.4	2.4E-07	0.1	6.3E-07	0.3
1987	1.4E-07	0.2	1.5E-07	0.3	1.5E-07	0.1	3.9E-07	0.2
1988	1.2E-07	0.2	1.3E-07	0.2	1.3E-07	0.1	3.2E-07	0.1
1989	9.1E-08	0.2	9.8E-08	0.2	9.8E-08	0.1	9.8E-08	0.0
1990	3.7E-08	0.1	4.2E-08	0.1	4.2E-08	0.0	4.2E-08	0.0
1991	2.5E-08	0.0	2.9E-08	0.0	2.9E-08	0.0	2.9E-08	0.0
1992	3.7E-08	0.1	4.0E-08	0.1	4.0E-08	0.0	4.0E-08	0.0
Total	6.1E-05	100.0	6.2E-05	100.0	1.7E-04	100.0	2.2E-04	100.0

Table 6.C 39-Year Effective Dose By Year For Outdoor Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	5.3E-07	0.0	1.1E-06	0.0	--	--	--	--
1955	7.2E-05	4.6	1.1E-04	4.3	2.7E-04	3.2	--	--
1956	8.4E-04	53.3	1.3E-03	49.7	5.9E-03	71.5	--	--
1957	1.9E-04	12.2	2.9E-04	11.6	7.5E-04	9.0	--	--
1958	3.7E-05	2.4	6.5E-05	2.6	1.0E-04	1.3	--	--
1959	1.2E-04	7.4	1.9E-04	7.4	4.4E-04	5.3	--	--
1960	2.1E-05	1.3	4.3E-05	1.7	6.6E-05	0.8	--	--
1961	6.6E-05	4.2	1.1E-04	4.4	3.3E-04	4.0	--	--
1962	1.9E-05	1.2	4.1E-05	1.6	3.5E-05	0.4	--	--
1963	1.9E-05	1.2	4.1E-05	1.6	3.1E-05	0.4	--	--
1964	1.8E-05	1.1	3.7E-05	1.5	2.8E-05	0.3	4.6E-05	12.7
1965	1.3E-05	0.8	2.9E-05	1.2	2.0E-05	0.2	3.2E-05	8.8
1966	1.2E-05	0.8	2.8E-05	1.1	1.8E-05	0.2	2.0E-05	5.4
1967	1.5E-05	0.9	3.3E-05	1.3	2.4E-05	0.3	2.6E-05	7.3
1968	1.3E-05	0.8	2.6E-05	1.0	2.1E-05	0.3	2.4E-05	6.5
1969	1.6E-05	1.0	2.8E-05	1.1	2.7E-05	0.3	4.0E-05	11.1
1970	8.2E-06	0.5	1.6E-05	0.6	1.4E-05	0.2	2.2E-05	6.2
1971	7.7E-06	0.5	1.5E-05	0.6	1.2E-05	0.1	1.2E-05	3.4
1972	8.7E-06	0.6	1.8E-05	0.7	1.3E-05	0.2	1.3E-05	3.6
1973	7.6E-06	0.5	1.7E-05	0.7	1.7E-05	0.2	1.1E-05	2.9
1974	6.2E-06	0.4	1.2E-05	0.5	1.2E-05	0.1	9.1E-06	2.5
1975	3.9E-06	0.3	7.9E-06	0.3	7.9E-06	0.1	5.8E-06	1.6
1976	3.9E-06	0.2	8.5E-06	0.3	8.5E-06	0.1	5.6E-06	1.5
1977	4.2E-06	0.3	8.5E-06	0.3	8.5E-06	0.1	6.2E-06	1.7
1978	4.8E-06	0.3	8.9E-06	0.4	8.9E-06	0.1	7.4E-06	2.0
1979	3.6E-06	0.2	7.1E-06	0.3	7.1E-06	0.1	5.3E-06	1.5
1980	3.9E-06	0.2	8.0E-06	0.3	8.0E-06	0.1	5.6E-06	1.6
1981	3.9E-06	0.2	7.8E-06	0.3	7.8E-06	0.1	5.8E-06	1.6
1982	4.3E-06	0.3	8.1E-06	0.3	8.1E-06	0.1	8.1E-06	2.2
1983	4.9E-06	0.3	8.1E-06	0.3	8.1E-06	0.1	8.1E-06	2.2
1984	6.0E-06	0.4	9.6E-06	0.4	9.6E-06	0.1	9.6E-06	2.7
1985	6.0E-06	0.4	1.0E-05	0.4	1.0E-05	0.1	1.0E-05	2.8
1986	3.9E-06	0.2	7.3E-06	0.3	7.3E-06	0.1	7.3E-06	2.0
1987	3.9E-06	0.2	8.0E-06	0.3	8.0E-06	0.1	8.0E-06	2.2
1988	2.8E-06	0.2	4.8E-06	0.2	4.8E-06	0.1	4.8E-06	1.3
1989	1.9E-06	0.1	2.8E-06	0.1	2.8E-06	0.0	2.8E-06	0.8
1990	1.8E-06	0.1	2.6E-06	0.1	2.6E-06	0.0	2.6E-06	0.7
1991	1.5E-06	0.1	2.2E-06	0.1	2.2E-06	0.0	2.2E-06	0.6
1992	1.1E-06	0.1	1.7E-06	0.1	1.7E-06	0.0	1.7E-06	0.5
Total	1.6E-03	100.0	2.5E-03	100.0	8.3E-03	100.0	3.6E-04	100.0

Table 6.C 39-Year Effective Dose (Sv) By Year For Outdoor Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	7.4E-07	0.1	8.4E-07	0.0	--	--	--	--
1955	4.4E-06	0.3	4.9E-06	0.3	2.3E-05	2.0	--	--
1956	2.2E-05	1.5	2.2E-05	1.3	1.4E-05	1.2	--	--
1957	7.1E-06	0.5	7.8E-06	0.5	6.9E-06	0.6	--	--
1958	2.5E-05	1.7	2.7E-05	1.6	8.4E-06	0.7	--	--
1959	1.3E-05	0.9	1.5E-05	0.9	5.1E-06	0.4	--	--
1960	3.0E-05	2.0	5.1E-05	3.0	2.1E-05	1.8	--	--
1961	3.4E-05	2.3	4.3E-05	2.6	1.9E-05	1.7	--	--
1962	6.7E-05	4.6	8.6E-05	5.1	3.5E-05	3.0	--	--
1963	5.3E-05	3.7	6.9E-05	4.1	2.8E-05	2.4	--	--
1964	8.1E-05	5.5	1.0E-04	6.0	4.0E-05	3.4	1.2E-04	8.1
1965	1.5E-04	10.2	1.6E-04	9.6	1.2E-04	10.5	3.2E-04	21.6
1966	4.8E-04	33.0	5.0E-04	29.5	4.8E-04	41.5	6.8E-04	46.6
1967	2.1E-04	14.6	2.3E-04	13.7	1.4E-04	12.3	1.5E-04	10.4
1968	8.7E-05	6.0	1.0E-04	6.0	4.4E-05	3.7	4.6E-05	3.2
1969	5.2E-05	3.5	5.6E-05	3.3	2.5E-05	2.2	3.1E-05	2.1
1970	6.8E-05	4.7	7.6E-05	4.5	3.5E-05	3.0	4.2E-05	2.9
1971	2.5E-05	1.7	3.4E-05	2.0	1.4E-05	1.2	1.8E-05	1.2
1972	7.6E-06	0.5	1.3E-05	0.8	4.7E-06	0.4	5.9E-06	0.4
1973	5.3E-06	0.4	1.3E-05	0.8	1.3E-05	1.2	4.5E-06	0.3
1974	5.7E-06	0.4	1.7E-05	1.0	1.7E-05	1.5	4.4E-06	0.3
1975	1.8E-06	0.1	3.0E-06	0.2	3.0E-06	0.3	1.3E-06	0.1
1976	1.7E-06	0.1	5.9E-06	0.3	5.9E-06	0.5	1.5E-06	0.1
1977	1.7E-06	0.1	3.8E-06	0.2	3.8E-06	0.3	1.3E-06	0.1
1978	7.9E-07	0.1	1.4E-06	0.1	1.4E-06	0.1	6.8E-07	0.0
1979	7.1E-07	0.0	1.3E-06	0.1	1.3E-06	0.1	6.1E-07	0.0
1980	1.6E-06	0.1	7.2E-06	0.4	7.2E-06	0.6	1.5E-06	0.1
1981	1.6E-06	0.1	3.6E-06	0.2	3.6E-06	0.3	1.2E-06	0.1
1982	1.1E-06	0.1	2.5E-06	0.1	2.5E-06	0.2	2.5E-06	0.2
1983	8.1E-07	0.1	2.1E-06	0.1	2.1E-06	0.2	2.1E-06	0.1
1984	2.2E-06	0.1	6.6E-06	0.4	6.6E-06	0.6	6.6E-06	0.5
1985	1.6E-06	0.1	5.9E-06	0.4	5.9E-06	0.5	5.9E-06	0.4
1986	1.9E-06	0.1	5.7E-06	0.3	5.7E-06	0.5	5.7E-06	0.4
1987	1.9E-06	0.1	2.9E-06	0.2	2.9E-06	0.2	2.9E-06	0.2
1988	2.3E-06	0.2	2.7E-06	0.2	2.7E-06	0.2	2.7E-06	0.2
1989	2.6E-06	0.2	2.8E-06	0.2	2.8E-06	0.2	2.8E-06	0.2
1990	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1
1991	9.4E-07	0.1	9.5E-07	0.1	9.5E-07	0.1	9.5E-07	0.1
1992	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1	1.2E-06	0.1
Total	1.5E-03	100.0	1.7E-03	100.0	1.2E-03	100.0	1.5E-03	100.0

Table 6.C 39-Year Effective Dose (Sv) By Year For Outdoor Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	1.3E-06	0.0	1.9E-06	0.0	--	--	--	--
1955	7.7E-05	2.5	1.1E-04	2.7	2.9E-04	3.1	--	--
1956	8.6E-04	28.3	1.3E-03	30.3	5.9E-03	62.9	--	--
1957	2.0E-04	6.5	3.0E-04	7.2	7.6E-04	8.0	--	--
1958	6.2E-05	2.1	9.2E-05	2.2	1.1E-04	1.2	--	--
1959	1.3E-04	4.3	2.0E-04	4.8	4.4E-04	4.7	--	--
1960	5.0E-05	1.7	9.3E-05	2.2	8.7E-05	0.9	--	--
1961	1.0E-04	3.3	1.5E-04	3.6	3.5E-04	3.7	--	--
1962	8.6E-05	2.8	1.3E-04	3.0	7.0E-05	0.7	--	--
1963	7.2E-05	2.4	1.1E-04	2.6	6.0E-05	0.6	--	--
1964	9.8E-05	3.2	1.4E-04	3.3	6.8E-05	0.7	1.6E-04	9.0
1965	1.6E-04	5.3	1.9E-04	4.5	1.4E-04	1.5	3.5E-04	19.1
1966	4.9E-04	16.3	5.3E-04	12.5	5.0E-04	5.3	7.0E-04	38.4
1967	2.3E-04	7.5	2.6E-04	6.3	1.7E-04	1.8	1.8E-04	9.8
1968	1.0E-04	3.3	1.3E-04	3.0	6.5E-05	0.7	7.0E-05	3.8
1969	6.7E-05	2.2	8.4E-05	2.0	5.2E-05	0.5	7.1E-05	3.9
1970	7.7E-05	2.5	9.1E-05	2.2	4.9E-05	0.5	6.4E-05	3.5
1971	3.3E-05	1.1	5.0E-05	1.2	2.7E-05	0.3	3.0E-05	1.7
1972	1.6E-05	0.5	3.2E-05	0.8	1.8E-05	0.2	1.9E-05	1.0
1973	1.3E-05	0.4	3.0E-05	0.7	3.0E-05	0.3	1.5E-05	0.8
1974	1.2E-05	0.4	2.9E-05	0.7	2.9E-05	0.3	1.3E-05	0.7
1975	5.8E-06	0.2	1.1E-05	0.3	1.1E-05	0.1	7.1E-06	0.4
1976	5.6E-06	0.2	1.4E-05	0.3	1.4E-05	0.2	7.1E-06	0.4
1977	5.9E-06	0.2	1.2E-05	0.3	1.2E-05	0.1	7.4E-06	0.4
1978	5.6E-06	0.2	1.0E-05	0.2	1.0E-05	0.1	8.1E-06	0.4
1979	4.3E-06	0.1	8.4E-06	0.2	8.4E-06	0.1	5.9E-06	0.3
1980	5.5E-06	0.2	1.5E-05	0.4	1.5E-05	0.2	7.2E-06	0.4
1981	5.5E-06	0.2	1.1E-05	0.3	1.1E-05	0.1	7.1E-06	0.4
1982	5.4E-06	0.2	1.1E-05	0.3	1.1E-05	0.1	1.1E-05	0.6
1983	5.7E-06	0.2	1.0E-05	0.2	1.0E-05	0.1	1.0E-05	0.6
1984	8.2E-06	0.3	1.6E-05	0.4	1.6E-05	0.2	1.6E-05	0.9
1985	7.6E-06	0.3	1.6E-05	0.4	1.6E-05	0.2	1.6E-05	0.9
1986	5.8E-06	0.2	1.3E-05	0.3	1.3E-05	0.1	1.3E-05	0.7
1987	5.8E-06	0.2	1.1E-05	0.3	1.1E-05	0.1	1.1E-05	0.6
1988	5.2E-06	0.2	7.4E-06	0.2	7.4E-06	0.1	7.4E-06	0.4
1989	4.5E-06	0.1	5.5E-06	0.1	5.5E-06	0.1	5.5E-06	0.3
1990	3.0E-06	0.1	3.9E-06	0.1	3.9E-06	0.0	3.9E-06	0.2
1991	2.4E-06	0.1	3.2E-06	0.1	3.2E-06	0.0	3.2E-06	0.2
1992	2.2E-06	0.1	2.9E-06	0.1	2.9E-06	0.0	2.9E-06	0.2
Total	3.0E-03	100.0	4.2E-03	100.0	9.4E-03	100.0	1.8E-03	100.0

Table 6.C Total Cancer Incident Risk By Year For Outdoor Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	2.3E-08	0.1	4.7E-08	0.1	--	--	--	--
1955	1.4E-06	3.4	2.3E-06	3.2	2.2E-05	2.7	--	--
1956	1.9E-05	45.5	2.9E-05	40.3	5.2E-04	63.6	--	--
1957	4.5E-06	10.9	7.1E-06	10.1	1.1E-04	13.9	--	--
1958	1.2E-06	2.9	2.2E-06	3.1	1.7E-05	2.1	--	--
1959	2.9E-06	7.0	5.0E-06	7.0	6.8E-05	8.2	--	--
1960	7.7E-07	1.8	1.7E-06	2.4	5.5E-06	0.7	--	--
1961	1.8E-06	4.3	3.2E-06	4.5	2.0E-05	2.4	--	--
1962	7.6E-07	1.8	1.7E-06	2.4	5.0E-06	0.6	--	--
1963	7.7E-07	1.9	1.8E-06	2.5	4.7E-06	0.6	--	--
1964	8.0E-07	1.9	1.7E-06	2.4	4.6E-06	0.6	5.3E-06	10.0
1965	5.8E-07	1.4	1.3E-06	1.9	3.2E-06	0.4	4.2E-06	8.0
1966	5.4E-07	1.3	1.3E-06	1.8	3.0E-06	0.4	4.0E-06	7.5
1967	6.1E-07	1.5	1.5E-06	2.1	4.7E-06	0.6	4.9E-06	9.3
1968	5.4E-07	1.3	1.2E-06	1.6	4.8E-06	0.6	5.1E-06	9.6
1969	4.8E-07	1.2	9.4E-07	1.3	4.5E-06	0.5	3.3E-06	6.2
1970	3.4E-07	0.8	6.8E-07	1.0	1.4E-06	0.2	2.1E-06	4.1
1971	3.5E-07	0.8	7.1E-07	1.0	1.4E-06	0.2	2.1E-06	3.9
1972	4.1E-07	1.0	8.6E-07	1.2	1.7E-06	0.2	2.3E-06	4.4
1973	3.6E-07	0.9	8.0E-07	1.1	2.2E-06	0.3	1.9E-06	3.6
1974	3.0E-07	0.7	5.7E-07	0.8	1.6E-06	0.2	1.6E-06	3.0
1975	1.9E-07	0.5	3.8E-07	0.5	1.0E-06	0.1	1.0E-06	1.9
1976	1.9E-07	0.4	4.1E-07	0.6	1.1E-06	0.1	1.2E-06	2.3
1977	2.0E-07	0.5	4.1E-07	0.6	1.1E-06	0.1	1.4E-06	2.6
1978	2.3E-07	0.5	4.2E-07	0.6	1.3E-06	0.2	2.5E-06	4.7
1979	1.7E-07	0.4	3.4E-07	0.5	9.3E-07	0.1	6.9E-07	1.3
1980	1.9E-07	0.4	3.9E-07	0.5	3.9E-07	0.0	7.3E-07	1.4
1981	1.9E-07	0.5	3.7E-07	0.5	3.7E-07	0.0	7.5E-07	1.4
1982	2.1E-07	0.5	3.9E-07	0.6	3.9E-07	0.0	1.1E-06	2.0
1983	2.4E-07	0.6	3.9E-07	0.6	3.9E-07	0.0	1.1E-06	2.0
1984	2.9E-07	0.7	4.7E-07	0.7	4.7E-07	0.1	1.3E-06	2.4
1985	2.9E-07	0.7	5.0E-07	0.7	5.0E-07	0.1	1.3E-06	2.5
1986	1.9E-07	0.4	3.5E-07	0.5	3.5E-07	0.0	9.6E-07	1.8
1987	1.9E-07	0.4	3.8E-07	0.5	3.8E-07	0.0	1.0E-06	2.0
1988	1.4E-07	0.3	2.3E-07	0.3	2.3E-07	0.0	6.2E-07	1.2
1989	9.1E-08	0.2	1.3E-07	0.2	1.3E-07	0.0	1.3E-07	0.3
1990	8.5E-08	0.2	1.3E-07	0.2	1.3E-07	0.0	1.3E-07	0.2
1991	7.1E-08	0.2	1.1E-07	0.2	1.1E-07	0.0	1.1E-07	0.2
1992	5.3E-08	0.1	8.0E-08	0.1	8.0E-08	0.0	8.0E-08	0.2
Total	4.2E-05	100.0	7.1E-05	100.0	8.2E-04	100.0	5.3E-05	100.0

Table 6.C Total Cancer Incident Risk By Year For Outdoor Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	3.0E-08	0.0	3.5E-08	0.0	--	--	--	--
1955	9.8E-08	0.2	1.1E-07	0.2	2.5E-07	0.1	--	--
1956	4.2E-07	0.7	4.4E-07	0.6	1.1E-06	0.6	--	--
1957	2.7E-07	0.4	3.0E-07	0.4	1.2E-06	0.6	--	--
1958	1.1E-06	1.8	1.2E-06	1.7	1.8E-06	1.0	--	--
1959	5.4E-07	0.9	6.1E-07	0.8	9.6E-07	0.5	--	--
1960	1.3E-06	2.0	2.1E-06	2.9	2.8E-06	1.6	--	--
1961	1.5E-06	2.3	1.8E-06	2.6	2.9E-06	1.6	--	--
1962	2.9E-06	4.6	3.7E-06	5.2	5.9E-06	3.3	--	--
1963	2.4E-06	3.8	3.0E-06	4.2	4.8E-06	2.7	--	--
1964	3.8E-06	6.0	4.6E-06	6.4	7.6E-06	4.3	1.0E-05	3.3
1965	6.9E-06	10.8	7.4E-06	10.2	2.2E-05	12.4	4.3E-05	14.5
1966	2.3E-05	36.1	2.3E-05	32.5	8.7E-05	48.9	1.8E-04	61.5
1967	9.2E-06	14.5	9.8E-06	13.5	1.9E-05	10.7	3.5E-05	11.6
1968	3.6E-06	5.7	4.1E-06	5.7	6.7E-06	3.8	1.0E-05	3.5
1969	1.7E-06	2.6	1.8E-06	2.5	2.9E-06	1.7	3.3E-06	1.1
1970	2.3E-06	3.6	2.5E-06	3.5	2.7E-06	1.5	4.6E-06	1.5
1971	7.8E-07	1.2	1.1E-06	1.6	9.4E-07	0.5	2.2E-06	0.7
1972	2.8E-07	0.4	4.9E-07	0.7	3.5E-07	0.2	8.7E-07	0.3
1973	2.0E-07	0.3	5.0E-07	0.7	1.4E-06	0.8	7.0E-07	0.2
1974	2.4E-07	0.4	6.7E-07	0.9	1.9E-06	1.1	7.5E-07	0.2
1975	7.4E-08	0.1	1.2E-07	0.2	3.3E-07	0.2	1.6E-07	0.1
1976	7.6E-08	0.1	2.4E-07	0.3	6.7E-07	0.4	2.3E-07	0.1
1977	7.5E-08	0.1	1.6E-07	0.2	4.3E-07	0.2	1.8E-07	0.1
1978	3.4E-08	0.1	5.5E-08	0.1	1.5E-07	0.1	6.5E-08	0.0
1979	3.1E-08	0.0	4.8E-08	0.1	1.3E-07	0.1	3.9E-08	0.0
1980	6.6E-08	0.1	2.6E-07	0.4	2.6E-07	0.1	9.1E-08	0.0
1981	5.9E-08	0.1	1.3E-07	0.2	1.3E-07	0.1	7.6E-08	0.0
1982	4.3E-08	0.1	1.0E-07	0.1	1.0E-07	0.1	2.8E-07	0.1
1983	3.4E-08	0.1	8.9E-08	0.1	8.9E-08	0.0	2.5E-07	0.1
1984	8.9E-08	0.1	2.9E-07	0.4	2.9E-07	0.2	8.4E-07	0.3
1985	6.6E-08	0.1	2.5E-07	0.3	2.5E-07	0.1	7.2E-07	0.2
1986	6.6E-08	0.1	2.0E-07	0.3	2.0E-07	0.1	5.5E-07	0.2
1987	8.1E-08	0.1	1.1E-07	0.2	1.1E-07	0.1	3.0E-07	0.1
1988	9.9E-08	0.2	1.1E-07	0.2	1.1E-07	0.1	3.0E-07	0.1
1989	8.5E-08	0.1	8.8E-08	0.1	8.8E-08	0.0	8.8E-08	0.0
1990	2.5E-08	0.0	2.6E-08	0.0	2.6E-08	0.0	2.6E-08	0.0
1991	1.5E-08	0.0	1.5E-08	0.0	1.5E-08	0.0	1.5E-08	0.0
1992	3.2E-08	0.1	3.3E-08	0.0	3.3E-08	0.0	3.3E-08	0.0
Total	6.3E-05	100.0	7.2E-05	100.0	1.8E-04	100.0	3.0E-04	100.0

Table 6.C Total Cancer Incident Risk By Year For Outdoor Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	5.4E-08	0.1	8.2E-08	0.1	--	--	--	--
1955	1.5E-06	1.5	2.4E-06	1.7	2.2E-05	2.2	--	--
1956	1.9E-05	18.5	2.9E-05	20.3	5.2E-04	52.4	--	--
1957	4.8E-06	4.6	7.4E-06	5.2	1.2E-04	11.6	--	--
1958	2.4E-06	2.2	3.4E-06	2.4	1.9E-05	1.9	--	--
1959	3.5E-06	3.3	5.6E-06	3.9	6.9E-05	6.9	--	--
1960	2.0E-06	1.9	3.8E-06	2.6	8.3E-06	0.8	--	--
1961	3.3E-06	3.1	5.0E-06	3.5	2.3E-05	2.3	--	--
1962	3.7E-06	3.5	5.4E-06	3.8	1.1E-05	1.1	--	--
1963	3.2E-06	3.1	4.8E-06	3.4	9.5E-06	1.0	--	--
1964	4.6E-06	4.4	6.3E-06	4.4	1.2E-05	1.2	1.5E-05	4.3
1965	7.4E-06	7.1	8.7E-06	6.1	2.5E-05	2.5	4.7E-05	13.5
1966	2.3E-05	22.3	2.5E-05	17.3	9.0E-05	9.0	1.9E-04	53.4
1967	9.8E-06	9.3	1.1E-05	7.9	2.4E-05	2.4	4.0E-05	11.3
1968	4.1E-06	3.9	5.3E-06	3.7	1.2E-05	1.2	1.6E-05	4.4
1969	2.2E-06	2.1	2.8E-06	1.9	7.4E-06	0.7	6.6E-06	1.9
1970	2.6E-06	2.5	3.2E-06	2.2	4.1E-06	0.4	6.7E-06	1.9
1971	1.1E-06	1.1	1.9E-06	1.3	2.3E-06	0.2	4.3E-06	1.2
1972	6.9E-07	0.7	1.4E-06	0.9	2.0E-06	0.2	3.2E-06	0.9
1973	5.6E-07	0.5	1.3E-06	0.9	3.6E-06	0.4	2.6E-06	0.7
1974	5.3E-07	0.5	1.2E-06	0.9	3.4E-06	0.3	2.3E-06	0.7
1975	2.6E-07	0.3	5.0E-07	0.3	1.4E-06	0.1	1.2E-06	0.3
1976	2.6E-07	0.2	6.5E-07	0.5	1.8E-06	0.2	1.5E-06	0.4
1977	2.7E-07	0.3	5.6E-07	0.4	1.5E-06	0.2	1.6E-06	0.4
1978	2.6E-07	0.2	4.8E-07	0.3	1.5E-06	0.1	2.6E-06	0.7
1979	2.0E-07	0.2	3.9E-07	0.3	1.1E-06	0.1	7.3E-07	0.2
1980	2.5E-07	0.2	6.5E-07	0.5	6.5E-07	0.1	8.2E-07	0.2
1981	2.5E-07	0.2	5.0E-07	0.4	5.0E-07	0.1	8.3E-07	0.2
1982	2.5E-07	0.2	4.9E-07	0.3	4.9E-07	0.0	1.4E-06	0.4
1983	2.7E-07	0.3	4.8E-07	0.3	4.8E-07	0.0	1.3E-06	0.4
1984	3.8E-07	0.4	7.6E-07	0.5	7.6E-07	0.1	2.1E-06	0.6
1985	3.6E-07	0.3	7.5E-07	0.5	7.5E-07	0.1	2.1E-06	0.6
1986	2.5E-07	0.2	5.5E-07	0.4	5.5E-07	0.1	1.5E-06	0.4
1987	2.7E-07	0.3	5.0E-07	0.3	5.0E-07	0.0	1.4E-06	0.4
1988	2.4E-07	0.2	3.4E-07	0.2	3.4E-07	0.0	9.2E-07	0.3
1989	1.8E-07	0.2	2.2E-07	0.2	2.2E-07	0.0	2.2E-07	0.1
1990	1.1E-07	0.1	1.5E-07	0.1	1.5E-07	0.0	1.5E-07	0.0
1991	8.5E-08	0.1	1.2E-07	0.1	1.2E-07	0.0	1.2E-07	0.0
1992	8.5E-08	0.1	1.1E-07	0.1	1.1E-07	0.0	1.1E-07	0.0
Total	1.1E-04	100.0	1.4E-04	100.0	1.0E-03	100.0	3.5E-04	100.0

Table 6.C Total Cancer Fatality Risk By Year For Outdoor Family From Atmospheric Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	1.6E-08	0.1	3.2E-08	0.1	--	--	--	--
1955	6.3E-07	4.9	1.0E-06	4.0	4.0E-06	3.2	--	--
1956	2.5E-06	19.1	3.8E-06	15.1	5.6E-05	45.8	--	--
1957	8.1E-07	6.3	1.5E-06	5.7	1.4E-05	11.2	--	--
1958	5.6E-07	4.4	1.1E-06	4.4	4.6E-06	3.8	--	--
1959	7.0E-07	5.4	1.5E-06	5.7	9.2E-06	7.5	--	--
1960	4.4E-07	3.4	1.0E-06	4.1	2.2E-06	1.8	--	--
1961	5.3E-07	4.1	1.2E-06	4.6	3.6E-06	2.9	--	--
1962	4.5E-07	3.5	1.1E-06	4.2	2.2E-06	1.8	--	--
1963	4.9E-07	3.8	1.2E-06	4.6	2.3E-06	1.9	--	--
1964	5.4E-07	4.2	1.2E-06	4.6	2.6E-06	2.2	2.9E-06	9.7
1965	3.9E-07	3.0	9.2E-07	3.6	1.8E-06	1.5	2.3E-06	7.5
1966	3.6E-07	2.8	8.8E-07	3.5	1.7E-06	1.4	2.1E-06	7.1
1967	3.9E-07	3.0	9.7E-07	3.8	2.3E-06	1.8	2.2E-06	7.4
1968	3.5E-07	2.7	7.7E-07	3.0	2.5E-06	2.0	2.5E-06	8.2
1969	3.0E-07	2.3	6.0E-07	2.4	2.0E-06	1.7	1.5E-06	5.1
1970	2.1E-07	1.7	4.4E-07	1.7	8.0E-07	0.6	1.1E-06	3.5
1971	2.4E-07	1.8	4.9E-07	1.9	8.8E-07	0.7	1.2E-06	4.0
1972	2.9E-07	2.3	6.1E-07	2.4	1.1E-06	0.9	1.5E-06	4.9
1973	2.6E-07	2.0	5.7E-07	2.2	1.5E-06	1.2	1.2E-06	4.1
1974	2.1E-07	1.6	4.1E-07	1.6	1.0E-06	0.9	1.0E-06	3.4
1975	1.4E-07	1.1	2.7E-07	1.1	6.9E-07	0.6	6.6E-07	2.2
1976	1.3E-07	1.0	2.9E-07	1.1	7.4E-07	0.6	8.0E-07	2.6
1977	1.4E-07	1.1	2.9E-07	1.1	7.4E-07	0.6	9.0E-07	3.0
1978	1.6E-07	1.2	2.9E-07	1.2	8.5E-07	0.7	1.5E-06	5.0
1979	1.2E-07	1.0	2.4E-07	1.0	6.2E-07	0.5	4.6E-07	1.5
1980	1.3E-07	1.0	2.8E-07	1.1	2.8E-07	0.2	4.9E-07	1.6
1981	1.3E-07	1.0	2.7E-07	1.1	2.7E-07	0.2	5.1E-07	1.7
1982	1.5E-07	1.1	2.8E-07	1.1	2.8E-07	0.2	7.2E-07	2.4
1983	1.7E-07	1.3	2.8E-07	1.1	2.8E-07	0.2	7.2E-07	2.4
1984	2.1E-07	1.6	3.3E-07	1.3	3.3E-07	0.3	8.5E-07	2.8
1985	2.1E-07	1.6	3.6E-07	1.4	3.6E-07	0.3	9.0E-07	3.0
1986	1.3E-07	1.0	2.5E-07	1.0	2.5E-07	0.2	6.5E-07	2.1
1987	1.3E-07	1.0	2.8E-07	1.1	2.8E-07	0.2	7.1E-07	2.3
1988	9.8E-08	0.8	1.6E-07	0.6	1.6E-07	0.1	4.2E-07	1.4
1989	6.5E-08	0.5	9.6E-08	0.4	9.6E-08	0.1	9.6E-08	0.3
1990	6.1E-08	0.5	9.2E-08	0.4	9.2E-08	0.1	9.2E-08	0.3
1991	5.1E-08	0.4	7.7E-08	0.3	7.7E-08	0.1	7.7E-08	0.3
1992	3.8E-08	0.3	5.8E-08	0.2	5.8E-08	0.0	5.8E-08	0.2
Total	1.3E-05	100.0	2.5E-05	100.0	1.2E-04	100.0	3.0E-05	100.0

Table 6.C Total Cancer Fatality Risk By Year For Outdoor Family From Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	2.2E-08	0.0	2.6E-08	0.0	--	--	--	--
1955	7.5E-08	0.2	8.7E-08	0.2	1.7E-07	0.1	--	--
1956	3.2E-07	0.7	3.4E-07	0.6	7.3E-07	0.6	--	--
1957	1.7E-07	0.4	1.9E-07	0.4	3.4E-07	0.3	--	--
1958	8.2E-07	1.7	8.8E-07	1.6	1.1E-06	1.0	--	--
1959	4.0E-07	0.8	4.5E-07	0.8	6.2E-07	0.5	--	--
1960	9.8E-07	2.0	1.6E-06	2.9	1.8E-06	1.6	--	--
1961	1.1E-06	2.2	1.3E-06	2.4	1.8E-06	1.6	--	--
1962	2.1E-06	4.4	2.7E-06	4.9	3.7E-06	3.2	--	--
1963	1.8E-06	3.7	2.2E-06	4.0	3.0E-06	2.6	--	--
1964	2.8E-06	5.7	3.3E-06	6.1	4.9E-06	4.3	6.3E-06	3.2
1965	5.2E-06	10.8	5.6E-06	10.2	1.4E-05	12.4	2.8E-05	14.5
1966	1.8E-05	36.9	1.8E-05	33.4	5.6E-05	48.7	1.2E-04	61.6
1967	7.1E-06	14.8	7.6E-06	13.9	1.3E-05	11.0	2.3E-05	11.7
1968	2.6E-06	5.5	3.0E-06	5.5	4.3E-06	3.8	6.7E-06	3.4
1969	1.2E-06	2.6	1.4E-06	2.5	1.9E-06	1.7	2.1E-06	1.1
1970	1.7E-06	3.5	1.9E-06	3.5	1.9E-06	1.7	3.0E-06	1.5
1971	6.1E-07	1.3	8.7E-07	1.6	6.6E-07	0.6	1.4E-06	0.7
1972	2.2E-07	0.4	3.7E-07	0.7	2.4E-07	0.2	5.6E-07	0.3
1973	1.6E-07	0.3	3.7E-07	0.7	9.7E-07	0.8	4.4E-07	0.2
1974	1.8E-07	0.4	4.9E-07	0.9	1.3E-06	1.1	4.7E-07	0.2
1975	5.8E-08	0.1	9.1E-08	0.2	2.3E-07	0.2	1.1E-07	0.1
1976	6.0E-08	0.1	1.8E-07	0.3	4.7E-07	0.4	1.4E-07	0.1
1977	5.8E-08	0.1	1.2E-07	0.2	3.0E-07	0.3	1.2E-07	0.1
1978	2.8E-08	0.1	4.3E-08	0.1	1.1E-07	0.1	4.4E-08	0.0
1979	2.5E-08	0.1	3.8E-08	0.1	9.7E-08	0.1	2.9E-08	0.0
1980	5.4E-08	0.1	2.0E-07	0.4	2.0E-07	0.2	6.7E-08	0.0
1981	4.7E-08	0.1	9.8E-08	0.2	9.8E-08	0.1	5.5E-08	0.0
1982	3.3E-08	0.1	7.5E-08	0.1	7.5E-08	0.1	2.0E-07	0.1
1983	2.6E-08	0.1	6.6E-08	0.1	6.6E-08	0.1	1.7E-07	0.1
1984	7.3E-08	0.2	2.2E-07	0.4	2.2E-07	0.2	5.8E-07	0.3
1985	5.3E-08	0.1	1.9E-07	0.3	1.9E-07	0.2	4.9E-07	0.3
1986	5.4E-08	0.1	1.5E-07	0.3	1.5E-07	0.1	3.9E-07	0.2
1987	6.7E-08	0.1	9.0E-08	0.2	9.0E-08	0.1	2.3E-07	0.1
1988	7.3E-08	0.2	8.3E-08	0.2	8.3E-08	0.1	2.1E-07	0.1
1989	6.7E-08	0.1	6.9E-08	0.1	6.9E-08	0.1	6.9E-08	0.0
1990	2.1E-08	0.0	2.1E-08	0.0	2.1E-08	0.0	2.1E-08	0.0
1991	1.2E-08	0.0	1.2E-08	0.0	1.2E-08	0.0	1.2E-08	0.0
1992	2.7E-08	0.1	2.7E-08	0.1	2.7E-08	0.0	2.7E-08	0.0
Total	4.8E-05	100.0	5.5E-05	100.0	1.1E-04	100.0	2.0E-04	100.0

Table 6.C Total Cancer Fatality Risk By Year For Outdoor Family From Atmospheric and Liquid Releases

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	3.8E-08	0.1	5.8E-08	0.1	--	--	--	--
1955	7.0E-07	1.2	1.1E-06	1.4	4.2E-06	1.8	--	--
1956	2.8E-06	4.6	4.2E-06	5.2	5.7E-05	24.0	--	--
1957	9.8E-07	1.6	1.6E-06	2.1	1.4E-05	5.9	--	--
1958	1.4E-06	2.3	2.0E-06	2.5	5.7E-06	2.4	--	--
1959	1.1E-06	1.8	1.9E-06	2.4	9.9E-06	4.2	--	--
1960	1.4E-06	2.3	2.6E-06	3.2	4.0E-06	1.7	--	--
1961	1.6E-06	2.6	2.5E-06	3.1	5.4E-06	2.3	--	--
1962	2.6E-06	4.2	3.7E-06	4.7	5.9E-06	2.5	--	--
1963	2.3E-06	3.7	3.4E-06	4.2	5.3E-06	2.3	--	--
1964	3.3E-06	5.4	4.5E-06	5.6	7.5E-06	3.2	9.2E-06	4.1
1965	5.6E-06	9.2	6.5E-06	8.1	1.6E-05	6.7	3.1E-05	13.5
1966	1.8E-05	29.7	1.9E-05	23.9	5.7E-05	24.2	1.2E-04	54.3
1967	7.5E-06	12.3	8.6E-06	10.7	1.5E-05	6.3	2.5E-05	11.1
1968	3.0E-06	4.9	3.8E-06	4.7	6.8E-06	2.9	9.1E-06	4.0
1969	1.5E-06	2.5	2.0E-06	2.4	4.0E-06	1.7	3.7E-06	1.6
1970	1.9E-06	3.1	2.3E-06	2.9	2.7E-06	1.1	4.0E-06	1.8
1971	8.4E-07	1.4	1.4E-06	1.7	1.5E-06	0.7	2.6E-06	1.2
1972	5.1E-07	0.8	9.8E-07	1.2	1.3E-06	0.6	2.0E-06	0.9
1973	4.1E-07	0.7	9.4E-07	1.2	2.4E-06	1.0	1.7E-06	0.7
1974	3.9E-07	0.6	9.0E-07	1.1	2.3E-06	1.0	1.5E-06	0.7
1975	1.9E-07	0.3	3.6E-07	0.5	9.2E-07	0.4	7.7E-07	0.3
1976	1.9E-07	0.3	4.7E-07	0.6	1.2E-06	0.5	9.4E-07	0.4
1977	2.0E-07	0.3	4.1E-07	0.5	1.0E-06	0.4	1.0E-06	0.5
1978	1.8E-07	0.3	3.4E-07	0.4	9.6E-07	0.4	1.6E-06	0.7
1979	1.5E-07	0.2	2.8E-07	0.4	7.2E-07	0.3	4.9E-07	0.2
1980	1.9E-07	0.3	4.7E-07	0.6	4.7E-07	0.2	5.6E-07	0.2
1981	1.8E-07	0.3	3.7E-07	0.5	3.7E-07	0.2	5.6E-07	0.2
1982	1.8E-07	0.3	3.6E-07	0.4	3.6E-07	0.2	9.1E-07	0.4
1983	2.0E-07	0.3	3.5E-07	0.4	3.5E-07	0.1	8.9E-07	0.4
1984	2.8E-07	0.5	5.5E-07	0.7	5.5E-07	0.2	1.4E-06	0.6
1985	2.6E-07	0.4	5.4E-07	0.7	5.4E-07	0.2	1.4E-06	0.6
1986	1.9E-07	0.3	4.0E-07	0.5	4.0E-07	0.2	1.0E-06	0.5
1987	2.0E-07	0.3	3.7E-07	0.5	3.7E-07	0.2	9.3E-07	0.4
1988	1.7E-07	0.3	2.5E-07	0.3	2.5E-07	0.1	6.3E-07	0.3
1989	1.3E-07	0.2	1.6E-07	0.2	1.6E-07	0.1	1.6E-07	0.1
1990	8.2E-08	0.1	1.1E-07	0.1	1.1E-07	0.0	1.1E-07	0.1
1991	6.3E-08	0.1	8.9E-08	0.1	8.9E-08	0.0	8.9E-08	0.0
1992	6.5E-08	0.1	8.5E-08	0.1	8.5E-08	0.0	8.5E-08	0.0
Total	6.1E-05	100.0	8.0E-05	100.0	2.4E-04	100.0	2.3E-04	100.0

Table 6.C Effective Dose By Year for Rural Family One

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	1.7E-07	0.1	1.7E-07	0.0	--	--	--	--
1955	2.0E-05	6.6	2.7E-05	6.5	5.8E-05	3.6	--	--
1956	1.6E-04	51.6	2.3E-04	53.6	1.2E-03	72.8	--	--
1957	3.4E-05	11.3	4.9E-05	11.6	1.4E-04	8.9	--	--
1958	6.6E-06	2.2	8.6E-06	2.0	1.7E-05	1.1	--	--
1959	2.1E-05	7.0	3.0E-05	7.0	8.2E-05	5.2	--	--
1960	3.9E-06	1.3	4.8E-06	1.1	1.0E-05	0.6	--	--
1961	1.1E-05	3.6	1.5E-05	3.5	5.5E-05	3.4	--	--
1962	4.0E-06	1.3	4.8E-06	1.1	6.6E-06	0.4	--	--
1963	3.8E-06	1.3	4.6E-06	1.1	5.9E-06	0.4	--	--
1964	3.9E-06	1.3	4.8E-06	1.1	5.9E-06	0.4	1.1E-05	14.7
1965	2.7E-06	0.9	3.3E-06	0.8	4.0E-06	0.3	6.4E-06	8.9
1966	2.6E-06	0.9	3.1E-06	0.7	3.9E-06	0.2	4.3E-06	5.9
1967	2.7E-06	0.9	3.2E-06	0.8	3.8E-06	0.2	4.4E-06	6.1
1968	2.4E-06	0.8	3.0E-06	0.7	3.6E-06	0.2	4.2E-06	5.9
1969	3.6E-06	1.2	4.7E-06	1.1	5.3E-06	0.3	6.8E-06	9.4
1970	1.6E-06	0.5	2.0E-06	0.5	2.5E-06	0.2	3.8E-06	5.2
1971	1.7E-06	0.6	2.1E-06	0.5	2.6E-06	0.2	2.7E-06	3.8
1972	2.0E-06	0.7	2.5E-06	0.6	2.9E-06	0.2	3.0E-06	4.2
1973	1.8E-06	0.6	2.2E-06	0.5	2.2E-06	0.1	2.6E-06	3.6
1974	1.5E-06	0.5	1.8E-06	0.4	1.8E-06	0.1	2.2E-06	3.1
1975	9.4E-07	0.3	1.2E-06	0.3	1.2E-06	0.1	1.5E-06	2.0
1976	9.1E-07	0.3	1.1E-06	0.3	1.1E-06	0.1	1.3E-06	1.8
1977	9.4E-07	0.3	1.2E-06	0.3	1.2E-06	0.1	1.4E-06	1.9
1978	1.0E-06	0.3	1.3E-06	0.3	1.3E-06	0.1	1.5E-06	2.1
1979	8.1E-07	0.3	1.0E-06	0.2	1.0E-06	0.1	1.2E-06	1.7
1980	8.7E-07	0.3	1.1E-06	0.3	1.1E-06	0.1	1.3E-06	1.8
1981	9.1E-07	0.3	1.1E-06	0.3	1.1E-06	0.1	1.4E-06	1.9
1982	9.7E-07	0.3	1.2E-06	0.3	1.2E-06	0.1	1.2E-06	1.7
1983	1.1E-06	0.4	1.4E-06	0.3	1.4E-06	0.1	1.4E-06	2.0
1984	1.4E-06	0.5	1.8E-06	0.4	1.8E-06	0.1	1.8E-06	2.5
1985	1.3E-06	0.4	1.7E-06	0.4	1.7E-06	0.1	1.7E-06	2.4
1986	9.9E-07	0.3	1.2E-06	0.3	1.2E-06	0.1	1.2E-06	1.7
1987	1.0E-06	0.3	1.3E-06	0.3	1.3E-06	0.1	1.3E-06	1.7
1988	7.4E-07	0.2	9.5E-07	0.2	9.5E-07	0.1	9.5E-07	1.3
1989	5.2E-07	0.2	6.8E-07	0.2	6.8E-07	0.0	6.8E-07	0.9
1990	4.0E-07	0.1	5.3E-07	0.1	5.3E-07	0.0	5.3E-07	0.7
1991	3.2E-07	0.1	4.2E-07	0.1	4.2E-07	0.0	4.2E-07	0.6
1992	2.3E-07	0.1	3.1E-07	0.1	3.1E-07	0.0	3.1E-07	0.4
Total	3.0E-04	100.0	4.2E-04	100.0	1.6E-03	100.0	7.2E-05	100.0

Table 6.C Total Cancer Incident Risk By Year For Rural Family One

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	8.0E-09	0.1	8.0E-09	0.1	--	--	--	--
1955	3.6E-07	4.3	4.9E-07	4.3	4.6E-06	2.9	--	--
1956	3.6E-06	42.7	5.1E-06	45.4	1.0E-04	64.5	--	--
1957	8.4E-07	10.1	1.2E-06	10.5	2.2E-05	13.7	--	--
1958	2.6E-07	3.1	3.3E-07	2.9	3.0E-06	1.9	--	--
1959	5.6E-07	6.7	7.7E-07	6.8	1.3E-05	8.1	--	--
1960	1.7E-07	2.0	2.0E-07	1.7	1.0E-06	0.7	--	--
1961	3.2E-07	3.9	4.2E-07	3.7	3.4E-06	2.1	--	--
1962	1.7E-07	2.1	2.1E-07	1.8	1.0E-06	0.7	--	--
1963	1.8E-07	2.1	2.1E-07	1.8	9.7E-07	0.6	--	--
1964	1.9E-07	2.2	2.3E-07	2.0	1.0E-06	0.7	1.3E-06	11.6
1965	1.3E-07	1.5	1.5E-07	1.3	6.9E-07	0.4	9.2E-07	8.4
1966	1.2E-07	1.4	1.4E-07	1.2	6.6E-07	0.4	8.9E-07	8.1
1967	1.3E-07	1.5	1.5E-07	1.3	7.9E-07	0.5	9.0E-07	8.2
1968	1.1E-07	1.3	1.4E-07	1.2	8.4E-07	0.5	9.6E-07	8.7
1969	1.0E-07	1.2	1.3E-07	1.2	7.5E-07	0.5	6.0E-07	5.5
1970	7.0E-08	0.8	8.7E-08	0.8	2.8E-07	0.2	4.3E-07	3.9
1971	7.9E-08	1.0	9.8E-08	0.9	3.2E-07	0.2	4.7E-07	4.3
1972	9.6E-08	1.1	1.2E-07	1.0	3.8E-07	0.2	5.5E-07	5.0
1973	8.6E-08	1.0	1.0E-07	0.9	2.8E-07	0.2	4.6E-07	4.2
1974	7.0E-08	0.8	8.7E-08	0.8	2.3E-07	0.1	4.0E-07	3.6
1975	4.5E-08	0.5	5.6E-08	0.5	1.5E-07	0.1	2.6E-07	2.3
1976	4.3E-08	0.5	5.2E-08	0.5	1.4E-07	0.1	2.8E-07	2.5
1977	4.5E-08	0.5	5.6E-08	0.5	1.5E-07	0.1	3.1E-07	2.8
1978	4.8E-08	0.6	6.2E-08	0.5	1.9E-07	0.1	4.7E-07	4.3
1979	3.9E-08	0.5	4.9E-08	0.4	1.3E-07	0.1	1.6E-07	1.4
1980	4.2E-08	0.5	5.1E-08	0.5	5.1E-08	0.0	1.6E-07	1.5
1981	4.4E-08	0.5	5.4E-08	0.5	5.4E-08	0.0	1.8E-07	1.6
1982	4.7E-08	0.6	5.8E-08	0.5	5.8E-08	0.0	1.6E-07	1.4
1983	5.3E-08	0.6	6.8E-08	0.6	6.8E-08	0.0	1.8E-07	1.7
1984	6.7E-08	0.8	8.7E-08	0.8	8.7E-08	0.1	2.3E-07	2.1
1985	6.4E-08	0.8	8.2E-08	0.7	8.2E-08	0.1	2.2E-07	2.0
1986	4.8E-08	0.6	5.8E-08	0.5	5.8E-08	0.0	1.6E-07	1.4
1987	4.9E-08	0.6	6.1E-08	0.5	6.1E-08	0.0	1.6E-07	1.5
1988	3.6E-08	0.4	4.6E-08	0.4	4.6E-08	0.0	1.2E-07	1.1
1989	2.5E-08	0.3	3.3E-08	0.3	3.3E-08	0.0	3.3E-08	0.3
1990	1.9E-08	0.2	2.5E-08	0.2	2.5E-08	0.0	2.5E-08	0.2
1991	1.5E-08	0.2	2.0E-08	0.2	2.0E-08	0.0	2.0E-08	0.2
1992	1.1E-08	0.1	1.5E-08	0.1	1.5E-08	0.0	1.5E-08	0.1

Total	8.3E-06	100.0	1.1E-05	100.0	1.6E-04	100.0	1.1E-05	100.0

Table 6.C Total Cancer Fatality Risk By Year For Rural Family One

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	5.7E-09	0.2	5.7E-09	0.1	--	--	--	--
1955	2.0E-07	6.6	2.6E-07	7.0	9.8E-07	3.9	--	--
1956	4.9E-07	16.2	6.7E-07	17.7	1.1E-05	44.0	--	--
1957	1.8E-07	6.0	2.3E-07	6.2	2.8E-06	11.0	--	--
1958	1.5E-07	5.1	1.9E-07	5.0	1.1E-06	4.5	--	--
1959	1.6E-07	5.4	2.0E-07	5.3	1.9E-06	7.6	--	--
1960	1.1E-07	3.6	1.3E-07	3.3	5.3E-07	2.1	--	--
1961	1.2E-07	4.1	1.5E-07	3.9	7.5E-07	3.0	--	--
1962	1.2E-07	3.8	1.4E-07	3.6	5.5E-07	2.2	--	--
1963	1.2E-07	4.0	1.4E-07	3.7	5.8E-07	2.3	--	--
1964	1.3E-07	4.4	1.6E-07	4.2	6.6E-07	2.6	8.0E-07	11.6
1965	8.8E-08	2.9	1.1E-07	2.8	4.3E-07	1.7	5.6E-07	8.2
1966	8.3E-08	2.8	9.8E-08	2.6	4.1E-07	1.6	5.2E-07	7.6
1967	8.8E-08	2.9	1.0E-07	2.7	4.7E-07	1.9	5.3E-07	7.7
1968	7.8E-08	2.6	9.5E-08	2.5	5.0E-07	2.0	5.6E-07	8.1
1969	7.6E-08	2.5	9.5E-08	2.5	4.6E-07	1.8	3.7E-07	5.3
1970	4.8E-08	1.6	5.9E-08	1.6	1.8E-07	0.7	2.5E-07	3.6
1971	5.5E-08	1.8	6.8E-08	1.8	2.0E-07	0.8	2.9E-07	4.2
1972	6.8E-08	2.3	8.4E-08	2.2	2.5E-07	1.0	3.5E-07	5.2
1973	6.1E-08	2.0	7.3E-08	1.9	1.9E-07	0.7	3.0E-07	4.4
1974	5.0E-08	1.7	6.2E-08	1.6	1.6E-07	0.6	2.6E-07	3.8
1975	3.2E-08	1.1	4.0E-08	1.1	1.0E-07	0.4	1.7E-07	2.5
1976	3.1E-08	1.0	3.7E-08	1.0	9.5E-08	0.4	1.8E-07	2.6
1977	3.2E-08	1.1	4.0E-08	1.1	1.0E-07	0.4	2.0E-07	2.9
1978	3.3E-08	1.1	4.3E-08	1.1	1.2E-07	0.5	2.9E-07	4.2
1979	2.8E-08	0.9	3.5E-08	0.9	8.8E-08	0.4	1.1E-07	1.5
1980	3.0E-08	1.0	3.7E-08	1.0	3.7E-08	0.1	1.1E-07	1.6
1981	3.1E-08	1.0	3.9E-08	1.0	3.9E-08	0.2	1.2E-07	1.7
1982	3.3E-08	1.1	4.2E-08	1.1	4.2E-08	0.2	1.1E-07	1.5
1983	3.8E-08	1.3	4.9E-08	1.3	4.9E-08	0.2	1.2E-07	1.8
1984	4.8E-08	1.6	6.3E-08	1.7	6.3E-08	0.2	1.6E-07	2.3
1985	4.6E-08	1.5	5.9E-08	1.6	5.9E-08	0.2	1.5E-07	2.2
1986	3.4E-08	1.1	4.2E-08	1.1	4.2E-08	0.2	1.1E-07	1.6
1987	3.5E-08	1.2	4.3E-08	1.1	4.3E-08	0.2	1.1E-07	1.6
1988	2.6E-08	0.9	3.3E-08	0.9	3.3E-08	0.1	8.3E-08	1.2
1989	1.8E-08	0.6	2.4E-08	0.6	2.4E-08	0.1	2.4E-08	0.3
1990	1.4E-08	0.5	1.8E-08	0.5	1.8E-08	0.1	1.8E-08	0.3
1991	1.1E-08	0.4	1.5E-08	0.4	1.5E-08	0.1	1.5E-08	0.2
1992	8.1E-09	0.3	1.1E-08	0.3	1.1E-08	0.0	1.1E-08	0.2

Total	3.0E-06	100.0	3.8E-06	100.0	2.5E-05	100.0	6.9E-06	100.0

Table 6.C Effective Dose By Year for Rural Family Two

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent	Dose(Sv)	Percent
1954	5.7E-07	0.1	5.8E-07	0.1	--	--	--	--
1955	4.5E-05	6.5	6.1E-05	6.3	1.4E-04	3.6	--	--
1956	3.7E-04	53.6	5.4E-04	55.5	2.8E-03	73.7	--	--
1957	8.1E-05	11.6	1.2E-04	11.9	3.3E-04	8.9	--	--
1958	1.5E-05	2.1	1.9E-05	2.0	3.7E-05	1.0	--	--
1959	4.9E-05	7.1	7.0E-05	7.1	1.9E-04	5.1	--	--
1960	8.4E-06	1.2	1.0E-05	1.1	2.2E-05	0.6	--	--
1961	2.5E-05	3.6	3.5E-05	3.6	1.3E-04	3.4	--	--
1962	8.4E-06	1.2	1.0E-05	1.0	1.4E-05	0.4	--	--
1963	7.9E-06	1.1	9.4E-06	1.0	1.2E-05	0.3	--	--
1964	8.0E-06	1.1	9.6E-06	1.0	1.2E-05	0.3	2.5E-05	14.9
1965	5.1E-06	0.7	6.1E-06	0.6	7.4E-06	0.2	1.4E-05	8.2
1966	4.9E-06	0.7	5.9E-06	0.6	7.3E-06	0.2	9.4E-06	5.7
1967	5.1E-06	0.7	6.0E-06	0.6	7.1E-06	0.2	9.5E-06	5.8
1968	4.8E-06	0.7	5.8E-06	0.6	7.1E-06	0.2	9.4E-06	5.7
1969	7.5E-06	1.1	9.7E-06	1.0	1.1E-05	0.3	1.5E-05	9.0
1970	3.1E-06	0.4	3.8E-06	0.4	4.9E-06	0.1	8.3E-06	5.0
1971	3.5E-06	0.5	4.3E-06	0.4	5.3E-06	0.1	6.5E-06	4.0
1972	3.9E-06	0.6	4.8E-06	0.5	5.7E-06	0.2	6.8E-06	4.1
1973	3.6E-06	0.5	4.3E-06	0.4	4.3E-06	0.1	6.4E-06	3.9
1974	2.9E-06	0.4	3.6E-06	0.4	3.6E-06	0.1	5.5E-06	3.4
1975	1.8E-06	0.3	2.3E-06	0.2	2.3E-06	0.1	3.6E-06	2.2
1976	1.8E-06	0.3	2.1E-06	0.2	2.1E-06	0.1	3.1E-06	1.9
1977	1.7E-06	0.3	2.2E-06	0.2	2.2E-06	0.1	3.1E-06	1.9
1978	2.0E-06	0.3	2.6E-06	0.3	2.6E-06	0.1	3.6E-06	2.2
1979	1.5E-06	0.2	1.9E-06	0.2	1.9E-06	0.1	2.8E-06	1.7
1980	1.7E-06	0.2	2.0E-06	0.2	2.0E-06	0.1	2.9E-06	1.8
1981	1.8E-06	0.3	2.2E-06	0.2	2.2E-06	0.1	3.1E-06	1.9
1982	1.9E-06	0.3	2.3E-06	0.2	2.3E-06	0.1	2.8E-06	1.7
1983	2.2E-06	0.3	2.7E-06	0.3	2.7E-06	0.1	3.2E-06	2.0
1984	2.7E-06	0.4	3.5E-06	0.4	3.5E-06	0.1	4.1E-06	2.5
1985	2.5E-06	0.4	3.2E-06	0.3	3.2E-06	0.1	3.8E-06	2.3
1986	2.1E-06	0.3	2.6E-06	0.3	2.6E-06	0.1	3.5E-06	2.1
1987	2.2E-06	0.3	2.7E-06	0.3	2.7E-06	0.1	3.4E-06	2.1
1988	1.6E-06	0.2	2.0E-06	0.2	2.0E-06	0.1	2.5E-06	1.5
1989	1.0E-06	0.1	1.4E-06	0.1	1.4E-06	0.0	1.9E-06	1.1
1990	7.4E-07	0.1	9.8E-07	0.1	9.8E-07	0.0	1.0E-06	0.6
1991	5.7E-07	0.1	7.6E-07	0.1	7.6E-07	0.0	8.3E-07	0.5
1992	4.2E-07	0.1	5.6E-07	0.1	5.6E-07	0.0	5.6E-07	0.3
Total	7.0E-04	100.0	9.7E-04	100.0	3.8E-03	100.0	1.6E-04	100.0

Table 6.C Total Cancer Incident Risk By Year For Rural Family Two

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	2.7E-08	0.1	2.8E-08	0.1	--	--	--	--
1955	8.2E-07	4.4	1.1E-06	4.4	1.1E-05	2.9	--	--
1956	8.5E-06	45.3	1.2E-05	48.1	2.4E-04	65.7	--	--
1957	2.0E-06	10.5	2.8E-06	10.9	5.1E-05	13.8	--	--
1958	5.7E-07	3.0	7.2E-07	2.8	6.7E-06	1.8	--	--
1959	1.3E-06	6.9	1.8E-06	7.0	3.0E-05	8.1	--	--
1960	3.5E-07	1.9	4.2E-07	1.6	2.2E-06	0.6	--	--
1961	7.3E-07	3.9	9.6E-07	3.8	7.8E-06	2.1	--	--
1962	3.7E-07	2.0	4.4E-07	1.7	2.1E-06	0.6	--	--
1963	3.6E-07	1.9	4.3E-07	1.7	2.0E-06	0.5	--	--
1964	3.8E-07	2.0	4.5E-07	1.8	2.0E-06	0.5	3.1E-06	12.2
1965	2.3E-07	1.2	2.7E-07	1.1	1.2E-06	0.3	2.0E-06	7.7
1966	2.2E-07	1.2	2.7E-07	1.0	1.2E-06	0.3	1.9E-06	7.7
1967	2.3E-07	1.3	2.7E-07	1.1	1.4E-06	0.4	1.9E-06	7.6
1968	2.2E-07	1.2	2.7E-07	1.0	1.7E-06	0.4	2.1E-06	8.4
1969	2.1E-07	1.1	2.6E-07	1.0	1.5E-06	0.4	1.3E-06	5.3
1970	1.3E-07	0.7	1.7E-07	0.7	5.4E-07	0.1	9.5E-07	3.8
1971	1.6E-07	0.9	2.0E-07	0.8	6.3E-07	0.2	1.1E-06	4.5
1972	1.9E-07	1.0	2.3E-07	0.9	7.4E-07	0.2	1.2E-06	4.9
1973	1.7E-07	0.9	2.0E-07	0.8	5.6E-07	0.1	1.1E-06	4.5
1974	1.4E-07	0.8	1.7E-07	0.7	4.7E-07	0.1	9.7E-07	3.9
1975	8.9E-08	0.5	1.1E-07	0.4	3.0E-07	0.1	6.3E-07	2.5
1976	8.3E-08	0.4	9.9E-08	0.4	2.7E-07	0.1	6.6E-07	2.6
1977	8.4E-08	0.4	1.0E-07	0.4	2.8E-07	0.1	6.7E-07	2.7
1978	9.5E-08	0.5	1.2E-07	0.5	4.0E-07	0.1	1.1E-06	4.3
1979	7.3E-08	0.4	9.1E-08	0.4	2.5E-07	0.1	3.7E-07	1.5
1980	7.9E-08	0.4	9.6E-08	0.4	9.6E-08	0.0	3.8E-07	1.5
1981	8.5E-08	0.5	1.0E-07	0.4	1.0E-07	0.0	4.0E-07	1.6
1982	9.0E-08	0.5	1.1E-07	0.4	1.1E-07	0.0	3.6E-07	1.4
1983	1.0E-07	0.6	1.3E-07	0.5	1.3E-07	0.0	4.2E-07	1.7
1984	1.3E-07	0.7	1.7E-07	0.7	1.7E-07	0.0	5.4E-07	2.1
1985	1.2E-07	0.7	1.6E-07	0.6	1.6E-07	0.0	5.0E-07	2.0
1986	1.0E-07	0.5	1.2E-07	0.5	1.2E-07	0.0	4.5E-07	1.8
1987	1.1E-07	0.6	1.3E-07	0.5	1.3E-07	0.0	4.5E-07	1.8
1988	7.5E-08	0.4	9.5E-08	0.4	9.5E-08	0.0	3.3E-07	1.3
1989	5.0E-08	0.3	6.6E-08	0.3	6.6E-08	0.0	9.1E-08	0.4
1990	3.6E-08	0.2	4.7E-08	0.2	4.7E-08	0.0	5.0E-08	0.2
1991	2.8E-08	0.1	3.7E-08	0.1	3.7E-08	0.0	4.0E-08	0.2
1992	2.0E-08	0.1	2.7E-08	0.1	2.7E-08	0.0	2.7E-08	0.1

Total	1.9E-05	100.0	2.5E-05	100.0	3.7E-04	100.0	2.5E-05	100.0

Table 6.C Total Cancer Fatality Risk By Year For Rural Family Two

Year	Adult Female		Adult Male		Child Born in 1955		Child Born in 1964	
	Risk	Percent	Risk	Percent	Risk	Percent	Risk	Percent
1954	2.0E-08	0.3	2.0E-08	0.2	--	--	--	--
1955	4.4E-07	7.0	5.8E-07	7.3	2.3E-06	4.0	--	--
1956	1.2E-06	18.1	1.6E-06	20.0	2.6E-05	46.9	--	--
1957	4.1E-07	6.4	5.3E-07	6.7	6.5E-06	11.4	--	--
1958	3.4E-07	5.3	4.1E-07	5.2	2.5E-06	4.4	--	--
1959	3.6E-07	5.7	4.5E-07	5.6	4.4E-06	7.7	--	--
1960	2.3E-07	3.6	2.6E-07	3.3	1.1E-06	1.9	--	--
1961	2.7E-07	4.2	3.2E-07	4.0	1.6E-06	2.9	--	--
1962	2.5E-07	3.8	2.8E-07	3.6	1.1E-06	2.0	--	--
1963	2.5E-07	4.0	2.9E-07	3.7	1.2E-06	2.1	--	--
1964	2.7E-07	4.2	3.2E-07	4.0	1.3E-06	2.3	1.9E-06	12.3
1965	1.6E-07	2.5	1.9E-07	2.4	7.7E-07	1.4	1.2E-06	7.5
1966	1.6E-07	2.4	1.8E-07	2.3	7.4E-07	1.3	1.1E-06	7.1
1967	1.6E-07	2.6	1.9E-07	2.4	8.7E-07	1.5	1.1E-06	7.1
1968	1.5E-07	2.4	1.8E-07	2.3	9.8E-07	1.7	1.2E-06	7.7
1969	1.5E-07	2.4	1.9E-07	2.4	9.2E-07	1.6	8.1E-07	5.2
1970	9.1E-08	1.4	1.1E-07	1.4	3.3E-07	0.6	5.5E-07	3.5
1971	1.1E-07	1.7	1.3E-07	1.7	4.1E-07	0.7	6.9E-07	4.4
1972	1.3E-07	2.1	1.6E-07	2.0	4.9E-07	0.9	8.0E-07	5.1
1973	1.2E-07	1.9	1.4E-07	1.8	3.7E-07	0.7	7.4E-07	4.7
1974	1.0E-07	1.6	1.2E-07	1.5	3.1E-07	0.6	6.3E-07	4.0
1975	6.4E-08	1.0	7.8E-08	1.0	2.0E-07	0.4	4.1E-07	2.6
1976	5.9E-08	0.9	7.1E-08	0.9	1.8E-07	0.3	4.3E-07	2.7
1977	6.0E-08	0.9	7.3E-08	0.9	1.9E-07	0.3	4.4E-07	2.8
1978	6.6E-08	1.0	8.4E-08	1.1	2.5E-07	0.4	6.8E-07	4.3
1979	5.2E-08	0.8	6.5E-08	0.8	1.6E-07	0.3	2.5E-07	1.6
1980	5.6E-08	0.9	6.8E-08	0.9	6.8E-08	0.1	2.5E-07	1.6
1981	6.1E-08	1.0	7.5E-08	0.9	7.5E-08	0.1	2.7E-07	1.7
1982	6.4E-08	1.0	8.0E-08	1.0	8.0E-08	0.1	2.4E-07	1.6
1983	7.5E-08	1.2	9.5E-08	1.2	9.5E-08	0.2	2.9E-07	1.8
1984	9.5E-08	1.5	1.2E-07	1.5	1.2E-07	0.2	3.6E-07	2.3
1985	8.8E-08	1.4	1.1E-07	1.4	1.1E-07	0.2	3.4E-07	2.1
1986	7.3E-08	1.2	8.8E-08	1.1	8.8E-08	0.2	3.1E-07	1.9
1987	7.6E-08	1.2	9.2E-08	1.2	9.2E-08	0.2	3.0E-07	1.9
1988	5.4E-08	0.8	6.8E-08	0.9	6.8E-08	0.1	2.2E-07	1.4
1989	3.6E-08	0.6	4.7E-08	0.6	4.7E-08	0.1	6.5E-08	0.4
1990	2.6E-08	0.4	3.4E-08	0.4	3.4E-08	0.1	3.6E-08	0.2
1991	2.0E-08	0.3	2.6E-08	0.3	2.6E-08	0.0	2.9E-08	0.2
1992	1.5E-08	0.2	1.9E-08	0.2	1.9E-08	0.0	1.9E-08	0.1

Total	6.4E-06	100.0	8.0E-06	100.0	5.6E-05	100.0	1.6E-05	100.0

APPENDIX J TABLES OF DOSES AND RISKS BY EXPOSURE ROUTE

This appendix presents the calculated 39-year Total Effective Dose, Total Cancer Incident Risk, and Total Cancer Fatality Risk for the hypothetical individual in each scenario. The 39-year Total Effective Dose, Total Cancer Incident Risk, and Total Cancer Fatality Risk are listed by exposure route and in separate tables grouped by different release pathways when applicable.

Tables are presented electronically via the following links for each scenario.

Delivery Family Scenario

Urban Family Scenario

Migrant Family Scenario

Outdoor Family Scenario

Near Water Family Scenario

Rural Family One Scenario

Rural Family Two Scenario

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Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Delivery Family From Atmospheric Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	5.9E-05	15.0	2.8E-06	24.2	2.0E-06	40.8
	Ingestion	2.8E-04	70.1	7.4E-06	62.9	2.2E-06	43.5
	Inhalation	5.9E-05	15.0	1.5E-06	12.8	7.8E-07	15.6
	Total	4.0E-04	100.0	1.2E-05	100.0	5.0E-06	100.0
Adult Male	External	9.7E-05	17.0	4.7E-06	27.2	3.3E-06	45.4
	Ingestion	4.0E-04	69.6	1.0E-05	61.1	3.0E-06	40.3
	Inhalation	7.7E-05	13.4	2.0E-06	11.6	1.1E-06	14.4
	Total	5.7E-04	100.0	1.7E-05	100.0	7.4E-06	100.0
Child born 1955	External	6.5E-05	3.0	1.0E-05	4.7	6.7E-06	17.7
	Ingestion	1.9E-03	89.5	1.9E-04	87.9	2.7E-05	72.2
	Inhalation	1.6E-04	7.5	1.6E-05	7.4	3.8E-06	10.1
	Total	2.1E-03	100.0	2.2E-04	100.0	3.8E-05	100.0
Child born 1964	External	2.8E-05	23.6	4.8E-06	26.1	3.1E-06	27.2
	Ingestion	7.4E-05	61.8	1.1E-05	61.8	6.9E-06	59.9
	Inhalation	1.7E-05	14.6	2.2E-06	12.1	1.5E-06	12.9
	Total	1.2E-04	100.0	1.8E-05	100.0	1.1E-05	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Delivery Family From Liquid Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	4.4E-05	0.8	1.7E-06	0.6	1.3E-06	0.6
	Ingestion	5.7E-03	99.2	2.7E-04	99.4	2.0E-04	99.4
	Total	5.7E-03	100.0	2.7E-04	100.0	2.0E-04	100.0
Adult Male	External	4.4E-05	0.8	1.7E-06	0.6	1.3E-06	0.6
	Ingestion	5.7E-03	99.2	2.7E-04	99.4	2.0E-04	99.4
	Total	5.7E-03	100.0	2.7E-04	100.0	2.0E-04	100.0
Child born 1955	External	4.4E-05	1.4	5.6E-06	1.2	3.7E-06	1.2
	Ingestion	3.0E-03	98.6	4.8E-04	98.8	3.1E-04	98.8
	Total	3.1E-03	100.0	4.8E-04	100.0	3.2E-04	100.0
Child born 1964	External	2.9E-05	1.5	4.0E-06	1.3	2.6E-06	1.3
	Ingestion	1.9E-03	98.5	3.1E-04	98.7	2.0E-04	98.7
	Total	2.0E-03	100.0	3.1E-04	100.0	2.1E-04	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Delivery Family From Atmospheric and Liquid Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	1.0E-04	1.7	4.6E-06	1.6	3.3E-06	1.6
	Ingestion	5.9E-03	97.3	2.8E-04	97.8	2.0E-04	98.0
	Inhalation	5.9E-05	1.0	1.5E-06	0.5	7.8E-07	0.4
	Total	6.1E-03	100.0	2.8E-04	100.0	2.0E-04	100.0
Adult Male	External	1.4E-04	2.2	6.4E-06	2.2	4.6E-06	2.2
	Ingestion	6.1E-03	96.5	2.8E-04	97.1	2.0E-04	97.3
	Inhalation	7.7E-05	1.2	2.0E-06	0.7	1.1E-06	0.5
	Total	6.3E-03	100.0	2.9E-04	100.0	2.1E-04	100.0
Child born 1955	External	1.1E-04	2.1	1.6E-05	2.3	1.0E-05	2.9
	Ingestion	4.9E-03	94.8	6.7E-04	95.5	3.4E-04	96.0
	Inhalation	1.6E-04	3.1	1.6E-05	2.3	3.8E-06	1.1
	Total	5.2E-03	100.0	7.0E-04	100.0	3.6E-04	100.0
Child born 1964	External	5.7E-05	2.7	8.7E-06	2.6	5.8E-06	2.7
	Ingestion	2.0E-03	96.4	3.2E-04	96.7	2.1E-04	96.6
	Inhalation	1.7E-05	0.8	2.2E-06	0.7	1.5E-06	0.7
	Total	2.1E-03	100.0	3.3E-04	100.0	2.2E-04	100.0

Table 6.x 39-Year Effective Doses and Risks via Exposure Route Over 39 Years for Urban Family

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	1.9E-05	5.9	9.3E-07	10.3	6.7E-07	21.0
	Ingestion	2.7E-04	82.2	7.1E-06	78.8	2.0E-06	63.3
	Inhalation	3.9E-05	11.9	9.8E-07	10.9	5.0E-07	15.7
	Total	3.3E-04	100.0	9.0E-06	100.0	3.2E-06	100.0
Adult Male	External	2.6E-04	35.5	1.2E-05	50.1	8.9E-06	68.6
	Ingestion	3.8E-04	52.2	9.9E-06	39.7	2.7E-06	20.5
	Inhalation	9.0E-05	12.3	2.5E-06	10.1	1.4E-06	10.8
	Total	7.3E-04	100.0	2.5E-05	100.0	1.3E-05	100.0
Child born 1955	External	6.0E-05	2.2	7.1E-06	2.7	4.8E-06	11.6
	Ingestion	2.5E-03	93.5	2.5E-04	93.0	3.4E-05	81.5
	Inhalation	1.2E-04	4.3	1.1E-05	4.3	2.9E-06	6.9
	Total	2.7E-03	100.0	2.7E-04	100.0	4.1E-05	100.0
Child born 1964	External	2.0E-05	18.9	3.0E-06	19.2	2.0E-06	20.5
	Ingestion	7.3E-05	67.9	1.1E-05	69.7	6.6E-06	67.6
	Inhalation	1.4E-05	13.2	1.8E-06	11.1	1.2E-06	11.9
	Total	1.1E-04	100.0	1.6E-05	100.0	9.8E-06	100.0

Table 6.x 39-Year Effective Doses and Risks via Exposure Route Over 39 Years for Migrant Family

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	4.4E-05	9.9	2.1E-06	17.7	1.5E-06	36.1
	Ingestion	3.4E-04	75.9	8.4E-06	70.3	1.9E-06	45.8
	Inhalation	6.4E-05	14.2	1.4E-06	12.0	7.6E-07	18.1
	Total	4.5E-04	100.0	1.2E-05	100.0	4.2E-06	100.0
Adult Male	External	4.5E-05	7.1	2.1E-06	13.2	1.5E-06	29.3
	Ingestion	4.9E-04	79.1	1.2E-05	74.9	2.7E-06	51.0
	Inhalation	8.6E-05	13.7	1.9E-06	11.9	1.0E-06	19.7
	Total	6.2E-04	100.0	1.6E-05	100.0	5.2E-06	100.0
Child born 1955	External	4.4E-05	2.0	7.2E-06	3.3	4.7E-06	14.1
	Ingestion	2.0E-03	90.7	1.9E-04	89.6	2.5E-05	75.3
	Inhalation	1.6E-04	7.3	1.5E-05	7.0	3.6E-06	10.7
	Total	2.2E-03	100.0	2.2E-04	100.0	3.4E-05	100.0
Child born 1964	External	1.9E-05	23.3	3.3E-06	26.5	2.2E-06	28.2
	Ingestion	4.8E-05	58.2	7.5E-06	59.9	4.4E-06	56.7
	Inhalation	1.5E-05	18.4	1.7E-06	13.6	1.2E-06	15.1
	Total	8.3E-05	100.0	1.3E-05	100.0	7.8E-06	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Outdoor Family From Atmospheric Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	9.4E-05	6.0	4.5E-06	10.8	3.2E-06	25.0
	Ingestion	1.4E-03	87.4	3.5E-05	83.1	8.4E-06	65.0
	Inhalation	1.0E-04	6.6	2.5E-06	6.1	1.3E-06	9.9
	Total	1.6E-03	100.0	4.2E-05	100.0	1.3E-05	100.0
Adult Male	External	3.2E-04	12.6	1.5E-05	21.5	1.1E-05	43.2
	Ingestion	2.1E-03	81.2	5.2E-05	72.7	1.2E-05	48.1
	Inhalation	1.6E-04	6.2	4.1E-06	5.8	2.2E-06	8.8
	Total	2.5E-03	100.0	7.1E-05	100.0	2.5E-05	100.0
Child born 1955	External	1.3E-04	1.6	1.9E-05	2.3	1.3E-05	10.2
	Ingestion	7.9E-03	94.9	7.7E-04	94.2	1.0E-04	84.4
	Inhalation	2.9E-04	3.5	2.8E-05	3.4	6.6E-06	5.4
	Total	8.3E-03	100.0	8.2E-04	100.0	1.2E-04	100.0
Child born 1964	External	5.3E-05	14.7	8.8E-06	16.6	5.8E-06	19.2
	Ingestion	2.8E-04	77.1	4.1E-05	76.6	2.2E-05	72.8
	Inhalation	3.0E-05	8.2	3.6E-06	6.8	2.4E-06	8.0
	Total	3.6E-04	100.0	5.3E-05	100.0	3.0E-05	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Outdoor Family From Liquid Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	8.2E-08	0.0	2.5E-09	0.0	2.1E-09	0.0
	Ingestion	1.5E-03	100.0	6.3E-05	100.0	4.8E-05	100.0
	Total	1.5E-03	100.0	6.3E-05	100.0	4.8E-05	100.0
Adult Male	External	2.3E-04	13.6	8.8E-06	12.2	6.4E-06	11.7
	Ingestion	1.5E-03	86.4	6.3E-05	87.8	4.8E-05	88.3
	Total	1.7E-03	100.0	7.2E-05	100.0	5.5E-05	100.0
Child born 1955	External	5.3E-05	4.5	3.9E-06	2.2	2.7E-06	2.3
	Ingestion	1.1E-03	95.5	1.7E-04	97.8	1.1E-04	97.7
	Total	1.2E-03	100.0	1.8E-04	100.0	1.1E-04	100.0
Child born 1964	External	1.7E-05	1.1	1.9E-06	0.6	1.3E-06	0.7
	Ingestion	1.4E-03	98.9	3.0E-04	99.4	1.9E-04	99.3
	Total	1.5E-03	100.0	3.0E-04	100.0	2.0E-04	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Outdoor Family From Atmospheric and Liquid Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	9.4E-05	3.1	4.5E-06	4.3	3.2E-06	5.3
	Ingestion	2.8E-03	93.5	9.8E-05	93.3	5.7E-05	92.6
	Inhalation	1.0E-04	3.4	2.5E-06	2.4	1.3E-06	2.1
	Total	3.0E-03	100.0	1.1E-04	100.0	6.1E-05	100.0
Adult Male	External	5.5E-04	13.0	2.4E-05	16.8	1.7E-05	21.7
	Ingestion	3.5E-03	83.3	1.1E-04	80.3	6.0E-05	75.5
	Inhalation	1.6E-04	3.7	4.1E-06	2.9	2.2E-06	2.8
	Total	4.2E-03	100.0	1.4E-04	100.0	8.0E-05	100.0
Child born 1955	External	1.8E-04	2.0	2.3E-05	2.3	1.5E-05	6.4
	Ingestion	9.0E-03	95.0	9.5E-04	94.9	2.2E-04	90.8
	Inhalation	2.9E-04	3.1	2.8E-05	2.8	6.6E-06	2.8
	Total	9.4E-03	100.0	1.0E-03	100.0	2.4E-04	100.0
Child born 1964	External	7.0E-05	3.8	1.1E-05	3.0	7.1E-06	3.1
	Ingestion	1.7E-03	94.5	3.4E-04	95.9	2.2E-04	95.8
	Inhalation	3.0E-05	1.6	3.6E-06	1.0	2.4E-06	1.1
	Total	1.8E-03	100.0	3.5E-04	100.0	2.3E-04	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Near Water Family From Atmospheric Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	3.9E-05	12.5	1.9E-06	20.8	1.3E-06	37.4
	Ingestion	2.3E-04	74.9	6.1E-06	68.1	1.7E-06	48.1
	Inhalation	3.9E-05	12.6	9.9E-07	11.1	5.2E-07	14.5
	Total	3.1E-04	100.0	8.9E-06	100.0	3.6E-06	100.0
Adult Male	External	3.9E-05	9.1	1.9E-06	15.7	1.3E-06	30.5
	Ingestion	3.3E-04	78.5	8.6E-06	73.0	2.3E-06	53.6
	Inhalation	5.2E-05	12.4	1.3E-06	11.3	7.0E-07	15.9
	Total	4.2E-04	100.0	1.2E-05	100.0	4.4E-06	100.0
Child born 1955	External	3.8E-05	2.3	6.3E-06	3.7	4.1E-06	14.5
	Ingestion	1.6E-03	91.6	1.5E-04	90.3	2.2E-05	76.8
	Inhalation	1.0E-04	6.1	1.0E-05	6.1	2.5E-06	8.7
	Total	1.7E-03	100.0	1.7E-04	100.0	2.8E-05	100.0
Child born 1964	External	1.8E-05	20.3	3.1E-06	22.8	2.0E-06	23.9
	Ingestion	5.8E-05	66.5	8.9E-06	66.2	5.4E-06	64.3
	Inhalation	1.2E-05	13.2	1.5E-06	11.0	9.9E-07	11.8
	Total	8.8E-05	100.0	1.3E-05	100.0	8.4E-06	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Near Water Family From Liquid Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	3.2E-04	18.0	1.2E-05	16.3	9.0E-06	15.7
	Ingestion	1.5E-03	82.0	6.3E-05	83.7	4.8E-05	84.3
	Total	1.8E-03	100.0	7.6E-05	100.0	5.7E-05	100.0
Adult Male	External	3.2E-04	18.0	1.2E-05	16.3	9.0E-06	15.7
	Ingestion	1.5E-03	82.0	6.3E-05	83.7	4.8E-05	84.3
	Total	1.8E-03	100.0	7.6E-05	100.0	5.7E-05	100.0
Child born 1955	External	3.2E-04	22.4	4.0E-05	18.5	2.6E-05	19.1
	Ingestion	1.1E-03	77.6	1.7E-04	81.5	1.1E-04	80.9
	Total	1.4E-03	100.0	2.1E-04	100.0	1.4E-04	100.0
Child born 1964	External	2.2E-04	13.3	3.0E-05	9.2	2.0E-05	9.4
	Ingestion	1.4E-03	86.7	3.0E-04	90.8	1.9E-04	90.6
	Total	1.7E-03	100.0	3.3E-04	100.0	2.1E-04	100.0

Table 6.x 39-Year Effective Dose and Risks via Exposure Route For Near Water Family From Atmospheric and Liquid Releases

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	3.6E-04	17.2	1.4E-05	16.8	1.0E-05	17.0
	Ingestion	1.7E-03	80.9	7.0E-05	82.0	5.0E-05	82.2
	Inhalation	3.9E-05	1.9	9.9E-07	1.2	5.2E-07	0.9
	Total	2.1E-03	100.0	8.5E-05	100.0	6.1E-05	100.0
Adult Male	External	3.6E-04	16.3	1.4E-05	16.2	1.0E-05	16.7
	Ingestion	1.8E-03	81.3	7.2E-05	82.2	5.1E-05	82.1
	Inhalation	5.2E-05	2.4	1.3E-06	1.5	7.0E-07	1.1
	Total	2.2E-03	100.0	8.8E-05	100.0	6.2E-05	100.0
Child born 1955	External	3.6E-04	11.5	4.6E-05	11.9	3.1E-05	18.3
	Ingestion	2.7E-03	85.2	3.3E-04	85.4	1.3E-04	80.2
	Inhalation	1.0E-04	3.3	1.0E-05	2.7	2.5E-06	1.5
	Total	3.1E-03	100.0	3.8E-04	100.0	1.7E-04	100.0
Child born 1964	External	2.4E-04	13.7	3.3E-05	9.8	2.2E-05	10.0
	Ingestion	1.5E-03	85.7	3.1E-04	89.8	2.0E-04	89.6
	Inhalation	1.2E-05	0.7	1.5E-06	0.4	9.9E-07	0.4
	Total	1.8E-03	100.0	3.4E-04	100.0	2.2E-04	100.0

Table 6.x 39-Year Effective Doses and Risks via Exposure Route Over 39 Years for Rural Family One

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	2.7E-05	8.8	1.3E-06	15.3	9.1E-07	30.3
	Ingestion	2.4E-04	79.8	6.2E-06	74.8	1.6E-06	54.7
	Inhalation	3.5E-05	11.4	8.3E-07	10.0	4.5E-07	15.0
	Total	3.0E-04	100.0	8.3E-06	100.0	3.0E-06	100.0
Adult Male	External	2.7E-05	6.3	1.3E-06	11.3	9.2E-07	24.3
	Ingestion	3.5E-04	82.7	8.9E-06	78.8	2.3E-06	59.6
	Inhalation	4.7E-05	11.0	1.1E-06	9.9	6.1E-07	16.1
	Total	4.2E-04	100.0	1.1E-05	100.0	3.8E-06	100.0
Child born 1955	External	2.6E-05	1.7	4.3E-06	2.7	2.8E-06	11.2
	Ingestion	1.5E-03	93.0	1.5E-04	92.1	2.0E-05	80.5
	Inhalation	8.5E-05	5.4	8.3E-06	5.2	2.1E-06	8.3
	Total	1.6E-03	100.0	1.6E-04	100.0	2.5E-05	100.0
Child born 1964	External	1.2E-05	16.8	2.1E-06	18.9	1.4E-06	19.9
	Ingestion	5.0E-05	69.5	7.7E-06	70.2	4.7E-06	68.2
	Inhalation	9.9E-06	13.7	1.2E-06	10.9	8.1E-07	11.8
	Total	7.2E-05	100.0	1.1E-05	100.0	6.9E-06	100.0

Table 6.x 39-Year Effective Doses and Risks via Exposure Route Over 39 Years for Rural Family Two

Receptor	Exposure Route	Effective Dose		Total Cancer Incidence Risk		Total Cancer Fatality Risk	
		Dose (Sv)	Percent	Risk	Percent	Risk	Percent
Adult Female	External	6.0E-05	8.6	2.9E-06	15.3	2.1E-06	32.3
	Ingestion	5.6E-04	81.0	1.4E-05	75.7	3.4E-06	53.5
	Inhalation	7.3E-05	10.4	1.7E-06	9.0	9.1E-07	14.3
	Total	7.0E-04	100.0	1.9E-05	100.0	6.4E-06	100.0
Adult Male	External	6.0E-05	6.2	2.9E-06	11.3	2.1E-06	25.9
	Ingestion	8.2E-04	83.8	2.0E-05	79.8	4.7E-06	58.8
	Inhalation	9.8E-05	10.0	2.3E-06	8.9	1.2E-06	15.3
	Total	9.7E-04	100.0	2.5E-05	100.0	8.0E-06	100.0
Child born 1955	External	5.9E-05	1.6	9.6E-06	2.6	6.3E-06	11.2
	Ingestion	3.5E-03	93.6	3.4E-04	92.7	4.6E-05	81.3
	Inhalation	1.8E-04	4.8	1.7E-05	4.7	4.2E-06	7.5
	Total	3.8E-03	100.0	3.7E-04	100.0	5.6E-05	100.0
Child born 1964	External	3.9E-05	23.6	6.6E-06	26.3	4.4E-06	27.7
	Ingestion	1.1E-04	63.8	1.6E-05	63.9	9.7E-06	61.7
	Inhalation	2.1E-05	12.5	2.5E-06	9.8	1.7E-06	10.6
	Total	1.6E-04	100.0	2.5E-05	100.0	1.6E-05	100.0

APPENDIX K TABLES OF DOSES AND RISKS BY PATHWAY AND RADIONUCLIDE

This appendix presents the calculated 39-year Total Effective Dose, Total Cancer Incident Risk, and Total Cancer Fatality Risk for the hypothetical individual in each scenario. The 39-year Total Effective Dose, Total Cancer Incident Risk, and Total Cancer Fatality Risk are listed by exposure route and isotope for each hypothetical individual in separate tables grouped by different release pathways when applicable.

Tables are presented electronically via the following links for each scenario.

Delivery Family Scenario

Urban Family Scenario

Migrant Family Scenario

Outdoor Family Scenario

Near Water Family Scenario

Rural Family One Scenario

Rural Family Two Scenario

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Location	Receptor	ReportRoute	ReportPathway	IsotopeNar	SumOfSun	SumOfSun	SumOfSun	AirWater	RunNum
Delivery Family	Adult Female	Ingestion	Fish	Ce-144	1.18E-06	5.55E-08	3.11E-08	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Co-60	9.72E-07	4.1E-08	2.79E-08	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Cs-134	4.6E-06	2.24E-07	1.61E-07	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Cs-137	0.004689	0.000228	0.000163	Water	0
Delivery Family	Adult Female	Ingestion	Fish	H-3	2.17E-06	1.05E-07	7.55E-08	Water	0
Delivery Family	Adult Female	Ingestion	Fish	I-129	4.04E-07	8.79E-09	9.02E-10	Water	0
Delivery Family	Adult Female	Ingestion	Fish	I-131	4.52E-06	1E-07	1.1E-08	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Nb-95	1.42E-06	5.47E-08	3.31E-08	Water	0
Delivery Family	Adult Female	Ingestion	Fish	P-32	0.000266	1.3E-05	1.02E-05	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Pu-238	1.55E-05	1.76E-07	1.47E-07	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Pu-239	7.24E-05	7.74E-07	6.47E-07	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Ru-106	1.56E-06	7.38E-08	4.35E-08	Water	0
Delivery Family	Adult Female	Ingestion	Fish	S-35	3.02E-06	1.57E-07	1.04E-07	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Sr-89	3.93E-06	1.88E-07	1.26E-07	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Sr-90	0.000591	2.47E-05	2.29E-05	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Tc-99	2.06E-08	7.52E-10	4.58E-10	Water	0
Delivery Family	Adult Female	Ingestion	Fish	U-234	3.01E-09	6.38E-11	4.44E-11	Water	0
Delivery Family	Adult Female	Ingestion	Fish	U-235	1.37E-09	2.98E-11	2.05E-11	Water	0
Delivery Family	Adult Female	Ingestion	Fish	U-236	1.7E-10	3.62E-12	2.5E-12	Water	0
Delivery Family	Adult Female	Ingestion	Fish	U-238	9.72E-08	2.09E-09	1.46E-09	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Zn-65	6.52E-06	3.11E-07	2.25E-07	Water	0
Delivery Family	Adult Female	Ingestion	Fish	Zr-95	1.57E-06	6.48E-08	3.95E-08	Water	0
Delivery Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	2.01E-07	8.91E-09	6.41E-09	Water	0
Delivery Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	3.26E-07	1.44E-08	1.04E-08	Water	0

Delivery Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	2.46E-07	9.62E-09	9.09E-09	Water	0
Delivery Family	Adult Female	External	Swimming	Cs-137	5.88E-08	3.53E-09	2.94E-09	Water	0
Delivery Family	Adult Female	External	Swimming	Sr-90	6.98E-11	4.19E-12	3.49E-12	Water	0
Delivery Family	Adult Female	External	Boating	Ce-144	1.68E-09	5.04E-11	4.2E-11	Water	0
Delivery Family	Adult Female	External	Boating	Co-60	8.48E-09	2.54E-10	2.12E-10	Water	0
Delivery Family	Adult Female	External	Boating	Cs-134	2.71E-10	8.15E-12	6.78E-12	Water	0
Delivery Family	Adult Female	External	Boating	Cs-137	8.58E-09	2.57E-10	2.14E-10	Water	0
Delivery Family	Adult Female	External	Boating	I-129	2.19E-12	6.56E-14	5.46E-14	Water	0
Delivery Family	Adult Female	External	Boating	I-131	7.22E-09	2.17E-10	1.81E-10	Water	0
Delivery Family	Adult Female	External	Boating	Nb-95	2.17E-08	6.5E-10	5.42E-10	Water	0
Delivery Family	Adult Female	External	Boating	P-32	5.21E-11	1.56E-12	1.3E-12	Water	0
Delivery Family	Adult Female	External	Boating	Pu-238	4.11E-15	1.23E-16	1.03E-16	Water	0
Delivery Family	Adult Female	External	Boating	Pu-239	1.67E-14	5.03E-16	4.19E-16	Water	0
Delivery Family	Adult Female	External	Boating	Ru-106	1.7E-08	5.11E-10	4.26E-10	Water	0
Delivery Family	Adult Female	External	Boating	S-35	3.45E-12	1.04E-13	8.62E-14	Water	0
Delivery Family	Adult Female	External	Boating	Sr-89	6.31E-11	1.89E-12	1.58E-12	Water	0
Delivery Family	Adult Female	External	Boating	Sr-90	1.85E-11	5.55E-13	4.62E-13	Water	0
Delivery Family	Adult Female	External	Boating	Tc-99	1.75E-12	5.24E-14	4.37E-14	Water	0
Delivery Family	Adult Female	External	Boating	U-234	2.95E-15	8.84E-17	7.36E-17	Water	0
Delivery Family	Adult Female	External	Boating	U-235	1.46E-12	4.38E-14	3.65E-14	Water	0
Delivery Family	Adult Female	External	Boating	U-236	1.12E-16	3.37E-18	2.81E-18	Water	0
Delivery Family	Adult Female	External	Boating	U-238	4.44E-14	1.33E-15	1.11E-15	Water	0
Delivery Family	Adult Female	External	Boating	Zn-65	3.41E-09	1.02E-10	8.53E-11	Water	0
Delivery Family	Adult Female	External	Boating	Zr-95	1.38E-08	4.14E-10	3.45E-10	Water	0
Delivery Family	Adult Female	External	Shoreline	Ce-144	2.24E-06	4.38E-08	3.44E-08	Water	0
Delivery Family	Adult Female	External	Shoreline	Co-60	5.1E-06	2.46E-07	1.75E-07	Water	0
Delivery Family	Adult Female	External	Shoreline	Cs-134	1.6E-07	7.65E-09	5.46E-09	Water	0
Delivery Family	Adult Female	External	Shoreline	Cs-137	1.19E-05	5.61E-07	4.01E-07	Water	0
Delivery Family	Adult Female	External	Shoreline	I-129	4.67E-09	1.77E-10	1.18E-10	Water	0
Delivery Family	Adult Female	External	Shoreline	I-131	1.63E-07	7.76E-09	5.56E-09	Water	0
Delivery Family	Adult Female	External	Shoreline	Nb-95	2.07E-06	9.95E-08	7.1E-08	Water	0
Delivery Family	Adult Female	External	Shoreline	P-32	2.78E-08	2.38E-10	2.26E-10	Water	0
Delivery Family	Adult Female	External	Shoreline	Pu-238	2.25E-11	6.65E-13	4.06E-13	Water	0

Delivery Family	Adult Female	External	Shoreline	Pu-239	4.36E-11	1.42E-12	9.07E-13	Water	0
Delivery Family	Adult Female	External	Shoreline	Ru-106	1.39E-05	4.4E-07	3.25E-07	Water	0
Delivery Family	Adult Female	External	Shoreline	S-35	3.13E-10	1.2E-11	8.05E-12	Water	0
Delivery Family	Adult Female	External	Shoreline	Sr-89	1.17E-07	9.99E-10	9.51E-10	Water	0
Delivery Family	Adult Female	External	Shoreline	Sr-90	2.04E-06	1.86E-08	1.74E-08	Water	0
Delivery Family	Adult Female	External	Shoreline	Tc-99	2.6E-10	1.07E-11	7.36E-12	Water	0
Delivery Family	Adult Female	External	Shoreline	U-234	8.88E-12	2.82E-13	1.79E-13	Water	0
Delivery Family	Adult Female	External	Shoreline	U-235	1.14E-09	5.33E-11	3.79E-11	Water	0
Delivery Family	Adult Female	External	Shoreline	U-236	4.56E-13	1.4E-14	8.7E-15	Water	0
Delivery Family	Adult Female	External	Shoreline	U-238	5.98E-08	9.9E-10	8.01E-10	Water	0
Delivery Family	Adult Female	External	Shoreline	Zn-65	1.39E-06	6.69E-08	4.77E-08	Water	0
Delivery Family	Adult Female	External	Shoreline	Zr-95	4.75E-06	2.28E-07	1.62E-07	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Ce-144	1.18E-06	5.55E-08	3.11E-08	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Co-60	9.72E-07	4.1E-08	2.79E-08	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Cs-134	4.6E-06	2.24E-07	1.61E-07	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Cs-137	0.004689	0.000228	0.000163	Water	0
Delivery Family	Adult Male	Ingestion	Fish	H-3	2.17E-06	1.05E-07	7.55E-08	Water	0
Delivery Family	Adult Male	Ingestion	Fish	I-129	4.04E-07	8.79E-09	9.02E-10	Water	0
Delivery Family	Adult Male	Ingestion	Fish	I-131	4.52E-06	1E-07	1.1E-08	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Nb-95	1.42E-06	5.47E-08	3.31E-08	Water	0
Delivery Family	Adult Male	Ingestion	Fish	P-32	0.000266	1.3E-05	1.02E-05	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Pu-238	1.55E-05	1.76E-07	1.47E-07	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Pu-239	7.24E-05	7.74E-07	6.47E-07	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Ru-106	1.56E-06	7.38E-08	4.35E-08	Water	0
Delivery Family	Adult Male	Ingestion	Fish	S-35	3.02E-06	1.57E-07	1.04E-07	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Sr-89	3.93E-06	1.88E-07	1.26E-07	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Sr-90	0.000591	2.47E-05	2.29E-05	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Tc-99	2.06E-08	7.52E-10	4.58E-10	Water	0
Delivery Family	Adult Male	Ingestion	Fish	U-234	3.01E-09	6.38E-11	4.44E-11	Water	0
Delivery Family	Adult Male	Ingestion	Fish	U-235	1.37E-09	2.98E-11	2.05E-11	Water	0
Delivery Family	Adult Male	Ingestion	Fish	U-236	1.7E-10	3.62E-12	2.5E-12	Water	0
Delivery Family	Adult Male	Ingestion	Fish	U-238	9.72E-08	2.09E-09	1.46E-09	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Zn-65	6.52E-06	3.11E-07	2.25E-07	Water	0
Delivery Family	Adult Male	Ingestion	Fish	Zr-95	1.57E-06	6.48E-08	3.95E-08	Water	0

Delivery Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	2.01E-07	8.91E-09	6.41E-09	Water	0
Delivery Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	3.26E-07	1.44E-08	1.04E-08	Water	0
Delivery Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	2.46E-07	9.62E-09	9.09E-09	Water	0
Delivery Family	Adult Male	External	Swimming	Cs-137	5.88E-08	3.53E-09	2.94E-09	Water	0
Delivery Family	Adult Male	External	Swimming	Sr-90	6.98E-11	4.19E-12	3.49E-12	Water	0
Delivery Family	Adult Male	External	Boating	Ce-144	1.68E-09	5.04E-11	4.2E-11	Water	0
Delivery Family	Adult Male	External	Boating	Co-60	8.48E-09	2.54E-10	2.12E-10	Water	0
Delivery Family	Adult Male	External	Boating	Cs-134	2.71E-10	8.15E-12	6.78E-12	Water	0
Delivery Family	Adult Male	External	Boating	Cs-137	8.58E-09	2.57E-10	2.14E-10	Water	0
Delivery Family	Adult Male	External	Boating	I-129	2.19E-12	6.56E-14	5.46E-14	Water	0
Delivery Family	Adult Male	External	Boating	I-131	7.22E-09	2.17E-10	1.81E-10	Water	0
Delivery Family	Adult Male	External	Boating	Nb-95	2.17E-08	6.5E-10	5.42E-10	Water	0
Delivery Family	Adult Male	External	Boating	P-32	5.21E-11	1.56E-12	1.3E-12	Water	0
Delivery Family	Adult Male	External	Boating	Pu-238	4.11E-15	1.23E-16	1.03E-16	Water	0
Delivery Family	Adult Male	External	Boating	Pu-239	1.67E-14	5.03E-16	4.19E-16	Water	0
Delivery Family	Adult Male	External	Boating	Ru-106	1.7E-08	5.11E-10	4.26E-10	Water	0
Delivery Family	Adult Male	External	Boating	S-35	3.45E-12	1.04E-13	8.62E-14	Water	0
Delivery Family	Adult Male	External	Boating	Sr-89	6.31E-11	1.89E-12	1.58E-12	Water	0
Delivery Family	Adult Male	External	Boating	Sr-90	1.85E-11	5.55E-13	4.62E-13	Water	0
Delivery Family	Adult Male	External	Boating	Tc-99	1.75E-12	5.24E-14	4.37E-14	Water	0
Delivery Family	Adult Male	External	Boating	U-234	2.95E-15	8.84E-17	7.36E-17	Water	0
Delivery Family	Adult Male	External	Boating	U-235	1.46E-12	4.38E-14	3.65E-14	Water	0
Delivery Family	Adult Male	External	Boating	U-236	1.12E-16	3.37E-18	2.81E-18	Water	0
Delivery Family	Adult Male	External	Boating	U-238	4.44E-14	1.33E-15	1.11E-15	Water	0
Delivery Family	Adult Male	External	Boating	Zn-65	3.41E-09	1.02E-10	8.53E-11	Water	0

Delivery Family	Adult Male	External	Boating	Zr-95	1.38E-08	4.14E-10	3.45E-10	Water	0
Delivery Family	Adult Male	External	Shoreline	Ce-144	2.24E-06	4.38E-08	3.44E-08	Water	0
Delivery Family	Adult Male	External	Shoreline	Co-60	5.1E-06	2.46E-07	1.75E-07	Water	0
Delivery Family	Adult Male	External	Shoreline	Cs-134	1.6E-07	7.65E-09	5.46E-09	Water	0
Delivery Family	Adult Male	External	Shoreline	Cs-137	1.19E-05	5.61E-07	4.01E-07	Water	0
Delivery Family	Adult Male	External	Shoreline	I-129	4.67E-09	1.77E-10	1.18E-10	Water	0
Delivery Family	Adult Male	External	Shoreline	I-131	1.63E-07	7.76E-09	5.56E-09	Water	0
Delivery Family	Adult Male	External	Shoreline	Nb-95	2.07E-06	9.95E-08	7.1E-08	Water	0
Delivery Family	Adult Male	External	Shoreline	P-32	2.78E-08	2.38E-10	2.26E-10	Water	0
Delivery Family	Adult Male	External	Shoreline	Pu-238	2.25E-11	6.65E-13	4.06E-13	Water	0
Delivery Family	Adult Male	External	Shoreline	Pu-239	4.36E-11	1.42E-12	9.07E-13	Water	0
Delivery Family	Adult Male	External	Shoreline	Ru-106	1.39E-05	4.4E-07	3.25E-07	Water	0
Delivery Family	Adult Male	External	Shoreline	S-35	3.13E-10	1.2E-11	8.05E-12	Water	0
Delivery Family	Adult Male	External	Shoreline	Sr-89	1.17E-07	9.99E-10	9.51E-10	Water	0
Delivery Family	Adult Male	External	Shoreline	Sr-90	2.04E-06	1.86E-08	1.74E-08	Water	0
Delivery Family	Adult Male	External	Shoreline	Tc-99	2.6E-10	1.07E-11	7.36E-12	Water	0
Delivery Family	Adult Male	External	Shoreline	U-234	8.88E-12	2.82E-13	1.79E-13	Water	0
Delivery Family	Adult Male	External	Shoreline	U-235	1.14E-09	5.33E-11	3.79E-11	Water	0
Delivery Family	Adult Male	External	Shoreline	U-236	4.56E-13	1.4E-14	8.7E-15	Water	0
Delivery Family	Adult Male	External	Shoreline	U-238	5.98E-08	9.9E-10	8.01E-10	Water	0
Delivery Family	Adult Male	External	Shoreline	Zn-65	1.39E-06	6.69E-08	4.77E-08	Water	0
Delivery Family	Adult Male	External	Shoreline	Zr-95	4.75E-06	2.28E-07	1.62E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Ce-144	1.4E-06	5.06E-07	2.8E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Co-60	1.51E-06	2.5E-07	1.59E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Cs-134	2.06E-06	3.32E-07	2.19E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Cs-137	0.002059	0.000357	0.000232	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	H-3	1.63E-06	2.4E-07	1.6E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	I-129	4.04E-07	8.79E-09	9.02E-10	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	I-131	7.21E-06	7.94E-07	8.31E-08	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Nb-95	1.48E-06	3.09E-07	1.76E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	P-32	0.000283	5.42E-05	3.46E-05	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Pu-238	7.22E-06	2.75E-07	2.02E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Pu-239	4.88E-05	1.58E-06	1.14E-06	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Ru-106	1.62E-06	4.72E-07	2.66E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	S-35	2.6E-06	6.21E-07	3.86E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Sr-89	3.65E-06	9.8E-07	5.71E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Sr-90	0.000581	5.9E-05	4.35E-05	Water	0

Delivery Family	Child born 1955	Ingestion	Fish	Tc-99	3.11E-08	3.92E-09	2.21E-09	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	U-234	2.8E-09	2.87E-10	1.76E-10	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	U-235	1.06E-09	1.08E-10	6.66E-11	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	U-236	1.65E-10	1.7E-11	1.04E-11	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	U-238	7.42E-08	7.17E-09	4.44E-09	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Zn-65	5.51E-06	9.16E-07	6.04E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Fish	Zr-95	1.62E-06	3.2E-07	1.81E-07	Water	0
Delivery Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	1.61E-07	3.01E-08	1.95E-08	Water	0
Delivery Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	4.31E-07	7.01E-08	4.64E-08	Water	0
Delivery Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	4.95E-07	4.81E-08	3.66E-08	Water	0
Delivery Family	Child born 1955	External	Swimming	Cs-137	5.84E-08	3.5E-09	2.92E-09	Water	0
Delivery Family	Child born 1955	External	Swimming	Sr-90	6.91E-11	4.15E-12	3.46E-12	Water	0
Delivery Family	Child born 1955	External	Boating	Ce-144	1.68E-09	5.04E-11	4.2E-11	Water	0
Delivery Family	Child born 1955	External	Boating	Co-60	8.47E-09	2.54E-10	2.12E-10	Water	0
Delivery Family	Child born 1955	External	Boating	Cs-134	2.71E-10	8.15E-12	6.78E-12	Water	0
Delivery Family	Child born 1955	External	Boating	Cs-137	8.58E-09	2.57E-10	2.14E-10	Water	0
Delivery Family	Child born 1955	External	Boating	I-129	2.19E-12	6.56E-14	5.46E-14	Water	0
Delivery Family	Child born 1955	External	Boating	I-131	7.22E-09	2.17E-10	1.81E-10	Water	0
Delivery Family	Child born 1955	External	Boating	Nb-95	2.17E-08	6.5E-10	5.42E-10	Water	0
Delivery Family	Child born 1955	External	Boating	P-32	5.21E-11	1.56E-12	1.3E-12	Water	0
Delivery Family	Child born 1955	External	Boating	Pu-238	4.11E-15	1.23E-16	1.03E-16	Water	0
Delivery Family	Child born 1955	External	Boating	Pu-239	1.67E-14	5.02E-16	4.18E-16	Water	0
Delivery Family	Child born 1955	External	Boating	Ru-106	1.7E-08	5.11E-10	4.26E-10	Water	0
Delivery Family	Child born 1955	External	Boating	S-35	3.45E-12	1.04E-13	8.62E-14	Water	0
Delivery Family	Child born 1955	External	Boating	Sr-89	6.31E-11	1.89E-12	1.58E-12	Water	0

Delivery Family	Child born 1955	External	Boating	Sr-90	1.85E-11	5.54E-13	4.62E-13	Water	0
Delivery Family	Child born 1955	External	Boating	Tc-99	1.7E-12	5.1E-14	4.26E-14	Water	0
Delivery Family	Child born 1955	External	Boating	U-234	2.95E-15	8.84E-17	7.36E-17	Water	0
Delivery Family	Child born 1955	External	Boating	U-235	1.46E-12	4.38E-14	3.65E-14	Water	0
Delivery Family	Child born 1955	External	Boating	U-236	1.12E-16	3.37E-18	2.81E-18	Water	0
Delivery Family	Child born 1955	External	Boating	U-238	4.44E-14	1.33E-15	1.11E-15	Water	0
Delivery Family	Child born 1955	External	Boating	Zn-65	3.41E-09	1.02E-10	8.53E-11	Water	0
Delivery Family	Child born 1955	External	Boating	Zr-95	1.38E-08	4.14E-10	3.45E-10	Water	0
Delivery Family	Child born 1955	External	Shoreline	Ce-144	2.24E-06	1.42E-07	1.03E-07	Water	0
Delivery Family	Child born 1955	External	Shoreline	Co-60	5.09E-06	8.19E-07	5.39E-07	Water	0
Delivery Family	Child born 1955	External	Shoreline	Cs-134	1.6E-07	2.71E-08	1.78E-08	Water	0
Delivery Family	Child born 1955	External	Shoreline	Cs-137	1.19E-05	2E-06	1.31E-06	Water	0
Delivery Family	Child born 1955	External	Shoreline	I-129	4.67E-09	1.77E-10	1.18E-10	Water	0
Delivery Family	Child born 1955	External	Shoreline	I-131	1.63E-07	2.91E-08	1.9E-08	Water	0
Delivery Family	Child born 1955	External	Shoreline	Nb-95	2.07E-06	3.17E-07	2.09E-07	Water	0
Delivery Family	Child born 1955	External	Shoreline	P-32	2.78E-08	6.41E-10	5.89E-10	Water	0
Delivery Family	Child born 1955	External	Shoreline	Pu-238	2.25E-11	2.51E-12	1.45E-12	Water	0
Delivery Family	Child born 1955	External	Shoreline	Pu-239	4.35E-11	5.35E-12	3.19E-12	Water	0
Delivery Family	Child born 1955	External	Shoreline	Ru-106	1.39E-05	1.31E-06	8.99E-07	Water	0
Delivery Family	Child born 1955	External	Shoreline	S-35	3.13E-10	4.55E-11	2.84E-11	Water	0
Delivery Family	Child born 1955	External	Shoreline	Sr-89	1.17E-07	2.55E-09	2.34E-09	Water	0
Delivery Family	Child born 1955	External	Shoreline	Sr-90	2.03E-06	5.01E-08	4.48E-08	Water	0
Delivery Family	Child born 1955	External	Shoreline	Tc-99	2.53E-10	2.3E-11	1.5E-11	Water	0
Delivery Family	Child born 1955	External	Shoreline	U-234	8.88E-12	1.14E-12	6.77E-13	Water	0
Delivery Family	Child born 1955	External	Shoreline	U-235	1.14E-09	1.95E-10	1.27E-10	Water	0
Delivery Family	Child born 1955	External	Shoreline	U-236	4.56E-13	5.69E-14	3.33E-14	Water	0
Delivery Family	Child born 1955	External	Shoreline	U-238	5.98E-08	3.23E-09	2.4E-09	Water	0
Delivery Family	Child born 1955	External	Shoreline	Zn-65	1.39E-06	2.43E-07	1.59E-07	Water	0
Delivery Family	Child born 1955	External	Shoreline	Zr-95	4.75E-06	6.31E-07	4.18E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Ce-144	1.68E-06	5.57E-07	3.07E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Co-60	1.39E-06	2.46E-07	1.56E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Cs-134	1.53E-06	2.96E-07	1.91E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Cs-137	0.001028	0.000158	0.000102	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	H-3	1.33E-06	1.87E-07	1.23E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	I-129	3.87E-07	1.73E-08	1.76E-09	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	I-131	1.42E-06	1.6E-07	1.67E-08	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Nb-95	1.41E-06	3.32E-07	1.88E-07	Water	0

Delivery Family	Child born 1964	Ingestion	Fish	P-32	0.000525	0.000121	7.9E-05	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Pu-238	9.61E-06	4.72E-07	3.31E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Pu-239	3.97E-05	1.71E-06	1.2E-06	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Ru-106	2.02E-06	6.39E-07	3.58E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	S-35	2.87E-06	6.55E-07	4.06E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Sr-89	7.13E-06	1.45E-06	8.44E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Sr-90	0.000312	2.3E-05	1.67E-05	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Tc-99	1.69E-08	2.45E-09	1.41E-09	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	U-234	1.69E-09	1.84E-10	1.12E-10	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	U-235	1.09E-09	1.65E-10	1E-10	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	U-236	8.84E-11	8.44E-12	5.12E-12	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	U-238	7.69E-08	1.12E-08	6.82E-09	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Zn-65	4.8E-06	6.42E-07	4.2E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Fish	Zr-95	1.61E-06	4.17E-07	2.35E-07	Water	0
Delivery Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	8.83E-08	1.38E-08	8.83E-09	Water	0
Delivery Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	4.35E-07	5.84E-08	3.85E-08	Water	0
Delivery Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	2.74E-07	1.52E-08	1.15E-08	Water	0
Delivery Family	Child born 1964	External	Swimming	Cs-137	2.58E-08	1.55E-09	1.29E-09	Water	0
Delivery Family	Child born 1964	External	Swimming	Sr-90	2.11E-11	1.27E-12	1.06E-12	Water	0
Delivery Family	Child born 1964	External	Boating	Ce-144	9.5E-10	2.85E-11	2.38E-11	Water	0
Delivery Family	Child born 1964	External	Boating	Co-60	5.14E-09	1.54E-10	1.29E-10	Water	0
Delivery Family	Child born 1964	External	Boating	Cs-134	2.71E-10	8.15E-12	6.78E-12	Water	0
Delivery Family	Child born 1964	External	Boating	Cs-137	6.04E-09	1.81E-10	1.51E-10	Water	0
Delivery Family	Child born 1964	External	Boating	I-129	2.19E-12	6.56E-14	5.46E-14	Water	0
Delivery Family	Child born 1964	External	Boating	I-131	9.64E-10	2.89E-11	2.41E-11	Water	0

Delivery Family	Child born 1964	External	Boating	Nb-95	1.39E-08	4.16E-10	3.47E-10	Water	0
Delivery Family	Child born 1964	External	Boating	P-32	5.21E-11	1.56E-12	1.3E-12	Water	0
Delivery Family	Child born 1964	External	Boating	Pu-238	4.11E-15	1.23E-16	1.03E-16	Water	0
Delivery Family	Child born 1964	External	Boating	Pu-239	1.23E-14	3.7E-16	3.08E-16	Water	0
Delivery Family	Child born 1964	External	Boating	Ru-106	1.27E-08	3.82E-10	3.18E-10	Water	0
Delivery Family	Child born 1964	External	Boating	S-35	1.9E-12	5.69E-14	4.74E-14	Water	0
Delivery Family	Child born 1964	External	Boating	Sr-89	4.68E-11	1.4E-12	1.17E-12	Water	0
Delivery Family	Child born 1964	External	Boating	Sr-90	1.48E-11	4.44E-13	3.7E-13	Water	0
Delivery Family	Child born 1964	External	Boating	Tc-99	1.27E-12	3.8E-14	3.17E-14	Water	0
Delivery Family	Child born 1964	External	Boating	U-234	1.42E-15	4.25E-17	3.54E-17	Water	0
Delivery Family	Child born 1964	External	Boating	U-235	1.25E-12	3.73E-14	3.11E-14	Water	0
Delivery Family	Child born 1964	External	Boating	U-236	4.37E-17	1.31E-18	1.09E-18	Water	0
Delivery Family	Child born 1964	External	Boating	U-238	3.85E-14	1.16E-15	9.64E-16	Water	0
Delivery Family	Child born 1964	External	Boating	Zn-65	1.5E-09	4.5E-11	3.75E-11	Water	0
Delivery Family	Child born 1964	External	Boating	Zr-95	1.03E-08	3.1E-10	2.58E-10	Water	0
Delivery Family	Child born 1964	External	Shoreline	Ce-144	1.27E-06	8.55E-08	6.21E-08	Water	0
Delivery Family	Child born 1964	External	Shoreline	Co-60	3.09E-06	5.46E-07	3.58E-07	Water	0
Delivery Family	Child born 1964	External	Shoreline	Cs-134	1.6E-07	2.89E-08	1.89E-08	Water	0
Delivery Family	Child born 1964	External	Shoreline	Cs-137	6.84E-06	1.19E-06	7.81E-07	Water	0
Delivery Family	Child born 1964	External	Shoreline	I-129	4.67E-09	3.74E-10	2.39E-10	Water	0
Delivery Family	Child born 1964	External	Shoreline	I-131	2.17E-08	3.92E-09	2.57E-09	Water	0
Delivery Family	Child born 1964	External	Shoreline	Nb-95	1.33E-06	2.28E-07	1.49E-07	Water	0
Delivery Family	Child born 1964	External	Shoreline	P-32	2.78E-08	7.17E-10	6.61E-10	Water	0
Delivery Family	Child born 1964	External	Shoreline	Pu-238	2.25E-11	2.77E-12	1.59E-12	Water	0
Delivery Family	Child born 1964	External	Shoreline	Pu-239	3.2E-11	4.17E-12	2.47E-12	Water	0
Delivery Family	Child born 1964	External	Shoreline	Ru-106	1.04E-05	1.15E-06	7.78E-07	Water	0
Delivery Family	Child born 1964	External	Shoreline	S-35	1.72E-10	2.56E-11	1.6E-11	Water	0
Delivery Family	Child born 1964	External	Shoreline	Sr-89	8.68E-08	2.11E-09	1.94E-09	Water	0
Delivery Family	Child born 1964	External	Shoreline	Sr-90	1.28E-06	3.43E-08	3.08E-08	Water	0
Delivery Family	Child born 1964	External	Shoreline	Tc-99	1.89E-10	1.76E-11	1.14E-11	Water	0
Delivery Family	Child born 1964	External	Shoreline	U-234	4.28E-12	5.61E-13	3.32E-13	Water	0
Delivery Family	Child born 1964	External	Shoreline	U-235	9.71E-10	1.72E-10	1.12E-10	Water	0
Delivery Family	Child born 1964	External	Shoreline	U-236	1.77E-13	2.26E-14	1.32E-14	Water	0
Delivery Family	Child born 1964	External	Shoreline	U-238	5.19E-08	2.97E-09	2.23E-09	Water	0
Delivery Family	Child born 1964	External	Shoreline	Zn-65	6.11E-07	1.11E-07	7.25E-08	Water	0
Delivery Family	Child born 1964	External	Shoreline	Zr-95	3.55E-06	5.85E-07	3.85E-07	Water	0

Location	Receptor	ReportRou	ReportPathway	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	AirWater	RunNum
Urban Family	Adult Female	Ingestion	Leafy Vegetables	Am-241	5.35E-11	5.21E-13	4.06E-13	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	C-14	5.27E-08	2.59E-09	1.86E-09	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	Cs-137	2.24E-09	1.09E-10	7.78E-11	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	H-3	1.54E-06	7.46E-08	5.36E-08	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	I-129	1.92E-08	4.17E-10	4.27E-11	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	I-131	6.89E-06	1.53E-07	1.68E-08	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	Pu-238	2.1E-08	2.39E-10	1.99E-10	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	Pu-239	1.48E-07	1.58E-09	1.32E-09	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	Ru-106	4.7E-08	2.22E-09	1.31E-09	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	Sr-89	9.58E-11	4.59E-12	3.08E-12	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	Sr-90	6.48E-08	2.72E-09	2.46E-09	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	U-234	2.48E-09	5.27E-11	3.66E-11	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	U-235	1.07E-10	2.32E-12	1.6E-12	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	U-236	1.65E-10	3.51E-12	2.43E-12	Air	0
Urban Family	Adult Female	Ingestion	Leafy Vegetables	U-238	4.62E-09	1.03E-10	7.11E-11	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	Am-241	1.83E-11	1.78E-13	1.39E-13	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	C-14	1.8E-07	8.86E-09	6.37E-09	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	Cs-137	8.28E-10	4.04E-11	2.88E-11	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	H-3	4.89E-06	2.37E-07	1.7E-07	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	I-129	6.58E-09	1.43E-10	1.47E-11	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	I-131	1.29E-06	2.87E-08	3.15E-09	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	Pu-238	7.18E-09	8.19E-11	6.83E-11	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	Pu-239	5.06E-08	5.41E-10	4.51E-10	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	Ru-106	1.6E-08	7.54E-10	4.44E-10	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	Sr-89	3.28E-11	1.57E-12	1.06E-12	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	Sr-90	2.78E-08	1.17E-09	1.05E-09	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	U-234	8.52E-10	1.81E-11	1.25E-11	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	U-235	3.66E-11	7.97E-13	5.48E-13	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	U-236	5.67E-11	1.2E-12	8.34E-13	Air	0
Urban Family	Adult Female	Ingestion	Root Vegetables	U-238	1.6E-09	3.6E-11	2.47E-11	Air	0
Urban Family	Adult Female	Ingestion	Fruit	Am-241	1.81E-11	1.76E-13	1.38E-13	Air	0
Urban Family	Adult Female	Ingestion	Fruit	C-14	1.79E-07	8.77E-09	6.31E-09	Air	0
Urban Family	Adult Female	Ingestion	Fruit	Cs-137	7.4E-10	3.61E-11	2.58E-11	Air	0
Urban Family	Adult Female	Ingestion	Fruit	H-3	4.82E-06	2.34E-07	1.68E-07	Air	0
Urban Family	Adult Female	Ingestion	Fruit	I-129	6.51E-09	1.42E-10	1.45E-11	Air	0
Urban Family	Adult Female	Ingestion	Fruit	I-131	2.33E-06	5.19E-08	5.69E-09	Air	0

Urban Family	Adult Female	Ingestion	Fruit	Pu-238	7.1E-09	8.1E-11	6.76E-11	Air	0
Urban Family	Adult Female	Ingestion	Fruit	Pu-239	5.01E-08	5.35E-10	4.46E-10	Air	0
Urban Family	Adult Female	Ingestion	Fruit	Ru-106	1.6E-08	7.56E-10	4.46E-10	Air	0
Urban Family	Adult Female	Ingestion	Fruit	Sr-89	3.26E-11	1.56E-12	1.05E-12	Air	0
Urban Family	Adult Female	Ingestion	Fruit	Sr-90	2.22E-08	9.33E-10	8.42E-10	Air	0
Urban Family	Adult Female	Ingestion	Fruit	U-234	8.43E-10	1.79E-11	1.24E-11	Air	0
Urban Family	Adult Female	Ingestion	Fruit	U-235	3.62E-11	7.88E-13	5.42E-13	Air	0
Urban Family	Adult Female	Ingestion	Fruit	U-236	5.58E-11	1.19E-12	8.23E-13	Air	0
Urban Family	Adult Female	Ingestion	Fruit	U-238	1.57E-09	3.51E-11	2.41E-11	Air	0
Urban Family	Adult Female	Ingestion	Grain	Am-241	2.24E-12	2.19E-14	1.7E-14	Air	0
Urban Family	Adult Female	Ingestion	Grain	C-14	9.54E-08	4.68E-09	3.37E-09	Air	0
Urban Family	Adult Female	Ingestion	Grain	Cs-137	8.96E-11	4.37E-12	3.12E-12	Air	0
Urban Family	Adult Female	Ingestion	Grain	H-3	6.83E-07	3.34E-08	2.39E-08	Air	0
Urban Family	Adult Female	Ingestion	Grain	I-129	8.16E-10	1.78E-11	1.82E-12	Air	0
Urban Family	Adult Female	Ingestion	Grain	I-131	2.81E-07	6.26E-09	6.86E-10	Air	0
Urban Family	Adult Female	Ingestion	Grain	Pu-238	8.86E-10	1.01E-11	8.44E-12	Air	0
Urban Family	Adult Female	Ingestion	Grain	Pu-239	6.2E-09	6.62E-11	5.54E-11	Air	0
Urban Family	Adult Female	Ingestion	Grain	Ru-106	1.97E-09	9.32E-11	5.49E-11	Air	0
Urban Family	Adult Female	Ingestion	Grain	Sr-89	4.14E-12	1.99E-13	1.33E-13	Air	0
Urban Family	Adult Female	Ingestion	Grain	Sr-90	3.05E-09	1.28E-10	1.16E-10	Air	0
Urban Family	Adult Female	Ingestion	Grain	U-234	1.05E-10	2.22E-12	1.54E-12	Air	0
Urban Family	Adult Female	Ingestion	Grain	U-235	4.48E-12	9.77E-14	6.71E-14	Air	0
Urban Family	Adult Female	Ingestion	Grain	U-236	6.93E-12	1.47E-13	1.02E-13	Air	0
Urban Family	Adult Female	Ingestion	Grain	U-238	1.94E-10	4.36E-12	2.99E-12	Air	0
Urban Family	Adult Female	Ingestion	Beef	Am-241	5.14E-13	5.02E-15	3.91E-15	Air	0
Urban Family	Adult Female	Ingestion	Beef	C-14	8.37E-07	4.11E-08	2.95E-08	Air	0
Urban Family	Adult Female	Ingestion	Beef	Cs-137	2.69E-08	1.31E-09	9.37E-10	Air	0
Urban Family	Adult Female	Ingestion	Beef	H-3	5.65E-06	2.75E-07	1.97E-07	Air	0
Urban Family	Adult Female	Ingestion	Beef	I-129	1.85E-07	4.02E-09	4.12E-10	Air	0
Urban Family	Adult Female	Ingestion	Beef	I-131	0.000107	2.37E-06	2.6E-07	Air	0
Urban Family	Adult Female	Ingestion	Beef	Pu-238	5.06E-11	5.77E-13	4.83E-13	Air	0
Urban Family	Adult Female	Ingestion	Beef	Pu-239	3.56E-10	3.8E-12	3.17E-12	Air	0
Urban Family	Adult Female	Ingestion	Beef	Ru-106	5.77E-07	2.73E-08	1.6E-08	Air	0
Urban Family	Adult Female	Ingestion	Beef	Sr-89	2.07E-10	9.92E-12	6.66E-12	Air	0
Urban Family	Adult Female	Ingestion	Beef	Sr-90	1.23E-07	5.17E-09	4.69E-09	Air	0
Urban Family	Adult Female	Ingestion	Beef	U-234	1.79E-10	3.8E-12	2.64E-12	Air	0
Urban Family	Adult Female	Ingestion	Beef	U-235	7.7E-12	1.68E-13	1.15E-13	Air	0

Urban Family	Adult Female	Ingestion	Beef	U-236	1.19E-11	2.53E-13	1.76E-13	Air	0
Urban Family	Adult Female	Ingestion	Beef	U-238	3.27E-10	7.13E-12	4.96E-12	Air	0
Urban Family	Adult Female	Ingestion	Poultry	Am-241	3.15E-16	3.07E-18	2.39E-18	Air	0
Urban Family	Adult Female	Ingestion	Poultry	C-14	3.19E-08	1.57E-09	1.13E-09	Air	0
Urban Family	Adult Female	Ingestion	Poultry	Cs-137	2.12E-11	1.03E-12	7.39E-13	Air	0
Urban Family	Adult Female	Ingestion	Poultry	H-3	9.19E-07	4.47E-08	3.21E-08	Air	0
Urban Family	Adult Female	Ingestion	Poultry	I-129	1.98E-13	4.3E-15	4.41E-16	Air	0
Urban Family	Adult Female	Ingestion	Poultry	I-131	1.3E-17	2.9E-19	3.18E-20	Air	0
Urban Family	Adult Female	Ingestion	Poultry	Pu-238	6.21E-14	7.05E-16	5.9E-16	Air	0
Urban Family	Adult Female	Ingestion	Poultry	Pu-239	4.36E-13	4.65E-15	3.9E-15	Air	0
Urban Family	Adult Female	Ingestion	Poultry	Ru-106	2.66E-10	1.26E-11	7.4E-12	Air	0
Urban Family	Adult Female	Ingestion	Poultry	Sr-89	7.53E-16	3.61E-17	2.42E-17	Air	0
Urban Family	Adult Female	Ingestion	Poultry	Sr-90	7.27E-12	3.04E-13	2.76E-13	Air	0
Urban Family	Adult Female	Ingestion	Poultry	U-234	2.45E-12	5.21E-14	3.61E-14	Air	0
Urban Family	Adult Female	Ingestion	Poultry	U-235	1.05E-13	2.3E-15	1.58E-15	Air	0
Urban Family	Adult Female	Ingestion	Poultry	U-236	1.63E-13	3.45E-15	2.4E-15	Air	0
Urban Family	Adult Female	Ingestion	Poultry	U-238	4.46E-12	9.74E-14	6.76E-14	Air	0
Urban Family	Adult Female	Ingestion	Milk	Am-241	8.54E-14	8.34E-16	6.49E-16	Air	0
Urban Family	Adult Female	Ingestion	Milk	C-14	9.04E-07	4.44E-08	3.19E-08	Air	0
Urban Family	Adult Female	Ingestion	Milk	Cs-137	1.93E-08	9.42E-10	6.73E-10	Air	0
Urban Family	Adult Female	Ingestion	Milk	H-3	1.8E-05	8.71E-07	6.26E-07	Air	0
Urban Family	Adult Female	Ingestion	Milk	I-129	1.93E-07	4.21E-09	4.32E-10	Air	0
Urban Family	Adult Female	Ingestion	Milk	I-131	0.000111	2.48E-06	2.72E-07	Air	0
Urban Family	Adult Female	Ingestion	Milk	Pu-238	2.46E-11	2.82E-13	2.35E-13	Air	0
Urban Family	Adult Female	Ingestion	Milk	Pu-239	1.73E-10	1.85E-12	1.55E-12	Air	0
Urban Family	Adult Female	Ingestion	Milk	Ru-106	1.65E-10	7.79E-12	4.6E-12	Air	0
Urban Family	Adult Female	Ingestion	Milk	Sr-89	3E-10	1.44E-11	9.63E-12	Air	0
Urban Family	Adult Female	Ingestion	Milk	Sr-90	1.9E-07	7.95E-09	7.28E-09	Air	0
Urban Family	Adult Female	Ingestion	Milk	U-234	1.06E-09	2.24E-11	1.56E-11	Air	0
Urban Family	Adult Female	Ingestion	Milk	U-235	4.54E-11	9.89E-13	6.8E-13	Air	0
Urban Family	Adult Female	Ingestion	Milk	U-236	7.04E-11	1.5E-12	1.04E-12	Air	0
Urban Family	Adult Female	Ingestion	Milk	U-238	1.91E-09	4.15E-11	2.89E-11	Air	0
Urban Family	Adult Female	Ingestion	Eggs	Am-241	3.88E-16	3.78E-18	2.94E-18	Air	0
Urban Family	Adult Female	Ingestion	Eggs	C-14	4.42E-08	2.17E-09	1.56E-09	Air	0
Urban Family	Adult Female	Ingestion	Eggs	Cs-137	1.57E-12	7.64E-14	5.46E-14	Air	0
Urban Family	Adult Female	Ingestion	Eggs	H-3	1.67E-06	8.13E-08	5.84E-08	Air	0
Urban Family	Adult Female	Ingestion	Eggs	I-129	1.09E-10	2.38E-12	2.44E-13	Air	0

Urban Family	Adult Female	Ingestion	Eggs	I-131	6.62E-15	1.47E-16	1.61E-17	Air	0
Urban Family	Adult Female	Ingestion	Eggs	Pu-238	1.9E-14	2.17E-16	1.81E-16	Air	0
Urban Family	Adult Female	Ingestion	Eggs	Pu-239	1.34E-13	1.43E-15	1.2E-15	Air	0
Urban Family	Adult Female	Ingestion	Eggs	Ru-106	3.07E-13	1.45E-14	8.53E-15	Air	0
Urban Family	Adult Female	Ingestion	Eggs	Sr-89	3.43E-15	1.64E-16	1.1E-16	Air	0
Urban Family	Adult Female	Ingestion	Eggs	Sr-90	3.35E-11	1.41E-12	1.28E-12	Air	0
Urban Family	Adult Female	Ingestion	Eggs	U-234	4.53E-12	9.61E-14	6.66E-14	Air	0
Urban Family	Adult Female	Ingestion	Eggs	U-235	1.94E-13	4.24E-15	2.91E-15	Air	0
Urban Family	Adult Female	Ingestion	Eggs	U-236	3.01E-13	6.37E-15	4.43E-15	Air	0
Urban Family	Adult Female	Ingestion	Eggs	U-238	8.25E-12	1.81E-13	1.25E-13	Air	0
Urban Family	Adult Female	Ingestion	Soil	Am-241	1.27E-14	1.24E-16	9.65E-17	Air	0
Urban Family	Adult Female	Ingestion	Soil	Cs-137	4.96E-13	2.42E-14	1.73E-14	Air	0
Urban Family	Adult Female	Ingestion	Soil	I-129	3.36E-12	7.31E-14	7.5E-15	Air	0
Urban Family	Adult Female	Ingestion	Soil	I-131	4.76E-10	1.06E-11	1.16E-12	Air	0
Urban Family	Adult Female	Ingestion	Soil	Pu-238	5.01E-12	5.7E-14	4.76E-14	Air	0
Urban Family	Adult Female	Ingestion	Soil	Pu-239	3.51E-11	3.76E-13	3.14E-13	Air	0
Urban Family	Adult Female	Ingestion	Soil	Ru-106	9.37E-12	4.43E-13	2.6E-13	Air	0
Urban Family	Adult Female	Ingestion	Soil	Sr-89	9.98E-15	4.79E-16	3.21E-16	Air	0
Urban Family	Adult Female	Ingestion	Soil	Sr-90	1.5E-11	6.31E-13	5.69E-13	Air	0
Urban Family	Adult Female	Ingestion	Soil	U-234	5.91E-13	1.26E-14	8.72E-15	Air	0
Urban Family	Adult Female	Ingestion	Soil	U-235	2.53E-14	5.52E-16	3.79E-16	Air	0
Urban Family	Adult Female	Ingestion	Soil	U-236	3.93E-14	8.34E-16	5.78E-16	Air	0
Urban Family	Adult Female	Ingestion	Soil	U-238	1.13E-12	2.6E-14	1.77E-14	Air	0
Urban Family	Adult Female	External	Air Immersion	Am-241	5.2E-16	2.28E-17	1.59E-17	Air	0
Urban Family	Adult Female	External	Air Immersion	Ar-41	1.67E-05	8.03E-07	5.76E-07	Air	0
Urban Family	Adult Female	External	Air Immersion	C-14	1.58E-12	1.53E-14	1.39E-14	Air	0
Urban Family	Adult Female	External	Air Immersion	Cs-137	1.17E-11	5.6E-13	4E-13	Air	0
Urban Family	Adult Female	External	Air Immersion	I-129	2.92E-13	1.13E-14	7.39E-15	Air	0
Urban Family	Adult Female	External	Air Immersion	I-131	1.47E-07	6.99E-09	5E-09	Air	0
Urban Family	Adult Female	External	Air Immersion	Pu-238	9.5E-16	3.5E-17	2.14E-17	Air	0
Urban Family	Adult Female	External	Air Immersion	Pu-239	6.04E-15	2.6E-16	1.76E-16	Air	0
Urban Family	Adult Female	External	Air Immersion	Ru-106	2.19E-10	9.67E-12	6.95E-12	Air	0
Urban Family	Adult Female	External	Air Immersion	Sr-89	6.56E-14	8.85E-16	7.45E-16	Air	0
Urban Family	Adult Female	External	Air Immersion	Sr-90	9.76E-13	1.18E-14	1.02E-14	Air	0
Urban Family	Adult Female	External	Air Immersion	U-234	9.04E-16	3.76E-17	2.52E-17	Air	0
Urban Family	Adult Female	External	Air Immersion	U-235	4.35E-14	2.04E-15	1.45E-15	Air	0
Urban Family	Adult Female	External	Air Immersion	U-236	4E-17	1.59E-18	1.03E-18	Air	0

Urban Family	Adult Female	External	Air Immersion	U-238	5.35E-15	1.9E-16	1.36E-16	Air	0
Urban Family	Adult Female	External	Ground Contaminat	Am-241	4.37E-13	1.85E-14	1.29E-14	Air	0
Urban Family	Adult Female	External	Ground Contaminat	Cs-137	6.04E-09	2.84E-10	2.03E-10	Air	0
Urban Family	Adult Female	External	Ground Contaminat	I-129	1.87E-10	7.09E-12	4.73E-12	Air	0
Urban Family	Adult Female	External	Ground Contaminat	I-131	2.4E-06	1.14E-07	8.18E-08	Air	0
Urban Family	Adult Female	External	Ground Contaminat	Pu-238	4.13E-12	1.22E-13	7.45E-14	Air	0
Urban Family	Adult Female	External	Ground Contaminat	Pu-239	1.2E-11	3.93E-13	2.5E-13	Air	0
Urban Family	Adult Female	External	Ground Contaminat	Ru-106	1.39E-07	4.38E-09	3.24E-09	Air	0
Urban Family	Adult Female	External	Ground Contaminat	Sr-89	8.04E-11	6.86E-13	6.53E-13	Air	0
Urban Family	Adult Female	External	Ground Contaminat	Sr-90	1.63E-08	1.5E-10	1.39E-10	Air	0
Urban Family	Adult Female	External	Ground Contaminat	U-234	2.1E-12	6.69E-14	4.24E-14	Air	0
Urban Family	Adult Female	External	Ground Contaminat	U-235	2.52E-11	1.18E-12	8.38E-13	Air	0
Urban Family	Adult Female	External	Ground Contaminat	U-236	1.27E-13	3.88E-15	2.41E-15	Air	0
Urban Family	Adult Female	External	Ground Contaminat	U-238	7.23E-10	1.2E-11	9.68E-12	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	Am-241	4.2E-09	5.48E-11	4.72E-11	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	C-14	4.98E-10	2.41E-11	1.73E-11	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	Cs-137	2.81E-10	1.32E-11	9.37E-12	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	H-3	8.37E-06	4.07E-07	2.92E-07	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	I-129	1.01E-08	2.2E-10	2.26E-11	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	I-131	1.76E-05	3.91E-07	4.22E-08	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	Pu-238	1.64E-06	2.3E-08	2.04E-08	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	Pu-239	1.14E-05	1.45E-07	1.28E-07	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	Ru-106	7.53E-08	4E-09	3.65E-09	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	Sr-89	1.2E-10	6.4E-12	5.92E-12	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	Sr-90	2.88E-08	1.43E-09	1.36E-09	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	U-234	6.73E-08	3.49E-09	3.3E-09	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	U-235	2.69E-09	1.39E-10	1.31E-10	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	U-236	4.35E-09	2.25E-10	2.13E-10	Air	0
Urban Family	Adult Female	Inhalation	Air Inhalation	U-238	1.1E-07	5.7E-09	5.36E-09	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	Am-241	1.4E-11	1.83E-13	1.58E-13	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	Cs-137	9.26E-13	4.34E-14	3.09E-14	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	I-129	1.28E-11	2.8E-13	2.87E-14	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	I-131	1.83E-09	4.07E-11	4.39E-12	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	Pu-238	5.49E-09	7.67E-11	6.82E-11	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	Pu-239	3.79E-08	4.86E-10	4.28E-10	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	Ru-106	2.02E-10	1.07E-11	9.75E-12	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	Sr-89	1.28E-13	6.86E-15	6.33E-15	Air	0

Urban Family	Adult Female	Inhalation	Resuspended Soil	Sr-90	9.91E-11	4.93E-12	4.65E-12	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	U-234	2.25E-10	1.17E-11	1.11E-11	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	U-235	9E-12	4.66E-13	4.4E-13	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	U-236	1.45E-11	7.51E-13	7.11E-13	Air	0
Urban Family	Adult Female	Inhalation	Resuspended Soil	U-238	3.69E-10	1.91E-11	1.79E-11	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	Am-241	5.35E-11	5.21E-13	4.06E-13	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	C-14	5.27E-08	2.59E-09	1.86E-09	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	Cs-137	2.24E-09	1.09E-10	7.78E-11	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	H-3	1.54E-06	7.46E-08	5.36E-08	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	I-129	1.92E-08	4.17E-10	4.27E-11	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	I-131	6.89E-06	1.53E-07	1.68E-08	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	Pu-238	2.1E-08	2.39E-10	1.99E-10	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	Pu-239	1.48E-07	1.58E-09	1.32E-09	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	Ru-106	4.7E-08	2.22E-09	1.31E-09	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	Sr-89	9.58E-11	4.59E-12	3.08E-12	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	Sr-90	6.48E-08	2.72E-09	2.46E-09	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	U-234	2.48E-09	5.27E-11	3.66E-11	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	U-235	1.07E-10	2.32E-12	1.6E-12	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	U-236	1.65E-10	3.51E-12	2.43E-12	Air	0
Urban Family	Adult Male	Ingestion	Leafy Vegetables	U-238	4.62E-09	1.03E-10	7.11E-11	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	Am-241	2.53E-11	2.47E-13	1.92E-13	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	C-14	2.5E-07	1.23E-08	8.83E-09	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	Cs-137	1.15E-09	5.59E-11	3.99E-11	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	H-3	6.77E-06	3.28E-07	2.36E-07	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	I-129	9.11E-09	1.98E-10	2.03E-11	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	I-131	1.79E-06	3.98E-08	4.36E-09	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	Pu-238	9.94E-09	1.13E-10	9.46E-11	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	Pu-239	7.01E-08	7.49E-10	6.24E-10	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	Ru-106	2.21E-08	1.04E-09	6.15E-10	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	Sr-89	4.55E-11	2.18E-12	1.46E-12	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	Sr-90	3.85E-08	1.62E-09	1.46E-09	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	U-234	1.18E-09	2.5E-11	1.74E-11	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	U-235	5.06E-11	1.1E-12	7.59E-13	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	U-236	7.85E-11	1.67E-12	1.15E-12	Air	0
Urban Family	Adult Male	Ingestion	Root Vegetables	U-238	2.21E-09	4.99E-11	3.42E-11	Air	0
Urban Family	Adult Male	Ingestion	Fruit	Am-241	1.76E-11	1.72E-13	1.34E-13	Air	0
Urban Family	Adult Male	Ingestion	Fruit	C-14	1.74E-07	8.55E-09	6.15E-09	Air	0

Urban Family	Adult Male	Ingestion	Fruit	Cs-137	7.22E-10	3.53E-11	2.52E-11	Air	0
Urban Family	Adult Male	Ingestion	Fruit	H-3	4.7E-06	2.28E-07	1.64E-07	Air	0
Urban Family	Adult Male	Ingestion	Fruit	I-129	6.35E-09	1.38E-10	1.42E-11	Air	0
Urban Family	Adult Male	Ingestion	Fruit	I-131	2.28E-06	5.07E-08	5.55E-09	Air	0
Urban Family	Adult Male	Ingestion	Fruit	Pu-238	6.93E-09	7.9E-11	6.59E-11	Air	0
Urban Family	Adult Male	Ingestion	Fruit	Pu-239	4.89E-08	5.22E-10	4.35E-10	Air	0
Urban Family	Adult Male	Ingestion	Fruit	Ru-106	1.56E-08	7.37E-10	4.35E-10	Air	0
Urban Family	Adult Male	Ingestion	Fruit	Sr-89	3.18E-11	1.52E-12	1.02E-12	Air	0
Urban Family	Adult Male	Ingestion	Fruit	Sr-90	2.16E-08	9.1E-10	8.21E-10	Air	0
Urban Family	Adult Male	Ingestion	Fruit	U-234	8.22E-10	1.74E-11	1.21E-11	Air	0
Urban Family	Adult Male	Ingestion	Fruit	U-235	3.53E-11	7.69E-13	5.29E-13	Air	0
Urban Family	Adult Male	Ingestion	Fruit	U-236	5.44E-11	1.16E-12	8.02E-13	Air	0
Urban Family	Adult Male	Ingestion	Fruit	U-238	1.53E-09	3.42E-11	2.35E-11	Air	0
Urban Family	Adult Male	Ingestion	Grain	Am-241	2.7E-12	2.64E-14	2.05E-14	Air	0
Urban Family	Adult Male	Ingestion	Grain	C-14	1.15E-07	5.65E-09	4.06E-09	Air	0
Urban Family	Adult Male	Ingestion	Grain	Cs-137	1.08E-10	5.27E-12	3.76E-12	Air	0
Urban Family	Adult Male	Ingestion	Grain	H-3	8.23E-07	4.02E-08	2.89E-08	Air	0
Urban Family	Adult Male	Ingestion	Grain	I-129	9.84E-10	2.14E-11	2.2E-12	Air	0
Urban Family	Adult Male	Ingestion	Grain	I-131	3.39E-07	7.54E-09	8.27E-10	Air	0
Urban Family	Adult Male	Ingestion	Grain	Pu-238	1.07E-09	1.22E-11	1.02E-11	Air	0
Urban Family	Adult Male	Ingestion	Grain	Pu-239	7.48E-09	7.98E-11	6.68E-11	Air	0
Urban Family	Adult Male	Ingestion	Grain	Ru-106	2.38E-09	1.12E-10	6.62E-11	Air	0
Urban Family	Adult Male	Ingestion	Grain	Sr-89	4.99E-12	2.39E-13	1.61E-13	Air	0
Urban Family	Adult Male	Ingestion	Grain	Sr-90	3.68E-09	1.54E-10	1.4E-10	Air	0
Urban Family	Adult Male	Ingestion	Grain	U-234	1.26E-10	2.68E-12	1.86E-12	Air	0
Urban Family	Adult Male	Ingestion	Grain	U-235	5.4E-12	1.18E-13	8.1E-14	Air	0
Urban Family	Adult Male	Ingestion	Grain	U-236	8.36E-12	1.78E-13	1.23E-13	Air	0
Urban Family	Adult Male	Ingestion	Grain	U-238	2.34E-10	5.26E-12	3.61E-12	Air	0
Urban Family	Adult Male	Ingestion	Beef	Am-241	8.08E-13	7.89E-15	6.14E-15	Air	0
Urban Family	Adult Male	Ingestion	Beef	C-14	1.31E-06	6.45E-08	4.64E-08	Air	0
Urban Family	Adult Male	Ingestion	Beef	Cs-137	4.23E-08	2.06E-09	1.47E-09	Air	0
Urban Family	Adult Male	Ingestion	Beef	H-3	8.88E-06	4.32E-07	3.1E-07	Air	0
Urban Family	Adult Male	Ingestion	Beef	I-129	2.9E-07	6.31E-09	6.48E-10	Air	0
Urban Family	Adult Male	Ingestion	Beef	I-131	0.000168	3.73E-06	4.09E-07	Air	0
Urban Family	Adult Male	Ingestion	Beef	Pu-238	7.95E-11	9.07E-13	7.59E-13	Air	0
Urban Family	Adult Male	Ingestion	Beef	Pu-239	5.59E-10	5.97E-12	4.98E-12	Air	0
Urban Family	Adult Male	Ingestion	Beef	Ru-106	9.06E-07	4.28E-08	2.52E-08	Air	0

Urban Family	Adult Male	Ingestion	Beef	Sr-89	3.25E-10	1.56E-11	1.05E-11	Air	0
Urban Family	Adult Male	Ingestion	Beef	Sr-90	1.94E-07	8.12E-09	7.37E-09	Air	0
Urban Family	Adult Male	Ingestion	Beef	U-234	2.82E-10	5.97E-12	4.15E-12	Air	0
Urban Family	Adult Male	Ingestion	Beef	U-235	1.21E-11	2.64E-13	1.81E-13	Air	0
Urban Family	Adult Male	Ingestion	Beef	U-236	1.87E-11	3.98E-13	2.76E-13	Air	0
Urban Family	Adult Male	Ingestion	Beef	U-238	5.14E-10	1.12E-11	7.79E-12	Air	0
Urban Family	Adult Male	Ingestion	Poultry	Am-241	3.91E-16	3.81E-18	2.97E-18	Air	0
Urban Family	Adult Male	Ingestion	Poultry	C-14	3.96E-08	1.94E-09	1.4E-09	Air	0
Urban Family	Adult Male	Ingestion	Poultry	Cs-137	2.63E-11	1.28E-12	9.17E-13	Air	0
Urban Family	Adult Male	Ingestion	Poultry	H-3	1.14E-06	5.55E-08	3.98E-08	Air	0
Urban Family	Adult Male	Ingestion	Poultry	I-129	2.46E-13	5.34E-15	5.48E-16	Air	0
Urban Family	Adult Male	Ingestion	Poultry	I-131	1.62E-17	3.61E-19	3.95E-20	Air	0
Urban Family	Adult Male	Ingestion	Poultry	Pu-238	7.71E-14	8.75E-16	7.32E-16	Air	0
Urban Family	Adult Male	Ingestion	Poultry	Pu-239	5.41E-13	5.77E-15	4.84E-15	Air	0
Urban Family	Adult Male	Ingestion	Poultry	Ru-106	3.3E-10	1.56E-11	9.19E-12	Air	0
Urban Family	Adult Male	Ingestion	Poultry	Sr-89	9.36E-16	4.49E-17	3.01E-17	Air	0
Urban Family	Adult Male	Ingestion	Poultry	Sr-90	9.03E-12	3.78E-13	3.43E-13	Air	0
Urban Family	Adult Male	Ingestion	Poultry	U-234	3.05E-12	6.47E-14	4.48E-14	Air	0
Urban Family	Adult Male	Ingestion	Poultry	U-235	1.31E-13	2.85E-15	1.96E-15	Air	0
Urban Family	Adult Male	Ingestion	Poultry	U-236	2.02E-13	4.29E-15	2.98E-15	Air	0
Urban Family	Adult Male	Ingestion	Poultry	U-238	5.54E-12	1.21E-13	8.39E-14	Air	0
Urban Family	Adult Male	Ingestion	Milk	Am-241	1.13E-13	1.11E-15	8.62E-16	Air	0
Urban Family	Adult Male	Ingestion	Milk	C-14	1.2E-06	5.89E-08	4.24E-08	Air	0
Urban Family	Adult Male	Ingestion	Milk	Cs-137	2.56E-08	1.25E-09	8.93E-10	Air	0
Urban Family	Adult Male	Ingestion	Milk	H-3	2.38E-05	1.16E-06	8.31E-07	Air	0
Urban Family	Adult Male	Ingestion	Milk	I-129	2.57E-07	5.59E-09	5.74E-10	Air	0
Urban Family	Adult Male	Ingestion	Milk	I-131	0.000148	3.29E-06	3.61E-07	Air	0
Urban Family	Adult Male	Ingestion	Milk	Pu-238	3.27E-11	3.74E-13	3.12E-13	Air	0
Urban Family	Adult Male	Ingestion	Milk	Pu-239	2.3E-10	2.46E-12	2.05E-12	Air	0
Urban Family	Adult Male	Ingestion	Milk	Ru-106	2.19E-10	1.03E-11	6.1E-12	Air	0
Urban Family	Adult Male	Ingestion	Milk	Sr-89	3.98E-10	1.91E-11	1.28E-11	Air	0
Urban Family	Adult Male	Ingestion	Milk	Sr-90	2.52E-07	1.06E-08	9.67E-09	Air	0
Urban Family	Adult Male	Ingestion	Milk	U-234	1.41E-09	2.98E-11	2.08E-11	Air	0
Urban Family	Adult Male	Ingestion	Milk	U-235	6.03E-11	1.31E-12	9.04E-13	Air	0
Urban Family	Adult Male	Ingestion	Milk	U-236	9.35E-11	1.99E-12	1.38E-12	Air	0
Urban Family	Adult Male	Ingestion	Milk	U-238	2.54E-09	5.51E-11	3.83E-11	Air	0
Urban Family	Adult Male	Ingestion	Eggs	Am-241	3.21E-16	3.13E-18	2.43E-18	Air	0

Urban Family	Adult Male	Ingestion	Eggs	C-14	3.66E-08	1.8E-09	1.29E-09	Air	0
Urban Family	Adult Male	Ingestion	Eggs	Cs-137	1.3E-12	6.32E-14	4.51E-14	Air	0
Urban Family	Adult Male	Ingestion	Eggs	H-3	1.38E-06	6.73E-08	4.83E-08	Air	0
Urban Family	Adult Male	Ingestion	Eggs	I-129	9.04E-11	1.97E-12	2.02E-13	Air	0
Urban Family	Adult Male	Ingestion	Eggs	I-131	5.47E-15	1.22E-16	1.33E-17	Air	0
Urban Family	Adult Male	Ingestion	Eggs	Pu-238	1.58E-14	1.8E-16	1.5E-16	Air	0
Urban Family	Adult Male	Ingestion	Eggs	Pu-239	1.11E-13	1.18E-15	9.91E-16	Air	0
Urban Family	Adult Male	Ingestion	Eggs	Ru-106	2.54E-13	1.2E-14	7.06E-15	Air	0
Urban Family	Adult Male	Ingestion	Eggs	Sr-89	2.84E-15	1.36E-16	9.13E-17	Air	0
Urban Family	Adult Male	Ingestion	Eggs	Sr-90	2.77E-11	1.16E-12	1.06E-12	Air	0
Urban Family	Adult Male	Ingestion	Eggs	U-234	3.75E-12	7.95E-14	5.51E-14	Air	0
Urban Family	Adult Male	Ingestion	Eggs	U-235	1.61E-13	3.51E-15	2.41E-15	Air	0
Urban Family	Adult Male	Ingestion	Eggs	U-236	2.49E-13	5.27E-15	3.66E-15	Air	0
Urban Family	Adult Male	Ingestion	Eggs	U-238	6.82E-12	1.49E-13	1.03E-13	Air	0
Urban Family	Adult Male	Ingestion	Soil	Am-241	2.37E-14	2.32E-16	1.8E-16	Air	0
Urban Family	Adult Male	Ingestion	Soil	Cs-137	9.27E-13	4.52E-14	3.22E-14	Air	0
Urban Family	Adult Male	Ingestion	Soil	I-129	6.32E-12	1.38E-13	1.41E-14	Air	0
Urban Family	Adult Male	Ingestion	Soil	I-131	9.54E-10	2.12E-11	2.32E-12	Air	0
Urban Family	Adult Male	Ingestion	Soil	Pu-238	9.36E-12	1.07E-13	8.91E-14	Air	0
Urban Family	Adult Male	Ingestion	Soil	Pu-239	6.57E-11	7.04E-13	5.88E-13	Air	0
Urban Family	Adult Male	Ingestion	Soil	Ru-106	1.75E-11	8.28E-13	4.87E-13	Air	0
Urban Family	Adult Male	Ingestion	Soil	Sr-89	1.87E-14	8.97E-16	6.01E-16	Air	0
Urban Family	Adult Male	Ingestion	Soil	Sr-90	2.8E-11	1.18E-12	1.06E-12	Air	0
Urban Family	Adult Male	Ingestion	Soil	U-234	1.1E-12	2.34E-14	1.63E-14	Air	0
Urban Family	Adult Male	Ingestion	Soil	U-235	4.74E-14	1.03E-15	7.1E-16	Air	0
Urban Family	Adult Male	Ingestion	Soil	U-236	7.34E-14	1.56E-15	1.08E-15	Air	0
Urban Family	Adult Male	Ingestion	Soil	U-238	2.11E-12	4.85E-14	3.31E-14	Air	0
Urban Family	Adult Male	External	Air Immersion	Am-241	7.89E-16	3.46E-17	2.41E-17	Air	0
Urban Family	Adult Male	External	Air Immersion	Ar-41	0.000254	1.22E-05	8.77E-06	Air	0
Urban Family	Adult Male	External	Air Immersion	C-14	4.45E-12	4.31E-14	3.9E-14	Air	0
Urban Family	Adult Male	External	Air Immersion	Cs-137	1.78E-11	8.5E-13	6.06E-13	Air	0
Urban Family	Adult Male	External	Air Immersion	I-129	4.08E-13	1.57E-14	1.03E-14	Air	0
Urban Family	Adult Male	External	Air Immersion	I-131	2.11E-07	1E-08	7.14E-09	Air	0
Urban Family	Adult Male	External	Air Immersion	Pu-238	1.44E-15	5.31E-17	3.24E-17	Air	0
Urban Family	Adult Male	External	Air Immersion	Pu-239	9.15E-15	3.94E-16	2.67E-16	Air	0
Urban Family	Adult Male	External	Air Immersion	Ru-106	3.32E-10	1.47E-11	1.06E-11	Air	0
Urban Family	Adult Male	External	Air Immersion	Sr-89	9.96E-14	1.34E-15	1.13E-15	Air	0

Urban Family	Adult Male	External	Air Immersion	Sr-90	1.27E-12	1.46E-14	1.28E-14	Air	0
Urban Family	Adult Male	External	Air Immersion	U-234	1.37E-15	5.69E-17	3.81E-17	Air	0
Urban Family	Adult Male	External	Air Immersion	U-235	6.58E-14	3.09E-15	2.19E-15	Air	0
Urban Family	Adult Male	External	Air Immersion	U-236	6.07E-17	2.42E-18	1.57E-18	Air	0
Urban Family	Adult Male	External	Air Immersion	U-238	5.57E-15	1.98E-16	1.4E-16	Air	0
Urban Family	Adult Male	External	Ground Contaminat	Am-241	8.19E-13	3.47E-14	2.42E-14	Air	0
Urban Family	Adult Male	External	Ground Contaminat	Cs-137	1.13E-08	5.33E-10	3.81E-10	Air	0
Urban Family	Adult Male	External	Ground Contaminat	I-129	3.54E-10	1.34E-11	8.91E-12	Air	0
Urban Family	Adult Male	External	Ground Contaminat	I-131	4.83E-06	2.29E-07	1.64E-07	Air	0
Urban Family	Adult Male	External	Ground Contaminat	Pu-238	7.75E-12	2.28E-13	1.4E-13	Air	0
Urban Family	Adult Male	External	Ground Contaminat	Pu-239	2.25E-11	7.36E-13	4.67E-13	Air	0
Urban Family	Adult Male	External	Ground Contaminat	Ru-106	2.6E-07	8.22E-09	6.07E-09	Air	0
Urban Family	Adult Male	External	Ground Contaminat	Sr-89	1.51E-10	1.29E-12	1.22E-12	Air	0
Urban Family	Adult Male	External	Ground Contaminat	Sr-90	3.06E-08	2.8E-10	2.61E-10	Air	0
Urban Family	Adult Male	External	Ground Contaminat	U-234	3.95E-12	1.25E-13	7.95E-14	Air	0
Urban Family	Adult Male	External	Ground Contaminat	U-235	4.72E-11	2.21E-12	1.57E-12	Air	0
Urban Family	Adult Male	External	Ground Contaminat	U-236	2.37E-13	7.27E-15	4.53E-15	Air	0
Urban Family	Adult Male	External	Ground Contaminat	U-238	1.36E-09	2.25E-11	1.82E-11	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	Am-241	8.57E-09	1.12E-10	9.63E-11	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	C-14	1.88E-09	9.11E-11	6.55E-11	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	Cs-137	5.73E-10	2.68E-11	1.91E-11	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	H-3	2.86E-05	1.39E-06	9.96E-07	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	I-129	1.9E-08	4.14E-10	4.24E-11	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	I-131	3.39E-05	7.53E-07	8.13E-08	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	Pu-238	3.35E-06	4.69E-08	4.17E-08	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	Pu-239	2.32E-05	2.96E-07	2.62E-07	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	Ru-106	1.54E-07	8.17E-09	7.45E-09	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	Sr-89	2.45E-10	1.31E-11	1.21E-11	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	Sr-90	5.82E-08	2.89E-09	2.74E-09	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	U-234	1.37E-07	7.12E-09	6.73E-09	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	U-235	5.48E-09	2.84E-10	2.68E-10	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	U-236	8.87E-09	4.59E-10	4.34E-10	Air	0
Urban Family	Adult Male	Inhalation	Air Inhalation	U-238	2.25E-07	1.16E-08	1.09E-08	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	Am-241	3.52E-11	4.6E-13	3.96E-13	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	Cs-137	2.32E-12	1.09E-13	7.75E-14	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	I-129	3.24E-11	7.07E-13	7.24E-14	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	I-131	4.9E-09	1.09E-10	1.18E-11	Air	0

Urban Family	Adult Male	Inhalation	Resuspended Soil	Pu-238	1.37E-08	1.92E-10	1.71E-10	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	Pu-239	9.54E-08	1.22E-09	1.08E-09	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	Ru-106	5.06E-10	2.68E-11	2.45E-11	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	Sr-89	3.23E-13	1.72E-14	1.59E-14	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	Sr-90	2.48E-10	1.23E-11	1.17E-11	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	U-234	5.63E-10	2.94E-11	2.77E-11	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	U-235	2.26E-11	1.17E-12	1.11E-12	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	U-236	3.65E-11	1.89E-12	1.79E-12	Air	0
Urban Family	Adult Male	Inhalation	Resuspended Soil	U-238	9.26E-10	4.8E-11	4.5E-11	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	Am-241	5.35E-11	7.3E-13	5.44E-13	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	C-14	3.99E-08	5.3E-09	3.54E-09	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	Cs-137	1.03E-09	8.82E-11	5.92E-11	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	H-3	1.15E-06	1.51E-07	1.01E-07	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	I-129	1.6E-08	1.21E-09	1.24E-10	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	I-131	1.23E-05	1.18E-06	1.23E-07	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-238	1.33E-08	5.93E-10	4.26E-10	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-239	1.72E-07	1.17E-09	8.17E-10	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	Ru-106	4.69E-08	1.59E-08	8.97E-09	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-89	9.94E-11	2.47E-11	1.44E-11	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-90	4.17E-08	3.44E-09	2.26E-09	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	U-234	1.56E-09	9.75E-11	5.99E-11	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	U-235	7.41E-11	5.95E-12	3.64E-12	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	U-236	1.03E-10	6.48E-12	3.98E-12	Air	0
Urban Family	Child born 1955	Ingestion	Leafy Vegetables	U-238	3.46E-09	3.32E-10	2.02E-10	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	Am-241	2.53E-11	3.46E-13	2.58E-13	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	C-14	2.15E-07	3E-08	2E-08	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	Cs-137	7.44E-10	7.1E-11	4.67E-11	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	H-3	5.7E-06	7.93E-07	5.3E-07	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	I-129	8.53E-09	6.75E-10	6.87E-11	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	I-131	5.11E-06	4.9E-07	5.13E-08	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	Pu-238	7.8E-09	3.51E-10	2.52E-10	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	Pu-239	3.73E-07	2.29E-09	1.59E-09	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	Ru-106	3.67E-08	1.1E-08	6.2E-09	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	Sr-89	1.05E-10	2.11E-11	1.23E-11	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	Sr-90	9.09E-08	5.97E-09	3.9E-09	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	U-234	2.48E-09	1.27E-10	7.76E-11	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	U-235	8.61E-11	5.67E-12	3.45E-12	Air	0

Urban Family	Child born 1955	Ingestion	Root Vegetables	U-236	1.65E-10	8.45E-12	5.16E-12	Air	0
Urban Family	Child born 1955	Ingestion	Root Vegetables	U-238	3.09E-09	2.69E-10	1.62E-10	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	Am-241	1.76E-11	2.41E-13	1.8E-13	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	C-14	2.17E-07	3.3E-08	2.18E-08	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	Cs-137	8.72E-10	9.51E-11	6.14E-11	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	H-3	5.7E-06	8.84E-07	5.87E-07	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	I-129	8.56E-09	7.33E-10	7.47E-11	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	I-131	1.52E-05	1.47E-06	1.53E-07	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	Pu-238	6.06E-09	2.73E-10	1.96E-10	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	Pu-239	8.63E-07	5.17E-09	3.58E-09	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	Ru-106	5.76E-08	1.5E-08	8.43E-09	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	Sr-89	1.93E-10	3.51E-11	2.04E-11	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	Sr-90	1.63E-07	1.01E-08	6.58E-09	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	U-234	5.28E-09	2.52E-10	1.53E-10	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	U-235	1.66E-10	1E-11	6.07E-12	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	U-236	3.48E-10	1.67E-11	1.01E-11	Air	0
Urban Family	Child born 1955	Ingestion	Fruit	U-238	5.19E-09	4.1E-10	2.46E-10	Air	0
Urban Family	Child born 1955	Ingestion	Grain	Am-241	2.7E-12	3.69E-14	2.75E-14	Air	0
Urban Family	Child born 1955	Ingestion	Grain	C-14	1.32E-07	1.96E-08	1.3E-08	Air	0
Urban Family	Child born 1955	Ingestion	Grain	Cs-137	7.52E-11	8E-12	5.24E-12	Air	0
Urban Family	Child born 1955	Ingestion	Grain	H-3	9.5E-07	1.44E-07	9.56E-08	Air	0
Urban Family	Child born 1955	Ingestion	Grain	I-129	1.29E-09	1.08E-10	1.1E-11	Air	0
Urban Family	Child born 1955	Ingestion	Grain	I-131	1.72E-06	1.65E-07	1.73E-08	Air	0
Urban Family	Child born 1955	Ingestion	Grain	Pu-238	9.18E-10	4.14E-11	2.98E-11	Air	0
Urban Family	Child born 1955	Ingestion	Grain	Pu-239	3.49E-08	2.21E-10	1.54E-10	Air	0
Urban Family	Child born 1955	Ingestion	Grain	Ru-106	4.8E-09	1.53E-09	8.61E-10	Air	0
Urban Family	Child born 1955	Ingestion	Grain	Sr-89	1.34E-11	3.18E-12	1.85E-12	Air	0
Urban Family	Child born 1955	Ingestion	Grain	Sr-90	8.59E-09	6.47E-10	4.24E-10	Air	0
Urban Family	Child born 1955	Ingestion	Grain	U-234	2.47E-10	1.35E-11	8.23E-12	Air	0
Urban Family	Child born 1955	Ingestion	Grain	U-235	9.9E-12	7.45E-13	4.52E-13	Air	0
Urban Family	Child born 1955	Ingestion	Grain	U-236	1.64E-11	8.93E-13	5.46E-13	Air	0
Urban Family	Child born 1955	Ingestion	Grain	U-238	4.07E-10	3.97E-11	2.39E-11	Air	0
Urban Family	Child born 1955	Ingestion	Beef	Am-241	8.08E-13	1.1E-14	8.23E-15	Air	0
Urban Family	Child born 1955	Ingestion	Beef	C-14	1.24E-06	1.77E-07	1.18E-07	Air	0
Urban Family	Child born 1955	Ingestion	Beef	Cs-137	2.8E-08	2.74E-09	1.8E-09	Air	0
Urban Family	Child born 1955	Ingestion	Beef	H-3	8.21E-06	1.17E-06	7.79E-07	Air	0
Urban Family	Child born 1955	Ingestion	Beef	I-129	3.06E-07	2.47E-08	2.52E-09	Air	0

Urban Family	Child born 1955	Ingestion	Beef	I-131	0.000494	4.73E-05	4.94E-06	Air	0
Urban Family	Child born 1955	Ingestion	Beef	Pu-238	7.49E-11	3.39E-12	2.44E-12	Air	0
Urban Family	Child born 1955	Ingestion	Beef	Pu-239	2.86E-09	1.77E-11	1.23E-11	Air	0
Urban Family	Child born 1955	Ingestion	Beef	Ru-106	1.6E-06	4.98E-07	2.8E-07	Air	0
Urban Family	Child born 1955	Ingestion	Beef	Sr-89	7.72E-10	1.6E-10	9.31E-11	Air	0
Urban Family	Child born 1955	Ingestion	Beef	Sr-90	4.42E-07	2.75E-08	1.82E-08	Air	0
Urban Family	Child born 1955	Ingestion	Beef	U-234	5.88E-10	3.09E-11	1.89E-11	Air	0
Urban Family	Child born 1955	Ingestion	Beef	U-235	2.09E-11	1.42E-12	8.64E-13	Air	0
Urban Family	Child born 1955	Ingestion	Beef	U-236	3.9E-11	2.05E-12	1.26E-12	Air	0
Urban Family	Child born 1955	Ingestion	Beef	U-238	7.38E-10	5.84E-11	3.57E-11	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	Am-241	3.91E-16	5.33E-18	3.98E-18	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	C-14	4.04E-08	5.9E-09	3.92E-09	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	Cs-137	1.52E-11	1.53E-12	1.01E-12	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	H-3	1.17E-06	1.72E-07	1.15E-07	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	I-129	2.82E-13	2.32E-14	2.37E-15	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	I-131	6.6E-17	6.38E-18	6.66E-19	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	Pu-238	7.86E-14	3.55E-15	2.55E-15	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	Pu-239	1.16E-12	7.85E-15	5.49E-15	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	Ru-106	5.17E-10	1.84E-10	1.03E-10	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	Sr-89	1.76E-15	4.64E-16	2.7E-16	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	Sr-90	1.12E-11	9.27E-13	6.15E-13	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	U-234	3.37E-12	2.09E-13	1.28E-13	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	U-235	1.56E-13	1.3E-14	7.94E-15	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	U-236	2.23E-13	1.38E-14	8.52E-15	Air	0
Urban Family	Child born 1955	Ingestion	Poultry	U-238	6.91E-12	6.44E-13	3.94E-13	Air	0
Urban Family	Child born 1955	Ingestion	Milk	Am-241	1.13E-13	1.55E-15	1.15E-15	Air	0
Urban Family	Child born 1955	Ingestion	Milk	C-14	2.64E-06	4.33E-07	2.86E-07	Air	0
Urban Family	Child born 1955	Ingestion	Milk	Cs-137	4.55E-08	5.47E-09	3.51E-09	Air	0
Urban Family	Child born 1955	Ingestion	Milk	H-3	5.2E-05	8.79E-06	5.82E-06	Air	0
Urban Family	Child born 1955	Ingestion	Milk	I-129	6.53E-07	5.94E-08	6.06E-09	Air	0
Urban Family	Child born 1955	Ingestion	Milk	I-131	0.001892	0.000182	1.91E-05	Air	0
Urban Family	Child born 1955	Ingestion	Milk	Pu-238	7.08E-11	3.27E-12	2.34E-12	Air	0
Urban Family	Child born 1955	Ingestion	Milk	Pu-239	5.96E-09	3.61E-11	2.51E-11	Air	0
Urban Family	Child born 1955	Ingestion	Milk	Ru-106	1.36E-09	3.88E-10	2.18E-10	Air	0
Urban Family	Child born 1955	Ingestion	Milk	Sr-89	3.96E-09	7.78E-10	4.52E-10	Air	0
Urban Family	Child born 1955	Ingestion	Milk	Sr-90	2.79E-06	1.52E-07	1.03E-07	Air	0
Urban Family	Child born 1955	Ingestion	Milk	U-234	1.37E-08	6.75E-10	4.11E-10	Air	0

Urban Family	Child born 1955	Ingestion	Milk	U-235	4.48E-10	2.86E-11	1.73E-11	Air	0
Urban Family	Child born 1955	Ingestion	Milk	U-236	9.07E-10	4.48E-11	2.73E-11	Air	0
Urban Family	Child born 1955	Ingestion	Milk	U-238	1.41E-08	1.06E-09	6.45E-10	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	Am-241	3.21E-16	4.39E-18	3.26E-18	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	C-14	5.29E-08	8.3E-09	5.5E-09	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	Cs-137	1E-12	1.16E-13	7.59E-14	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	H-3	2.04E-06	3.27E-07	2.17E-07	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	I-129	1.51E-10	1.32E-11	1.34E-12	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	I-131	4.27E-14	4.13E-15	4.31E-16	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	Pu-238	2.33E-14	1.07E-15	7.64E-16	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	Pu-239	4.6E-13	3.07E-15	2.14E-15	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	Ru-106	6.39E-13	2.26E-13	1.27E-13	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	Sr-89	9.44E-15	2.5E-15	1.46E-15	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	Sr-90	6.64E-11	5.54E-12	3.66E-12	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	U-234	7.47E-12	4.48E-13	2.74E-13	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	U-235	3.34E-13	2.8E-14	1.7E-14	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	U-236	4.95E-13	2.97E-14	1.82E-14	Air	0
Urban Family	Child born 1955	Ingestion	Eggs	U-238	1.45E-11	1.4E-12	8.5E-13	Air	0
Urban Family	Child born 1955	Ingestion	Soil	Am-241	2.37E-14	3.24E-16	2.42E-16	Air	0
Urban Family	Child born 1955	Ingestion	Soil	Cs-137	1.12E-12	1.25E-13	8.07E-14	Air	0
Urban Family	Child born 1955	Ingestion	Soil	I-129	9.43E-12	8.19E-13	8.35E-14	Air	0
Urban Family	Child born 1955	Ingestion	Soil	I-131	6.86E-09	6.61E-10	6.9E-11	Air	0
Urban Family	Child born 1955	Ingestion	Soil	Pu-238	9.67E-12	4.38E-13	3.14E-13	Air	0
Urban Family	Child born 1955	Ingestion	Soil	Pu-239	1.11E-09	6.69E-12	4.63E-12	Air	0
Urban Family	Child born 1955	Ingestion	Soil	Ru-106	6.66E-11	1.81E-11	1.01E-11	Air	0
Urban Family	Child born 1955	Ingestion	Soil	Sr-89	1.15E-13	2.2E-14	1.28E-14	Air	0
Urban Family	Child born 1955	Ingestion	Soil	Sr-90	2.06E-10	1.31E-11	8.55E-12	Air	0
Urban Family	Child born 1955	Ingestion	Soil	U-234	6.86E-12	3.33E-13	2.02E-13	Air	0
Urban Family	Child born 1955	Ingestion	Soil	U-235	2.21E-13	1.38E-14	8.34E-15	Air	0
Urban Family	Child born 1955	Ingestion	Soil	U-236	4.56E-13	2.2E-14	1.34E-14	Air	0
Urban Family	Child born 1955	Ingestion	Soil	U-238	7.51E-12	6.81E-13	4.05E-13	Air	0
Urban Family	Child born 1955	External	Air Immersion	Am-241	7.89E-16	5.53E-17	3.71E-17	Air	0
Urban Family	Child born 1955	External	Air Immersion	Ar-41	5.71E-05	6.65E-06	4.45E-06	Air	0
Urban Family	Child born 1955	External	Air Immersion	C-14	2.62E-12	5.28E-14	4.59E-14	Air	0
Urban Family	Child born 1955	External	Air Immersion	Cs-137	1.36E-11	1.71E-12	1.13E-12	Air	0
Urban Family	Child born 1955	External	Air Immersion	I-129	3.29E-13	3.92E-14	2.4E-14	Air	0
Urban Family	Child born 1955	External	Air Immersion	I-131	1.47E-07	2.65E-08	1.73E-08	Air	0

Urban Family	Child born 1955	External	Air Immersion	Pu-238	9.76E-16	1.42E-16	8.07E-17	Air	0
Urban Family	Child born 1955	External	Air Immersion	Pu-239	6.04E-15	1.02E-15	6.31E-16	Air	0
Urban Family	Child born 1955	External	Air Immersion	Ru-106	2.46E-10	3.64E-11	2.41E-11	Air	0
Urban Family	Child born 1955	External	Air Immersion	Sr-89	6.7E-14	2.81E-15	2.2E-15	Air	0
Urban Family	Child born 1955	External	Air Immersion	Sr-90	9.77E-13	3.88E-14	3.14E-14	Air	0
Urban Family	Child born 1955	External	Air Immersion	U-234	9.14E-16	1.46E-16	9.02E-17	Air	0
Urban Family	Child born 1955	External	Air Immersion	U-235	4.52E-14	7.44E-15	4.86E-15	Air	0
Urban Family	Child born 1955	External	Air Immersion	U-236	4.04E-17	6.33E-18	3.79E-18	Air	0
Urban Family	Child born 1955	External	Air Immersion	U-238	5.38E-15	6.64E-16	4.35E-16	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	Am-241	8.19E-13	5.6E-14	3.75E-14	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	Cs-137	7.73E-09	9.08E-10	6.04E-10	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	I-129	2.41E-10	2.7E-11	1.69E-11	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	I-131	2.41E-06	4.36E-07	2.85E-07	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	Pu-238	4.34E-12	5.08E-13	2.93E-13	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	Pu-239	1.2E-11	1.62E-12	9.56E-13	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	Ru-106	1.68E-07	1.72E-08	1.17E-08	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	Sr-89	8.38E-11	1.95E-12	1.8E-12	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	Sr-90	1.65E-08	4.61E-10	4.14E-10	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	U-234	2.15E-12	2.76E-13	1.63E-13	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	U-235	2.7E-11	4.41E-12	2.88E-12	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	U-236	1.3E-13	1.61E-14	9.41E-15	Air	0
Urban Family	Child born 1955	External	Ground Contaminat	U-238	8E-10	4.03E-11	3.02E-11	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	Am-241	8.57E-09	1.47E-10	1.26E-10	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	C-14	1.16E-09	1.46E-10	9.72E-11	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	Cs-137	3.35E-10	2.98E-11	1.97E-11	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	H-3	1.83E-05	2.24E-06	1.5E-06	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	I-129	1.79E-08	1.43E-09	1.46E-10	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	I-131	8.73E-05	8.53E-06	8.84E-07	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	Pu-238	2.25E-06	1.07E-07	9.51E-08	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	Pu-239	7.58E-06	3.49E-07	3.05E-07	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	Ru-106	1.4E-07	2.46E-08	2.1E-08	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	Sr-89	2.22E-10	4.22E-11	3.52E-11	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	Sr-90	4.91E-08	6.1E-09	5.52E-09	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	U-234	1.13E-07	1.56E-08	1.47E-08	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	U-235	4.76E-09	6.83E-10	6.44E-10	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	U-236	7.35E-09	1.01E-09	9.57E-10	Air	0
Urban Family	Child born 1955	Inhalation	Air Inhalation	U-238	2.02E-07	2.97E-08	2.8E-08	Air	0

Urban Family	Child born 1955	Inhalation	Resuspended Soil	Am-241	3.52E-11	6.05E-13	5.19E-13	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	Cs-137	1.24E-12	1.05E-13	6.95E-14	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	I-129	2.54E-11	1.94E-12	1.98E-13	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	I-131	9.06E-09	8.87E-10	9.18E-11	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	Pu-238	7.67E-09	3.6E-10	3.2E-10	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	Pu-239	2.53E-08	1.17E-09	1.02E-09	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	Ru-106	3.96E-10	6.83E-11	5.83E-11	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	Sr-89	2.4E-13	4.54E-14	3.79E-14	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	Sr-90	1.75E-10	2.26E-11	1.98E-11	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	U-234	3.8E-10	5.24E-11	4.95E-11	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	U-235	1.62E-11	2.31E-12	2.18E-12	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	U-236	2.47E-11	3.39E-12	3.21E-12	Air	0
Urban Family	Child born 1955	Inhalation	Resuspended Soil	U-238	6.96E-10	1.01E-10	9.53E-11	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	Am-241	4.19E-11	1.03E-12	7.17E-13	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	C-14	2.38E-08	3.82E-09	2.53E-09	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	Cs-137	7.58E-10	1.02E-10	6.89E-11	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	H-3	6.99E-07	1.03E-07	6.85E-08	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	I-129	8.92E-09	7.86E-10	8.02E-11	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	I-131	6.44E-08	5.85E-09	6.11E-10	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-238	1.36E-08	4.7E-10	3.36E-10	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-239	2.65E-09	1.02E-10	7.27E-11	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	Ru-106	2.92E-08	1.33E-08	7.45E-09	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-89	4.19E-11	1.02E-11	5.91E-12	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-90	5.82E-10	6.69E-11	4.52E-11	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	U-234	3.94E-10	3.64E-11	2.25E-11	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	U-235	2.55E-11	2.47E-12	1.51E-12	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	U-236	2.62E-11	2.42E-12	1.49E-12	Air	0
Urban Family	Child born 1964	Ingestion	Leafy Vegetables	U-238	1.4E-09	1.45E-10	8.81E-11	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	Am-241	2.23E-11	5.65E-13	3.91E-13	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	C-14	1.38E-07	2.27E-08	1.5E-08	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	Cs-137	4.04E-10	5.51E-11	3.69E-11	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	H-3	3.92E-06	5.79E-07	3.85E-07	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	I-129	5.51E-09	5.09E-10	5.19E-11	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	I-131	2.33E-08	2.25E-09	2.35E-10	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	Pu-238	7.04E-09	2.44E-10	1.75E-10	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	Pu-239	1.7E-09	6.38E-11	4.53E-11	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	Ru-106	1.86E-08	8.4E-09	4.71E-09	Air	0

Urban Family	Child born 1964	Ingestion	Root Vegetables	Sr-89	2.74E-11	6.32E-12	3.68E-12	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	Sr-90	6.76E-10	6.73E-11	4.48E-11	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	U-234	3.03E-10	2.53E-11	1.55E-11	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	U-235	1.98E-11	1.77E-12	1.08E-12	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	U-236	2.01E-11	1.68E-12	1.03E-12	Air	0
Urban Family	Child born 1964	Ingestion	Root Vegetables	U-238	1.1E-09	1.1E-10	6.61E-11	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	Am-241	1.65E-11	4.25E-13	2.94E-13	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	C-14	1.57E-07	2.69E-08	1.77E-08	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	Cs-137	2.92E-10	4.1E-11	2.73E-11	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	H-3	4.74E-06	7.09E-07	4.69E-07	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	I-129	6.74E-09	6.68E-10	6.81E-11	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	I-131	6.5E-08	6.49E-09	6.78E-10	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	Pu-238	8.6E-09	2.98E-10	2.13E-10	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	Pu-239	2.48E-09	9.18E-11	6.48E-11	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	Ru-106	2.52E-08	1.06E-08	5.95E-09	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	Sr-89	4.12E-11	9.1E-12	5.29E-12	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	Sr-90	9.89E-10	9.11E-11	6.02E-11	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	U-234	4.98E-10	3.91E-11	2.39E-11	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	U-235	3.19E-11	2.75E-12	1.67E-12	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	U-236	3.32E-11	2.6E-12	1.59E-12	Air	0
Urban Family	Child born 1964	Ingestion	Fruit	U-238	1.74E-09	1.64E-10	9.86E-11	Air	0
Urban Family	Child born 1964	Ingestion	Grain	Am-241	2.51E-12	6.42E-14	4.45E-14	Air	0
Urban Family	Child born 1964	Ingestion	Grain	C-14	8.92E-08	1.51E-08	9.94E-09	Air	0
Urban Family	Child born 1964	Ingestion	Grain	Cs-137	4.06E-11	5.73E-12	3.83E-12	Air	0
Urban Family	Child born 1964	Ingestion	Grain	H-3	6.24E-07	9.95E-08	6.59E-08	Air	0
Urban Family	Child born 1964	Ingestion	Grain	I-129	8.53E-10	8.1E-11	8.27E-12	Air	0
Urban Family	Child born 1964	Ingestion	Grain	I-131	7.65E-09	7.39E-10	7.72E-11	Air	0
Urban Family	Child born 1964	Ingestion	Grain	Pu-238	1.37E-09	4.76E-11	3.4E-11	Air	0
Urban Family	Child born 1964	Ingestion	Grain	Pu-239	2.99E-10	1.21E-11	8.56E-12	Air	0
Urban Family	Child born 1964	Ingestion	Grain	Ru-106	3.14E-09	1.38E-09	7.73E-10	Air	0
Urban Family	Child born 1964	Ingestion	Grain	Sr-89	4.84E-12	1.18E-12	6.85E-13	Air	0
Urban Family	Child born 1964	Ingestion	Grain	Sr-90	8.74E-11	9.93E-12	6.62E-12	Air	0
Urban Family	Child born 1964	Ingestion	Grain	U-234	4.62E-11	4.33E-12	2.66E-12	Air	0
Urban Family	Child born 1964	Ingestion	Grain	U-235	2.91E-12	2.97E-13	1.8E-13	Air	0
Urban Family	Child born 1964	Ingestion	Grain	U-236	3.07E-12	2.88E-13	1.77E-13	Air	0
Urban Family	Child born 1964	Ingestion	Grain	U-238	1.58E-10	1.76E-11	1.06E-11	Air	0
Urban Family	Child born 1964	Ingestion	Beef	Am-241	7.93E-13	2.06E-14	1.42E-14	Air	0

Urban Family	Child born 1964	Ingestion	Beef	C-14	8.01E-07	1.32E-07	8.75E-08	Air	0
Urban Family	Child born 1964	Ingestion	Beef	Cs-137	1.51E-08	2.07E-09	1.39E-09	Air	0
Urban Family	Child born 1964	Ingestion	Beef	H-3	5.48E-06	8.3E-07	5.52E-07	Air	0
Urban Family	Child born 1964	Ingestion	Beef	I-129	1.96E-07	1.81E-08	1.84E-09	Air	0
Urban Family	Child born 1964	Ingestion	Beef	I-131	2.43E-06	2.28E-07	2.38E-08	Air	0
Urban Family	Child born 1964	Ingestion	Beef	Pu-238	6.87E-11	2.39E-12	1.71E-12	Air	0
Urban Family	Child born 1964	Ingestion	Beef	Pu-239	1.51E-11	5.67E-13	4.03E-13	Air	0
Urban Family	Child born 1964	Ingestion	Beef	Ru-106	8.66E-07	3.93E-07	2.2E-07	Air	0
Urban Family	Child born 1964	Ingestion	Beef	Sr-89	2.23E-10	5.16E-11	3E-11	Air	0
Urban Family	Child born 1964	Ingestion	Beef	Sr-90	3.49E-09	3.32E-10	2.25E-10	Air	0
Urban Family	Child born 1964	Ingestion	Beef	U-234	7.92E-11	6.67E-12	4.11E-12	Air	0
Urban Family	Child born 1964	Ingestion	Beef	U-235	5.04E-12	4.57E-13	2.78E-13	Air	0
Urban Family	Child born 1964	Ingestion	Beef	U-236	5.26E-12	4.44E-13	2.73E-13	Air	0
Urban Family	Child born 1964	Ingestion	Beef	U-238	2.64E-10	2.37E-11	1.45E-11	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	Am-241	4.03E-16	1.05E-17	7.28E-18	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	C-14	2.65E-08	4.46E-09	2.95E-09	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	Cs-137	9.44E-12	1.31E-12	8.8E-13	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	H-3	7.34E-07	1.15E-07	7.66E-08	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	I-129	1.83E-13	1.7E-14	1.73E-15	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	I-131	2.74E-19	2.71E-20	2.83E-21	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	Pu-238	7.27E-14	2.52E-15	1.8E-15	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	Pu-239	1.62E-14	6.77E-16	4.79E-16	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	Ru-106	3.61E-10	1.7E-10	9.52E-11	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	Sr-89	6.55E-16	1.65E-16	9.62E-17	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	Sr-90	1.5E-13	1.75E-14	1.18E-14	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	U-234	7.9E-13	7.81E-14	4.79E-14	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	U-235	5.2E-14	5.51E-15	3.35E-15	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	U-236	5.25E-14	5.17E-15	3.19E-15	Air	0
Urban Family	Child born 1964	Ingestion	Poultry	U-238	2.75E-12	2.88E-13	1.76E-13	Air	0
Urban Family	Child born 1964	Ingestion	Milk	Am-241	2.01E-13	5.66E-15	3.88E-15	Air	0
Urban Family	Child born 1964	Ingestion	Milk	C-14	1.99E-06	3.49E-07	2.3E-07	Air	0
Urban Family	Child born 1964	Ingestion	Milk	Cs-137	1.24E-08	1.85E-09	1.22E-09	Air	0
Urban Family	Child born 1964	Ingestion	Milk	H-3	3.99E-05	6.29E-06	4.16E-06	Air	0
Urban Family	Child born 1964	Ingestion	Milk	I-129	5.27E-07	5.22E-08	5.33E-09	Air	0
Urban Family	Child born 1964	Ingestion	Milk	I-131	7.77E-06	7.68E-07	8.03E-08	Air	0
Urban Family	Child born 1964	Ingestion	Milk	Pu-238	8.56E-11	2.99E-12	2.13E-12	Air	0
Urban Family	Child born 1964	Ingestion	Milk	Pu-239	2.22E-11	8.56E-13	6.04E-13	Air	0

Urban Family	Child born 1964	Ingestion	Milk	Ru-106	7.11E-10	3.12E-10	1.75E-10	Air	0
Urban Family	Child born 1964	Ingestion	Milk	Sr-89	9.65E-10	2.21E-10	1.29E-10	Air	0
Urban Family	Child born 1964	Ingestion	Milk	Sr-90	2.16E-08	1.82E-09	1.25E-09	Air	0
Urban Family	Child born 1964	Ingestion	Milk	U-234	1.5E-09	1.25E-10	7.64E-11	Air	0
Urban Family	Child born 1964	Ingestion	Milk	U-235	9.38E-11	8.59E-12	5.21E-12	Air	0
Urban Family	Child born 1964	Ingestion	Milk	U-236	9.95E-11	8.29E-12	5.08E-12	Air	0
Urban Family	Child born 1964	Ingestion	Milk	U-238	4.83E-09	4.29E-10	2.62E-10	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	Am-241	4.26E-16	1.16E-17	7.97E-18	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	C-14	3.74E-08	6.49E-09	4.28E-09	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	Cs-137	5.12E-13	7.39E-14	4.93E-14	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	H-3	1.33E-06	2.18E-07	1.44E-07	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	I-129	1.08E-10	1.03E-11	1.06E-12	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	I-131	1.66E-16	1.69E-17	1.76E-18	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	Pu-238	2.4E-14	8.36E-16	5.97E-16	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	Pu-239	5.69E-15	2.46E-16	1.74E-16	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	Ru-106	4.73E-13	2.21E-13	1.24E-13	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	Sr-89	3.37E-15	8.62E-16	5.01E-16	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	Sr-90	8.36E-13	9.99E-14	6.7E-14	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	U-234	1.66E-12	1.68E-13	1.03E-13	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	U-235	1.09E-13	1.2E-14	7.27E-15	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	U-236	1.11E-13	1.12E-14	6.86E-15	Air	0
Urban Family	Child born 1964	Ingestion	Eggs	U-238	5.75E-12	6.33E-13	3.86E-13	Air	0
Urban Family	Child born 1964	Ingestion	Soil	Am-241	2.47E-14	6.47E-16	4.46E-16	Air	0
Urban Family	Child born 1964	Ingestion	Soil	Cs-137	3.82E-13	5.42E-14	3.6E-14	Air	0
Urban Family	Child born 1964	Ingestion	Soil	I-129	7.42E-12	7.35E-13	7.5E-14	Air	0
Urban Family	Child born 1964	Ingestion	Soil	I-131	2.85E-11	2.86E-12	2.99E-13	Air	0
Urban Family	Child born 1964	Ingestion	Soil	Pu-238	1.32E-11	4.56E-13	3.26E-13	Air	0
Urban Family	Child born 1964	Ingestion	Soil	Pu-239	3.68E-12	1.41E-13	9.97E-14	Air	0
Urban Family	Child born 1964	Ingestion	Soil	Ru-106	3.19E-11	1.37E-11	7.68E-12	Air	0
Urban Family	Child born 1964	Ingestion	Soil	Sr-89	2.62E-14	5.94E-15	3.45E-15	Air	0
Urban Family	Child born 1964	Ingestion	Soil	Sr-90	1.37E-12	1.33E-13	8.88E-14	Air	0
Urban Family	Child born 1964	Ingestion	Soil	U-234	7.01E-13	5.75E-14	3.52E-14	Air	0
Urban Family	Child born 1964	Ingestion	Soil	U-235	4.49E-14	4.04E-15	2.45E-15	Air	0
Urban Family	Child born 1964	Ingestion	Soil	U-236	4.67E-14	3.82E-15	2.34E-15	Air	0
Urban Family	Child born 1964	Ingestion	Soil	U-238	2.57E-12	2.79E-13	1.66E-13	Air	0
Urban Family	Child born 1964	External	Air Immersion	Am-241	6.29E-16	7.74E-17	5.04E-17	Air	0
Urban Family	Child born 1964	External	Air Immersion	Ar-41	2.02E-05	3.03E-06	2.01E-06	Air	0

Urban Family	Child born 1964	External	Air Immersion	C-14	1.46E-12	3.7E-14	3.2E-14	Air	0
Urban Family	Child born 1964	External	Air Immersion	Cs-137	6.76E-12	9.55E-13	6.35E-13	Air	0
Urban Family	Child born 1964	External	Air Immersion	I-129	2.17E-13	2.99E-14	1.82E-14	Air	0
Urban Family	Child born 1964	External	Air Immersion	I-131	8.45E-10	1.51E-10	9.87E-11	Air	0
Urban Family	Child born 1964	External	Air Immersion	Pu-238	9.55E-16	1.44E-16	8.16E-17	Air	0
Urban Family	Child born 1964	External	Air Immersion	Pu-239	1.96E-16	3.18E-17	1.98E-17	Air	0
Urban Family	Child born 1964	External	Air Immersion	Ru-106	1.32E-10	2.18E-11	1.43E-11	Air	0
Urban Family	Child born 1964	External	Air Immersion	Sr-89	2.3E-14	9.87E-16	7.69E-16	Air	0
Urban Family	Child born 1964	External	Air Immersion	Sr-90	1.21E-14	4.49E-16	3.64E-16	Air	0
Urban Family	Child born 1964	External	Air Immersion	U-234	2.06E-16	3.27E-17	2.01E-17	Air	0
Urban Family	Child born 1964	External	Air Immersion	U-235	1.52E-14	2.47E-15	1.62E-15	Air	0
Urban Family	Child born 1964	External	Air Immersion	U-236	9.14E-18	1.42E-18	8.52E-19	Air	0
Urban Family	Child born 1964	External	Air Immersion	U-238	2.19E-15	2.72E-16	1.78E-16	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	Am-241	5.94E-13	7.03E-14	4.58E-14	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	Cs-137	4.17E-09	5.8E-10	3.85E-10	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	I-129	1.48E-10	1.96E-11	1.22E-11	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	I-131	1.44E-08	2.58E-09	1.69E-09	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	Pu-238	4.23E-12	5.14E-13	2.96E-13	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	Pu-239	4E-13	5.13E-14	3.04E-14	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	Ru-106	8.5E-08	9.73E-09	6.6E-09	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	Sr-89	2.89E-11	6.76E-13	6.22E-13	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	Sr-90	2.44E-10	6.08E-12	5.47E-12	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	U-234	4.91E-13	6.23E-14	3.69E-14	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	U-235	9.17E-12	1.48E-12	9.69E-13	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	U-236	2.97E-14	3.65E-15	2.14E-15	Air	0
Urban Family	Child born 1964	External	Ground Contaminat	U-238	3.36E-10	1.7E-11	1.28E-11	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	Am-241	6.93E-09	1.99E-10	1.72E-10	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	C-14	6.61E-10	1.05E-10	6.95E-11	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	Cs-137	2.01E-10	2.7E-11	1.8E-11	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	H-3	1.11E-05	1.58E-06	1.05E-06	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	I-129	1.1E-08	1.02E-09	1.04E-10	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	I-131	4.01E-07	3.82E-08	3.95E-09	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	Pu-238	2.12E-06	8.23E-08	7.32E-08	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	Pu-239	4.22E-07	1.69E-08	1.5E-08	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	Ru-106	7.9E-08	1.87E-08	1.59E-08	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	Sr-89	7.95E-11	1.53E-11	1.29E-11	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	Sr-90	6.34E-10	8.83E-11	8.02E-11	Air	0

Urban Family	Child born 1964	Inhalation	Air Inhalation	U-234	2.72E-08	4.18E-09	3.95E-09	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	U-235	1.63E-09	2.45E-10	2.31E-10	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	U-236	1.78E-09	2.72E-10	2.57E-10	Air	0
Urban Family	Child born 1964	Inhalation	Air Inhalation	U-238	8.38E-08	1.24E-08	1.18E-08	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	Am-241	2.58E-11	7.27E-13	6.28E-13	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	Cs-137	7.97E-13	1.06E-13	7.12E-14	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	I-129	1.47E-11	1.34E-12	1.36E-13	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	I-131	4.3E-11	4.1E-12	4.25E-13	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	Pu-238	7.12E-09	2.76E-10	2.45E-10	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	Pu-239	1.44E-09	5.71E-11	5.04E-11	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	Ru-106	2.12E-10	5E-11	4.25E-11	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	Sr-89	8.58E-14	1.65E-14	1.39E-14	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	Sr-90	2.51E-12	3.5E-13	3.1E-13	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	U-234	9.2E-11	1.41E-11	1.33E-11	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	U-235	5.62E-12	8.35E-13	7.87E-13	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	U-236	5.99E-12	9.13E-13	8.65E-13	Air	0
Urban Family	Child born 1964	Inhalation	Resuspended Soil	U-238	2.91E-10	4.27E-11	4.03E-11	Air	0

Location	Receptor	ReportRou	ReportPathway	IsotopeNa	SumOfSumO	SumOfSumOfTI	SumOfSumOfTF	AirWater	RunNum
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	Am-241	1.3068E-10	1.2766E-12	9.93175E-13	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	C-14	6.1107E-08	2.99908E-09	2.15698E-09	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	Cs-137	5.4234E-09	2.6438E-10	1.88626E-10	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	H-3	1.8564E-06	9.00188E-08	6.46965E-08	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	I-129	4.3912E-08	9.55314E-10	9.8086E-11	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	I-131	2.4165E-05	5.38123E-07	5.88582E-08	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	Pu-238	5.1451E-08	5.86797E-10	4.89863E-10	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	Pu-239	3.6166E-07	3.86204E-09	3.2237E-09	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	Ru-106	1.1327E-07	5.34894E-09	3.15095E-09	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	Sr-89	2.3124E-10	1.10915E-11	7.43337E-12	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	Sr-90	1.5861E-07	6.6492E-09	6.03338E-09	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	U-234	6.0772E-09	1.28835E-10	8.95667E-11	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	U-235	2.6054E-10	5.68007E-12	3.90491E-12	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	U-236	4.0385E-10	8.59326E-12	5.94946E-12	Air	0
Migrant Family	Adult Female	Ingestion	Leafy Vegetables	U-238	1.1283E-08	2.51821E-10	1.73247E-10	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	Am-241	4.4744E-11	4.37254E-13	3.40073E-13	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	C-14	2.093E-07	1.02723E-08	7.38799E-09	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	Cs-137	1.9901E-09	9.70507E-11	6.92709E-11	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	H-3	5.8996E-06	2.86297E-07	2.05662E-07	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	I-129	1.506E-08	3.27576E-10	3.36385E-11	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	I-131	2.6931E-06	6.01021E-08	6.5788E-09	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	Pu-238	1.7623E-08	2.00977E-10	1.67776E-10	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	Pu-239	1.2388E-07	1.32282E-09	1.10416E-09	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	Ru-106	3.8011E-08	1.79493E-09	1.05732E-09	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	Sr-89	7.2846E-11	3.48955E-12	2.33995E-12	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	Sr-90	6.6959E-08	2.81918E-09	2.53726E-09	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	U-234	2.0819E-09	4.43267E-11	3.08264E-11	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	U-235	8.9285E-11	1.94768E-12	1.33859E-12	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	U-236	1.3844E-10	2.94486E-12	2.03886E-12	Air	0
Migrant Family	Adult Female	Ingestion	Root Vegetables	U-238	3.9232E-09	8.87938E-11	6.07729E-11	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	Am-241	4.4275E-11	4.32667E-13	3.36506E-13	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	C-14	2.071E-07	1.01645E-08	7.31049E-09	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	Cs-137	1.8059E-09	8.80558E-11	6.2768E-11	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	H-3	5.826E-06	2.82629E-07	2.03034E-07	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	I-129	1.4902E-08	3.2414E-10	3.32856E-11	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	I-131	8.1902E-06	1.82342E-07	1.99484E-08	Air	0

Migrant Family	Adult Female	Ingestion	Fruit	Pu-238	1.7438E-08	1.98886E-10	1.66026E-10	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	Pu-239	1.2258E-07	1.30893E-09	1.09258E-09	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	Ru-106	3.8548E-08	1.82011E-09	1.07227E-09	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	Sr-89	7.8859E-11	3.77997E-12	2.5346E-12	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	Sr-90	5.4373E-08	2.27898E-09	2.07136E-09	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	U-234	2.0597E-09	4.36828E-11	3.03688E-11	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	U-235	8.832E-11	1.92603E-12	1.32379E-12	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	U-236	1.3689E-10	2.91261E-12	2.01656E-12	Air	0
Migrant Family	Adult Female	Ingestion	Fruit	U-238	3.8309E-09	8.54894E-11	5.87949E-11	Air	0
Migrant Family	Adult Female	Ingestion	Grain	Am-241	5.4867E-12	5.35378E-14	4.16595E-14	Air	0
Migrant Family	Adult Female	Ingestion	Grain	C-14	1.1055E-07	5.42685E-09	3.90437E-09	Air	0
Migrant Family	Adult Female	Ingestion	Grain	Cs-137	2.1895E-10	1.06771E-11	7.62091E-12	Air	0
Migrant Family	Adult Female	Ingestion	Grain	H-3	8.2461E-07	4.02786E-08	2.88977E-08	Air	0
Migrant Family	Adult Female	Ingestion	Grain	I-129	1.8697E-09	4.06646E-11	4.16993E-12	Air	0
Migrant Family	Adult Female	Ingestion	Grain	I-131	9.8543E-07	2.1933E-08	2.40025E-09	Air	0
Migrant Family	Adult Female	Ingestion	Grain	Pu-238	2.1688E-09	2.46357E-11	2.0531E-11	Air	0
Migrant Family	Adult Female	Ingestion	Grain	Pu-239	1.5178E-08	1.62393E-10	1.35697E-10	Air	0
Migrant Family	Adult Female	Ingestion	Grain	Ru-106	4.7531E-09	2.24495E-10	1.32239E-10	Air	0
Migrant Family	Adult Female	Ingestion	Grain	Sr-89	1.0002E-11	4.79101E-13	3.21444E-13	Air	0
Migrant Family	Adult Female	Ingestion	Grain	Sr-90	7.351E-09	3.08831E-10	2.79995E-10	Air	0
Migrant Family	Adult Female	Ingestion	Grain	U-234	2.5477E-10	5.41822E-12	3.77086E-12	Air	0
Migrant Family	Adult Female	Ingestion	Grain	U-235	1.0952E-11	2.38823E-13	1.64086E-13	Air	0
Migrant Family	Adult Female	Ingestion	Grain	U-236	1.7002E-11	3.61366E-13	2.50427E-13	Air	0
Migrant Family	Adult Female	Ingestion	Grain	U-238	4.7488E-10	1.06134E-11	7.2938E-12	Air	0
Migrant Family	Adult Female	Ingestion	Beef	Am-241	1.2597E-12	1.22928E-14	9.57106E-15	Air	0
Migrant Family	Adult Female	Ingestion	Beef	C-14	9.6942E-07	4.75907E-08	3.42511E-08	Air	0
Migrant Family	Adult Female	Ingestion	Beef	Cs-137	6.5314E-08	3.17921E-09	2.27888E-09	Air	0
Migrant Family	Adult Female	Ingestion	Beef	H-3	6.8159E-06	3.318E-07	2.38112E-07	Air	0
Migrant Family	Adult Female	Ingestion	Beef	I-129	4.2302E-07	9.19954E-09	9.44537E-10	Air	0
Migrant Family	Adult Female	Ingestion	Beef	I-131	0.00022303	4.96961E-06	5.4526E-07	Air	0
Migrant Family	Adult Female	Ingestion	Beef	Pu-238	1.2399E-10	1.41257E-12	1.17845E-12	Air	0
Migrant Family	Adult Female	Ingestion	Beef	Pu-239	8.7213E-10	9.31493E-12	7.7881E-12	Air	0
Migrant Family	Adult Female	Ingestion	Beef	Ru-106	1.3733E-06	6.48661E-08	3.82361E-08	Air	0
Migrant Family	Adult Female	Ingestion	Beef	Sr-89	4.6162E-10	2.20892E-11	1.48368E-11	Air	0
Migrant Family	Adult Female	Ingestion	Beef	Sr-90	3.0494E-07	1.28029E-08	1.1613E-08	Air	0
Migrant Family	Adult Female	Ingestion	Beef	U-234	4.3916E-10	9.31849E-12	6.4773E-12	Air	0
Migrant Family	Adult Female	Ingestion	Beef	U-235	1.8853E-11	4.11099E-13	2.82535E-13	Air	0

Migrant Family	Adult Female	Ingestion	Beef	U-236	2.9262E-11	6.20559E-13	4.2991E-13	Air	0
Migrant Family	Adult Female	Ingestion	Beef	U-238	8.0114E-10	1.75142E-11	1.21492E-11	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	Am-241	7.7081E-16	7.52135E-18	5.85385E-18	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	C-14	3.6988E-08	1.81564E-09	1.3062E-09	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	Cs-137	5.167E-11	2.51665E-12	1.79891E-12	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	H-3	1.1089E-06	5.39219E-08	3.8728E-08	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	I-129	4.5054E-13	9.81193E-15	1.00644E-15	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	I-131	2.7243E-17	6.05647E-19	6.63434E-20	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	Pu-238	1.512E-13	1.72E-15	1.44023E-15	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	Pu-239	1.0639E-12	1.13771E-14	9.5122E-15	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	Ru-106	6.3342E-10	2.99213E-11	1.76348E-11	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	Sr-89	1.6646E-15	7.97803E-17	5.3518E-17	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	Sr-90	1.7198E-11	7.21331E-13	6.55145E-13	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	U-234	5.9924E-12	1.272E-13	8.83563E-14	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	U-235	2.5724E-13	5.60783E-15	3.85522E-15	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	U-236	4.0013E-13	8.48144E-15	5.87497E-15	Air	0
Migrant Family	Adult Female	Ingestion	Poultry	U-238	1.0922E-11	2.37896E-13	1.65178E-13	Air	0
Migrant Family	Adult Female	Ingestion	Milk	Am-241	3.5467E-14	3.46033E-16	2.69506E-16	Air	0
Migrant Family	Adult Female	Ingestion	Milk	C-14	3.1573E-07	1.55018E-08	1.11559E-08	Air	0
Migrant Family	Adult Female	Ingestion	Milk	Cs-137	7.9999E-09	3.90305E-10	2.7855E-10	Air	0
Migrant Family	Adult Female	Ingestion	Milk	H-3	6.3486E-06	3.08068E-07	2.21321E-07	Air	0
Migrant Family	Adult Female	Ingestion	Milk	I-129	7.9372E-08	1.72653E-09	1.77271E-10	Air	0
Migrant Family	Adult Female	Ingestion	Milk	I-131	4.496E-05	9.99807E-07	1.09767E-07	Air	0
Migrant Family	Adult Female	Ingestion	Milk	Pu-238	1.0229E-11	1.16986E-13	9.7487E-14	Air	0
Migrant Family	Adult Female	Ingestion	Milk	Pu-239	7.1936E-11	7.6845E-13	6.42682E-13	Air	0
Migrant Family	Adult Female	Ingestion	Milk	Ru-106	6.8156E-11	3.21969E-12	1.8992E-12	Air	0
Migrant Family	Adult Female	Ingestion	Milk	Sr-89	1.2237E-10	5.86672E-12	3.93157E-12	Air	0
Migrant Family	Adult Female	Ingestion	Milk	Sr-90	7.8972E-08	3.30511E-09	3.0263E-09	Air	0
Migrant Family	Adult Female	Ingestion	Milk	U-234	4.4021E-10	9.31476E-12	6.48611E-12	Air	0
Migrant Family	Adult Female	Ingestion	Milk	U-235	1.8861E-11	4.10579E-13	2.82615E-13	Air	0
Migrant Family	Adult Female	Ingestion	Milk	U-236	2.9226E-11	6.20933E-13	4.30144E-13	Air	0
Migrant Family	Adult Female	Ingestion	Milk	U-238	7.9414E-10	1.7214E-11	1.19802E-11	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	Am-241	4.74E-16	4.62392E-18	3.60241E-18	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	C-14	2.5595E-08	1.25643E-09	9.04047E-10	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	Cs-137	1.9093E-12	9.31605E-14	6.64864E-14	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	H-3	1.0117E-06	4.91534E-08	3.53066E-08	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	I-129	1.2482E-10	2.71578E-12	2.78479E-13	Air	0

Migrant Family	Adult Female	Ingestion	Eggs	I-131	1.1627E-14	2.58707E-16	2.83456E-17	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	Pu-238	2.3332E-14	2.65017E-16	2.22012E-16	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	Pu-239	1.6411E-13	1.75228E-15	1.47003E-15	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	Ru-106	3.6917E-13	1.74371E-14	1.02674E-14	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	Sr-89	4.1132E-15	1.97411E-16	1.32303E-16	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	Sr-90	3.7719E-11	1.5673E-12	1.45661E-12	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	U-234	5.5315E-12	1.17415E-13	8.15597E-14	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	U-235	2.3661E-13	5.13761E-15	3.53695E-15	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	U-236	3.6935E-13	7.82902E-15	5.42305E-15	Air	0
Migrant Family	Adult Female	Ingestion	Eggs	U-238	9.9823E-12	2.149E-13	1.49857E-13	Air	0
Migrant Family	Adult Female	Ingestion	Soil	Am-241	2.6886E-14	2.62173E-16	2.0428E-16	Air	0
Migrant Family	Adult Female	Ingestion	Soil	Cs-137	1.0518E-12	5.12805E-14	3.66215E-14	Air	0
Migrant Family	Adult Female	Ingestion	Soil	I-129	6.9001E-12	1.50278E-13	1.54086E-14	Air	0
Migrant Family	Adult Female	Ingestion	Soil	I-131	9.8746E-10	2.19714E-11	2.40808E-12	Air	0
Migrant Family	Adult Female	Ingestion	Soil	Pu-238	1.0571E-11	1.20603E-13	1.00514E-13	Air	0
Migrant Family	Adult Female	Ingestion	Soil	Pu-239	7.4418E-11	7.96582E-13	6.646E-13	Air	0
Migrant Family	Adult Female	Ingestion	Soil	Ru-106	1.9825E-11	9.36471E-13	5.51728E-13	Air	0
Migrant Family	Adult Female	Ingestion	Soil	Sr-89	2.1205E-14	1.01618E-15	6.81406E-16	Air	0
Migrant Family	Adult Female	Ingestion	Soil	Sr-90	3.225E-11	1.35539E-12	1.22171E-12	Air	0
Migrant Family	Adult Female	Ingestion	Soil	U-234	1.2496E-12	2.64889E-14	1.84125E-14	Air	0
Migrant Family	Adult Female	Ingestion	Soil	U-235	5.3633E-14	1.17095E-15	8.03774E-16	Air	0
Migrant Family	Adult Female	Ingestion	Soil	U-236	8.3179E-14	1.76953E-15	1.22577E-15	Air	0
Migrant Family	Adult Female	Ingestion	Soil	U-238	2.3893E-12	5.49495E-14	3.74344E-14	Air	0
Migrant Family	Adult Female	External	Air Immersion	Am-241	7.6225E-16	3.34045E-17	2.32762E-17	Air	0
Migrant Family	Adult Female	External	Air Immersion	Ar-41	3.8638E-05	1.86102E-06	1.33193E-06	Air	0
Migrant Family	Adult Female	External	Air Immersion	C-14	1.8323E-12	1.77723E-14	1.60724E-14	Air	0
Migrant Family	Adult Female	External	Air Immersion	Cs-137	1.7131E-11	8.19357E-13	5.85432E-13	Air	0
Migrant Family	Adult Female	External	Air Immersion	I-129	3.9965E-13	1.53791E-14	1.01079E-14	Air	0
Migrant Family	Adult Female	External	Air Immersion	I-131	2.0368E-07	9.65446E-09	6.91314E-09	Air	0
Migrant Family	Adult Female	External	Air Immersion	Pu-238	1.393E-15	5.10143E-17	3.12202E-17	Air	0
Migrant Family	Adult Female	External	Air Immersion	Pu-239	8.8251E-15	3.8089E-16	2.58103E-16	Air	0
Migrant Family	Adult Female	External	Air Immersion	Ru-106	3.2071E-10	1.41945E-11	1.01901E-11	Air	0
Migrant Family	Adult Female	External	Air Immersion	Sr-89	9.6189E-14	1.30006E-15	1.09344E-15	Air	0
Migrant Family	Adult Female	External	Air Immersion	Sr-90	1.1101E-12	1.2215E-14	1.07881E-14	Air	0
Migrant Family	Adult Female	External	Air Immersion	U-234	1.3226E-15	5.51642E-17	3.69084E-17	Air	0
Migrant Family	Adult Female	External	Air Immersion	U-235	6.3497E-14	2.97774E-15	2.11499E-15	Air	0
Migrant Family	Adult Female	External	Air Immersion	U-236	5.8572E-17	2.33217E-18	1.51427E-18	Air	0

Migrant Family	Adult Female	External	Air Immersion	U-238	3.6919E-15	1.3236E-16	9.23375E-17	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	Am-241	9.3759E-13	3.9816E-14	2.77119E-14	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	Cs-137	1.3029E-08	6.12236E-10	4.37587E-10	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	I-129	3.9102E-10	1.47782E-11	9.84532E-12	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	I-131	5.0624E-06	2.39763E-07	1.71888E-07	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	Pu-238	8.879E-12	2.61905E-13	1.60156E-13	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	Pu-239	2.5739E-11	8.41294E-13	5.36651E-13	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	Ru-106	2.9818E-07	9.41536E-09	6.94896E-09	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	Sr-89	1.7319E-10	1.47663E-12	1.40572E-12	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	Sr-90	3.5535E-08	3.25315E-10	3.03189E-10	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	U-234	4.53E-12	1.43459E-13	9.09791E-14	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	U-235	5.4196E-11	2.53215E-12	1.80313E-12	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	U-236	2.729E-13	8.35769E-15	5.21384E-15	Air	0
Migrant Family	Adult Female	External	Ground Contaminat	U-238	1.5557E-09	2.57261E-11	2.07961E-11	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	Am-241	6.1523E-09	8.02612E-11	6.91798E-11	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	C-14	5.7697E-10	2.79102E-11	2.00531E-11	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	Cs-137	4.1146E-10	1.9281E-11	1.37466E-11	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	H-3	1.0047E-05	4.88205E-07	3.50015E-07	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	I-129	1.3828E-08	3.01714E-10	3.08915E-11	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	I-131	2.4335E-05	5.41827E-07	5.84906E-08	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	Pu-238	2.4054E-06	3.36708E-08	2.98691E-08	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	Pu-239	1.6663E-05	2.13577E-07	1.88921E-07	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	Ru-106	1.1044E-07	5.8708E-09	5.34938E-09	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	Sr-89	1.7628E-10	9.41911E-12	8.69703E-12	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	Sr-90	4.2488E-08	2.1233E-09	2.01327E-09	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	U-234	9.8278E-08	5.12117E-09	4.83532E-09	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	U-235	3.9402E-09	2.04339E-10	1.92771E-10	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	U-236	6.3722E-09	3.28871E-10	3.11508E-10	Air	0
Migrant Family	Adult Female	Inhalation	Air Inhalation	U-238	1.6149E-07	8.35756E-09	7.85348E-09	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	Am-241	2.9739E-09	3.87844E-11	3.34312E-11	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	Cs-137	1.9596E-10	9.18097E-12	6.54935E-12	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	I-129	2.6404E-09	5.75707E-11	5.89785E-12	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	I-131	3.7871E-07	8.41285E-09	9.06893E-10	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	Pu-238	1.164E-06	1.63432E-08	1.44755E-08	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	Pu-239	8.0695E-06	1.03067E-07	9.11989E-08	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	Ru-106	4.2723E-08	2.26693E-09	2.06853E-09	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	Sr-89	2.7267E-11	1.45513E-12	1.34432E-12	Air	0

Migrant Family	Adult Female	Inhalation	Resuspended Soil	Sr-90	2.1292E-08	1.06089E-09	1.00158E-09	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	U-234	4.7483E-08	2.47026E-09	2.34202E-09	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	U-235	1.9048E-09	9.87627E-11	9.31023E-11	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	U-236	3.0848E-09	1.59387E-10	1.50698E-10	Air	0
Migrant Family	Adult Female	Inhalation	Resuspended Soil	U-238	7.8183E-08	4.04841E-09	3.80136E-09	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	Am-241	1.3068E-10	1.2766E-12	9.93175E-13	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	C-14	6.1107E-08	2.99908E-09	2.15698E-09	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	Cs-137	5.4234E-09	2.6438E-10	1.88626E-10	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	H-3	1.8564E-06	9.00188E-08	6.46965E-08	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	I-129	4.3912E-08	9.55314E-10	9.8086E-11	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	I-131	2.4165E-05	5.38123E-07	5.88582E-08	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	Pu-238	5.1451E-08	5.86797E-10	4.89863E-10	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	Pu-239	3.6166E-07	3.86204E-09	3.2237E-09	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	Ru-106	1.1327E-07	5.34894E-09	3.15095E-09	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	Sr-89	2.3124E-10	1.10915E-11	7.43337E-12	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	Sr-90	1.5861E-07	6.6492E-09	6.03338E-09	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	U-234	6.0772E-09	1.28835E-10	8.95667E-11	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	U-235	2.6054E-10	5.68007E-12	3.90491E-12	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	U-236	4.0385E-10	8.59326E-12	5.94946E-12	Air	0
Migrant Family	Adult Male	Ingestion	Leafy Vegetables	U-238	1.1283E-08	2.51821E-10	1.73247E-10	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	Am-241	6.1954E-11	6.05429E-13	4.70871E-13	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	C-14	2.898E-07	1.42232E-08	1.02295E-08	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	Cs-137	2.7555E-09	1.34378E-10	9.59136E-11	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	H-3	8.1686E-06	3.96412E-07	2.84763E-07	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	I-129	2.0852E-08	4.53567E-10	4.65764E-11	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	I-131	3.7288E-06	8.32182E-08	9.1091E-09	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	Pu-238	2.44E-08	2.78276E-10	2.32305E-10	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	Pu-239	1.7152E-07	1.83159E-09	1.52884E-09	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	Ru-106	5.2631E-08	2.48528E-09	1.46398E-09	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	Sr-89	1.0086E-10	4.83169E-12	3.23993E-12	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	Sr-90	9.2712E-08	3.90348E-09	3.51313E-09	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	U-234	2.8826E-09	6.13754E-11	4.26827E-11	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	U-235	1.2362E-10	2.69679E-12	1.85343E-12	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	U-236	1.9168E-10	4.07749E-12	2.82304E-12	Air	0
Migrant Family	Adult Male	Ingestion	Root Vegetables	U-238	5.4321E-09	1.22945E-10	8.41471E-11	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	Am-241	4.318E-11	4.21965E-13	3.28183E-13	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	C-14	2.0198E-07	9.91313E-09	7.12967E-09	Air	0

Migrant Family	Adult Male	Ingestion	Fruit	Cs-137	1.7612E-09	8.58777E-11	6.12154E-11	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	H-3	5.6819E-06	2.75638E-07	1.98012E-07	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	I-129	1.4533E-08	3.16122E-10	3.24623E-11	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	I-131	7.9876E-06	1.77832E-07	1.9455E-08	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	Pu-238	1.7006E-08	1.93967E-10	1.6192E-10	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	Pu-239	1.1954E-07	1.27656E-09	1.06556E-09	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	Ru-106	3.7594E-08	1.77509E-09	1.04575E-09	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	Sr-89	7.6909E-11	3.68647E-12	2.47191E-12	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	Sr-90	5.3028E-08	2.22261E-09	2.02013E-09	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	U-234	2.0088E-09	4.26023E-11	2.96177E-11	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	U-235	8.6135E-11	1.87839E-12	1.29104E-12	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	U-236	1.3351E-10	2.84056E-12	1.96668E-12	Air	0
Migrant Family	Adult Male	Ingestion	Fruit	U-238	3.7361E-09	8.33748E-11	5.73406E-11	Air	0
Migrant Family	Adult Male	Ingestion	Grain	Am-241	6.6163E-12	6.45603E-14	5.02364E-14	Air	0
Migrant Family	Adult Male	Ingestion	Grain	C-14	1.3331E-07	6.54414E-09	4.70821E-09	Air	0
Migrant Family	Adult Male	Ingestion	Grain	Cs-137	2.6403E-10	1.28753E-11	9.18992E-12	Air	0
Migrant Family	Adult Male	Ingestion	Grain	H-3	9.9439E-07	4.85712E-08	3.48473E-08	Air	0
Migrant Family	Adult Male	Ingestion	Grain	I-129	2.2546E-09	4.90367E-11	5.02845E-12	Air	0
Migrant Family	Adult Male	Ingestion	Grain	I-131	1.1883E-06	2.64486E-08	2.89442E-09	Air	0
Migrant Family	Adult Male	Ingestion	Grain	Pu-238	2.6153E-09	2.97077E-11	2.47579E-11	Air	0
Migrant Family	Adult Male	Ingestion	Grain	Pu-239	1.8303E-08	1.95827E-10	1.63634E-10	Air	0
Migrant Family	Adult Male	Ingestion	Grain	Ru-106	5.7316E-09	2.70715E-10	1.59465E-10	Air	0
Migrant Family	Adult Male	Ingestion	Grain	Sr-89	1.2062E-11	5.77739E-13	3.87624E-13	Air	0
Migrant Family	Adult Male	Ingestion	Grain	Sr-90	8.8645E-09	3.72414E-10	3.37641E-10	Air	0
Migrant Family	Adult Male	Ingestion	Grain	U-234	3.0723E-10	6.53374E-12	4.54721E-12	Air	0
Migrant Family	Adult Male	Ingestion	Grain	U-235	1.3207E-11	2.87992E-13	1.97868E-13	Air	0
Migrant Family	Adult Male	Ingestion	Grain	U-236	2.0503E-11	4.35765E-13	3.01985E-13	Air	0
Migrant Family	Adult Male	Ingestion	Grain	U-238	5.7264E-10	1.27985E-11	8.79547E-12	Air	0
Migrant Family	Adult Male	Ingestion	Beef	Am-241	1.9795E-12	1.93172E-14	1.50402E-14	Air	0
Migrant Family	Adult Male	Ingestion	Beef	C-14	1.5234E-06	7.47854E-08	5.38232E-08	Air	0
Migrant Family	Adult Male	Ingestion	Beef	Cs-137	1.0264E-07	4.9959E-09	3.58109E-09	Air	0
Migrant Family	Adult Male	Ingestion	Beef	H-3	1.0711E-05	5.21401E-07	3.74175E-07	Air	0
Migrant Family	Adult Male	Ingestion	Beef	I-129	6.6474E-07	1.44564E-08	1.48427E-09	Air	0
Migrant Family	Adult Male	Ingestion	Beef	I-131	0.00035047	7.80938E-06	8.56837E-07	Air	0
Migrant Family	Adult Male	Ingestion	Beef	Pu-238	1.9484E-10	2.21975E-12	1.85184E-12	Air	0
Migrant Family	Adult Male	Ingestion	Beef	Pu-239	1.3705E-09	1.46377E-11	1.22384E-11	Air	0
Migrant Family	Adult Male	Ingestion	Beef	Ru-106	2.1581E-06	1.01932E-07	6.00853E-08	Air	0

Migrant Family	Adult Male	Ingestion	Beef	Sr-89	7.2541E-10	3.47115E-11	2.33149E-11	Air	0
Migrant Family	Adult Male	Ingestion	Beef	Sr-90	4.7918E-07	2.01189E-08	1.82491E-08	Air	0
Migrant Family	Adult Male	Ingestion	Beef	U-234	6.901E-10	1.46433E-11	1.01786E-11	Air	0
Migrant Family	Adult Male	Ingestion	Beef	U-235	2.9626E-11	6.46013E-13	4.43983E-13	Air	0
Migrant Family	Adult Male	Ingestion	Beef	U-236	4.5983E-11	9.75165E-13	6.75572E-13	Air	0
Migrant Family	Adult Male	Ingestion	Beef	U-238	1.2589E-09	2.75223E-11	1.90916E-11	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	Am-241	9.5717E-16	9.3397E-18	7.26906E-18	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	C-14	4.593E-08	2.25458E-09	1.62199E-09	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	Cs-137	6.4162E-11	3.12506E-12	2.23381E-12	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	H-3	1.377E-06	6.6958E-08	4.80908E-08	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	I-129	5.5946E-13	1.2184E-14	1.24975E-15	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	I-131	3.383E-17	7.52067E-19	8.23825E-20	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	Pu-238	1.8775E-13	2.13582E-15	1.78842E-15	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	Pu-239	1.3212E-12	1.41277E-14	1.18119E-14	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	Ru-106	7.8655E-10	3.71551E-11	2.18981E-11	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	Sr-89	2.0671E-15	9.90678E-17	6.64565E-17	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	Sr-90	2.1355E-11	8.95718E-13	8.13532E-13	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	U-234	7.4412E-12	1.57952E-13	1.09717E-13	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	U-235	3.1943E-13	6.96357E-15	4.78725E-15	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	U-236	4.9686E-13	1.05319E-14	7.29529E-15	Air	0
Migrant Family	Adult Male	Ingestion	Poultry	U-238	1.3563E-11	2.95409E-13	2.05112E-13	Air	0
Migrant Family	Adult Male	Ingestion	Milk	Am-241	4.7098E-14	4.59507E-16	3.57885E-16	Air	0
Migrant Family	Adult Male	Ingestion	Milk	C-14	4.1927E-07	2.05853E-08	1.48142E-08	Air	0
Migrant Family	Adult Male	Ingestion	Milk	Cs-137	1.0623E-08	5.18296E-10	3.69894E-10	Air	0
Migrant Family	Adult Male	Ingestion	Milk	H-3	8.4304E-06	4.09092E-07	2.93898E-07	Air	0
Migrant Family	Adult Male	Ingestion	Milk	I-129	1.054E-07	2.29271E-09	2.35404E-10	Air	0
Migrant Family	Adult Male	Ingestion	Milk	I-131	5.9704E-05	1.32767E-06	1.45763E-07	Air	0
Migrant Family	Adult Male	Ingestion	Milk	Pu-238	1.3583E-11	1.55348E-13	1.29456E-13	Air	0
Migrant Family	Adult Male	Ingestion	Milk	Pu-239	9.5526E-11	1.02045E-12	8.53436E-13	Air	0
Migrant Family	Adult Male	Ingestion	Milk	Ru-106	9.0506E-11	4.27552E-12	2.522E-12	Air	0
Migrant Family	Adult Male	Ingestion	Milk	Sr-89	1.625E-10	7.79058E-12	5.22084E-12	Air	0
Migrant Family	Adult Male	Ingestion	Milk	Sr-90	1.0487E-07	4.38895E-09	4.01871E-09	Air	0
Migrant Family	Adult Male	Ingestion	Milk	U-234	5.8457E-10	1.23693E-11	8.61308E-12	Air	0
Migrant Family	Adult Male	Ingestion	Milk	U-235	2.5047E-11	5.45219E-13	3.75292E-13	Air	0
Migrant Family	Adult Male	Ingestion	Milk	U-236	3.881E-11	8.24554E-13	5.71201E-13	Air	0
Migrant Family	Adult Male	Ingestion	Milk	U-238	1.0546E-09	2.28589E-11	1.59088E-11	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	Am-241	7.8436E-16	7.65149E-18	5.96113E-18	Air	0

Migrant Family	Adult Male	Ingestion	Eggs	C-14	4.2354E-08	2.07909E-09	1.49598E-09	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	Cs-137	3.1594E-12	1.54158E-13	1.10019E-13	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	H-3	1.674E-06	8.13372E-08	5.84241E-08	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	I-129	2.0655E-10	4.49396E-12	4.60816E-13	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	I-131	1.924E-14	4.28098E-16	4.69053E-17	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	Pu-238	3.8609E-14	4.38541E-16	3.67378E-16	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	Pu-239	2.7157E-13	2.8996E-15	2.43256E-15	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	Ru-106	6.1088E-13	2.88543E-14	1.699E-14	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	Sr-89	6.8063E-15	3.26668E-16	2.1893E-16	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	Sr-90	6.2417E-11	2.59351E-12	2.41035E-12	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	U-234	9.1533E-12	1.94294E-13	1.34962E-13	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	U-235	3.9153E-13	8.50152E-15	5.8528E-15	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	U-236	6.1119E-13	1.29552E-14	8.97385E-15	Air	0
Migrant Family	Adult Male	Ingestion	Eggs	U-238	1.6518E-11	3.55608E-13	2.47977E-13	Air	0
Migrant Family	Adult Male	Ingestion	Soil	Am-241	2.6886E-14	2.62173E-16	2.0428E-16	Air	0
Migrant Family	Adult Male	Ingestion	Soil	Cs-137	1.0518E-12	5.12805E-14	3.66215E-14	Air	0
Migrant Family	Adult Male	Ingestion	Soil	I-129	6.9001E-12	1.50278E-13	1.54086E-14	Air	0
Migrant Family	Adult Male	Ingestion	Soil	I-131	9.8746E-10	2.19714E-11	2.40808E-12	Air	0
Migrant Family	Adult Male	Ingestion	Soil	Pu-238	1.0571E-11	1.20603E-13	1.00514E-13	Air	0
Migrant Family	Adult Male	Ingestion	Soil	Pu-239	7.4418E-11	7.96582E-13	6.646E-13	Air	0
Migrant Family	Adult Male	Ingestion	Soil	Ru-106	1.9825E-11	9.36471E-13	5.51728E-13	Air	0
Migrant Family	Adult Male	Ingestion	Soil	Sr-89	2.1205E-14	1.01618E-15	6.81406E-16	Air	0
Migrant Family	Adult Male	Ingestion	Soil	Sr-90	3.225E-11	1.35539E-12	1.22171E-12	Air	0
Migrant Family	Adult Male	Ingestion	Soil	U-234	1.2496E-12	2.64889E-14	1.84125E-14	Air	0
Migrant Family	Adult Male	Ingestion	Soil	U-235	5.3633E-14	1.17095E-15	8.03774E-16	Air	0
Migrant Family	Adult Male	Ingestion	Soil	U-236	8.3179E-14	1.76953E-15	1.22577E-15	Air	0
Migrant Family	Adult Male	Ingestion	Soil	U-238	2.3893E-12	5.49495E-14	3.74344E-14	Air	0
Migrant Family	Adult Male	External	Air Immersion	Am-241	7.6225E-16	3.34045E-17	2.32762E-17	Air	0
Migrant Family	Adult Male	External	Air Immersion	Ar-41	3.8638E-05	1.86102E-06	1.33193E-06	Air	0
Migrant Family	Adult Male	External	Air Immersion	C-14	1.8323E-12	1.77723E-14	1.60724E-14	Air	0
Migrant Family	Adult Male	External	Air Immersion	Cs-137	1.7131E-11	8.19357E-13	5.85432E-13	Air	0
Migrant Family	Adult Male	External	Air Immersion	I-129	3.9965E-13	1.53791E-14	1.01079E-14	Air	0
Migrant Family	Adult Male	External	Air Immersion	I-131	2.0368E-07	9.65446E-09	6.91314E-09	Air	0
Migrant Family	Adult Male	External	Air Immersion	Pu-238	1.393E-15	5.10143E-17	3.12202E-17	Air	0
Migrant Family	Adult Male	External	Air Immersion	Pu-239	8.8251E-15	3.8089E-16	2.58103E-16	Air	0
Migrant Family	Adult Male	External	Air Immersion	Ru-106	3.2071E-10	1.41945E-11	1.01901E-11	Air	0
Migrant Family	Adult Male	External	Air Immersion	Sr-89	9.6189E-14	1.30006E-15	1.09344E-15	Air	0

Migrant Family	Adult Male	External	Air Immersion	Sr-90	1.1101E-12	1.2215E-14	1.07881E-14	Air	0
Migrant Family	Adult Male	External	Air Immersion	U-234	1.3226E-15	5.51642E-17	3.69084E-17	Air	0
Migrant Family	Adult Male	External	Air Immersion	U-235	6.3497E-14	2.97774E-15	2.11499E-15	Air	0
Migrant Family	Adult Male	External	Air Immersion	U-236	5.8572E-17	2.33217E-18	1.51427E-18	Air	0
Migrant Family	Adult Male	External	Air Immersion	U-238	3.6919E-15	1.3236E-16	9.23375E-17	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	Am-241	1.0021E-12	4.25538E-14	2.96174E-14	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	Cs-137	1.3925E-08	6.54334E-10	4.67676E-10	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	I-129	4.1791E-10	1.57944E-11	1.05223E-11	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	I-131	5.4105E-06	2.56249E-07	1.83708E-07	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	Pu-238	9.4896E-12	2.79914E-13	1.71169E-13	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	Pu-239	2.7509E-11	8.99142E-13	5.73551E-13	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	Ru-106	3.1869E-07	1.00628E-08	7.42677E-09	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	Sr-89	1.851E-10	1.57816E-12	1.50238E-12	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	Sr-90	3.7978E-08	3.47684E-10	3.24037E-10	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	U-234	4.8414E-12	1.53323E-13	9.72349E-14	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	U-235	5.7923E-11	2.70626E-12	1.92711E-12	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	U-236	2.9166E-13	8.93237E-15	5.57235E-15	Air	0
Migrant Family	Adult Male	External	Ground Contaminat	U-238	1.6627E-09	2.74951E-11	2.2226E-11	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	Am-241	8.2746E-09	1.07949E-10	9.30448E-11	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	C-14	7.7601E-10	3.75383E-11	2.69708E-11	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	Cs-137	5.534E-10	2.59324E-11	1.84888E-11	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	H-3	1.3513E-05	6.56621E-07	4.70759E-07	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	I-129	1.8598E-08	4.05797E-10	4.15482E-11	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	I-131	3.273E-05	7.28742E-07	7.8668E-08	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	Pu-238	3.2352E-06	4.52862E-08	4.01731E-08	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	Pu-239	2.2412E-05	2.87254E-07	2.54093E-07	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	Ru-106	1.4854E-07	7.89605E-09	7.19475E-09	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	Sr-89	2.371E-10	1.26684E-11	1.16972E-11	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	Sr-90	5.7145E-08	2.85578E-09	2.70779E-09	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	U-234	1.3218E-07	6.88782E-09	6.50336E-09	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	U-235	5.2995E-09	2.7483E-10	2.59271E-10	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	U-236	8.5704E-09	4.42322E-10	4.18969E-10	Air	0
Migrant Family	Adult Male	Inhalation	Air Inhalation	U-238	2.172E-07	1.12407E-08	1.05627E-08	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	Am-241	3.9997E-09	5.21638E-11	4.4964E-11	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	Cs-137	2.6357E-10	1.23481E-11	8.80868E-12	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	I-129	3.5513E-09	7.74309E-11	7.93244E-12	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	I-131	5.0936E-07	1.1315E-08	1.21974E-09	Air	0

Migrant Family	Adult Male	Inhalation	Resuspended Soil	Pu-238	1.5655E-06	2.1981E-08	1.94692E-08	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	Pu-239	1.0853E-05	1.38623E-07	1.2266E-07	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	Ru-106	5.7461E-08	3.04895E-09	2.78211E-09	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	Sr-89	3.6674E-11	1.95711E-12	1.80807E-12	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	Sr-90	2.8637E-08	1.42687E-09	1.34709E-09	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	U-234	6.3863E-08	3.32243E-09	3.14994E-09	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	U-235	2.5619E-09	1.32833E-10	1.2522E-10	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	U-236	4.149E-09	2.14371E-10	2.02684E-10	Air	0
Migrant Family	Adult Male	Inhalation	Resuspended Soil	U-238	1.0515E-07	5.44499E-09	5.11271E-09	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	Am-241	1.3068E-10	1.78819E-12	1.33005E-12	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	C-14	4.6298E-08	6.14072E-09	4.10096E-09	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	Cs-137	2.5074E-09	2.14149E-10	1.43676E-10	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	H-3	1.3757E-06	1.81168E-07	1.21336E-07	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	I-129	3.6579E-08	2.78413E-09	2.84006E-10	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	I-131	4.3225E-05	4.13052E-06	4.31044E-07	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	Pu-238	3.269E-08	1.45695E-09	1.04755E-09	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	Pu-239	4.2053E-07	2.86722E-09	1.99888E-09	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	Ru-106	1.1293E-07	3.83784E-08	2.15928E-08	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	Sr-89	2.4008E-10	5.97885E-11	3.48417E-11	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	Sr-90	1.0197E-07	8.24422E-09	5.4596E-09	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	U-234	3.8283E-09	2.38661E-10	1.46711E-10	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	U-235	1.8119E-10	1.455E-11	8.89476E-12	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	U-236	2.5394E-10	1.58665E-11	9.76424E-12	Air	0
Migrant Family	Child born 195	Ingestion	Leafy Vegetables	U-238	8.4355E-09	8.03422E-10	4.87822E-10	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	Am-241	6.1954E-11	8.48053E-13	6.30634E-13	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	C-14	2.4981E-07	3.4753E-08	2.31503E-08	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	Cs-137	1.7871E-09	1.70805E-10	1.12239E-10	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	H-3	6.8729E-06	9.59947E-07	6.4091E-07	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	I-129	1.9521E-08	1.54366E-09	1.57523E-10	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	I-131	1.0658E-05	1.02699E-06	1.07239E-07	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	Pu-238	1.9162E-08	8.61634E-10	6.19016E-10	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	Pu-239	9.1356E-07	5.59171E-09	3.88116E-09	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	Ru-106	8.751E-08	2.62654E-08	1.47536E-08	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	Sr-89	2.3181E-10	4.68088E-11	2.72597E-11	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	Sr-90	2.1747E-07	1.438E-08	9.39795E-09	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	U-234	6.0672E-09	3.12284E-10	1.90521E-10	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	U-235	2.1023E-10	1.38663E-11	8.41937E-12	Air	0

Migrant Family	Child born 195	Ingestion	Root Vegetables	U-236	4.0269E-10	2.06802E-11	1.26152E-11	Air	0
Migrant Family	Child born 195	Ingestion	Root Vegetables	U-238	7.5929E-09	6.70083E-10	4.02322E-10	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	Am-241	4.318E-11	5.91067E-13	4.39533E-13	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	C-14	2.5185E-07	3.81558E-08	2.52713E-08	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	Cs-137	2.1284E-09	2.31793E-10	1.49181E-10	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	H-3	6.9501E-06	1.08514E-06	7.20164E-07	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	I-129	1.9592E-08	1.67689E-09	1.7113E-10	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	I-131	5.3499E-05	5.15444E-06	5.37871E-07	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	Pu-238	1.487E-08	6.7122E-10	4.82044E-10	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	Pu-239	2.111E-06	1.26423E-08	8.7662E-09	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	Ru-106	1.386E-07	3.61661E-08	2.02603E-08	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	Sr-89	4.6844E-10	8.5053E-11	4.94686E-11	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	Sr-90	3.935E-07	2.35405E-08	1.55452E-08	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	U-234	1.2887E-08	6.14953E-10	3.73726E-10	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	U-235	4.0602E-10	2.44574E-11	1.47893E-11	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	U-236	8.5513E-10	4.08862E-11	2.48459E-11	Air	0
Migrant Family	Child born 195	Ingestion	Fruit	U-238	1.2675E-08	9.9216E-10	5.96333E-10	Air	0
Migrant Family	Child born 195	Ingestion	Grain	Am-241	6.6163E-12	9.03971E-14	6.72804E-14	Air	0
Migrant Family	Child born 195	Ingestion	Grain	C-14	1.531E-07	2.27128E-08	1.50656E-08	Air	0
Migrant Family	Child born 195	Ingestion	Grain	Cs-137	1.8375E-10	1.95463E-11	1.27978E-11	Air	0
Migrant Family	Child born 195	Ingestion	Grain	H-3	1.1519E-06	1.75649E-07	1.1657E-07	Air	0
Migrant Family	Child born 195	Ingestion	Grain	I-129	2.9446E-09	2.47452E-10	2.52108E-11	Air	0
Migrant Family	Child born 195	Ingestion	Grain	I-131	6.0286E-06	5.79925E-07	6.05378E-08	Air	0
Migrant Family	Child born 195	Ingestion	Grain	Pu-238	2.2461E-09	1.00923E-10	7.23535E-11	Air	0
Migrant Family	Child born 195	Ingestion	Grain	Pu-239	8.5392E-08	5.41471E-10	3.76555E-10	Air	0
Migrant Family	Child born 195	Ingestion	Grain	Ru-106	1.155E-08	3.69483E-09	2.07564E-09	Air	0
Migrant Family	Child born 195	Ingestion	Grain	Sr-89	3.2443E-11	7.67815E-12	4.47361E-12	Air	0
Migrant Family	Child born 195	Ingestion	Grain	Sr-90	2.0497E-08	1.48776E-09	9.86135E-10	Air	0
Migrant Family	Child born 195	Ingestion	Grain	U-234	6.0242E-10	3.29236E-11	2.01296E-11	Air	0
Migrant Family	Child born 195	Ingestion	Grain	U-235	2.4186E-11	1.81682E-12	1.10347E-12	Air	0
Migrant Family	Child born 195	Ingestion	Grain	U-236	4.0157E-11	2.18886E-12	1.33865E-12	Air	0
Migrant Family	Child born 195	Ingestion	Grain	U-238	9.9388E-10	9.58141E-11	5.77524E-11	Air	0
Migrant Family	Child born 195	Ingestion	Beef	Am-241	1.9795E-12	2.70474E-14	2.01399E-14	Air	0
Migrant Family	Child born 195	Ingestion	Beef	C-14	1.442E-06	2.05E-07	1.36475E-07	Air	0
Migrant Family	Child born 195	Ingestion	Beef	Cs-137	6.7843E-08	6.63724E-09	4.37627E-09	Air	0
Migrant Family	Child born 195	Ingestion	Beef	H-3	9.8804E-06	1.41082E-06	9.39825E-07	Air	0
Migrant Family	Child born 195	Ingestion	Beef	I-129	7.0153E-07	5.65435E-08	5.76779E-09	Air	0

Migrant Family	Child born 195	Ingestion	Beef	I-131	0.00103262	9.90121E-05	1.03642E-05	Air	0
Migrant Family	Child born 195	Ingestion	Beef	Pu-238	1.8344E-10	8.29092E-12	5.9485E-12	Air	0
Migrant Family	Child born 195	Ingestion	Beef	Pu-239	7.0238E-09	4.33744E-11	3.01678E-11	Air	0
Migrant Family	Child born 195	Ingestion	Beef	Ru-106	3.8137E-06	1.18567E-06	6.66684E-07	Air	0
Migrant Family	Child born 195	Ingestion	Beef	Sr-89	1.7237E-09	3.55336E-10	2.07401E-10	Air	0
Migrant Family	Child born 195	Ingestion	Beef	Sr-90	1.086E-06	6.81073E-08	4.51823E-08	Air	0
Migrant Family	Child born 195	Ingestion	Beef	U-234	1.4408E-09	7.57934E-11	4.62709E-11	Air	0
Migrant Family	Child born 195	Ingestion	Beef	U-235	5.1284E-11	3.47969E-12	2.11458E-12	Air	0
Migrant Family	Child born 195	Ingestion	Beef	U-236	9.5867E-11	5.03195E-12	3.07509E-12	Air	0
Migrant Family	Child born 195	Ingestion	Beef	U-238	1.8075E-09	1.43793E-10	8.78459E-11	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	Am-241	9.5717E-16	1.30767E-17	9.73329E-18	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	C-14	4.6804E-08	6.83076E-09	4.5403E-09	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	Cs-137	3.7013E-11	3.72354E-12	2.46223E-12	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	H-3	1.4085E-06	2.0928E-07	1.3931E-07	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	I-129	6.4139E-13	5.29176E-14	5.39291E-15	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	I-131	1.3816E-16	1.33095E-17	1.39085E-18	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	Pu-238	1.9145E-13	8.65933E-15	6.23582E-15	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	Pu-239	2.8289E-12	1.92054E-14	1.33915E-14	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	Ru-106	1.2313E-09	4.36616E-10	2.4555E-10	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	Sr-89	3.8934E-15	1.02432E-15	5.97037E-16	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	Sr-90	2.6544E-11	2.22174E-12	1.4775E-12	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	U-234	8.2344E-12	5.10984E-13	3.13339E-13	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	U-235	3.8117E-13	3.18293E-14	1.93813E-14	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	U-236	5.4878E-13	3.39667E-14	2.08655E-14	Air	0
Migrant Family	Child born 195	Ingestion	Poultry	U-238	1.6916E-11	1.57288E-12	9.6211E-13	Air	0
Migrant Family	Child born 195	Ingestion	Milk	Am-241	4.7098E-14	6.43422E-16	4.79323E-16	Air	0
Migrant Family	Child born 195	Ingestion	Milk	C-14	9.3109E-07	1.52373E-07	1.00646E-07	Air	0
Migrant Family	Child born 195	Ingestion	Milk	Cs-137	1.9804E-08	2.37207E-09	1.5205E-09	Air	0
Migrant Family	Child born 195	Ingestion	Milk	H-3	1.8458E-05	3.12359E-06	2.06642E-06	Air	0
Migrant Family	Child born 195	Ingestion	Milk	I-129	2.6841E-07	2.44173E-08	2.49122E-09	Air	0
Migrant Family	Child born 195	Ingestion	Milk	I-131	0.00076647	7.37082E-05	7.72032E-06	Air	0
Migrant Family	Child born 195	Ingestion	Milk	Pu-238	2.9406E-11	1.35781E-12	9.71566E-13	Air	0
Migrant Family	Child born 195	Ingestion	Milk	Pu-239	2.7022E-09	1.63128E-11	1.13374E-11	Air	0
Migrant Family	Child born 195	Ingestion	Milk	Ru-106	5.873E-10	1.64967E-10	9.25974E-11	Air	0
Migrant Family	Child born 195	Ingestion	Milk	Sr-89	1.7207E-09	3.29872E-10	1.91752E-10	Air	0
Migrant Family	Child born 195	Ingestion	Milk	Sr-90	1.2531E-06	6.74571E-08	4.57939E-08	Air	0
Migrant Family	Child born 195	Ingestion	Milk	U-234	6.1591E-09	3.01146E-10	1.8349E-10	Air	0

Migrant Family	Child born 195	Ingestion	Milk	U-235	1.9907E-10	1.24993E-11	7.57818E-12	Air	0
Migrant Family	Child born 195	Ingestion	Milk	U-236	4.0814E-10	2.00092E-11	1.21805E-11	Air	0
Migrant Family	Child born 195	Ingestion	Milk	U-238	6.142E-09	4.51784E-10	2.75781E-10	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	Am-241	7.8436E-16	1.07137E-17	7.98049E-18	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	C-14	3.833E-08	5.45037E-09	3.62809E-09	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	Cs-137	1.7256E-12	1.66913E-13	1.10413E-13	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	H-3	1.5342E-06	2.23081E-07	1.48606E-07	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	I-129	2.045E-10	1.64934E-11	1.68021E-12	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	I-131	7.5246E-14	7.26899E-15	7.59863E-16	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	Pu-238	2.9574E-14	1.32317E-15	9.54096E-16	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	Pu-239	5.6518E-13	3.75944E-15	2.62797E-15	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	Ru-106	8.4125E-13	2.89121E-13	1.6241E-13	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	Sr-89	1.1458E-14	3.02998E-15	1.76405E-15	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	Sr-90	7.1806E-11	4.62121E-12	3.28174E-12	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	U-234	9.2219E-12	5.51379E-13	3.37656E-13	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	U-235	4.2066E-13	3.39656E-14	2.07106E-14	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	U-236	6.1462E-13	3.6653E-14	2.24826E-14	Air	0
Migrant Family	Child born 195	Ingestion	Eggs	U-238	1.8322E-11	1.61583E-12	9.94012E-13	Air	0
Migrant Family	Child born 195	Ingestion	Soil	Am-241	2.6886E-14	3.66976E-16	2.73564E-16	Air	0
Migrant Family	Child born 195	Ingestion	Soil	Cs-137	2.1017E-12	2.51553E-13	1.61399E-13	Air	0
Migrant Family	Child born 195	Ingestion	Soil	I-129	1.7489E-11	1.60203E-12	1.63135E-13	Air	0
Migrant Family	Child born 195	Ingestion	Soil	I-131	1.4287E-08	1.37689E-09	1.43972E-10	Air	0
Migrant Family	Child born 195	Ingestion	Soil	Pu-238	1.9974E-11	9.18099E-13	6.57144E-13	Air	0
Migrant Family	Child born 195	Ingestion	Soil	Pu-239	2.3528E-09	1.4195E-11	9.83908E-12	Air	0
Migrant Family	Child born 195	Ingestion	Soil	Ru-106	1.3702E-10	3.74796E-11	2.10005E-11	Air	0
Migrant Family	Child born 195	Ingestion	Soil	Sr-89	2.4493E-13	4.66909E-14	2.71674E-14	Air	0
Migrant Family	Child born 195	Ingestion	Soil	Sr-90	4.3859E-10	2.80665E-11	1.83334E-11	Air	0
Migrant Family	Child born 195	Ingestion	Soil	U-234	1.4515E-11	7.02719E-13	4.27169E-13	Air	0
Migrant Family	Child born 195	Ingestion	Soil	U-235	4.6666E-13	2.92146E-14	1.76323E-14	Air	0
Migrant Family	Child born 195	Ingestion	Soil	U-236	9.6489E-13	4.68105E-14	2.84722E-14	Air	0
Migrant Family	Child born 195	Ingestion	Soil	U-238	1.5682E-11	1.435E-12	8.53333E-13	Air	0
Migrant Family	Child born 195	External	Air Immersion	Am-241	7.6225E-16	5.33457E-17	3.57801E-17	Air	0
Migrant Family	Child born 195	External	Air Immersion	Ar-41	3.8347E-05	6.20354E-06	4.08216E-06	Air	0
Migrant Family	Child born 195	External	Air Immersion	C-14	1.8323E-12	4.25688E-14	3.67685E-14	Air	0
Migrant Family	Child born 195	External	Air Immersion	Cs-137	1.7131E-11	2.36012E-12	1.56298E-12	Air	0
Migrant Family	Child born 195	External	Air Immersion	I-129	3.9965E-13	4.96818E-14	3.03944E-14	Air	0
Migrant Family	Child born 195	External	Air Immersion	I-131	2.0368E-07	3.65493E-08	2.3981E-08	Air	0

Migrant Family	Child born 195	External	Air Immersion	Pu-238	1.393E-15	2.04137E-16	1.15776E-16	Air	0
Migrant Family	Child born 195	External	Air Immersion	Pu-239	8.8251E-15	1.48927E-15	9.23755E-16	Air	0
Migrant Family	Child born 195	External	Air Immersion	Ru-106	3.2071E-10	4.85413E-11	3.2041E-11	Air	0
Migrant Family	Child born 195	External	Air Immersion	Sr-89	9.6189E-14	4.06689E-15	3.17945E-15	Air	0
Migrant Family	Child born 195	External	Air Immersion	Sr-90	1.1101E-12	3.924E-14	3.27858E-14	Air	0
Migrant Family	Child born 195	External	Air Immersion	U-234	1.3226E-15	2.13637E-16	1.31398E-16	Air	0
Migrant Family	Child born 195	External	Air Immersion	U-235	6.3497E-14	1.06524E-14	6.97007E-15	Air	0
Migrant Family	Child born 195	External	Air Immersion	U-236	5.8572E-17	9.24303E-18	5.53071E-18	Air	0
Migrant Family	Child born 195	External	Air Immersion	U-238	3.6919E-15	4.70316E-16	3.01132E-16	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	Am-241	1.0021E-12	6.85425E-14	4.59306E-14	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	Cs-137	1.3361E-08	1.79431E-09	1.18757E-09	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	I-129	4.0259E-10	4.83876E-11	3.02152E-11	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	I-131	5.0798E-06	9.15202E-07	5.98762E-07	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	Pu-238	8.9597E-12	1.06382E-12	6.12146E-13	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	Pu-239	2.5822E-11	3.46491E-12	2.05348E-12	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	Ru-106	3.0477E-07	3.20627E-08	2.18281E-08	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	Sr-89	1.7468E-10	4.10257E-12	3.79223E-12	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	Sr-90	3.5656E-08	9.98808E-10	8.98086E-10	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	U-234	4.5555E-12	5.86076E-13	3.47257E-13	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	U-235	5.4778E-11	9.21839E-12	6.02173E-12	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	U-236	2.7443E-13	3.44144E-14	2.01552E-14	Air	0
Migrant Family	Child born 195	External	Ground Contaminat	U-238	1.5784E-09	8.28511E-11	6.19982E-11	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	Am-241	8.2746E-09	1.42104E-10	1.21846E-10	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	C-14	8.4103E-10	1.24237E-10	8.21338E-11	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	Cs-137	4.0078E-10	3.93288E-11	2.57851E-11	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	H-3	1.3618E-05	2.00883E-06	1.33217E-06	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	I-129	2.216E-08	1.85453E-09	1.88532E-10	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	I-131	0.0001208	1.18209E-05	1.22438E-06	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	Pu-238	3.2139E-06	1.54557E-07	1.3717E-07	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	Pu-239	1.1088E-05	5.11829E-07	4.48784E-07	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	Ru-106	1.8659E-07	3.40004E-08	2.89612E-08	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	Sr-89	3.2101E-10	6.15073E-11	5.12454E-11	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	Sr-90	7.2133E-08	9.02805E-09	8.16644E-09	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	U-234	1.637E-07	2.27692E-08	2.14666E-08	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	U-235	6.7725E-09	9.86216E-10	9.29858E-10	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	U-236	1.0684E-08	1.4746E-09	1.39441E-09	Air	0
Migrant Family	Child born 195	Inhalation	Air Inhalation	U-238	2.8318E-07	4.25809E-08	4.02481E-08	Air	0

Migrant Family	Child born 195	Inhalation	Resuspended Soil	Am-241	3.9997E-09	6.86174E-11	5.88505E-11	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	Cs-137	1.9099E-10	1.87238E-11	1.22789E-11	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	I-129	4.2318E-09	3.53902E-10	3.60085E-11	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	I-131	1.8807E-06	1.83546E-07	1.89849E-08	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	Pu-238	1.5552E-06	7.50329E-08	6.64866E-08	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	Pu-239	5.3698E-06	2.47035E-07	2.16674E-07	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	Ru-106	7.2183E-08	1.31303E-08	1.11962E-08	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	Sr-89	4.966E-11	9.49891E-12	7.91933E-12	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	Sr-90	3.7407E-08	4.88134E-09	4.2766E-09	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	U-234	7.9093E-08	1.09851E-08	1.03978E-08	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	U-235	3.2746E-09	4.7689E-10	4.49294E-10	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	U-236	5.1723E-09	7.14309E-10	6.74524E-10	Air	0
Migrant Family	Child born 195	Inhalation	Resuspended Soil	U-238	1.3713E-07	2.06352E-08	1.94851E-08	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	Am-241	1.0237E-10	2.52621E-12	1.75387E-12	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	C-14	2.7687E-08	4.42205E-09	2.93197E-09	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	Cs-137	1.8359E-09	2.48483E-10	1.67104E-10	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	H-3	8.275E-07	1.21085E-07	8.08052E-08	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	I-129	2.0433E-08	1.80108E-09	1.83934E-10	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	I-131	2.1445E-07	1.94598E-08	2.03367E-09	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	Pu-238	3.3319E-08	1.15477E-09	8.26171E-10	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	Pu-239	6.4972E-09	2.49691E-10	1.78064E-10	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	Ru-106	7.0372E-08	3.20211E-08	1.79428E-08	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	Sr-89	1.0138E-10	2.45386E-11	1.42629E-11	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	Sr-90	1.5975E-09	1.80631E-10	1.22295E-10	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	U-234	9.6675E-10	8.91461E-11	5.49783E-11	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	U-235	6.2396E-11	6.04637E-12	3.70327E-12	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	U-236	6.4037E-11	5.91972E-12	3.65737E-12	Air	0
Migrant Family	Child born 196	Ingestion	Leafy Vegetables	U-238	3.4014E-09	3.50815E-10	2.13129E-10	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	Am-241	5.4526E-11	1.38462E-12	9.57652E-13	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	C-14	1.6003E-07	2.62639E-08	1.73855E-08	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	Cs-137	9.71E-10	1.32197E-10	8.85758E-11	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	H-3	4.6281E-06	6.81599E-07	4.53178E-07	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	I-129	1.2603E-08	1.16417E-09	1.18865E-10	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	I-131	4.6313E-08	4.46326E-09	4.6578E-10	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	Pu-238	1.7276E-08	5.99603E-10	4.28952E-10	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	Pu-239	4.1559E-09	1.56146E-10	1.10846E-10	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	Ru-106	4.4328E-08	2.00249E-08	1.12282E-08	Air	0

Migrant Family	Child born 196	Ingestion	Root Vegetables	Sr-89	6.0715E-11	1.40156E-11	8.1468E-12	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	Sr-90	1.8863E-09	1.88431E-10	1.24995E-10	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	U-234	7.4211E-10	6.19663E-11	3.8038E-11	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	U-235	4.8344E-11	4.34138E-12	2.64427E-12	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	U-236	4.9303E-11	4.11367E-12	2.52918E-12	Air	0
Migrant Family	Child born 196	Ingestion	Root Vegetables	U-238	2.7038E-09	2.73979E-10	1.64736E-10	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	Am-241	4.0487E-11	1.04226E-12	7.19667E-13	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	C-14	1.826E-07	3.11142E-08	2.05243E-08	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	Cs-137	7.1099E-10	9.97857E-11	6.62803E-11	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	H-3	5.6002E-06	8.3452E-07	5.51951E-07	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	I-129	1.5423E-08	1.52918E-09	1.56217E-10	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	I-131	2.1628E-07	2.15473E-08	2.25109E-09	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	Pu-238	2.1108E-08	7.32679E-10	5.23843E-10	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	Pu-239	6.0804E-09	2.24672E-10	1.5877E-10	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	Ru-106	6.0663E-08	2.55805E-08	1.43425E-08	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	Sr-89	9.9477E-11	2.19793E-11	1.27834E-11	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	Sr-90	2.8271E-09	2.52233E-10	1.67702E-10	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	U-234	1.2221E-09	9.59987E-11	5.86933E-11	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	U-235	7.7935E-11	6.71718E-12	4.07562E-12	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	U-236	8.1123E-11	6.36804E-12	3.90154E-12	Air	0
Migrant Family	Child born 196	Ingestion	Fruit	U-238	4.2293E-09	3.96442E-10	2.38415E-10	Air	0
Migrant Family	Child born 196	Ingestion	Grain	Am-241	6.1381E-12	1.57337E-13	1.08779E-13	Air	0
Migrant Family	Child born 196	Ingestion	Grain	C-14	1.0348E-07	1.74334E-08	1.15164E-08	Air	0
Migrant Family	Child born 196	Ingestion	Grain	Cs-137	9.9109E-11	1.40055E-11	9.3699E-12	Air	0
Migrant Family	Child born 196	Ingestion	Grain	H-3	7.3413E-07	1.16774E-07	7.73003E-08	Air	0
Migrant Family	Child born 196	Ingestion	Grain	I-129	1.9543E-09	1.85506E-10	1.8918E-11	Air	0
Migrant Family	Child born 196	Ingestion	Grain	I-131	2.5483E-08	2.45978E-09	2.57118E-10	Air	0
Migrant Family	Child born 196	Ingestion	Grain	Pu-238	3.3574E-09	1.16015E-10	8.28062E-11	Air	0
Migrant Family	Child born 196	Ingestion	Grain	Pu-239	7.3363E-10	2.96653E-11	2.10105E-11	Air	0
Migrant Family	Child born 196	Ingestion	Grain	Ru-106	7.5563E-09	3.32101E-09	1.86056E-09	Air	0
Migrant Family	Child born 196	Ingestion	Grain	Sr-89	1.1689E-11	2.84342E-12	1.65403E-12	Air	0
Migrant Family	Child born 196	Ingestion	Grain	Sr-90	2.4106E-10	2.63915E-11	1.77671E-11	Air	0
Migrant Family	Child born 196	Ingestion	Grain	U-234	1.1322E-10	1.06155E-11	6.51924E-12	Air	0
Migrant Family	Child born 196	Ingestion	Grain	U-235	7.1234E-12	7.24351E-13	4.41047E-13	Air	0
Migrant Family	Child born 196	Ingestion	Grain	U-236	7.5168E-12	7.04122E-13	4.33395E-13	Air	0
Migrant Family	Child born 196	Ingestion	Grain	U-238	3.8585E-10	4.25176E-11	2.56781E-11	Air	0
Migrant Family	Child born 196	Ingestion	Beef	Am-241	1.9419E-12	5.03597E-14	3.4783E-14	Air	0

Migrant Family	Child born 196	Ingestion	Beef	C-14	9.2819E-07	1.5316E-07	1.01357E-07	Air	0
Migrant Family	Child born 196	Ingestion	Beef	Cs-137	3.6627E-08	5.0139E-09	3.36512E-09	Air	0
Migrant Family	Child born 196	Ingestion	Beef	H-3	6.461E-06	9.76434E-07	6.48445E-07	Air	0
Migrant Family	Child born 196	Ingestion	Beef	I-129	4.4989E-07	4.13855E-08	4.22245E-09	Air	0
Migrant Family	Child born 196	Ingestion	Beef	I-131	4.826E-06	4.51903E-07	4.71789E-08	Air	0
Migrant Family	Child born 196	Ingestion	Beef	Pu-238	1.6846E-10	5.84406E-12	4.17756E-12	Air	0
Migrant Family	Child born 196	Ingestion	Beef	Pu-239	3.7199E-11	1.39127E-12	9.88829E-13	Air	0
Migrant Family	Child born 196	Ingestion	Beef	Ru-106	2.0635E-06	9.3431E-07	5.23964E-07	Air	0
Migrant Family	Child born 196	Ingestion	Beef	Sr-89	4.9647E-10	1.15076E-10	6.68695E-11	Air	0
Migrant Family	Child born 196	Ingestion	Beef	Sr-90	9.9195E-09	9.46651E-10	6.39201E-10	Air	0
Migrant Family	Child born 196	Ingestion	Beef	U-234	1.9393E-10	1.63217E-11	1.00524E-11	Air	0
Migrant Family	Child born 196	Ingestion	Beef	U-235	1.2336E-11	1.11721E-12	6.80575E-13	Air	0
Migrant Family	Child born 196	Ingestion	Beef	U-236	1.288E-11	1.08486E-12	6.68445E-13	Air	0
Migrant Family	Child born 196	Ingestion	Beef	U-238	6.4716E-10	5.83537E-11	3.57015E-11	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	Am-241	9.873E-16	2.58408E-17	1.78232E-17	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	C-14	3.0722E-08	5.1632E-09	3.41597E-09	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	Cs-137	2.304E-11	3.20234E-12	2.14684E-12	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	H-3	8.6424E-07	1.3535E-07	8.98503E-08	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	I-129	4.1712E-13	3.86853E-14	3.94616E-15	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	I-131	5.4528E-19	5.37962E-20	5.6228E-21	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	Pu-238	1.7722E-13	6.14204E-15	4.40627E-15	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	Pu-239	3.9676E-14	1.66338E-15	1.17548E-15	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	Ru-106	8.6012E-10	4.0392E-10	2.26452E-10	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	Sr-89	1.4489E-15	3.65183E-16	2.12493E-16	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	Sr-90	4.0725E-13	4.79076E-14	3.22833E-14	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	U-234	1.9332E-12	1.91017E-13	1.17274E-13	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	U-235	1.2701E-13	1.34685E-14	8.18877E-15	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	U-236	1.2862E-13	1.26783E-14	7.80098E-15	Air	0
Migrant Family	Child born 196	Ingestion	Poultry	U-238	6.7399E-12	7.03708E-13	4.30975E-13	Air	0
Migrant Family	Child born 196	Ingestion	Milk	Am-241	8.3406E-14	2.35157E-15	1.60973E-15	Air	0
Migrant Family	Child born 196	Ingestion	Milk	C-14	7.065E-07	1.23569E-07	8.14498E-08	Air	0
Migrant Family	Child born 196	Ingestion	Milk	Cs-137	5.2027E-09	7.70076E-10	5.09139E-10	Air	0
Migrant Family	Child born 196	Ingestion	Milk	H-3	1.451E-05	2.26181E-06	1.49319E-06	Air	0
Migrant Family	Child born 196	Ingestion	Milk	I-129	2.1869E-07	2.1714E-08	2.2176E-09	Air	0
Migrant Family	Child born 196	Ingestion	Milk	I-131	3.1433E-06	3.10126E-07	3.24178E-08	Air	0
Migrant Family	Child born 196	Ingestion	Milk	Pu-238	3.5552E-11	1.24005E-12	8.8484E-13	Air	0
Migrant Family	Child born 196	Ingestion	Milk	Pu-239	9.3391E-12	3.56319E-13	2.51237E-13	Air	0

Migrant Family	Child born 196	Ingestion	Milk	Ru-106	2.9652E-10	1.29297E-10	7.24998E-11	Air	0
Migrant Family	Child born 196	Ingestion	Milk	Sr-89	4.0374E-10	9.14768E-11	5.32185E-11	Air	0
Migrant Family	Child born 196	Ingestion	Milk	Sr-90	9.5804E-09	7.91521E-10	5.43558E-10	Air	0
Migrant Family	Child born 196	Ingestion	Milk	U-234	6.4595E-10	5.28382E-11	3.23823E-11	Air	0
Migrant Family	Child born 196	Ingestion	Milk	U-235	4.0438E-11	3.63577E-12	2.20458E-12	Air	0
Migrant Family	Child born 196	Ingestion	Milk	U-236	4.2922E-11	3.51313E-12	2.15259E-12	Air	0
Migrant Family	Child born 196	Ingestion	Milk	U-238	2.0789E-09	1.8166E-10	1.10958E-10	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	Am-241	6.8059E-16	1.71883E-17	1.1915E-17	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	C-14	2.4982E-08	4.17187E-09	2.75952E-09	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	Cs-137	1.1154E-12	1.53842E-13	1.03079E-13	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	H-3	9.4838E-07	1.46715E-07	9.74933E-08	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	I-129	1.3246E-10	1.23317E-11	1.258E-12	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	I-131	2.7666E-16	2.80716E-17	2.93041E-18	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	Pu-238	2.963E-14	1.02419E-15	7.35158E-16	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	Pu-239	7.1395E-15	3.05177E-16	2.15649E-16	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	Ru-106	5.7038E-13	2.66218E-13	1.49039E-13	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	Sr-89	4.0766E-15	1.03898E-15	6.0424E-16	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	Sr-90	1.0411E-12	9.82754E-14	7.07942E-14	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	U-234	2.0685E-12	2.07856E-13	1.27493E-13	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	U-235	1.3931E-13	1.47081E-14	8.95437E-15	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	U-236	1.3759E-13	1.37968E-14	8.48029E-15	Air	0
Migrant Family	Child born 196	Ingestion	Eggs	U-238	7.3945E-12	7.43145E-13	4.57923E-13	Air	0
Migrant Family	Child born 196	Ingestion	Soil	Am-241	4.2834E-14	1.19265E-15	8.18347E-16	Air	0
Migrant Family	Child born 196	Ingestion	Soil	Cs-137	5.2636E-13	7.83057E-14	5.15605E-14	Air	0
Migrant Family	Child born 196	Ingestion	Soil	I-129	1.473E-11	1.48362E-12	1.51286E-13	Air	0
Migrant Family	Child born 196	Ingestion	Soil	I-131	5.6047E-11	5.62672E-12	5.88189E-13	Air	0
Migrant Family	Child born 196	Ingestion	Soil	Pu-238	2.7763E-11	9.65519E-13	6.88997E-13	Air	0
Migrant Family	Child born 196	Ingestion	Soil	Pu-239	7.7614E-12	2.99268E-13	2.11212E-13	Air	0
Migrant Family	Child born 196	Ingestion	Soil	Ru-106	6.764E-11	2.91164E-11	1.63178E-11	Air	0
Migrant Family	Child born 196	Ingestion	Soil	Sr-89	5.5514E-14	1.25987E-14	7.32227E-15	Air	0
Migrant Family	Child born 196	Ingestion	Soil	Sr-90	3.3665E-12	3.25049E-13	2.14306E-13	Air	0
Migrant Family	Child born 196	Ingestion	Soil	U-234	1.482E-12	1.2171E-13	7.441E-14	Air	0
Migrant Family	Child born 196	Ingestion	Soil	U-235	9.3628E-14	8.49611E-15	5.15357E-15	Air	0
Migrant Family	Child born 196	Ingestion	Soil	U-236	9.8593E-14	8.08657E-15	4.95472E-15	Air	0
Migrant Family	Child born 196	Ingestion	Soil	U-238	5.3439E-12	5.8457E-13	3.47221E-13	Air	0
Migrant Family	Child born 196	External	Air Immersion	Am-241	7.6225E-16	9.66312E-17	6.27655E-17	Air	0
Migrant Family	Child born 196	External	Air Immersion	Ar-41	1.9175E-05	3.30769E-06	2.17138E-06	Air	0

Migrant Family	Child born 196	External	Air Immersion	C-14	1.207E-12	3.20747E-14	2.76194E-14	Air	0
Migrant Family	Child born 196	External	Air Immersion	Cs-137	7.1415E-12	1.03276E-12	6.85148E-13	Air	0
Migrant Family	Child born 196	External	Air Immersion	I-129	2.8318E-13	3.94903E-14	2.40453E-14	Air	0
Migrant Family	Child born 196	External	Air Immersion	I-131	1.1292E-09	2.01321E-10	1.31843E-10	Air	0
Migrant Family	Child born 196	External	Air Immersion	Pu-238	1.393E-15	2.09456E-16	1.18613E-16	Air	0
Migrant Family	Child born 196	External	Air Immersion	Pu-239	2.8355E-16	4.61701E-17	2.87651E-17	Air	0
Migrant Family	Child born 196	External	Air Immersion	Ru-106	1.9365E-10	3.19193E-11	2.09368E-11	Air	0
Migrant Family	Child born 196	External	Air Immersion	Sr-89	3.3415E-14	1.43867E-15	1.12017E-15	Air	0
Migrant Family	Child born 196	External	Air Immersion	Sr-90	1.3969E-14	4.67968E-16	3.91925E-16	Air	0
Migrant Family	Child born 196	External	Air Immersion	U-234	2.9661E-16	4.72978E-17	2.91619E-17	Air	0
Migrant Family	Child born 196	External	Air Immersion	U-235	2.0864E-14	3.46387E-15	2.26803E-15	Air	0
Migrant Family	Child born 196	External	Air Immersion	U-236	1.3144E-17	2.05811E-18	1.23238E-18	Air	0
Migrant Family	Child born 196	External	Air Immersion	U-238	1.5064E-15	1.92182E-16	1.23215E-16	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	Am-241	9.6707E-13	1.19782E-13	7.78311E-14	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	Cs-137	5.7379E-09	8.17354E-10	5.41889E-10	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	I-129	2.8135E-10	3.80217E-11	2.36584E-11	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	I-131	2.8712E-08	5.14429E-09	3.36796E-09	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	Pu-238	9.0365E-12	1.10044E-12	6.32207E-13	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	Pu-239	8.3711E-13	1.08941E-13	6.44762E-14	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	Ru-106	1.8172E-07	2.08177E-08	1.40945E-08	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	Sr-89	6.0988E-11	1.43058E-12	1.31823E-12	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	Sr-90	4.8437E-10	1.30305E-11	1.16964E-11	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	U-234	1.0262E-12	1.31432E-13	7.7868E-14	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	U-235	1.8107E-11	3.01393E-12	1.96914E-12	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	U-236	6.195E-14	7.71182E-15	4.50132E-15	Air	0
Migrant Family	Child born 196	External	Ground Contaminat	U-238	6.4453E-10	3.39482E-11	2.54389E-11	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	Am-241	8.4039E-09	2.52923E-10	2.1862E-10	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	C-14	5.5842E-10	9.42486E-11	6.20496E-11	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	Cs-137	2.0474E-10	2.80871E-11	1.87244E-11	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	H-3	8.86E-06	1.36928E-06	9.05414E-07	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	I-129	1.441E-08	1.35911E-09	1.38229E-10	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	I-131	5.3549E-07	5.09719E-08	5.27032E-09	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	Pu-238	3.0911E-06	1.20215E-07	1.06719E-07	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	Pu-239	6.0743E-07	2.46164E-08	2.17355E-08	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	Ru-106	1.1553E-07	2.74294E-08	2.32479E-08	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	Sr-89	1.158E-10	2.23757E-11	1.88629E-11	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	Sr-90	9.6365E-10	1.37361E-10	1.24709E-10	Air	0

Migrant Family	Child born 196	Inhalation	Air Inhalation	U-234	3.9313E-08	6.08898E-09	5.74615E-09	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	U-235	2.2848E-09	3.4976E-10	3.29778E-10	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	U-236	2.5657E-09	3.95019E-10	3.73141E-10	Air	0
Migrant Family	Child born 196	Inhalation	Air Inhalation	U-238	1.1588E-07	1.76079E-08	1.66384E-08	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	Am-241	4.0623E-09	1.22128E-10	1.0559E-10	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	Cs-137	9.7767E-11	1.33972E-11	8.92847E-12	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	I-129	2.7512E-09	2.5931E-10	2.63826E-11	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	I-131	8.4655E-09	8.04578E-10	8.32689E-11	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	Pu-238	1.4958E-06	5.83498E-08	5.17194E-08	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	Pu-239	2.945E-07	1.193E-08	1.05345E-08	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	Ru-106	4.4661E-08	1.0576E-08	8.98202E-09	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	Sr-89	1.7897E-11	3.45647E-12	2.91487E-12	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	Sr-90	5.2081E-10	7.76933E-11	6.83133E-11	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	U-234	1.9063E-08	2.94355E-09	2.78402E-09	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	U-235	1.1056E-09	1.69151E-10	1.59441E-10	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	U-236	1.2403E-09	1.90809E-10	1.80405E-10	Air	0
Migrant Family	Child born 196	Inhalation	Resuspended Soil	U-238	5.6107E-08	8.53584E-09	8.06098E-09	Air	0

Location	Receptor	ReportRoute	ReportPathway	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	AirWater	RunNum
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Am-241	2.17E-10	2.12E-12	1.65E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	C-14	1.23E-07	6.05E-09	4.35E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Cs-137	9.13E-09	4.45E-10	3.18E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	H-3	3.67E-06	1.78E-07	1.28E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	I-129	7.7E-08	1.68E-09	1.72E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	I-131	4.68E-05	1.04E-06	1.14E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Pu-238	8.57E-08	9.75E-10	8.15E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Pu-239	6.02E-07	6.42E-09	5.38E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Ru-106	1.94E-07	9.14E-09	5.39E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Sr-89	4.24E-10	2.03E-11	1.36E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Sr-90	3.03E-07	1.27E-08	1.15E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-234	1.01E-08	2.14E-10	1.49E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-235	4.33E-10	9.44E-12	6.49E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-236	6.72E-10	1.43E-11	9.91E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-238	1.87E-08	4.15E-10	2.86E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Am-241	7.43E-11	7.26E-13	5.65E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	C-14	4.22E-07	2.07E-08	1.49E-08	Air	0

Outdoor Family	Adult Female	Ingestion	Root Vegetables	Cs-137	3.38E-09	1.65E-10	1.18E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	H-3	1.16E-05	5.65E-07	4.06E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	I-129	2.64E-08	5.76E-10	5.91E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	I-131	5.23E-06	1.17E-07	1.27E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Pu-238	2.94E-08	3.34E-10	2.79E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Pu-239	2.06E-07	2.2E-09	1.84E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Ru-106	6.5E-08	3.07E-09	1.81E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Sr-89	1.34E-10	6.42E-12	4.3E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Sr-90	1.31E-07	5.52E-09	4.97E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-234	3.48E-09	7.37E-11	5.13E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-235	1.49E-10	3.24E-12	2.23E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-236	2.3E-10	4.9E-12	3.39E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-238	6.5E-09	1.47E-10	1.01E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	Am-241	7.36E-11	7.18E-13	5.59E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	C-14	4.18E-07	2.05E-08	1.47E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	Cs-137	3.03E-09	1.48E-10	1.06E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	H-3	1.15E-05	5.58E-07	4.01E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	I-129	2.62E-08	5.7E-10	5.85E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	I-131	1.59E-05	3.53E-07	3.87E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	Pu-238	2.9E-08	3.31E-10	2.76E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	Pu-239	2.04E-07	2.18E-09	1.82E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	Ru-106	6.59E-08	3.11E-09	1.83E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	Sr-89	1.44E-10	6.92E-12	4.64E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	Sr-90	1.04E-07	4.37E-09	3.95E-09	Air	0

Outdoor Family	Adult Female	Ingestion	Fruit	U-234	3.42E-09	7.26E-11	5.05E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	U-235	1.47E-10	3.2E-12	2.2E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	U-236	2.28E-10	4.85E-12	3.36E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Fruit	U-238	6.34E-09	1.41E-10	9.7E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	Am-241	9.12E-12	8.9E-14	6.93E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	C-14	2.23E-07	1.1E-08	7.88E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	Cs-137	3.66E-10	1.79E-11	1.27E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	H-3	1.63E-06	7.97E-08	5.71E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	I-129	3.28E-09	7.14E-11	7.31E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	I-131	1.92E-06	4.26E-08	4.67E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	Pu-238	3.59E-09	4.1E-11	3.41E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	Pu-239	2.52E-08	2.7E-10	2.25E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	Ru-106	8.12E-09	3.84E-10	2.26E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	Sr-89	1.83E-11	8.8E-13	5.91E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	Sr-90	1.42E-08	5.97E-10	5.42E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	U-234	4.25E-10	9.02E-12	6.27E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	U-235	1.82E-11	3.97E-13	2.73E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	U-236	2.83E-11	6E-13	4.16E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Grain	U-238	7.85E-10	1.74E-11	1.2E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	Am-241	4.23E-12	4.12E-14	3.21E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	C-14	1.17E-05	5.75E-07	4.13E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	Cs-137	2.21E-07	1.08E-08	7.69E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	H-3	6.56E-05	3.19E-06	2.29E-06	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	I-129	1.53E-06	3.33E-08	3.41E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	I-131	0.000969	2.16E-05	2.37E-06	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	Pu-238	4.16E-10	4.76E-12	3.95E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	Pu-239	2.92E-09	3.11E-11	2.61E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	Ru-106	4.74E-06	2.24E-07	1.32E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	Sr-89	1.71E-09	8.17E-11	5.48E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	Sr-90	1.03E-06	4.32E-08	3.92E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	U-234	1.47E-09	3.12E-11	2.17E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	U-235	6.32E-11	1.38E-12	9.47E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	U-236	9.79E-11	2.08E-12	1.44E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Beef	U-238	2.69E-09	5.86E-11	4.07E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	Am-241	2.58E-15	2.51E-17	1.96E-17	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	C-14	4.45E-07	2.19E-08	1.57E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	Cs-137	1.74E-10	8.47E-12	6.05E-12	Air	0

Outdoor Family	Adult Female	Ingestion	Poultry	H-3	1.05E-05	5.13E-07	3.68E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	I-129	1.63E-12	3.55E-14	3.64E-15	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	I-131	1.18E-16	2.63E-18	2.87E-19	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	Pu-238	5.07E-13	5.78E-15	4.83E-15	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	Pu-239	3.58E-12	3.82E-14	3.2E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	Ru-106	2.18E-09	1.03E-10	6.07E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	Sr-89	6.19E-15	2.97E-16	1.99E-16	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	Sr-90	6.05E-11	2.54E-12	2.3E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-234	2.01E-11	4.26E-13	2.96E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-235	8.62E-13	1.88E-14	1.29E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-236	1.34E-12	2.84E-14	1.96E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-238	3.65E-11	7.96E-13	5.53E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	Am-241	1.18E-13	1.15E-15	8.96E-16	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	C-14	1.27E-06	6.26E-08	4.5E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	Cs-137	2.71E-08	1.32E-09	9.41E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	H-3	2.51E-05	1.22E-06	8.75E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	I-129	2.78E-07	6.06E-09	6.21E-10	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	I-131	0.000174	3.87E-06	4.24E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	Pu-238	3.41E-11	3.88E-13	3.24E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	Pu-239	2.39E-10	2.56E-12	2.14E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	Ru-106	2.33E-10	1.1E-11	6.48E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	Sr-89	4.48E-10	2.15E-11	1.44E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	Sr-90	3.02E-07	1.26E-08	1.16E-08	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	U-234	1.46E-09	3.11E-11	2.16E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	U-235	6.27E-11	1.37E-12	9.39E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	U-236	9.7E-11	2.06E-12	1.43E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Milk	U-238	2.65E-09	5.73E-11	3.98E-11	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	Am-241	1.58E-15	1.54E-17	1.2E-17	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	C-14	1.03E-07	5.07E-09	3.65E-09	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	Cs-137	6.42E-12	3.13E-13	2.23E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	H-3	3.99E-06	1.94E-07	1.39E-07	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	I-129	4.39E-10	9.57E-12	9.82E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	I-131	4.5E-14	1E-15	1.1E-16	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	Pu-238	7.74E-14	8.82E-16	7.34E-16	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	Pu-239	5.46E-13	5.85E-15	4.88E-15	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	Ru-106	1.26E-12	5.96E-14	3.51E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	Sr-89	1.52E-14	7.28E-16	4.88E-16	Air	0

Outdoor Family	Adult Female	Ingestion	Eggs	Sr-90	1.5E-10	6.26E-12	5.81E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-234	1.84E-11	3.91E-13	2.72E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-235	7.88E-13	1.71E-14	1.18E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-236	1.22E-12	2.6E-14	1.8E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-238	3.32E-11	7.14E-13	4.99E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	Am-241	5.17E-14	5.04E-16	3.93E-16	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	Cs-137	2.03E-12	9.87E-14	7.06E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	I-129	1.35E-11	2.93E-13	3.01E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	I-131	1.93E-09	4.3E-11	4.71E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	Pu-238	2.03E-11	2.32E-13	1.93E-13	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	Pu-239	1.43E-10	1.53E-12	1.28E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	Ru-106	3.81E-11	1.8E-12	1.06E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	Sr-89	4.07E-14	1.95E-15	1.31E-15	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	Sr-90	7.1E-11	2.99E-12	2.69E-12	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	U-234	2.4E-12	5.09E-14	3.54E-14	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	U-235	1.03E-13	2.25E-15	1.54E-15	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	U-236	1.59E-13	3.39E-15	2.34E-15	Air	0
Outdoor Family	Adult Female	Ingestion	Soil	U-238	4.59E-12	1.06E-13	7.19E-14	Air	0
Outdoor Family	Adult Female	External	Air Immersion	Am-241	1.49E-15	6.55E-17	4.56E-17	Air	0
Outdoor Family	Adult Female	External	Air Immersion	Ar-41	8.32E-05	4E-06	2.87E-06	Air	0
Outdoor Family	Adult Female	External	Air Immersion	C-14	3.7E-12	3.58E-14	3.24E-14	Air	0
Outdoor Family	Adult Female	External	Air Immersion	Cs-137	3.37E-11	1.61E-12	1.15E-12	Air	0
Outdoor Family	Adult Female	External	Air Immersion	I-129	7.51E-13	2.89E-14	1.9E-14	Air	0
Outdoor Family	Adult Female	External	Air Immersion	I-131	3.84E-07	1.83E-08	1.31E-08	Air	0
Outdoor Family	Adult Female	External	Air Immersion	Pu-238	2.73E-15	1E-16	6.13E-17	Air	0
Outdoor Family	Adult Female	External	Air Immersion	Pu-239	1.74E-14	7.46E-16	5.08E-16	Air	0
Outdoor Family	Adult Female	External	Air Immersion	Ru-106	6.28E-10	2.78E-11	1.99E-11	Air	0

Outdoor Family	Adult Female	External	Air Immersion	Sr-89	1.88E-13	2.54E-15	2.14E-15	Air	0
Outdoor Family	Adult Female	External	Air Immersion	Sr-90	2.28E-12	2.47E-14	2.2E-14	Air	0
Outdoor Family	Adult Female	External	Air Immersion	U-234	2.6E-15	1.08E-16	7.25E-17	Air	0
Outdoor Family	Adult Female	External	Air Immersion	U-235	1.24E-13	5.83E-15	4.14E-15	Air	0
Outdoor Family	Adult Female	External	Air Immersion	U-236	1.15E-16	4.57E-18	2.97E-18	Air	0
Outdoor Family	Adult Female	External	Air Immersion	U-238	6.66E-15	2.39E-16	1.66E-16	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	Am-241	1.78E-12	7.56E-14	5.26E-14	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	Cs-137	2.49E-08	1.17E-09	8.34E-10	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	I-129	7.56E-10	2.86E-11	1.9E-11	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	I-131	9.76E-06	4.64E-07	3.33E-07	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	Pu-238	1.69E-11	4.98E-13	3.04E-13	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	Pu-239	4.89E-11	1.6E-12	1.02E-12	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	Ru-106	5.67E-07	1.79E-08	1.32E-08	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	Sr-89	3.29E-10	2.81E-12	2.67E-12	Air	0

Outdoor Family	Adult Female	External	Ground Contamination	Sr-90	7.75E-08	7.09E-10	6.6E-10	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	U-234	8.59E-12	2.73E-13	1.73E-13	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	U-235	1.03E-10	4.82E-12	3.43E-12	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	U-236	5.17E-13	1.58E-14	9.87E-15	Air	0
Outdoor Family	Adult Female	External	Ground Contamination	U-238	2.95E-09	4.89E-11	3.95E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Am-241	1.2E-08	1.57E-10	1.35E-10	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	C-14	1.16E-09	5.63E-11	4.05E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Cs-137	8.08E-10	3.79E-11	2.7E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	H-3	2E-05	9.73E-07	6.98E-07	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	I-129	2.6E-08	5.67E-10	5.8E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	I-131	4.59E-05	1.02E-06	1.1E-07	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Pu-238	4.68E-06	6.57E-08	5.84E-08	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Pu-239	3.27E-05	4.18E-07	3.69E-07	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Ru-106	2.16E-07	1.15E-08	1.05E-08	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Sr-89	3.45E-10	1.84E-11	1.7E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Sr-90	9.05E-08	4.51E-09	4.3E-09	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-234	1.93E-07	1E-08	9.48E-09	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-235	7.72E-09	4E-10	3.78E-10	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-236	1.25E-08	6.44E-10	6.1E-10	Air	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-238	3.16E-07	1.64E-08	1.54E-08	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Am-241	5.71E-11	7.45E-13	6.42E-13	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Cs-137	3.78E-12	1.77E-13	1.26E-13	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	I-129	5.16E-11	1.13E-12	1.15E-13	Air	0

Outdoor Family	Adult Female	Inhalation	Resuspended Soil	I-131	7.41E-09	1.65E-10	1.78E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Pu-238	2.22E-08	3.11E-10	2.77E-10	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Pu-239	1.55E-07	1.98E-09	1.75E-09	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Ru-106	8.2E-10	4.35E-11	3.97E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Sr-89	5.24E-13	2.8E-14	2.58E-14	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Sr-90	4.69E-10	2.34E-11	2.21E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-234	9.15E-10	4.75E-11	4.49E-11	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-235	3.67E-11	1.9E-12	1.79E-12	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-236	5.9E-11	3.06E-12	2.89E-12	Air	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-238	1.5E-09	7.78E-11	7.31E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Am-241	2.17E-10	2.12E-12	1.65E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	C-14	1.23E-07	6.05E-09	4.35E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Cs-137	9.13E-09	4.45E-10	3.18E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	H-3	3.67E-06	1.78E-07	1.28E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	I-129	7.7E-08	1.68E-09	1.72E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	I-131	4.68E-05	1.04E-06	1.14E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Pu-238	8.57E-08	9.75E-10	8.15E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Pu-239	6.02E-07	6.42E-09	5.38E-09	Air	0

Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Ru-106	1.94E-07	9.14E-09	5.39E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Sr-89	4.24E-10	2.03E-11	1.36E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Sr-90	3.03E-07	1.27E-08	1.15E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-234	1.01E-08	2.14E-10	1.49E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-235	4.33E-10	9.44E-12	6.49E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-236	6.72E-10	1.43E-11	9.91E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-238	1.87E-08	4.15E-10	2.86E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Am-241	1.03E-10	1E-12	7.82E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	C-14	5.85E-07	2.87E-08	2.06E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Cs-137	4.69E-09	2.28E-10	1.63E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	H-3	1.61E-05	7.83E-07	5.62E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	I-129	3.66E-08	7.98E-10	8.18E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	I-131	7.24E-06	1.62E-07	1.76E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Pu-238	4.06E-08	4.63E-10	3.86E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Pu-239	2.86E-07	3.05E-09	2.55E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Ru-106	9E-08	4.25E-09	2.5E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Sr-89	1.85E-10	8.89E-12	5.95E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Sr-90	1.82E-07	7.65E-09	6.88E-09	Air	0

Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-234	4.81E-09	1.02E-10	7.1E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-235	2.06E-10	4.48E-12	3.09E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-236	3.19E-10	6.78E-12	4.7E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-238	9E-09	2.03E-10	1.39E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	Am-241	7.17E-11	7E-13	5.45E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	C-14	4.08E-07	2E-08	1.44E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	Cs-137	2.96E-09	1.44E-10	1.03E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	H-3	1.12E-05	5.44E-07	3.91E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	I-129	2.55E-08	5.56E-10	5.7E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	I-131	1.55E-05	3.44E-07	3.77E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	Pu-238	2.83E-08	3.22E-10	2.69E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	Pu-239	1.99E-07	2.12E-09	1.78E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	Ru-106	6.42E-08	3.04E-09	1.79E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	Sr-89	1.41E-10	6.75E-12	4.53E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	Sr-90	1.02E-07	4.27E-09	3.85E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-234	3.34E-09	7.08E-11	4.92E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-235	1.43E-10	3.12E-12	2.15E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-236	2.22E-10	4.73E-12	3.28E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-238	6.18E-09	1.37E-10	9.46E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	Am-241	1.1E-11	1.07E-13	8.36E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	C-14	2.69E-07	1.32E-08	9.5E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	Cs-137	4.42E-10	2.15E-11	1.54E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	H-3	1.97E-06	9.61E-08	6.89E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	I-129	3.96E-09	8.61E-11	8.82E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	I-131	2.31E-06	5.14E-08	5.63E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	Pu-238	4.33E-09	4.94E-11	4.11E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	Pu-239	3.04E-08	3.25E-10	2.71E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	Ru-106	9.79E-09	4.63E-10	2.72E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	Sr-89	2.21E-11	1.06E-12	7.12E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	Sr-90	1.71E-08	7.2E-10	6.53E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	U-234	5.12E-10	1.09E-11	7.56E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	U-235	2.2E-11	4.78E-13	3.29E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Grain	U-236	3.41E-11	7.24E-13	5.02E-13	Air	0

Outdoor Family	Adult Male	Ingestion	Grain	U-238	9.46E-10	2.1E-11	1.45E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	Am-241	6.64E-12	6.48E-14	5.04E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	C-14	1.84E-05	9.03E-07	6.5E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	Cs-137	3.47E-07	1.69E-08	1.21E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	H-3	0.000103	5.02E-06	3.6E-06	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	I-129	2.4E-06	5.22E-08	5.36E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	I-131	0.001522	3.39E-05	3.72E-06	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	Pu-238	6.54E-10	7.48E-12	6.21E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	Pu-239	4.59E-09	4.89E-11	4.1E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	Ru-106	7.44E-06	3.52E-07	2.07E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	Sr-89	2.68E-09	1.28E-10	8.61E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	Sr-90	1.62E-06	6.78E-08	6.15E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	U-234	2.32E-09	4.9E-11	3.41E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	U-235	9.93E-11	2.17E-12	1.49E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	U-236	1.54E-10	3.27E-12	2.27E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Beef	U-238	4.22E-09	9.21E-11	6.39E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	Am-241	3.21E-15	3.13E-17	2.44E-17	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	C-14	5.56E-07	2.73E-08	1.96E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	Cs-137	2.17E-10	1.06E-11	7.54E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	H-3	1.32E-05	6.4E-07	4.6E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	I-129	2.03E-12	4.43E-14	4.54E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	I-131	1.47E-16	3.27E-18	3.58E-19	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	Pu-238	6.32E-13	7.2E-15	6.01E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	Pu-239	4.46E-12	4.76E-14	3.98E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	Ru-106	2.72E-09	1.28E-10	7.57E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	Sr-89	7.71E-15	3.7E-16	2.48E-16	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	Sr-90	7.54E-11	3.16E-12	2.87E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-234	2.51E-11	5.31E-13	3.69E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-235	1.07E-12	2.34E-14	1.61E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-236	1.66E-12	3.53E-14	2.45E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-238	4.55E-11	9.92E-13	6.89E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	Am-241	1.57E-13	1.53E-15	1.19E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	C-14	1.69E-06	8.31E-08	5.97E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	Cs-137	3.59E-08	1.75E-09	1.25E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	H-3	3.33E-05	1.62E-06	1.16E-06	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	I-129	3.7E-07	8.05E-09	8.25E-10	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	I-131	0.000232	5.14E-06	5.63E-07	Air	0

Outdoor Family	Adult Male	Ingestion	Milk	Pu-238	4.53E-11	5.16E-13	4.31E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	Pu-239	3.18E-10	3.4E-12	2.84E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	Ru-106	3.09E-10	1.46E-11	8.6E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	Sr-89	5.95E-10	2.85E-11	1.91E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	Sr-90	4.01E-07	1.68E-08	1.54E-08	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	U-234	1.94E-09	4.12E-11	2.86E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	U-235	8.33E-11	1.81E-12	1.25E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	U-236	1.29E-10	2.74E-12	1.9E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Milk	U-238	3.52E-09	7.61E-11	5.29E-11	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	Am-241	2.61E-15	2.55E-17	1.98E-17	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	C-14	1.71E-07	8.39E-09	6.04E-09	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	Cs-137	1.06E-11	5.17E-13	3.7E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	H-3	6.6E-06	3.21E-07	2.31E-07	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	I-129	7.27E-10	1.58E-11	1.62E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	I-131	7.45E-14	1.66E-15	1.82E-16	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	Pu-238	1.28E-13	1.46E-15	1.21E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	Pu-239	9.03E-13	9.68E-15	8.07E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	Ru-106	2.09E-12	9.86E-14	5.81E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	Sr-89	2.51E-14	1.2E-15	8.08E-16	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	Sr-90	2.48E-10	1.04E-11	9.62E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-234	3.05E-11	6.48E-13	4.5E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-235	1.3E-12	2.83E-14	1.95E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-236	2.02E-12	4.3E-14	2.98E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-238	5.49E-11	1.18E-12	8.25E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	Am-241	5.37E-14	5.24E-16	4.08E-16	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	Cs-137	2.1E-12	1.03E-13	7.33E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	I-129	1.41E-11	3.07E-13	3.15E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	I-131	2.07E-09	4.61E-11	5.05E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	Pu-238	2.11E-11	2.41E-13	2.01E-13	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	Pu-239	1.49E-10	1.59E-12	1.33E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	Ru-106	3.96E-11	1.87E-12	1.1E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	Sr-89	4.23E-14	2.03E-15	1.36E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	Sr-90	7.11E-11	2.99E-12	2.7E-12	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	U-234	2.49E-12	5.29E-14	3.68E-14	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	U-235	1.07E-13	2.34E-15	1.61E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	U-236	1.66E-13	3.52E-15	2.44E-15	Air	0
Outdoor Family	Adult Male	Ingestion	Soil	U-238	4.77E-12	1.1E-13	7.47E-14	Air	0

Outdoor Family	Adult Male	External	Air Immersion	Am-241	1.54E-15	6.75E-17	4.71E-17	Air	0
Outdoor Family	Adult Male	External	Air Immersion	Ar-41	0.000306	1.47E-05	1.05E-05	Air	0
Outdoor Family	Adult Male	External	Air Immersion	C-14	6.08E-12	5.89E-14	5.33E-14	Air	0
Outdoor Family	Adult Male	External	Air Immersion	Cs-137	3.47E-11	1.66E-12	1.19E-12	Air	0
Outdoor Family	Adult Male	External	Air Immersion	I-129	7.62E-13	2.93E-14	1.93E-14	Air	0
Outdoor Family	Adult Male	External	Air Immersion	I-131	3.93E-07	1.87E-08	1.34E-08	Air	0
Outdoor Family	Adult Male	External	Air Immersion	Pu-238	2.82E-15	1.04E-16	6.32E-17	Air	0
Outdoor Family	Adult Male	External	Air Immersion	Pu-239	1.79E-14	7.7E-16	5.23E-16	Air	0
Outdoor Family	Adult Male	External	Air Immersion	Ru-106	6.48E-10	2.87E-11	2.06E-11	Air	0
Outdoor Family	Adult Male	External	Air Immersion	Sr-89	1.94E-13	2.62E-15	2.21E-15	Air	0
Outdoor Family	Adult Male	External	Air Immersion	Sr-90	2.28E-12	2.46E-14	2.19E-14	Air	0
Outdoor Family	Adult Male	External	Air Immersion	U-234	2.67E-15	1.11E-16	7.47E-17	Air	0
Outdoor Family	Adult Male	External	Air Immersion	U-235	1.28E-13	6.01E-15	4.27E-15	Air	0
Outdoor Family	Adult Male	External	Air Immersion	U-236	1.19E-16	4.72E-18	3.06E-18	Air	0
Outdoor Family	Adult Male	External	Air Immersion	U-238	6.58E-15	2.36E-16	1.64E-16	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	Am-241	1.94E-12	8.23E-14	5.73E-14	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	Cs-137	2.7E-08	1.27E-09	9.07E-10	Air	0

Outdoor Family	Adult Male	External	Ground Contamination	I-129	8.29E-10	3.13E-11	2.09E-11	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	I-131	1.1E-05	5.24E-07	3.76E-07	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	Pu-238	1.84E-11	5.42E-13	3.31E-13	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	Pu-239	5.33E-11	1.74E-12	1.11E-12	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	Ru-106	6.17E-07	1.95E-08	1.44E-08	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	Sr-89	3.58E-10	3.05E-12	2.91E-12	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	Sr-90	8.08E-08	7.4E-10	6.89E-10	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	U-234	9.36E-12	2.97E-13	1.88E-13	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	U-235	1.12E-10	5.24E-12	3.73E-12	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	U-236	5.63E-13	1.72E-14	1.07E-14	Air	0
Outdoor Family	Adult Male	External	Ground Contamination	U-238	3.22E-09	5.32E-11	4.3E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Am-241	1.67E-08	2.18E-10	1.88E-10	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	C-14	2.57E-09	1.25E-10	8.95E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Cs-137	1.12E-09	5.25E-11	3.74E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	H-3	4.07E-05	1.98E-06	1.42E-06	Air	0

Outdoor Family	Adult Male	Inhalation	Air Inhalation	I-129	3.55E-08	7.74E-10	7.92E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	I-131	6.32E-05	1.41E-06	1.52E-07	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Pu-238	6.5E-06	9.13E-08	8.12E-08	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Pu-239	4.53E-05	5.8E-07	5.11E-07	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Ru-106	3E-07	1.59E-08	1.45E-08	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Sr-89	4.79E-10	2.56E-11	2.36E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Sr-90	1.22E-07	6.09E-09	5.79E-09	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-234	2.67E-07	1.39E-08	1.31E-08	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-235	1.07E-08	5.55E-10	5.24E-10	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-236	1.73E-08	8.94E-10	8.46E-10	Air	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-238	4.39E-07	2.27E-08	2.13E-08	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Am-241	7.99E-11	1.04E-12	8.99E-13	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Cs-137	5.29E-12	2.47E-13	1.77E-13	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	I-129	7.26E-11	1.58E-12	1.62E-13	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	I-131	1.07E-08	2.38E-10	2.57E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Pu-238	3.11E-08	4.35E-10	3.88E-10	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Pu-239	2.16E-07	2.77E-09	2.45E-09	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Ru-106	1.15E-09	6.09E-11	5.55E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Sr-89	7.33E-13	3.91E-14	3.61E-14	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Sr-90	6.32E-10	3.15E-11	2.97E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-234	1.28E-09	6.65E-11	6.28E-11	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-235	5.13E-11	2.66E-12	2.51E-12	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-236	8.26E-11	4.28E-12	4.05E-12	Air	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-238	2.1E-09	1.09E-10	1.02E-10	Air	0

Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Am-241	2.17E-10	2.97E-12	2.21E-12	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	C-14	9.35E-08	1.24E-08	8.28E-09	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Cs-137	4.24E-09	3.64E-10	2.45E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	H-3	2.73E-06	3.59E-07	2.41E-07	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	I-129	6.42E-08	4.88E-09	4.98E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	I-131	8.37E-05	8.01E-06	8.36E-07	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-238	5.44E-08	2.42E-09	1.74E-09	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-239	7E-07	4.78E-09	3.34E-09	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Ru-106	1.93E-07	6.56E-08	3.69E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-89	4.4E-10	1.09E-10	6.38E-11	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-90	2.01E-07	1.75E-08	1.17E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	U-234	6.37E-09	3.97E-10	2.44E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	U-235	3.01E-10	2.42E-11	1.48E-11	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	U-236	4.23E-10	2.64E-11	1.62E-11	Air	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	U-238	1.39E-08	1.3E-09	7.91E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	Am-241	1.03E-10	1.41E-12	1.05E-12	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	C-14	5.04E-07	7.02E-08	4.67E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	Cs-137	3.05E-09	2.92E-10	1.92E-10	Air	0

Outdoor Family	Child born 1955	Ingestion	Root Vegetables	H-3	1.36E-05	1.89E-06	1.26E-06	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	I-129	3.43E-08	2.71E-09	2.77E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	I-131	2.07E-05	1.99E-06	2.07E-07	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	Pu-238	3.19E-08	1.43E-09	1.03E-09	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	Pu-239	1.52E-06	9.29E-09	6.48E-09	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	Ru-106	1.5E-07	4.49E-08	2.52E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	Sr-89	4.25E-10	8.61E-11	5.01E-11	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	Sr-90	3.95E-07	2.78E-08	1.82E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	U-234	1.01E-08	5.19E-10	3.17E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	U-235	3.51E-10	2.3E-11	1.4E-11	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	U-236	6.7E-10	3.44E-11	2.1E-11	Air	0
Outdoor Family	Child born 1955	Ingestion	Root Vegetables	U-238	1.26E-08	1.09E-09	6.58E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	Am-241	7.17E-11	9.81E-13	7.3E-13	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	C-14	5.07E-07	7.69E-08	5.09E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	Cs-137	3.57E-09	3.89E-10	2.51E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	H-3	1.36E-05	2.12E-06	1.41E-06	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	I-129	3.44E-08	2.95E-09	3E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	I-131	0.000104	9.97E-06	1.04E-06	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	Pu-238	2.48E-08	1.12E-09	8.02E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	Pu-239	3.51E-06	2.1E-08	1.46E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	Ru-106	2.37E-07	6.18E-08	3.46E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	Sr-89	8.58E-10	1.56E-10	9.06E-11	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	Sr-90	6.81E-07	4.25E-08	2.81E-08	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	U-234	2.14E-08	1.02E-09	6.2E-10	Air	0
Outdoor Family	Child born 1955	Ingestion	Fruit	U-235	6.75E-10	4.06E-11	2.46E-11	Air	0

Outdoor Family	Child born 195	Ingestion	Fruit	U-236	1.42E-09	6.81E-11	4.14E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Fruit	U-238	2.09E-08	1.6E-09	9.65E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	Am-241	1.1E-11	1.5E-13	1.12E-13	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	C-14	3.09E-07	4.58E-08	3.04E-08	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	Cs-137	3.08E-10	3.28E-11	2.15E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	H-3	2.27E-06	3.45E-07	2.29E-07	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	I-129	5.17E-09	4.34E-10	4.42E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	I-131	1.17E-05	1.13E-06	1.18E-07	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	Pu-238	3.72E-09	1.68E-10	1.2E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	Pu-239	1.42E-07	8.99E-10	6.25E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	Ru-106	1.97E-08	6.31E-09	3.55E-09	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	Sr-89	5.94E-11	1.41E-11	8.22E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	Sr-90	3.83E-08	2.99E-09	1.99E-09	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	U-234	1E-09	5.48E-11	3.34E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	U-235	4.03E-11	3.02E-12	1.83E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	U-236	6.68E-11	3.64E-12	2.22E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Grain	U-238	1.64E-09	1.54E-10	9.34E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	Am-241	6.64E-12	9.07E-14	6.76E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	C-14	1.74E-05	2.49E-06	1.66E-06	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	Cs-137	2.3E-07	2.24E-08	1.48E-08	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	H-3	9.68E-05	1.35E-05	9.01E-06	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	I-129	2.53E-06	2.04E-07	2.08E-08	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	I-131	0.00438	0.000426	4.45E-05	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	Pu-238	6.16E-10	2.79E-11	1.99E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	Pu-239	2.35E-08	1.45E-10	1.01E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	Ru-106	1.32E-05	4.09E-06	2.3E-06	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	Sr-89	6.36E-09	1.31E-09	7.65E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	Sr-90	3.67E-06	2.28E-07	1.52E-07	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	U-234	4.83E-09	2.54E-10	1.55E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	U-235	1.72E-10	1.17E-11	7.08E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	U-236	3.21E-10	1.69E-11	1.03E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Beef	U-238	6.05E-09	4.79E-10	2.93E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	Am-241	3.21E-15	4.38E-17	3.27E-17	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	C-14	5.66E-07	8.3E-08	5.51E-08	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	Cs-137	1.25E-10	1.25E-11	8.29E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	H-3	1.33E-05	1.91E-06	1.27E-06	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	I-129	2.33E-12	1.92E-13	1.96E-14	Air	0

Outdoor Family	Child born 195	Ingestion	Poultry	I-131	5.85E-16	5.71E-17	5.96E-18	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	Pu-238	6.43E-13	2.91E-14	2.09E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	Pu-239	9.43E-12	6.4E-14	4.46E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	Ru-106	4.25E-09	1.51E-09	8.47E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	Sr-89	1.45E-14	3.81E-15	2.22E-15	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	Sr-90	9.33E-11	7.7E-12	5.12E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	U-234	2.75E-11	1.71E-12	1.05E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	U-235	1.28E-12	1.07E-13	6.49E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	U-236	1.82E-12	1.13E-13	6.95E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Poultry	U-238	5.66E-11	5.27E-12	3.23E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	Am-241	1.57E-13	2.14E-15	1.59E-15	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	C-14	3.75E-06	6.14E-07	4.05E-07	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	Cs-137	6.69E-08	7.98E-09	5.13E-09	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	H-3	7.25E-05	1.22E-05	8.09E-06	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	I-129	9.42E-07	8.57E-08	8.73E-09	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	I-131	0.002973	0.000285	2.98E-05	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	Pu-238	9.81E-11	4.51E-12	3.23E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	Pu-239	8.98E-09	5.42E-11	3.77E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	Ru-106	2.01E-09	5.64E-10	3.16E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	Sr-89	6.3E-09	1.21E-09	7.03E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	Sr-90	4.37E-06	2.49E-07	1.7E-07	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	U-234	2.04E-08	1E-09	6.1E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	U-235	6.61E-10	4.15E-11	2.52E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	U-236	1.35E-09	6.64E-11	4.04E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Milk	U-238	2.05E-08	1.5E-09	9.17E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	Am-241	2.61E-15	3.56E-17	2.65E-17	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	C-14	1.55E-07	2.2E-08	1.46E-08	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	Cs-137	5.81E-12	5.64E-13	3.74E-13	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	H-3	6.04E-06	8.75E-07	5.83E-07	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	I-129	7.19E-10	5.81E-11	5.93E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	I-131	2.91E-13	2.82E-14	2.94E-15	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	Pu-238	9.81E-14	4.4E-15	3.15E-15	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	Pu-239	1.88E-12	1.26E-14	8.73E-15	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	Ru-106	2.87E-12	9.88E-13	5.55E-13	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	Sr-89	4.23E-14	1.12E-14	6.52E-15	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	Sr-90	2.84E-10	2E-11	1.42E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	U-234	3.07E-11	1.84E-12	1.12E-12	Air	0

Outdoor Family	Child born 195	Ingestion	Eggs	U-235	1.4E-12	1.13E-13	6.89E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	U-236	2.03E-12	1.22E-13	7.47E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Eggs	U-238	6.09E-11	5.37E-12	3.3E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	Am-241	5.37E-14	7.34E-16	5.46E-16	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	Cs-137	4.05E-12	4.84E-13	3.11E-13	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	I-129	3.43E-11	3.13E-12	3.19E-13	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	I-131	2.79E-08	2.68E-09	2.81E-10	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	Pu-238	3.84E-11	1.76E-12	1.26E-12	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	Pu-239	4.51E-09	2.71E-11	1.89E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	Ru-106	2.63E-10	7.19E-11	4.03E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	Sr-89	4.69E-13	8.94E-14	5.21E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	Sr-90	8.77E-10	5.92E-11	3.88E-11	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	U-234	2.78E-11	1.35E-12	8.19E-13	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	U-235	8.95E-13	5.59E-14	3.38E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	U-236	1.84E-12	8.93E-14	5.43E-14	Air	0
Outdoor Family	Child born 195	Ingestion	Soil	U-238	3.01E-11	2.75E-12	1.63E-12	Air	0
Outdoor Family	Child born 195	External	Air Immersion	Am-241	1.54E-15	1.08E-16	7.23E-17	Air	0
Outdoor Family	Child born 195	External	Air Immersion	Ar-41	0.000121	1.71E-05	1.13E-05	Air	0
Outdoor Family	Child born 195	External	Air Immersion	C-14	4.56E-12	9.92E-14	8.59E-14	Air	0
Outdoor Family	Child born 195	External	Air Immersion	Cs-137	3.4E-11	4.65E-12	3.07E-12	Air	0
Outdoor Family	Child born 195	External	Air Immersion	I-129	7.54E-13	9.37E-14	5.73E-14	Air	0
Outdoor Family	Child born 195	External	Air Immersion	I-131	3.84E-07	6.91E-08	4.53E-08	Air	0
Outdoor Family	Child born 195	External	Air Immersion	Pu-238	2.73E-15	4.02E-16	2.28E-16	Air	0
Outdoor Family	Child born 195	External	Air Immersion	Pu-239	1.74E-14	2.92E-15	1.82E-15	Air	0
Outdoor Family	Child born 195	External	Air Immersion	Ru-106	6.33E-10	9.56E-11	6.31E-11	Air	0
Outdoor Family	Child born 195	External	Air Immersion	Sr-89	1.89E-13	7.96E-15	6.24E-15	Air	0

Outdoor Family	Child born 195	External	Air Immersion	Sr-90	2.29E-12	7.9E-14	6.64E-14	Air	0
Outdoor Family	Child born 195	External	Air Immersion	U-234	2.6E-15	4.19E-16	2.58E-16	Air	0
Outdoor Family	Child born 195	External	Air Immersion	U-235	1.24E-13	2.09E-14	1.36E-14	Air	0
Outdoor Family	Child born 195	External	Air Immersion	U-236	1.15E-16	1.81E-17	1.08E-17	Air	0
Outdoor Family	Child born 195	External	Air Immersion	U-238	6.65E-15	8.52E-16	5.43E-16	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	Am-241	1.94E-12	1.33E-13	8.89E-14	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	Cs-137	2.56E-08	3.42E-09	2.27E-09	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	I-129	7.85E-10	9.4E-11	5.87E-11	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	I-131	9.79E-06	1.77E-06	1.16E-06	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	Pu-238	1.7E-11	2.03E-12	1.16E-12	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	Pu-239	4.91E-11	6.59E-12	3.9E-12	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	Ru-106	5.82E-07	6.12E-08	4.17E-08	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	Sr-89	3.32E-10	7.8E-12	7.21E-12	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	Sr-90	7.79E-08	2.16E-09	1.94E-09	Air	0

Outdoor Family	Child born 195	External	Ground Contamination	U-234	8.64E-12	1.11E-12	6.6E-13	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	U-235	1.04E-10	1.75E-11	1.14E-11	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	U-236	5.2E-13	6.52E-14	3.81E-14	Air	0
Outdoor Family	Child born 195	External	Ground Contamination	U-238	3E-09	1.58E-10	1.18E-10	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	Am-241	1.67E-08	2.87E-10	2.46E-10	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	C-14	2.06E-09	2.83E-10	1.88E-10	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	Cs-137	7.98E-10	7.77E-11	5.09E-11	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	H-3	3.28E-05	4.47E-06	2.98E-06	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	I-129	4.18E-08	3.49E-09	3.55E-10	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	I-131	0.000228	2.23E-05	2.31E-06	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	Pu-238	6.26E-06	3.02E-07	2.69E-07	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	Pu-239	2.18E-05	1E-06	8.77E-07	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	Ru-106	3.68E-07	6.67E-08	5.69E-08	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	Sr-89	6.29E-10	1.2E-10	1E-10	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	Sr-90	1.52E-07	1.96E-08	1.78E-08	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	U-234	3.21E-07	4.46E-08	4.21E-08	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	U-235	1.33E-08	1.93E-09	1.82E-09	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	U-236	2.09E-08	2.89E-09	2.73E-09	Air	0
Outdoor Family	Child born 195	Inhalation	Air Inhalation	U-238	5.56E-07	8.35E-08	7.88E-08	Air	0
Outdoor Family	Child born 195	Inhalation	Resuspended Soil	Am-241	7.99E-11	1.37E-12	1.18E-12	Air	0
Outdoor Family	Child born 195	Inhalation	Resuspended Soil	Cs-137	3.75E-12	3.64E-13	2.39E-13	Air	0
Outdoor Family	Child born 195	Inhalation	Resuspended Soil	I-129	8.37E-11	6.96E-12	7.08E-13	Air	0
Outdoor Family	Child born 195	Inhalation	Resuspended Soil	I-131	3.68E-08	3.6E-09	3.72E-10	Air	0
Outdoor Family	Child born 195	Inhalation	Resuspended Soil	Pu-238	2.98E-08	1.43E-09	1.27E-09	Air	0

Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	Pu-239	1.03E-07	4.75E-09	4.16E-09	Air	0
Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	Ru-106	1.4E-09	2.53E-10	2.16E-10	Air	0
Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	Sr-89	9.56E-13	1.83E-13	1.52E-13	Air	0
Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	Sr-90	8.1E-10	1.11E-10	9.73E-11	Air	0
Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	U-234	1.53E-09	2.11E-10	1.99E-10	Air	0
Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	U-235	6.31E-11	9.18E-12	8.65E-12	Air	0
Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	U-236	9.89E-11	1.37E-11	1.3E-11	Air	0
Outdoor Family	Child born 1955	Inhalation	Resuspended Soil	U-238	2.64E-09	3.97E-10	3.75E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	Am-241	1.7E-10	4.19E-12	2.92E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	C-14	5.61E-08	8.97E-09	5.94E-09	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	Cs-137	3.1E-09	4.19E-10	2.83E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	H-3	1.66E-06	2.44E-07	1.63E-07	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	I-129	3.58E-08	3.16E-09	3.23E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	I-131	4.42E-07	4.01E-08	4.19E-09	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-238	5.55E-08	1.92E-09	1.37E-09	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-239	1.12E-08	4.3E-10	3.06E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	Ru-106	1.2E-07	5.46E-08	3.07E-08	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-89	1.85E-10	4.49E-11	2.61E-11	Air	0

Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-90	6.43E-09	7.49E-10	5.02E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	U-234	1.61E-09	1.49E-10	9.18E-11	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	U-235	1.04E-10	1.01E-11	6.16E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	U-236	1.07E-10	9.83E-12	6.08E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Leafy Vegetables	U-238	5.62E-09	5.67E-10	3.46E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	Am-241	9.06E-11	2.3E-12	1.59E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	C-14	3.24E-07	5.33E-08	3.53E-08	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	Cs-137	1.66E-09	2.26E-10	1.51E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	H-3	9.29E-06	1.37E-06	9.14E-07	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	I-129	2.21E-08	2.05E-09	2.09E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	I-131	9.84E-08	9.43E-09	9.86E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	Pu-238	2.88E-08	9.97E-10	7.13E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	Pu-239	7.12E-09	2.68E-10	1.9E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	Ru-106	7.58E-08	3.42E-08	1.92E-08	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	Sr-89	1.12E-10	2.58E-11	1.5E-11	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	Sr-90	8.55E-09	8.55E-10	5.63E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	U-234	1.24E-09	1.03E-10	6.34E-11	Air	0
Outdoor Family	Child born 1964	Ingestion	Root Vegetables	U-235	8.05E-11	7.23E-12	4.4E-12	Air	0

Outdoor Family	Child born 196	Ingestion	Root Vegetables	U-236	8.19E-11	6.83E-12	4.2E-12	Air	0
Outdoor Family	Child born 196	Ingestion	Root Vegetables	U-238	4.48E-09	4.47E-10	2.69E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	Am-241	6.73E-11	1.73E-12	1.2E-12	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	C-14	3.71E-07	6.33E-08	4.17E-08	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	Cs-137	1.2E-09	1.68E-10	1.12E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	H-3	1.13E-05	1.69E-06	1.12E-06	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	I-129	2.71E-08	2.69E-09	2.74E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	I-131	4.7E-07	4.64E-08	4.85E-09	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	Pu-238	3.52E-08	1.22E-09	8.71E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	Pu-239	1.04E-08	3.85E-10	2.72E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	Ru-106	1.04E-07	4.38E-08	2.45E-08	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	Sr-89	1.82E-10	4.02E-11	2.34E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	Sr-90	1.3E-08	1.14E-09	7.56E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	U-234	2.03E-09	1.59E-10	9.78E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	U-235	1.3E-10	1.12E-11	6.77E-12	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	U-236	1.35E-10	1.06E-11	6.49E-12	Air	0
Outdoor Family	Child born 196	Ingestion	Fruit	U-238	6.98E-09	6.39E-10	3.85E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	Am-241	1.02E-11	2.61E-13	1.81E-13	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	C-14	2.1E-07	3.55E-08	2.34E-08	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	Cs-137	1.67E-10	2.36E-11	1.57E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	H-3	1.48E-06	2.37E-07	1.57E-07	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	I-129	3.43E-09	3.26E-10	3.32E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	I-131	5.3E-08	5.11E-09	5.34E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	Pu-238	5.56E-09	1.93E-10	1.38E-10	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	Pu-239	1.26E-09	5.08E-11	3.6E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	Ru-106	1.29E-08	5.67E-09	3.18E-09	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	Sr-89	2.15E-11	5.22E-12	3.03E-12	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	Sr-90	1.05E-09	1.16E-10	7.76E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	U-234	1.88E-10	1.76E-11	1.08E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	U-235	1.19E-11	1.2E-12	7.33E-13	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	U-236	1.25E-11	1.17E-12	7.2E-13	Air	0
Outdoor Family	Child born 196	Ingestion	Grain	U-238	6.35E-10	6.87E-11	4.15E-11	Air	0
Outdoor Family	Child born 196	Ingestion	Beef	Am-241	6.51E-12	1.69E-13	1.17E-13	Air	0
Outdoor Family	Child born 196	Ingestion	Beef	C-14	1.14E-05	1.9E-06	1.26E-06	Air	0
Outdoor Family	Child born 196	Ingestion	Beef	Cs-137	1.24E-07	1.7E-08	1.14E-08	Air	0

Outdoor Family	Child born 1964	Ingestion	Beef	H-3	7.35E-05	1.14E-05	7.58E-06	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	I-129	1.62E-06	1.49E-07	1.53E-08	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	I-131	6.92E-05	6.57E-06	6.86E-07	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	Pu-238	5.65E-10	1.97E-11	1.4E-11	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	Pu-239	1.25E-10	4.65E-12	3.31E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	Ru-106	7.11E-06	3.22E-06	1.81E-06	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	Sr-89	1.83E-09	4.24E-10	2.47E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	Sr-90	4.89E-08	4.58E-09	3.17E-09	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	U-234	6.49E-10	5.47E-11	3.37E-11	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	U-235	4.12E-11	3.74E-12	2.28E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	U-236	4.32E-11	3.64E-12	2.24E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Beef	U-238	2.17E-09	1.95E-10	1.19E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	Am-241	3.31E-15	8.64E-17	5.97E-17	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	C-14	3.8E-07	6.45E-08	4.26E-08	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	Cs-137	7.77E-11	1.08E-11	7.24E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	H-3	1E-05	1.61E-06	1.07E-06	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	I-129	1.51E-12	1.4E-13	1.43E-14	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	I-131	7.68E-18	7.74E-19	8.09E-20	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	Pu-238	5.95E-13	2.07E-14	1.48E-14	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	Pu-239	1.33E-13	5.56E-15	3.95E-15	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	Ru-106	2.97E-09	1.39E-09	7.81E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	Sr-89	5.4E-15	1.36E-15	7.91E-16	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	Sr-90	2.05E-12	2.37E-13	1.63E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	U-234	6.48E-12	6.4E-13	3.94E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	U-235	4.26E-13	4.52E-14	2.75E-14	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	U-236	4.3E-13	4.26E-14	2.62E-14	Air	0
Outdoor Family	Child born 1964	Ingestion	Poultry	U-238	2.26E-11	2.36E-12	1.45E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	Am-241	2.78E-13	7.82E-15	5.35E-15	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	C-14	2.87E-06	5.03E-07	3.31E-07	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	Cs-137	1.79E-08	2.64E-09	1.74E-09	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	H-3	5.88E-05	9.19E-06	6.07E-06	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	I-129	7.67E-07	7.62E-08	7.77E-09	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	I-131	1.35E-05	1.32E-06	1.38E-07	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	Pu-238	1.19E-10	4.12E-12	2.94E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	Pu-239	3.18E-11	1.22E-12	8.6E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	Ru-106	1.01E-09	4.41E-10	2.47E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	Sr-89	1.48E-09	3.35E-10	1.95E-10	Air	0

Outdoor Family	Child born 1964	Ingestion	Milk	Sr-90	8.73E-08	7.16E-09	4.9E-09	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	U-234	2.15E-09	1.76E-10	1.08E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	U-235	1.34E-10	1.21E-11	7.32E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	U-236	1.43E-10	1.17E-11	7.15E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Milk	U-238	6.91E-09	6.03E-10	3.68E-10	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	Am-241	2.27E-15	5.72E-17	3.96E-17	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	C-14	1.01E-07	1.7E-08	1.12E-08	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	Cs-137	3.76E-12	5.19E-13	3.48E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	H-3	3.82E-06	5.94E-07	3.95E-07	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	I-129	4.66E-10	4.35E-11	4.44E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	I-131	1.15E-15	1.16E-16	1.21E-17	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	Pu-238	9.83E-14	3.41E-15	2.43E-15	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	Pu-239	2.45E-14	1.04E-15	7.38E-16	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	Ru-106	1.95E-12	9.09E-13	5.1E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	Sr-89	1.5E-14	3.83E-15	2.23E-15	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	Sr-90	9.34E-12	9.02E-13	6.44E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	U-234	6.9E-12	6.91E-13	4.24E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	U-235	4.65E-13	4.91E-14	2.99E-14	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	U-236	4.56E-13	4.58E-14	2.82E-14	Air	0
Outdoor Family	Child born 1964	Ingestion	Eggs	U-238	2.46E-11	2.47E-12	1.52E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	Am-241	8.3E-14	2.3E-15	1.58E-15	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	Cs-137	1.05E-12	1.55E-13	1.03E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	I-129	2.88E-11	2.89E-12	2.95E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	I-131	1.22E-10	1.21E-11	1.27E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	Pu-238	5.33E-11	1.85E-12	1.32E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	Pu-239	1.52E-11	5.9E-13	4.16E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	Ru-106	1.3E-10	5.58E-11	3.12E-11	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	Sr-89	1.06E-13	2.42E-14	1.4E-14	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	Sr-90	1.78E-11	1.71E-12	1.12E-12	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	U-234	2.84E-12	2.33E-13	1.43E-13	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	U-235	1.8E-13	1.63E-14	9.87E-15	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	U-236	1.89E-13	1.55E-14	9.51E-15	Air	0
Outdoor Family	Child born 1964	Ingestion	Soil	U-238	1.02E-11	1.12E-12	6.66E-13	Air	0
Outdoor Family	Child born 1964	External	Air Immersion	Am-241	1.51E-15	1.91E-16	1.24E-16	Air	0
Outdoor Family	Child born 1964	External	Air Immersion	Ar-41	5.3E-05	8.73E-06	5.75E-06	Air	0

Outdoor Family	Child born 196	External	Air Immersion	C-14	2.8E-12	7.28E-14	6.27E-14	Air	0
Outdoor Family	Child born 196	External	Air Immersion	Cs-137	1.44E-11	2.08E-12	1.38E-12	Air	0
Outdoor Family	Child born 196	External	Air Immersion	I-129	5.33E-13	7.43E-14	4.52E-14	Air	0
Outdoor Family	Child born 196	External	Air Immersion	I-131	2.28E-09	4.06E-10	2.66E-10	Air	0
Outdoor Family	Child born 196	External	Air Immersion	Pu-238	2.73E-15	4.12E-16	2.33E-16	Air	0
Outdoor Family	Child born 196	External	Air Immersion	Pu-239	5.66E-16	9.22E-17	5.74E-17	Air	0
Outdoor Family	Child born 196	External	Air Immersion	Ru-106	3.79E-10	6.23E-11	4.09E-11	Air	0
Outdoor Family	Child born 196	External	Air Immersion	Sr-89	6.55E-14	2.82E-15	2.19E-15	Air	0
Outdoor Family	Child born 196	External	Air Immersion	Sr-90	4.97E-14	1.59E-15	1.36E-15	Air	0
Outdoor Family	Child born 196	External	Air Immersion	U-234	5.84E-16	9.31E-17	5.73E-17	Air	0
Outdoor Family	Child born 196	External	Air Immersion	U-235	4.1E-14	6.8E-15	4.45E-15	Air	0
Outdoor Family	Child born 196	External	Air Immersion	U-236	2.58E-17	4.04E-18	2.42E-18	Air	0
Outdoor Family	Child born 196	External	Air Immersion	U-238	2.71E-15	3.48E-16	2.22E-16	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	Am-241	1.85E-12	2.29E-13	1.49E-13	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	Cs-137	1.11E-08	1.59E-09	1.05E-09	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	I-129	5.46E-10	7.37E-11	4.58E-11	Air	0

Outdoor Family	Child born 196	External	Ground Contamination	I-131	6E-08	1.08E-08	7.05E-09	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	Pu-238	1.72E-11	2.09E-12	1.2E-12	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	Pu-239	1.64E-12	2.14E-13	1.27E-13	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	Ru-106	3.45E-07	3.96E-08	2.68E-08	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	Sr-89	1.16E-10	2.72E-12	2.5E-12	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	Sr-90	2.38E-09	6.49E-11	5.83E-11	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	U-234	1.96E-12	2.5E-13	1.48E-13	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	U-235	3.45E-11	5.74E-12	3.75E-12	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	U-236	1.18E-13	1.46E-14	8.56E-15	Air	0
Outdoor Family	Child born 196	External	Ground Contamination	U-238	1.23E-09	6.47E-11	4.84E-11	Air	0
Outdoor Family	Child born 196	Inhalation	Air Inhalation	Am-241	1.67E-08	4.99E-10	4.32E-10	Air	0
Outdoor Family	Child born 196	Inhalation	Air Inhalation	C-14	1.28E-09	2.11E-10	1.39E-10	Air	0
Outdoor Family	Child born 196	Inhalation	Air Inhalation	Cs-137	4.16E-10	5.69E-11	3.79E-11	Air	0
Outdoor Family	Child born 196	Inhalation	Air Inhalation	H-3	2.08E-05	3.12E-06	2.07E-06	Air	0
Outdoor Family	Child born 196	Inhalation	Air Inhalation	I-129	2.71E-08	2.55E-09	2.6E-10	Air	0
Outdoor Family	Child born 196	Inhalation	Air Inhalation	I-131	1.08E-06	1.03E-07	1.06E-08	Air	0
Outdoor Family	Child born 196	Inhalation	Air Inhalation	Pu-238	6.01E-06	2.35E-07	2.09E-07	Air	0

Outdoor Family	Child born 1964	Inhalation	Air Inhalation	Pu-239	1.21E-06	4.92E-08	4.34E-08	Air	0
Outdoor Family	Child born 1964	Inhalation	Air Inhalation	Ru-106	2.26E-07	5.35E-08	4.54E-08	Air	0
Outdoor Family	Child born 1964	Inhalation	Air Inhalation	Sr-89	2.27E-10	4.38E-11	3.69E-11	Air	0
Outdoor Family	Child born 1964	Inhalation	Air Inhalation	Sr-90	3.81E-09	5.42E-10	4.93E-10	Air	0
Outdoor Family	Child born 1964	Inhalation	Air Inhalation	U-234	7.73E-08	1.2E-08	1.13E-08	Air	0
Outdoor Family	Child born 1964	Inhalation	Air Inhalation	U-235	4.5E-09	6.87E-10	6.47E-10	Air	0
Outdoor Family	Child born 1964	Inhalation	Air Inhalation	U-236	5.03E-09	7.76E-10	7.32E-10	Air	0
Outdoor Family	Child born 1964	Inhalation	Air Inhalation	U-238	2.28E-07	3.46E-08	3.27E-08	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	Am-241	7.93E-11	2.37E-12	2.05E-12	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	Cs-137	1.97E-12	2.68E-13	1.79E-13	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	I-129	5.41E-11	5.08E-12	5.17E-13	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	I-131	1.79E-10	1.7E-11	1.76E-12	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	Pu-238	2.86E-08	1.11E-09	9.89E-10	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	Pu-239	5.85E-09	2.37E-10	2.09E-10	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	Ru-106	8.58E-10	2.03E-10	1.72E-10	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	Sr-89	3.45E-13	6.65E-14	5.6E-14	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	Sr-90	2.63E-11	3.92E-12	3.44E-12	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	U-234	3.67E-10	5.67E-11	5.35E-11	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	U-235	2.14E-11	3.26E-12	3.08E-12	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	U-236	2.39E-11	3.68E-12	3.47E-12	Air	0
Outdoor Family	Child born 1964	Inhalation	Resuspended Soil	U-238	1.08E-09	1.65E-10	1.55E-10	Air	0

Location	Receptor	ReportRoute	ReportPath	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	AirWater	RunNum
Outdoor Family	Adult Female	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Water	0
Outdoor Family	Adult Female	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Water	0
Outdoor Family	Adult Female	External	Boating	Ce-144	1.68E-09	5.04E-11	4.2E-11	Water	0
Outdoor Family	Adult Female	External	Boating	Co-60	8.48E-09	2.54E-10	2.12E-10	Water	0
Outdoor Family	Adult Female	External	Boating	Cs-134	2.71E-10	8.15E-12	6.78E-12	Water	0
Outdoor Family	Adult Female	External	Boating	Cs-137	8.58E-09	2.57E-10	2.14E-10	Water	0
Outdoor Family	Adult Female	External	Boating	I-129	2.19E-12	6.56E-14	5.46E-14	Water	0
Outdoor Family	Adult Female	External	Boating	I-131	7.22E-09	2.17E-10	1.81E-10	Water	0
Outdoor Family	Adult Female	External	Boating	Nb-95	2.17E-08	6.5E-10	5.42E-10	Water	0
Outdoor Family	Adult Female	External	Boating	P-32	5.21E-11	1.56E-12	1.3E-12	Water	0
Outdoor Family	Adult Female	External	Boating	Pu-238	4.11E-15	1.23E-16	1.03E-16	Water	0
Outdoor Family	Adult Female	External	Boating	Pu-239	1.67E-14	5.03E-16	4.19E-16	Water	0
Outdoor Family	Adult Female	External	Boating	Ru-106	1.7E-08	5.11E-10	4.26E-10	Water	0
Outdoor Family	Adult Female	External	Boating	S-35	3.45E-12	1.04E-13	8.62E-14	Water	0
Outdoor Family	Adult Female	External	Boating	Sr-89	6.31E-11	1.89E-12	1.58E-12	Water	0
Outdoor Family	Adult Female	External	Boating	Sr-90	1.85E-11	5.55E-13	4.62E-13	Water	0

Outdoor Family	Adult Female	External	Boating	Tc-99	1.75E-12	5.24E-14	4.37E-14	Water	0
Outdoor Family	Adult Female	External	Boating	U-234	2.95E-15	8.84E-17	7.36E-17	Water	0
Outdoor Family	Adult Female	External	Boating	U-235	1.46E-12	4.38E-14	3.65E-14	Water	0
Outdoor Family	Adult Female	External	Boating	U-236	1.12E-16	3.37E-18	2.81E-18	Water	0
Outdoor Family	Adult Female	External	Boating	U-238	4.44E-14	1.33E-15	1.11E-15	Water	0
Outdoor Family	Adult Female	External	Boating	Zn-65	3.41E-09	1.02E-10	8.53E-11	Water	0
Outdoor Family	Adult Female	External	Boating	Zr-95	1.38E-08	4.14E-10	3.45E-10	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Water	0
Outdoor Family	Adult Male	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Water	0
Outdoor Family	Adult Male	External	Boating	Ce-144	6.23E-09	1.87E-10	1.56E-10	Water	0
Outdoor Family	Adult Male	External	Boating	Co-60	3.15E-08	9.44E-10	7.87E-10	Water	0
Outdoor Family	Adult Male	External	Boating	Cs-134	1.01E-09	3.02E-11	2.52E-11	Water	0
Outdoor Family	Adult Male	External	Boating	Cs-137	3.18E-08	9.55E-10	7.95E-10	Water	0
Outdoor Family	Adult Male	External	Boating	I-129	8.11E-12	2.43E-13	2.03E-13	Water	0
Outdoor Family	Adult Male	External	Boating	I-131	2.68E-08	8.04E-10	6.71E-10	Water	0
Outdoor Family	Adult Male	External	Boating	Nb-95	8.04E-08	2.41E-09	2.01E-09	Water	0
Outdoor Family	Adult Male	External	Boating	P-32	1.93E-10	5.78E-12	4.83E-12	Water	0

Outdoor Family	Adult Male	External	Boating	Pu-238	1.52E-14	4.58E-16	3.81E-16	Water	0
Outdoor Family	Adult Male	External	Boating	Pu-239	6.21E-14	1.86E-15	1.55E-15	Water	0
Outdoor Family	Adult Male	External	Boating	Ru-106	6.32E-08	1.9E-09	1.58E-09	Water	0
Outdoor Family	Adult Male	External	Boating	S-35	1.28E-11	3.84E-13	3.2E-13	Water	0
Outdoor Family	Adult Male	External	Boating	Sr-89	2.34E-10	7.02E-12	5.85E-12	Water	0
Outdoor Family	Adult Male	External	Boating	Sr-90	6.86E-11	2.06E-12	1.72E-12	Water	0
Outdoor Family	Adult Male	External	Boating	Tc-99	6.48E-12	1.94E-13	1.62E-13	Water	0
Outdoor Family	Adult Male	External	Boating	U-234	1.09E-14	3.28E-16	2.73E-16	Water	0
Outdoor Family	Adult Male	External	Boating	U-235	5.42E-12	1.62E-13	1.35E-13	Water	0
Outdoor Family	Adult Male	External	Boating	U-236	4.16E-16	1.25E-17	1.04E-17	Water	0
Outdoor Family	Adult Male	External	Boating	U-238	1.65E-13	4.94E-15	4.12E-15	Water	0
Outdoor Family	Adult Male	External	Boating	Zn-65	1.27E-08	3.8E-10	3.16E-10	Water	0
Outdoor Family	Adult Male	External	Boating	Zr-95	5.12E-08	1.54E-09	1.28E-09	Water	0
Outdoor Family	Adult Male	External	Shoreline	Ce-144	1.37E-05	2.68E-07	2.1E-07	Water	0
Outdoor Family	Adult Male	External	Shoreline	Co-60	3.12E-05	1.51E-06	1.07E-06	Water	0
Outdoor Family	Adult Male	External	Shoreline	Cs-134	9.78E-07	4.68E-08	3.34E-08	Water	0
Outdoor Family	Adult Male	External	Shoreline	Cs-137	3.7E-05	1.74E-06	1.24E-06	Water	0
Outdoor Family	Adult Male	External	Shoreline	I-129	2.86E-08	1.08E-09	7.21E-10	Water	0
Outdoor Family	Adult Male	External	Shoreline	I-131	1E-06	4.75E-08	3.4E-08	Water	0
Outdoor Family	Adult Male	External	Shoreline	Nb-95	1.27E-05	6.09E-07	4.34E-07	Water	0
Outdoor Family	Adult Male	External	Shoreline	P-32	1.7E-07	1.46E-09	1.38E-09	Water	0
Outdoor Family	Adult Male	External	Shoreline	Pu-238	1.37E-10	4.07E-12	2.48E-12	Water	0
Outdoor Family	Adult Male	External	Shoreline	Pu-239	2.66E-10	8.7E-12	5.55E-12	Water	0
Outdoor Family	Adult Male	External	Shoreline	Ru-106	8.51E-05	2.69E-06	1.99E-06	Water	0
Outdoor Family	Adult Male	External	Shoreline	S-35	1.91E-09	7.34E-11	4.92E-11	Water	0
Outdoor Family	Adult Male	External	Shoreline	Sr-89	7.16E-07	6.11E-09	5.82E-09	Water	0
Outdoor Family	Adult Male	External	Shoreline	Sr-90	8.14E-06	7.44E-08	6.94E-08	Water	0
Outdoor Family	Adult Male	External	Shoreline	Tc-99	1.59E-09	6.53E-11	4.5E-11	Water	0
Outdoor Family	Adult Male	External	Shoreline	U-234	5.43E-11	1.72E-12	1.09E-12	Water	0
Outdoor Family	Adult Male	External	Shoreline	U-235	6.97E-09	3.26E-10	2.32E-10	Water	0
Outdoor Family	Adult Male	External	Shoreline	U-236	2.79E-12	8.54E-14	5.32E-14	Water	0
Outdoor Family	Adult Male	External	Shoreline	U-238	3.66E-07	6.06E-09	4.9E-09	Water	0
Outdoor Family	Adult Male	External	Shoreline	Zn-65	8.51E-06	4.09E-07	2.92E-07	Water	0
Outdoor Family	Adult Male	External	Shoreline	Zr-95	2.91E-05	1.39E-06	9.94E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Ce-144	2.8E-06	1.01E-06	5.59E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Co-60	3.02E-06	5E-07	3.19E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Cs-134	4.12E-06	6.64E-07	4.38E-07	Water	0

Outdoor Family	Child born 1955	Ingestion	Fish	Cs-137	0.000231	4.16E-05	2.7E-05	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	H-3	1E-06	1.32E-07	8.87E-08	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	I-131	1.44E-05	1.59E-06	1.66E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Nb-95	2.97E-06	6.18E-07	3.52E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	P-32	0.000565	0.000108	6.92E-05	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Pu-238	1.44E-05	5.5E-07	4.04E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Pu-239	9.75E-05	3.17E-06	2.29E-06	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Ru-106	3.24E-06	9.43E-07	5.32E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	S-35	5.2E-06	1.24E-06	7.73E-07	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Sr-89	7.31E-06	1.96E-06	1.14E-06	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Sr-90	0.000142	8.88E-06	6.88E-06	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Tc-99	6.22E-08	7.83E-09	4.42E-09	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	U-234	5.61E-09	5.73E-10	3.51E-10	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	U-235	2.12E-09	2.17E-10	1.33E-10	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	U-236	3.31E-10	3.4E-11	2.08E-11	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	U-238	1.48E-07	1.43E-08	8.88E-09	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Zn-65	1.1E-05	1.83E-06	1.21E-06	Water	0
Outdoor Family	Child born 1955	Ingestion	Fish	Zr-95	3.24E-06	6.4E-07	3.63E-07	Water	0
Outdoor Family	Child born 1955	External	Boating	Ce-144	2.11E-09	6.34E-11	5.29E-11	Water	0
Outdoor Family	Child born 1955	External	Boating	Co-60	1.21E-08	3.63E-10	3.03E-10	Water	0
Outdoor Family	Child born 1955	External	Boating	Cs-134	3.22E-10	9.65E-12	8.03E-12	Water	0
Outdoor Family	Child born 1955	External	Boating	Cs-137	8.94E-09	2.68E-10	2.24E-10	Water	0
Outdoor Family	Child born 1955	External	Boating	I-129	8.11E-12	2.43E-13	2.03E-13	Water	0
Outdoor Family	Child born 1955	External	Boating	I-131	7.23E-09	2.17E-10	1.81E-10	Water	0
Outdoor Family	Child born 1955	External	Boating	Nb-95	3.69E-08	1.11E-09	9.22E-10	Water	0
Outdoor Family	Child born 1955	External	Boating	P-32	5.27E-11	1.58E-12	1.32E-12	Water	0
Outdoor Family	Child born 1955	External	Boating	Pu-238	4.63E-15	1.39E-16	1.16E-16	Water	0
Outdoor Family	Child born 1955	External	Boating	Pu-239	1.84E-14	5.54E-16	4.61E-16	Water	0
Outdoor Family	Child born 1955	External	Boating	Ru-106	3.21E-08	9.62E-10	8.01E-10	Water	0
Outdoor Family	Child born 1955	External	Boating	S-35	3.5E-12	1.05E-13	8.76E-14	Water	0
Outdoor Family	Child born 1955	External	Boating	Sr-89	7.03E-11	2.11E-12	1.76E-12	Water	0
Outdoor Family	Child born 1955	External	Boating	Sr-90	2.39E-11	7.15E-13	5.97E-13	Water	0
Outdoor Family	Child born 1955	External	Boating	Tc-99	4.54E-12	1.36E-13	1.14E-13	Water	0
Outdoor Family	Child born 1955	External	Boating	U-234	3.04E-15	9.12E-17	7.6E-17	Water	0
Outdoor Family	Child born 1955	External	Boating	U-235	1.53E-12	4.6E-14	3.84E-14	Water	0
Outdoor Family	Child born 1955	External	Boating	U-236	1.17E-16	3.5E-18	2.92E-18	Water	0

Outdoor Family	Child born 1955	External	Boating	U-238	4.67E-14	1.4E-15	1.17E-15	Water	0
Outdoor Family	Child born 1955	External	Boating	Zn-65	4.15E-09	1.24E-10	1.04E-10	Water	0
Outdoor Family	Child born 1955	External	Boating	Zr-95	3.07E-08	9.19E-10	7.67E-10	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Ce-144	1.31E-06	5.63E-08	4.17E-08	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Co-60	4.94E-06	4.75E-07	3.22E-07	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Cs-134	6.66E-08	8.18E-09	5.46E-09	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Cs-137	5.89E-07	5.19E-08	3.53E-08	Water	0
Outdoor Family	Child born 1955	External	Shoreline	I-129	2.86E-08	1.08E-09	7.21E-10	Water	0
Outdoor Family	Child born 1955	External	Shoreline	I-131	3.57E-10	4.77E-11	3.19E-11	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Nb-95	3.28E-06	2.96E-07	2.01E-07	Water	0
Outdoor Family	Child born 1955	External	Shoreline	P-32	7.88E-10	1.4E-11	1.29E-11	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Pu-238	6.39E-12	5.13E-13	3.03E-13	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Pu-239	1.01E-11	5.09E-13	3.16E-13	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Ru-106	2.77E-05	1.78E-06	1.24E-06	Water	0
Outdoor Family	Child born 1955	External	Shoreline	S-35	1.1E-11	1.16E-12	7.39E-13	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Sr-89	2.99E-08	5.21E-10	4.85E-10	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Sr-90	8.73E-07	1.16E-08	1.06E-08	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Tc-99	9.53E-10	4.97E-11	3.36E-11	Water	0
Outdoor Family	Child born 1955	External	Shoreline	U-234	6.58E-13	4.31E-14	2.63E-14	Water	0
Outdoor Family	Child born 1955	External	Shoreline	U-235	1.3E-10	1.08E-11	7.34E-12	Water	0
Outdoor Family	Child born 1955	External	Shoreline	U-236	3.94E-14	2.51E-15	1.51E-15	Water	0
Outdoor Family	Child born 1955	External	Shoreline	U-238	6.97E-09	1.92E-10	1.49E-10	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Zn-65	6.78E-07	8.24E-08	5.51E-08	Water	0
Outdoor Family	Child born 1955	External	Shoreline	Zr-95	1.31E-05	1.1E-06	7.5E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Ce-144	3.36E-06	1.11E-06	6.14E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Co-60	2.77E-06	4.92E-07	3.11E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Cs-134	3.06E-06	5.92E-07	3.82E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Cs-137	0.000155	2.9E-05	1.84E-05	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	H-3	7.87E-07	1.21E-07	8.04E-08	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	I-129	7.75E-07	3.45E-08	3.53E-09	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	I-131	2.84E-06	3.2E-07	3.34E-08	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Nb-95	2.82E-06	6.63E-07	3.75E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	P-32	0.001049	0.000241	0.000158	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Pu-238	1.92E-05	9.43E-07	6.62E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Pu-239	7.93E-05	3.42E-06	2.41E-06	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Ru-106	4.03E-06	1.28E-06	7.17E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	S-35	5.73E-06	1.31E-06	8.13E-07	Water	0

Outdoor Family	Child born 1964	Ingestion	Fish	Sr-89	1.43E-05	2.91E-06	1.69E-06	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Sr-90	9.03E-05	1.18E-05	8.52E-06	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Tc-99	3.39E-08	4.9E-09	2.81E-09	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	U-234	3.38E-09	3.68E-10	2.24E-10	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	U-235	2.18E-09	3.31E-10	2E-10	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	U-236	1.77E-10	1.69E-11	1.02E-11	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	U-238	1.54E-07	2.24E-08	1.36E-08	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Zn-65	9.59E-06	1.28E-06	8.39E-07	Water	0
Outdoor Family	Child born 1964	Ingestion	Fish	Zr-95	3.21E-06	8.34E-07	4.7E-07	Water	0
Outdoor Family	Child born 1964	External	Boating	Ce-144	1.02E-09	3.07E-11	2.56E-11	Water	0
Outdoor Family	Child born 1964	External	Boating	Co-60	6.46E-09	1.94E-10	1.61E-10	Water	0
Outdoor Family	Child born 1964	External	Boating	Cs-134	2.76E-10	8.3E-12	6.91E-12	Water	0
Outdoor Family	Child born 1964	External	Boating	Cs-137	6.2E-09	1.86E-10	1.55E-10	Water	0
Outdoor Family	Child born 1964	External	Boating	I-129	7.49E-12	2.25E-13	1.87E-13	Water	0
Outdoor Family	Child born 1964	External	Boating	I-131	9.64E-10	2.89E-11	2.41E-11	Water	0
Outdoor Family	Child born 1964	External	Boating	Nb-95	2.06E-08	6.19E-10	5.16E-10	Water	0
Outdoor Family	Child born 1964	External	Boating	P-32	5.21E-11	1.56E-12	1.31E-12	Water	0
Outdoor Family	Child born 1964	External	Boating	Pu-238	4.16E-15	1.25E-16	1.04E-16	Water	0
Outdoor Family	Child born 1964	External	Boating	Pu-239	1.35E-14	4.06E-16	3.38E-16	Water	0
Outdoor Family	Child born 1964	External	Boating	Ru-106	1.6E-08	4.8E-10	4E-10	Water	0
Outdoor Family	Child born 1964	External	Boating	S-35	1.9E-12	5.7E-14	4.75E-14	Water	0
Outdoor Family	Child born 1964	External	Boating	Sr-89	4.75E-11	1.42E-12	1.19E-12	Water	0
Outdoor Family	Child born 1964	External	Boating	Sr-90	1.76E-11	5.27E-13	4.4E-13	Water	0
Outdoor Family	Child born 1964	External	Boating	Tc-99	3.56E-12	1.07E-13	8.9E-14	Water	0
Outdoor Family	Child born 1964	External	Boating	U-234	1.44E-15	4.31E-17	3.59E-17	Water	0
Outdoor Family	Child born 1964	External	Boating	U-235	1.26E-12	3.79E-14	3.15E-14	Water	0
Outdoor Family	Child born 1964	External	Boating	U-236	4.46E-17	1.34E-18	1.12E-18	Water	0
Outdoor Family	Child born 1964	External	Boating	U-238	3.91E-14	1.17E-15	9.77E-16	Water	0
Outdoor Family	Child born 1964	External	Boating	Zn-65	1.58E-09	4.72E-11	3.94E-11	Water	0
Outdoor Family	Child born 1964	External	Boating	Zr-95	1.86E-08	5.57E-10	4.65E-10	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Ce-144	2.14E-07	1.09E-08	8.01E-09	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Co-60	1.78E-06	2.42E-07	1.61E-07	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Cs-134	6.67E-09	8.93E-10	5.94E-10	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Cs-137	2.65E-07	2.99E-08	2.01E-08	Water	0
Outdoor Family	Child born 1964	External	Shoreline	I-129	2.56E-08	1.97E-09	1.26E-09	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Nb-95	1.46E-06	1.98E-07	1.32E-07	Water	0
Outdoor Family	Child born 1964	External	Shoreline	P-32	6.87E-11	1.18E-12	1.1E-12	Water	0

Outdoor Family	Child born 1964	External	Shoreline	Pu-238	6.53E-13	6.21E-14	3.65E-14	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Pu-239	7.02E-12	3.42E-13	2.13E-13	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Ru-106	6.03E-06	5.21E-07	3.6E-07	Water	0
Outdoor Family	Child born 1964	External	Shoreline	S-35	8.69E-13	7.33E-14	4.7E-14	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Sr-89	2.84E-09	5.3E-11	4.93E-11	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Sr-90	4.53E-07	8.08E-09	7.3E-09	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Tc-99	7.69E-10	4.92E-11	3.27E-11	Water	0
Outdoor Family	Child born 1964	External	Shoreline	U-234	1.3E-13	1.31E-14	7.87E-15	Water	0
Outdoor Family	Child born 1964	External	Shoreline	U-235	3.03E-11	3.71E-12	2.47E-12	Water	0
Outdoor Family	Child born 1964	External	Shoreline	U-236	7.75E-15	7.56E-16	4.51E-16	Water	0
Outdoor Family	Child born 1964	External	Shoreline	U-238	1.63E-09	6.44E-11	4.9E-11	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Zn-65	6.86E-08	9.32E-09	6.21E-09	Water	0
Outdoor Family	Child born 1964	External	Shoreline	Zr-95	6.41E-06	8.66E-07	5.77E-07	Water	0

Location	Receptor	ReportRoute	ReportPathway	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	Expr1	RunNum
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Am-241	2.17E-10	2.12E-12	1.65E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	C-14	1.23E-07	6.05E-09	4.35E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Cs-137	9.13E-09	4.45E-10	3.18E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	H-3	3.67E-06	1.78E-07	1.28E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	I-129	7.7E-08	1.68E-09	1.72E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	I-131	4.68E-05	1.04E-06	1.14E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Pu-238	8.57E-08	9.75E-10	8.15E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Pu-239	6.02E-07	6.42E-09	5.38E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Ru-106	1.94E-07	9.14E-09	5.39E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Sr-89	4.24E-10	2.03E-11	1.36E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	Sr-90	3.03E-07	1.27E-08	1.15E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-234	1.01E-08	2.14E-10	1.49E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-235	4.33E-10	9.44E-12	6.49E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-236	6.72E-10	1.43E-11	9.91E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Leafy Vegetables	U-238	1.87E-08	4.15E-10	2.86E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Am-241	7.43E-11	7.26E-13	5.65E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	C-14	4.22E-07	2.07E-08	1.49E-08	Both	0

Outdoor Family	Adult Female	Ingestion	Root Vegetables	Cs-137	3.38E-09	1.65E-10	1.18E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	H-3	1.16E-05	5.65E-07	4.06E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	I-129	2.64E-08	5.76E-10	5.91E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	I-131	5.23E-06	1.17E-07	1.27E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Pu-238	2.94E-08	3.34E-10	2.79E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Pu-239	2.06E-07	2.2E-09	1.84E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Ru-106	6.5E-08	3.07E-09	1.81E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Sr-89	1.34E-10	6.42E-12	4.3E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	Sr-90	1.31E-07	5.52E-09	4.97E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-234	3.48E-09	7.37E-11	5.13E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-235	1.49E-10	3.24E-12	2.23E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-236	2.3E-10	4.9E-12	3.39E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Root Vegetables	U-238	6.5E-09	1.47E-10	1.01E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	Am-241	7.36E-11	7.18E-13	5.59E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	C-14	4.18E-07	2.05E-08	1.47E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	Cs-137	3.03E-09	1.48E-10	1.06E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	H-3	1.15E-05	5.58E-07	4.01E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	I-129	2.62E-08	5.7E-10	5.85E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	I-131	1.59E-05	3.53E-07	3.87E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	Pu-238	2.9E-08	3.31E-10	2.76E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	Pu-239	2.04E-07	2.18E-09	1.82E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	Ru-106	6.59E-08	3.11E-09	1.83E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	Sr-89	1.44E-10	6.92E-12	4.64E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	Sr-90	1.04E-07	4.37E-09	3.95E-09	Both	0

Outdoor Family	Adult Female	Ingestion	Fruit	U-234	3.42E-09	7.26E-11	5.05E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	U-235	1.47E-10	3.2E-12	2.2E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	U-236	2.28E-10	4.85E-12	3.36E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Fruit	U-238	6.34E-09	1.41E-10	9.7E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	Am-241	9.12E-12	8.9E-14	6.93E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	C-14	2.23E-07	1.1E-08	7.88E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	Cs-137	3.66E-10	1.79E-11	1.27E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	H-3	1.63E-06	7.97E-08	5.71E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	I-129	3.28E-09	7.14E-11	7.31E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	I-131	1.92E-06	4.26E-08	4.67E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	Pu-238	3.59E-09	4.1E-11	3.41E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	Pu-239	2.52E-08	2.7E-10	2.25E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	Ru-106	8.12E-09	3.84E-10	2.26E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	Sr-89	1.83E-11	8.8E-13	5.91E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	Sr-90	1.42E-08	5.97E-10	5.42E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	U-234	4.25E-10	9.02E-12	6.27E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	U-235	1.82E-11	3.97E-13	2.73E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	U-236	2.83E-11	6E-13	4.16E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Grain	U-238	7.85E-10	1.74E-11	1.2E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	Am-241	4.23E-12	4.12E-14	3.21E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	C-14	1.17E-05	5.75E-07	4.13E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	Cs-137	2.21E-07	1.08E-08	7.69E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	H-3	6.56E-05	3.19E-06	2.29E-06	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	I-129	1.53E-06	3.33E-08	3.41E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	I-131	0.000969	2.16E-05	2.37E-06	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	Pu-238	4.16E-10	4.76E-12	3.95E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	Pu-239	2.92E-09	3.11E-11	2.61E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	Ru-106	4.74E-06	2.24E-07	1.32E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	Sr-89	1.71E-09	8.17E-11	5.48E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	Sr-90	1.03E-06	4.32E-08	3.92E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	U-234	1.47E-09	3.12E-11	2.17E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	U-235	6.32E-11	1.38E-12	9.47E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	U-236	9.79E-11	2.08E-12	1.44E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Beef	U-238	2.69E-09	5.86E-11	4.07E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	Am-241	2.58E-15	2.51E-17	1.96E-17	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	C-14	4.45E-07	2.19E-08	1.57E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	Cs-137	1.74E-10	8.47E-12	6.05E-12	Both	0

Outdoor Family	Adult Female	Ingestion	Poultry	H-3	1.05E-05	5.13E-07	3.68E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	I-129	1.63E-12	3.55E-14	3.64E-15	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	I-131	1.18E-16	2.63E-18	2.87E-19	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	Pu-238	5.07E-13	5.78E-15	4.83E-15	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	Pu-239	3.58E-12	3.82E-14	3.2E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	Ru-106	2.18E-09	1.03E-10	6.07E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	Sr-89	6.19E-15	2.97E-16	1.99E-16	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	Sr-90	6.05E-11	2.54E-12	2.3E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-234	2.01E-11	4.26E-13	2.96E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-235	8.62E-13	1.88E-14	1.29E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-236	1.34E-12	2.84E-14	1.96E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Poultry	U-238	3.65E-11	7.96E-13	5.53E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	Am-241	1.18E-13	1.15E-15	8.96E-16	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	C-14	1.27E-06	6.26E-08	4.5E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	Cs-137	2.71E-08	1.32E-09	9.41E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	H-3	2.51E-05	1.22E-06	8.75E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	I-129	2.78E-07	6.06E-09	6.21E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	I-131	0.000174	3.87E-06	4.24E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	Pu-238	3.41E-11	3.88E-13	3.24E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	Pu-239	2.39E-10	2.56E-12	2.14E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	Ru-106	2.33E-10	1.1E-11	6.48E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	Sr-89	4.48E-10	2.15E-11	1.44E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	Sr-90	3.02E-07	1.26E-08	1.16E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	U-234	1.46E-09	3.11E-11	2.16E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	U-235	6.27E-11	1.37E-12	9.39E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	U-236	9.7E-11	2.06E-12	1.43E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Milk	U-238	2.65E-09	5.73E-11	3.98E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	Am-241	1.58E-15	1.54E-17	1.2E-17	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	C-14	1.03E-07	5.07E-09	3.65E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	Cs-137	6.42E-12	3.13E-13	2.23E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	H-3	3.99E-06	1.94E-07	1.39E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	I-129	4.39E-10	9.57E-12	9.82E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	I-131	4.5E-14	1E-15	1.1E-16	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	Pu-238	7.74E-14	8.82E-16	7.34E-16	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	Pu-239	5.46E-13	5.85E-15	4.88E-15	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	Ru-106	1.26E-12	5.96E-14	3.51E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	Sr-89	1.52E-14	7.28E-16	4.88E-16	Both	0

Outdoor Family	Adult Female	Ingestion	Eggs	Sr-90	1.5E-10	6.26E-12	5.81E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-234	1.84E-11	3.91E-13	2.72E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-235	7.88E-13	1.71E-14	1.18E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-236	1.22E-12	2.6E-14	1.8E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Eggs	U-238	3.32E-11	7.14E-13	4.99E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	Am-241	5.17E-14	5.04E-16	3.93E-16	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	Cs-137	2.03E-12	9.87E-14	7.06E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	I-129	1.35E-11	2.93E-13	3.01E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	I-131	1.93E-09	4.3E-11	4.71E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	Pu-238	2.03E-11	2.32E-13	1.93E-13	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	Pu-239	1.43E-10	1.53E-12	1.28E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	Ru-106	3.81E-11	1.8E-12	1.06E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	Sr-89	4.07E-14	1.95E-15	1.31E-15	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	Sr-90	7.1E-11	2.99E-12	2.69E-12	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	U-234	2.4E-12	5.09E-14	3.54E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	U-235	1.03E-13	2.25E-15	1.54E-15	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	U-236	1.59E-13	3.39E-15	2.34E-15	Both	0
Outdoor Family	Adult Female	Ingestion	Soil	U-238	4.59E-12	1.06E-13	7.19E-14	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Both	0

Outdoor Family	Adult Female	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Both	0
Outdoor Family	Adult Female	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Am-241	1.49E-15	6.55E-17	4.56E-17	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Ar-41	8.32E-05	4E-06	2.87E-06	Both	0
Outdoor Family	Adult Female	External	Air Immersion	C-14	3.7E-12	3.58E-14	3.24E-14	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Cs-137	3.37E-11	1.61E-12	1.15E-12	Both	0
Outdoor Family	Adult Female	External	Air Immersion	I-129	7.51E-13	2.89E-14	1.9E-14	Both	0
Outdoor Family	Adult Female	External	Air Immersion	I-131	3.84E-07	1.83E-08	1.31E-08	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Pu-238	2.73E-15	1E-16	6.13E-17	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Pu-239	1.74E-14	7.46E-16	5.08E-16	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Ru-106	6.28E-10	2.78E-11	1.99E-11	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Sr-89	1.88E-13	2.54E-15	2.14E-15	Both	0
Outdoor Family	Adult Female	External	Air Immersion	Sr-90	2.28E-12	2.47E-14	2.2E-14	Both	0
Outdoor Family	Adult Female	External	Air Immersion	U-234	2.6E-15	1.08E-16	7.25E-17	Both	0
Outdoor Family	Adult Female	External	Air Immersion	U-235	1.24E-13	5.83E-15	4.14E-15	Both	0
Outdoor Family	Adult Female	External	Air Immersion	U-236	1.15E-16	4.57E-18	2.97E-18	Both	0
Outdoor Family	Adult Female	External	Air Immersion	U-238	6.66E-15	2.39E-16	1.66E-16	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	Am-241	1.78E-12	7.56E-14	5.26E-14	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	Cs-137	2.49E-08	1.17E-09	8.34E-10	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	I-129	7.56E-10	2.86E-11	1.9E-11	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	I-131	9.76E-06	4.64E-07	3.33E-07	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	Pu-238	1.69E-11	4.98E-13	3.04E-13	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	Pu-239	4.89E-11	1.6E-12	1.02E-12	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	Ru-106	5.67E-07	1.79E-08	1.32E-08	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	Sr-89	3.29E-10	2.81E-12	2.67E-12	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	Sr-90	7.75E-08	7.09E-10	6.6E-10	Both	0

Outdoor Family	Adult Female	External	Ground Contamination	U-234	8.59E-12	2.73E-13	1.73E-13	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	U-235	1.03E-10	4.82E-12	3.43E-12	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	U-236	5.17E-13	1.58E-14	9.87E-15	Both	0
Outdoor Family	Adult Female	External	Ground Contamination	U-238	2.95E-09	4.89E-11	3.95E-11	Both	0
Outdoor Family	Adult Female	External	Boating	Ce-144	1.68E-09	5.04E-11	4.2E-11	Both	0
Outdoor Family	Adult Female	External	Boating	Co-60	8.48E-09	2.54E-10	2.12E-10	Both	0
Outdoor Family	Adult Female	External	Boating	Cs-134	2.71E-10	8.15E-12	6.78E-12	Both	0
Outdoor Family	Adult Female	External	Boating	Cs-137	8.58E-09	2.57E-10	2.14E-10	Both	0
Outdoor Family	Adult Female	External	Boating	I-129	2.19E-12	6.56E-14	5.46E-14	Both	0
Outdoor Family	Adult Female	External	Boating	I-131	7.22E-09	2.17E-10	1.81E-10	Both	0
Outdoor Family	Adult Female	External	Boating	Nb-95	2.17E-08	6.5E-10	5.42E-10	Both	0
Outdoor Family	Adult Female	External	Boating	P-32	5.21E-11	1.56E-12	1.3E-12	Both	0
Outdoor Family	Adult Female	External	Boating	Pu-238	4.11E-15	1.23E-16	1.03E-16	Both	0
Outdoor Family	Adult Female	External	Boating	Pu-239	1.67E-14	5.03E-16	4.19E-16	Both	0
Outdoor Family	Adult Female	External	Boating	Ru-106	1.7E-08	5.11E-10	4.26E-10	Both	0
Outdoor Family	Adult Female	External	Boating	S-35	3.45E-12	1.04E-13	8.62E-14	Both	0
Outdoor Family	Adult Female	External	Boating	Sr-89	6.31E-11	1.89E-12	1.58E-12	Both	0
Outdoor Family	Adult Female	External	Boating	Sr-90	1.85E-11	5.55E-13	4.62E-13	Both	0
Outdoor Family	Adult Female	External	Boating	Tc-99	1.75E-12	5.24E-14	4.37E-14	Both	0
Outdoor Family	Adult Female	External	Boating	U-234	2.95E-15	8.84E-17	7.36E-17	Both	0
Outdoor Family	Adult Female	External	Boating	U-235	1.46E-12	4.38E-14	3.65E-14	Both	0
Outdoor Family	Adult Female	External	Boating	U-236	1.12E-16	3.37E-18	2.81E-18	Both	0
Outdoor Family	Adult Female	External	Boating	U-238	4.44E-14	1.33E-15	1.11E-15	Both	0
Outdoor Family	Adult Female	External	Boating	Zn-65	3.41E-09	1.02E-10	8.53E-11	Both	0
Outdoor Family	Adult Female	External	Boating	Zr-95	1.38E-08	4.14E-10	3.45E-10	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Am-241	1.2E-08	1.57E-10	1.35E-10	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	C-14	1.16E-09	5.63E-11	4.05E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Cs-137	8.08E-10	3.79E-11	2.7E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	H-3	2E-05	9.73E-07	6.98E-07	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	I-129	2.6E-08	5.67E-10	5.8E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	I-131	4.59E-05	1.02E-06	1.1E-07	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Pu-238	4.68E-06	6.57E-08	5.84E-08	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Pu-239	3.27E-05	4.18E-07	3.69E-07	Both	0

Outdoor Family	Adult Female	Inhalation	Air Inhalation	Ru-106	2.16E-07	1.15E-08	1.05E-08	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Sr-89	3.45E-10	1.84E-11	1.7E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	Sr-90	9.05E-08	4.51E-09	4.3E-09	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-234	1.93E-07	1E-08	9.48E-09	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-235	7.72E-09	4E-10	3.78E-10	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-236	1.25E-08	6.44E-10	6.1E-10	Both	0
Outdoor Family	Adult Female	Inhalation	Air Inhalation	U-238	3.16E-07	1.64E-08	1.54E-08	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Am-241	5.71E-11	7.45E-13	6.42E-13	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Cs-137	3.78E-12	1.77E-13	1.26E-13	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	I-129	5.16E-11	1.13E-12	1.15E-13	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	I-131	7.41E-09	1.65E-10	1.78E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Pu-238	2.22E-08	3.11E-10	2.77E-10	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Pu-239	1.55E-07	1.98E-09	1.75E-09	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Ru-106	8.2E-10	4.35E-11	3.97E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Sr-89	5.24E-13	2.8E-14	2.58E-14	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	Sr-90	4.69E-10	2.34E-11	2.21E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-234	9.15E-10	4.75E-11	4.49E-11	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-235	3.67E-11	1.9E-12	1.79E-12	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-236	5.9E-11	3.06E-12	2.89E-12	Both	0
Outdoor Family	Adult Female	Inhalation	Resuspended Soil	U-238	1.5E-09	7.78E-11	7.31E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Am-241	2.17E-10	2.12E-12	1.65E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	C-14	1.23E-07	6.05E-09	4.35E-09	Both	0

Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Cs-137	9.13E-09	4.45E-10	3.18E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	H-3	3.67E-06	1.78E-07	1.28E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	I-129	7.7E-08	1.68E-09	1.72E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	I-131	4.68E-05	1.04E-06	1.14E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Pu-238	8.57E-08	9.75E-10	8.15E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Pu-239	6.02E-07	6.42E-09	5.38E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Ru-106	1.94E-07	9.14E-09	5.39E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Sr-89	4.24E-10	2.03E-11	1.36E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	Sr-90	3.03E-07	1.27E-08	1.15E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-234	1.01E-08	2.14E-10	1.49E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-235	4.33E-10	9.44E-12	6.49E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-236	6.72E-10	1.43E-11	9.91E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Leafy Vegetables	U-238	1.87E-08	4.15E-10	2.86E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Am-241	1.03E-10	1E-12	7.82E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	C-14	5.85E-07	2.87E-08	2.06E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Cs-137	4.69E-09	2.28E-10	1.63E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	H-3	1.61E-05	7.83E-07	5.62E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	I-129	3.66E-08	7.98E-10	8.18E-11	Both	0

Outdoor Family	Adult Male	Ingestion	Root Vegetables	I-131	7.24E-06	1.62E-07	1.76E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Pu-238	4.06E-08	4.63E-10	3.86E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Pu-239	2.86E-07	3.05E-09	2.55E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Ru-106	9E-08	4.25E-09	2.5E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Sr-89	1.85E-10	8.89E-12	5.95E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	Sr-90	1.82E-07	7.65E-09	6.88E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-234	4.81E-09	1.02E-10	7.1E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-235	2.06E-10	4.48E-12	3.09E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-236	3.19E-10	6.78E-12	4.7E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Root Vegetables	U-238	9E-09	2.03E-10	1.39E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	Am-241	7.17E-11	7E-13	5.45E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	C-14	4.08E-07	2E-08	1.44E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	Cs-137	2.96E-09	1.44E-10	1.03E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	H-3	1.12E-05	5.44E-07	3.91E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	I-129	2.55E-08	5.56E-10	5.7E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	I-131	1.55E-05	3.44E-07	3.77E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	Pu-238	2.83E-08	3.22E-10	2.69E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	Pu-239	1.99E-07	2.12E-09	1.78E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	Ru-106	6.42E-08	3.04E-09	1.79E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	Sr-89	1.41E-10	6.75E-12	4.53E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	Sr-90	1.02E-07	4.27E-09	3.85E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-234	3.34E-09	7.08E-11	4.92E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-235	1.43E-10	3.12E-12	2.15E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-236	2.22E-10	4.73E-12	3.28E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Fruit	U-238	6.18E-09	1.37E-10	9.46E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	Am-241	1.1E-11	1.07E-13	8.36E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	C-14	2.69E-07	1.32E-08	9.5E-09	Both	0

Outdoor Family	Adult Male	Ingestion	Grain	Cs-137	4.42E-10	2.15E-11	1.54E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	H-3	1.97E-06	9.61E-08	6.89E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	I-129	3.96E-09	8.61E-11	8.82E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	I-131	2.31E-06	5.14E-08	5.63E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	Pu-238	4.33E-09	4.94E-11	4.11E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	Pu-239	3.04E-08	3.25E-10	2.71E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	Ru-106	9.79E-09	4.63E-10	2.72E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	Sr-89	2.21E-11	1.06E-12	7.12E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	Sr-90	1.71E-08	7.2E-10	6.53E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	U-234	5.12E-10	1.09E-11	7.56E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	U-235	2.2E-11	4.78E-13	3.29E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	U-236	3.41E-11	7.24E-13	5.02E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Grain	U-238	9.46E-10	2.1E-11	1.45E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	Am-241	6.64E-12	6.48E-14	5.04E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	C-14	1.84E-05	9.03E-07	6.5E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	Cs-137	3.47E-07	1.69E-08	1.21E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	H-3	0.000103	5.02E-06	3.6E-06	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	I-129	2.4E-06	5.22E-08	5.36E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	I-131	0.001522	3.39E-05	3.72E-06	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	Pu-238	6.54E-10	7.48E-12	6.21E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	Pu-239	4.59E-09	4.89E-11	4.1E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	Ru-106	7.44E-06	3.52E-07	2.07E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	Sr-89	2.68E-09	1.28E-10	8.61E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	Sr-90	1.62E-06	6.78E-08	6.15E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	U-234	2.32E-09	4.9E-11	3.41E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	U-235	9.93E-11	2.17E-12	1.49E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	U-236	1.54E-10	3.27E-12	2.27E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Beef	U-238	4.22E-09	9.21E-11	6.39E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	Am-241	3.21E-15	3.13E-17	2.44E-17	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	C-14	5.56E-07	2.73E-08	1.96E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	Cs-137	2.17E-10	1.06E-11	7.54E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	H-3	1.32E-05	6.4E-07	4.6E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	I-129	2.03E-12	4.43E-14	4.54E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	I-131	1.47E-16	3.27E-18	3.58E-19	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	Pu-238	6.32E-13	7.2E-15	6.01E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	Pu-239	4.46E-12	4.76E-14	3.98E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	Ru-106	2.72E-09	1.28E-10	7.57E-11	Both	0

Outdoor Family	Adult Male	Ingestion	Poultry	Sr-89	7.71E-15	3.7E-16	2.48E-16	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	Sr-90	7.54E-11	3.16E-12	2.87E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-234	2.51E-11	5.31E-13	3.69E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-235	1.07E-12	2.34E-14	1.61E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-236	1.66E-12	3.53E-14	2.45E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Poultry	U-238	4.55E-11	9.92E-13	6.89E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	Am-241	1.57E-13	1.53E-15	1.19E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	C-14	1.69E-06	8.31E-08	5.97E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	Cs-137	3.59E-08	1.75E-09	1.25E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	H-3	3.33E-05	1.62E-06	1.16E-06	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	I-129	3.7E-07	8.05E-09	8.25E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	I-131	0.000232	5.14E-06	5.63E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	Pu-238	4.53E-11	5.16E-13	4.31E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	Pu-239	3.18E-10	3.4E-12	2.84E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	Ru-106	3.09E-10	1.46E-11	8.6E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	Sr-89	5.95E-10	2.85E-11	1.91E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	Sr-90	4.01E-07	1.68E-08	1.54E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	U-234	1.94E-09	4.12E-11	2.86E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	U-235	8.33E-11	1.81E-12	1.25E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	U-236	1.29E-10	2.74E-12	1.9E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Milk	U-238	3.52E-09	7.61E-11	5.29E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	Am-241	2.61E-15	2.55E-17	1.98E-17	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	C-14	1.71E-07	8.39E-09	6.04E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	Cs-137	1.06E-11	5.17E-13	3.7E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	H-3	6.6E-06	3.21E-07	2.31E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	I-129	7.27E-10	1.58E-11	1.62E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	I-131	7.45E-14	1.66E-15	1.82E-16	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	Pu-238	1.28E-13	1.46E-15	1.21E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	Pu-239	9.03E-13	9.68E-15	8.07E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	Ru-106	2.09E-12	9.86E-14	5.81E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	Sr-89	2.51E-14	1.2E-15	8.08E-16	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	Sr-90	2.48E-10	1.04E-11	9.62E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-234	3.05E-11	6.48E-13	4.5E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-235	1.3E-12	2.83E-14	1.95E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-236	2.02E-12	4.3E-14	2.98E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Eggs	U-238	5.49E-11	1.18E-12	8.25E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	Am-241	5.37E-14	5.24E-16	4.08E-16	Both	0

Outdoor Family	Adult Male	Ingestion	Soil	Cs-137	2.1E-12	1.03E-13	7.33E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	I-129	1.41E-11	3.07E-13	3.15E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	I-131	2.07E-09	4.61E-11	5.05E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	Pu-238	2.11E-11	2.41E-13	2.01E-13	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	Pu-239	1.49E-10	1.59E-12	1.33E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	Ru-106	3.96E-11	1.87E-12	1.1E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	Sr-89	4.23E-14	2.03E-15	1.36E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	Sr-90	7.11E-11	2.99E-12	2.7E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	U-234	2.49E-12	5.29E-14	3.68E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	U-235	1.07E-13	2.34E-15	1.61E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	U-236	1.66E-13	3.52E-15	2.44E-15	Both	0
Outdoor Family	Adult Male	Ingestion	Soil	U-238	4.77E-12	1.1E-13	7.47E-14	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Both	0
Outdoor Family	Adult Male	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Both	0
Outdoor Family	Adult Male	External	Air Immersion	Am-241	1.54E-15	6.75E-17	4.71E-17	Both	0
Outdoor Family	Adult Male	External	Air Immersion	Ar-41	0.000306	1.47E-05	1.05E-05	Both	0
Outdoor Family	Adult Male	External	Air Immersion	C-14	6.08E-12	5.89E-14	5.33E-14	Both	0

Outdoor Family	Adult Male	External	Air Immersion	Cs-137	3.47E-11	1.66E-12	1.19E-12	Both	0
Outdoor Family	Adult Male	External	Air Immersion	I-129	7.62E-13	2.93E-14	1.93E-14	Both	0
Outdoor Family	Adult Male	External	Air Immersion	I-131	3.93E-07	1.87E-08	1.34E-08	Both	0
Outdoor Family	Adult Male	External	Air Immersion	Pu-238	2.82E-15	1.04E-16	6.32E-17	Both	0
Outdoor Family	Adult Male	External	Air Immersion	Pu-239	1.79E-14	7.7E-16	5.23E-16	Both	0
Outdoor Family	Adult Male	External	Air Immersion	Ru-106	6.48E-10	2.87E-11	2.06E-11	Both	0
Outdoor Family	Adult Male	External	Air Immersion	Sr-89	1.94E-13	2.62E-15	2.21E-15	Both	0
Outdoor Family	Adult Male	External	Air Immersion	Sr-90	2.28E-12	2.46E-14	2.19E-14	Both	0
Outdoor Family	Adult Male	External	Air Immersion	U-234	2.67E-15	1.11E-16	7.47E-17	Both	0
Outdoor Family	Adult Male	External	Air Immersion	U-235	1.28E-13	6.01E-15	4.27E-15	Both	0
Outdoor Family	Adult Male	External	Air Immersion	U-236	1.19E-16	4.72E-18	3.06E-18	Both	0
Outdoor Family	Adult Male	External	Air Immersion	U-238	6.58E-15	2.36E-16	1.64E-16	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	Am-241	1.94E-12	8.23E-14	5.73E-14	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	Cs-137	2.7E-08	1.27E-09	9.07E-10	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	I-129	8.29E-10	3.13E-11	2.09E-11	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	I-131	1.1E-05	5.24E-07	3.76E-07	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	Pu-238	1.84E-11	5.42E-13	3.31E-13	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	Pu-239	5.33E-11	1.74E-12	1.11E-12	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	Ru-106	6.17E-07	1.95E-08	1.44E-08	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	Sr-89	3.58E-10	3.05E-12	2.91E-12	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	Sr-90	8.08E-08	7.4E-10	6.89E-10	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	U-234	9.36E-12	2.97E-13	1.88E-13	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	U-235	1.12E-10	5.24E-12	3.73E-12	Both	0
Outdoor Family	Adult Male	External	Ground Contamination	U-236	5.63E-13	1.72E-14	1.07E-14	Both	0

Outdoor Family	Adult Male	External	Ground Contamination	U-238	3.22E-09	5.32E-11	4.3E-11	Both	0
Outdoor Family	Adult Male	External	Boating	Ce-144	6.23E-09	1.87E-10	1.56E-10	Both	0
Outdoor Family	Adult Male	External	Boating	Co-60	3.15E-08	9.44E-10	7.87E-10	Both	0
Outdoor Family	Adult Male	External	Boating	Cs-134	1.01E-09	3.02E-11	2.52E-11	Both	0
Outdoor Family	Adult Male	External	Boating	Cs-137	3.18E-08	9.55E-10	7.95E-10	Both	0
Outdoor Family	Adult Male	External	Boating	I-129	8.11E-12	2.43E-13	2.03E-13	Both	0
Outdoor Family	Adult Male	External	Boating	I-131	2.68E-08	8.04E-10	6.71E-10	Both	0
Outdoor Family	Adult Male	External	Boating	Nb-95	8.04E-08	2.41E-09	2.01E-09	Both	0
Outdoor Family	Adult Male	External	Boating	P-32	1.93E-10	5.78E-12	4.83E-12	Both	0
Outdoor Family	Adult Male	External	Boating	Pu-238	1.52E-14	4.58E-16	3.81E-16	Both	0
Outdoor Family	Adult Male	External	Boating	Pu-239	6.21E-14	1.86E-15	1.55E-15	Both	0
Outdoor Family	Adult Male	External	Boating	Ru-106	6.32E-08	1.9E-09	1.58E-09	Both	0
Outdoor Family	Adult Male	External	Boating	S-35	1.28E-11	3.84E-13	3.2E-13	Both	0
Outdoor Family	Adult Male	External	Boating	Sr-89	2.34E-10	7.02E-12	5.85E-12	Both	0
Outdoor Family	Adult Male	External	Boating	Sr-90	6.86E-11	2.06E-12	1.72E-12	Both	0
Outdoor Family	Adult Male	External	Boating	Tc-99	6.48E-12	1.94E-13	1.62E-13	Both	0
Outdoor Family	Adult Male	External	Boating	U-234	1.09E-14	3.28E-16	2.73E-16	Both	0
Outdoor Family	Adult Male	External	Boating	U-235	5.42E-12	1.62E-13	1.35E-13	Both	0
Outdoor Family	Adult Male	External	Boating	U-236	4.16E-16	1.25E-17	1.04E-17	Both	0
Outdoor Family	Adult Male	External	Boating	U-238	1.65E-13	4.94E-15	4.12E-15	Both	0
Outdoor Family	Adult Male	External	Boating	Zn-65	1.27E-08	3.8E-10	3.16E-10	Both	0
Outdoor Family	Adult Male	External	Boating	Zr-95	5.12E-08	1.54E-09	1.28E-09	Both	0
Outdoor Family	Adult Male	External	Shoreline	Ce-144	1.37E-05	2.68E-07	2.1E-07	Both	0
Outdoor Family	Adult Male	External	Shoreline	Co-60	3.12E-05	1.51E-06	1.07E-06	Both	0
Outdoor Family	Adult Male	External	Shoreline	Cs-134	9.78E-07	4.68E-08	3.34E-08	Both	0
Outdoor Family	Adult Male	External	Shoreline	Cs-137	3.7E-05	1.74E-06	1.24E-06	Both	0
Outdoor Family	Adult Male	External	Shoreline	I-129	2.86E-08	1.08E-09	7.21E-10	Both	0
Outdoor Family	Adult Male	External	Shoreline	I-131	1E-06	4.75E-08	3.4E-08	Both	0
Outdoor Family	Adult Male	External	Shoreline	Nb-95	1.27E-05	6.09E-07	4.34E-07	Both	0
Outdoor Family	Adult Male	External	Shoreline	P-32	1.7E-07	1.46E-09	1.38E-09	Both	0
Outdoor Family	Adult Male	External	Shoreline	Pu-238	1.37E-10	4.07E-12	2.48E-12	Both	0
Outdoor Family	Adult Male	External	Shoreline	Pu-239	2.66E-10	8.7E-12	5.55E-12	Both	0
Outdoor Family	Adult Male	External	Shoreline	Ru-106	8.51E-05	2.69E-06	1.99E-06	Both	0
Outdoor Family	Adult Male	External	Shoreline	S-35	1.91E-09	7.34E-11	4.92E-11	Both	0
Outdoor Family	Adult Male	External	Shoreline	Sr-89	7.16E-07	6.11E-09	5.82E-09	Both	0
Outdoor Family	Adult Male	External	Shoreline	Sr-90	8.14E-06	7.44E-08	6.94E-08	Both	0

Outdoor Family	Adult Male	External	Shoreline	Tc-99	1.59E-09	6.53E-11	4.5E-11	Both	0
Outdoor Family	Adult Male	External	Shoreline	U-234	5.43E-11	1.72E-12	1.09E-12	Both	0
Outdoor Family	Adult Male	External	Shoreline	U-235	6.97E-09	3.26E-10	2.32E-10	Both	0
Outdoor Family	Adult Male	External	Shoreline	U-236	2.79E-12	8.54E-14	5.32E-14	Both	0
Outdoor Family	Adult Male	External	Shoreline	U-238	3.66E-07	6.06E-09	4.9E-09	Both	0
Outdoor Family	Adult Male	External	Shoreline	Zn-65	8.51E-06	4.09E-07	2.92E-07	Both	0
Outdoor Family	Adult Male	External	Shoreline	Zr-95	2.91E-05	1.39E-06	9.94E-07	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Am-241	1.67E-08	2.18E-10	1.88E-10	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	C-14	2.57E-09	1.25E-10	8.95E-11	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Cs-137	1.12E-09	5.25E-11	3.74E-11	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	H-3	4.07E-05	1.98E-06	1.42E-06	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	I-129	3.55E-08	7.74E-10	7.92E-11	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	I-131	6.32E-05	1.41E-06	1.52E-07	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Pu-238	6.5E-06	9.13E-08	8.12E-08	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Pu-239	4.53E-05	5.8E-07	5.11E-07	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Ru-106	3E-07	1.59E-08	1.45E-08	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Sr-89	4.79E-10	2.56E-11	2.36E-11	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	Sr-90	1.22E-07	6.09E-09	5.79E-09	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-234	2.67E-07	1.39E-08	1.31E-08	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-235	1.07E-08	5.55E-10	5.24E-10	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-236	1.73E-08	8.94E-10	8.46E-10	Both	0
Outdoor Family	Adult Male	Inhalation	Air Inhalation	U-238	4.39E-07	2.27E-08	2.13E-08	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Am-241	7.99E-11	1.04E-12	8.99E-13	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Cs-137	5.29E-12	2.47E-13	1.77E-13	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	I-129	7.26E-11	1.58E-12	1.62E-13	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	I-131	1.07E-08	2.38E-10	2.57E-11	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Pu-238	3.11E-08	4.35E-10	3.88E-10	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Pu-239	2.16E-07	2.77E-09	2.45E-09	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Ru-106	1.15E-09	6.09E-11	5.55E-11	Both	0

Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Sr-89	7.33E-13	3.91E-14	3.61E-14	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	Sr-90	6.32E-10	3.15E-11	2.97E-11	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-234	1.28E-09	6.65E-11	6.28E-11	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-235	5.13E-11	2.66E-12	2.51E-12	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-236	8.26E-11	4.28E-12	4.05E-12	Both	0
Outdoor Family	Adult Male	Inhalation	Resuspended Soil	U-238	2.1E-09	1.09E-10	1.02E-10	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Am-241	2.17E-10	2.97E-12	2.21E-12	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	C-14	9.35E-08	1.24E-08	8.28E-09	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Cs-137	4.24E-09	3.64E-10	2.45E-10	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	H-3	2.73E-06	3.59E-07	2.41E-07	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	I-129	6.42E-08	4.88E-09	4.98E-10	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	I-131	8.37E-05	8.01E-06	8.36E-07	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-238	5.44E-08	2.42E-09	1.74E-09	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-239	7E-07	4.78E-09	3.34E-09	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Ru-106	1.93E-07	6.56E-08	3.69E-08	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-89	4.4E-10	1.09E-10	6.38E-11	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-90	2.01E-07	1.75E-08	1.17E-08	Both	0
Outdoor Family	Child born 1955	Ingestion	Leafy Vegetables	U-234	6.37E-09	3.97E-10	2.44E-10	Both	0

Outdoor Family	Child born 1955 Ingestion	Leafy Vegetables	U-235	3.01E-10	2.42E-11	1.48E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Leafy Vegetables	U-236	4.23E-10	2.64E-11	1.62E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Leafy Vegetables	U-238	1.39E-08	1.3E-09	7.91E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	Am-241	1.03E-10	1.41E-12	1.05E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	C-14	5.04E-07	7.02E-08	4.67E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	Cs-137	3.05E-09	2.92E-10	1.92E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	H-3	1.36E-05	1.89E-06	1.26E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	I-129	3.43E-08	2.71E-09	2.77E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	I-131	2.07E-05	1.99E-06	2.07E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	Pu-238	3.19E-08	1.43E-09	1.03E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	Pu-239	1.52E-06	9.29E-09	6.48E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	Ru-106	1.5E-07	4.49E-08	2.52E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	Sr-89	4.25E-10	8.61E-11	5.01E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	Sr-90	3.95E-07	2.78E-08	1.82E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	U-234	1.01E-08	5.19E-10	3.17E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	U-235	3.51E-10	2.3E-11	1.4E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	U-236	6.7E-10	3.44E-11	2.1E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Root Vegetables	U-238	1.26E-08	1.09E-09	6.58E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	Am-241	7.17E-11	9.81E-13	7.3E-13	Both	0

Outdoor Family	Child born 1955 Ingestion	Fruit	C-14	5.07E-07	7.69E-08	5.09E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	Cs-137	3.57E-09	3.89E-10	2.51E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	H-3	1.36E-05	2.12E-06	1.41E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	I-129	3.44E-08	2.95E-09	3E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	I-131	0.000104	9.97E-06	1.04E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	Pu-238	2.48E-08	1.12E-09	8.02E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	Pu-239	3.51E-06	2.1E-08	1.46E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	Ru-106	2.37E-07	6.18E-08	3.46E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	Sr-89	8.58E-10	1.56E-10	9.06E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	Sr-90	6.81E-07	4.25E-08	2.81E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	U-234	2.14E-08	1.02E-09	6.2E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	U-235	6.75E-10	4.06E-11	2.46E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	U-236	1.42E-09	6.81E-11	4.14E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Fruit	U-238	2.09E-08	1.6E-09	9.65E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	Am-241	1.1E-11	1.5E-13	1.12E-13	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	C-14	3.09E-07	4.58E-08	3.04E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	Cs-137	3.08E-10	3.28E-11	2.15E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	H-3	2.27E-06	3.45E-07	2.29E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	I-129	5.17E-09	4.34E-10	4.42E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	I-131	1.17E-05	1.13E-06	1.18E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	Pu-238	3.72E-09	1.68E-10	1.2E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	Pu-239	1.42E-07	8.99E-10	6.25E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	Ru-106	1.97E-08	6.31E-09	3.55E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	Sr-89	5.94E-11	1.41E-11	8.22E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	Sr-90	3.83E-08	2.99E-09	1.99E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	U-234	1E-09	5.48E-11	3.34E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	U-235	4.03E-11	3.02E-12	1.83E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	U-236	6.68E-11	3.64E-12	2.22E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Grain	U-238	1.64E-09	1.54E-10	9.34E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	Am-241	6.64E-12	9.07E-14	6.76E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	C-14	1.74E-05	2.49E-06	1.66E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	Cs-137	2.3E-07	2.24E-08	1.48E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	H-3	9.68E-05	1.35E-05	9.01E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	I-129	2.53E-06	2.04E-07	2.08E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	I-131	0.00438	0.000426	4.45E-05	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	Pu-238	6.16E-10	2.79E-11	1.99E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	Pu-239	2.35E-08	1.45E-10	1.01E-10	Both	0

Outdoor Family	Child born 1955 Ingestion	Beef	Ru-106	1.32E-05	4.09E-06	2.3E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	Sr-89	6.36E-09	1.31E-09	7.65E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	Sr-90	3.67E-06	2.28E-07	1.52E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	U-234	4.83E-09	2.54E-10	1.55E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	U-235	1.72E-10	1.17E-11	7.08E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	U-236	3.21E-10	1.69E-11	1.03E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Beef	U-238	6.05E-09	4.79E-10	2.93E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	Am-241	3.21E-15	4.38E-17	3.27E-17	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	C-14	5.66E-07	8.3E-08	5.51E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	Cs-137	1.25E-10	1.25E-11	8.29E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	H-3	1.33E-05	1.91E-06	1.27E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	I-129	2.33E-12	1.92E-13	1.96E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	I-131	5.85E-16	5.71E-17	5.96E-18	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	Pu-238	6.43E-13	2.91E-14	2.09E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	Pu-239	9.43E-12	6.4E-14	4.46E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	Ru-106	4.25E-09	1.51E-09	8.47E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	Sr-89	1.45E-14	3.81E-15	2.22E-15	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	Sr-90	9.33E-11	7.7E-12	5.12E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	U-234	2.75E-11	1.71E-12	1.05E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	U-235	1.28E-12	1.07E-13	6.49E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	U-236	1.82E-12	1.13E-13	6.95E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Poultry	U-238	5.66E-11	5.27E-12	3.23E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	Am-241	1.57E-13	2.14E-15	1.59E-15	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	C-14	3.75E-06	6.14E-07	4.05E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	Cs-137	6.69E-08	7.98E-09	5.13E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	H-3	7.25E-05	1.22E-05	8.09E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	I-129	9.42E-07	8.57E-08	8.73E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	I-131	0.002973	0.000285	2.98E-05	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	Pu-238	9.81E-11	4.51E-12	3.23E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	Pu-239	8.98E-09	5.42E-11	3.77E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	Ru-106	2.01E-09	5.64E-10	3.16E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	Sr-89	6.3E-09	1.21E-09	7.03E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	Sr-90	4.37E-06	2.49E-07	1.7E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	U-234	2.04E-08	1E-09	6.1E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	U-235	6.61E-10	4.15E-11	2.52E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	U-236	1.35E-09	6.64E-11	4.04E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Milk	U-238	2.05E-08	1.5E-09	9.17E-10	Both	0

Outdoor Family	Child born 1955 Ingestion	Eggs	Am-241	2.61E-15	3.56E-17	2.65E-17	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	C-14	1.55E-07	2.2E-08	1.46E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	Cs-137	5.81E-12	5.64E-13	3.74E-13	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	H-3	6.04E-06	8.75E-07	5.83E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	I-129	7.19E-10	5.81E-11	5.93E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	I-131	2.91E-13	2.82E-14	2.94E-15	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	Pu-238	9.81E-14	4.4E-15	3.15E-15	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	Pu-239	1.88E-12	1.26E-14	8.73E-15	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	Ru-106	2.87E-12	9.88E-13	5.55E-13	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	Sr-89	4.23E-14	1.12E-14	6.52E-15	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	Sr-90	2.84E-10	2E-11	1.42E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	U-234	3.07E-11	1.84E-12	1.12E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	U-235	1.4E-12	1.13E-13	6.89E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	U-236	2.03E-12	1.22E-13	7.47E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Eggs	U-238	6.09E-11	5.37E-12	3.3E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	Am-241	5.37E-14	7.34E-16	5.46E-16	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	Cs-137	4.05E-12	4.84E-13	3.11E-13	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	I-129	3.43E-11	3.13E-12	3.19E-13	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	I-131	2.79E-08	2.68E-09	2.81E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	Pu-238	3.84E-11	1.76E-12	1.26E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	Pu-239	4.51E-09	2.71E-11	1.89E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	Ru-106	2.63E-10	7.19E-11	4.03E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	Sr-89	4.69E-13	8.94E-14	5.21E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	Sr-90	8.77E-10	5.92E-11	3.88E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	U-234	2.78E-11	1.35E-12	8.19E-13	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	U-235	8.95E-13	5.59E-14	3.38E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	U-236	1.84E-12	8.93E-14	5.43E-14	Both	0
Outdoor Family	Child born 1955 Ingestion	Soil	U-238	3.01E-11	2.75E-12	1.63E-12	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Ce-144	2.8E-06	1.01E-06	5.59E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Co-60	3.02E-06	5E-07	3.19E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Cs-134	4.12E-06	6.64E-07	4.38E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Cs-137	0.000231	4.16E-05	2.7E-05	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	H-3	1E-06	1.32E-07	8.87E-08	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	I-131	1.44E-05	1.59E-06	1.66E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Nb-95	2.97E-06	6.18E-07	3.52E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	P-32	0.000565	0.000108	6.92E-05	Both	0

Outdoor Family	Child born 1955 Ingestion	Fish	Pu-238	1.44E-05	5.5E-07	4.04E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Pu-239	9.75E-05	3.17E-06	2.29E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Ru-106	3.24E-06	9.43E-07	5.32E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	S-35	5.2E-06	1.24E-06	7.73E-07	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Sr-89	7.31E-06	1.96E-06	1.14E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Sr-90	0.000142	8.88E-06	6.88E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Tc-99	6.22E-08	7.83E-09	4.42E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	U-234	5.61E-09	5.73E-10	3.51E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	U-235	2.12E-09	2.17E-10	1.33E-10	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	U-236	3.31E-10	3.4E-11	2.08E-11	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	U-238	1.48E-07	1.43E-08	8.88E-09	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Zn-65	1.1E-05	1.83E-06	1.21E-06	Both	0
Outdoor Family	Child born 1955 Ingestion	Fish	Zr-95	3.24E-06	6.4E-07	3.63E-07	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Am-241	1.54E-15	1.08E-16	7.23E-17	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Ar-41	0.000121	1.71E-05	1.13E-05	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	C-14	4.56E-12	9.92E-14	8.59E-14	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Cs-137	3.4E-11	4.65E-12	3.07E-12	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	I-129	7.54E-13	9.37E-14	5.73E-14	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	I-131	3.84E-07	6.91E-08	4.53E-08	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Pu-238	2.73E-15	4.02E-16	2.28E-16	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Pu-239	1.74E-14	2.92E-15	1.82E-15	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Ru-106	6.33E-10	9.56E-11	6.31E-11	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Sr-89	1.89E-13	7.96E-15	6.24E-15	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	Sr-90	2.29E-12	7.9E-14	6.64E-14	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	U-234	2.6E-15	4.19E-16	2.58E-16	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	U-235	1.24E-13	2.09E-14	1.36E-14	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	U-236	1.15E-16	1.81E-17	1.08E-17	Both	0
Outdoor Family	Child born 1955 External	Air Immersion	U-238	6.65E-15	8.52E-16	5.43E-16	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	Am-241	1.94E-12	1.33E-13	8.89E-14	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	Cs-137	2.56E-08	3.42E-09	2.27E-09	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	I-129	7.85E-10	9.4E-11	5.87E-11	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	I-131	9.79E-06	1.77E-06	1.16E-06	Both	0

Outdoor Family	Child born 1955 External	Ground Contamination	Pu-238	1.7E-11	2.03E-12	1.16E-12	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	Pu-239	4.91E-11	6.59E-12	3.9E-12	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	Ru-106	5.82E-07	6.12E-08	4.17E-08	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	Sr-89	3.32E-10	7.8E-12	7.21E-12	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	Sr-90	7.79E-08	2.16E-09	1.94E-09	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	U-234	8.64E-12	1.11E-12	6.6E-13	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	U-235	1.04E-10	1.75E-11	1.14E-11	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	U-236	5.2E-13	6.52E-14	3.81E-14	Both	0
Outdoor Family	Child born 1955 External	Ground Contamination	U-238	3E-09	1.58E-10	1.18E-10	Both	0
Outdoor Family	Child born 1955 External	Boating	Ce-144	2.11E-09	6.34E-11	5.29E-11	Both	0
Outdoor Family	Child born 1955 External	Boating	Co-60	1.21E-08	3.63E-10	3.03E-10	Both	0
Outdoor Family	Child born 1955 External	Boating	Cs-134	3.22E-10	9.65E-12	8.03E-12	Both	0
Outdoor Family	Child born 1955 External	Boating	Cs-137	8.94E-09	2.68E-10	2.24E-10	Both	0
Outdoor Family	Child born 1955 External	Boating	I-129	8.11E-12	2.43E-13	2.03E-13	Both	0
Outdoor Family	Child born 1955 External	Boating	I-131	7.23E-09	2.17E-10	1.81E-10	Both	0
Outdoor Family	Child born 1955 External	Boating	Nb-95	3.69E-08	1.11E-09	9.22E-10	Both	0
Outdoor Family	Child born 1955 External	Boating	P-32	5.27E-11	1.58E-12	1.32E-12	Both	0
Outdoor Family	Child born 1955 External	Boating	Pu-238	4.63E-15	1.39E-16	1.16E-16	Both	0
Outdoor Family	Child born 1955 External	Boating	Pu-239	1.84E-14	5.54E-16	4.61E-16	Both	0
Outdoor Family	Child born 1955 External	Boating	Ru-106	3.21E-08	9.62E-10	8.01E-10	Both	0
Outdoor Family	Child born 1955 External	Boating	S-35	3.5E-12	1.05E-13	8.76E-14	Both	0
Outdoor Family	Child born 1955 External	Boating	Sr-89	7.03E-11	2.11E-12	1.76E-12	Both	0
Outdoor Family	Child born 1955 External	Boating	Sr-90	2.39E-11	7.15E-13	5.97E-13	Both	0
Outdoor Family	Child born 1955 External	Boating	Tc-99	4.54E-12	1.36E-13	1.14E-13	Both	0
Outdoor Family	Child born 1955 External	Boating	U-234	3.04E-15	9.12E-17	7.6E-17	Both	0
Outdoor Family	Child born 1955 External	Boating	U-235	1.53E-12	4.6E-14	3.84E-14	Both	0
Outdoor Family	Child born 1955 External	Boating	U-236	1.17E-16	3.5E-18	2.92E-18	Both	0
Outdoor Family	Child born 1955 External	Boating	U-238	4.67E-14	1.4E-15	1.17E-15	Both	0

Outdoor Family	Child born 1955 External	Boating	Zn-65	4.15E-09	1.24E-10	1.04E-10	Both	0
Outdoor Family	Child born 1955 External	Boating	Zr-95	3.07E-08	9.19E-10	7.67E-10	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Ce-144	1.31E-06	5.63E-08	4.17E-08	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Co-60	4.94E-06	4.75E-07	3.22E-07	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Cs-134	6.66E-08	8.18E-09	5.46E-09	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Cs-137	5.89E-07	5.19E-08	3.53E-08	Both	0
Outdoor Family	Child born 1955 External	Shoreline	I-129	2.86E-08	1.08E-09	7.21E-10	Both	0
Outdoor Family	Child born 1955 External	Shoreline	I-131	3.57E-10	4.77E-11	3.19E-11	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Nb-95	3.28E-06	2.96E-07	2.01E-07	Both	0
Outdoor Family	Child born 1955 External	Shoreline	P-32	7.88E-10	1.4E-11	1.29E-11	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Pu-238	6.39E-12	5.13E-13	3.03E-13	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Pu-239	1.01E-11	5.09E-13	3.16E-13	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Ru-106	2.77E-05	1.78E-06	1.24E-06	Both	0
Outdoor Family	Child born 1955 External	Shoreline	S-35	1.1E-11	1.16E-12	7.39E-13	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Sr-89	2.99E-08	5.21E-10	4.85E-10	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Sr-90	8.73E-07	1.16E-08	1.06E-08	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Tc-99	9.53E-10	4.97E-11	3.36E-11	Both	0
Outdoor Family	Child born 1955 External	Shoreline	U-234	6.58E-13	4.31E-14	2.63E-14	Both	0
Outdoor Family	Child born 1955 External	Shoreline	U-235	1.3E-10	1.08E-11	7.34E-12	Both	0
Outdoor Family	Child born 1955 External	Shoreline	U-236	3.94E-14	2.51E-15	1.51E-15	Both	0
Outdoor Family	Child born 1955 External	Shoreline	U-238	6.97E-09	1.92E-10	1.49E-10	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Zn-65	6.78E-07	8.24E-08	5.51E-08	Both	0
Outdoor Family	Child born 1955 External	Shoreline	Zr-95	1.31E-05	1.1E-06	7.5E-07	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	Am-241	1.67E-08	2.87E-10	2.46E-10	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	C-14	2.06E-09	2.83E-10	1.88E-10	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	Cs-137	7.98E-10	7.77E-11	5.09E-11	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	H-3	3.28E-05	4.47E-06	2.98E-06	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	I-129	4.18E-08	3.49E-09	3.55E-10	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	I-131	0.000228	2.23E-05	2.31E-06	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	Pu-238	6.26E-06	3.02E-07	2.69E-07	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	Pu-239	2.18E-05	1E-06	8.77E-07	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	Ru-106	3.68E-07	6.67E-08	5.69E-08	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	Sr-89	6.29E-10	1.2E-10	1E-10	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	Sr-90	1.52E-07	1.96E-08	1.78E-08	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	U-234	3.21E-07	4.46E-08	4.21E-08	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	U-235	1.33E-08	1.93E-09	1.82E-09	Both	0
Outdoor Family	Child born 1955 Inhalation	Air Inhalation	U-236	2.09E-08	2.89E-09	2.73E-09	Both	0

Outdoor Family	Child born 1955 Inhalation	Air Inhalation	U-238	5.56E-07	8.35E-08	7.88E-08	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	Am-241	7.99E-11	1.37E-12	1.18E-12	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	Cs-137	3.75E-12	3.64E-13	2.39E-13	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	I-129	8.37E-11	6.96E-12	7.08E-13	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	I-131	3.68E-08	3.6E-09	3.72E-10	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	Pu-238	2.98E-08	1.43E-09	1.27E-09	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	Pu-239	1.03E-07	4.75E-09	4.16E-09	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	Ru-106	1.4E-09	2.53E-10	2.16E-10	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	Sr-89	9.56E-13	1.83E-13	1.52E-13	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	Sr-90	8.1E-10	1.11E-10	9.73E-11	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	U-234	1.53E-09	2.11E-10	1.99E-10	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	U-235	6.31E-11	9.18E-12	8.65E-12	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	U-236	9.89E-11	1.37E-11	1.3E-11	Both	0
Outdoor Family	Child born 1955 Inhalation	Resuspended Soil	U-238	2.64E-09	3.97E-10	3.75E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	Am-241	1.7E-10	4.19E-12	2.92E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	C-14	5.61E-08	8.97E-09	5.94E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	Cs-137	3.1E-09	4.19E-10	2.83E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	H-3	1.66E-06	2.44E-07	1.63E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	I-129	3.58E-08	3.16E-09	3.23E-10	Both	0

Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	I-131	4.42E-07	4.01E-08	4.19E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	Pu-238	5.55E-08	1.92E-09	1.37E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	Pu-239	1.12E-08	4.3E-10	3.06E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	Ru-106	1.2E-07	5.46E-08	3.07E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	Sr-89	1.85E-10	4.49E-11	2.61E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	Sr-90	6.43E-09	7.49E-10	5.02E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	U-234	1.61E-09	1.49E-10	9.18E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	U-235	1.04E-10	1.01E-11	6.16E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	U-236	1.07E-10	9.83E-12	6.08E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Leafy Vegetables	U-238	5.62E-09	5.67E-10	3.46E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	Am-241	9.06E-11	2.3E-12	1.59E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	C-14	3.24E-07	5.33E-08	3.53E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	Cs-137	1.66E-09	2.26E-10	1.51E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	H-3	9.29E-06	1.37E-06	9.14E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	I-129	2.21E-08	2.05E-09	2.09E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	I-131	9.84E-08	9.43E-09	9.86E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	Pu-238	2.88E-08	9.97E-10	7.13E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	Pu-239	7.12E-09	2.68E-10	1.9E-10	Both	0

Outdoor Family	Child born 1964 Ingestion	Root Vegetables	Ru-106	7.58E-08	3.42E-08	1.92E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	Sr-89	1.12E-10	2.58E-11	1.5E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	Sr-90	8.55E-09	8.55E-10	5.63E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	U-234	1.24E-09	1.03E-10	6.34E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	U-235	8.05E-11	7.23E-12	4.4E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	U-236	8.19E-11	6.83E-12	4.2E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Root Vegetables	U-238	4.48E-09	4.47E-10	2.69E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	Am-241	6.73E-11	1.73E-12	1.2E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	C-14	3.71E-07	6.33E-08	4.17E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	Cs-137	1.2E-09	1.68E-10	1.12E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	H-3	1.13E-05	1.69E-06	1.12E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	I-129	2.71E-08	2.69E-09	2.74E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	I-131	4.7E-07	4.64E-08	4.85E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	Pu-238	3.52E-08	1.22E-09	8.71E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	Pu-239	1.04E-08	3.85E-10	2.72E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	Ru-106	1.04E-07	4.38E-08	2.45E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	Sr-89	1.82E-10	4.02E-11	2.34E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	Sr-90	1.3E-08	1.14E-09	7.56E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	U-234	2.03E-09	1.59E-10	9.78E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	U-235	1.3E-10	1.12E-11	6.77E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	U-236	1.35E-10	1.06E-11	6.49E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Fruit	U-238	6.98E-09	6.39E-10	3.85E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	Am-241	1.02E-11	2.61E-13	1.81E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	C-14	2.1E-07	3.55E-08	2.34E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	Cs-137	1.67E-10	2.36E-11	1.57E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	H-3	1.48E-06	2.37E-07	1.57E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	I-129	3.43E-09	3.26E-10	3.32E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	I-131	5.3E-08	5.11E-09	5.34E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	Pu-238	5.56E-09	1.93E-10	1.38E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	Pu-239	1.26E-09	5.08E-11	3.6E-11	Both	0

Outdoor Family	Child born 1964 Ingestion	Grain	Ru-106	1.29E-08	5.67E-09	3.18E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	Sr-89	2.15E-11	5.22E-12	3.03E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	Sr-90	1.05E-09	1.16E-10	7.76E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	U-234	1.88E-10	1.76E-11	1.08E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	U-235	1.19E-11	1.2E-12	7.33E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	U-236	1.25E-11	1.17E-12	7.2E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Grain	U-238	6.35E-10	6.87E-11	4.15E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	Am-241	6.51E-12	1.69E-13	1.17E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	C-14	1.14E-05	1.9E-06	1.26E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	Cs-137	1.24E-07	1.7E-08	1.14E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	H-3	7.35E-05	1.14E-05	7.58E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	I-129	1.62E-06	1.49E-07	1.53E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	I-131	6.92E-05	6.57E-06	6.86E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	Pu-238	5.65E-10	1.97E-11	1.4E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	Pu-239	1.25E-10	4.65E-12	3.31E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	Ru-106	7.11E-06	3.22E-06	1.81E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	Sr-89	1.83E-09	4.24E-10	2.47E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	Sr-90	4.89E-08	4.58E-09	3.17E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	U-234	6.49E-10	5.47E-11	3.37E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	U-235	4.12E-11	3.74E-12	2.28E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	U-236	4.32E-11	3.64E-12	2.24E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Beef	U-238	2.17E-09	1.95E-10	1.19E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	Am-241	3.31E-15	8.64E-17	5.97E-17	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	C-14	3.8E-07	6.45E-08	4.26E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	Cs-137	7.77E-11	1.08E-11	7.24E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	H-3	1E-05	1.61E-06	1.07E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	I-129	1.51E-12	1.4E-13	1.43E-14	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	I-131	7.68E-18	7.74E-19	8.09E-20	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	Pu-238	5.95E-13	2.07E-14	1.48E-14	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	Pu-239	1.33E-13	5.56E-15	3.95E-15	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	Ru-106	2.97E-09	1.39E-09	7.81E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	Sr-89	5.4E-15	1.36E-15	7.91E-16	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	Sr-90	2.05E-12	2.37E-13	1.63E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	U-234	6.48E-12	6.4E-13	3.94E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	U-235	4.26E-13	4.52E-14	2.75E-14	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	U-236	4.3E-13	4.26E-14	2.62E-14	Both	0
Outdoor Family	Child born 1964 Ingestion	Poultry	U-238	2.26E-11	2.36E-12	1.45E-12	Both	0

Outdoor Family	Child born 1964 Ingestion	Milk	Am-241	2.78E-13	7.82E-15	5.35E-15	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	C-14	2.87E-06	5.03E-07	3.31E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	Cs-137	1.79E-08	2.64E-09	1.74E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	H-3	5.88E-05	9.19E-06	6.07E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	I-129	7.67E-07	7.62E-08	7.77E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	I-131	1.35E-05	1.32E-06	1.38E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	Pu-238	1.19E-10	4.12E-12	2.94E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	Pu-239	3.18E-11	1.22E-12	8.6E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	Ru-106	1.01E-09	4.41E-10	2.47E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	Sr-89	1.48E-09	3.35E-10	1.95E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	Sr-90	8.73E-08	7.16E-09	4.9E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	U-234	2.15E-09	1.76E-10	1.08E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	U-235	1.34E-10	1.21E-11	7.32E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	U-236	1.43E-10	1.17E-11	7.15E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Milk	U-238	6.91E-09	6.03E-10	3.68E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	Am-241	2.27E-15	5.72E-17	3.96E-17	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	C-14	1.01E-07	1.7E-08	1.12E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	Cs-137	3.76E-12	5.19E-13	3.48E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	H-3	3.82E-06	5.94E-07	3.95E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	I-129	4.66E-10	4.35E-11	4.44E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	I-131	1.15E-15	1.16E-16	1.21E-17	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	Pu-238	9.83E-14	3.41E-15	2.43E-15	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	Pu-239	2.45E-14	1.04E-15	7.38E-16	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	Ru-106	1.95E-12	9.09E-13	5.1E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	Sr-89	1.5E-14	3.83E-15	2.23E-15	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	Sr-90	9.34E-12	9.02E-13	6.44E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	U-234	6.9E-12	6.91E-13	4.24E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	U-235	4.65E-13	4.91E-14	2.99E-14	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	U-236	4.56E-13	4.58E-14	2.82E-14	Both	0
Outdoor Family	Child born 1964 Ingestion	Eggs	U-238	2.46E-11	2.47E-12	1.52E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	Am-241	8.3E-14	2.3E-15	1.58E-15	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	Cs-137	1.05E-12	1.55E-13	1.03E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	I-129	2.88E-11	2.89E-12	2.95E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	I-131	1.22E-10	1.21E-11	1.27E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	Pu-238	5.33E-11	1.85E-12	1.32E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	Pu-239	1.52E-11	5.9E-13	4.16E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	Ru-106	1.3E-10	5.58E-11	3.12E-11	Both	0

Outdoor Family	Child born 1964 Ingestion	Soil	Sr-89	1.06E-13	2.42E-14	1.4E-14	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	Sr-90	1.78E-11	1.71E-12	1.12E-12	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	U-234	2.84E-12	2.33E-13	1.43E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	U-235	1.8E-13	1.63E-14	9.87E-15	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	U-236	1.89E-13	1.55E-14	9.51E-15	Both	0
Outdoor Family	Child born 1964 Ingestion	Soil	U-238	1.02E-11	1.12E-12	6.66E-13	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Ce-144	3.36E-06	1.11E-06	6.14E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Co-60	2.77E-06	4.92E-07	3.11E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Cs-134	3.06E-06	5.92E-07	3.82E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Cs-137	0.000155	2.9E-05	1.84E-05	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	H-3	7.87E-07	1.21E-07	8.04E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	I-129	7.75E-07	3.45E-08	3.53E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	I-131	2.84E-06	3.2E-07	3.34E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Nb-95	2.82E-06	6.63E-07	3.75E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	P-32	0.001049	0.000241	0.000158	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Pu-238	1.92E-05	9.43E-07	6.62E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Pu-239	7.93E-05	3.42E-06	2.41E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Ru-106	4.03E-06	1.28E-06	7.17E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	S-35	5.73E-06	1.31E-06	8.13E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Sr-89	1.43E-05	2.91E-06	1.69E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Sr-90	9.03E-05	1.18E-05	8.52E-06	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Tc-99	3.39E-08	4.9E-09	2.81E-09	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	U-234	3.38E-09	3.68E-10	2.24E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	U-235	2.18E-09	3.31E-10	2E-10	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	U-236	1.77E-10	1.69E-11	1.02E-11	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	U-238	1.54E-07	2.24E-08	1.36E-08	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Zn-65	9.59E-06	1.28E-06	8.39E-07	Both	0
Outdoor Family	Child born 1964 Ingestion	Fish	Zr-95	3.21E-06	8.34E-07	4.7E-07	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	Am-241	1.51E-15	1.91E-16	1.24E-16	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	Ar-41	5.3E-05	8.73E-06	5.75E-06	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	C-14	2.8E-12	7.28E-14	6.27E-14	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	Cs-137	1.44E-11	2.08E-12	1.38E-12	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	I-129	5.33E-13	7.43E-14	4.52E-14	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	I-131	2.28E-09	4.06E-10	2.66E-10	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	Pu-238	2.73E-15	4.12E-16	2.33E-16	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	Pu-239	5.66E-16	9.22E-17	5.74E-17	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	Ru-106	3.79E-10	6.23E-11	4.09E-11	Both	0

Outdoor Family	Child born 1964 External	Air Immersion	Sr-89	6.55E-14	2.82E-15	2.19E-15	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	Sr-90	4.97E-14	1.59E-15	1.36E-15	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	U-234	5.84E-16	9.31E-17	5.73E-17	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	U-235	4.1E-14	6.8E-15	4.45E-15	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	U-236	2.58E-17	4.04E-18	2.42E-18	Both	0
Outdoor Family	Child born 1964 External	Air Immersion	U-238	2.71E-15	3.48E-16	2.22E-16	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	Am-241	1.85E-12	2.29E-13	1.49E-13	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	Cs-137	1.11E-08	1.59E-09	1.05E-09	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	I-129	5.46E-10	7.37E-11	4.58E-11	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	I-131	6E-08	1.08E-08	7.05E-09	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	Pu-238	1.72E-11	2.09E-12	1.2E-12	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	Pu-239	1.64E-12	2.14E-13	1.27E-13	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	Ru-106	3.45E-07	3.96E-08	2.68E-08	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	Sr-89	1.16E-10	2.72E-12	2.5E-12	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	Sr-90	2.38E-09	6.49E-11	5.83E-11	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	U-234	1.96E-12	2.5E-13	1.48E-13	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	U-235	3.45E-11	5.74E-12	3.75E-12	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	U-236	1.18E-13	1.46E-14	8.56E-15	Both	0
Outdoor Family	Child born 1964 External	Ground Contamination	U-238	1.23E-09	6.47E-11	4.84E-11	Both	0
Outdoor Family	Child born 1964 External	Boating	Ce-144	1.02E-09	3.07E-11	2.56E-11	Both	0
Outdoor Family	Child born 1964 External	Boating	Co-60	6.46E-09	1.94E-10	1.61E-10	Both	0
Outdoor Family	Child born 1964 External	Boating	Cs-134	2.76E-10	8.3E-12	6.91E-12	Both	0
Outdoor Family	Child born 1964 External	Boating	Cs-137	6.2E-09	1.86E-10	1.55E-10	Both	0
Outdoor Family	Child born 1964 External	Boating	I-129	7.49E-12	2.25E-13	1.87E-13	Both	0

Outdoor Family	Child born 1964 External	Boating	I-131	9.64E-10	2.89E-11	2.41E-11	Both	0
Outdoor Family	Child born 1964 External	Boating	Nb-95	2.06E-08	6.19E-10	5.16E-10	Both	0
Outdoor Family	Child born 1964 External	Boating	P-32	5.21E-11	1.56E-12	1.31E-12	Both	0
Outdoor Family	Child born 1964 External	Boating	Pu-238	4.16E-15	1.25E-16	1.04E-16	Both	0
Outdoor Family	Child born 1964 External	Boating	Pu-239	1.35E-14	4.06E-16	3.38E-16	Both	0
Outdoor Family	Child born 1964 External	Boating	Ru-106	1.6E-08	4.8E-10	4E-10	Both	0
Outdoor Family	Child born 1964 External	Boating	S-35	1.9E-12	5.7E-14	4.75E-14	Both	0
Outdoor Family	Child born 1964 External	Boating	Sr-89	4.75E-11	1.42E-12	1.19E-12	Both	0
Outdoor Family	Child born 1964 External	Boating	Sr-90	1.76E-11	5.27E-13	4.4E-13	Both	0
Outdoor Family	Child born 1964 External	Boating	Tc-99	3.56E-12	1.07E-13	8.9E-14	Both	0
Outdoor Family	Child born 1964 External	Boating	U-234	1.44E-15	4.31E-17	3.59E-17	Both	0
Outdoor Family	Child born 1964 External	Boating	U-235	1.26E-12	3.79E-14	3.15E-14	Both	0
Outdoor Family	Child born 1964 External	Boating	U-236	4.46E-17	1.34E-18	1.12E-18	Both	0
Outdoor Family	Child born 1964 External	Boating	U-238	3.91E-14	1.17E-15	9.77E-16	Both	0
Outdoor Family	Child born 1964 External	Boating	Zn-65	1.58E-09	4.72E-11	3.94E-11	Both	0
Outdoor Family	Child born 1964 External	Boating	Zr-95	1.86E-08	5.57E-10	4.65E-10	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Ce-144	2.14E-07	1.09E-08	8.01E-09	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Co-60	1.78E-06	2.42E-07	1.61E-07	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Cs-134	6.67E-09	8.93E-10	5.94E-10	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Cs-137	2.65E-07	2.99E-08	2.01E-08	Both	0
Outdoor Family	Child born 1964 External	Shoreline	I-129	2.56E-08	1.97E-09	1.26E-09	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Nb-95	1.46E-06	1.98E-07	1.32E-07	Both	0
Outdoor Family	Child born 1964 External	Shoreline	P-32	6.87E-11	1.18E-12	1.1E-12	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Pu-238	6.53E-13	6.21E-14	3.65E-14	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Pu-239	7.02E-12	3.42E-13	2.13E-13	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Ru-106	6.03E-06	5.21E-07	3.6E-07	Both	0
Outdoor Family	Child born 1964 External	Shoreline	S-35	8.69E-13	7.33E-14	4.7E-14	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Sr-89	2.84E-09	5.3E-11	4.93E-11	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Sr-90	4.53E-07	8.08E-09	7.3E-09	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Tc-99	7.69E-10	4.92E-11	3.27E-11	Both	0
Outdoor Family	Child born 1964 External	Shoreline	U-234	1.3E-13	1.31E-14	7.87E-15	Both	0
Outdoor Family	Child born 1964 External	Shoreline	U-235	3.03E-11	3.71E-12	2.47E-12	Both	0
Outdoor Family	Child born 1964 External	Shoreline	U-236	7.75E-15	7.56E-16	4.51E-16	Both	0
Outdoor Family	Child born 1964 External	Shoreline	U-238	1.63E-09	6.44E-11	4.9E-11	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Zn-65	6.86E-08	9.32E-09	6.21E-09	Both	0
Outdoor Family	Child born 1964 External	Shoreline	Zr-95	6.41E-06	8.66E-07	5.77E-07	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	Am-241	1.67E-08	4.99E-10	4.32E-10	Both	0

Outdoor Family	Child born 1964 Inhalation	Air Inhalation	C-14	1.28E-09	2.11E-10	1.39E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	Cs-137	4.16E-10	5.69E-11	3.79E-11	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	H-3	2.08E-05	3.12E-06	2.07E-06	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	I-129	2.71E-08	2.55E-09	2.6E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	I-131	1.08E-06	1.03E-07	1.06E-08	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	Pu-238	6.01E-06	2.35E-07	2.09E-07	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	Pu-239	1.21E-06	4.92E-08	4.34E-08	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	Ru-106	2.26E-07	5.35E-08	4.54E-08	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	Sr-89	2.27E-10	4.38E-11	3.69E-11	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	Sr-90	3.81E-09	5.42E-10	4.93E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	U-234	7.73E-08	1.2E-08	1.13E-08	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	U-235	4.5E-09	6.87E-10	6.47E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	U-236	5.03E-09	7.76E-10	7.32E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Air Inhalation	U-238	2.28E-07	3.46E-08	3.27E-08	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	Am-241	7.93E-11	2.37E-12	2.05E-12	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	Cs-137	1.97E-12	2.68E-13	1.79E-13	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	I-129	5.41E-11	5.08E-12	5.17E-13	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	I-131	1.79E-10	1.7E-11	1.76E-12	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	Pu-238	2.86E-08	1.11E-09	9.89E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	Pu-239	5.85E-09	2.37E-10	2.09E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	Ru-106	8.58E-10	2.03E-10	1.72E-10	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	Sr-89	3.45E-13	6.65E-14	5.6E-14	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	Sr-90	2.63E-11	3.92E-12	3.44E-12	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	U-234	3.67E-10	5.67E-11	5.35E-11	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	U-235	2.14E-11	3.26E-12	3.08E-12	Both	0

Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	U-236	2.39E-11	3.68E-12	3.47E-12	Both	0
Outdoor Family	Child born 1964 Inhalation	Resuspended Soil	U-238	1.08E-09	1.65E-10	1.55E-10	Both	0

Location	Receptor	ReportRou	ReportPathway	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	AirWater	RunNum
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Am-241	6.18E-11	6.02E-13	4.69E-13	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	C-14	6E-08	2.95E-09	2.12E-09	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Cs-137	2.58E-09	1.26E-10	8.99E-11	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	H-3	1.63E-06	7.91E-08	5.68E-08	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	I-129	2.23E-08	4.85E-10	4.97E-11	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	I-131	1.35E-05	3.01E-07	3.3E-08	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Pu-238	2.43E-08	2.77E-10	2.31E-10	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Pu-239	1.71E-07	1.82E-09	1.52E-09	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Ru-106	5.5E-08	2.6E-09	1.53E-09	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Sr-89	1.2E-10	5.76E-12	3.87E-12	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Sr-90	7.17E-08	3.01E-09	2.73E-09	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-234	2.87E-09	6.08E-11	4.23E-11	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-235	1.23E-10	2.69E-12	1.84E-12	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-236	1.91E-10	4.05E-12	2.8E-12	Air	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-238	5.31E-09	1.18E-10	8.11E-11	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Am-241	2.11E-11	2.06E-13	1.61E-13	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	C-14	2.06E-07	1.01E-08	7.26E-09	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Cs-137	9.55E-10	4.66E-11	3.33E-11	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	H-3	5.17E-06	2.51E-07	1.8E-07	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	I-129	7.64E-09	1.66E-10	1.71E-11	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	I-131	1.51E-06	3.36E-08	3.68E-09	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Pu-238	8.31E-09	9.49E-11	7.92E-11	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Pu-239	5.85E-08	6.24E-10	5.22E-10	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Ru-106	1.85E-08	8.72E-10	5.14E-10	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Sr-89	3.8E-11	1.82E-12	1.22E-12	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Sr-90	3.11E-08	1.31E-09	1.18E-09	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-234	9.86E-10	2.09E-11	1.45E-11	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-235	4.22E-11	9.21E-13	6.32E-13	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-236	6.54E-11	1.39E-12	9.64E-13	Air	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-238	1.85E-09	4.16E-11	2.85E-11	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	Am-241	2.09E-11	2.04E-13	1.59E-13	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	C-14	2.03E-07	9.99E-09	7.18E-09	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	Cs-137	8.56E-10	4.18E-11	2.98E-11	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	H-3	5.1E-06	2.48E-07	1.78E-07	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	I-129	7.56E-09	1.65E-10	1.69E-11	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	I-131	4.59E-06	1.02E-07	1.12E-08	Air	0

Near Water Family	Adult Female	Ingestion	Fruit	Pu-238	8.22E-09	9.39E-11	7.84E-11	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	Pu-239	5.79E-08	6.17E-10	5.16E-10	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	Ru-106	1.87E-08	8.85E-10	5.21E-10	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	Sr-89	4.09E-11	1.96E-12	1.32E-12	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	Sr-90	2.46E-08	1.03E-09	9.37E-10	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	U-234	9.73E-10	2.06E-11	1.43E-11	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	U-235	4.18E-11	9.11E-13	6.25E-13	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	U-236	6.47E-11	1.38E-12	9.53E-13	Air	0
Near Water Family	Adult Female	Ingestion	Fruit	U-238	1.8E-09	3.99E-11	2.75E-11	Air	0
Near Water Family	Adult Female	Ingestion	Grain	Am-241	1.29E-12	1.26E-14	9.83E-15	Air	0
Near Water Family	Adult Female	Ingestion	Grain	C-14	5.43E-08	2.67E-09	1.92E-09	Air	0
Near Water Family	Adult Female	Ingestion	Grain	Cs-137	5.18E-11	2.52E-12	1.8E-12	Air	0
Near Water Family	Adult Female	Ingestion	Grain	H-3	3.62E-07	1.77E-08	1.27E-08	Air	0
Near Water Family	Adult Female	Ingestion	Grain	I-129	4.74E-10	1.03E-11	1.06E-12	Air	0
Near Water Family	Adult Female	Ingestion	Grain	I-131	2.76E-07	6.15E-09	6.73E-10	Air	0
Near Water Family	Adult Female	Ingestion	Grain	Pu-238	5.12E-10	5.84E-12	4.87E-12	Air	0
Near Water Family	Adult Female	Ingestion	Grain	Pu-239	3.59E-09	3.83E-11	3.2E-11	Air	0
Near Water Family	Adult Female	Ingestion	Grain	Ru-106	1.15E-09	5.45E-11	3.21E-11	Air	0
Near Water Family	Adult Female	Ingestion	Grain	Sr-89	2.6E-12	1.25E-13	8.36E-14	Air	0
Near Water Family	Adult Female	Ingestion	Grain	Sr-90	1.68E-09	7.05E-11	6.41E-11	Air	0
Near Water Family	Adult Female	Ingestion	Grain	U-234	6.03E-11	1.28E-12	8.89E-13	Air	0
Near Water Family	Adult Female	Ingestion	Grain	U-235	2.58E-12	5.64E-14	3.87E-14	Air	0
Near Water Family	Adult Female	Ingestion	Grain	U-236	4.01E-12	8.53E-14	5.9E-14	Air	0
Near Water Family	Adult Female	Ingestion	Grain	U-238	1.12E-10	2.48E-12	1.71E-12	Air	0
Near Water Family	Adult Female	Ingestion	Beef	Am-241	5.95E-13	5.8E-15	4.52E-15	Air	0
Near Water Family	Adult Female	Ingestion	Beef	C-14	9.52E-07	4.67E-08	3.36E-08	Air	0
Near Water Family	Adult Female	Ingestion	Beef	Cs-137	3.11E-08	1.52E-09	1.08E-09	Air	0
Near Water Family	Adult Female	Ingestion	Beef	H-3	5.98E-06	2.91E-07	2.09E-07	Air	0
Near Water Family	Adult Female	Ingestion	Beef	I-129	2.15E-07	4.67E-09	4.79E-10	Air	0
Near Water Family	Adult Female	Ingestion	Beef	I-131	0.000125	2.78E-06	3.04E-07	Air	0
Near Water Family	Adult Female	Ingestion	Beef	Pu-238	5.85E-11	6.69E-13	5.58E-13	Air	0
Near Water Family	Adult Female	Ingestion	Beef	Pu-239	4.11E-10	4.39E-12	3.67E-12	Air	0
Near Water Family	Adult Female	Ingestion	Beef	Ru-106	6.67E-07	3.15E-08	1.86E-08	Air	0
Near Water Family	Adult Female	Ingestion	Beef	Sr-89	2.4E-10	1.15E-11	7.71E-12	Air	0
Near Water Family	Adult Female	Ingestion	Beef	Sr-90	1.38E-07	5.81E-09	5.27E-09	Air	0
Near Water Family	Adult Female	Ingestion	Beef	U-234	2.08E-10	4.41E-12	3.07E-12	Air	0
Near Water Family	Adult Female	Ingestion	Beef	U-235	8.9E-12	1.94E-13	1.33E-13	Air	0

Near Water Family	Adult Female	Ingestion	Beef	U-236	1.38E-11	2.93E-13	2.03E-13	Air	0
Near Water Family	Adult Female	Ingestion	Beef	U-238	3.78E-10	8.25E-12	5.71E-12	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	Am-241	3.64E-16	3.55E-18	2.77E-18	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	C-14	3.64E-08	1.78E-09	1.28E-09	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	Cs-137	2.45E-11	1.2E-12	8.52E-13	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	H-3	9.7E-07	4.72E-08	3.39E-08	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	I-129	2.3E-13	5E-15	5.13E-16	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	I-131	1.52E-17	3.39E-19	3.7E-20	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	Pu-238	7.16E-14	8.16E-16	6.8E-16	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	Pu-239	5.06E-13	5.39E-15	4.49E-15	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	Ru-106	3.07E-10	1.45E-11	8.55E-12	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	Sr-89	8.71E-16	4.17E-17	2.8E-17	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	Sr-90	8.11E-12	3.41E-13	3.09E-13	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	U-234	2.84E-12	6E-14	4.18E-14	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	U-235	1.22E-13	2.65E-15	1.82E-15	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	U-236	1.89E-13	3.99E-15	2.77E-15	Air	0
Near Water Family	Adult Female	Ingestion	Poultry	U-238	5.16E-12	1.12E-13	7.81E-14	Air	0
Near Water Family	Adult Female	Ingestion	Milk	Am-241	3.35E-14	3.27E-16	2.54E-16	Air	0
Near Water Family	Adult Female	Ingestion	Milk	C-14	6.2E-07	3.05E-08	2.19E-08	Air	0
Near Water Family	Adult Female	Ingestion	Milk	Cs-137	7.66E-09	3.73E-10	2.66E-10	Air	0
Near Water Family	Adult Female	Ingestion	Milk	H-3	1.11E-05	5.4E-07	3.88E-07	Air	0
Near Water Family	Adult Female	Ingestion	Milk	I-129	8.05E-08	1.75E-09	1.8E-10	Air	0
Near Water Family	Adult Female	Ingestion	Milk	I-131	5.03E-05	1.12E-06	1.23E-07	Air	0
Near Water Family	Adult Female	Ingestion	Milk	Pu-238	9.65E-12	1.1E-13	9.2E-14	Air	0
Near Water Family	Adult Female	Ingestion	Milk	Pu-239	6.77E-11	7.25E-13	6.06E-13	Air	0
Near Water Family	Adult Female	Ingestion	Milk	Ru-106	6.62E-11	3.13E-12	1.84E-12	Air	0
Near Water Family	Adult Female	Ingestion	Milk	Sr-89	1.27E-10	6.1E-12	4.09E-12	Air	0
Near Water Family	Adult Female	Ingestion	Milk	Sr-90	7.15E-08	2.99E-09	2.74E-09	Air	0
Near Water Family	Adult Female	Ingestion	Milk	U-234	4.15E-10	8.8E-12	6.12E-12	Air	0
Near Water Family	Adult Female	Ingestion	Milk	U-235	1.78E-11	3.87E-13	2.66E-13	Air	0
Near Water Family	Adult Female	Ingestion	Milk	U-236	2.76E-11	5.87E-13	4.06E-13	Air	0
Near Water Family	Adult Female	Ingestion	Milk	U-238	7.51E-10	1.63E-11	1.13E-11	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	Am-241	4.47E-16	4.37E-18	3.4E-18	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	C-14	5.02E-08	2.47E-09	1.77E-09	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	Cs-137	1.81E-12	8.84E-14	6.31E-14	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	H-3	1.77E-06	8.6E-08	6.18E-08	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	I-129	1.27E-10	2.77E-12	2.84E-13	Air	0

Near Water Family	Adult Female	Ingestion	Eggs	I-131	1.3E-14	2.89E-16	3.17E-17	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	Pu-238	2.19E-14	2.5E-16	2.09E-16	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	Pu-239	1.55E-13	1.66E-15	1.38E-15	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	Ru-106	3.58E-13	1.69E-14	9.97E-15	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	Sr-89	4.31E-15	2.06E-16	1.38E-16	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	Sr-90	3.55E-11	1.48E-12	1.38E-12	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	U-234	5.23E-12	1.11E-13	7.72E-14	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	U-235	2.24E-13	4.86E-15	3.34E-15	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	U-236	3.48E-13	7.38E-15	5.12E-15	Air	0
Near Water Family	Adult Female	Ingestion	Eggs	U-238	9.43E-12	2.03E-13	1.42E-13	Air	0
Near Water Family	Adult Female	Ingestion	Soil	Am-241	1.47E-14	1.43E-16	1.12E-16	Air	0
Near Water Family	Adult Female	Ingestion	Soil	Cs-137	5.72E-13	2.79E-14	1.99E-14	Air	0
Near Water Family	Adult Female	Ingestion	Soil	I-129	3.89E-12	8.48E-14	8.7E-15	Air	0
Near Water Family	Adult Female	Ingestion	Soil	I-131	5.59E-10	1.24E-11	1.36E-12	Air	0
Near Water Family	Adult Female	Ingestion	Soil	Pu-238	5.78E-12	6.6E-14	5.51E-14	Air	0
Near Water Family	Adult Female	Ingestion	Soil	Pu-239	4.05E-11	4.34E-13	3.63E-13	Air	0
Near Water Family	Adult Female	Ingestion	Soil	Ru-106	1.08E-11	5.11E-13	3.01E-13	Air	0
Near Water Family	Adult Female	Ingestion	Soil	Sr-89	1.15E-14	5.53E-16	3.71E-16	Air	0
Near Water Family	Adult Female	Ingestion	Soil	Sr-90	1.68E-11	7.07E-13	6.38E-13	Air	0
Near Water Family	Adult Female	Ingestion	Soil	U-234	6.82E-13	1.44E-14	1.01E-14	Air	0
Near Water Family	Adult Female	Ingestion	Soil	U-235	2.93E-14	6.39E-16	4.39E-16	Air	0
Near Water Family	Adult Female	Ingestion	Soil	U-236	4.54E-14	9.65E-16	6.69E-16	Air	0
Near Water Family	Adult Female	Ingestion	Soil	U-238	1.31E-12	3E-14	2.04E-14	Air	0
Near Water Family	Adult Female	External	Air Immersion	Am-241	5.22E-16	2.29E-17	1.6E-17	Air	0
Near Water Family	Adult Female	External	Air Immersion	Ar-41	3.56E-05	1.71E-06	1.23E-06	Air	0
Near Water Family	Adult Female	External	Air Immersion	C-14	1.8E-12	1.75E-14	1.58E-14	Air	0
Near Water Family	Adult Female	External	Air Immersion	Cs-137	1.18E-11	5.62E-13	4.01E-13	Air	0
Near Water Family	Adult Female	External	Air Immersion	I-129	2.73E-13	1.05E-14	6.9E-15	Air	0
Near Water Family	Adult Female	External	Air Immersion	I-131	1.39E-07	6.59E-09	4.7E-09	Air	0
Near Water Family	Adult Female	External	Air Immersion	Pu-238	9.56E-16	3.51E-17	2.15E-17	Air	0
Near Water Family	Adult Female	External	Air Immersion	Pu-239	6.05E-15	2.6E-16	1.77E-16	Air	0
Near Water Family	Adult Female	External	Air Immersion	Ru-106	2.2E-10	9.71E-12	6.98E-12	Air	0
Near Water Family	Adult Female	External	Air Immersion	Sr-89	6.58E-14	8.88E-16	7.47E-16	Air	0
Near Water Family	Adult Female	External	Air Immersion	Sr-90	8.93E-13	1.06E-14	9.2E-15	Air	0
Near Water Family	Adult Female	External	Air Immersion	U-234	9.06E-16	3.77E-17	2.53E-17	Air	0
Near Water Family	Adult Female	External	Air Immersion	U-235	4.36E-14	2.04E-15	1.45E-15	Air	0
Near Water Family	Adult Female	External	Air Immersion	U-236	4.03E-17	1.6E-18	1.04E-18	Air	0

Near Water Family	Adult Female	External	Air Immersion	U-238	4.53E-15	1.61E-16	1.15E-16	Air	0
Near Water Family	Adult Female	External	Ground Contamination	Am-241	4.95E-13	2.1E-14	1.46E-14	Air	0
Near Water Family	Adult Female	External	Ground Contamination	Cs-137	6.86E-09	3.23E-10	2.31E-10	Air	0
Near Water Family	Adult Female	External	Ground Contamination	I-129	2.13E-10	8.07E-12	5.38E-12	Air	0
Near Water Family	Adult Female	External	Ground Contamination	I-131	2.75E-06	1.31E-07	9.37E-08	Air	0
Near Water Family	Adult Female	External	Ground Contamination	Pu-238	4.7E-12	1.39E-13	8.47E-14	Air	0
Near Water Family	Adult Female	External	Ground Contamination	Pu-239	1.36E-11	4.43E-13	2.83E-13	Air	0
Near Water Family	Adult Female	External	Ground Contamination	Ru-106	1.57E-07	4.98E-09	3.68E-09	Air	0
Near Water Family	Adult Female	External	Ground Contamination	Sr-89	9.12E-11	7.77E-13	7.4E-13	Air	0
Near Water Family	Adult Female	External	Ground Contamination	Sr-90	1.8E-08	1.64E-10	1.53E-10	Air	0
Near Water Family	Adult Female	External	Ground Contamination	U-234	2.39E-12	7.57E-14	4.81E-14	Air	0
Near Water Family	Adult Female	External	Ground Contamination	U-235	2.86E-11	1.34E-12	9.54E-13	Air	0
Near Water Family	Adult Female	External	Ground Contamination	U-236	1.44E-13	4.41E-15	2.75E-15	Air	0
Near Water Family	Adult Female	External	Ground Contamination	U-238	8.21E-10	1.36E-11	1.1E-11	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Am-241	4.21E-09	5.5E-11	4.74E-11	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	C-14	5.67E-10	2.74E-11	1.97E-11	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Cs-137	2.82E-10	1.32E-11	9.41E-12	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	H-3	8.98E-06	4.36E-07	3.13E-07	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	I-129	9.45E-09	2.06E-10	2.11E-11	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	I-131	1.66E-05	3.69E-07	3.98E-08	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Pu-238	1.65E-06	2.31E-08	2.05E-08	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Pu-239	1.14E-05	1.46E-07	1.29E-07	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Ru-106	7.57E-08	4.01E-09	3.66E-09	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Sr-89	1.2E-10	6.43E-12	5.94E-12	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Sr-90	2.81E-08	1.4E-09	1.32E-09	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	U-234	6.74E-08	3.5E-09	3.31E-09	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	U-235	2.7E-09	1.4E-10	1.32E-10	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	U-236	4.36E-09	2.26E-10	2.14E-10	Air	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	U-238	1.11E-07	5.73E-09	5.38E-09	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Am-241	1.62E-11	2.12E-13	1.82E-13	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Cs-137	1.07E-12	5E-14	3.56E-14	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	I-129	1.49E-11	3.25E-13	3.33E-14	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	I-131	2.13E-09	4.76E-11	5.13E-12	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Pu-238	6.31E-09	8.87E-11	7.89E-11	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Pu-239	4.37E-08	5.61E-10	4.96E-10	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Ru-106	2.33E-10	1.24E-11	1.13E-11	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Sr-89	1.48E-13	7.93E-15	7.32E-15	Air	0

Near Water Family	Adult Female	Inhalation	Resuspended Soil	Sr-90	1.11E-10	5.53E-12	5.23E-12	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-234	2.6E-10	1.35E-11	1.28E-11	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-235	1.04E-11	5.38E-13	5.08E-13	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-236	1.68E-11	8.69E-13	8.21E-13	Air	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-238	4.27E-10	2.21E-11	2.08E-11	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Am-241	6.18E-11	6.02E-13	4.69E-13	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	C-14	6E-08	2.95E-09	2.12E-09	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Cs-137	2.58E-09	1.26E-10	8.99E-11	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	H-3	1.63E-06	7.91E-08	5.68E-08	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	I-129	2.23E-08	4.85E-10	4.97E-11	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	I-131	1.35E-05	3.01E-07	3.3E-08	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Pu-238	2.43E-08	2.77E-10	2.31E-10	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Pu-239	1.71E-07	1.82E-09	1.52E-09	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Ru-106	5.5E-08	2.6E-09	1.53E-09	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Sr-89	1.2E-10	5.76E-12	3.87E-12	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Sr-90	7.17E-08	3.01E-09	2.73E-09	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-234	2.87E-09	6.08E-11	4.23E-11	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-235	1.23E-10	2.69E-12	1.84E-12	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-236	1.91E-10	4.05E-12	2.8E-12	Air	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-238	5.31E-09	1.18E-10	8.11E-11	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Am-241	2.92E-11	2.85E-13	2.22E-13	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	C-14	2.85E-07	1.4E-08	1E-08	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Cs-137	1.32E-09	6.46E-11	4.61E-11	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	H-3	7.15E-06	3.47E-07	2.49E-07	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	I-129	1.06E-08	2.3E-10	2.36E-11	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	I-131	2.09E-06	4.65E-08	5.09E-09	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Pu-238	1.15E-08	1.31E-10	1.1E-10	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Pu-239	8.1E-08	8.64E-10	7.23E-10	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Ru-106	2.56E-08	1.21E-09	7.11E-10	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Sr-89	5.26E-11	2.52E-12	1.69E-12	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Sr-90	4.31E-08	1.81E-09	1.63E-09	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	U-234	1.37E-09	2.9E-11	2.01E-11	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	U-235	5.85E-11	1.28E-12	8.75E-13	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	U-236	9.06E-11	1.92E-12	1.33E-12	Air	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	U-238	2.56E-09	5.76E-11	3.95E-11	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	Am-241	2.04E-11	1.99E-13	1.55E-13	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	C-14	1.98E-07	9.74E-09	7E-09	Air	0

Near Water Family	Adult Male	Ingestion	Fruit	Cs-137	8.35E-10	4.08E-11	2.91E-11	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	H-3	4.97E-06	2.41E-07	1.73E-07	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	I-129	7.38E-09	1.61E-10	1.65E-11	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	I-131	4.47E-06	9.96E-08	1.09E-08	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	Pu-238	8.02E-09	9.16E-11	7.64E-11	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	Pu-239	5.64E-08	6.02E-10	5.04E-10	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	Ru-106	1.83E-08	8.63E-10	5.08E-10	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	Sr-89	3.99E-11	1.91E-12	1.28E-12	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	Sr-90	2.4E-08	1.01E-09	9.13E-10	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	U-234	9.48E-10	2.01E-11	1.4E-11	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	U-235	4.07E-11	8.88E-13	6.1E-13	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	U-236	6.31E-11	1.34E-12	9.29E-13	Air	0
Near Water Family	Adult Male	Ingestion	Fruit	U-238	1.75E-09	3.89E-11	2.68E-11	Air	0
Near Water Family	Adult Male	Ingestion	Grain	Am-241	1.56E-12	1.52E-14	1.19E-14	Air	0
Near Water Family	Adult Male	Ingestion	Grain	C-14	6.55E-08	3.22E-09	2.31E-09	Air	0
Near Water Family	Adult Male	Ingestion	Grain	Cs-137	6.24E-11	3.04E-12	2.17E-12	Air	0
Near Water Family	Adult Male	Ingestion	Grain	H-3	4.37E-07	2.13E-08	1.53E-08	Air	0
Near Water Family	Adult Male	Ingestion	Grain	I-129	5.72E-10	1.24E-11	1.28E-12	Air	0
Near Water Family	Adult Male	Ingestion	Grain	I-131	3.33E-07	7.42E-09	8.12E-10	Air	0
Near Water Family	Adult Male	Ingestion	Grain	Pu-238	6.18E-10	7.04E-12	5.87E-12	Air	0
Near Water Family	Adult Male	Ingestion	Grain	Pu-239	4.32E-09	4.62E-11	3.86E-11	Air	0
Near Water Family	Adult Male	Ingestion	Grain	Ru-106	1.39E-09	6.57E-11	3.87E-11	Air	0
Near Water Family	Adult Male	Ingestion	Grain	Sr-89	3.14E-12	1.5E-13	1.01E-13	Air	0
Near Water Family	Adult Male	Ingestion	Grain	Sr-90	2.03E-09	8.51E-11	7.73E-11	Air	0
Near Water Family	Adult Male	Ingestion	Grain	U-234	7.27E-11	1.54E-12	1.07E-12	Air	0
Near Water Family	Adult Male	Ingestion	Grain	U-235	3.12E-12	6.8E-14	4.67E-14	Air	0
Near Water Family	Adult Male	Ingestion	Grain	U-236	4.83E-12	1.03E-13	7.12E-14	Air	0
Near Water Family	Adult Male	Ingestion	Grain	U-238	1.35E-10	2.99E-12	2.06E-12	Air	0
Near Water Family	Adult Male	Ingestion	Beef	Am-241	9.34E-13	9.11E-15	7.1E-15	Air	0
Near Water Family	Adult Male	Ingestion	Beef	C-14	1.5E-06	7.34E-08	5.28E-08	Air	0
Near Water Family	Adult Male	Ingestion	Beef	Cs-137	4.88E-08	2.38E-09	1.7E-09	Air	0
Near Water Family	Adult Male	Ingestion	Beef	H-3	9.4E-06	4.58E-07	3.29E-07	Air	0
Near Water Family	Adult Male	Ingestion	Beef	I-129	3.37E-07	7.34E-09	7.52E-10	Air	0
Near Water Family	Adult Male	Ingestion	Beef	I-131	0.000196	4.37E-06	4.78E-07	Air	0
Near Water Family	Adult Male	Ingestion	Beef	Pu-238	9.2E-11	1.05E-12	8.76E-13	Air	0
Near Water Family	Adult Male	Ingestion	Beef	Pu-239	6.46E-10	6.89E-12	5.77E-12	Air	0
Near Water Family	Adult Male	Ingestion	Beef	Ru-106	1.05E-06	4.95E-08	2.92E-08	Air	0

Near Water Family	Adult Male	Ingestion	Beef	Sr-89	3.77E-10	1.8E-11	1.21E-11	Air	0
Near Water Family	Adult Male	Ingestion	Beef	Sr-90	2.18E-07	9.13E-09	8.28E-09	Air	0
Near Water Family	Adult Male	Ingestion	Beef	U-234	3.26E-10	6.93E-12	4.82E-12	Air	0
Near Water Family	Adult Male	Ingestion	Beef	U-235	1.4E-11	3.05E-13	2.09E-13	Air	0
Near Water Family	Adult Male	Ingestion	Beef	U-236	2.17E-11	4.6E-13	3.19E-13	Air	0
Near Water Family	Adult Male	Ingestion	Beef	U-238	5.94E-10	1.3E-11	8.98E-12	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	Am-241	4.52E-16	4.41E-18	3.43E-18	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	C-14	4.51E-08	2.22E-09	1.59E-09	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	Cs-137	3.04E-11	1.48E-12	1.06E-12	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	H-3	1.2E-06	5.86E-08	4.21E-08	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	I-129	2.85E-13	6.2E-15	6.37E-16	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	I-131	1.88E-17	4.2E-19	4.59E-20	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	Pu-238	8.89E-14	1.01E-15	8.44E-16	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	Pu-239	6.29E-13	6.69E-15	5.58E-15	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	Ru-106	3.82E-10	1.8E-11	1.06E-11	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	Sr-89	1.08E-15	5.18E-17	3.47E-17	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	Sr-90	1.01E-11	4.23E-13	3.84E-13	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	U-234	3.52E-12	7.46E-14	5.19E-14	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	U-235	1.51E-13	3.29E-15	2.26E-15	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	U-236	2.34E-13	4.96E-15	3.44E-15	Air	0
Near Water Family	Adult Male	Ingestion	Poultry	U-238	6.41E-12	1.4E-13	9.69E-14	Air	0
Near Water Family	Adult Male	Ingestion	Milk	Am-241	4.45E-14	4.34E-16	3.38E-16	Air	0
Near Water Family	Adult Male	Ingestion	Milk	C-14	8.24E-07	4.05E-08	2.91E-08	Air	0
Near Water Family	Adult Male	Ingestion	Milk	Cs-137	1.02E-08	4.95E-10	3.54E-10	Air	0
Near Water Family	Adult Male	Ingestion	Milk	H-3	1.48E-05	7.18E-07	5.16E-07	Air	0
Near Water Family	Adult Male	Ingestion	Milk	I-129	1.07E-07	2.33E-09	2.39E-10	Air	0
Near Water Family	Adult Male	Ingestion	Milk	I-131	6.68E-05	1.49E-06	1.63E-07	Air	0
Near Water Family	Adult Male	Ingestion	Milk	Pu-238	1.28E-11	1.46E-13	1.22E-13	Air	0
Near Water Family	Adult Male	Ingestion	Milk	Pu-239	8.98E-11	9.62E-13	8.05E-13	Air	0
Near Water Family	Adult Male	Ingestion	Milk	Ru-106	8.79E-11	4.15E-12	2.44E-12	Air	0
Near Water Family	Adult Male	Ingestion	Milk	Sr-89	1.69E-10	8.1E-12	5.43E-12	Air	0
Near Water Family	Adult Male	Ingestion	Milk	Sr-90	9.49E-08	3.97E-09	3.64E-09	Air	0
Near Water Family	Adult Male	Ingestion	Milk	U-234	5.51E-10	1.17E-11	8.13E-12	Air	0
Near Water Family	Adult Male	Ingestion	Milk	U-235	2.36E-11	5.14E-13	3.54E-13	Air	0
Near Water Family	Adult Male	Ingestion	Milk	U-236	3.67E-11	7.8E-13	5.39E-13	Air	0
Near Water Family	Adult Male	Ingestion	Milk	U-238	9.98E-10	2.16E-11	1.5E-11	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	Am-241	7.4E-16	7.22E-18	5.63E-18	Air	0

Near Water Family	Adult Male	Ingestion	Eggs	C-14	8.31E-08	4.08E-09	2.94E-09	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	Cs-137	3E-12	1.46E-13	1.04E-13	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	H-3	2.93E-06	1.42E-07	1.02E-07	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	I-129	2.1E-10	4.58E-12	4.7E-13	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	I-131	2.15E-14	4.78E-16	5.24E-17	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	Pu-238	3.63E-14	4.13E-16	3.45E-16	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	Pu-239	2.56E-13	2.74E-15	2.29E-15	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	Ru-106	5.93E-13	2.8E-14	1.65E-14	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	Sr-89	7.14E-15	3.41E-16	2.29E-16	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	Sr-90	5.87E-11	2.44E-12	2.28E-12	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	U-234	8.66E-12	1.83E-13	1.28E-13	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	U-235	3.7E-13	8.04E-15	5.53E-15	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	U-236	5.76E-13	1.22E-14	8.47E-15	Air	0
Near Water Family	Adult Male	Ingestion	Eggs	U-238	1.56E-11	3.36E-13	2.34E-13	Air	0
Near Water Family	Adult Male	Ingestion	Soil	Am-241	1.47E-14	1.43E-16	1.12E-16	Air	0
Near Water Family	Adult Male	Ingestion	Soil	Cs-137	5.72E-13	2.79E-14	1.99E-14	Air	0
Near Water Family	Adult Male	Ingestion	Soil	I-129	3.89E-12	8.48E-14	8.7E-15	Air	0
Near Water Family	Adult Male	Ingestion	Soil	I-131	5.59E-10	1.24E-11	1.36E-12	Air	0
Near Water Family	Adult Male	Ingestion	Soil	Pu-238	5.78E-12	6.6E-14	5.51E-14	Air	0
Near Water Family	Adult Male	Ingestion	Soil	Pu-239	4.05E-11	4.34E-13	3.63E-13	Air	0
Near Water Family	Adult Male	Ingestion	Soil	Ru-106	1.08E-11	5.11E-13	3.01E-13	Air	0
Near Water Family	Adult Male	Ingestion	Soil	Sr-89	1.15E-14	5.53E-16	3.71E-16	Air	0
Near Water Family	Adult Male	Ingestion	Soil	Sr-90	1.68E-11	7.07E-13	6.38E-13	Air	0
Near Water Family	Adult Male	Ingestion	Soil	U-234	6.82E-13	1.44E-14	1.01E-14	Air	0
Near Water Family	Adult Male	Ingestion	Soil	U-235	2.93E-14	6.39E-16	4.39E-16	Air	0
Near Water Family	Adult Male	Ingestion	Soil	U-236	4.54E-14	9.65E-16	6.69E-16	Air	0
Near Water Family	Adult Male	Ingestion	Soil	U-238	1.31E-12	3E-14	2.04E-14	Air	0
Near Water Family	Adult Male	External	Air Immersion	Am-241	5.22E-16	2.29E-17	1.6E-17	Air	0
Near Water Family	Adult Male	External	Air Immersion	Ar-41	3.56E-05	1.71E-06	1.23E-06	Air	0
Near Water Family	Adult Male	External	Air Immersion	C-14	1.8E-12	1.75E-14	1.58E-14	Air	0
Near Water Family	Adult Male	External	Air Immersion	Cs-137	1.18E-11	5.62E-13	4.01E-13	Air	0
Near Water Family	Adult Male	External	Air Immersion	I-129	2.73E-13	1.05E-14	6.9E-15	Air	0
Near Water Family	Adult Male	External	Air Immersion	I-131	1.39E-07	6.59E-09	4.7E-09	Air	0
Near Water Family	Adult Male	External	Air Immersion	Pu-238	9.56E-16	3.51E-17	2.15E-17	Air	0
Near Water Family	Adult Male	External	Air Immersion	Pu-239	6.05E-15	2.6E-16	1.77E-16	Air	0
Near Water Family	Adult Male	External	Air Immersion	Ru-106	2.2E-10	9.71E-12	6.98E-12	Air	0
Near Water Family	Adult Male	External	Air Immersion	Sr-89	6.58E-14	8.88E-16	7.47E-16	Air	0

Near Water Family	Adult Male	External	Air Immersion	Sr-90	8.93E-13	1.06E-14	9.2E-15	Air	0
Near Water Family	Adult Male	External	Air Immersion	U-234	9.06E-16	3.77E-17	2.53E-17	Air	0
Near Water Family	Adult Male	External	Air Immersion	U-235	4.36E-14	2.04E-15	1.45E-15	Air	0
Near Water Family	Adult Male	External	Air Immersion	U-236	4.03E-17	1.6E-18	1.04E-18	Air	0
Near Water Family	Adult Male	External	Air Immersion	U-238	4.53E-15	1.61E-16	1.15E-16	Air	0
Near Water Family	Adult Male	External	Ground Contamination	Am-241	4.95E-13	2.1E-14	1.46E-14	Air	0
Near Water Family	Adult Male	External	Ground Contamination	Cs-137	6.85E-09	3.22E-10	2.3E-10	Air	0
Near Water Family	Adult Male	External	Ground Contamination	I-129	2.13E-10	8.06E-12	5.38E-12	Air	0
Near Water Family	Adult Male	External	Ground Contamination	I-131	2.75E-06	1.31E-07	9.36E-08	Air	0
Near Water Family	Adult Male	External	Ground Contamination	Pu-238	4.69E-12	1.39E-13	8.47E-14	Air	0
Near Water Family	Adult Male	External	Ground Contamination	Pu-239	1.36E-11	4.42E-13	2.83E-13	Air	0
Near Water Family	Adult Male	External	Ground Contamination	Ru-106	1.57E-07	4.97E-09	3.67E-09	Air	0
Near Water Family	Adult Male	External	Ground Contamination	Sr-89	9.11E-11	7.77E-13	7.4E-13	Air	0
Near Water Family	Adult Male	External	Ground Contamination	Sr-90	1.79E-08	1.64E-10	1.53E-10	Air	0
Near Water Family	Adult Male	External	Ground Contamination	U-234	2.39E-12	7.56E-14	4.81E-14	Air	0
Near Water Family	Adult Male	External	Ground Contamination	U-235	2.86E-11	1.34E-12	9.54E-13	Air	0
Near Water Family	Adult Male	External	Ground Contamination	U-236	1.44E-13	4.41E-15	2.74E-15	Air	0
Near Water Family	Adult Male	External	Ground Contamination	U-238	8.21E-10	1.36E-11	1.1E-11	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Am-241	5.67E-09	7.39E-11	6.37E-11	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	C-14	7.62E-10	3.69E-11	2.65E-11	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Cs-137	3.79E-10	1.77E-11	1.27E-11	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	H-3	1.21E-05	5.87E-07	4.21E-07	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	I-129	1.27E-08	2.77E-10	2.84E-11	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	I-131	2.23E-05	4.97E-07	5.36E-08	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Pu-238	2.22E-06	3.1E-08	2.76E-08	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Pu-239	1.53E-05	1.96E-07	1.73E-07	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Ru-106	1.02E-07	5.4E-09	4.93E-09	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Sr-89	1.62E-10	8.65E-12	7.99E-12	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Sr-90	3.77E-08	1.88E-09	1.78E-09	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-234	9.07E-08	4.7E-09	4.46E-09	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-235	3.62E-09	1.88E-10	1.77E-10	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-236	5.87E-09	3.04E-10	2.87E-10	Air	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-238	1.49E-07	7.71E-09	7.23E-09	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Am-241	2.18E-11	2.85E-13	2.45E-13	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Cs-137	1.44E-12	6.73E-14	4.79E-14	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	I-129	2.01E-11	4.37E-13	4.48E-14	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	I-131	2.87E-09	6.4E-11	6.9E-12	Air	0

Near Water Family	Adult Male	Inhalation	Resuspended Soil	Pu-238	8.49E-09	1.19E-10	1.06E-10	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Pu-239	5.88E-08	7.55E-10	6.68E-10	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Ru-106	3.13E-10	1.66E-11	1.52E-11	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Sr-89	2E-13	1.07E-14	9.84E-15	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Sr-90	1.49E-10	7.44E-12	7.04E-12	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-234	3.5E-10	1.82E-11	1.72E-11	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-235	1.4E-11	7.24E-13	6.83E-13	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-236	2.26E-11	1.17E-12	1.1E-12	Air	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-238	5.74E-10	2.97E-11	2.79E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Am-241	6.18E-11	8.43E-13	6.28E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	C-14	4.54E-08	6.05E-09	4.04E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Cs-137	1.19E-09	1.02E-10	6.82E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	H-3	1.23E-06	1.6E-07	1.07E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	I-129	1.85E-08	1.41E-09	1.44E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	I-131	2.42E-05	2.31E-06	2.41E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-238	1.54E-08	6.88E-10	4.95E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-239	1.99E-07	1.35E-09	9.44E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Ru-106	5.48E-08	1.86E-08	1.05E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-89	1.25E-10	3.11E-11	1.81E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-90	4.55E-08	3.55E-09	2.35E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-234	1.81E-09	1.13E-10	6.93E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-235	8.56E-11	6.88E-12	4.2E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-236	1.2E-10	7.48E-12	4.6E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-238	3.95E-09	3.69E-10	2.24E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Am-241	2.92E-11	4E-13	2.98E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	C-14	2.45E-07	3.42E-08	2.28E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Cs-137	8.57E-10	8.2E-11	5.39E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	H-3	6.05E-06	8.34E-07	5.57E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	I-129	9.91E-09	7.84E-10	7.99E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	I-131	5.95E-06	5.73E-07	5.98E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Pu-238	9.04E-09	4.07E-10	2.92E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Pu-239	4.32E-07	2.64E-09	1.83E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Ru-106	4.25E-08	1.28E-08	7.17E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Sr-89	1.21E-10	2.44E-11	1.42E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Sr-90	1.04E-07	6.71E-09	4.38E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-234	2.88E-09	1.48E-10	8.97E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-235	9.95E-11	6.56E-12	3.98E-12	Air	0

Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-236	1.9E-10	9.76E-12	5.96E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-238	3.56E-09	3.11E-10	1.87E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	Am-241	2.04E-11	2.79E-13	2.08E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	C-14	2.48E-07	3.76E-08	2.49E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	Cs-137	1.01E-09	1.1E-10	7.09E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	H-3	5.96E-06	9.14E-07	6.07E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	I-129	9.94E-09	8.52E-10	8.68E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	I-131	2.98E-05	2.88E-06	3E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	Pu-238	7.01E-09	3.17E-10	2.28E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	Pu-239	9.97E-07	5.97E-09	4.14E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	Ru-106	6.74E-08	1.76E-08	9.84E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	Sr-89	2.43E-10	4.41E-11	2.57E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	Sr-90	1.84E-07	1.08E-08	7.12E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-234	6.09E-09	2.9E-10	1.77E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-235	1.92E-10	1.16E-11	6.98E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-236	4.04E-10	1.93E-11	1.17E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-238	5.93E-09	4.54E-10	2.74E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	Am-241	1.56E-12	2.13E-14	1.59E-14	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	C-14	7.3E-08	1.08E-08	7.13E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	Cs-137	4.3E-11	4.55E-12	2.98E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	H-3	4.86E-07	7.25E-08	4.81E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	I-129	7.31E-10	6.13E-11	6.24E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	I-131	1.68E-06	1.62E-07	1.69E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	Pu-238	4.63E-10	2.08E-11	1.49E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	Pu-239	2.02E-08	1.27E-10	8.86E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	Ru-106	2.73E-09	8.59E-10	4.82E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	Sr-89	8.21E-12	1.94E-12	1.13E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	Sr-90	4.74E-09	3.31E-10	2.2E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	U-234	1.41E-10	7.57E-12	4.63E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	U-235	5.63E-12	4.22E-13	2.56E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	U-236	9.33E-12	5.04E-13	3.08E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Grain	U-238	2.3E-10	2.18E-11	1.32E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	Am-241	9.34E-13	1.28E-14	9.5E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	C-14	1.42E-06	2.02E-07	1.34E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	Cs-137	3.23E-08	3.16E-09	2.08E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	H-3	8.73E-06	1.23E-06	8.22E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	I-129	3.56E-07	2.87E-08	2.92E-09	Air	0

Near Water Family	Child born 1955	Ingestion	Beef	I-131	0.000577	5.53E-05	5.77E-06	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	Pu-238	8.66E-11	3.93E-12	2.82E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	Pu-239	3.31E-09	2.04E-11	1.42E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	Ru-106	1.85E-06	5.76E-07	3.24E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	Sr-89	8.95E-10	1.85E-10	1.08E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	Sr-90	5.05E-07	3.09E-08	2.04E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	U-234	6.82E-10	3.59E-11	2.19E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	U-235	2.42E-11	1.64E-12	9.97E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	U-236	4.51E-11	2.37E-12	1.45E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Beef	U-238	8.52E-10	6.76E-11	4.12E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	Am-241	4.52E-16	6.17E-18	4.6E-18	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	C-14	4.6E-08	6.73E-09	4.47E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	Cs-137	1.75E-11	1.76E-12	1.16E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	H-3	1.23E-06	1.8E-07	1.2E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	I-129	3.27E-13	2.69E-14	2.75E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	I-131	7.67E-17	7.42E-18	7.74E-19	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	Pu-238	9.06E-14	4.11E-15	2.94E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	Pu-239	1.35E-12	9.09E-15	6.32E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	Ru-106	5.98E-10	2.12E-10	1.19E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	Sr-89	2.04E-15	5.36E-16	3.12E-16	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	Sr-90	1.25E-11	1.01E-12	6.71E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-234	3.9E-12	2.41E-13	1.48E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-235	1.8E-13	1.5E-14	9.15E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-236	2.59E-13	1.6E-14	9.86E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-238	7.99E-12	7.43E-13	4.55E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	Am-241	4.45E-14	6.08E-16	4.52E-16	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	C-14	1.83E-06	3.01E-07	1.98E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	Cs-137	1.9E-08	2.27E-09	1.45E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	H-3	3.16E-05	5.27E-06	3.49E-06	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	I-129	2.72E-07	2.48E-08	2.53E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	I-131	0.000854	8.23E-05	8.6E-06	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	Pu-238	2.77E-11	1.28E-12	9.17E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	Pu-239	2.54E-09	1.54E-11	1.07E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	Ru-106	5.7E-10	1.6E-10	8.99E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	Sr-89	1.79E-09	3.43E-10	1.99E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	Sr-90	1.17E-06	6.17E-08	4.19E-08	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	U-234	5.81E-09	2.84E-10	1.73E-10	Air	0

Near Water Family	Child born 1955	Ingestion	Milk	U-235	1.88E-10	1.18E-11	7.14E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	U-236	3.86E-10	1.89E-11	1.15E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Milk	U-238	5.81E-09	4.26E-10	2.6E-10	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	Am-241	7.4E-16	1.01E-17	7.54E-18	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	C-14	7.52E-08	1.07E-08	7.14E-09	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	Cs-137	1.64E-12	1.58E-13	1.05E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	H-3	2.67E-06	3.81E-07	2.54E-07	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	I-129	2.08E-10	1.68E-11	1.71E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	I-131	8.38E-14	8.1E-15	8.46E-16	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	Pu-238	2.78E-14	1.25E-15	8.96E-16	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	Pu-239	5.34E-13	3.55E-15	2.47E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	Ru-106	8.16E-13	2.8E-13	1.58E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	Sr-89	1.2E-14	3.17E-15	1.85E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	Sr-90	6.76E-11	4.22E-12	3E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-234	8.73E-12	5.21E-13	3.19E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-235	3.97E-13	3.21E-14	1.96E-14	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-236	5.79E-13	3.46E-14	2.12E-14	Air	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-238	1.73E-11	1.53E-12	9.4E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	Am-241	1.47E-14	2E-16	1.49E-16	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	Cs-137	1.14E-12	1.37E-13	8.77E-14	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	I-129	9.84E-12	9.02E-13	9.19E-14	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	I-131	8.03E-09	7.74E-10	8.07E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	Pu-238	1.09E-11	5.01E-13	3.59E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	Pu-239	1.28E-09	7.71E-12	5.36E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	Ru-106	7.48E-11	2.04E-11	1.14E-11	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	Sr-89	1.33E-13	2.53E-14	1.48E-14	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	Sr-90	2.36E-10	1.48E-11	9.66E-12	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	U-234	7.91E-12	3.82E-13	2.33E-13	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	U-235	2.55E-13	1.59E-14	9.61E-15	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	U-236	5.25E-13	2.54E-14	1.55E-14	Air	0
Near Water Family	Child born 1955	Ingestion	Soil	U-238	8.55E-12	7.82E-13	4.65E-13	Air	0
Near Water Family	Child born 1955	External	Air Immersion	Am-241	5.22E-16	3.66E-17	2.45E-17	Air	0
Near Water Family	Child born 1955	External	Air Immersion	Ar-41	3.53E-05	5.71E-06	3.76E-06	Air	0
Near Water Family	Child born 1955	External	Air Immersion	C-14	1.8E-12	4.19E-14	3.62E-14	Air	0
Near Water Family	Child born 1955	External	Air Immersion	Cs-137	1.18E-11	1.62E-12	1.07E-12	Air	0
Near Water Family	Child born 1955	External	Air Immersion	I-129	2.73E-13	3.4E-14	2.08E-14	Air	0
Near Water Family	Child born 1955	External	Air Immersion	I-131	1.39E-07	2.49E-08	1.63E-08	Air	0

Near Water Family	Child born 1955	External	Air Immersion	Pu-238	9.56E-16	1.41E-16	7.97E-17	Air	0
Near Water Family	Child born 1955	External	Air Immersion	Pu-239	6.05E-15	1.02E-15	6.33E-16	Air	0
Near Water Family	Child born 1955	External	Air Immersion	Ru-106	2.2E-10	3.32E-11	2.19E-11	Air	0
Near Water Family	Child born 1955	External	Air Immersion	Sr-89	6.58E-14	2.78E-15	2.17E-15	Air	0
Near Water Family	Child born 1955	External	Air Immersion	Sr-90	8.93E-13	3.47E-14	2.83E-14	Air	0
Near Water Family	Child born 1955	External	Air Immersion	U-234	9.06E-16	1.46E-16	9E-17	Air	0
Near Water Family	Child born 1955	External	Air Immersion	U-235	4.36E-14	7.31E-15	4.78E-15	Air	0
Near Water Family	Child born 1955	External	Air Immersion	U-236	4.03E-17	6.35E-18	3.79E-18	Air	0
Near Water Family	Child born 1955	External	Air Immersion	U-238	4.53E-15	5.65E-16	3.69E-16	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	Am-241	4.95E-13	3.38E-14	2.27E-14	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	Cs-137	6.88E-09	9.38E-10	6.21E-10	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	I-129	2.15E-10	2.61E-11	1.63E-11	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	I-131	2.76E-06	5E-07	3.26E-07	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	Pu-238	4.72E-12	5.63E-13	3.23E-13	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	Pu-239	1.37E-11	1.82E-12	1.08E-12	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	Ru-106	1.58E-07	1.67E-08	1.14E-08	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	Sr-89	9.17E-11	2.16E-12	1.99E-12	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	Sr-90	1.8E-08	5.04E-10	4.54E-10	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	U-234	2.4E-12	3.09E-13	1.84E-13	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	U-235	2.88E-11	4.86E-12	3.18E-12	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	U-236	1.45E-13	1.81E-14	1.06E-14	Air	0
Near Water Family	Child born 1955	External	Ground Contamination	U-238	8.27E-10	4.36E-11	3.26E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Am-241	5.67E-09	9.73E-11	8.34E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	C-14	8.27E-10	1.23E-10	8.09E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Cs-137	2.75E-10	2.69E-11	1.76E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	H-3	1.22E-05	1.78E-06	1.18E-06	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	I-129	1.51E-08	1.27E-09	1.29E-10	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	I-131	8.22E-05	8.05E-06	8.33E-07	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Pu-238	2.2E-06	1.06E-07	9.42E-08	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Pu-239	7.59E-06	3.49E-07	3.06E-07	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Ru-106	1.28E-07	2.32E-08	1.98E-08	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Sr-89	2.19E-10	4.2E-11	3.5E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Sr-90	4.79E-08	5.89E-09	5.32E-09	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-234	1.12E-07	1.56E-08	1.47E-08	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-235	4.63E-09	6.76E-10	6.36E-10	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-236	7.31E-09	1.01E-09	9.56E-10	Air	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-238	1.94E-07	2.92E-08	2.76E-08	Air	0

Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Am-241	2.18E-11	3.75E-13	3.21E-13	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Cs-137	1.04E-12	1.02E-13	6.68E-14	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	I-129	2.39E-11	2E-12	2.03E-13	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	I-131	1.06E-08	1.04E-09	1.07E-10	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Pu-238	8.43E-09	4.07E-10	3.62E-10	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Pu-239	2.91E-08	1.34E-09	1.18E-09	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Ru-106	3.94E-10	7.16E-11	6.11E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Sr-89	2.7E-13	5.17E-14	4.31E-14	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Sr-90	1.97E-10	2.52E-11	2.21E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-234	4.33E-10	6.01E-11	5.68E-11	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-235	1.78E-11	2.6E-12	2.45E-12	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-236	2.82E-11	3.89E-12	3.67E-12	Air	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-238	7.49E-10	1.13E-10	1.06E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Am-241	4.84E-11	1.19E-12	8.28E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	C-14	2.7E-08	4.33E-09	2.87E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Cs-137	8.74E-10	1.18E-10	7.96E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	H-3	7.64E-07	1.13E-07	7.51E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	I-129	1.04E-08	9.14E-10	9.32E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	I-131	1.38E-07	1.26E-08	1.31E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-238	1.57E-08	5.45E-10	3.9E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-239	3.03E-09	1.17E-10	8.32E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Ru-106	3.42E-08	1.55E-08	8.7E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-89	5.26E-11	1.27E-11	7.41E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-90	4.57E-10	4.9E-11	3.39E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-234	4.55E-10	4.21E-11	2.6E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-235	2.94E-11	2.85E-12	1.75E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-236	3.03E-11	2.8E-12	1.73E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-238	1.59E-09	1.61E-10	9.82E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Am-241	2.57E-11	6.53E-13	4.52E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	C-14	1.56E-07	2.58E-08	1.7E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Cs-137	4.66E-10	6.35E-11	4.26E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	H-3	4.28E-06	6.35E-07	4.22E-07	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	I-129	6.4E-09	5.91E-10	6.03E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	I-131	2.99E-08	2.89E-09	3.02E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Pu-238	8.15E-09	2.83E-10	2.03E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Pu-239	1.94E-09	7.31E-11	5.18E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Ru-106	2.15E-08	9.72E-09	5.45E-09	Air	0

Near Water Family	Child born 1964	Ingestion	Root Vegetables	Sr-89	3.16E-11	7.3E-12	4.25E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Sr-90	4.85E-10	4.82E-11	3.25E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-234	3.5E-10	2.92E-11	1.79E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-235	2.28E-11	2.05E-12	1.25E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-236	2.33E-11	1.94E-12	1.2E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-238	1.27E-09	1.27E-10	7.65E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	Am-241	1.91E-11	4.91E-13	3.4E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	C-14	1.79E-07	3.05E-08	2.01E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	Cs-137	3.37E-10	4.73E-11	3.15E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	H-3	5.2E-06	7.81E-07	5.17E-07	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	I-129	7.83E-09	7.77E-10	7.93E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	I-131	1.4E-07	1.4E-08	1.46E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	Pu-238	9.95E-09	3.46E-10	2.47E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	Pu-239	2.84E-09	1.05E-10	7.43E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	Ru-106	2.95E-08	1.24E-08	6.96E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	Sr-89	5.17E-11	1.14E-11	6.64E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	Sr-90	6.54E-10	5.88E-11	3.96E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-234	5.76E-10	4.53E-11	2.77E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-235	3.68E-11	3.17E-12	1.92E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-236	3.83E-11	3.01E-12	1.84E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-238	1.98E-09	1.82E-10	1.1E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	Am-241	1.34E-12	3.38E-14	2.35E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	C-14	4.91E-08	8.27E-09	5.45E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	Cs-137	2.34E-11	3.3E-12	2.2E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	H-3	3.35E-07	5.35E-08	3.54E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	I-129	4.82E-10	4.6E-11	4.69E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	I-131	8.22E-09	7.95E-10	8.3E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	Pu-238	7.91E-10	2.74E-11	1.96E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	Pu-239	1.71E-10	6.93E-12	4.91E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	Ru-106	1.78E-09	7.73E-10	4.33E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	Sr-89	3.03E-12	7.36E-13	4.28E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	Sr-90	3.08E-11	3.3E-12	2.25E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	U-234	2.66E-11	2.5E-12	1.53E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	U-235	1.67E-12	1.7E-13	1.04E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	U-236	1.77E-12	1.66E-13	1.02E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Grain	U-238	8.96E-11	9.72E-12	5.88E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	Am-241	9.17E-13	2.38E-14	1.64E-14	Air	0

Near Water Family	Child born 1964	Ingestion	Beef	C-14	9.09E-07	1.5E-07	9.95E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	Cs-137	1.74E-08	2.39E-09	1.6E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	H-3	5.99E-06	9.12E-07	6.06E-07	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	I-129	2.28E-07	2.1E-08	2.14E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	I-131	3.11E-06	2.91E-07	3.05E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	Pu-238	7.95E-11	2.77E-12	1.98E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	Pu-239	1.74E-11	6.5E-13	4.62E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	Ru-106	1E-06	4.53E-07	2.54E-07	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	Sr-89	2.58E-10	5.97E-11	3.47E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	Sr-90	2.55E-09	2.41E-10	1.66E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	U-234	9.14E-11	7.7E-12	4.73E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	U-235	5.82E-12	5.28E-13	3.21E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	U-236	6.09E-12	5.13E-13	3.16E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Beef	U-238	3.05E-10	2.74E-11	1.68E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	Am-241	4.66E-16	1.22E-17	8.42E-18	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	C-14	3.01E-08	5.07E-09	3.35E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	Cs-137	1.09E-11	1.51E-12	1.01E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	H-3	8.05E-07	1.27E-07	8.43E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	I-129	2.13E-13	1.97E-14	2.01E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	I-131	3.51E-19	3.48E-20	3.64E-21	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	Pu-238	8.39E-14	2.91E-15	2.08E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	Pu-239	1.85E-14	7.77E-16	5.5E-16	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	Ru-106	4.17E-10	1.96E-10	1.1E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	Sr-89	7.59E-16	1.91E-16	1.11E-16	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	Sr-90	1.12E-13	1.26E-14	8.65E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-234	9.12E-13	9.01E-14	5.53E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-235	6E-14	6.37E-15	3.88E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-236	6.07E-14	5.99E-15	3.69E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-238	3.18E-12	3.33E-13	2.03E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	Am-241	7.87E-14	2.22E-15	1.52E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	C-14	1.39E-06	2.43E-07	1.6E-07	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	Cs-137	4.96E-09	7.34E-10	4.85E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	H-3	2.72E-05	4.27E-06	2.82E-06	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	I-129	2.22E-07	2.21E-08	2.25E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	I-131	4.05E-06	4.02E-07	4.19E-08	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	Pu-238	3.35E-11	1.17E-12	8.35E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	Pu-239	8.75E-12	3.33E-13	2.36E-13	Air	0

Near Water Family	Child born 1964	Ingestion	Milk	Ru-106	2.88E-10	1.25E-10	7.03E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	Sr-89	4.19E-10	9.5E-11	5.52E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	Sr-90	4.52E-09	3.77E-10	2.61E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	U-234	6.1E-10	4.99E-11	3.06E-11	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	U-235	3.81E-11	3.43E-12	2.08E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	U-236	4.06E-11	3.32E-12	2.04E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Milk	U-238	1.97E-09	1.71E-10	1.05E-10	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	Am-241	6.43E-16	1.62E-17	1.13E-17	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	C-14	4.88E-08	8.19E-09	5.41E-09	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	Cs-137	1.05E-12	1.46E-13	9.75E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	H-3	1.76E-06	2.75E-07	1.82E-07	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	I-129	1.35E-10	1.26E-11	1.28E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	I-131	3.57E-16	3.64E-17	3.8E-18	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	Pu-238	2.78E-14	9.65E-16	6.91E-16	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	Pu-239	6.67E-15	2.85E-16	2.02E-16	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	Ru-106	5.53E-13	2.58E-13	1.45E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	Sr-89	4.27E-15	1.09E-15	6.32E-16	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	Sr-90	5.64E-13	5.16E-14	3.78E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-234	1.95E-12	1.96E-13	1.2E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-235	1.32E-13	1.39E-14	8.48E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-236	1.3E-13	1.3E-14	8.02E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-238	6.98E-12	7.03E-13	4.32E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	Am-241	2.33E-14	6.5E-16	4.46E-16	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	Cs-137	2.85E-13	4.24E-14	2.8E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	I-129	8.29E-12	8.35E-13	8.52E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	I-131	3.64E-11	3.67E-12	3.83E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	Pu-238	1.51E-11	5.27E-13	3.76E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	Pu-239	4.19E-12	1.62E-13	1.14E-13	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	Ru-106	3.68E-11	1.59E-11	8.87E-12	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	Sr-89	3.01E-14	6.84E-15	3.98E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	Sr-90	8.93E-13	8.73E-14	5.8E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	U-234	8.07E-13	6.61E-14	4.05E-14	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	U-235	5.1E-14	4.63E-15	2.8E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	U-236	5.37E-14	4.4E-15	2.7E-15	Air	0
Near Water Family	Child born 1964	Ingestion	Soil	U-238	2.91E-12	3.18E-13	1.89E-13	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Am-241	5.22E-16	6.62E-17	4.3E-17	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Ar-41	1.77E-05	3.05E-06	2E-06	Air	0

Near Water Family	Child born 1964	External	Air Immersion	C-14	1.18E-12	3.15E-14	2.71E-14	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Cs-137	4.9E-12	7.08E-13	4.7E-13	Air	0
Near Water Family	Child born 1964	External	Air Immersion	I-129	1.93E-13	2.7E-14	1.64E-14	Air	0
Near Water Family	Child born 1964	External	Air Immersion	I-131	8.47E-10	1.51E-10	9.91E-11	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Pu-238	9.56E-16	1.44E-16	8.17E-17	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Pu-239	1.92E-16	3.14E-17	1.95E-17	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Ru-106	1.32E-10	2.18E-11	1.43E-11	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Sr-89	2.29E-14	9.84E-16	7.65E-16	Air	0
Near Water Family	Child born 1964	External	Air Immersion	Sr-90	7.39E-15	2.75E-16	2.23E-16	Air	0
Near Water Family	Child born 1964	External	Air Immersion	U-234	2.03E-16	3.24E-17	2E-17	Air	0
Near Water Family	Child born 1964	External	Air Immersion	U-235	1.43E-14	2.38E-15	1.56E-15	Air	0
Near Water Family	Child born 1964	External	Air Immersion	U-236	9E-18	1.41E-18	8.43E-19	Air	0
Near Water Family	Child born 1964	External	Air Immersion	U-238	1.85E-15	2.3E-16	1.5E-16	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	Am-241	4.97E-13	6.18E-14	4.02E-14	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	Cs-137	2.86E-09	4.11E-10	2.73E-10	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	I-129	1.52E-10	2.06E-11	1.29E-11	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	I-131	1.8E-08	3.23E-09	2.11E-09	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	Pu-238	4.78E-12	5.83E-13	3.34E-13	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	Pu-239	4.36E-13	5.69E-14	3.38E-14	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	Ru-106	9.58E-08	1.1E-08	7.45E-09	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	Sr-89	3.21E-11	7.53E-13	6.93E-13	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	Sr-90	1.44E-10	3.74E-12	3.36E-12	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	U-234	5.42E-13	6.93E-14	4.11E-14	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	U-235	9.47E-12	1.58E-12	1.03E-12	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	U-236	3.27E-14	4.06E-15	2.37E-15	Air	0
Near Water Family	Child born 1964	External	Ground Contamination	U-238	3.37E-10	1.78E-11	1.34E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Am-241	5.75E-09	1.73E-10	1.5E-10	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	C-14	5.47E-10	9.26E-11	6.09E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Cs-137	1.4E-10	1.92E-11	1.28E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	H-3	8.41E-06	1.31E-06	8.66E-07	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	I-129	9.84E-09	9.28E-10	9.44E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	I-131	4.03E-07	3.83E-08	3.97E-09	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Pu-238	2.12E-06	8.24E-08	7.33E-08	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Pu-239	4.12E-07	1.67E-08	1.47E-08	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Ru-106	7.92E-08	1.87E-08	1.59E-08	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Sr-89	7.91E-11	1.53E-11	1.29E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Sr-90	3.79E-10	5.4E-11	4.9E-11	Air	0

Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-234	2.7E-08	4.17E-09	3.94E-09	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-235	1.57E-09	2.4E-10	2.26E-10	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-236	1.76E-09	2.7E-10	2.56E-10	Air	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-238	7.94E-08	1.21E-08	1.14E-08	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Am-241	2.22E-11	6.67E-13	5.76E-13	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Cs-137	5.31E-13	7.27E-14	4.84E-14	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	I-129	1.55E-11	1.46E-12	1.49E-13	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	I-131	5.5E-11	5.25E-12	5.43E-13	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Pu-238	8.11E-09	3.17E-10	2.82E-10	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Pu-239	1.59E-09	6.43E-11	5.68E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Ru-106	2.44E-10	5.76E-11	4.9E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Sr-89	9.76E-14	1.89E-14	1.59E-14	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Sr-90	1.53E-12	2.28E-13	2.02E-13	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-234	1.04E-10	1.6E-11	1.52E-11	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-235	6.02E-12	9.22E-13	8.7E-13	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-236	6.76E-12	1.04E-12	9.84E-13	Air	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-238	3.06E-10	4.66E-11	4.4E-11	Air	0

Location	Receptor	ReportRou	ReportPathway	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	AirWater	RunNum
Near Water Family	Adult Female	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Water	0
Near Water Family	Adult Female	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Water	0
Near Water Family	Adult Female	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Water	0
Near Water Family	Adult Female	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Water	0
Near Water Family	Adult Female	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Water	0
Near Water Family	Adult Female	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Water	0
Near Water Family	Adult Female	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Water	0
Near Water Family	Adult Female	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Water	0
Near Water Family	Adult Female	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Water	0
Near Water Family	Adult Female	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Water	0
Near Water Family	Adult Female	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Ce-144	3.63E-08	1.49E-09	8.36E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Co-60	2.98E-09	1.13E-10	7.76E-11	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Cs-134	9E-10	3.98E-11	2.87E-11	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Cs-137	5.56E-08	2.47E-09	1.77E-09	Water	0

Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	H-3	5.94E-07	2.62E-08	1.89E-08	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	I-129	9.28E-09	1.86E-10	1.91E-11	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	I-131	1.13E-07	2.32E-09	2.56E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Nb-95	4.44E-09	1.52E-10	9.21E-11	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	P-32	5.12E-09	2.32E-10	1.83E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Pu-238	3.02E-09	3.11E-11	2.59E-11	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Pu-239	1.42E-08	1.36E-10	1.14E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Ru-106	1.44E-07	5.99E-09	3.55E-09	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	S-35	3.49E-09	1.66E-10	1.11E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Sr-89	8.14E-09	3.52E-10	2.38E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Sr-90	1.24E-07	4.83E-09	4.56E-09	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Tc-99	9.46E-10	3.03E-11	1.84E-11	Water	0

Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	U-234	2.77E-10	5.31E-12	3.69E-12	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	U-235	1.26E-10	2.45E-12	1.7E-12	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	U-236	1.56E-11	3E-13	2.09E-13	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	U-238	8.91E-09	1.73E-10	1.21E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Zn-65	6E-09	2.61E-10	1.9E-10	Water	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During	Zr-95	4.81E-09	1.76E-10	1.08E-10	Water	0
Near Water Family	Adult Female	External	Swimming	Ce-144	3.18E-09	1.91E-10	1.59E-10	Water	0
Near Water Family	Adult Female	External	Swimming	Co-60	1.61E-08	9.65E-10	8.04E-10	Water	0
Near Water Family	Adult Female	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Water	0
Near Water Family	Adult Female	External	Swimming	Cs-137	1.63E-08	9.77E-10	8.14E-10	Water	0
Near Water Family	Adult Female	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Water	0
Near Water Family	Adult Female	External	Swimming	I-131	1.37E-08	8.22E-10	6.85E-10	Water	0
Near Water Family	Adult Female	External	Swimming	Nb-95	4.11E-08	2.46E-09	2.06E-09	Water	0
Near Water Family	Adult Female	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Water	0
Near Water Family	Adult Female	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Water	0
Near Water Family	Adult Female	External	Swimming	Pu-239	3.18E-14	1.9E-15	1.59E-15	Water	0
Near Water Family	Adult Female	External	Swimming	Ru-106	3.23E-08	1.94E-09	1.61E-09	Water	0
Near Water Family	Adult Female	External	Swimming	S-35	6.54E-12	3.93E-13	3.27E-13	Water	0
Near Water Family	Adult Female	External	Swimming	Sr-89	1.2E-10	7.18E-12	5.99E-12	Water	0
Near Water Family	Adult Female	External	Swimming	Sr-90	3.51E-11	2.1E-12	1.75E-12	Water	0
Near Water Family	Adult Female	External	Swimming	Tc-99	3.31E-12	1.99E-13	1.66E-13	Water	0
Near Water Family	Adult Female	External	Swimming	U-234	5.59E-15	3.35E-16	2.79E-16	Water	0
Near Water Family	Adult Female	External	Swimming	U-235	2.77E-12	1.66E-13	1.38E-13	Water	0
Near Water Family	Adult Female	External	Swimming	U-236	2.13E-16	1.28E-17	1.06E-17	Water	0
Near Water Family	Adult Female	External	Swimming	U-238	8.43E-14	5.05E-15	4.21E-15	Water	0

Near Water Family	Adult Female	External	Swimming	Zn-65	6.47E-09	3.88E-10	3.24E-10	Water	0
Near Water Family	Adult Female	External	Swimming	Zr-95	2.62E-08	1.57E-09	1.31E-09	Water	0
Near Water Family	Adult Female	External	Boating	Ce-144	3.36E-09	1.01E-10	8.41E-11	Water	0
Near Water Family	Adult Female	External	Boating	Co-60	1.7E-08	5.09E-10	4.24E-10	Water	0
Near Water Family	Adult Female	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Water	0
Near Water Family	Adult Female	External	Boating	Cs-137	1.72E-08	5.15E-10	4.29E-10	Water	0
Near Water Family	Adult Female	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Water	0
Near Water Family	Adult Female	External	Boating	I-131	1.44E-08	4.34E-10	3.62E-10	Water	0
Near Water Family	Adult Female	External	Boating	Nb-95	4.34E-08	1.3E-09	1.08E-09	Water	0
Near Water Family	Adult Female	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Water	0
Near Water Family	Adult Female	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Water	0
Near Water Family	Adult Female	External	Boating	Pu-239	3.35E-14	1.01E-15	8.37E-16	Water	0
Near Water Family	Adult Female	External	Boating	Ru-106	3.41E-08	1.02E-09	8.52E-10	Water	0
Near Water Family	Adult Female	External	Boating	S-35	6.89E-12	2.07E-13	1.72E-13	Water	0
Near Water Family	Adult Female	External	Boating	Sr-89	1.26E-10	3.79E-12	3.16E-12	Water	0
Near Water Family	Adult Female	External	Boating	Sr-90	3.7E-11	1.11E-12	9.25E-13	Water	0
Near Water Family	Adult Female	External	Boating	Tc-99	3.49E-12	1.05E-13	8.74E-14	Water	0
Near Water Family	Adult Female	External	Boating	U-234	5.89E-15	1.77E-16	1.47E-16	Water	0
Near Water Family	Adult Female	External	Boating	U-235	2.92E-12	8.76E-14	7.3E-14	Water	0
Near Water Family	Adult Female	External	Boating	U-236	2.25E-16	6.74E-18	5.62E-18	Water	0
Near Water Family	Adult Female	External	Boating	U-238	8.88E-14	2.67E-15	2.22E-15	Water	0
Near Water Family	Adult Female	External	Boating	Zn-65	6.83E-09	2.05E-10	1.71E-10	Water	0
Near Water Family	Adult Female	External	Boating	Zr-95	2.76E-08	8.28E-10	6.9E-10	Water	0
Near Water Family	Adult Female	External	Shoreline	Ce-144	1.93E-05	3.76E-07	2.95E-07	Water	0
Near Water Family	Adult Female	External	Shoreline	Co-60	4.38E-05	2.11E-06	1.51E-06	Water	0
Near Water Family	Adult Female	External	Shoreline	Cs-134	1.37E-06	6.57E-08	4.69E-08	Water	0
Near Water Family	Adult Female	External	Shoreline	Cs-137	5.2E-05	2.44E-06	1.75E-06	Water	0
Near Water Family	Adult Female	External	Shoreline	I-129	4.01E-08	1.52E-09	1.01E-09	Water	0
Near Water Family	Adult Female	External	Shoreline	I-131	1.4E-06	6.66E-08	4.78E-08	Water	0
Near Water Family	Adult Female	External	Shoreline	Nb-95	1.78E-05	8.55E-07	6.1E-07	Water	0
Near Water Family	Adult Female	External	Shoreline	P-32	2.39E-07	2.04E-09	1.94E-09	Water	0
Near Water Family	Adult Female	External	Shoreline	Pu-238	1.93E-10	5.71E-12	3.49E-12	Water	0
Near Water Family	Adult Female	External	Shoreline	Pu-239	3.74E-10	1.22E-11	7.79E-12	Water	0
Near Water Family	Adult Female	External	Shoreline	Ru-106	0.000119	3.78E-06	2.79E-06	Water	0
Near Water Family	Adult Female	External	Shoreline	S-35	2.69E-09	1.03E-10	6.91E-11	Water	0
Near Water Family	Adult Female	External	Shoreline	Sr-89	1.01E-06	8.58E-09	8.16E-09	Water	0
Near Water Family	Adult Female	External	Shoreline	Sr-90	1.14E-05	1.04E-07	9.74E-08	Water	0

Near Water Family	Adult Female	External	Shoreline	Tc-99	2.23E-09	9.17E-11	6.32E-11	Water	0
Near Water Family	Adult Female	External	Shoreline	U-234	7.63E-11	2.42E-12	1.54E-12	Water	0
Near Water Family	Adult Female	External	Shoreline	U-235	9.78E-09	4.57E-10	3.25E-10	Water	0
Near Water Family	Adult Female	External	Shoreline	U-236	3.92E-12	1.2E-13	7.47E-14	Water	0
Near Water Family	Adult Female	External	Shoreline	U-238	5.14E-07	8.51E-09	6.88E-09	Water	0
Near Water Family	Adult Female	External	Shoreline	Zn-65	1.19E-05	5.74E-07	4.1E-07	Water	0
Near Water Family	Adult Female	External	Shoreline	Zr-95	4.08E-05	1.96E-06	1.4E-06	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Water	0
Near Water Family	Adult Male	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Water	0
Near Water Family	Adult Male	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Water	0
Near Water Family	Adult Male	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Water	0
Near Water Family	Adult Male	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Water	0
Near Water Family	Adult Male	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Water	0
Near Water Family	Adult Male	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Water	0
Near Water Family	Adult Male	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Water	0
Near Water Family	Adult Male	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Water	0
Near Water Family	Adult Male	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Water	0
Near Water Family	Adult Male	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Ce-144	3.63E-08	1.49E-09	8.36E-10	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Co-60	2.98E-09	1.13E-10	7.76E-11	Water	0

Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Cs-134	9E-10	3.98E-11	2.87E-11	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Cs-137	5.56E-08	2.47E-09	1.77E-09	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	H-3	5.94E-07	2.62E-08	1.89E-08	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	I-129	9.28E-09	1.86E-10	1.91E-11	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	I-131	1.13E-07	2.32E-09	2.56E-10	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Nb-95	4.44E-09	1.52E-10	9.21E-11	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	P-32	5.12E-09	2.32E-10	1.83E-10	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Pu-238	3.02E-09	3.11E-11	2.59E-11	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Pu-239	1.42E-08	1.36E-10	1.14E-10	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Ru-106	1.44E-07	5.99E-09	3.55E-09	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	S-35	3.49E-09	1.66E-10	1.11E-10	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Sr-89	8.14E-09	3.52E-10	2.38E-10	Water	0

Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Sr-90	1.24E-07	4.83E-09	4.56E-09	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Tc-99	9.46E-10	3.03E-11	1.84E-11	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	U-234	2.77E-10	5.31E-12	3.69E-12	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	U-235	1.26E-10	2.45E-12	1.7E-12	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	U-236	1.56E-11	3E-13	2.09E-13	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	U-238	8.91E-09	1.73E-10	1.21E-10	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Zn-65	6E-09	2.61E-10	1.9E-10	Water	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During	Zr-95	4.81E-09	1.76E-10	1.08E-10	Water	0
Near Water Family	Adult Male	External	Swimming	Ce-144	3.18E-09	1.91E-10	1.59E-10	Water	0
Near Water Family	Adult Male	External	Swimming	Co-60	1.61E-08	9.65E-10	8.04E-10	Water	0
Near Water Family	Adult Male	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Water	0
Near Water Family	Adult Male	External	Swimming	Cs-137	1.63E-08	9.77E-10	8.14E-10	Water	0
Near Water Family	Adult Male	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Water	0
Near Water Family	Adult Male	External	Swimming	I-131	1.37E-08	8.22E-10	6.85E-10	Water	0
Near Water Family	Adult Male	External	Swimming	Nb-95	4.11E-08	2.46E-09	2.06E-09	Water	0
Near Water Family	Adult Male	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Water	0
Near Water Family	Adult Male	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Water	0
Near Water Family	Adult Male	External	Swimming	Pu-239	3.18E-14	1.9E-15	1.59E-15	Water	0
Near Water Family	Adult Male	External	Swimming	Ru-106	3.23E-08	1.94E-09	1.61E-09	Water	0
Near Water Family	Adult Male	External	Swimming	S-35	6.54E-12	3.93E-13	3.27E-13	Water	0
Near Water Family	Adult Male	External	Swimming	Sr-89	1.2E-10	7.18E-12	5.99E-12	Water	0

Near Water Family	Adult Male	External	Swimming	Sr-90	3.51E-11	2.1E-12	1.75E-12	Water	0
Near Water Family	Adult Male	External	Swimming	Tc-99	3.31E-12	1.99E-13	1.66E-13	Water	0
Near Water Family	Adult Male	External	Swimming	U-234	5.59E-15	3.35E-16	2.79E-16	Water	0
Near Water Family	Adult Male	External	Swimming	U-235	2.77E-12	1.66E-13	1.38E-13	Water	0
Near Water Family	Adult Male	External	Swimming	U-236	2.13E-16	1.28E-17	1.06E-17	Water	0
Near Water Family	Adult Male	External	Swimming	U-238	8.43E-14	5.05E-15	4.21E-15	Water	0
Near Water Family	Adult Male	External	Swimming	Zn-65	6.47E-09	3.88E-10	3.24E-10	Water	0
Near Water Family	Adult Male	External	Swimming	Zr-95	2.62E-08	1.57E-09	1.31E-09	Water	0
Near Water Family	Adult Male	External	Boating	Ce-144	3.36E-09	1.01E-10	8.41E-11	Water	0
Near Water Family	Adult Male	External	Boating	Co-60	1.7E-08	5.09E-10	4.24E-10	Water	0
Near Water Family	Adult Male	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Water	0
Near Water Family	Adult Male	External	Boating	Cs-137	1.72E-08	5.15E-10	4.29E-10	Water	0
Near Water Family	Adult Male	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Water	0
Near Water Family	Adult Male	External	Boating	I-131	1.44E-08	4.34E-10	3.62E-10	Water	0
Near Water Family	Adult Male	External	Boating	Nb-95	4.34E-08	1.3E-09	1.08E-09	Water	0
Near Water Family	Adult Male	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Water	0
Near Water Family	Adult Male	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Water	0
Near Water Family	Adult Male	External	Boating	Pu-239	3.35E-14	1.01E-15	8.37E-16	Water	0
Near Water Family	Adult Male	External	Boating	Ru-106	3.41E-08	1.02E-09	8.52E-10	Water	0
Near Water Family	Adult Male	External	Boating	S-35	6.89E-12	2.07E-13	1.72E-13	Water	0
Near Water Family	Adult Male	External	Boating	Sr-89	1.26E-10	3.79E-12	3.16E-12	Water	0
Near Water Family	Adult Male	External	Boating	Sr-90	3.7E-11	1.11E-12	9.25E-13	Water	0
Near Water Family	Adult Male	External	Boating	Tc-99	3.49E-12	1.05E-13	8.74E-14	Water	0
Near Water Family	Adult Male	External	Boating	U-234	5.89E-15	1.77E-16	1.47E-16	Water	0
Near Water Family	Adult Male	External	Boating	U-235	2.92E-12	8.76E-14	7.3E-14	Water	0
Near Water Family	Adult Male	External	Boating	U-236	2.25E-16	6.74E-18	5.62E-18	Water	0
Near Water Family	Adult Male	External	Boating	U-238	8.88E-14	2.67E-15	2.22E-15	Water	0
Near Water Family	Adult Male	External	Boating	Zn-65	6.83E-09	2.05E-10	1.71E-10	Water	0
Near Water Family	Adult Male	External	Boating	Zr-95	2.76E-08	8.28E-10	6.9E-10	Water	0
Near Water Family	Adult Male	External	Shoreline	Ce-144	1.93E-05	3.76E-07	2.95E-07	Water	0
Near Water Family	Adult Male	External	Shoreline	Co-60	4.38E-05	2.11E-06	1.51E-06	Water	0
Near Water Family	Adult Male	External	Shoreline	Cs-134	1.37E-06	6.57E-08	4.69E-08	Water	0
Near Water Family	Adult Male	External	Shoreline	Cs-137	5.2E-05	2.44E-06	1.75E-06	Water	0
Near Water Family	Adult Male	External	Shoreline	I-129	4.01E-08	1.52E-09	1.01E-09	Water	0
Near Water Family	Adult Male	External	Shoreline	I-131	1.4E-06	6.66E-08	4.78E-08	Water	0
Near Water Family	Adult Male	External	Shoreline	Nb-95	1.78E-05	8.55E-07	6.1E-07	Water	0
Near Water Family	Adult Male	External	Shoreline	P-32	2.39E-07	2.04E-09	1.94E-09	Water	0

Near Water Family	Adult Male	External	Shoreline	Pu-238	1.93E-10	5.71E-12	3.49E-12	Water	0
Near Water Family	Adult Male	External	Shoreline	Pu-239	3.74E-10	1.22E-11	7.79E-12	Water	0
Near Water Family	Adult Male	External	Shoreline	Ru-106	0.000119	3.78E-06	2.79E-06	Water	0
Near Water Family	Adult Male	External	Shoreline	S-35	2.69E-09	1.03E-10	6.91E-11	Water	0
Near Water Family	Adult Male	External	Shoreline	Sr-89	1.01E-06	8.58E-09	8.16E-09	Water	0
Near Water Family	Adult Male	External	Shoreline	Sr-90	1.14E-05	1.04E-07	9.74E-08	Water	0
Near Water Family	Adult Male	External	Shoreline	Tc-99	2.23E-09	9.17E-11	6.32E-11	Water	0
Near Water Family	Adult Male	External	Shoreline	U-234	7.63E-11	2.42E-12	1.54E-12	Water	0
Near Water Family	Adult Male	External	Shoreline	U-235	9.78E-09	4.57E-10	3.25E-10	Water	0
Near Water Family	Adult Male	External	Shoreline	U-236	3.92E-12	1.2E-13	7.47E-14	Water	0
Near Water Family	Adult Male	External	Shoreline	U-238	5.14E-07	8.51E-09	6.88E-09	Water	0
Near Water Family	Adult Male	External	Shoreline	Zn-65	1.19E-05	5.74E-07	4.1E-07	Water	0
Near Water Family	Adult Male	External	Shoreline	Zr-95	4.08E-05	1.96E-06	1.4E-06	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Ce-144	2.8E-06	1.01E-06	5.59E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Co-60	3.02E-06	5E-07	3.19E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Cs-134	4.12E-06	6.64E-07	4.38E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Cs-137	0.000231	4.16E-05	2.7E-05	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	H-3	1E-06	1.32E-07	8.87E-08	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	I-131	1.44E-05	1.59E-06	1.66E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Nb-95	2.97E-06	6.18E-07	3.52E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	P-32	0.000565	0.000108	6.92E-05	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Pu-238	1.44E-05	5.5E-07	4.04E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Pu-239	9.75E-05	3.17E-06	2.29E-06	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Ru-106	3.24E-06	9.43E-07	5.32E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	S-35	5.2E-06	1.24E-06	7.73E-07	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Sr-89	7.31E-06	1.96E-06	1.14E-06	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Sr-90	0.000142	8.88E-06	6.88E-06	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Tc-99	6.22E-08	7.83E-09	4.42E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	U-234	5.61E-09	5.73E-10	3.51E-10	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	U-235	2.12E-09	2.17E-10	1.33E-10	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	U-236	3.31E-10	3.4E-11	2.08E-11	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	U-238	1.48E-07	1.43E-08	8.88E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Zn-65	1.1E-05	1.83E-06	1.21E-06	Water	0
Near Water Family	Child born 1955	Ingestion	Fish	Zr-95	3.24E-06	6.4E-07	3.63E-07	Water	0

Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Ce-144	8.28E-08	3.06E-08	1.69E-08	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Co-60	8.89E-09	1.49E-09	9.51E-10	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Cs-134	7.75E-10	1.27E-10	8.38E-11	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Cs-137	4.65E-08	8.42E-09	5.48E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	H-3	7.35E-07	1.09E-07	7.26E-08	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	I-129	9.28E-09	1.86E-10	1.91E-11	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	I-131	3.83E-07	4.3E-08	4.48E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Nb-95	8.16E-09	1.81E-09	1.03E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	P-32	1.08E-08	2.08E-09	1.33E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Pu-238	2.93E-09	1.15E-10	8.38E-11	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Pu-239	2.04E-08	6.77E-10	4.9E-10	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Ru-106	2.56E-07	8.08E-08	4.54E-08	Water	0

Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	S-35	6.11E-09	1.48E-09	9.18E-10	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Sr-89	1.53E-08	4.11E-09	2.4E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Sr-90	2.88E-07	1.57E-08	1.26E-08	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Tc-99	2.55E-09	3.64E-10	2.03E-10	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	U-234	5.67E-10	5.84E-11	3.59E-11	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	U-235	2.05E-10	2.08E-11	1.28E-11	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	U-236	3.34E-11	3.48E-12	2.13E-12	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	U-238	1.43E-08	1.38E-09	8.56E-10	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Zn-65	9.69E-09	1.64E-09	1.08E-09	Water	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During	Zr-95	7.81E-09	1.74E-09	9.82E-10	Water	0
Near Water Family	Child born 1955	External	Swimming	Ce-144	3.18E-09	1.91E-10	1.59E-10	Water	0
Near Water Family	Child born 1955	External	Swimming	Co-60	1.6E-08	9.63E-10	8.03E-10	Water	0
Near Water Family	Child born 1955	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Water	0
Near Water Family	Child born 1955	External	Swimming	Cs-137	1.63E-08	9.76E-10	8.13E-10	Water	0
Near Water Family	Child born 1955	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Water	0
Near Water Family	Child born 1955	External	Swimming	I-131	1.37E-08	8.22E-10	6.85E-10	Water	0
Near Water Family	Child born 1955	External	Swimming	Nb-95	4.11E-08	2.46E-09	2.06E-09	Water	0

Near Water Family	Child born 1955	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Water	0
Near Water Family	Child born 1955	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Water	0
Near Water Family	Child born 1955	External	Swimming	Pu-239	3.17E-14	1.9E-15	1.59E-15	Water	0
Near Water Family	Child born 1955	External	Swimming	Ru-106	3.23E-08	1.94E-09	1.61E-09	Water	0
Near Water Family	Child born 1955	External	Swimming	S-35	6.54E-12	3.93E-13	3.27E-13	Water	0
Near Water Family	Child born 1955	External	Swimming	Sr-89	1.2E-10	7.18E-12	5.99E-12	Water	0
Near Water Family	Child born 1955	External	Swimming	Sr-90	3.51E-11	2.1E-12	1.75E-12	Water	0
Near Water Family	Child born 1955	External	Swimming	Tc-99	3.23E-12	1.94E-13	1.61E-13	Water	0
Near Water Family	Child born 1955	External	Swimming	U-234	5.59E-15	3.35E-16	2.79E-16	Water	0
Near Water Family	Child born 1955	External	Swimming	U-235	2.77E-12	1.66E-13	1.38E-13	Water	0
Near Water Family	Child born 1955	External	Swimming	U-236	2.13E-16	1.28E-17	1.06E-17	Water	0
Near Water Family	Child born 1955	External	Swimming	U-238	8.43E-14	5.05E-15	4.21E-15	Water	0
Near Water Family	Child born 1955	External	Swimming	Zn-65	6.47E-09	3.88E-10	3.24E-10	Water	0
Near Water Family	Child born 1955	External	Swimming	Zr-95	2.62E-08	1.57E-09	1.31E-09	Water	0
Near Water Family	Child born 1955	External	Boating	Ce-144	3.36E-09	1.01E-10	8.41E-11	Water	0
Near Water Family	Child born 1955	External	Boating	Co-60	1.69E-08	5.08E-10	4.24E-10	Water	0
Near Water Family	Child born 1955	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Water	0
Near Water Family	Child born 1955	External	Boating	Cs-137	1.72E-08	5.14E-10	4.29E-10	Water	0
Near Water Family	Child born 1955	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Water	0
Near Water Family	Child born 1955	External	Boating	I-131	1.44E-08	4.34E-10	3.62E-10	Water	0
Near Water Family	Child born 1955	External	Boating	Nb-95	4.34E-08	1.3E-09	1.08E-09	Water	0
Near Water Family	Child born 1955	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Water	0
Near Water Family	Child born 1955	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Water	0
Near Water Family	Child born 1955	External	Boating	Pu-239	3.35E-14	1E-15	8.37E-16	Water	0
Near Water Family	Child born 1955	External	Boating	Ru-106	3.41E-08	1.02E-09	8.52E-10	Water	0
Near Water Family	Child born 1955	External	Boating	S-35	6.89E-12	2.07E-13	1.72E-13	Water	0
Near Water Family	Child born 1955	External	Boating	Sr-89	1.26E-10	3.79E-12	3.16E-12	Water	0
Near Water Family	Child born 1955	External	Boating	Sr-90	3.7E-11	1.11E-12	9.24E-13	Water	0
Near Water Family	Child born 1955	External	Boating	Tc-99	3.4E-12	1.02E-13	8.51E-14	Water	0
Near Water Family	Child born 1955	External	Boating	U-234	5.89E-15	1.77E-16	1.47E-16	Water	0
Near Water Family	Child born 1955	External	Boating	U-235	2.92E-12	8.76E-14	7.3E-14	Water	0
Near Water Family	Child born 1955	External	Boating	U-236	2.25E-16	6.74E-18	5.62E-18	Water	0
Near Water Family	Child born 1955	External	Boating	U-238	8.88E-14	2.67E-15	2.22E-15	Water	0
Near Water Family	Child born 1955	External	Boating	Zn-65	6.83E-09	2.05E-10	1.71E-10	Water	0
Near Water Family	Child born 1955	External	Boating	Zr-95	2.76E-08	8.28E-10	6.9E-10	Water	0
Near Water Family	Child born 1955	External	Shoreline	Ce-144	1.93E-05	1.22E-06	8.82E-07	Water	0
Near Water Family	Child born 1955	External	Shoreline	Co-60	4.37E-05	7.03E-06	4.63E-06	Water	0

Near Water Family	Child born 1955	External	Shoreline	Cs-134	1.37E-06	2.33E-07	1.53E-07	Water	0
Near Water Family	Child born 1955	External	Shoreline	Cs-137	5.2E-05	8.91E-06	5.85E-06	Water	0
Near Water Family	Child born 1955	External	Shoreline	I-129	4.01E-08	1.52E-09	1.01E-09	Water	0
Near Water Family	Child born 1955	External	Shoreline	I-131	1.4E-06	2.5E-07	1.64E-07	Water	0
Near Water Family	Child born 1955	External	Shoreline	Nb-95	1.78E-05	2.72E-06	1.79E-06	Water	0
Near Water Family	Child born 1955	External	Shoreline	P-32	2.39E-07	5.5E-09	5.05E-09	Water	0
Near Water Family	Child born 1955	External	Shoreline	Pu-238	1.93E-10	2.15E-11	1.24E-11	Water	0
Near Water Family	Child born 1955	External	Shoreline	Pu-239	3.74E-10	4.6E-11	2.74E-11	Water	0
Near Water Family	Child born 1955	External	Shoreline	Ru-106	0.000119	1.13E-05	7.72E-06	Water	0
Near Water Family	Child born 1955	External	Shoreline	S-35	2.69E-09	3.91E-10	2.44E-10	Water	0
Near Water Family	Child born 1955	External	Shoreline	Sr-89	1.01E-06	2.19E-08	2.01E-08	Water	0
Near Water Family	Child born 1955	External	Shoreline	Sr-90	1.14E-05	2.73E-07	2.44E-07	Water	0
Near Water Family	Child born 1955	External	Shoreline	Tc-99	2.17E-09	1.98E-10	1.29E-10	Water	0
Near Water Family	Child born 1955	External	Shoreline	U-234	7.63E-11	9.8E-12	5.81E-12	Water	0
Near Water Family	Child born 1955	External	Shoreline	U-235	9.78E-09	1.68E-09	1.09E-09	Water	0
Near Water Family	Child born 1955	External	Shoreline	U-236	3.92E-12	4.89E-13	2.86E-13	Water	0
Near Water Family	Child born 1955	External	Shoreline	U-238	5.14E-07	2.77E-08	2.06E-08	Water	0
Near Water Family	Child born 1955	External	Shoreline	Zn-65	1.19E-05	2.08E-06	1.37E-06	Water	0
Near Water Family	Child born 1955	External	Shoreline	Zr-95	4.08E-05	5.42E-06	3.59E-06	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Ce-144	3.36E-06	1.11E-06	6.14E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Co-60	2.77E-06	4.92E-07	3.11E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Cs-134	3.06E-06	5.92E-07	3.82E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Cs-137	0.000155	2.9E-05	1.84E-05	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	H-3	7.87E-07	1.21E-07	8.04E-08	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	I-129	7.75E-07	3.45E-08	3.53E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	I-131	2.84E-06	3.2E-07	3.34E-08	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Nb-95	2.82E-06	6.63E-07	3.75E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	P-32	0.001049	0.000241	0.000158	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Pu-238	1.92E-05	9.43E-07	6.62E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Pu-239	7.93E-05	3.42E-06	2.41E-06	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Ru-106	4.03E-06	1.28E-06	7.17E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	S-35	5.73E-06	1.31E-06	8.13E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Sr-89	1.43E-05	2.91E-06	1.69E-06	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Sr-90	9.03E-05	1.18E-05	8.52E-06	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Tc-99	3.39E-08	4.9E-09	2.81E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	U-234	3.38E-09	3.68E-10	2.24E-10	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	U-235	2.18E-09	3.31E-10	2E-10	Water	0

Near Water Family	Child born 1964	Ingestion	Fish	U-236	1.77E-10	1.69E-11	1.02E-11	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	U-238	1.54E-07	2.24E-08	1.36E-08	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Zn-65	9.59E-06	1.28E-06	8.39E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Fish	Zr-95	3.21E-06	8.34E-07	4.7E-07	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Ce-144	1.19E-07	3.89E-08	2.16E-08	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Co-60	9.36E-09	1.66E-09	1.05E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Cs-134	6.74E-10	1.32E-10	8.48E-11	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Cs-137	3.44E-08	6.47E-09	4.12E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	H-3	6.75E-07	1.1E-07	7.24E-08	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	I-129	9.59E-09	4.23E-10	4.32E-11	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	I-131	8.11E-08	9.23E-09	9.59E-10	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Nb-95	9.31E-09	2.21E-09	1.25E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	P-32	2.38E-08	5.41E-09	3.54E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Pu-238	3.92E-09	2.05E-10	1.44E-10	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Pu-239	1.67E-08	7.72E-10	5.46E-10	Water	0

Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Ru-106	4.04E-07	1.28E-07	7.19E-08	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	S-35	7.54E-09	1.74E-09	1.08E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Sr-89	3.29E-08	6.67E-09	3.88E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Sr-90	1.94E-07	2.28E-08	1.72E-08	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Tc-99	1.16E-09	2.02E-10	1.15E-10	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	U-234	3.57E-10	3.91E-11	2.39E-11	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	U-235	2.29E-10	3.48E-11	2.1E-11	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	U-236	1.87E-11	1.8E-12	1.1E-12	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	U-238	1.62E-08	2.37E-09	1.45E-09	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Zn-65	1.02E-08	1.37E-09	8.94E-10	Water	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During	Zr-95	9.66E-09	2.57E-09	1.45E-09	Water	0
Near Water Family	Child born 1964	External	Swimming	Ce-144	1.8E-09	1.08E-10	9.01E-11	Water	0
Near Water Family	Child born 1964	External	Swimming	Co-60	9.75E-09	5.85E-10	4.88E-10	Water	0
Near Water Family	Child born 1964	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Water	0
Near Water Family	Child born 1964	External	Swimming	Cs-137	1.14E-08	6.87E-10	5.72E-10	Water	0

Near Water Family	Child born 1964	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Water	0
Near Water Family	Child born 1964	External	Swimming	I-131	1.83E-09	1.1E-10	9.13E-11	Water	0
Near Water Family	Child born 1964	External	Swimming	Nb-95	2.63E-08	1.58E-09	1.31E-09	Water	0
Near Water Family	Child born 1964	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Water	0
Near Water Family	Child born 1964	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Water	0
Near Water Family	Child born 1964	External	Swimming	Pu-239	2.34E-14	1.4E-15	1.17E-15	Water	0
Near Water Family	Child born 1964	External	Swimming	Ru-106	2.41E-08	1.45E-09	1.21E-09	Water	0
Near Water Family	Child born 1964	External	Swimming	S-35	3.6E-12	2.16E-13	1.8E-13	Water	0
Near Water Family	Child born 1964	External	Swimming	Sr-89	8.86E-11	5.33E-12	4.44E-12	Water	0
Near Water Family	Child born 1964	External	Swimming	Sr-90	2.81E-11	1.68E-12	1.4E-12	Water	0
Near Water Family	Child born 1964	External	Swimming	Tc-99	2.41E-12	1.44E-13	1.2E-13	Water	0
Near Water Family	Child born 1964	External	Swimming	U-234	2.69E-15	1.61E-16	1.34E-16	Water	0
Near Water Family	Child born 1964	External	Swimming	U-235	2.36E-12	1.42E-13	1.18E-13	Water	0
Near Water Family	Child born 1964	External	Swimming	U-236	8.29E-17	4.97E-18	4.15E-18	Water	0
Near Water Family	Child born 1964	External	Swimming	U-238	7.31E-14	4.39E-15	3.65E-15	Water	0
Near Water Family	Child born 1964	External	Swimming	Zn-65	2.84E-09	1.71E-10	1.42E-10	Water	0
Near Water Family	Child born 1964	External	Swimming	Zr-95	1.96E-08	1.17E-09	9.79E-10	Water	0
Near Water Family	Child born 1964	External	Boating	Ce-144	1.9E-09	5.71E-11	4.76E-11	Water	0
Near Water Family	Child born 1964	External	Boating	Co-60	1.03E-08	3.09E-10	2.57E-10	Water	0
Near Water Family	Child born 1964	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Water	0
Near Water Family	Child born 1964	External	Boating	Cs-137	1.21E-08	3.62E-10	3.02E-10	Water	0
Near Water Family	Child born 1964	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Water	0
Near Water Family	Child born 1964	External	Boating	I-131	1.93E-09	5.78E-11	4.81E-11	Water	0
Near Water Family	Child born 1964	External	Boating	Nb-95	2.77E-08	8.32E-10	6.93E-10	Water	0
Near Water Family	Child born 1964	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Water	0
Near Water Family	Child born 1964	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Water	0
Near Water Family	Child born 1964	External	Boating	Pu-239	2.46E-14	7.4E-16	6.16E-16	Water	0
Near Water Family	Child born 1964	External	Boating	Ru-106	2.55E-08	7.64E-10	6.37E-10	Water	0
Near Water Family	Child born 1964	External	Boating	S-35	3.79E-12	1.14E-13	9.48E-14	Water	0
Near Water Family	Child born 1964	External	Boating	Sr-89	9.37E-11	2.81E-12	2.34E-12	Water	0
Near Water Family	Child born 1964	External	Boating	Sr-90	2.96E-11	8.88E-13	7.4E-13	Water	0
Near Water Family	Child born 1964	External	Boating	Tc-99	2.54E-12	7.6E-14	6.34E-14	Water	0
Near Water Family	Child born 1964	External	Boating	U-234	2.83E-15	8.51E-17	7.08E-17	Water	0
Near Water Family	Child born 1964	External	Boating	U-235	2.49E-12	7.47E-14	6.22E-14	Water	0
Near Water Family	Child born 1964	External	Boating	U-236	8.75E-17	2.63E-18	2.19E-18	Water	0
Near Water Family	Child born 1964	External	Boating	U-238	7.7E-14	2.31E-15	1.93E-15	Water	0
Near Water Family	Child born 1964	External	Boating	Zn-65	3E-09	9E-11	7.5E-11	Water	0

Near Water Family	Child born 1964	External	Boating	Zr-95	2.06E-08	6.2E-10	5.17E-10	Water	0
Near Water Family	Child born 1964	External	Shoreline	Ce-144	1.09E-05	7.35E-07	5.34E-07	Water	0
Near Water Family	Child born 1964	External	Shoreline	Co-60	2.66E-05	4.69E-06	3.08E-06	Water	0
Near Water Family	Child born 1964	External	Shoreline	Cs-134	1.37E-06	2.48E-07	1.62E-07	Water	0
Near Water Family	Child born 1964	External	Shoreline	Cs-137	3.66E-05	6.5E-06	4.26E-06	Water	0
Near Water Family	Child born 1964	External	Shoreline	I-129	4.01E-08	3.22E-09	2.05E-09	Water	0
Near Water Family	Child born 1964	External	Shoreline	I-131	1.87E-07	3.37E-08	2.2E-08	Water	0
Near Water Family	Child born 1964	External	Shoreline	Nb-95	1.14E-05	1.96E-06	1.28E-06	Water	0
Near Water Family	Child born 1964	External	Shoreline	P-32	2.39E-07	6.15E-09	5.68E-09	Water	0
Near Water Family	Child born 1964	External	Shoreline	Pu-238	1.93E-10	2.38E-11	1.36E-11	Water	0
Near Water Family	Child born 1964	External	Shoreline	Pu-239	2.75E-10	3.59E-11	2.13E-11	Water	0
Near Water Family	Child born 1964	External	Shoreline	Ru-106	8.92E-05	9.84E-06	6.68E-06	Water	0
Near Water Family	Child born 1964	External	Shoreline	S-35	1.48E-09	2.2E-10	1.37E-10	Water	0
Near Water Family	Child born 1964	External	Shoreline	Sr-89	7.46E-07	1.81E-08	1.67E-08	Water	0
Near Water Family	Child born 1964	External	Shoreline	Sr-90	9.15E-06	2.46E-07	2.21E-07	Water	0
Near Water Family	Child born 1964	External	Shoreline	Tc-99	1.62E-09	1.51E-10	9.79E-11	Water	0
Near Water Family	Child born 1964	External	Shoreline	U-234	3.67E-11	4.81E-12	2.85E-12	Water	0
Near Water Family	Child born 1964	External	Shoreline	U-235	8.34E-09	1.48E-09	9.62E-10	Water	0
Near Water Family	Child born 1964	External	Shoreline	U-236	1.52E-12	1.94E-13	1.13E-13	Water	0
Near Water Family	Child born 1964	External	Shoreline	U-238	4.46E-07	2.55E-08	1.91E-08	Water	0
Near Water Family	Child born 1964	External	Shoreline	Zn-65	5.25E-06	9.53E-07	6.22E-07	Water	0
Near Water Family	Child born 1964	External	Shoreline	Zr-95	3.05E-05	5.03E-06	3.3E-06	Water	0

Location	Receptor	ReportRou	ReportPathway	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	Expr1	RunNum
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Am-241	6.18E-11	6.02E-13	4.69E-13	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	C-14	6E-08	2.95E-09	2.12E-09	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Cs-137	2.58E-09	1.26E-10	8.99E-11	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	H-3	1.63E-06	7.91E-08	5.68E-08	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	I-129	2.23E-08	4.85E-10	4.97E-11	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	I-131	1.35E-05	3.01E-07	3.3E-08	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Pu-238	2.43E-08	2.77E-10	2.31E-10	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Pu-239	1.71E-07	1.82E-09	1.52E-09	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Ru-106	5.5E-08	2.6E-09	1.53E-09	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Sr-89	1.2E-10	5.76E-12	3.87E-12	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	Sr-90	7.17E-08	3.01E-09	2.73E-09	Both	0

Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-234	2.87E-09	6.08E-11	4.23E-11	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-235	1.23E-10	2.69E-12	1.84E-12	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-236	1.91E-10	4.05E-12	2.8E-12	Both	0
Near Water Family	Adult Female	Ingestion	Leafy Vegetables	U-238	5.31E-09	1.18E-10	8.11E-11	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Am-241	2.11E-11	2.06E-13	1.61E-13	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	C-14	2.06E-07	1.01E-08	7.26E-09	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Cs-137	9.55E-10	4.66E-11	3.33E-11	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	H-3	5.17E-06	2.51E-07	1.8E-07	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	I-129	7.64E-09	1.66E-10	1.71E-11	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	I-131	1.51E-06	3.36E-08	3.68E-09	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Pu-238	8.31E-09	9.49E-11	7.92E-11	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Pu-239	5.85E-08	6.24E-10	5.22E-10	Both	0

Near Water Family	Adult Female	Ingestion	Root Vegetables	Ru-106	1.85E-08	8.72E-10	5.14E-10	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Sr-89	3.8E-11	1.82E-12	1.22E-12	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	Sr-90	3.11E-08	1.31E-09	1.18E-09	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-234	9.86E-10	2.09E-11	1.45E-11	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-235	4.22E-11	9.21E-13	6.32E-13	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-236	6.54E-11	1.39E-12	9.64E-13	Both	0
Near Water Family	Adult Female	Ingestion	Root Vegetables	U-238	1.85E-09	4.16E-11	2.85E-11	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	Am-241	2.09E-11	2.04E-13	1.59E-13	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	C-14	2.03E-07	9.99E-09	7.18E-09	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	Cs-137	8.56E-10	4.18E-11	2.98E-11	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	H-3	5.1E-06	2.48E-07	1.78E-07	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	I-129	7.56E-09	1.65E-10	1.69E-11	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	I-131	4.59E-06	1.02E-07	1.12E-08	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	Pu-238	8.22E-09	9.39E-11	7.84E-11	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	Pu-239	5.79E-08	6.17E-10	5.16E-10	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	Ru-106	1.87E-08	8.85E-10	5.21E-10	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	Sr-89	4.09E-11	1.96E-12	1.32E-12	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	Sr-90	2.46E-08	1.03E-09	9.37E-10	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	U-234	9.73E-10	2.06E-11	1.43E-11	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	U-235	4.18E-11	9.11E-13	6.25E-13	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	U-236	6.47E-11	1.38E-12	9.53E-13	Both	0
Near Water Family	Adult Female	Ingestion	Fruit	U-238	1.8E-09	3.99E-11	2.75E-11	Both	0
Near Water Family	Adult Female	Ingestion	Grain	Am-241	1.29E-12	1.26E-14	9.83E-15	Both	0

Near Water Family	Adult Female	Ingestion	Grain	C-14	5.43E-08	2.67E-09	1.92E-09	Both	0
Near Water Family	Adult Female	Ingestion	Grain	Cs-137	5.18E-11	2.52E-12	1.8E-12	Both	0
Near Water Family	Adult Female	Ingestion	Grain	H-3	3.62E-07	1.77E-08	1.27E-08	Both	0
Near Water Family	Adult Female	Ingestion	Grain	I-129	4.74E-10	1.03E-11	1.06E-12	Both	0
Near Water Family	Adult Female	Ingestion	Grain	I-131	2.76E-07	6.15E-09	6.73E-10	Both	0
Near Water Family	Adult Female	Ingestion	Grain	Pu-238	5.12E-10	5.84E-12	4.87E-12	Both	0
Near Water Family	Adult Female	Ingestion	Grain	Pu-239	3.59E-09	3.83E-11	3.2E-11	Both	0
Near Water Family	Adult Female	Ingestion	Grain	Ru-106	1.15E-09	5.45E-11	3.21E-11	Both	0
Near Water Family	Adult Female	Ingestion	Grain	Sr-89	2.6E-12	1.25E-13	8.36E-14	Both	0
Near Water Family	Adult Female	Ingestion	Grain	Sr-90	1.68E-09	7.05E-11	6.41E-11	Both	0
Near Water Family	Adult Female	Ingestion	Grain	U-234	6.03E-11	1.28E-12	8.89E-13	Both	0
Near Water Family	Adult Female	Ingestion	Grain	U-235	2.58E-12	5.64E-14	3.87E-14	Both	0
Near Water Family	Adult Female	Ingestion	Grain	U-236	4.01E-12	8.53E-14	5.9E-14	Both	0
Near Water Family	Adult Female	Ingestion	Grain	U-238	1.12E-10	2.48E-12	1.71E-12	Both	0
Near Water Family	Adult Female	Ingestion	Beef	Am-241	5.95E-13	5.8E-15	4.52E-15	Both	0
Near Water Family	Adult Female	Ingestion	Beef	C-14	9.52E-07	4.67E-08	3.36E-08	Both	0
Near Water Family	Adult Female	Ingestion	Beef	Cs-137	3.11E-08	1.52E-09	1.08E-09	Both	0
Near Water Family	Adult Female	Ingestion	Beef	H-3	5.98E-06	2.91E-07	2.09E-07	Both	0
Near Water Family	Adult Female	Ingestion	Beef	I-129	2.15E-07	4.67E-09	4.79E-10	Both	0
Near Water Family	Adult Female	Ingestion	Beef	I-131	0.000125	2.78E-06	3.04E-07	Both	0
Near Water Family	Adult Female	Ingestion	Beef	Pu-238	5.85E-11	6.69E-13	5.58E-13	Both	0
Near Water Family	Adult Female	Ingestion	Beef	Pu-239	4.11E-10	4.39E-12	3.67E-12	Both	0
Near Water Family	Adult Female	Ingestion	Beef	Ru-106	6.67E-07	3.15E-08	1.86E-08	Both	0
Near Water Family	Adult Female	Ingestion	Beef	Sr-89	2.4E-10	1.15E-11	7.71E-12	Both	0
Near Water Family	Adult Female	Ingestion	Beef	Sr-90	1.38E-07	5.81E-09	5.27E-09	Both	0
Near Water Family	Adult Female	Ingestion	Beef	U-234	2.08E-10	4.41E-12	3.07E-12	Both	0
Near Water Family	Adult Female	Ingestion	Beef	U-235	8.9E-12	1.94E-13	1.33E-13	Both	0
Near Water Family	Adult Female	Ingestion	Beef	U-236	1.38E-11	2.93E-13	2.03E-13	Both	0
Near Water Family	Adult Female	Ingestion	Beef	U-238	3.78E-10	8.25E-12	5.71E-12	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	Am-241	3.64E-16	3.55E-18	2.77E-18	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	C-14	3.64E-08	1.78E-09	1.28E-09	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	Cs-137	2.45E-11	1.2E-12	8.52E-13	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	H-3	9.7E-07	4.72E-08	3.39E-08	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	I-129	2.3E-13	5E-15	5.13E-16	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	I-131	1.52E-17	3.39E-19	3.7E-20	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	Pu-238	7.16E-14	8.16E-16	6.8E-16	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	Pu-239	5.06E-13	5.39E-15	4.49E-15	Both	0

Near Water Family	Adult Female	Ingestion	Poultry	Ru-106	3.07E-10	1.45E-11	8.55E-12	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	Sr-89	8.71E-16	4.17E-17	2.8E-17	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	Sr-90	8.11E-12	3.41E-13	3.09E-13	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	U-234	2.84E-12	6E-14	4.18E-14	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	U-235	1.22E-13	2.65E-15	1.82E-15	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	U-236	1.89E-13	3.99E-15	2.77E-15	Both	0
Near Water Family	Adult Female	Ingestion	Poultry	U-238	5.16E-12	1.12E-13	7.81E-14	Both	0
Near Water Family	Adult Female	Ingestion	Milk	Am-241	3.35E-14	3.27E-16	2.54E-16	Both	0
Near Water Family	Adult Female	Ingestion	Milk	C-14	6.2E-07	3.05E-08	2.19E-08	Both	0
Near Water Family	Adult Female	Ingestion	Milk	Cs-137	7.66E-09	3.73E-10	2.66E-10	Both	0
Near Water Family	Adult Female	Ingestion	Milk	H-3	1.11E-05	5.4E-07	3.88E-07	Both	0
Near Water Family	Adult Female	Ingestion	Milk	I-129	8.05E-08	1.75E-09	1.8E-10	Both	0
Near Water Family	Adult Female	Ingestion	Milk	I-131	5.03E-05	1.12E-06	1.23E-07	Both	0
Near Water Family	Adult Female	Ingestion	Milk	Pu-238	9.65E-12	1.1E-13	9.2E-14	Both	0
Near Water Family	Adult Female	Ingestion	Milk	Pu-239	6.77E-11	7.25E-13	6.06E-13	Both	0
Near Water Family	Adult Female	Ingestion	Milk	Ru-106	6.62E-11	3.13E-12	1.84E-12	Both	0
Near Water Family	Adult Female	Ingestion	Milk	Sr-89	1.27E-10	6.1E-12	4.09E-12	Both	0
Near Water Family	Adult Female	Ingestion	Milk	Sr-90	7.15E-08	2.99E-09	2.74E-09	Both	0
Near Water Family	Adult Female	Ingestion	Milk	U-234	4.15E-10	8.8E-12	6.12E-12	Both	0
Near Water Family	Adult Female	Ingestion	Milk	U-235	1.78E-11	3.87E-13	2.66E-13	Both	0
Near Water Family	Adult Female	Ingestion	Milk	U-236	2.76E-11	5.87E-13	4.06E-13	Both	0
Near Water Family	Adult Female	Ingestion	Milk	U-238	7.51E-10	1.63E-11	1.13E-11	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	Am-241	4.47E-16	4.37E-18	3.4E-18	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	C-14	5.02E-08	2.47E-09	1.77E-09	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	Cs-137	1.81E-12	8.84E-14	6.31E-14	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	H-3	1.77E-06	8.6E-08	6.18E-08	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	I-129	1.27E-10	2.77E-12	2.84E-13	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	I-131	1.3E-14	2.89E-16	3.17E-17	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	Pu-238	2.19E-14	2.5E-16	2.09E-16	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	Pu-239	1.55E-13	1.66E-15	1.38E-15	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	Ru-106	3.58E-13	1.69E-14	9.97E-15	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	Sr-89	4.31E-15	2.06E-16	1.38E-16	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	Sr-90	3.55E-11	1.48E-12	1.38E-12	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	U-234	5.23E-12	1.11E-13	7.72E-14	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	U-235	2.24E-13	4.86E-15	3.34E-15	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	U-236	3.48E-13	7.38E-15	5.12E-15	Both	0
Near Water Family	Adult Female	Ingestion	Eggs	U-238	9.43E-12	2.03E-13	1.42E-13	Both	0

Near Water Family	Adult Female	Ingestion	Soil	Am-241	1.47E-14	1.43E-16	1.12E-16	Both	0
Near Water Family	Adult Female	Ingestion	Soil	Cs-137	5.72E-13	2.79E-14	1.99E-14	Both	0
Near Water Family	Adult Female	Ingestion	Soil	I-129	3.89E-12	8.48E-14	8.7E-15	Both	0
Near Water Family	Adult Female	Ingestion	Soil	I-131	5.59E-10	1.24E-11	1.36E-12	Both	0
Near Water Family	Adult Female	Ingestion	Soil	Pu-238	5.78E-12	6.6E-14	5.51E-14	Both	0
Near Water Family	Adult Female	Ingestion	Soil	Pu-239	4.05E-11	4.34E-13	3.63E-13	Both	0
Near Water Family	Adult Female	Ingestion	Soil	Ru-106	1.08E-11	5.11E-13	3.01E-13	Both	0
Near Water Family	Adult Female	Ingestion	Soil	Sr-89	1.15E-14	5.53E-16	3.71E-16	Both	0
Near Water Family	Adult Female	Ingestion	Soil	Sr-90	1.68E-11	7.07E-13	6.38E-13	Both	0
Near Water Family	Adult Female	Ingestion	Soil	U-234	6.82E-13	1.44E-14	1.01E-14	Both	0
Near Water Family	Adult Female	Ingestion	Soil	U-235	2.93E-14	6.39E-16	4.39E-16	Both	0
Near Water Family	Adult Female	Ingestion	Soil	U-236	4.54E-14	9.65E-16	6.69E-16	Both	0
Near Water Family	Adult Female	Ingestion	Soil	U-238	1.31E-12	3E-14	2.04E-14	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Both	0
Near Water Family	Adult Female	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Both	0
Near Water Family	Adult Female	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Both	0
Near Water Family	Adult Female	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Both	0
Near Water Family	Adult Female	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Both	0
Near Water Family	Adult Female	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Both	0
Near Water Family	Adult Female	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Both	0
Near Water Family	Adult Female	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Both	0
Near Water Family	Adult Female	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Both	0
Near Water Family	Adult Female	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Both	0
Near Water Family	Adult Female	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Both	0

Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Ce-144	3.63E-08	1.49E-09	8.36E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Co-60	2.98E-09	1.13E-10	7.76E-11	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-134	9E-10	3.98E-11	2.87E-11	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	5.56E-08	2.47E-09	1.77E-09	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	5.94E-07	2.62E-08	1.89E-08	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	I-129	9.28E-09	1.86E-10	1.91E-11	Both	0

Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	I-131	1.13E-07	2.32E-09	2.56E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Nb-95	4.44E-09	1.52E-10	9.21E-11	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	P-32	5.12E-09	2.32E-10	1.83E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-238	3.02E-09	3.11E-11	2.59E-11	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-239	1.42E-08	1.36E-10	1.14E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Ru-106	1.44E-07	5.99E-09	3.55E-09	Both	0

Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	S-35	3.49E-09	1.66E-10	1.11E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-89	8.14E-09	3.52E-10	2.38E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	1.24E-07	4.83E-09	4.56E-09	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Tc-99	9.46E-10	3.03E-11	1.84E-11	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	U-234	2.77E-10	5.31E-12	3.69E-12	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	U-235	1.26E-10	2.45E-12	1.7E-12	Both	0

Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	U-236	1.56E-11	3E-13	2.09E-13	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	U-238	8.91E-09	1.73E-10	1.21E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Zn-65	6E-09	2.61E-10	1.9E-10	Both	0
Near Water Family	Adult Female	Ingestion	Inadvertent Water Ingestion During Swimming	Zr-95	4.81E-09	1.76E-10	1.08E-10	Both	0
Near Water Family	Adult Female	External	Air Immersion	Am-241	5.22E-16	2.29E-17	1.6E-17	Both	0
Near Water Family	Adult Female	External	Air Immersion	Ar-41	3.56E-05	1.71E-06	1.23E-06	Both	0
Near Water Family	Adult Female	External	Air Immersion	C-14	1.8E-12	1.75E-14	1.58E-14	Both	0
Near Water Family	Adult Female	External	Air Immersion	Cs-137	1.18E-11	5.62E-13	4.01E-13	Both	0

Near Water Family	Adult Female	External	Air Immersion	I-129	2.73E-13	1.05E-14	6.9E-15	Both	0
Near Water Family	Adult Female	External	Air Immersion	I-131	1.39E-07	6.59E-09	4.7E-09	Both	0
Near Water Family	Adult Female	External	Air Immersion	Pu-238	9.56E-16	3.51E-17	2.15E-17	Both	0
Near Water Family	Adult Female	External	Air Immersion	Pu-239	6.05E-15	2.6E-16	1.77E-16	Both	0
Near Water Family	Adult Female	External	Air Immersion	Ru-106	2.2E-10	9.71E-12	6.98E-12	Both	0
Near Water Family	Adult Female	External	Air Immersion	Sr-89	6.58E-14	8.88E-16	7.47E-16	Both	0
Near Water Family	Adult Female	External	Air Immersion	Sr-90	8.93E-13	1.06E-14	9.2E-15	Both	0
Near Water Family	Adult Female	External	Air Immersion	U-234	9.06E-16	3.77E-17	2.53E-17	Both	0
Near Water Family	Adult Female	External	Air Immersion	U-235	4.36E-14	2.04E-15	1.45E-15	Both	0
Near Water Family	Adult Female	External	Air Immersion	U-236	4.03E-17	1.6E-18	1.04E-18	Both	0
Near Water Family	Adult Female	External	Air Immersion	U-238	4.53E-15	1.61E-16	1.15E-16	Both	0
Near Water Family	Adult Female	External	Ground Contamination	Am-241	4.95E-13	2.1E-14	1.46E-14	Both	0

Near Water Family	Adult Female	External	Ground Contamination	Cs-137	6.86E-09	3.23E-10	2.31E-10	Both	0
Near Water Family	Adult Female	External	Ground Contamination	I-129	2.13E-10	8.07E-12	5.38E-12	Both	0
Near Water Family	Adult Female	External	Ground Contamination	I-131	2.75E-06	1.31E-07	9.37E-08	Both	0
Near Water Family	Adult Female	External	Ground Contamination	Pu-238	4.7E-12	1.39E-13	8.47E-14	Both	0
Near Water Family	Adult Female	External	Ground Contamination	Pu-239	1.36E-11	4.43E-13	2.83E-13	Both	0
Near Water Family	Adult Female	External	Ground Contamination	Ru-106	1.57E-07	4.98E-09	3.68E-09	Both	0
Near Water Family	Adult Female	External	Ground Contamination	Sr-89	9.12E-11	7.77E-13	7.4E-13	Both	0
Near Water Family	Adult Female	External	Ground Contamination	Sr-90	1.8E-08	1.64E-10	1.53E-10	Both	0
Near Water Family	Adult Female	External	Ground Contamination	U-234	2.39E-12	7.57E-14	4.81E-14	Both	0
Near Water Family	Adult Female	External	Ground Contamination	U-235	2.86E-11	1.34E-12	9.54E-13	Both	0
Near Water Family	Adult Female	External	Ground Contamination	U-236	1.44E-13	4.41E-15	2.75E-15	Both	0
Near Water Family	Adult Female	External	Ground Contamination	U-238	8.21E-10	1.36E-11	1.1E-11	Both	0

Near Water Family	Adult Female	External	Swimming	Ce-144	3.18E-09	1.91E-10	1.59E-10	Both	0
Near Water Family	Adult Female	External	Swimming	Co-60	1.61E-08	9.65E-10	8.04E-10	Both	0
Near Water Family	Adult Female	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Both	0
Near Water Family	Adult Female	External	Swimming	Cs-137	1.63E-08	9.77E-10	8.14E-10	Both	0
Near Water Family	Adult Female	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Both	0
Near Water Family	Adult Female	External	Swimming	I-131	1.37E-08	8.22E-10	6.85E-10	Both	0
Near Water Family	Adult Female	External	Swimming	Nb-95	4.11E-08	2.46E-09	2.06E-09	Both	0
Near Water Family	Adult Female	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Both	0
Near Water Family	Adult Female	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Both	0
Near Water Family	Adult Female	External	Swimming	Pu-239	3.18E-14	1.9E-15	1.59E-15	Both	0
Near Water Family	Adult Female	External	Swimming	Ru-106	3.23E-08	1.94E-09	1.61E-09	Both	0
Near Water Family	Adult Female	External	Swimming	S-35	6.54E-12	3.93E-13	3.27E-13	Both	0
Near Water Family	Adult Female	External	Swimming	Sr-89	1.2E-10	7.18E-12	5.99E-12	Both	0
Near Water Family	Adult Female	External	Swimming	Sr-90	3.51E-11	2.1E-12	1.75E-12	Both	0
Near Water Family	Adult Female	External	Swimming	Tc-99	3.31E-12	1.99E-13	1.66E-13	Both	0
Near Water Family	Adult Female	External	Swimming	U-234	5.59E-15	3.35E-16	2.79E-16	Both	0
Near Water Family	Adult Female	External	Swimming	U-235	2.77E-12	1.66E-13	1.38E-13	Both	0
Near Water Family	Adult Female	External	Swimming	U-236	2.13E-16	1.28E-17	1.06E-17	Both	0

Near Water Family	Adult Female	External	Swimming	U-238	8.43E-14	5.05E-15	4.21E-15	Both	0
Near Water Family	Adult Female	External	Swimming	Zn-65	6.47E-09	3.88E-10	3.24E-10	Both	0
Near Water Family	Adult Female	External	Swimming	Zr-95	2.62E-08	1.57E-09	1.31E-09	Both	0
Near Water Family	Adult Female	External	Boating	Ce-144	3.36E-09	1.01E-10	8.41E-11	Both	0
Near Water Family	Adult Female	External	Boating	Co-60	1.7E-08	5.09E-10	4.24E-10	Both	0
Near Water Family	Adult Female	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Both	0
Near Water Family	Adult Female	External	Boating	Cs-137	1.72E-08	5.15E-10	4.29E-10	Both	0
Near Water Family	Adult Female	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Both	0
Near Water Family	Adult Female	External	Boating	I-131	1.44E-08	4.34E-10	3.62E-10	Both	0
Near Water Family	Adult Female	External	Boating	Nb-95	4.34E-08	1.3E-09	1.08E-09	Both	0
Near Water Family	Adult Female	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Both	0
Near Water Family	Adult Female	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Both	0
Near Water Family	Adult Female	External	Boating	Pu-239	3.35E-14	1.01E-15	8.37E-16	Both	0
Near Water Family	Adult Female	External	Boating	Ru-106	3.41E-08	1.02E-09	8.52E-10	Both	0
Near Water Family	Adult Female	External	Boating	S-35	6.89E-12	2.07E-13	1.72E-13	Both	0
Near Water Family	Adult Female	External	Boating	Sr-89	1.26E-10	3.79E-12	3.16E-12	Both	0
Near Water Family	Adult Female	External	Boating	Sr-90	3.7E-11	1.11E-12	9.25E-13	Both	0
Near Water Family	Adult Female	External	Boating	Tc-99	3.49E-12	1.05E-13	8.74E-14	Both	0
Near Water Family	Adult Female	External	Boating	U-234	5.89E-15	1.77E-16	1.47E-16	Both	0
Near Water Family	Adult Female	External	Boating	U-235	2.92E-12	8.76E-14	7.3E-14	Both	0
Near Water Family	Adult Female	External	Boating	U-236	2.25E-16	6.74E-18	5.62E-18	Both	0
Near Water Family	Adult Female	External	Boating	U-238	8.88E-14	2.67E-15	2.22E-15	Both	0
Near Water Family	Adult Female	External	Boating	Zn-65	6.83E-09	2.05E-10	1.71E-10	Both	0
Near Water Family	Adult Female	External	Boating	Zr-95	2.76E-08	8.28E-10	6.9E-10	Both	0
Near Water Family	Adult Female	External	Shoreline	Ce-144	1.93E-05	3.76E-07	2.95E-07	Both	0
Near Water Family	Adult Female	External	Shoreline	Co-60	4.38E-05	2.11E-06	1.51E-06	Both	0
Near Water Family	Adult Female	External	Shoreline	Cs-134	1.37E-06	6.57E-08	4.69E-08	Both	0
Near Water Family	Adult Female	External	Shoreline	Cs-137	5.2E-05	2.44E-06	1.75E-06	Both	0
Near Water Family	Adult Female	External	Shoreline	I-129	4.01E-08	1.52E-09	1.01E-09	Both	0
Near Water Family	Adult Female	External	Shoreline	I-131	1.4E-06	6.66E-08	4.78E-08	Both	0
Near Water Family	Adult Female	External	Shoreline	Nb-95	1.78E-05	8.55E-07	6.1E-07	Both	0
Near Water Family	Adult Female	External	Shoreline	P-32	2.39E-07	2.04E-09	1.94E-09	Both	0
Near Water Family	Adult Female	External	Shoreline	Pu-238	1.93E-10	5.71E-12	3.49E-12	Both	0
Near Water Family	Adult Female	External	Shoreline	Pu-239	3.74E-10	1.22E-11	7.79E-12	Both	0

Near Water Family	Adult Female	External	Shoreline	Ru-106	0.000119	3.78E-06	2.79E-06	Both	0
Near Water Family	Adult Female	External	Shoreline	S-35	2.69E-09	1.03E-10	6.91E-11	Both	0
Near Water Family	Adult Female	External	Shoreline	Sr-89	1.01E-06	8.58E-09	8.16E-09	Both	0
Near Water Family	Adult Female	External	Shoreline	Sr-90	1.14E-05	1.04E-07	9.74E-08	Both	0
Near Water Family	Adult Female	External	Shoreline	Tc-99	2.23E-09	9.17E-11	6.32E-11	Both	0
Near Water Family	Adult Female	External	Shoreline	U-234	7.63E-11	2.42E-12	1.54E-12	Both	0
Near Water Family	Adult Female	External	Shoreline	U-235	9.78E-09	4.57E-10	3.25E-10	Both	0
Near Water Family	Adult Female	External	Shoreline	U-236	3.92E-12	1.2E-13	7.47E-14	Both	0
Near Water Family	Adult Female	External	Shoreline	U-238	5.14E-07	8.51E-09	6.88E-09	Both	0
Near Water Family	Adult Female	External	Shoreline	Zn-65	1.19E-05	5.74E-07	4.1E-07	Both	0
Near Water Family	Adult Female	External	Shoreline	Zr-95	4.08E-05	1.96E-06	1.4E-06	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Am-241	4.21E-09	5.5E-11	4.74E-11	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	C-14	5.67E-10	2.74E-11	1.97E-11	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Cs-137	2.82E-10	1.32E-11	9.41E-12	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	H-3	8.98E-06	4.36E-07	3.13E-07	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	I-129	9.45E-09	2.06E-10	2.11E-11	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	I-131	1.66E-05	3.69E-07	3.98E-08	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Pu-238	1.65E-06	2.31E-08	2.05E-08	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Pu-239	1.14E-05	1.46E-07	1.29E-07	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Ru-106	7.57E-08	4.01E-09	3.66E-09	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Sr-89	1.2E-10	6.43E-12	5.94E-12	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	Sr-90	2.81E-08	1.4E-09	1.32E-09	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	U-234	6.74E-08	3.5E-09	3.31E-09	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	U-235	2.7E-09	1.4E-10	1.32E-10	Both	0

Near Water Family	Adult Female	Inhalation	Air Inhalation	U-236	4.36E-09	2.26E-10	2.14E-10	Both	0
Near Water Family	Adult Female	Inhalation	Air Inhalation	U-238	1.11E-07	5.73E-09	5.38E-09	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Am-241	1.62E-11	2.12E-13	1.82E-13	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Cs-137	1.07E-12	5E-14	3.56E-14	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	I-129	1.49E-11	3.25E-13	3.33E-14	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	I-131	2.13E-09	4.76E-11	5.13E-12	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Pu-238	6.31E-09	8.87E-11	7.89E-11	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Pu-239	4.37E-08	5.61E-10	4.96E-10	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Ru-106	2.33E-10	1.24E-11	1.13E-11	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Sr-89	1.48E-13	7.93E-15	7.32E-15	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	Sr-90	1.11E-10	5.53E-12	5.23E-12	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-234	2.6E-10	1.35E-11	1.28E-11	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-235	1.04E-11	5.38E-13	5.08E-13	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-236	1.68E-11	8.69E-13	8.21E-13	Both	0
Near Water Family	Adult Female	Inhalation	Resuspended Soil	U-238	4.27E-10	2.21E-11	2.08E-11	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Am-241	6.18E-11	6.02E-13	4.69E-13	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	C-14	6E-08	2.95E-09	2.12E-09	Both	0

Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Cs-137	2.58E-09	1.26E-10	8.99E-11	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	H-3	1.63E-06	7.91E-08	5.68E-08	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	I-129	2.23E-08	4.85E-10	4.97E-11	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	I-131	1.35E-05	3.01E-07	3.3E-08	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Pu-238	2.43E-08	2.77E-10	2.31E-10	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Pu-239	1.71E-07	1.82E-09	1.52E-09	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Ru-106	5.5E-08	2.6E-09	1.53E-09	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Sr-89	1.2E-10	5.76E-12	3.87E-12	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	Sr-90	7.17E-08	3.01E-09	2.73E-09	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-234	2.87E-09	6.08E-11	4.23E-11	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-235	1.23E-10	2.69E-12	1.84E-12	Both	0
Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-236	1.91E-10	4.05E-12	2.8E-12	Both	0

Near Water Family	Adult Male	Ingestion	Leafy Vegetables	U-238	5.31E-09	1.18E-10	8.11E-11	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Am-241	2.92E-11	2.85E-13	2.22E-13	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	C-14	2.85E-07	1.4E-08	1E-08	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Cs-137	1.32E-09	6.46E-11	4.61E-11	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	H-3	7.15E-06	3.47E-07	2.49E-07	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	I-129	1.06E-08	2.3E-10	2.36E-11	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	I-131	2.09E-06	4.65E-08	5.09E-09	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Pu-238	1.15E-08	1.31E-10	1.1E-10	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Pu-239	8.1E-08	8.64E-10	7.23E-10	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Ru-106	2.56E-08	1.21E-09	7.11E-10	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Sr-89	5.26E-11	2.52E-12	1.69E-12	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	Sr-90	4.31E-08	1.81E-09	1.63E-09	Both	0

Near Water Family	Adult Male	Ingestion	Root Vegetables	U-234	1.37E-09	2.9E-11	2.01E-11	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	U-235	5.85E-11	1.28E-12	8.75E-13	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	U-236	9.06E-11	1.92E-12	1.33E-12	Both	0
Near Water Family	Adult Male	Ingestion	Root Vegetables	U-238	2.56E-09	5.76E-11	3.95E-11	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	Am-241	2.04E-11	1.99E-13	1.55E-13	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	C-14	1.98E-07	9.74E-09	7E-09	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	Cs-137	8.35E-10	4.08E-11	2.91E-11	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	H-3	4.97E-06	2.41E-07	1.73E-07	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	I-129	7.38E-09	1.61E-10	1.65E-11	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	I-131	4.47E-06	9.96E-08	1.09E-08	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	Pu-238	8.02E-09	9.16E-11	7.64E-11	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	Pu-239	5.64E-08	6.02E-10	5.04E-10	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	Ru-106	1.83E-08	8.63E-10	5.08E-10	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	Sr-89	3.99E-11	1.91E-12	1.28E-12	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	Sr-90	2.4E-08	1.01E-09	9.13E-10	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	U-234	9.48E-10	2.01E-11	1.4E-11	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	U-235	4.07E-11	8.88E-13	6.1E-13	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	U-236	6.31E-11	1.34E-12	9.29E-13	Both	0
Near Water Family	Adult Male	Ingestion	Fruit	U-238	1.75E-09	3.89E-11	2.68E-11	Both	0
Near Water Family	Adult Male	Ingestion	Grain	Am-241	1.56E-12	1.52E-14	1.19E-14	Both	0
Near Water Family	Adult Male	Ingestion	Grain	C-14	6.55E-08	3.22E-09	2.31E-09	Both	0
Near Water Family	Adult Male	Ingestion	Grain	Cs-137	6.24E-11	3.04E-12	2.17E-12	Both	0
Near Water Family	Adult Male	Ingestion	Grain	H-3	4.37E-07	2.13E-08	1.53E-08	Both	0
Near Water Family	Adult Male	Ingestion	Grain	I-129	5.72E-10	1.24E-11	1.28E-12	Both	0
Near Water Family	Adult Male	Ingestion	Grain	I-131	3.33E-07	7.42E-09	8.12E-10	Both	0
Near Water Family	Adult Male	Ingestion	Grain	Pu-238	6.18E-10	7.04E-12	5.87E-12	Both	0
Near Water Family	Adult Male	Ingestion	Grain	Pu-239	4.32E-09	4.62E-11	3.86E-11	Both	0
Near Water Family	Adult Male	Ingestion	Grain	Ru-106	1.39E-09	6.57E-11	3.87E-11	Both	0
Near Water Family	Adult Male	Ingestion	Grain	Sr-89	3.14E-12	1.5E-13	1.01E-13	Both	0

Near Water Family	Adult Male	Ingestion	Grain	Sr-90	2.03E-09	8.51E-11	7.73E-11	Both	0
Near Water Family	Adult Male	Ingestion	Grain	U-234	7.27E-11	1.54E-12	1.07E-12	Both	0
Near Water Family	Adult Male	Ingestion	Grain	U-235	3.12E-12	6.8E-14	4.67E-14	Both	0
Near Water Family	Adult Male	Ingestion	Grain	U-236	4.83E-12	1.03E-13	7.12E-14	Both	0
Near Water Family	Adult Male	Ingestion	Grain	U-238	1.35E-10	2.99E-12	2.06E-12	Both	0
Near Water Family	Adult Male	Ingestion	Beef	Am-241	9.34E-13	9.11E-15	7.1E-15	Both	0
Near Water Family	Adult Male	Ingestion	Beef	C-14	1.5E-06	7.34E-08	5.28E-08	Both	0
Near Water Family	Adult Male	Ingestion	Beef	Cs-137	4.88E-08	2.38E-09	1.7E-09	Both	0
Near Water Family	Adult Male	Ingestion	Beef	H-3	9.4E-06	4.58E-07	3.29E-07	Both	0
Near Water Family	Adult Male	Ingestion	Beef	I-129	3.37E-07	7.34E-09	7.52E-10	Both	0
Near Water Family	Adult Male	Ingestion	Beef	I-131	0.000196	4.37E-06	4.78E-07	Both	0
Near Water Family	Adult Male	Ingestion	Beef	Pu-238	9.2E-11	1.05E-12	8.76E-13	Both	0
Near Water Family	Adult Male	Ingestion	Beef	Pu-239	6.46E-10	6.89E-12	5.77E-12	Both	0
Near Water Family	Adult Male	Ingestion	Beef	Ru-106	1.05E-06	4.95E-08	2.92E-08	Both	0
Near Water Family	Adult Male	Ingestion	Beef	Sr-89	3.77E-10	1.8E-11	1.21E-11	Both	0
Near Water Family	Adult Male	Ingestion	Beef	Sr-90	2.18E-07	9.13E-09	8.28E-09	Both	0
Near Water Family	Adult Male	Ingestion	Beef	U-234	3.26E-10	6.93E-12	4.82E-12	Both	0
Near Water Family	Adult Male	Ingestion	Beef	U-235	1.4E-11	3.05E-13	2.09E-13	Both	0
Near Water Family	Adult Male	Ingestion	Beef	U-236	2.17E-11	4.6E-13	3.19E-13	Both	0
Near Water Family	Adult Male	Ingestion	Beef	U-238	5.94E-10	1.3E-11	8.98E-12	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	Am-241	4.52E-16	4.41E-18	3.43E-18	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	C-14	4.51E-08	2.22E-09	1.59E-09	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	Cs-137	3.04E-11	1.48E-12	1.06E-12	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	H-3	1.2E-06	5.86E-08	4.21E-08	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	I-129	2.85E-13	6.2E-15	6.37E-16	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	I-131	1.88E-17	4.2E-19	4.59E-20	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	Pu-238	8.89E-14	1.01E-15	8.44E-16	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	Pu-239	6.29E-13	6.69E-15	5.58E-15	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	Ru-106	3.82E-10	1.8E-11	1.06E-11	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	Sr-89	1.08E-15	5.18E-17	3.47E-17	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	Sr-90	1.01E-11	4.23E-13	3.84E-13	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	U-234	3.52E-12	7.46E-14	5.19E-14	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	U-235	1.51E-13	3.29E-15	2.26E-15	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	U-236	2.34E-13	4.96E-15	3.44E-15	Both	0
Near Water Family	Adult Male	Ingestion	Poultry	U-238	6.41E-12	1.4E-13	9.69E-14	Both	0
Near Water Family	Adult Male	Ingestion	Milk	Am-241	4.45E-14	4.34E-16	3.38E-16	Both	0
Near Water Family	Adult Male	Ingestion	Milk	C-14	8.24E-07	4.05E-08	2.91E-08	Both	0

Near Water Family	Adult Male	Ingestion	Milk	Cs-137	1.02E-08	4.95E-10	3.54E-10	Both	0
Near Water Family	Adult Male	Ingestion	Milk	H-3	1.48E-05	7.18E-07	5.16E-07	Both	0
Near Water Family	Adult Male	Ingestion	Milk	I-129	1.07E-07	2.33E-09	2.39E-10	Both	0
Near Water Family	Adult Male	Ingestion	Milk	I-131	6.68E-05	1.49E-06	1.63E-07	Both	0
Near Water Family	Adult Male	Ingestion	Milk	Pu-238	1.28E-11	1.46E-13	1.22E-13	Both	0
Near Water Family	Adult Male	Ingestion	Milk	Pu-239	8.98E-11	9.62E-13	8.05E-13	Both	0
Near Water Family	Adult Male	Ingestion	Milk	Ru-106	8.79E-11	4.15E-12	2.44E-12	Both	0
Near Water Family	Adult Male	Ingestion	Milk	Sr-89	1.69E-10	8.1E-12	5.43E-12	Both	0
Near Water Family	Adult Male	Ingestion	Milk	Sr-90	9.49E-08	3.97E-09	3.64E-09	Both	0
Near Water Family	Adult Male	Ingestion	Milk	U-234	5.51E-10	1.17E-11	8.13E-12	Both	0
Near Water Family	Adult Male	Ingestion	Milk	U-235	2.36E-11	5.14E-13	3.54E-13	Both	0
Near Water Family	Adult Male	Ingestion	Milk	U-236	3.67E-11	7.8E-13	5.39E-13	Both	0
Near Water Family	Adult Male	Ingestion	Milk	U-238	9.98E-10	2.16E-11	1.5E-11	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	Am-241	7.4E-16	7.22E-18	5.63E-18	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	C-14	8.31E-08	4.08E-09	2.94E-09	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	Cs-137	3E-12	1.46E-13	1.04E-13	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	H-3	2.93E-06	1.42E-07	1.02E-07	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	I-129	2.1E-10	4.58E-12	4.7E-13	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	I-131	2.15E-14	4.78E-16	5.24E-17	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	Pu-238	3.63E-14	4.13E-16	3.45E-16	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	Pu-239	2.56E-13	2.74E-15	2.29E-15	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	Ru-106	5.93E-13	2.8E-14	1.65E-14	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	Sr-89	7.14E-15	3.41E-16	2.29E-16	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	Sr-90	5.87E-11	2.44E-12	2.28E-12	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	U-234	8.66E-12	1.83E-13	1.28E-13	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	U-235	3.7E-13	8.04E-15	5.53E-15	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	U-236	5.76E-13	1.22E-14	8.47E-15	Both	0
Near Water Family	Adult Male	Ingestion	Eggs	U-238	1.56E-11	3.36E-13	2.34E-13	Both	0
Near Water Family	Adult Male	Ingestion	Soil	Am-241	1.47E-14	1.43E-16	1.12E-16	Both	0
Near Water Family	Adult Male	Ingestion	Soil	Cs-137	5.72E-13	2.79E-14	1.99E-14	Both	0
Near Water Family	Adult Male	Ingestion	Soil	I-129	3.89E-12	8.48E-14	8.7E-15	Both	0
Near Water Family	Adult Male	Ingestion	Soil	I-131	5.59E-10	1.24E-11	1.36E-12	Both	0
Near Water Family	Adult Male	Ingestion	Soil	Pu-238	5.78E-12	6.6E-14	5.51E-14	Both	0
Near Water Family	Adult Male	Ingestion	Soil	Pu-239	4.05E-11	4.34E-13	3.63E-13	Both	0
Near Water Family	Adult Male	Ingestion	Soil	Ru-106	1.08E-11	5.11E-13	3.01E-13	Both	0
Near Water Family	Adult Male	Ingestion	Soil	Sr-89	1.15E-14	5.53E-16	3.71E-16	Both	0
Near Water Family	Adult Male	Ingestion	Soil	Sr-90	1.68E-11	7.07E-13	6.38E-13	Both	0

Near Water Family	Adult Male	Ingestion	Soil	U-234	6.82E-13	1.44E-14	1.01E-14	Both	0
Near Water Family	Adult Male	Ingestion	Soil	U-235	2.93E-14	6.39E-16	4.39E-16	Both	0
Near Water Family	Adult Male	Ingestion	Soil	U-236	4.54E-14	9.65E-16	6.69E-16	Both	0
Near Water Family	Adult Male	Ingestion	Soil	U-238	1.31E-12	3E-14	2.04E-14	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Ce-144	2.36E-06	1.11E-07	6.22E-08	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Co-60	1.94E-06	8.19E-08	5.57E-08	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Cs-134	9.21E-06	4.47E-07	3.21E-07	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Cs-137	0.000568	2.77E-05	1.98E-05	Both	0
Near Water Family	Adult Male	Ingestion	Fish	H-3	1.29E-06	6.26E-08	4.5E-08	Both	0
Near Water Family	Adult Male	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Both	0
Near Water Family	Adult Male	Ingestion	Fish	I-131	9.04E-06	2.01E-07	2.2E-08	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Nb-95	2.84E-06	1.09E-07	6.63E-08	Both	0
Near Water Family	Adult Male	Ingestion	Fish	P-32	0.000531	2.6E-05	2.04E-05	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Pu-238	3.1E-05	3.52E-07	2.95E-07	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Pu-239	0.000145	1.55E-06	1.29E-06	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Ru-106	3.12E-06	1.48E-07	8.69E-08	Both	0
Near Water Family	Adult Male	Ingestion	Fish	S-35	6.04E-06	3.13E-07	2.09E-07	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Sr-89	7.85E-06	3.77E-07	2.52E-07	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Sr-90	0.000124	5.16E-06	4.8E-06	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Tc-99	4.11E-08	1.5E-09	9.16E-10	Both	0
Near Water Family	Adult Male	Ingestion	Fish	U-234	6.02E-09	1.28E-10	8.88E-11	Both	0
Near Water Family	Adult Male	Ingestion	Fish	U-235	2.75E-09	5.97E-11	4.11E-11	Both	0
Near Water Family	Adult Male	Ingestion	Fish	U-236	3.4E-10	7.24E-12	5.01E-12	Both	0
Near Water Family	Adult Male	Ingestion	Fish	U-238	1.94E-07	4.19E-09	2.92E-09	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Zn-65	1.3E-05	6.23E-07	4.5E-07	Both	0
Near Water Family	Adult Male	Ingestion	Fish	Zr-95	3.14E-06	1.3E-07	7.9E-08	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Ce-144	3.63E-08	1.49E-09	8.36E-10	Both	0

Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Co-60	2.98E-09	1.13E-10	7.76E-11	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-134	9E-10	3.98E-11	2.87E-11	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	5.56E-08	2.47E-09	1.77E-09	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	5.94E-07	2.62E-08	1.89E-08	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	I-129	9.28E-09	1.86E-10	1.91E-11	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	I-131	1.13E-07	2.32E-09	2.56E-10	Both	0

Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Nb-95	4.44E-09	1.52E-10	9.21E-11	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	P-32	5.12E-09	2.32E-10	1.83E-10	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-238	3.02E-09	3.11E-11	2.59E-11	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-239	1.42E-08	1.36E-10	1.14E-10	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Ru-106	1.44E-07	5.99E-09	3.55E-09	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	S-35	3.49E-09	1.66E-10	1.11E-10	Both	0

Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-89	8.14E-09	3.52E-10	2.38E-10	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	1.24E-07	4.83E-09	4.56E-09	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Tc-99	9.46E-10	3.03E-11	1.84E-11	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	U-234	2.77E-10	5.31E-12	3.69E-12	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	U-235	1.26E-10	2.45E-12	1.7E-12	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	U-236	1.56E-11	3E-13	2.09E-13	Both	0

Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	U-238	8.91E-09	1.73E-10	1.21E-10	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Zn-65	6E-09	2.61E-10	1.9E-10	Both	0
Near Water Family	Adult Male	Ingestion	Inadvertent Water Ingestion During Swimming	Zr-95	4.81E-09	1.76E-10	1.08E-10	Both	0
Near Water Family	Adult Male	External	Air Immersion	Am-241	5.22E-16	2.29E-17	1.6E-17	Both	0
Near Water Family	Adult Male	External	Air Immersion	Ar-41	3.56E-05	1.71E-06	1.23E-06	Both	0
Near Water Family	Adult Male	External	Air Immersion	C-14	1.8E-12	1.75E-14	1.58E-14	Both	0
Near Water Family	Adult Male	External	Air Immersion	Cs-137	1.18E-11	5.62E-13	4.01E-13	Both	0
Near Water Family	Adult Male	External	Air Immersion	I-129	2.73E-13	1.05E-14	6.9E-15	Both	0
Near Water Family	Adult Male	External	Air Immersion	I-131	1.39E-07	6.59E-09	4.7E-09	Both	0

Near Water Family	Adult Male	External	Air Immersion	Pu-238	9.56E-16	3.51E-17	2.15E-17	Both	0
Near Water Family	Adult Male	External	Air Immersion	Pu-239	6.05E-15	2.6E-16	1.77E-16	Both	0
Near Water Family	Adult Male	External	Air Immersion	Ru-106	2.2E-10	9.71E-12	6.98E-12	Both	0
Near Water Family	Adult Male	External	Air Immersion	Sr-89	6.58E-14	8.88E-16	7.47E-16	Both	0
Near Water Family	Adult Male	External	Air Immersion	Sr-90	8.93E-13	1.06E-14	9.2E-15	Both	0
Near Water Family	Adult Male	External	Air Immersion	U-234	9.06E-16	3.77E-17	2.53E-17	Both	0
Near Water Family	Adult Male	External	Air Immersion	U-235	4.36E-14	2.04E-15	1.45E-15	Both	0
Near Water Family	Adult Male	External	Air Immersion	U-236	4.03E-17	1.6E-18	1.04E-18	Both	0
Near Water Family	Adult Male	External	Air Immersion	U-238	4.53E-15	1.61E-16	1.15E-16	Both	0
Near Water Family	Adult Male	External	Ground Contamination	Am-241	4.95E-13	2.1E-14	1.46E-14	Both	0
Near Water Family	Adult Male	External	Ground Contamination	Cs-137	6.85E-09	3.22E-10	2.3E-10	Both	0
Near Water Family	Adult Male	External	Ground Contamination	I-129	2.13E-10	8.06E-12	5.38E-12	Both	0

Near Water Family	Adult Male	External	Ground Contamination	I-131	2.75E-06	1.31E-07	9.36E-08	Both	0
Near Water Family	Adult Male	External	Ground Contamination	Pu-238	4.69E-12	1.39E-13	8.47E-14	Both	0
Near Water Family	Adult Male	External	Ground Contamination	Pu-239	1.36E-11	4.42E-13	2.83E-13	Both	0
Near Water Family	Adult Male	External	Ground Contamination	Ru-106	1.57E-07	4.97E-09	3.67E-09	Both	0
Near Water Family	Adult Male	External	Ground Contamination	Sr-89	9.11E-11	7.77E-13	7.4E-13	Both	0
Near Water Family	Adult Male	External	Ground Contamination	Sr-90	1.79E-08	1.64E-10	1.53E-10	Both	0
Near Water Family	Adult Male	External	Ground Contamination	U-234	2.39E-12	7.56E-14	4.81E-14	Both	0
Near Water Family	Adult Male	External	Ground Contamination	U-235	2.86E-11	1.34E-12	9.54E-13	Both	0
Near Water Family	Adult Male	External	Ground Contamination	U-236	1.44E-13	4.41E-15	2.74E-15	Both	0
Near Water Family	Adult Male	External	Ground Contamination	U-238	8.21E-10	1.36E-11	1.1E-11	Both	0
Near Water Family	Adult Male	External	Swimming	Ce-144	3.18E-09	1.91E-10	1.59E-10	Both	0
Near Water Family	Adult Male	External	Swimming	Co-60	1.61E-08	9.65E-10	8.04E-10	Both	0
Near Water Family	Adult Male	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Both	0

Near Water Family	Adult Male	External	Swimming	Cs-137	1.63E-08	9.77E-10	8.14E-10	Both	0
Near Water Family	Adult Male	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Both	0
Near Water Family	Adult Male	External	Swimming	I-131	1.37E-08	8.22E-10	6.85E-10	Both	0
Near Water Family	Adult Male	External	Swimming	Nb-95	4.11E-08	2.46E-09	2.06E-09	Both	0
Near Water Family	Adult Male	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Both	0
Near Water Family	Adult Male	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Both	0
Near Water Family	Adult Male	External	Swimming	Pu-239	3.18E-14	1.9E-15	1.59E-15	Both	0
Near Water Family	Adult Male	External	Swimming	Ru-106	3.23E-08	1.94E-09	1.61E-09	Both	0
Near Water Family	Adult Male	External	Swimming	S-35	6.54E-12	3.93E-13	3.27E-13	Both	0
Near Water Family	Adult Male	External	Swimming	Sr-89	1.2E-10	7.18E-12	5.99E-12	Both	0
Near Water Family	Adult Male	External	Swimming	Sr-90	3.51E-11	2.1E-12	1.75E-12	Both	0
Near Water Family	Adult Male	External	Swimming	Tc-99	3.31E-12	1.99E-13	1.66E-13	Both	0
Near Water Family	Adult Male	External	Swimming	U-234	5.59E-15	3.35E-16	2.79E-16	Both	0
Near Water Family	Adult Male	External	Swimming	U-235	2.77E-12	1.66E-13	1.38E-13	Both	0
Near Water Family	Adult Male	External	Swimming	U-236	2.13E-16	1.28E-17	1.06E-17	Both	0
Near Water Family	Adult Male	External	Swimming	U-238	8.43E-14	5.05E-15	4.21E-15	Both	0
Near Water Family	Adult Male	External	Swimming	Zn-65	6.47E-09	3.88E-10	3.24E-10	Both	0
Near Water Family	Adult Male	External	Swimming	Zr-95	2.62E-08	1.57E-09	1.31E-09	Both	0
Near Water Family	Adult Male	External	Boating	Ce-144	3.36E-09	1.01E-10	8.41E-11	Both	0

Near Water Family	Adult Male	External	Boating	Co-60	1.7E-08	5.09E-10	4.24E-10	Both	0
Near Water Family	Adult Male	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Both	0
Near Water Family	Adult Male	External	Boating	Cs-137	1.72E-08	5.15E-10	4.29E-10	Both	0
Near Water Family	Adult Male	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Both	0
Near Water Family	Adult Male	External	Boating	I-131	1.44E-08	4.34E-10	3.62E-10	Both	0
Near Water Family	Adult Male	External	Boating	Nb-95	4.34E-08	1.3E-09	1.08E-09	Both	0
Near Water Family	Adult Male	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Both	0
Near Water Family	Adult Male	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Both	0
Near Water Family	Adult Male	External	Boating	Pu-239	3.35E-14	1.01E-15	8.37E-16	Both	0
Near Water Family	Adult Male	External	Boating	Ru-106	3.41E-08	1.02E-09	8.52E-10	Both	0
Near Water Family	Adult Male	External	Boating	S-35	6.89E-12	2.07E-13	1.72E-13	Both	0
Near Water Family	Adult Male	External	Boating	Sr-89	1.26E-10	3.79E-12	3.16E-12	Both	0
Near Water Family	Adult Male	External	Boating	Sr-90	3.7E-11	1.11E-12	9.25E-13	Both	0
Near Water Family	Adult Male	External	Boating	Tc-99	3.49E-12	1.05E-13	8.74E-14	Both	0
Near Water Family	Adult Male	External	Boating	U-234	5.89E-15	1.77E-16	1.47E-16	Both	0
Near Water Family	Adult Male	External	Boating	U-235	2.92E-12	8.76E-14	7.3E-14	Both	0
Near Water Family	Adult Male	External	Boating	U-236	2.25E-16	6.74E-18	5.62E-18	Both	0
Near Water Family	Adult Male	External	Boating	U-238	8.88E-14	2.67E-15	2.22E-15	Both	0
Near Water Family	Adult Male	External	Boating	Zn-65	6.83E-09	2.05E-10	1.71E-10	Both	0
Near Water Family	Adult Male	External	Boating	Zr-95	2.76E-08	8.28E-10	6.9E-10	Both	0
Near Water Family	Adult Male	External	Shoreline	Ce-144	1.93E-05	3.76E-07	2.95E-07	Both	0
Near Water Family	Adult Male	External	Shoreline	Co-60	4.38E-05	2.11E-06	1.51E-06	Both	0
Near Water Family	Adult Male	External	Shoreline	Cs-134	1.37E-06	6.57E-08	4.69E-08	Both	0
Near Water Family	Adult Male	External	Shoreline	Cs-137	5.2E-05	2.44E-06	1.75E-06	Both	0
Near Water Family	Adult Male	External	Shoreline	I-129	4.01E-08	1.52E-09	1.01E-09	Both	0
Near Water Family	Adult Male	External	Shoreline	I-131	1.4E-06	6.66E-08	4.78E-08	Both	0
Near Water Family	Adult Male	External	Shoreline	Nb-95	1.78E-05	8.55E-07	6.1E-07	Both	0
Near Water Family	Adult Male	External	Shoreline	P-32	2.39E-07	2.04E-09	1.94E-09	Both	0
Near Water Family	Adult Male	External	Shoreline	Pu-238	1.93E-10	5.71E-12	3.49E-12	Both	0
Near Water Family	Adult Male	External	Shoreline	Pu-239	3.74E-10	1.22E-11	7.79E-12	Both	0
Near Water Family	Adult Male	External	Shoreline	Ru-106	0.000119	3.78E-06	2.79E-06	Both	0
Near Water Family	Adult Male	External	Shoreline	S-35	2.69E-09	1.03E-10	6.91E-11	Both	0
Near Water Family	Adult Male	External	Shoreline	Sr-89	1.01E-06	8.58E-09	8.16E-09	Both	0
Near Water Family	Adult Male	External	Shoreline	Sr-90	1.14E-05	1.04E-07	9.74E-08	Both	0
Near Water Family	Adult Male	External	Shoreline	Tc-99	2.23E-09	9.17E-11	6.32E-11	Both	0
Near Water Family	Adult Male	External	Shoreline	U-234	7.63E-11	2.42E-12	1.54E-12	Both	0
Near Water Family	Adult Male	External	Shoreline	U-235	9.78E-09	4.57E-10	3.25E-10	Both	0

Near Water Family	Adult Male	External	Shoreline	U-236	3.92E-12	1.2E-13	7.47E-14	Both	0
Near Water Family	Adult Male	External	Shoreline	U-238	5.14E-07	8.51E-09	6.88E-09	Both	0
Near Water Family	Adult Male	External	Shoreline	Zn-65	1.19E-05	5.74E-07	4.1E-07	Both	0
Near Water Family	Adult Male	External	Shoreline	Zr-95	4.08E-05	1.96E-06	1.4E-06	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Am-241	5.67E-09	7.39E-11	6.37E-11	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	C-14	7.62E-10	3.69E-11	2.65E-11	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Cs-137	3.79E-10	1.77E-11	1.27E-11	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	H-3	1.21E-05	5.87E-07	4.21E-07	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	I-129	1.27E-08	2.77E-10	2.84E-11	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	I-131	2.23E-05	4.97E-07	5.36E-08	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Pu-238	2.22E-06	3.1E-08	2.76E-08	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Pu-239	1.53E-05	1.96E-07	1.73E-07	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Ru-106	1.02E-07	5.4E-09	4.93E-09	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Sr-89	1.62E-10	8.65E-12	7.99E-12	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	Sr-90	3.77E-08	1.88E-09	1.78E-09	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-234	9.07E-08	4.7E-09	4.46E-09	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-235	3.62E-09	1.88E-10	1.77E-10	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-236	5.87E-09	3.04E-10	2.87E-10	Both	0
Near Water Family	Adult Male	Inhalation	Air Inhalation	U-238	1.49E-07	7.71E-09	7.23E-09	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Am-241	2.18E-11	2.85E-13	2.45E-13	Both	0

Near Water Family	Adult Male	Inhalation	Resuspended Soil	Cs-137	1.44E-12	6.73E-14	4.79E-14	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	I-129	2.01E-11	4.37E-13	4.48E-14	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	I-131	2.87E-09	6.4E-11	6.9E-12	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Pu-238	8.49E-09	1.19E-10	1.06E-10	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Pu-239	5.88E-08	7.55E-10	6.68E-10	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Ru-106	3.13E-10	1.66E-11	1.52E-11	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Sr-89	2E-13	1.07E-14	9.84E-15	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	Sr-90	1.49E-10	7.44E-12	7.04E-12	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-234	3.5E-10	1.82E-11	1.72E-11	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-235	1.4E-11	7.24E-13	6.83E-13	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-236	2.26E-11	1.17E-12	1.1E-12	Both	0
Near Water Family	Adult Male	Inhalation	Resuspended Soil	U-238	5.74E-10	2.97E-11	2.79E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Am-241	6.18E-11	8.43E-13	6.28E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	C-14	4.54E-08	6.05E-09	4.04E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Cs-137	1.19E-09	1.02E-10	6.82E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	H-3	1.23E-06	1.6E-07	1.07E-07	Both	0

Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	I-129	1.85E-08	1.41E-09	1.44E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	I-131	2.42E-05	2.31E-06	2.41E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-238	1.54E-08	6.88E-10	4.95E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Pu-239	1.99E-07	1.35E-09	9.44E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Ru-106	5.48E-08	1.86E-08	1.05E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-89	1.25E-10	3.11E-11	1.81E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	Sr-90	4.55E-08	3.55E-09	2.35E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-234	1.81E-09	1.13E-10	6.93E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-235	8.56E-11	6.88E-12	4.2E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-236	1.2E-10	7.48E-12	4.6E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Leafy Vegetables	U-238	3.95E-09	3.69E-10	2.24E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Am-241	2.92E-11	4E-13	2.98E-13	Both	0

Near Water Family	Child born 1955	Ingestion	Root Vegetables	C-14	2.45E-07	3.42E-08	2.28E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Cs-137	8.57E-10	8.2E-11	5.39E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	H-3	6.05E-06	8.34E-07	5.57E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	I-129	9.91E-09	7.84E-10	7.99E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	I-131	5.95E-06	5.73E-07	5.98E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Pu-238	9.04E-09	4.07E-10	2.92E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Pu-239	4.32E-07	2.64E-09	1.83E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Ru-106	4.25E-08	1.28E-08	7.17E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Sr-89	1.21E-10	2.44E-11	1.42E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	Sr-90	1.04E-07	6.71E-09	4.38E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-234	2.88E-09	1.48E-10	8.97E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-235	9.95E-11	6.56E-12	3.98E-12	Both	0

Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-236	1.9E-10	9.76E-12	5.96E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Root Vegetables	U-238	3.56E-09	3.11E-10	1.87E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	Am-241	2.04E-11	2.79E-13	2.08E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	C-14	2.48E-07	3.76E-08	2.49E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	Cs-137	1.01E-09	1.1E-10	7.09E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	H-3	5.96E-06	9.14E-07	6.07E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	I-129	9.94E-09	8.52E-10	8.68E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	I-131	2.98E-05	2.88E-06	3E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	Pu-238	7.01E-09	3.17E-10	2.28E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	Pu-239	9.97E-07	5.97E-09	4.14E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	Ru-106	6.74E-08	1.76E-08	9.84E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	Sr-89	2.43E-10	4.41E-11	2.57E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	Sr-90	1.84E-07	1.08E-08	7.12E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-234	6.09E-09	2.9E-10	1.77E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-235	1.92E-10	1.16E-11	6.98E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-236	4.04E-10	1.93E-11	1.17E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Fruit	U-238	5.93E-09	4.54E-10	2.74E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	Am-241	1.56E-12	2.13E-14	1.59E-14	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	C-14	7.3E-08	1.08E-08	7.13E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	Cs-137	4.3E-11	4.55E-12	2.98E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	H-3	4.86E-07	7.25E-08	4.81E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	I-129	7.31E-10	6.13E-11	6.24E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	I-131	1.68E-06	1.62E-07	1.69E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	Pu-238	4.63E-10	2.08E-11	1.49E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	Pu-239	2.02E-08	1.27E-10	8.86E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	Ru-106	2.73E-09	8.59E-10	4.82E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	Sr-89	8.21E-12	1.94E-12	1.13E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	Sr-90	4.74E-09	3.31E-10	2.2E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	U-234	1.41E-10	7.57E-12	4.63E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	U-235	5.63E-12	4.22E-13	2.56E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	U-236	9.33E-12	5.04E-13	3.08E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Grain	U-238	2.3E-10	2.18E-11	1.32E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	Am-241	9.34E-13	1.28E-14	9.5E-15	Both	0

Near Water Family	Child born 1955	Ingestion	Beef	C-14	1.42E-06	2.02E-07	1.34E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	Cs-137	3.23E-08	3.16E-09	2.08E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	H-3	8.73E-06	1.23E-06	8.22E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	I-129	3.56E-07	2.87E-08	2.92E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	I-131	0.000577	5.53E-05	5.77E-06	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	Pu-238	8.66E-11	3.93E-12	2.82E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	Pu-239	3.31E-09	2.04E-11	1.42E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	Ru-106	1.85E-06	5.76E-07	3.24E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	Sr-89	8.95E-10	1.85E-10	1.08E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	Sr-90	5.05E-07	3.09E-08	2.04E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	U-234	6.82E-10	3.59E-11	2.19E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	U-235	2.42E-11	1.64E-12	9.97E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	U-236	4.51E-11	2.37E-12	1.45E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Beef	U-238	8.52E-10	6.76E-11	4.12E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	Am-241	4.52E-16	6.17E-18	4.6E-18	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	C-14	4.6E-08	6.73E-09	4.47E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	Cs-137	1.75E-11	1.76E-12	1.16E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	H-3	1.23E-06	1.8E-07	1.2E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	I-129	3.27E-13	2.69E-14	2.75E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	I-131	7.67E-17	7.42E-18	7.74E-19	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	Pu-238	9.06E-14	4.11E-15	2.94E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	Pu-239	1.35E-12	9.09E-15	6.32E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	Ru-106	5.98E-10	2.12E-10	1.19E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	Sr-89	2.04E-15	5.36E-16	3.12E-16	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	Sr-90	1.25E-11	1.01E-12	6.71E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-234	3.9E-12	2.41E-13	1.48E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-235	1.8E-13	1.5E-14	9.15E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-236	2.59E-13	1.6E-14	9.86E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Poultry	U-238	7.99E-12	7.43E-13	4.55E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	Am-241	4.45E-14	6.08E-16	4.52E-16	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	C-14	1.83E-06	3.01E-07	1.98E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	Cs-137	1.9E-08	2.27E-09	1.45E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	H-3	3.16E-05	5.27E-06	3.49E-06	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	I-129	2.72E-07	2.48E-08	2.53E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	I-131	0.000854	8.23E-05	8.6E-06	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	Pu-238	2.77E-11	1.28E-12	9.17E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	Pu-239	2.54E-09	1.54E-11	1.07E-11	Both	0

Near Water Family	Child born 1955	Ingestion	Milk	Ru-106	5.7E-10	1.6E-10	8.99E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	Sr-89	1.79E-09	3.43E-10	1.99E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	Sr-90	1.17E-06	6.17E-08	4.19E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	U-234	5.81E-09	2.84E-10	1.73E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	U-235	1.88E-10	1.18E-11	7.14E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	U-236	3.86E-10	1.89E-11	1.15E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Milk	U-238	5.81E-09	4.26E-10	2.6E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	Am-241	7.4E-16	1.01E-17	7.54E-18	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	C-14	7.52E-08	1.07E-08	7.14E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	Cs-137	1.64E-12	1.58E-13	1.05E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	H-3	2.67E-06	3.81E-07	2.54E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	I-129	2.08E-10	1.68E-11	1.71E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	I-131	8.38E-14	8.1E-15	8.46E-16	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	Pu-238	2.78E-14	1.25E-15	8.96E-16	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	Pu-239	5.34E-13	3.55E-15	2.47E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	Ru-106	8.16E-13	2.8E-13	1.58E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	Sr-89	1.2E-14	3.17E-15	1.85E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	Sr-90	6.76E-11	4.22E-12	3E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-234	8.73E-12	5.21E-13	3.19E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-235	3.97E-13	3.21E-14	1.96E-14	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-236	5.79E-13	3.46E-14	2.12E-14	Both	0
Near Water Family	Child born 1955	Ingestion	Eggs	U-238	1.73E-11	1.53E-12	9.4E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	Am-241	1.47E-14	2E-16	1.49E-16	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	Cs-137	1.14E-12	1.37E-13	8.77E-14	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	I-129	9.84E-12	9.02E-13	9.19E-14	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	I-131	8.03E-09	7.74E-10	8.07E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	Pu-238	1.09E-11	5.01E-13	3.59E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	Pu-239	1.28E-09	7.71E-12	5.36E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	Ru-106	7.48E-11	2.04E-11	1.14E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	Sr-89	1.33E-13	2.53E-14	1.48E-14	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	Sr-90	2.36E-10	1.48E-11	9.66E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	U-234	7.91E-12	3.82E-13	2.33E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	U-235	2.55E-13	1.59E-14	9.61E-15	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	U-236	5.25E-13	2.54E-14	1.55E-14	Both	0
Near Water Family	Child born 1955	Ingestion	Soil	U-238	8.55E-12	7.82E-13	4.65E-13	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Ce-144	2.8E-06	1.01E-06	5.59E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Co-60	3.02E-06	5E-07	3.19E-07	Both	0

Near Water Family	Child born 1955	Ingestion	Fish	Cs-134	4.12E-06	6.64E-07	4.38E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Cs-137	0.000231	4.16E-05	2.7E-05	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	H-3	1E-06	1.32E-07	8.87E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	I-129	8.08E-07	1.76E-08	1.8E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	I-131	1.44E-05	1.59E-06	1.66E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Nb-95	2.97E-06	6.18E-07	3.52E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	P-32	0.000565	0.000108	6.92E-05	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Pu-238	1.44E-05	5.5E-07	4.04E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Pu-239	9.75E-05	3.17E-06	2.29E-06	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Ru-106	3.24E-06	9.43E-07	5.32E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	S-35	5.2E-06	1.24E-06	7.73E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Sr-89	7.31E-06	1.96E-06	1.14E-06	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Sr-90	0.000142	8.88E-06	6.88E-06	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Tc-99	6.22E-08	7.83E-09	4.42E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	U-234	5.61E-09	5.73E-10	3.51E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	U-235	2.12E-09	2.17E-10	1.33E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	U-236	3.31E-10	3.4E-11	2.08E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	U-238	1.48E-07	1.43E-08	8.88E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Zn-65	1.1E-05	1.83E-06	1.21E-06	Both	0
Near Water Family	Child born 1955	Ingestion	Fish	Zr-95	3.24E-06	6.4E-07	3.63E-07	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Ce-144	8.28E-08	3.06E-08	1.69E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Co-60	8.89E-09	1.49E-09	9.51E-10	Both	0

Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-134	7.75E-10	1.27E-10	8.38E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	4.65E-08	8.42E-09	5.48E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	7.35E-07	1.09E-07	7.26E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	I-129	9.28E-09	1.86E-10	1.91E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	I-131	3.83E-07	4.3E-08	4.48E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Nb-95	8.16E-09	1.81E-09	1.03E-09	Both	0

Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	P-32	1.08E-08	2.08E-09	1.33E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-238	2.93E-09	1.15E-10	8.38E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-239	2.04E-08	6.77E-10	4.9E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Ru-106	2.56E-07	8.08E-08	4.54E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	S-35	6.11E-09	1.48E-09	9.18E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-89	1.53E-08	4.11E-09	2.4E-09	Both	0

Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	2.88E-07	1.57E-08	1.26E-08	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Tc-99	2.55E-09	3.64E-10	2.03E-10	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	U-234	5.67E-10	5.84E-11	3.59E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	U-235	2.05E-10	2.08E-11	1.28E-11	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	U-236	3.34E-11	3.48E-12	2.13E-12	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	U-238	1.43E-08	1.38E-09	8.56E-10	Both	0

Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Zn-65	9.69E-09	1.64E-09	1.08E-09	Both	0
Near Water Family	Child born 1955	Ingestion	Inadvertent Water Ingestion During Swimming	Zr-95	7.81E-09	1.74E-09	9.82E-10	Both	0
Near Water Family	Child born 1955	External	Air Immersion	Am-241	5.22E-16	3.66E-17	2.45E-17	Both	0
Near Water Family	Child born 1955	External	Air Immersion	Ar-41	3.53E-05	5.71E-06	3.76E-06	Both	0
Near Water Family	Child born 1955	External	Air Immersion	C-14	1.8E-12	4.19E-14	3.62E-14	Both	0
Near Water Family	Child born 1955	External	Air Immersion	Cs-137	1.18E-11	1.62E-12	1.07E-12	Both	0
Near Water Family	Child born 1955	External	Air Immersion	I-129	2.73E-13	3.4E-14	2.08E-14	Both	0
Near Water Family	Child born 1955	External	Air Immersion	I-131	1.39E-07	2.49E-08	1.63E-08	Both	0
Near Water Family	Child born 1955	External	Air Immersion	Pu-238	9.56E-16	1.41E-16	7.97E-17	Both	0
Near Water Family	Child born 1955	External	Air Immersion	Pu-239	6.05E-15	1.02E-15	6.33E-16	Both	0

Near Water Family	Child born 1955	External	Air Immersion	Ru-106	2.2E-10	3.32E-11	2.19E-11	Both	0
Near Water Family	Child born 1955	External	Air Immersion	Sr-89	6.58E-14	2.78E-15	2.17E-15	Both	0
Near Water Family	Child born 1955	External	Air Immersion	Sr-90	8.93E-13	3.47E-14	2.83E-14	Both	0
Near Water Family	Child born 1955	External	Air Immersion	U-234	9.06E-16	1.46E-16	9E-17	Both	0
Near Water Family	Child born 1955	External	Air Immersion	U-235	4.36E-14	7.31E-15	4.78E-15	Both	0
Near Water Family	Child born 1955	External	Air Immersion	U-236	4.03E-17	6.35E-18	3.79E-18	Both	0
Near Water Family	Child born 1955	External	Air Immersion	U-238	4.53E-15	5.65E-16	3.69E-16	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	Am-241	4.95E-13	3.38E-14	2.27E-14	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	Cs-137	6.88E-09	9.38E-10	6.21E-10	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	I-129	2.15E-10	2.61E-11	1.63E-11	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	I-131	2.76E-06	5E-07	3.26E-07	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	Pu-238	4.72E-12	5.63E-13	3.23E-13	Both	0

Near Water Family	Child born 1955	External	Ground Contamination	Pu-239	1.37E-11	1.82E-12	1.08E-12	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	Ru-106	1.58E-07	1.67E-08	1.14E-08	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	Sr-89	9.17E-11	2.16E-12	1.99E-12	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	Sr-90	1.8E-08	5.04E-10	4.54E-10	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	U-234	2.4E-12	3.09E-13	1.84E-13	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	U-235	2.88E-11	4.86E-12	3.18E-12	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	U-236	1.45E-13	1.81E-14	1.06E-14	Both	0
Near Water Family	Child born 1955	External	Ground Contamination	U-238	8.27E-10	4.36E-11	3.26E-11	Both	0
Near Water Family	Child born 1955	External	Swimming	Ce-144	3.18E-09	1.91E-10	1.59E-10	Both	0
Near Water Family	Child born 1955	External	Swimming	Co-60	1.6E-08	9.63E-10	8.03E-10	Both	0
Near Water Family	Child born 1955	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Both	0
Near Water Family	Child born 1955	External	Swimming	Cs-137	1.63E-08	9.76E-10	8.13E-10	Both	0
Near Water Family	Child born 1955	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Both	0
Near Water Family	Child born 1955	External	Swimming	I-131	1.37E-08	8.22E-10	6.85E-10	Both	0

Near Water Family	Child born 1955	External	Swimming	Nb-95	4.11E-08	2.46E-09	2.06E-09	Both	0
Near Water Family	Child born 1955	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Both	0
Near Water Family	Child born 1955	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Both	0
Near Water Family	Child born 1955	External	Swimming	Pu-239	3.17E-14	1.9E-15	1.59E-15	Both	0
Near Water Family	Child born 1955	External	Swimming	Ru-106	3.23E-08	1.94E-09	1.61E-09	Both	0
Near Water Family	Child born 1955	External	Swimming	S-35	6.54E-12	3.93E-13	3.27E-13	Both	0
Near Water Family	Child born 1955	External	Swimming	Sr-89	1.2E-10	7.18E-12	5.99E-12	Both	0
Near Water Family	Child born 1955	External	Swimming	Sr-90	3.51E-11	2.1E-12	1.75E-12	Both	0
Near Water Family	Child born 1955	External	Swimming	Tc-99	3.23E-12	1.94E-13	1.61E-13	Both	0
Near Water Family	Child born 1955	External	Swimming	U-234	5.59E-15	3.35E-16	2.79E-16	Both	0
Near Water Family	Child born 1955	External	Swimming	U-235	2.77E-12	1.66E-13	1.38E-13	Both	0
Near Water Family	Child born 1955	External	Swimming	U-236	2.13E-16	1.28E-17	1.06E-17	Both	0
Near Water Family	Child born 1955	External	Swimming	U-238	8.43E-14	5.05E-15	4.21E-15	Both	0
Near Water Family	Child born 1955	External	Swimming	Zn-65	6.47E-09	3.88E-10	3.24E-10	Both	0
Near Water Family	Child born 1955	External	Swimming	Zr-95	2.62E-08	1.57E-09	1.31E-09	Both	0
Near Water Family	Child born 1955	External	Boating	Ce-144	3.36E-09	1.01E-10	8.41E-11	Both	0
Near Water Family	Child born 1955	External	Boating	Co-60	1.69E-08	5.08E-10	4.24E-10	Both	0
Near Water Family	Child born 1955	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Both	0
Near Water Family	Child born 1955	External	Boating	Cs-137	1.72E-08	5.14E-10	4.29E-10	Both	0
Near Water Family	Child born 1955	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Both	0
Near Water Family	Child born 1955	External	Boating	I-131	1.44E-08	4.34E-10	3.62E-10	Both	0
Near Water Family	Child born 1955	External	Boating	Nb-95	4.34E-08	1.3E-09	1.08E-09	Both	0

Near Water Family	Child born 1955	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Both	0
Near Water Family	Child born 1955	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Both	0
Near Water Family	Child born 1955	External	Boating	Pu-239	3.35E-14	1E-15	8.37E-16	Both	0
Near Water Family	Child born 1955	External	Boating	Ru-106	3.41E-08	1.02E-09	8.52E-10	Both	0
Near Water Family	Child born 1955	External	Boating	S-35	6.89E-12	2.07E-13	1.72E-13	Both	0
Near Water Family	Child born 1955	External	Boating	Sr-89	1.26E-10	3.79E-12	3.16E-12	Both	0
Near Water Family	Child born 1955	External	Boating	Sr-90	3.7E-11	1.11E-12	9.24E-13	Both	0
Near Water Family	Child born 1955	External	Boating	Tc-99	3.4E-12	1.02E-13	8.51E-14	Both	0
Near Water Family	Child born 1955	External	Boating	U-234	5.89E-15	1.77E-16	1.47E-16	Both	0
Near Water Family	Child born 1955	External	Boating	U-235	2.92E-12	8.76E-14	7.3E-14	Both	0
Near Water Family	Child born 1955	External	Boating	U-236	2.25E-16	6.74E-18	5.62E-18	Both	0
Near Water Family	Child born 1955	External	Boating	U-238	8.88E-14	2.67E-15	2.22E-15	Both	0
Near Water Family	Child born 1955	External	Boating	Zn-65	6.83E-09	2.05E-10	1.71E-10	Both	0
Near Water Family	Child born 1955	External	Boating	Zr-95	2.76E-08	8.28E-10	6.9E-10	Both	0
Near Water Family	Child born 1955	External	Shoreline	Ce-144	1.93E-05	1.22E-06	8.82E-07	Both	0
Near Water Family	Child born 1955	External	Shoreline	Co-60	4.37E-05	7.03E-06	4.63E-06	Both	0
Near Water Family	Child born 1955	External	Shoreline	Cs-134	1.37E-06	2.33E-07	1.53E-07	Both	0
Near Water Family	Child born 1955	External	Shoreline	Cs-137	5.2E-05	8.91E-06	5.85E-06	Both	0
Near Water Family	Child born 1955	External	Shoreline	I-129	4.01E-08	1.52E-09	1.01E-09	Both	0
Near Water Family	Child born 1955	External	Shoreline	I-131	1.4E-06	2.5E-07	1.64E-07	Both	0
Near Water Family	Child born 1955	External	Shoreline	Nb-95	1.78E-05	2.72E-06	1.79E-06	Both	0
Near Water Family	Child born 1955	External	Shoreline	P-32	2.39E-07	5.5E-09	5.05E-09	Both	0
Near Water Family	Child born 1955	External	Shoreline	Pu-238	1.93E-10	2.15E-11	1.24E-11	Both	0
Near Water Family	Child born 1955	External	Shoreline	Pu-239	3.74E-10	4.6E-11	2.74E-11	Both	0
Near Water Family	Child born 1955	External	Shoreline	Ru-106	0.000119	1.13E-05	7.72E-06	Both	0
Near Water Family	Child born 1955	External	Shoreline	S-35	2.69E-09	3.91E-10	2.44E-10	Both	0
Near Water Family	Child born 1955	External	Shoreline	Sr-89	1.01E-06	2.19E-08	2.01E-08	Both	0
Near Water Family	Child born 1955	External	Shoreline	Sr-90	1.14E-05	2.73E-07	2.44E-07	Both	0
Near Water Family	Child born 1955	External	Shoreline	Tc-99	2.17E-09	1.98E-10	1.29E-10	Both	0
Near Water Family	Child born 1955	External	Shoreline	U-234	7.63E-11	9.8E-12	5.81E-12	Both	0
Near Water Family	Child born 1955	External	Shoreline	U-235	9.78E-09	1.68E-09	1.09E-09	Both	0
Near Water Family	Child born 1955	External	Shoreline	U-236	3.92E-12	4.89E-13	2.86E-13	Both	0
Near Water Family	Child born 1955	External	Shoreline	U-238	5.14E-07	2.77E-08	2.06E-08	Both	0
Near Water Family	Child born 1955	External	Shoreline	Zn-65	1.19E-05	2.08E-06	1.37E-06	Both	0
Near Water Family	Child born 1955	External	Shoreline	Zr-95	4.08E-05	5.42E-06	3.59E-06	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Am-241	5.67E-09	9.73E-11	8.34E-11	Both	0

Near Water Family	Child born 1955	Inhalation	Air Inhalation	C-14	8.27E-10	1.23E-10	8.09E-11	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Cs-137	2.75E-10	2.69E-11	1.76E-11	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	H-3	1.22E-05	1.78E-06	1.18E-06	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	I-129	1.51E-08	1.27E-09	1.29E-10	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	I-131	8.22E-05	8.05E-06	8.33E-07	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Pu-238	2.2E-06	1.06E-07	9.42E-08	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Pu-239	7.59E-06	3.49E-07	3.06E-07	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Ru-106	1.28E-07	2.32E-08	1.98E-08	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Sr-89	2.19E-10	4.2E-11	3.5E-11	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	Sr-90	4.79E-08	5.89E-09	5.32E-09	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-234	1.12E-07	1.56E-08	1.47E-08	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-235	4.63E-09	6.76E-10	6.36E-10	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-236	7.31E-09	1.01E-09	9.56E-10	Both	0
Near Water Family	Child born 1955	Inhalation	Air Inhalation	U-238	1.94E-07	2.92E-08	2.76E-08	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Am-241	2.18E-11	3.75E-13	3.21E-13	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Cs-137	1.04E-12	1.02E-13	6.68E-14	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	I-129	2.39E-11	2E-12	2.03E-13	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	I-131	1.06E-08	1.04E-09	1.07E-10	Both	0

Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Pu-238	8.43E-09	4.07E-10	3.62E-10	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Pu-239	2.91E-08	1.34E-09	1.18E-09	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Ru-106	3.94E-10	7.16E-11	6.11E-11	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Sr-89	2.7E-13	5.17E-14	4.31E-14	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	Sr-90	1.97E-10	2.52E-11	2.21E-11	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-234	4.33E-10	6.01E-11	5.68E-11	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-235	1.78E-11	2.6E-12	2.45E-12	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-236	2.82E-11	3.89E-12	3.67E-12	Both	0
Near Water Family	Child born 1955	Inhalation	Resuspended Soil	U-238	7.49E-10	1.13E-10	1.06E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Am-241	4.84E-11	1.19E-12	8.28E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	C-14	2.7E-08	4.33E-09	2.87E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Cs-137	8.74E-10	1.18E-10	7.96E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	H-3	7.64E-07	1.13E-07	7.51E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	I-129	1.04E-08	9.14E-10	9.32E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	I-131	1.38E-07	1.26E-08	1.31E-09	Both	0

Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-238	1.57E-08	5.45E-10	3.9E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Pu-239	3.03E-09	1.17E-10	8.32E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Ru-106	3.42E-08	1.55E-08	8.7E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-89	5.26E-11	1.27E-11	7.41E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	Sr-90	4.57E-10	4.9E-11	3.39E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-234	4.55E-10	4.21E-11	2.6E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-235	2.94E-11	2.85E-12	1.75E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-236	3.03E-11	2.8E-12	1.73E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Leafy Vegetables	U-238	1.59E-09	1.61E-10	9.82E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Am-241	2.57E-11	6.53E-13	4.52E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	C-14	1.56E-07	2.58E-08	1.7E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Cs-137	4.66E-10	6.35E-11	4.26E-11	Both	0

Near Water Family	Child born 1964	Ingestion	Root Vegetables	H-3	4.28E-06	6.35E-07	4.22E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	I-129	6.4E-09	5.91E-10	6.03E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	I-131	2.99E-08	2.89E-09	3.02E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Pu-238	8.15E-09	2.83E-10	2.03E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Pu-239	1.94E-09	7.31E-11	5.18E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Ru-106	2.15E-08	9.72E-09	5.45E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Sr-89	3.16E-11	7.3E-12	4.25E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	Sr-90	4.85E-10	4.82E-11	3.25E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-234	3.5E-10	2.92E-11	1.79E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-235	2.28E-11	2.05E-12	1.25E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-236	2.33E-11	1.94E-12	1.2E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Root Vegetables	U-238	1.27E-09	1.27E-10	7.65E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	Am-241	1.91E-11	4.91E-13	3.4E-13	Both	0

Near Water Family	Child born 1964	Ingestion	Fruit	C-14	1.79E-07	3.05E-08	2.01E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	Cs-137	3.37E-10	4.73E-11	3.15E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	H-3	5.2E-06	7.81E-07	5.17E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	I-129	7.83E-09	7.77E-10	7.93E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	I-131	1.4E-07	1.4E-08	1.46E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	Pu-238	9.95E-09	3.46E-10	2.47E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	Pu-239	2.84E-09	1.05E-10	7.43E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	Ru-106	2.95E-08	1.24E-08	6.96E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	Sr-89	5.17E-11	1.14E-11	6.64E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	Sr-90	6.54E-10	5.88E-11	3.96E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-234	5.76E-10	4.53E-11	2.77E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-235	3.68E-11	3.17E-12	1.92E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-236	3.83E-11	3.01E-12	1.84E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Fruit	U-238	1.98E-09	1.82E-10	1.1E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	Am-241	1.34E-12	3.38E-14	2.35E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	C-14	4.91E-08	8.27E-09	5.45E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	Cs-137	2.34E-11	3.3E-12	2.2E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	H-3	3.35E-07	5.35E-08	3.54E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	I-129	4.82E-10	4.6E-11	4.69E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	I-131	8.22E-09	7.95E-10	8.3E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	Pu-238	7.91E-10	2.74E-11	1.96E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	Pu-239	1.71E-10	6.93E-12	4.91E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	Ru-106	1.78E-09	7.73E-10	4.33E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	Sr-89	3.03E-12	7.36E-13	4.28E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	Sr-90	3.08E-11	3.3E-12	2.25E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	U-234	2.66E-11	2.5E-12	1.53E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	U-235	1.67E-12	1.7E-13	1.04E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	U-236	1.77E-12	1.66E-13	1.02E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Grain	U-238	8.96E-11	9.72E-12	5.88E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	Am-241	9.17E-13	2.38E-14	1.64E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	C-14	9.09E-07	1.5E-07	9.95E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	Cs-137	1.74E-08	2.39E-09	1.6E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	H-3	5.99E-06	9.12E-07	6.06E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	I-129	2.28E-07	2.1E-08	2.14E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	I-131	3.11E-06	2.91E-07	3.05E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	Pu-238	7.95E-11	2.77E-12	1.98E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	Pu-239	1.74E-11	6.5E-13	4.62E-13	Both	0

Near Water Family	Child born 1964	Ingestion	Beef	Ru-106	1E-06	4.53E-07	2.54E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	Sr-89	2.58E-10	5.97E-11	3.47E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	Sr-90	2.55E-09	2.41E-10	1.66E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	U-234	9.14E-11	7.7E-12	4.73E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	U-235	5.82E-12	5.28E-13	3.21E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	U-236	6.09E-12	5.13E-13	3.16E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Beef	U-238	3.05E-10	2.74E-11	1.68E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	Am-241	4.66E-16	1.22E-17	8.42E-18	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	C-14	3.01E-08	5.07E-09	3.35E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	Cs-137	1.09E-11	1.51E-12	1.01E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	H-3	8.05E-07	1.27E-07	8.43E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	I-129	2.13E-13	1.97E-14	2.01E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	I-131	3.51E-19	3.48E-20	3.64E-21	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	Pu-238	8.39E-14	2.91E-15	2.08E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	Pu-239	1.85E-14	7.77E-16	5.5E-16	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	Ru-106	4.17E-10	1.96E-10	1.1E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	Sr-89	7.59E-16	1.91E-16	1.11E-16	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	Sr-90	1.12E-13	1.26E-14	8.65E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-234	9.12E-13	9.01E-14	5.53E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-235	6E-14	6.37E-15	3.88E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-236	6.07E-14	5.99E-15	3.69E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Poultry	U-238	3.18E-12	3.33E-13	2.03E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	Am-241	7.87E-14	2.22E-15	1.52E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	C-14	1.39E-06	2.43E-07	1.6E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	Cs-137	4.96E-09	7.34E-10	4.85E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	H-3	2.72E-05	4.27E-06	2.82E-06	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	I-129	2.22E-07	2.21E-08	2.25E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	I-131	4.05E-06	4.02E-07	4.19E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	Pu-238	3.35E-11	1.17E-12	8.35E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	Pu-239	8.75E-12	3.33E-13	2.36E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	Ru-106	2.88E-10	1.25E-10	7.03E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	Sr-89	4.19E-10	9.5E-11	5.52E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	Sr-90	4.52E-09	3.77E-10	2.61E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	U-234	6.1E-10	4.99E-11	3.06E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	U-235	3.81E-11	3.43E-12	2.08E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	U-236	4.06E-11	3.32E-12	2.04E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Milk	U-238	1.97E-09	1.71E-10	1.05E-10	Both	0

Near Water Family	Child born 1964	Ingestion	Eggs	Am-241	6.43E-16	1.62E-17	1.13E-17	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	C-14	4.88E-08	8.19E-09	5.41E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	Cs-137	1.05E-12	1.46E-13	9.75E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	H-3	1.76E-06	2.75E-07	1.82E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	I-129	1.35E-10	1.26E-11	1.28E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	I-131	3.57E-16	3.64E-17	3.8E-18	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	Pu-238	2.78E-14	9.65E-16	6.91E-16	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	Pu-239	6.67E-15	2.85E-16	2.02E-16	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	Ru-106	5.53E-13	2.58E-13	1.45E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	Sr-89	4.27E-15	1.09E-15	6.32E-16	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	Sr-90	5.64E-13	5.16E-14	3.78E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-234	1.95E-12	1.96E-13	1.2E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-235	1.32E-13	1.39E-14	8.48E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-236	1.3E-13	1.3E-14	8.02E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Eggs	U-238	6.98E-12	7.03E-13	4.32E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	Am-241	2.33E-14	6.5E-16	4.46E-16	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	Cs-137	2.85E-13	4.24E-14	2.8E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	I-129	8.29E-12	8.35E-13	8.52E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	I-131	3.64E-11	3.67E-12	3.83E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	Pu-238	1.51E-11	5.27E-13	3.76E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	Pu-239	4.19E-12	1.62E-13	1.14E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	Ru-106	3.68E-11	1.59E-11	8.87E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	Sr-89	3.01E-14	6.84E-15	3.98E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	Sr-90	8.93E-13	8.73E-14	5.8E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	U-234	8.07E-13	6.61E-14	4.05E-14	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	U-235	5.1E-14	4.63E-15	2.8E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	U-236	5.37E-14	4.4E-15	2.7E-15	Both	0
Near Water Family	Child born 1964	Ingestion	Soil	U-238	2.91E-12	3.18E-13	1.89E-13	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Ce-144	3.36E-06	1.11E-06	6.14E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Co-60	2.77E-06	4.92E-07	3.11E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Cs-134	3.06E-06	5.92E-07	3.82E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Cs-137	0.000155	2.9E-05	1.84E-05	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	H-3	7.87E-07	1.21E-07	8.04E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	I-129	7.75E-07	3.45E-08	3.53E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	I-131	2.84E-06	3.2E-07	3.34E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Nb-95	2.82E-06	6.63E-07	3.75E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	P-32	0.001049	0.000241	0.000158	Both	0

Near Water Family	Child born 1964	Ingestion	Fish	Pu-238	1.92E-05	9.43E-07	6.62E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Pu-239	7.93E-05	3.42E-06	2.41E-06	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Ru-106	4.03E-06	1.28E-06	7.17E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	S-35	5.73E-06	1.31E-06	8.13E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Sr-89	1.43E-05	2.91E-06	1.69E-06	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Sr-90	9.03E-05	1.18E-05	8.52E-06	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Tc-99	3.39E-08	4.9E-09	2.81E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	U-234	3.38E-09	3.68E-10	2.24E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	U-235	2.18E-09	3.31E-10	2E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	U-236	1.77E-10	1.69E-11	1.02E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	U-238	1.54E-07	2.24E-08	1.36E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Zn-65	9.59E-06	1.28E-06	8.39E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Fish	Zr-95	3.21E-06	8.34E-07	4.7E-07	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Ce-144	1.19E-07	3.89E-08	2.16E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Co-60	9.36E-09	1.66E-09	1.05E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-134	6.74E-10	1.32E-10	8.48E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Cs-137	3.44E-08	6.47E-09	4.12E-09	Both	0

Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	H-3	6.75E-07	1.1E-07	7.24E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	I-129	9.59E-09	4.23E-10	4.32E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	I-131	8.11E-08	9.23E-09	9.59E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Nb-95	9.31E-09	2.21E-09	1.25E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	P-32	2.38E-08	5.41E-09	3.54E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-238	3.92E-09	2.05E-10	1.44E-10	Both	0

Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Pu-239	1.67E-08	7.72E-10	5.46E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Ru-106	4.04E-07	1.28E-07	7.19E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	S-35	7.54E-09	1.74E-09	1.08E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-89	3.29E-08	6.67E-09	3.88E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Sr-90	1.94E-07	2.28E-08	1.72E-08	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Tc-99	1.16E-09	2.02E-10	1.15E-10	Both	0

Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	U-234	3.57E-10	3.91E-11	2.39E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	U-235	2.29E-10	3.48E-11	2.1E-11	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	U-236	1.87E-11	1.8E-12	1.1E-12	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	U-238	1.62E-08	2.37E-09	1.45E-09	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Zn-65	1.02E-08	1.37E-09	8.94E-10	Both	0
Near Water Family	Child born 1964	Ingestion	Inadvertent Water Ingestion During Swimming	Zr-95	9.66E-09	2.57E-09	1.45E-09	Both	0

Near Water Family	Child born 1964	External	Air Immersion	Am-241	5.22E-16	6.62E-17	4.3E-17	Both	0
Near Water Family	Child born 1964	External	Air Immersion	Ar-41	1.77E-05	3.05E-06	2E-06	Both	0
Near Water Family	Child born 1964	External	Air Immersion	C-14	1.18E-12	3.15E-14	2.71E-14	Both	0
Near Water Family	Child born 1964	External	Air Immersion	Cs-137	4.9E-12	7.08E-13	4.7E-13	Both	0
Near Water Family	Child born 1964	External	Air Immersion	I-129	1.93E-13	2.7E-14	1.64E-14	Both	0
Near Water Family	Child born 1964	External	Air Immersion	I-131	8.47E-10	1.51E-10	9.91E-11	Both	0
Near Water Family	Child born 1964	External	Air Immersion	Pu-238	9.56E-16	1.44E-16	8.17E-17	Both	0
Near Water Family	Child born 1964	External	Air Immersion	Pu-239	1.92E-16	3.14E-17	1.95E-17	Both	0
Near Water Family	Child born 1964	External	Air Immersion	Ru-106	1.32E-10	2.18E-11	1.43E-11	Both	0
Near Water Family	Child born 1964	External	Air Immersion	Sr-89	2.29E-14	9.84E-16	7.65E-16	Both	0
Near Water Family	Child born 1964	External	Air Immersion	Sr-90	7.39E-15	2.75E-16	2.23E-16	Both	0
Near Water Family	Child born 1964	External	Air Immersion	U-234	2.03E-16	3.24E-17	2E-17	Both	0

Near Water Family	Child born 1964	External	Air Immersion	U-235	1.43E-14	2.38E-15	1.56E-15	Both	0
Near Water Family	Child born 1964	External	Air Immersion	U-236	9E-18	1.41E-18	8.43E-19	Both	0
Near Water Family	Child born 1964	External	Air Immersion	U-238	1.85E-15	2.3E-16	1.5E-16	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	Am-241	4.97E-13	6.18E-14	4.02E-14	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	Cs-137	2.86E-09	4.11E-10	2.73E-10	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	I-129	1.52E-10	2.06E-11	1.29E-11	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	I-131	1.8E-08	3.23E-09	2.11E-09	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	Pu-238	4.78E-12	5.83E-13	3.34E-13	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	Pu-239	4.36E-13	5.69E-14	3.38E-14	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	Ru-106	9.58E-08	1.1E-08	7.45E-09	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	Sr-89	3.21E-11	7.53E-13	6.93E-13	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	Sr-90	1.44E-10	3.74E-12	3.36E-12	Both	0

Near Water Family	Child born 1964	External	Ground Contamination	U-234	5.42E-13	6.93E-14	4.11E-14	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	U-235	9.47E-12	1.58E-12	1.03E-12	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	U-236	3.27E-14	4.06E-15	2.37E-15	Both	0
Near Water Family	Child born 1964	External	Ground Contamination	U-238	3.37E-10	1.78E-11	1.34E-11	Both	0
Near Water Family	Child born 1964	External	Swimming	Ce-144	1.8E-09	1.08E-10	9.01E-11	Both	0
Near Water Family	Child born 1964	External	Swimming	Co-60	9.75E-09	5.85E-10	4.88E-10	Both	0
Near Water Family	Child born 1964	External	Swimming	Cs-134	5.15E-10	3.09E-11	2.57E-11	Both	0
Near Water Family	Child born 1964	External	Swimming	Cs-137	1.14E-08	6.87E-10	5.72E-10	Both	0
Near Water Family	Child born 1964	External	Swimming	I-129	4.15E-12	2.49E-13	2.07E-13	Both	0
Near Water Family	Child born 1964	External	Swimming	I-131	1.83E-09	1.1E-10	9.13E-11	Both	0
Near Water Family	Child born 1964	External	Swimming	Nb-95	2.63E-08	1.58E-09	1.31E-09	Both	0
Near Water Family	Child born 1964	External	Swimming	P-32	9.87E-11	5.92E-12	4.93E-12	Both	0
Near Water Family	Child born 1964	External	Swimming	Pu-238	7.8E-15	4.68E-16	3.9E-16	Both	0
Near Water Family	Child born 1964	External	Swimming	Pu-239	2.34E-14	1.4E-15	1.17E-15	Both	0
Near Water Family	Child born 1964	External	Swimming	Ru-106	2.41E-08	1.45E-09	1.21E-09	Both	0
Near Water Family	Child born 1964	External	Swimming	S-35	3.6E-12	2.16E-13	1.8E-13	Both	0

Near Water Family	Child born 1964	External	Swimming	Sr-89	8.86E-11	5.33E-12	4.44E-12	Both	0
Near Water Family	Child born 1964	External	Swimming	Sr-90	2.81E-11	1.68E-12	1.4E-12	Both	0
Near Water Family	Child born 1964	External	Swimming	Tc-99	2.41E-12	1.44E-13	1.2E-13	Both	0
Near Water Family	Child born 1964	External	Swimming	U-234	2.69E-15	1.61E-16	1.34E-16	Both	0
Near Water Family	Child born 1964	External	Swimming	U-235	2.36E-12	1.42E-13	1.18E-13	Both	0
Near Water Family	Child born 1964	External	Swimming	U-236	8.29E-17	4.97E-18	4.15E-18	Both	0
Near Water Family	Child born 1964	External	Swimming	U-238	7.31E-14	4.39E-15	3.65E-15	Both	0
Near Water Family	Child born 1964	External	Swimming	Zn-65	2.84E-09	1.71E-10	1.42E-10	Both	0
Near Water Family	Child born 1964	External	Swimming	Zr-95	1.96E-08	1.17E-09	9.79E-10	Both	0
Near Water Family	Child born 1964	External	Boating	Ce-144	1.9E-09	5.71E-11	4.76E-11	Both	0
Near Water Family	Child born 1964	External	Boating	Co-60	1.03E-08	3.09E-10	2.57E-10	Both	0
Near Water Family	Child born 1964	External	Boating	Cs-134	5.43E-10	1.63E-11	1.36E-11	Both	0
Near Water Family	Child born 1964	External	Boating	Cs-137	1.21E-08	3.62E-10	3.02E-10	Both	0
Near Water Family	Child born 1964	External	Boating	I-129	4.37E-12	1.31E-13	1.09E-13	Both	0
Near Water Family	Child born 1964	External	Boating	I-131	1.93E-09	5.78E-11	4.81E-11	Both	0
Near Water Family	Child born 1964	External	Boating	Nb-95	2.77E-08	8.32E-10	6.93E-10	Both	0
Near Water Family	Child born 1964	External	Boating	P-32	1.04E-10	3.12E-12	2.61E-12	Both	0
Near Water Family	Child born 1964	External	Boating	Pu-238	8.22E-15	2.47E-16	2.06E-16	Both	0
Near Water Family	Child born 1964	External	Boating	Pu-239	2.46E-14	7.4E-16	6.16E-16	Both	0
Near Water Family	Child born 1964	External	Boating	Ru-106	2.55E-08	7.64E-10	6.37E-10	Both	0
Near Water Family	Child born 1964	External	Boating	S-35	3.79E-12	1.14E-13	9.48E-14	Both	0
Near Water Family	Child born 1964	External	Boating	Sr-89	9.37E-11	2.81E-12	2.34E-12	Both	0
Near Water Family	Child born 1964	External	Boating	Sr-90	2.96E-11	8.88E-13	7.4E-13	Both	0
Near Water Family	Child born 1964	External	Boating	Tc-99	2.54E-12	7.6E-14	6.34E-14	Both	0
Near Water Family	Child born 1964	External	Boating	U-234	2.83E-15	8.51E-17	7.08E-17	Both	0
Near Water Family	Child born 1964	External	Boating	U-235	2.49E-12	7.47E-14	6.22E-14	Both	0
Near Water Family	Child born 1964	External	Boating	U-236	8.75E-17	2.63E-18	2.19E-18	Both	0
Near Water Family	Child born 1964	External	Boating	U-238	7.7E-14	2.31E-15	1.93E-15	Both	0

Near Water Family	Child born 1964	External	Boating	Zn-65	3E-09	9E-11	7.5E-11	Both	0
Near Water Family	Child born 1964	External	Boating	Zr-95	2.06E-08	6.2E-10	5.17E-10	Both	0
Near Water Family	Child born 1964	External	Shoreline	Ce-144	1.09E-05	7.35E-07	5.34E-07	Both	0
Near Water Family	Child born 1964	External	Shoreline	Co-60	2.66E-05	4.69E-06	3.08E-06	Both	0
Near Water Family	Child born 1964	External	Shoreline	Cs-134	1.37E-06	2.48E-07	1.62E-07	Both	0
Near Water Family	Child born 1964	External	Shoreline	Cs-137	3.66E-05	6.5E-06	4.26E-06	Both	0
Near Water Family	Child born 1964	External	Shoreline	I-129	4.01E-08	3.22E-09	2.05E-09	Both	0
Near Water Family	Child born 1964	External	Shoreline	I-131	1.87E-07	3.37E-08	2.2E-08	Both	0
Near Water Family	Child born 1964	External	Shoreline	Nb-95	1.14E-05	1.96E-06	1.28E-06	Both	0
Near Water Family	Child born 1964	External	Shoreline	P-32	2.39E-07	6.15E-09	5.68E-09	Both	0
Near Water Family	Child born 1964	External	Shoreline	Pu-238	1.93E-10	2.38E-11	1.36E-11	Both	0
Near Water Family	Child born 1964	External	Shoreline	Pu-239	2.75E-10	3.59E-11	2.13E-11	Both	0
Near Water Family	Child born 1964	External	Shoreline	Ru-106	8.92E-05	9.84E-06	6.68E-06	Both	0
Near Water Family	Child born 1964	External	Shoreline	S-35	1.48E-09	2.2E-10	1.37E-10	Both	0
Near Water Family	Child born 1964	External	Shoreline	Sr-89	7.46E-07	1.81E-08	1.67E-08	Both	0
Near Water Family	Child born 1964	External	Shoreline	Sr-90	9.15E-06	2.46E-07	2.21E-07	Both	0
Near Water Family	Child born 1964	External	Shoreline	Tc-99	1.62E-09	1.51E-10	9.79E-11	Both	0
Near Water Family	Child born 1964	External	Shoreline	U-234	3.67E-11	4.81E-12	2.85E-12	Both	0
Near Water Family	Child born 1964	External	Shoreline	U-235	8.34E-09	1.48E-09	9.62E-10	Both	0
Near Water Family	Child born 1964	External	Shoreline	U-236	1.52E-12	1.94E-13	1.13E-13	Both	0
Near Water Family	Child born 1964	External	Shoreline	U-238	4.46E-07	2.55E-08	1.91E-08	Both	0
Near Water Family	Child born 1964	External	Shoreline	Zn-65	5.25E-06	9.53E-07	6.22E-07	Both	0
Near Water Family	Child born 1964	External	Shoreline	Zr-95	3.05E-05	5.03E-06	3.3E-06	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Am-241	5.75E-09	1.73E-10	1.5E-10	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	C-14	5.47E-10	9.26E-11	6.09E-11	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Cs-137	1.4E-10	1.92E-11	1.28E-11	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	H-3	8.41E-06	1.31E-06	8.66E-07	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	I-129	9.84E-09	9.28E-10	9.44E-11	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	I-131	4.03E-07	3.83E-08	3.97E-09	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Pu-238	2.12E-06	8.24E-08	7.33E-08	Both	0

Near Water Family	Child born 1964	Inhalation	Air Inhalation	Pu-239	4.12E-07	1.67E-08	1.47E-08	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Ru-106	7.92E-08	1.87E-08	1.59E-08	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Sr-89	7.91E-11	1.53E-11	1.29E-11	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	Sr-90	3.79E-10	5.4E-11	4.9E-11	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-234	2.7E-08	4.17E-09	3.94E-09	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-235	1.57E-09	2.4E-10	2.26E-10	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-236	1.76E-09	2.7E-10	2.56E-10	Both	0
Near Water Family	Child born 1964	Inhalation	Air Inhalation	U-238	7.94E-08	1.21E-08	1.14E-08	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Am-241	2.22E-11	6.67E-13	5.76E-13	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Cs-137	5.31E-13	7.27E-14	4.84E-14	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	I-129	1.55E-11	1.46E-12	1.49E-13	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	I-131	5.5E-11	5.25E-12	5.43E-13	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Pu-238	8.11E-09	3.17E-10	2.82E-10	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Pu-239	1.59E-09	6.43E-11	5.68E-11	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Ru-106	2.44E-10	5.76E-11	4.9E-11	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Sr-89	9.76E-14	1.89E-14	1.59E-14	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	Sr-90	1.53E-12	2.28E-13	2.02E-13	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-234	1.04E-10	1.6E-11	1.52E-11	Both	0

Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-235	6.02E-12	9.22E-13	8.7E-13	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-236	6.76E-12	1.04E-12	9.84E-13	Both	0
Near Water Family	Child born 1964	Inhalation	Resuspended Soil	U-238	3.06E-10	4.66E-11	4.4E-11	Both	0

Location	Receptor	ReportRou	ReportPathway	IsotopeNar	SumOfSun	SumOfSun	SumOfSun	AirWater	RunNum
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	Am-241	6.71E-11	6.55E-13	5.1E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	C-14	6.01E-08	2.95E-09	2.12E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	Cs-137	3.07E-09	1.5E-10	1.07E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	H-3	1.63E-06	7.9E-08	5.68E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	I-129	2.49E-08	5.42E-10	5.55E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	I-131	1.58E-05	3.52E-07	3.85E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	Pu-238	2.64E-08	3.02E-10	2.52E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	Pu-239	2.21E-07	2.36E-09	1.98E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	Ru-106	6.14E-08	2.9E-09	1.71E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	Sr-89	1.31E-10	6.3E-12	4.22E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	Sr-90	9.33E-08	3.92E-09	3.55E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	U-234	3.59E-09	7.59E-11	5.3E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	U-235	1.5E-10	3.26E-12	2.25E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	U-236	2.38E-10	5.07E-12	3.51E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Leafy Vegetables	U-238	6.37E-09	1.42E-10	9.79E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	Am-241	2.29E-11	2.24E-13	1.74E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	C-14	2.06E-07	1.01E-08	7.26E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	Cs-137	1.13E-09	5.49E-11	3.92E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	H-3	5.15E-06	2.5E-07	1.8E-07	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	I-129	8.53E-09	1.86E-10	1.9E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	I-131	1.77E-06	3.93E-08	4.3E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	Pu-238	9.05E-09	1.03E-10	8.63E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	Pu-239	7.58E-08	8.08E-10	6.77E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	Ru-106	2.06E-08	9.71E-10	5.72E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	Sr-89	4.13E-11	1.98E-12	1.33E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	Sr-90	3.93E-08	1.65E-09	1.49E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	U-234	1.23E-09	2.6E-11	1.81E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	U-235	5.14E-11	1.12E-12	7.7E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	U-236	8.16E-11	1.74E-12	1.2E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Root Vegetables	U-238	2.21E-09	5E-11	3.42E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	Am-241	2.27E-11	2.22E-13	1.73E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	C-14	2.04E-07	1E-08	7.19E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	Cs-137	1.02E-09	4.98E-11	3.56E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	H-3	5.09E-06	2.47E-07	1.77E-07	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	I-129	8.44E-09	1.84E-10	1.88E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	I-131	5.35E-06	1.19E-07	1.3E-08	Air	0

Rural Family #1	Adult Female	Ingestion	Fruit	Pu-238	8.96E-09	1.02E-10	8.55E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	Pu-239	7.5E-08	8E-10	6.7E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	Ru-106	2.08E-08	9.85E-10	5.8E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	Sr-89	4.49E-11	2.15E-12	1.44E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	Sr-90	3.19E-08	1.34E-09	1.22E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	U-234	1.22E-09	2.57E-11	1.8E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	U-235	5.08E-11	1.11E-12	7.61E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	U-236	8.08E-11	1.72E-12	1.19E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Fruit	U-238	2.16E-09	4.82E-11	3.32E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	Am-241	2.25E-12	2.2E-14	1.71E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	C-14	8.43E-08	4.14E-09	2.98E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	Cs-137	8.97E-11	4.37E-12	3.12E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	H-3	5.6E-07	2.73E-08	1.96E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	I-129	8.24E-10	1.79E-11	1.84E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	I-131	4.34E-07	9.67E-09	1.06E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	Pu-238	8.87E-10	1.01E-11	8.44E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	Pu-239	6.23E-09	6.66E-11	5.56E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	Ru-106	1.95E-09	9.23E-11	5.43E-11	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	Sr-89	4.1E-12	1.97E-13	1.32E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	Sr-90	2.89E-09	1.21E-10	1.1E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	U-234	1.05E-10	2.22E-12	1.55E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	U-235	4.49E-12	9.79E-14	6.73E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	U-236	6.97E-12	1.48E-13	1.03E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Grain	U-238	1.95E-10	4.36E-12	3E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	Am-241	6.46E-13	6.3E-15	4.91E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	C-14	9.53E-07	4.68E-08	3.36E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	Cs-137	3.7E-08	1.8E-09	1.29E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	H-3	5.96E-06	2.9E-07	2.08E-07	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	I-129	2.39E-07	5.21E-09	5.35E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	I-131	0.000146	3.24E-06	3.54E-07	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	Pu-238	6.36E-11	7.25E-13	6.06E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	Pu-239	5.33E-10	5.68E-12	4.74E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	Ru-106	7.43E-07	3.51E-08	2.07E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	Sr-89	2.62E-10	1.26E-11	8.43E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	Sr-90	1.79E-07	7.5E-09	6.81E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	U-234	2.6E-10	5.5E-12	3.83E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	U-235	1.08E-11	2.36E-13	1.62E-13	Air	0

Rural Family #1	Adult Female	Ingestion	Beef	U-236	1.72E-11	3.66E-13	2.53E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Beef	U-238	4.51E-10	9.85E-12	6.83E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	Am-241	3.96E-16	3.86E-18	3.01E-18	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	C-14	3.64E-08	1.79E-09	1.29E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	Cs-137	2.92E-11	1.42E-12	1.02E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	H-3	9.7E-07	4.72E-08	3.39E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	I-129	2.56E-13	5.56E-15	5.71E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	I-131	1.78E-17	3.96E-19	4.33E-20	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	Pu-238	7.78E-14	8.87E-16	7.39E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	Pu-239	6.52E-13	6.96E-15	5.81E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	Ru-106	3.43E-10	1.62E-11	9.55E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	Sr-89	9.48E-16	4.54E-17	3.04E-17	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	Sr-90	1.01E-11	4.24E-13	3.85E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	U-234	3.55E-12	7.52E-14	5.22E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	U-235	1.48E-13	3.23E-15	2.22E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	U-236	2.36E-13	5E-15	3.47E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Poultry	U-238	6.15E-12	1.34E-13	9.32E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	Am-241	2.91E-14	2.84E-16	2.21E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	C-14	4.81E-07	2.36E-08	1.7E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	Cs-137	6.57E-09	3.2E-10	2.29E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	H-3	8.61E-06	4.18E-07	3E-07	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	I-129	7.01E-08	1.53E-09	1.56E-10	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	I-131	3.95E-05	8.79E-07	9.62E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	Pu-238	8.43E-12	9.6E-14	7.99E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	Pu-239	5.88E-11	6.31E-13	5.26E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	Ru-106	5.6E-11	2.64E-12	1.56E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	Sr-89	1E-10	4.81E-12	3.23E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	Sr-90	6.21E-08	2.6E-09	2.38E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	U-234	3.61E-10	7.66E-12	5.34E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	U-235	1.54E-11	3.37E-13	2.32E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	U-236	2.4E-11	5.11E-13	3.54E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Milk	U-238	6.53E-10	1.41E-11	9.84E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	Am-241	3.89E-16	3.79E-18	2.96E-18	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	C-14	3.9E-08	1.92E-09	1.38E-09	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	Cs-137	1.57E-12	7.62E-14	5.45E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	H-3	1.37E-06	6.65E-08	4.77E-08	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	I-129	1.1E-10	2.39E-12	2.46E-13	Air	0

Rural Family #1	Adult Female	Ingestion	Eggs	I-131	1.02E-14	2.27E-16	2.49E-17	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	Pu-238	1.91E-14	2.18E-16	1.82E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	Pu-239	1.34E-13	1.44E-15	1.2E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	Ru-106	3.03E-13	1.43E-14	8.43E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	Sr-89	3.37E-15	1.62E-16	1.09E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	Sr-90	2.96E-11	1.23E-12	1.15E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	U-234	4.55E-12	9.65E-14	6.7E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	U-235	1.94E-13	4.22E-15	2.9E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	U-236	3.03E-13	6.42E-15	4.45E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Eggs	U-238	8.19E-12	1.76E-13	1.23E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	Am-241	1.1E-14	1.08E-16	8.39E-17	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	Cs-137	4.31E-13	2.1E-14	1.5E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	I-129	3.04E-12	6.62E-14	6.8E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	I-131	4.33E-10	9.67E-12	1.06E-12	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	Pu-238	4.35E-12	4.96E-14	4.13E-14	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	Pu-239	3.05E-11	3.26E-13	2.73E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	Ru-106	8.15E-12	3.85E-13	2.27E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	Sr-89	8.68E-15	4.16E-16	2.79E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	Sr-90	1.27E-11	5.33E-13	4.81E-13	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	U-234	5.15E-13	1.09E-14	7.57E-15	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	U-235	2.2E-14	4.8E-16	3.3E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	U-236	3.42E-14	7.25E-16	5.03E-16	Air	0
Rural Family #1	Adult Female	Ingestion	Soil	U-238	9.83E-13	2.26E-14	1.54E-14	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Am-241	4.23E-16	1.85E-17	1.29E-17	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Ar-41	2.41E-05	1.16E-06	8.31E-07	Air	0
Rural Family #1	Adult Female	External	Air Immersion	C-14	1.4E-12	1.35E-14	1.23E-14	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Cs-137	9.51E-12	4.55E-13	3.24E-13	Air	0
Rural Family #1	Adult Female	External	Air Immersion	I-129	2.13E-13	8.21E-15	5.39E-15	Air	0
Rural Family #1	Adult Female	External	Air Immersion	I-131	1.08E-07	5.13E-09	3.66E-09	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Pu-238	7.74E-16	2.84E-17	1.74E-17	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Pu-239	4.9E-15	2.11E-16	1.43E-16	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Ru-106	1.77E-10	7.84E-12	5.64E-12	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Sr-89	5.32E-14	7.18E-16	6.05E-16	Air	0
Rural Family #1	Adult Female	External	Air Immersion	Sr-90	7.47E-13	8.95E-15	7.76E-15	Air	0
Rural Family #1	Adult Female	External	Air Immersion	U-234	7.33E-16	3.05E-17	2.05E-17	Air	0
Rural Family #1	Adult Female	External	Air Immersion	U-235	3.54E-14	1.66E-15	1.18E-15	Air	0
Rural Family #1	Adult Female	External	Air Immersion	U-236	3.25E-17	1.29E-18	8.41E-19	Air	0

Rural Family #1	Adult Female	External	Air Immersion	U-238	3.96E-15	1.41E-16	1E-16	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	Am-241	3.85E-13	1.63E-14	1.14E-14	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	Cs-137	5.34E-09	2.51E-10	1.79E-10	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	I-129	1.72E-10	6.51E-12	4.34E-12	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	I-131	2.22E-06	1.05E-07	7.58E-08	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	Pu-238	3.64E-12	1.08E-13	6.57E-14	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	Pu-239	1.06E-11	3.45E-13	2.2E-13	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	Ru-106	1.23E-07	3.87E-09	2.86E-09	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	Sr-89	7.09E-11	6.05E-13	5.76E-13	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	Sr-90	1.41E-08	1.28E-10	1.2E-10	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	U-234	1.86E-12	5.89E-14	3.74E-14	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	U-235	2.23E-11	1.04E-12	7.4E-13	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	U-236	1.12E-13	3.42E-15	2.13E-15	Air	0
Rural Family #1	Adult Female	External	Ground Contamination	U-238	6.39E-10	1.06E-11	8.55E-12	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	Am-241	3.41E-09	4.45E-11	3.84E-11	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	C-14	4.39E-10	2.13E-11	1.53E-11	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	Cs-137	2.28E-10	1.07E-11	7.61E-12	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	H-3	6.96E-06	3.38E-07	2.43E-07	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	I-129	7.38E-09	1.61E-10	1.65E-11	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	I-131	1.29E-05	2.86E-07	3.1E-08	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	Pu-238	1.33E-06	1.87E-08	1.66E-08	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	Pu-239	9.23E-06	1.18E-07	1.04E-07	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	Ru-106	6.12E-08	3.25E-09	2.96E-09	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	Sr-89	9.74E-11	5.2E-12	4.8E-12	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	Sr-90	2.28E-08	1.14E-09	1.08E-09	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	U-234	5.45E-08	2.83E-09	2.68E-09	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	U-235	2.18E-09	1.13E-10	1.07E-10	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	U-236	3.52E-09	1.82E-10	1.73E-10	Air	0
Rural Family #1	Adult Female	Inhalation	Air Inhalation	U-238	8.94E-08	4.63E-09	4.35E-09	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	Am-241	1.22E-09	1.59E-11	1.37E-11	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	Cs-137	8.03E-11	3.76E-12	2.68E-12	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	I-129	1.16E-09	2.54E-11	2.6E-12	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	I-131	1.66E-07	3.7E-09	3.99E-10	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	Pu-238	4.77E-07	6.67E-09	5.94E-09	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	Pu-239	3.31E-06	4.24E-08	3.75E-08	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	Ru-106	1.75E-08	9.29E-10	8.48E-10	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	Sr-89	1.12E-11	5.97E-13	5.51E-13	Air	0

Rural Family #1	Adult Female	Inhalation	Resuspended Soil	Sr-90	8.36E-09	4.17E-10	3.93E-10	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	U-234	1.95E-08	1.01E-09	9.6E-10	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	U-235	7.83E-10	4.05E-11	3.83E-11	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	U-236	1.26E-09	6.54E-11	6.19E-11	Air	0
Rural Family #1	Adult Female	Inhalation	Resuspended Soil	U-238	3.21E-08	1.66E-09	1.56E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	Am-241	6.71E-11	6.55E-13	5.1E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	C-14	6.01E-08	2.95E-09	2.12E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	Cs-137	3.07E-09	1.5E-10	1.07E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	H-3	1.63E-06	7.9E-08	5.68E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	I-129	2.49E-08	5.42E-10	5.55E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	I-131	1.58E-05	3.52E-07	3.85E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	Pu-238	2.64E-08	3.02E-10	2.52E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	Pu-239	2.21E-07	2.36E-09	1.98E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	Ru-106	6.14E-08	2.9E-09	1.71E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	Sr-89	1.31E-10	6.3E-12	4.22E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	Sr-90	9.33E-08	3.92E-09	3.55E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	U-234	3.59E-09	7.59E-11	5.3E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	U-235	1.5E-10	3.26E-12	2.25E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	U-236	2.38E-10	5.07E-12	3.51E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Leafy Vegetables	U-238	6.37E-09	1.42E-10	9.79E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	Am-241	3.18E-11	3.1E-13	2.41E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	C-14	2.85E-07	1.4E-08	1.01E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	Cs-137	1.56E-09	7.6E-11	5.43E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	H-3	7.14E-06	3.46E-07	2.49E-07	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	I-129	1.18E-08	2.57E-10	2.63E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	I-131	2.45E-06	5.44E-08	5.96E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	Pu-238	1.25E-08	1.43E-10	1.19E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	Pu-239	1.05E-07	1.12E-09	9.37E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	Ru-106	2.85E-08	1.35E-09	7.92E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	Sr-89	5.72E-11	2.74E-12	1.84E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	Sr-90	5.44E-08	2.29E-09	2.06E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	U-234	1.7E-09	3.6E-11	2.51E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	U-235	7.11E-11	1.55E-12	1.07E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	U-236	1.13E-10	2.41E-12	1.67E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Root Vegetables	U-238	3.06E-09	6.93E-11	4.74E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	Am-241	2.21E-11	2.16E-13	1.68E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	C-14	1.98E-07	9.74E-09	7.01E-09	Air	0

Rural Family #1	Adult Male	Ingestion	Fruit	Cs-137	9.95E-10	4.86E-11	3.47E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	H-3	4.96E-06	2.41E-07	1.73E-07	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	I-129	8.23E-09	1.79E-10	1.84E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	I-131	5.22E-06	1.16E-07	1.27E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	Pu-238	8.73E-09	9.97E-11	8.33E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	Pu-239	7.32E-08	7.8E-10	6.53E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	Ru-106	2.03E-08	9.6E-10	5.66E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	Sr-89	4.37E-11	2.1E-12	1.41E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	Sr-90	3.11E-08	1.31E-09	1.18E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	U-234	1.19E-09	2.51E-11	1.75E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	U-235	4.95E-11	1.08E-12	7.42E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	U-236	7.87E-11	1.68E-12	1.16E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Fruit	U-238	2.11E-09	4.7E-11	3.23E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	Am-241	2.72E-12	2.65E-14	2.07E-14	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	C-14	1.02E-07	4.99E-09	3.59E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	Cs-137	1.08E-10	5.27E-12	3.77E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	H-3	6.75E-07	3.3E-08	2.36E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	I-129	9.94E-10	2.16E-11	2.22E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	I-131	5.23E-07	1.17E-08	1.28E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	Pu-238	1.07E-09	1.22E-11	1.02E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	Pu-239	7.52E-09	8.03E-11	6.7E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	Ru-106	2.35E-09	1.11E-10	6.55E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	Sr-89	4.94E-12	2.37E-13	1.59E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	Sr-90	3.48E-09	1.46E-10	1.33E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	U-234	1.27E-10	2.68E-12	1.87E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	U-235	5.42E-12	1.18E-13	8.11E-14	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	U-236	8.41E-12	1.79E-13	1.24E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Grain	U-238	2.35E-10	5.26E-12	3.62E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	Am-241	1.02E-12	9.91E-15	7.71E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	C-14	1.5E-06	7.35E-08	5.29E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	Cs-137	5.81E-08	2.83E-09	2.02E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	H-3	9.37E-06	4.56E-07	3.28E-07	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	I-129	3.76E-07	8.19E-09	8.4E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	I-131	0.000229	5.09E-06	5.57E-07	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	Pu-238	9.99E-11	1.14E-12	9.52E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	Pu-239	8.38E-10	8.93E-12	7.46E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	Ru-106	1.17E-06	5.52E-08	3.25E-08	Air	0

Rural Family #1	Adult Male	Ingestion	Beef	Sr-89	4.11E-10	1.97E-11	1.33E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	Sr-90	2.81E-07	1.18E-08	1.07E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	U-234	4.08E-10	8.65E-12	6.02E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	U-235	1.7E-11	3.71E-13	2.55E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	U-236	2.71E-11	5.75E-13	3.97E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Beef	U-238	7.09E-10	1.55E-11	1.07E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	Am-241	4.9E-16	4.78E-18	3.73E-18	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	C-14	4.5E-08	2.21E-09	1.59E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	Cs-137	3.62E-11	1.77E-12	1.26E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	H-3	1.2E-06	5.84E-08	4.19E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	I-129	3.16E-13	6.88E-15	7.06E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	I-131	2.21E-17	4.92E-19	5.38E-20	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	Pu-238	9.62E-14	1.1E-15	9.14E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	Pu-239	8.1E-13	8.65E-15	7.21E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	Ru-106	4.24E-10	2.01E-11	1.18E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	Sr-89	1.17E-15	5.63E-17	3.77E-17	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	Sr-90	1.25E-11	5.27E-13	4.78E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	U-234	4.4E-12	9.34E-14	6.48E-14	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	U-235	1.83E-13	4E-15	2.75E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	U-236	2.93E-13	6.2E-15	4.3E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Poultry	U-238	7.63E-12	1.66E-13	1.15E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	Am-241	3.87E-14	3.77E-16	2.94E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	C-14	6.39E-07	3.14E-08	2.26E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	Cs-137	8.72E-09	4.25E-10	3.04E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	H-3	1.14E-05	5.55E-07	3.99E-07	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	I-129	9.31E-08	2.03E-09	2.08E-10	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	I-131	5.25E-05	1.17E-06	1.28E-07	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	Pu-238	1.12E-11	1.28E-13	1.06E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	Pu-239	7.81E-11	8.37E-13	6.99E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	Ru-106	7.44E-11	3.51E-12	2.07E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	Sr-89	1.33E-10	6.39E-12	4.28E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	Sr-90	8.24E-08	3.45E-09	3.17E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	U-234	4.8E-10	1.02E-11	7.09E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	U-235	2.05E-11	4.47E-13	3.07E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	U-236	3.19E-11	6.79E-13	4.71E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Milk	U-238	8.67E-10	1.88E-11	1.31E-11	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	Am-241	6.44E-16	6.28E-18	4.9E-18	Air	0

Rural Family #1	Adult Male	Ingestion	Eggs	C-14	6.46E-08	3.17E-09	2.28E-09	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	Cs-137	2.59E-12	1.26E-13	9.02E-14	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	H-3	2.26E-06	1.1E-07	7.9E-08	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	I-129	1.82E-10	3.96E-12	4.07E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	I-131	1.69E-14	3.76E-16	4.12E-17	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	Pu-238	3.17E-14	3.6E-16	3.01E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	Pu-239	2.22E-13	2.39E-15	1.99E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	Ru-106	5.02E-13	2.37E-14	1.4E-14	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	Sr-89	5.58E-15	2.68E-16	1.8E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	Sr-90	4.9E-11	2.04E-12	1.9E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	U-234	7.53E-12	1.6E-13	1.11E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	U-235	3.21E-13	6.98E-15	4.8E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	U-236	5.01E-13	1.06E-14	7.37E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Eggs	U-238	1.35E-11	2.92E-13	2.04E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	Am-241	1.1E-14	1.08E-16	8.39E-17	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	Cs-137	4.31E-13	2.1E-14	1.5E-14	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	I-129	3.04E-12	6.62E-14	6.8E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	I-131	4.33E-10	9.67E-12	1.06E-12	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	Pu-238	4.35E-12	4.96E-14	4.13E-14	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	Pu-239	3.05E-11	3.26E-13	2.73E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	Ru-106	8.15E-12	3.85E-13	2.27E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	Sr-89	8.68E-15	4.16E-16	2.79E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	Sr-90	1.27E-11	5.33E-13	4.81E-13	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	U-234	5.15E-13	1.09E-14	7.57E-15	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	U-235	2.2E-14	4.8E-16	3.3E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	U-236	3.42E-14	7.25E-16	5.03E-16	Air	0
Rural Family #1	Adult Male	Ingestion	Soil	U-238	9.83E-13	2.26E-14	1.54E-14	Air	0
Rural Family #1	Adult Male	External	Air Immersion	Am-241	4.23E-16	1.85E-17	1.29E-17	Air	0
Rural Family #1	Adult Male	External	Air Immersion	Ar-41	2.41E-05	1.16E-06	8.31E-07	Air	0
Rural Family #1	Adult Male	External	Air Immersion	C-14	1.4E-12	1.35E-14	1.23E-14	Air	0
Rural Family #1	Adult Male	External	Air Immersion	Cs-137	9.51E-12	4.55E-13	3.24E-13	Air	0
Rural Family #1	Adult Male	External	Air Immersion	I-129	2.13E-13	8.21E-15	5.39E-15	Air	0
Rural Family #1	Adult Male	External	Air Immersion	I-131	1.08E-07	5.13E-09	3.66E-09	Air	0
Rural Family #1	Adult Male	External	Air Immersion	Pu-238	7.74E-16	2.84E-17	1.74E-17	Air	0
Rural Family #1	Adult Male	External	Air Immersion	Pu-239	4.9E-15	2.11E-16	1.43E-16	Air	0
Rural Family #1	Adult Male	External	Air Immersion	Ru-106	1.77E-10	7.84E-12	5.64E-12	Air	0
Rural Family #1	Adult Male	External	Air Immersion	Sr-89	5.32E-14	7.18E-16	6.05E-16	Air	0

Rural Family #1	Adult Male	External	Air Immersion	Sr-90	7.47E-13	8.95E-15	7.76E-15	Air	0
Rural Family #1	Adult Male	External	Air Immersion	U-234	7.33E-16	3.05E-17	2.05E-17	Air	0
Rural Family #1	Adult Male	External	Air Immersion	U-235	3.54E-14	1.66E-15	1.18E-15	Air	0
Rural Family #1	Adult Male	External	Air Immersion	U-236	3.25E-17	1.29E-18	8.41E-19	Air	0
Rural Family #1	Adult Male	External	Air Immersion	U-238	3.96E-15	1.41E-16	1E-16	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	Am-241	4.11E-13	1.75E-14	1.22E-14	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	Cs-137	5.71E-09	2.69E-10	1.92E-10	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	I-129	1.84E-10	6.96E-12	4.64E-12	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	I-131	2.37E-06	1.13E-07	8.1E-08	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	Pu-238	3.9E-12	1.15E-13	7.02E-14	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	Pu-239	1.13E-11	3.69E-13	2.35E-13	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	Ru-106	1.31E-07	4.14E-09	3.06E-09	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	Sr-89	7.58E-11	6.47E-13	6.16E-13	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	Sr-90	1.5E-08	1.37E-10	1.28E-10	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	U-234	1.99E-12	6.3E-14	4E-14	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	U-235	2.38E-11	1.11E-12	7.9E-13	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	U-236	1.19E-13	3.66E-15	2.28E-15	Air	0
Rural Family #1	Adult Male	External	Ground Contamination	U-238	6.83E-10	1.13E-11	9.14E-12	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	Am-241	4.59E-09	5.99E-11	5.16E-11	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	C-14	5.91E-10	2.86E-11	2.05E-11	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	Cs-137	3.07E-10	1.44E-11	1.02E-11	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	H-3	9.36E-06	4.55E-07	3.26E-07	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	I-129	9.92E-09	2.16E-10	2.22E-11	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	I-131	1.73E-05	3.85E-07	4.16E-08	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	Pu-238	1.79E-06	2.51E-08	2.23E-08	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	Pu-239	1.24E-05	1.58E-07	1.4E-07	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	Ru-106	8.23E-08	4.37E-09	3.98E-09	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	Sr-89	1.31E-10	6.99E-12	6.46E-12	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	Sr-90	3.06E-08	1.53E-09	1.45E-09	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	U-234	7.33E-08	3.81E-09	3.6E-09	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	U-235	2.94E-09	1.52E-10	1.44E-10	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	U-236	4.74E-09	2.45E-10	2.32E-10	Air	0
Rural Family #1	Adult Male	Inhalation	Air Inhalation	U-238	1.2E-07	6.23E-09	5.85E-09	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	Am-241	1.64E-09	2.14E-11	1.84E-11	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	Cs-137	1.08E-10	5.06E-12	3.6E-12	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	I-129	1.57E-09	3.42E-11	3.5E-12	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	I-131	2.24E-07	4.98E-09	5.37E-10	Air	0

Rural Family #1	Adult Male	Inhalation	Resuspended Soil	Pu-238	6.41E-07	8.97E-09	7.99E-09	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	Pu-239	4.45E-06	5.7E-08	5.04E-08	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	Ru-106	2.35E-08	1.25E-09	1.14E-09	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	Sr-89	1.5E-11	8.03E-13	7.41E-13	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	Sr-90	1.12E-08	5.61E-10	5.29E-10	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	U-234	2.63E-08	1.36E-09	1.29E-09	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	U-235	1.05E-09	5.45E-11	5.15E-11	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	U-236	1.7E-09	8.79E-11	8.33E-11	Air	0
Rural Family #1	Adult Male	Inhalation	Resuspended Soil	U-238	4.32E-08	2.24E-09	2.1E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	Am-241	6.71E-11	9.17E-13	6.84E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	C-14	4.48E-08	6.02E-09	4.02E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	Cs-137	1.32E-09	1.15E-10	7.69E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	H-3	1.21E-06	1.6E-07	1.07E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	I-129	2.04E-08	1.57E-09	1.59E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	I-131	2.81E-05	2.7E-06	2.82E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	Pu-238	1.67E-08	7.47E-10	5.37E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	Pu-239	2.58E-07	1.73E-09	1.21E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	Ru-106	6.11E-08	2.06E-08	1.16E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	Sr-89	1.36E-10	3.39E-11	1.98E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	Sr-90	5.92E-08	4.64E-09	3.06E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	U-234	2.22E-09	1.34E-10	8.27E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	U-235	1.02E-10	8.14E-12	4.97E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	U-236	1.47E-10	8.95E-12	5.5E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Leafy Vegetables	U-238	4.68E-09	4.48E-10	2.72E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	Am-241	3.18E-11	4.34E-13	3.23E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	C-14	2.45E-07	3.45E-08	2.3E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	Cs-137	9.86E-10	9.6E-11	6.29E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	H-3	6.01E-06	8.42E-07	5.62E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	I-129	1.1E-08	8.77E-10	8.93E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	I-131	6.99E-06	6.73E-07	7.03E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	Pu-238	9.84E-09	4.43E-10	3.18E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	Pu-239	5.63E-07	3.42E-09	2.38E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	Ru-106	4.95E-08	1.46E-08	8.18E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	Sr-89	1.36E-10	2.73E-11	1.59E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	Sr-90	1.31E-07	8.48E-09	5.54E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	U-234	3.66E-09	1.84E-10	1.13E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	U-235	1.24E-10	8.09E-12	4.91E-12	Air	0

Rural Family #1	Child born 1955	Ingestion	Root Vegetables	U-236	2.42E-10	1.23E-11	7.47E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Root Vegetables	U-238	4.4E-09	3.86E-10	2.32E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	Am-241	2.21E-11	3.03E-13	2.25E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	C-14	2.52E-07	3.88E-08	2.57E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	Cs-137	1.23E-09	1.35E-10	8.72E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	H-3	6.03E-06	9.42E-07	6.25E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	I-129	1.11E-08	9.67E-10	9.85E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	I-131	3.5E-05	3.38E-06	3.53E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	Pu-238	7.64E-09	3.45E-10	2.48E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	Pu-239	1.3E-06	7.76E-09	5.4E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	Ru-106	8.1E-08	2.08E-08	1.16E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	Sr-89	2.82E-10	5.08E-11	2.96E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	Sr-90	2.39E-07	1.41E-08	9.3E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	U-234	7.88E-09	3.72E-10	2.27E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	U-235	2.45E-10	1.46E-11	8.84E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	U-236	5.21E-10	2.48E-11	1.5E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Fruit	U-238	7.55E-09	5.86E-10	3.52E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	Am-241	2.72E-12	3.71E-14	2.77E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	C-14	1.17E-07	1.74E-08	1.15E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	Cs-137	7.52E-11	8E-12	5.24E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	H-3	7.75E-07	1.16E-07	7.72E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	I-129	1.3E-09	1.09E-10	1.11E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	I-131	2.65E-06	2.55E-07	2.66E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	Pu-238	9.18E-10	4.14E-11	2.98E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	Pu-239	3.51E-08	2.22E-10	1.54E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	Ru-106	4.74E-09	1.52E-09	8.53E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	Sr-89	1.33E-11	3.15E-12	1.83E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	Sr-90	8.15E-09	5.74E-10	3.8E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	U-234	2.48E-10	1.35E-11	8.26E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	U-235	9.92E-12	7.45E-13	4.53E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	U-236	1.65E-11	8.99E-13	5.49E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Grain	U-238	4.09E-10	3.94E-11	2.38E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	Am-241	1.02E-12	1.39E-14	1.03E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	C-14	1.41E-06	2.03E-07	1.35E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	Cs-137	3.73E-08	3.71E-09	2.43E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	H-3	8.66E-06	1.24E-06	8.27E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	I-129	3.93E-07	3.2E-08	3.26E-09	Air	0

Rural Family #1	Child born 1955	Ingestion	Beef	I-131	0.000673	6.47E-05	6.75E-06	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	Pu-238	9.41E-11	4.26E-12	3.06E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	Pu-239	4.32E-09	2.65E-11	1.84E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	Ru-106	2.14E-06	6.53E-07	3.67E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	Sr-89	1E-09	2.06E-10	1.2E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	Sr-90	6.53E-07	4E-08	2.65E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	U-234	8.67E-10	4.47E-11	2.73E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	U-235	3.02E-11	2.01E-12	1.22E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	U-236	5.74E-11	2.96E-12	1.8E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Beef	U-238	1.04E-09	8.2E-11	5E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	Am-241	4.9E-16	6.7E-18	4.99E-18	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	C-14	4.59E-08	6.8E-09	4.52E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	Cs-137	1.99E-11	2.05E-12	1.35E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	H-3	1.23E-06	1.83E-07	1.22E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	I-129	3.61E-13	3.01E-14	3.07E-15	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	I-131	9.01E-17	8.73E-18	9.1E-19	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	Pu-238	9.84E-14	4.46E-15	3.2E-15	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	Pu-239	1.74E-12	1.16E-14	8.08E-15	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	Ru-106	6.77E-10	2.38E-10	1.34E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	Sr-89	2.24E-15	5.92E-16	3.45E-16	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	Sr-90	1.55E-11	1.26E-12	8.36E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	U-234	4.82E-12	2.91E-13	1.78E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	U-235	2.18E-13	1.81E-14	1.1E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	U-236	3.2E-13	1.93E-14	1.19E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Poultry	U-238	9.55E-12	8.94E-13	5.47E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	Am-241	3.87E-14	5.28E-16	3.94E-16	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	C-14	1.42E-06	2.33E-07	1.54E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	Cs-137	1.63E-08	1.94E-09	1.25E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	H-3	2.44E-05	4.07E-06	2.7E-06	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	I-129	2.37E-07	2.16E-08	2.2E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	I-131	0.000671	6.47E-05	6.75E-06	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	Pu-238	2.42E-11	1.11E-12	7.96E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	Pu-239	2.21E-09	1.34E-11	9.29E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	Ru-106	4.83E-10	1.35E-10	7.6E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	Sr-89	1.41E-09	2.7E-10	1.57E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	Sr-90	1.01E-06	5.36E-08	3.64E-08	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	U-234	5.06E-09	2.48E-10	1.51E-10	Air	0

Rural Family #1	Child born 1955	Ingestion	Milk	U-235	1.63E-10	1.02E-11	6.2E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	U-236	3.35E-10	1.65E-11	1E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Milk	U-238	5.05E-09	3.71E-10	2.27E-10	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	Am-241	6.44E-16	8.79E-18	6.56E-18	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	C-14	5.84E-08	8.33E-09	5.54E-09	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	Cs-137	1.41E-12	1.36E-13	9.04E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	H-3	2.06E-06	2.95E-07	1.96E-07	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	I-129	1.8E-10	1.45E-11	1.48E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	I-131	6.59E-14	6.37E-15	6.66E-16	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	Pu-238	2.42E-14	1.09E-15	7.81E-16	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	Pu-239	4.63E-13	3.09E-15	2.15E-15	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	Ru-106	6.91E-13	2.38E-13	1.33E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	Sr-89	9.4E-15	2.49E-15	1.45E-15	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	Sr-90	5.64E-11	3.53E-12	2.5E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	U-234	7.59E-12	4.53E-13	2.78E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	U-235	3.45E-13	2.79E-14	1.7E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	U-236	5.04E-13	3.01E-14	1.85E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Eggs	U-238	1.5E-11	1.33E-12	8.16E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	Am-241	1.1E-14	1.51E-16	1.12E-16	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	Cs-137	8.62E-13	1.03E-13	6.62E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	I-129	7.74E-12	7.08E-13	7.23E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	I-131	6.22E-09	6.03E-10	6.28E-11	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	Pu-238	8.54E-12	3.93E-13	2.81E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	Pu-239	9.61E-10	5.8E-12	4.03E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	Ru-106	5.66E-11	1.55E-11	8.69E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	Sr-89	1E-13	1.91E-14	1.11E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	Sr-90	1.77E-10	1.12E-11	7.29E-12	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	U-234	5.98E-12	2.9E-13	1.76E-13	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	U-235	1.92E-13	1.2E-14	7.24E-15	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	U-236	3.97E-13	1.92E-14	1.17E-14	Air	0
Rural Family #1	Child born 1955	Ingestion	Soil	U-238	6.46E-12	5.9E-13	3.51E-13	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	Am-241	4.23E-16	2.96E-17	1.99E-17	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	Ar-41	2.38E-05	3.85E-06	2.54E-06	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	C-14	1.4E-12	3.27E-14	2.82E-14	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	Cs-137	9.53E-12	1.31E-12	8.67E-13	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	I-129	2.16E-13	2.69E-14	1.64E-14	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	I-131	1.08E-07	1.94E-08	1.27E-08	Air	0

Rural Family #1	Child born 1955	External	Air Immersion	Pu-238	8.02E-16	1.18E-16	6.68E-17	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	Pu-239	4.91E-15	8.24E-16	5.12E-16	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	Ru-106	1.79E-10	2.72E-11	1.8E-11	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	Sr-89	5.37E-14	2.27E-15	1.78E-15	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	Sr-90	7.47E-13	2.93E-14	2.39E-14	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	U-234	7.38E-16	1.19E-16	7.33E-17	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	U-235	3.56E-14	5.97E-15	3.91E-15	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	U-236	3.27E-17	5.15E-18	3.09E-18	Air	0
Rural Family #1	Child born 1955	External	Air Immersion	U-238	4E-15	4.96E-16	3.25E-16	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	Am-241	4.11E-13	2.82E-14	1.89E-14	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	Cs-137	5.49E-09	7.39E-10	4.88E-10	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	I-129	1.79E-10	2.15E-11	1.34E-11	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	I-131	2.22E-06	4.02E-07	2.64E-07	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	Pu-238	3.83E-12	4.56E-13	2.62E-13	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	Pu-239	1.06E-11	1.42E-12	8.42E-13	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	Ru-106	1.27E-07	1.34E-08	9.11E-09	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	Sr-89	7.23E-11	1.7E-12	1.57E-12	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	Sr-90	1.41E-08	3.95E-10	3.55E-10	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	U-234	1.88E-12	2.42E-13	1.44E-13	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	U-235	2.26E-11	3.81E-12	2.49E-12	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	U-236	1.13E-13	1.42E-14	8.3E-15	Air	0
Rural Family #1	Child born 1955	External	Ground Contamination	U-238	6.52E-10	3.42E-11	2.56E-11	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	Am-241	4.59E-09	7.88E-11	6.76E-11	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	C-14	6.44E-10	9.55E-11	6.31E-11	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	Cs-137	2.23E-10	2.19E-11	1.43E-11	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	H-3	9.52E-06	1.39E-06	9.21E-07	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	I-129	1.2E-08	1E-09	1.02E-10	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	I-131	6.37E-05	6.24E-06	6.47E-07	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	Pu-238	1.85E-06	8.9E-08	7.91E-08	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	Pu-239	6.15E-06	2.83E-07	2.48E-07	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	Ru-106	1.05E-07	1.91E-08	1.63E-08	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	Sr-89	1.79E-10	3.42E-11	2.86E-11	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	Sr-90	3.89E-08	4.8E-09	4.33E-09	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	U-234	9.13E-08	1.27E-08	1.2E-08	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	U-235	3.77E-09	5.5E-10	5.19E-10	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	U-236	5.95E-09	8.25E-10	7.8E-10	Air	0
Rural Family #1	Child born 1955	Inhalation	Air Inhalation	U-238	1.57E-07	2.37E-08	2.24E-08	Air	0

Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	Am-241	1.64E-09	2.81E-11	2.41E-11	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	Cs-137	7.72E-11	7.52E-12	4.92E-12	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	I-129	1.81E-09	1.51E-10	1.53E-11	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	I-131	8.23E-07	8.06E-08	8.34E-09	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	Pu-238	5.51E-07	2.64E-08	2.35E-08	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	Pu-239	2.19E-06	1.01E-07	8.85E-08	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	Ru-106	2.84E-08	5.11E-09	4.35E-09	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	Sr-89	1.97E-11	3.77E-12	3.14E-12	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	Sr-90	1.48E-08	1.9E-09	1.66E-09	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	U-234	3.18E-08	4.36E-09	4.11E-09	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	U-235	1.32E-09	1.9E-10	1.8E-10	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	U-236	2.07E-09	2.83E-10	2.68E-10	Air	0
Rural Family #1	Child born 1955	Inhalation	Resuspended Soil	U-238	5.53E-08	8.28E-09	7.82E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	Am-241	5.24E-11	1.29E-12	8.99E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	C-14	2.62E-08	4.2E-09	2.79E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	Cs-137	9.42E-10	1.27E-10	8.57E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	H-3	7.39E-07	1.09E-07	7.27E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	I-129	1.12E-08	9.91E-10	1.01E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	I-131	1.33E-07	1.21E-08	1.26E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	Pu-238	1.71E-08	5.92E-10	4.24E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	Pu-239	3.28E-09	1.27E-10	9.02E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	Ru-106	3.6E-08	1.64E-08	9.17E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	Sr-89	5.18E-11	1.25E-11	7.28E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	Sr-90	5.08E-10	5.5E-11	3.79E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	U-234	4.94E-10	4.56E-11	2.81E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	U-235	3.19E-11	3.09E-12	1.89E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	U-236	3.28E-11	3.03E-12	1.87E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Leafy Vegetables	U-238	1.74E-09	1.8E-10	1.09E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	Am-241	2.8E-11	7.09E-13	4.91E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	C-14	1.52E-07	2.5E-08	1.66E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	Cs-137	4.98E-10	6.78E-11	4.55E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	H-3	4.14E-06	6.15E-07	4.09E-07	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	I-129	6.95E-09	6.43E-10	6.55E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	I-131	2.89E-08	2.79E-09	2.91E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	Pu-238	8.87E-09	3.08E-10	2.21E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	Pu-239	2.11E-09	7.95E-11	5.65E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	Ru-106	2.28E-08	1.03E-08	5.76E-09	Air	0

Rural Family #1	Child born 1964	Ingestion	Root Vegetables	Sr-89	3.11E-11	7.18E-12	4.18E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	Sr-90	5.3E-10	5.27E-11	3.55E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	U-234	3.81E-10	3.18E-11	1.95E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	U-235	2.48E-11	2.23E-12	1.36E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	U-236	2.53E-11	2.11E-12	1.3E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Root Vegetables	U-238	1.39E-09	1.41E-10	8.46E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	Am-241	2.08E-11	5.34E-13	3.69E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	C-14	1.74E-07	2.97E-08	1.96E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	Cs-137	3.64E-10	5.11E-11	3.4E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	H-3	5.04E-06	7.58E-07	5.01E-07	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	I-129	8.51E-09	8.45E-10	8.6E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	I-131	1.35E-07	1.35E-08	1.41E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	Pu-238	1.08E-08	3.77E-10	2.69E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	Pu-239	3.09E-09	1.15E-10	8.08E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	Ru-106	3.11E-08	1.31E-08	7.36E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	Sr-89	5.1E-11	1.13E-11	6.55E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	Sr-90	7.41E-10	6.69E-11	4.49E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	U-234	6.25E-10	4.92E-11	3.01E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	U-235	4E-11	3.45E-12	2.09E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	U-236	4.17E-11	3.27E-12	2.01E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Fruit	U-238	2.17E-09	2.03E-10	1.23E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	Am-241	2.52E-12	6.45E-14	4.47E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	C-14	7.88E-08	1.33E-08	8.78E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	Cs-137	4.06E-11	5.73E-12	3.82E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	H-3	5.33E-07	8.53E-08	5.65E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	I-129	8.62E-10	8.18E-11	8.35E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	I-131	1.27E-08	1.23E-09	1.28E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	Pu-238	1.37E-09	4.76E-11	3.41E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	Pu-239	2.98E-10	1.2E-11	8.53E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	Ru-106	3.1E-09	1.36E-09	7.64E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	Sr-89	4.79E-12	1.17E-12	6.77E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	Sr-90	5.52E-11	5.94E-12	4.05E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	U-234	4.64E-11	4.35E-12	2.67E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	U-235	2.92E-12	2.98E-13	1.81E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	U-236	3.09E-12	2.9E-13	1.78E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Grain	U-238	1.59E-10	1.75E-11	1.05E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	Am-241	9.96E-13	2.58E-14	1.78E-14	Air	0

Rural Family #1	Child born 1964	Ingestion	Beef	C-14	8.82E-07	1.46E-07	9.66E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	Cs-137	1.88E-08	2.57E-09	1.72E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	H-3	5.81E-06	8.85E-07	5.87E-07	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	I-129	2.48E-07	2.28E-08	2.33E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	I-131	3E-06	2.81E-07	2.94E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	Pu-238	8.63E-11	3E-12	2.15E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	Pu-239	1.89E-11	7.08E-13	5.03E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	Ru-106	1.06E-06	4.79E-07	2.68E-07	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	Sr-89	2.54E-10	5.88E-11	3.42E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	Sr-90	2.87E-09	2.71E-10	1.86E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	U-234	9.95E-11	8.39E-12	5.15E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	U-235	6.32E-12	5.73E-13	3.49E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	U-236	6.62E-12	5.57E-13	3.43E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Beef	U-238	3.32E-10	2.99E-11	1.83E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	Am-241	5.07E-16	1.33E-17	9.16E-18	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	C-14	2.92E-08	4.92E-09	3.25E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	Cs-137	1.17E-11	1.64E-12	1.1E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	H-3	7.8E-07	1.23E-07	8.17E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	I-129	2.3E-13	2.13E-14	2.17E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	I-131	3.39E-19	3.36E-20	3.51E-21	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	Pu-238	9.1E-14	3.16E-15	2.26E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	Pu-239	2.01E-14	8.44E-16	5.98E-16	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	Ru-106	4.4E-10	2.07E-10	1.16E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	Sr-89	7.44E-16	1.87E-16	1.09E-16	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	Sr-90	1.2E-13	1.36E-14	9.28E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	U-234	9.93E-13	9.77E-14	6.01E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	U-235	6.53E-14	6.91E-15	4.21E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	U-236	6.6E-14	6.5E-15	4.01E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Poultry	U-238	3.46E-12	3.6E-13	2.2E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	Am-241	6.86E-14	1.93E-15	1.32E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	C-14	1.08E-06	1.89E-07	1.24E-07	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	Cs-137	4.25E-09	6.3E-10	4.17E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	H-3	2.11E-05	3.32E-06	2.19E-06	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	I-129	1.93E-07	1.92E-08	1.96E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	I-131	3.13E-06	3.1E-07	3.24E-08	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	Pu-238	2.93E-11	1.02E-12	7.25E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	Pu-239	7.62E-12	2.9E-13	2.05E-13	Air	0

Rural Family #1	Child born 1964	Ingestion	Milk	Ru-106	2.44E-10	1.06E-10	5.94E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	Sr-89	3.31E-10	7.5E-11	4.36E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	Sr-90	4.07E-09	3.39E-10	2.35E-10	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	U-234	5.31E-10	4.33E-11	2.65E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	U-235	3.31E-11	2.98E-12	1.81E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	U-236	3.53E-11	2.89E-12	1.77E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Milk	U-238	1.71E-09	1.49E-10	9.1E-11	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	Am-241	5.59E-16	1.41E-17	9.79E-18	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	C-14	3.79E-08	6.36E-09	4.21E-09	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	Cs-137	9.12E-13	1.26E-13	8.43E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	H-3	1.37E-06	2.13E-07	1.42E-07	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	I-129	1.17E-10	1.09E-11	1.11E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	I-131	2.76E-16	2.81E-17	2.94E-18	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	Pu-238	2.43E-14	8.42E-16	6.02E-16	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	Pu-239	5.8E-15	2.48E-16	1.76E-16	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	Ru-106	4.68E-13	2.19E-13	1.22E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	Sr-89	3.34E-15	8.51E-16	4.95E-16	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	Sr-90	4.85E-13	4.44E-14	3.25E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	U-234	1.7E-12	1.7E-13	1.05E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	U-235	1.15E-13	1.21E-14	7.37E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	U-236	1.13E-13	1.13E-14	6.97E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Eggs	U-238	6.06E-12	6.1E-13	3.75E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	Am-241	1.81E-14	5.07E-16	3.47E-16	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	Cs-137	2.15E-13	3.2E-14	2.11E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	I-129	6.52E-12	6.55E-13	6.69E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	I-131	2.79E-11	2.81E-12	2.93E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	Pu-238	1.14E-11	3.96E-13	2.83E-13	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	Pu-239	3.16E-12	1.22E-13	8.59E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	Ru-106	2.79E-11	1.21E-11	6.74E-12	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	Sr-89	2.27E-14	5.15E-15	2.99E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	Sr-90	7.02E-13	6.86E-14	4.55E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	U-234	6.09E-13	4.99E-14	3.05E-14	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	U-235	3.84E-14	3.49E-15	2.11E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	U-236	4.04E-14	3.31E-15	2.03E-15	Air	0
Rural Family #1	Child born 1964	Ingestion	Soil	U-238	2.19E-12	2.4E-13	1.42E-13	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Am-241	4.33E-16	5.5E-17	3.58E-17	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Ar-41	1.2E-05	2.07E-06	1.36E-06	Air	0

Rural Family #1	Child born 1964	External	Air Immersion	C-14	9.22E-13	2.45E-14	2.11E-14	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Cs-137	3.96E-12	5.72E-13	3.8E-13	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	I-129	1.53E-13	2.13E-14	1.3E-14	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	I-131	6.64E-10	1.18E-10	7.76E-11	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Pu-238	7.75E-16	1.17E-16	6.6E-17	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Pu-239	1.56E-16	2.54E-17	1.58E-17	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Ru-106	1.08E-10	1.78E-11	1.17E-11	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Sr-89	1.85E-14	7.96E-16	6.2E-16	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	Sr-90	6.58E-15	2.49E-16	2.01E-16	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	U-234	1.65E-16	2.63E-17	1.62E-17	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	U-235	1.17E-14	1.94E-15	1.27E-15	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	U-236	7.33E-18	1.15E-18	6.85E-19	Air	0
Rural Family #1	Child born 1964	External	Air Immersion	U-238	1.62E-15	2.02E-16	1.32E-16	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	Am-241	4.07E-13	5.06E-14	3.29E-14	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	Cs-137	2.35E-09	3.35E-10	2.22E-10	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	I-129	1.25E-10	1.69E-11	1.05E-11	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	I-131	1.43E-08	2.56E-09	1.68E-09	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	Pu-238	3.71E-12	4.52E-13	2.6E-13	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	Pu-239	3.4E-13	4.43E-14	2.62E-14	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	Ru-106	7.58E-08	8.69E-09	5.89E-09	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	Sr-89	2.51E-11	5.88E-13	5.41E-13	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	Sr-90	1.16E-10	3.02E-12	2.71E-12	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	U-234	4.24E-13	5.41E-14	3.2E-14	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	U-235	7.45E-12	1.24E-12	8.1E-13	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	U-236	2.55E-14	3.17E-15	1.85E-15	Air	0
Rural Family #1	Child born 1964	External	Ground Contamination	U-238	2.66E-10	1.4E-11	1.05E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	Am-241	4.77E-09	1.44E-10	1.25E-10	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	C-14	4.26E-10	7.23E-11	4.76E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	Cs-137	1.14E-10	1.56E-11	1.04E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	H-3	6.56E-06	1.02E-06	6.76E-07	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	I-129	7.82E-09	7.35E-10	7.49E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	I-131	3.16E-07	3.01E-08	3.11E-09	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	Pu-238	1.72E-06	6.68E-08	5.93E-08	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	Pu-239	3.34E-07	1.35E-08	1.19E-08	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	Ru-106	6.47E-08	1.54E-08	1.3E-08	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	Sr-89	6.41E-11	1.24E-11	1.04E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	Sr-90	3.26E-10	4.64E-11	4.21E-11	Air	0

Rural Family #1	Child born 1964	Inhalation	Air Inhalation	U-234	2.19E-08	3.37E-09	3.19E-09	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	U-235	1.27E-09	1.94E-10	1.83E-10	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	U-236	1.43E-09	2.2E-10	2.07E-10	Air	0
Rural Family #1	Child born 1964	Inhalation	Air Inhalation	U-238	6.43E-08	9.79E-09	9.25E-09	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	Am-241	1.52E-09	4.51E-11	3.9E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	Cs-137	3.98E-11	5.47E-12	3.63E-12	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	I-129	1.17E-09	1.1E-10	1.12E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	I-131	4.21E-09	4.02E-10	4.16E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	Pu-238	6.1E-07	2.37E-08	2.11E-08	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	Pu-239	1.19E-07	4.85E-09	4.27E-09	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	Ru-106	1.75E-08	4.1E-09	3.48E-09	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	Sr-89	7.3E-12	1.41E-12	1.19E-12	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	Sr-90	1.19E-10	1.77E-11	1.56E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	U-234	7.76E-09	1.2E-09	1.13E-09	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	U-235	4.5E-10	6.88E-11	6.5E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	U-236	5.07E-10	7.8E-11	7.37E-11	Air	0
Rural Family #1	Child born 1964	Inhalation	Resuspended Soil	U-238	2.29E-08	3.48E-09	3.28E-09	Air	0

Location	Receptor	ReportRou	ReportPathway	IsotopeNar	SumOfSum	SumOfSum	SumOfSum	AirWater	RunNum
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	Am-241	1.65E-10	1.61E-12	1.25E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	C-14	1.1E-07	5.39E-09	3.88E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	Cs-137	7.53E-09	3.67E-10	2.62E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	H-3	3.1E-06	1.5E-07	1.08E-07	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	I-129	5.93E-08	1.29E-09	1.32E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	I-131	3.77E-05	8.39E-07	9.2E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	Pu-238	6.5E-08	7.44E-10	6.19E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	Pu-239	5.42E-07	5.8E-09	4.84E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	Ru-106	1.51E-07	7.11E-09	4.19E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	Sr-89	3.23E-10	1.55E-11	1.04E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	Sr-90	2.29E-07	9.62E-09	8.71E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	U-234	8.82E-09	1.87E-10	1.3E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	U-235	3.68E-10	8.02E-12	5.51E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	U-236	5.86E-10	1.24E-11	8.63E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Leafy Vegetables	U-238	1.56E-08	3.49E-10	2.4E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	Am-241	5.64E-11	5.5E-13	4.28E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	C-14	3.76E-07	1.84E-08	1.33E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	Cs-137	2.76E-09	1.35E-10	9.61E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	H-3	9.81E-06	4.76E-07	3.42E-07	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	I-129	2.03E-08	4.42E-10	4.54E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	I-131	4.21E-06	9.37E-08	1.03E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	Pu-238	2.22E-08	2.52E-10	2.11E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	Pu-239	1.86E-07	1.98E-09	1.66E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	Ru-106	5.05E-08	2.38E-09	1.4E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	Sr-89	1.02E-10	4.87E-12	3.27E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	Sr-90	9.66E-08	4.06E-09	3.65E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	U-234	3.02E-09	6.4E-11	4.46E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	U-235	1.26E-10	2.75E-12	1.89E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	U-236	2.01E-10	4.26E-12	2.96E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Root Vegetables	U-238	5.42E-09	1.23E-10	8.4E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	Am-241	5.58E-11	5.44E-13	4.24E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	C-14	3.72E-07	1.83E-08	1.31E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	Cs-137	2.51E-09	1.22E-10	8.73E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	H-3	9.7E-06	4.71E-07	3.38E-07	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	I-129	2.01E-08	4.38E-10	4.49E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	I-131	1.28E-05	2.84E-07	3.12E-08	Air	0

Rural Family #2	Adult Female	Ingestion	Fruit	Pu-238	2.2E-08	2.52E-10	2.1E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	Pu-239	1.84E-07	1.96E-09	1.64E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	Ru-106	5.12E-08	2.42E-09	1.42E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	Sr-89	1.1E-10	5.28E-12	3.54E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	Sr-90	7.85E-08	3.3E-09	2.99E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	U-234	2.99E-09	6.33E-11	4.41E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	U-235	1.25E-10	2.72E-12	1.87E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	U-236	1.99E-10	4.22E-12	2.92E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Fruit	U-238	5.3E-09	1.18E-10	8.13E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	Am-241	5.53E-12	5.39E-14	4.2E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	C-14	1.54E-07	7.56E-09	5.44E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	Cs-137	2.2E-10	1.07E-11	7.65E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	H-3	1.06E-06	5.18E-08	3.72E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	I-129	1.96E-09	4.27E-11	4.38E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	I-131	1.04E-06	2.31E-08	2.52E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	Pu-238	2.17E-09	2.48E-11	2.07E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	Pu-239	1.53E-08	1.63E-10	1.36E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	Ru-106	4.79E-09	2.26E-10	1.33E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	Sr-89	1.01E-11	4.82E-13	3.24E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	Sr-90	7.08E-09	2.97E-10	2.7E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	U-234	2.57E-10	5.45E-12	3.79E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	U-235	1.11E-11	2.41E-13	1.65E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	U-236	1.71E-11	3.64E-13	2.52E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Grain	U-238	4.79E-10	1.07E-11	7.36E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	Am-241	1.59E-12	1.55E-14	1.21E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	C-14	1.74E-06	8.55E-08	6.15E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	Cs-137	9.04E-08	4.41E-09	3.15E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	H-3	1.14E-05	5.52E-07	3.97E-07	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	I-129	5.7E-07	1.24E-08	1.27E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	I-131	0.000348	7.74E-06	8.48E-07	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	Pu-238	1.56E-10	1.78E-12	1.48E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	Pu-239	1.31E-09	1.4E-11	1.17E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	Ru-106	1.83E-06	8.62E-08	5.07E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	Sr-89	6.44E-10	3.08E-11	2.07E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	Sr-90	4.4E-07	1.85E-08	1.68E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	U-234	6.38E-10	1.35E-11	9.4E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	U-235	2.66E-11	5.8E-13	3.98E-13	Air	0

Rural Family #2	Adult Female	Ingestion	Beef	U-236	4.22E-11	8.98E-13	6.22E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Beef	U-238	1.11E-09	2.42E-11	1.68E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	Am-241	9.71E-16	9.48E-18	7.39E-18	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	C-14	6.66E-08	3.27E-09	2.35E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	Cs-137	7.17E-11	3.5E-12	2.5E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	H-3	1.85E-06	8.98E-08	6.45E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	I-129	6.09E-13	1.33E-14	1.36E-15	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	I-131	4.26E-17	9.47E-19	1.04E-19	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	Pu-238	1.92E-13	2.19E-15	1.82E-15	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	Pu-239	1.6E-12	1.71E-14	1.43E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	Ru-106	8.42E-10	3.98E-11	2.34E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	Sr-89	2.33E-15	1.12E-16	7.48E-17	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	Sr-90	2.48E-11	1.04E-12	9.45E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	U-234	8.71E-12	1.85E-13	1.28E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	U-235	3.64E-13	7.9E-15	5.44E-15	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	U-236	5.78E-13	1.23E-14	8.53E-15	Air	0
Rural Family #2	Adult Female	Ingestion	Poultry	U-238	1.51E-11	3.29E-13	2.29E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	Am-241	7.14E-14	6.97E-16	5.43E-16	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	C-14	8.8E-07	4.32E-08	3.11E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	Cs-137	1.61E-08	7.85E-10	5.6E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	H-3	1.63E-05	7.92E-07	5.69E-07	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	I-129	1.67E-07	3.63E-09	3.73E-10	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	I-131	9.45E-05	2.1E-06	2.3E-07	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	Pu-238	2.06E-11	2.35E-13	1.96E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	Pu-239	1.45E-10	1.55E-12	1.29E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	Ru-106	1.37E-10	6.49E-12	3.82E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	Sr-89	2.46E-10	1.18E-11	7.92E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	Sr-90	1.52E-07	6.37E-09	5.83E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	U-234	8.85E-10	1.88E-11	1.31E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	U-235	3.8E-11	8.28E-13	5.69E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	U-236	5.88E-11	1.25E-12	8.66E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Milk	U-238	1.6E-09	3.47E-11	2.41E-11	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	Am-241	9.57E-16	9.33E-18	7.27E-18	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	C-14	7.13E-08	3.5E-09	2.52E-09	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	Cs-137	3.84E-12	1.87E-13	1.34E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	H-3	2.6E-06	1.26E-07	9.06E-08	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	I-129	2.62E-10	5.7E-12	5.86E-13	Air	0

Rural Family #2	Adult Female	Ingestion	Eggs	I-131	2.44E-14	5.44E-16	5.95E-17	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	Pu-238	4.69E-14	5.35E-16	4.47E-16	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	Pu-239	3.3E-13	3.53E-15	2.95E-15	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	Ru-106	7.44E-13	3.51E-14	2.07E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	Sr-89	8.28E-15	3.97E-16	2.66E-16	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	Sr-90	7.27E-11	3.03E-12	2.82E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	U-234	1.12E-11	2.37E-13	1.65E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	U-235	4.77E-13	1.03E-14	7.12E-15	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	U-236	7.42E-13	1.58E-14	1.09E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Eggs	U-238	2.01E-11	4.33E-13	3.02E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	Am-241	2.71E-14	2.64E-16	2.06E-16	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	Cs-137	1.06E-12	5.16E-14	3.68E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	I-129	7.26E-12	1.58E-13	1.62E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	I-131	1.04E-09	2.3E-11	2.52E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	Pu-238	1.07E-11	1.21E-13	1.01E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	Pu-239	7.49E-11	8.01E-13	6.69E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	Ru-106	2E-11	9.43E-13	5.55E-13	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	Sr-89	2.13E-14	1.02E-15	6.86E-16	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	Sr-90	3.11E-11	1.31E-12	1.18E-12	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	U-234	1.26E-12	2.67E-14	1.85E-14	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	U-235	5.41E-14	1.18E-15	8.1E-16	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	U-236	8.37E-14	1.78E-15	1.24E-15	Air	0
Rural Family #2	Adult Female	Ingestion	Soil	U-238	2.41E-12	5.54E-14	3.77E-14	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Am-241	8.63E-16	3.79E-17	2.64E-17	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Ar-41	5.39E-05	2.59E-06	1.86E-06	Air	0
Rural Family #2	Adult Female	External	Air Immersion	C-14	2.55E-12	2.48E-14	2.24E-14	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Cs-137	1.94E-11	9.3E-13	6.64E-13	Air	0
Rural Family #2	Adult Female	External	Air Immersion	I-129	4.53E-13	1.74E-14	1.15E-14	Air	0
Rural Family #2	Adult Female	External	Air Immersion	I-131	2.3E-07	1.1E-08	7.82E-09	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Pu-238	1.58E-15	5.78E-17	3.55E-17	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Pu-239	1E-14	4.31E-16	2.93E-16	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Ru-106	3.63E-10	1.61E-11	1.15E-11	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Sr-89	1.09E-13	1.47E-15	1.24E-15	Air	0
Rural Family #2	Adult Female	External	Air Immersion	Sr-90	1.39E-12	1.62E-14	1.41E-14	Air	0
Rural Family #2	Adult Female	External	Air Immersion	U-234	1.5E-15	6.24E-17	4.18E-17	Air	0
Rural Family #2	Adult Female	External	Air Immersion	U-235	7.2E-14	3.38E-15	2.4E-15	Air	0
Rural Family #2	Adult Female	External	Air Immersion	U-236	6.64E-17	2.64E-18	1.71E-18	Air	0

Rural Family #2	Adult Female	External	Air Immersion	U-238	6.35E-15	2.26E-16	1.6E-16	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	Am-241	9.46E-13	4.01E-14	2.79E-14	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	Cs-137	1.31E-08	6.15E-10	4.4E-10	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	I-129	4.11E-10	1.55E-11	1.04E-11	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	I-131	5.29E-06	2.51E-07	1.8E-07	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	Pu-238	8.92E-12	2.64E-13	1.62E-13	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	Pu-239	2.6E-11	8.49E-13	5.41E-13	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	Ru-106	3E-07	9.48E-09	7.01E-09	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	Sr-89	1.75E-10	1.49E-12	1.42E-12	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	Sr-90	3.44E-08	3.15E-10	2.93E-10	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	U-234	4.54E-12	1.44E-13	9.13E-14	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	U-235	5.46E-11	2.55E-12	1.81E-12	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	U-236	2.74E-13	8.41E-15	5.23E-15	Air	0
Rural Family #2	Adult Female	External	Ground Contamina	U-238	1.56E-09	2.59E-11	2.1E-11	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	Am-241	6.97E-09	9.09E-11	7.84E-11	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	C-14	8.04E-10	3.89E-11	2.8E-11	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	Cs-137	4.66E-10	2.18E-11	1.56E-11	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	H-3	1.3E-05	6.33E-07	4.54E-07	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	I-129	1.57E-08	3.42E-10	3.5E-11	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	I-131	2.75E-05	6.13E-07	6.61E-08	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	Pu-238	2.72E-06	3.82E-08	3.41E-08	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	Pu-239	1.89E-05	2.41E-07	2.14E-07	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	Ru-106	1.25E-07	6.64E-09	6.06E-09	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	Sr-89	2E-10	1.06E-11	9.83E-12	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	Sr-90	4.66E-08	2.32E-09	2.2E-09	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	U-234	1.11E-07	5.81E-09	5.49E-09	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	U-235	4.46E-09	2.31E-10	2.18E-10	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	U-236	7.21E-09	3.73E-10	3.52E-10	Air	0
Rural Family #2	Adult Female	Inhalation	Air Inhalation	U-238	1.83E-07	9.47E-09	8.89E-09	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	Am-241	3E-09	3.91E-11	3.37E-11	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	Cs-137	1.97E-10	9.23E-12	6.59E-12	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	I-129	2.77E-09	6.05E-11	6.19E-12	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	I-131	3.98E-07	8.85E-09	9.54E-10	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	Pu-238	1.17E-06	1.64E-08	1.45E-08	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	Pu-239	8.13E-06	1.04E-07	9.18E-08	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	Ru-106	4.3E-08	2.28E-09	2.08E-09	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	Sr-89	2.74E-11	1.47E-12	1.35E-12	Air	0

Rural Family #2	Adult Female	Inhalation	Resuspended Soil	Sr-90	2.05E-08	1.02E-09	9.66E-10	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	U-234	4.79E-08	2.49E-09	2.36E-09	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	U-235	1.92E-09	9.96E-11	9.4E-11	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	U-236	3.1E-09	1.6E-10	1.52E-10	Air	0
Rural Family #2	Adult Female	Inhalation	Resuspended Soil	U-238	7.87E-08	4.08E-09	3.83E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	Am-241	1.64E-10	1.6E-12	1.25E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	C-14	1.1E-07	5.37E-09	3.87E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	Cs-137	7.51E-09	3.66E-10	2.61E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	H-3	3.09E-06	1.5E-07	1.08E-07	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	I-129	5.91E-08	1.29E-09	1.32E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	I-131	3.77E-05	8.39E-07	9.2E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	Pu-238	6.46E-08	7.4E-10	6.16E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	Pu-239	5.42E-07	5.79E-09	4.84E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	Ru-106	1.5E-07	7.09E-09	4.17E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	Sr-89	3.23E-10	1.54E-11	1.04E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	Sr-90	2.29E-07	9.62E-09	8.7E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	U-234	8.81E-09	1.87E-10	1.3E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	U-235	3.67E-10	8E-12	5.5E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	U-236	5.85E-10	1.24E-11	8.62E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Leafy Vegetables	U-238	1.56E-08	3.48E-10	2.4E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	Am-241	7.8E-11	7.61E-13	5.93E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	C-14	5.21E-07	2.55E-08	1.84E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	Cs-137	3.82E-09	1.87E-10	1.33E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	H-3	1.36E-05	6.6E-07	4.74E-07	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	I-129	2.81E-08	6.12E-10	6.29E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	I-131	5.83E-06	1.3E-07	1.42E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	Pu-238	3.07E-08	3.5E-10	2.92E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	Pu-239	2.57E-07	2.75E-09	2.3E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	Ru-106	6.99E-08	3.3E-09	1.94E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	Sr-89	1.41E-10	6.74E-12	4.52E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	Sr-90	1.34E-07	5.63E-09	5.06E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	U-234	4.18E-09	8.86E-11	6.17E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	U-235	1.74E-10	3.81E-12	2.62E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	U-236	2.78E-10	5.9E-12	4.09E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Root Vegetables	U-238	7.51E-09	1.7E-10	1.16E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	Am-241	5.44E-11	5.31E-13	4.13E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	C-14	3.63E-07	1.78E-08	1.28E-08	Air	0

Rural Family #2	Adult Male	Ingestion	Fruit	Cs-137	2.45E-09	1.19E-10	8.51E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	H-3	9.45E-06	4.59E-07	3.29E-07	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	I-129	1.96E-08	4.27E-10	4.38E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	I-131	1.25E-05	2.77E-07	3.04E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	Pu-238	2.14E-08	2.46E-10	2.04E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	Pu-239	1.79E-07	1.92E-09	1.6E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	Ru-106	4.99E-08	2.36E-09	1.39E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	Sr-89	1.07E-10	5.15E-12	3.45E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	Sr-90	7.66E-08	3.22E-09	2.91E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	U-234	2.91E-09	6.18E-11	4.3E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	U-235	1.22E-10	2.65E-12	1.82E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	U-236	1.94E-10	4.11E-12	2.85E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Fruit	U-238	5.16E-09	1.15E-10	7.93E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	Am-241	6.67E-12	6.5E-14	5.07E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	C-14	1.86E-07	9.12E-09	6.56E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	Cs-137	2.65E-10	1.29E-11	9.23E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	H-3	1.28E-06	6.24E-08	4.48E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	I-129	2.37E-09	5.15E-11	5.29E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	I-131	1.25E-06	2.79E-08	3.04E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	Pu-238	2.62E-09	3E-11	2.5E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	Pu-239	1.84E-08	1.97E-10	1.64E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	Ru-106	5.77E-09	2.73E-10	1.61E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	Sr-89	1.21E-11	5.81E-13	3.9E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	Sr-90	8.54E-09	3.58E-10	3.25E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	U-234	3.1E-10	6.57E-12	4.57E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	U-235	1.33E-11	2.9E-13	1.99E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	U-236	2.06E-11	4.38E-13	3.04E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Grain	U-238	5.77E-10	1.29E-11	8.88E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	Am-241	2.49E-12	2.43E-14	1.89E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	C-14	2.74E-06	1.34E-07	9.66E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	Cs-137	1.42E-07	6.94E-09	4.96E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	H-3	1.78E-05	8.68E-07	6.23E-07	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	I-129	8.96E-07	1.95E-08	2E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	I-131	0.000547	1.22E-05	1.33E-06	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	Pu-238	2.45E-10	2.79E-12	2.33E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	Pu-239	2.05E-09	2.2E-11	1.84E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	Ru-106	2.87E-06	1.35E-07	7.98E-08	Air	0

Rural Family #2	Adult Male	Ingestion	Beef	Sr-89	1.01E-09	4.85E-11	3.25E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	Sr-90	6.92E-07	2.9E-08	2.63E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	U-234	1E-09	2.12E-11	1.48E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	U-235	4.18E-11	9.11E-13	6.25E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	U-236	6.64E-11	1.41E-12	9.78E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Beef	U-238	1.74E-09	3.8E-11	2.64E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	Am-241	1.2E-15	1.17E-17	9.13E-18	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	C-14	8.24E-08	4.05E-09	2.91E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	Cs-137	8.88E-11	4.33E-12	3.09E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	H-3	2.29E-06	1.11E-07	7.99E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	I-129	7.54E-13	1.64E-14	1.68E-15	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	I-131	5.29E-17	1.18E-18	1.29E-19	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	Pu-238	2.37E-13	2.7E-15	2.25E-15	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	Pu-239	1.99E-12	2.12E-14	1.77E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	Ru-106	1.04E-09	4.93E-11	2.9E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	Sr-89	2.89E-15	1.38E-16	9.28E-17	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	Sr-90	3.08E-11	1.29E-12	1.17E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	U-234	1.08E-11	2.29E-13	1.59E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	U-235	4.51E-13	9.8E-15	6.75E-15	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	U-236	7.17E-13	1.53E-14	1.06E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Poultry	U-238	1.87E-11	4.08E-13	2.83E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	Am-241	9.49E-14	9.25E-16	7.21E-16	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	C-14	1.17E-06	5.73E-08	4.13E-08	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	Cs-137	2.14E-08	1.04E-09	7.44E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	H-3	2.17E-05	1.05E-06	7.55E-07	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	I-129	2.22E-07	4.82E-09	4.95E-10	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	I-131	0.000125	2.79E-06	3.06E-07	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	Pu-238	2.73E-11	3.12E-13	2.6E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	Pu-239	1.92E-10	2.06E-12	1.72E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	Ru-106	1.83E-10	8.62E-12	5.08E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	Sr-89	3.27E-10	1.57E-11	1.05E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	Sr-90	2.02E-07	8.46E-09	7.75E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	U-234	1.17E-09	2.5E-11	1.74E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	U-235	5.04E-11	1.1E-12	7.55E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	U-236	7.81E-11	1.66E-12	1.15E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Milk	U-238	2.13E-09	4.61E-11	3.21E-11	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	Am-241	1.58E-15	1.54E-17	1.2E-17	Air	0

Rural Family #2	Adult Male	Ingestion	Eggs	C-14	1.18E-07	5.79E-09	4.17E-09	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	Cs-137	6.35E-12	3.09E-13	2.21E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	H-3	4.3E-06	2.09E-07	1.5E-07	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	I-129	4.34E-10	9.44E-12	9.69E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	I-131	4.04E-14	9E-16	9.84E-17	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	Pu-238	7.77E-14	8.86E-16	7.4E-16	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	Pu-239	5.47E-13	5.85E-15	4.88E-15	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	Ru-106	1.23E-12	5.81E-14	3.42E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	Sr-89	1.37E-14	6.57E-16	4.41E-16	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	Sr-90	1.2E-10	5.02E-12	4.66E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	U-234	1.85E-11	3.92E-13	2.73E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	U-235	7.89E-13	1.71E-14	1.18E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	U-236	1.23E-12	2.61E-14	1.81E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Eggs	U-238	3.32E-11	7.16E-13	5E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	Am-241	2.71E-14	2.64E-16	2.06E-16	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	Cs-137	1.06E-12	5.16E-14	3.68E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	I-129	7.26E-12	1.58E-13	1.62E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	I-131	1.04E-09	2.3E-11	2.52E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	Pu-238	1.07E-11	1.21E-13	1.01E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	Pu-239	7.49E-11	8.01E-13	6.69E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	Ru-106	2E-11	9.43E-13	5.55E-13	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	Sr-89	2.13E-14	1.02E-15	6.86E-16	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	Sr-90	3.11E-11	1.31E-12	1.18E-12	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	U-234	1.26E-12	2.67E-14	1.85E-14	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	U-235	5.41E-14	1.18E-15	8.1E-16	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	U-236	8.37E-14	1.78E-15	1.24E-15	Air	0
Rural Family #2	Adult Male	Ingestion	Soil	U-238	2.41E-12	5.54E-14	3.77E-14	Air	0
Rural Family #2	Adult Male	External	Air Immersion	Am-241	8.63E-16	3.79E-17	2.64E-17	Air	0
Rural Family #2	Adult Male	External	Air Immersion	Ar-41	5.39E-05	2.59E-06	1.86E-06	Air	0
Rural Family #2	Adult Male	External	Air Immersion	C-14	2.55E-12	2.48E-14	2.24E-14	Air	0
Rural Family #2	Adult Male	External	Air Immersion	Cs-137	1.94E-11	9.3E-13	6.64E-13	Air	0
Rural Family #2	Adult Male	External	Air Immersion	I-129	4.53E-13	1.74E-14	1.15E-14	Air	0
Rural Family #2	Adult Male	External	Air Immersion	I-131	2.3E-07	1.1E-08	7.82E-09	Air	0
Rural Family #2	Adult Male	External	Air Immersion	Pu-238	1.58E-15	5.78E-17	3.55E-17	Air	0
Rural Family #2	Adult Male	External	Air Immersion	Pu-239	1E-14	4.31E-16	2.93E-16	Air	0
Rural Family #2	Adult Male	External	Air Immersion	Ru-106	3.63E-10	1.61E-11	1.15E-11	Air	0
Rural Family #2	Adult Male	External	Air Immersion	Sr-89	1.09E-13	1.47E-15	1.24E-15	Air	0

Rural Family #2	Adult Male	External	Air Immersion	Sr-90	1.39E-12	1.62E-14	1.41E-14	Air	0
Rural Family #2	Adult Male	External	Air Immersion	U-234	1.5E-15	6.24E-17	4.18E-17	Air	0
Rural Family #2	Adult Male	External	Air Immersion	U-235	7.2E-14	3.38E-15	2.4E-15	Air	0
Rural Family #2	Adult Male	External	Air Immersion	U-236	6.64E-17	2.64E-18	1.71E-18	Air	0
Rural Family #2	Adult Male	External	Air Immersion	U-238	6.35E-15	2.26E-16	1.6E-16	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	Am-241	1.01E-12	4.29E-14	2.98E-14	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	Cs-137	1.4E-08	6.58E-10	4.7E-10	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	I-129	4.39E-10	1.66E-11	1.11E-11	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	I-131	5.65E-06	2.69E-07	1.93E-07	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	Pu-238	9.53E-12	2.82E-13	1.73E-13	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	Pu-239	2.78E-11	9.07E-13	5.78E-13	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	Ru-106	3.21E-07	1.01E-08	7.49E-09	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	Sr-89	1.87E-10	1.59E-12	1.51E-12	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	Sr-90	3.67E-08	3.36E-10	3.13E-10	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	U-234	4.85E-12	1.54E-13	9.76E-14	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	U-235	5.83E-11	2.73E-12	1.94E-12	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	U-236	2.93E-13	8.99E-15	5.58E-15	Air	0
Rural Family #2	Adult Male	External	Ground Contamina	U-238	1.67E-09	2.77E-11	2.24E-11	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	Am-241	9.37E-09	1.22E-10	1.05E-10	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	C-14	1.08E-09	5.23E-11	3.76E-11	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	Cs-137	6.27E-10	2.94E-11	2.09E-11	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	H-3	1.75E-05	8.52E-07	6.11E-07	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	I-129	2.11E-08	4.6E-10	4.71E-11	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	I-131	3.7E-05	8.24E-07	8.9E-08	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	Pu-238	3.66E-06	5.14E-08	4.58E-08	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	Pu-239	2.54E-05	3.25E-07	2.87E-07	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	Ru-106	1.68E-07	8.94E-09	8.16E-09	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	Sr-89	2.69E-10	1.43E-11	1.32E-11	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	Sr-90	6.27E-08	3.12E-09	2.96E-09	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	U-234	1.5E-07	7.81E-09	7.38E-09	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	U-235	6E-09	3.11E-10	2.93E-10	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	U-236	9.69E-09	5.01E-10	4.74E-10	Air	0
Rural Family #2	Adult Male	Inhalation	Air Inhalation	U-238	2.46E-07	1.27E-08	1.2E-08	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	Am-241	4.04E-09	5.26E-11	4.54E-11	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	Cs-137	2.66E-10	1.24E-11	8.86E-12	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	I-129	3.73E-09	8.14E-11	8.33E-12	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	I-131	5.35E-07	1.19E-08	1.28E-09	Air	0

Rural Family #2	Adult Male	Inhalation	Resuspended Soil	Pu-238	1.57E-06	2.2E-08	1.96E-08	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	Pu-239	1.09E-05	1.4E-07	1.23E-07	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	Ru-106	5.78E-08	3.07E-09	2.8E-09	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	Sr-89	3.69E-11	1.97E-12	1.82E-12	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	Sr-90	2.76E-08	1.38E-09	1.3E-09	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	U-234	6.44E-08	3.35E-09	3.17E-09	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	U-235	2.58E-09	1.34E-10	1.26E-10	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	U-236	4.17E-09	2.16E-10	2.04E-10	Air	0
Rural Family #2	Adult Male	Inhalation	Resuspended Soil	U-238	1.06E-07	5.49E-09	5.15E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	Am-241	1.64E-10	2.24E-12	1.67E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	C-14	8.18E-08	1.1E-08	7.32E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	Cs-137	3.23E-09	2.81E-10	1.88E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	H-3	2.28E-06	3.02E-07	2.02E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	I-129	4.86E-08	3.73E-09	3.8E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	I-131	6.73E-05	6.45E-06	6.75E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	Pu-238	4.12E-08	1.84E-09	1.32E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	Pu-239	6.32E-07	4.24E-09	2.96E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	Ru-106	1.5E-07	5.06E-08	2.85E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	Sr-89	3.34E-10	8.34E-11	4.86E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	Sr-90	1.45E-07	1.14E-08	7.52E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	U-234	5.44E-09	3.31E-10	2.03E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	U-235	2.51E-10	2E-11	1.22E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	U-236	3.61E-10	2.19E-11	1.35E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Leafy Vegetables	U-238	1.15E-08	1.1E-09	6.67E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	Am-241	7.8E-11	1.07E-12	7.94E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	C-14	4.15E-07	5.79E-08	3.86E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	Cs-137	2.36E-09	2.25E-10	1.48E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	H-3	1.06E-05	1.48E-06	9.87E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	I-129	2.29E-08	1.79E-09	1.83E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	I-131	1.65E-05	1.6E-06	1.67E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	Pu-238	2.41E-08	1.08E-09	7.78E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	Pu-239	1.38E-06	8.36E-09	5.81E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	Ru-106	1.15E-07	3.38E-08	1.9E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	Sr-89	3.24E-10	6.48E-11	3.78E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	Sr-90	3.21E-07	2.08E-08	1.35E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	U-234	8.92E-09	4.46E-10	2.72E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	U-235	2.97E-10	1.9E-11	1.15E-11	Air	0

Rural Family #2	Child born 1955	Ingestion	Root Vegetables	U-236	5.92E-10	2.96E-11	1.81E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Root Vegetables	U-238	1.02E-08	8.83E-10	5.29E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	Am-241	5.44E-11	7.43E-13	5.54E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	C-14	4.62E-07	7.11E-08	4.71E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	Cs-137	3.02E-09	3.33E-10	2.14E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	H-3	1.16E-05	1.83E-06	1.22E-06	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	I-129	2.66E-08	2.3E-09	2.35E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	I-131	8.37E-05	8.07E-06	8.44E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	Pu-238	1.88E-08	8.51E-10	6.09E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	Pu-239	3.18E-06	1.91E-08	1.32E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	Ru-106	1.99E-07	5.1E-08	2.86E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	Sr-89	6.92E-10	1.25E-10	7.26E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	Sr-90	5.88E-07	3.47E-08	2.28E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	U-234	1.93E-08	9.15E-10	5.57E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	U-235	6.02E-10	3.59E-11	2.17E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	U-236	1.28E-09	6.07E-11	3.7E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Fruit	U-238	1.85E-08	1.44E-09	8.63E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	Am-241	6.67E-12	9.11E-14	6.79E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	C-14	2.14E-07	3.18E-08	2.11E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	Cs-137	1.85E-10	1.96E-11	1.28E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	H-3	1.47E-06	2.23E-07	1.48E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	I-129	3.09E-09	2.6E-10	2.65E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	I-131	6.34E-06	6.1E-07	6.36E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	Pu-238	2.25E-09	1.02E-10	7.3E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	Pu-239	8.6E-08	5.44E-10	3.78E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	Ru-106	1.16E-08	3.72E-09	2.09E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	Sr-89	3.26E-11	7.73E-12	4.51E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	Sr-90	1.99E-08	1.41E-09	9.32E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	U-234	6.08E-10	3.31E-11	2.02E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	U-235	2.44E-11	1.83E-12	1.11E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	U-236	4.04E-11	2.2E-12	1.35E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Grain	U-238	1E-09	9.65E-11	5.83E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	Am-241	2.49E-12	3.4E-14	2.54E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	C-14	2.57E-06	3.7E-07	2.46E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	Cs-137	9.12E-08	9.11E-09	5.97E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	H-3	1.64E-05	2.36E-06	1.57E-06	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	I-129	9.37E-07	7.62E-08	7.78E-09	Air	0

Rural Family #2	Child born 1955	Ingestion	Beef	I-131	0.00161	0.000155	1.62E-05	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	Pu-238	2.31E-10	1.04E-11	7.49E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	Pu-239	1.06E-08	6.51E-11	4.53E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	Ru-106	5.26E-06	1.6E-06	9E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	Sr-89	2.47E-09	5.07E-10	2.95E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	Sr-90	1.6E-06	9.82E-08	6.51E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	U-234	2.13E-09	1.1E-10	6.69E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	U-235	7.39E-11	4.94E-12	3E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	U-236	1.41E-10	7.26E-12	4.44E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Beef	U-238	2.55E-09	2.01E-10	1.23E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	Am-241	1.2E-15	1.64E-17	1.22E-17	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	C-14	8.4E-08	1.24E-08	8.26E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	Cs-137	4.87E-11	5.02E-12	3.31E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	H-3	2.34E-06	3.51E-07	2.34E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	I-129	8.61E-13	7.17E-14	7.3E-15	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	I-131	2.16E-16	2.09E-17	2.18E-18	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	Pu-238	2.43E-13	1.1E-14	7.89E-15	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	Pu-239	4.28E-12	2.85E-14	1.99E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	Ru-106	1.66E-09	5.85E-10	3.29E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	Sr-89	5.49E-15	1.45E-15	8.48E-16	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	Sr-90	3.81E-11	3.11E-12	2.05E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	U-234	1.18E-11	7.15E-13	4.38E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	U-235	5.36E-13	4.44E-14	2.7E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	U-236	7.83E-13	4.75E-14	2.91E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Poultry	U-238	2.34E-11	2.2E-12	1.34E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	Am-241	9.49E-14	1.3E-15	9.66E-16	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	C-14	2.61E-06	4.26E-07	2.82E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	Cs-137	3.98E-08	4.77E-09	3.06E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	H-3	4.68E-05	7.86E-06	5.2E-06	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	I-129	5.65E-07	5.14E-08	5.24E-09	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	I-131	0.001607	0.000155	1.62E-05	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	Pu-238	5.92E-11	2.73E-12	1.95E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	Pu-239	5.44E-09	3.29E-11	2.28E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	Ru-106	1.19E-09	3.33E-10	1.87E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	Sr-89	3.47E-09	6.64E-10	3.86E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	Sr-90	2.48E-06	1.31E-07	8.92E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	U-234	1.24E-08	6.08E-10	3.7E-10	Air	0

Rural Family #2	Child born 1955	Ingestion	Milk	U-235	4E-10	2.52E-11	1.53E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	U-236	8.21E-10	4.03E-11	2.45E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Milk	U-238	1.24E-08	9.11E-10	5.56E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	Am-241	1.58E-15	2.16E-17	1.61E-17	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	C-14	1.07E-07	1.52E-08	1.01E-08	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	Cs-137	3.47E-12	3.34E-13	2.22E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	H-3	3.93E-06	5.65E-07	3.76E-07	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	I-129	4.3E-10	3.46E-11	3.53E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	I-131	1.58E-13	1.53E-14	1.59E-15	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	Pu-238	5.95E-14	2.67E-15	1.92E-15	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	Pu-239	1.14E-12	7.58E-15	5.27E-15	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	Ru-106	1.69E-12	5.82E-13	3.27E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	Sr-89	2.31E-14	6.09E-15	3.55E-15	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	Sr-90	1.39E-10	8.69E-12	6.16E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	U-234	1.86E-11	1.11E-12	6.82E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	U-235	8.48E-13	6.84E-14	4.17E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	U-236	1.23E-12	7.38E-14	4.53E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Eggs	U-238	3.69E-11	3.25E-12	2E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	Am-241	2.71E-14	3.7E-16	2.76E-16	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	Cs-137	2.11E-12	2.53E-13	1.62E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	I-129	1.84E-11	1.68E-12	1.71E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	I-131	1.49E-08	1.44E-09	1.5E-10	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	Pu-238	2.01E-11	9.2E-13	6.61E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	Pu-239	2.36E-09	1.42E-11	9.88E-12	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	Ru-106	1.38E-10	3.76E-11	2.11E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	Sr-89	2.46E-13	4.69E-14	2.73E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	Sr-90	4.35E-10	2.74E-11	1.79E-11	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	U-234	1.46E-11	7.05E-13	4.29E-13	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	U-235	4.7E-13	2.93E-14	1.77E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	U-236	9.68E-13	4.7E-14	2.86E-14	Air	0
Rural Family #2	Child born 1955	Ingestion	Soil	U-238	1.58E-11	1.44E-12	8.57E-13	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	Am-241	8.63E-16	6.04E-17	4.05E-17	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	Ar-41	5.33E-05	8.58E-06	5.65E-06	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	C-14	2.55E-12	5.94E-14	5.14E-14	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	Cs-137	1.94E-11	2.68E-12	1.77E-12	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	I-129	4.53E-13	5.64E-14	3.45E-14	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	I-131	2.3E-07	4.15E-08	2.71E-08	Air	0

Rural Family #2	Child born 1955	External	Air Immersion	Pu-238	1.58E-15	2.31E-16	1.32E-16	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	Pu-239	1E-14	1.68E-15	1.05E-15	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	Ru-106	3.63E-10	5.49E-11	3.63E-11	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	Sr-89	1.09E-13	4.6E-15	3.6E-15	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	Sr-90	1.39E-12	5.26E-14	4.33E-14	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	U-234	1.5E-15	2.42E-16	1.49E-16	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	U-235	7.2E-14	1.21E-14	7.92E-15	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	U-236	6.64E-17	1.05E-17	6.26E-18	Air	0
Rural Family #2	Child born 1955	External	Air Immersion	U-238	6.35E-15	7.95E-16	5.17E-16	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	Am-241	1.01E-12	6.91E-14	4.63E-14	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	Cs-137	1.34E-08	1.81E-09	1.2E-09	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	I-129	4.23E-10	5.09E-11	3.18E-11	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	I-131	5.31E-06	9.6E-07	6.28E-07	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	Pu-238	9E-12	1.07E-12	6.18E-13	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	Pu-239	2.61E-11	3.5E-12	2.07E-12	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	Ru-106	3.07E-07	3.23E-08	2.2E-08	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	Sr-89	1.76E-10	4.13E-12	3.82E-12	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	Sr-90	3.45E-08	9.67E-10	8.7E-10	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	U-234	4.57E-12	5.89E-13	3.49E-13	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	U-235	5.52E-11	9.3E-12	6.06E-12	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	U-236	2.76E-13	3.46E-14	2.02E-14	Air	0
Rural Family #2	Child born 1955	External	Ground Contamina	U-238	1.59E-09	8.35E-11	6.26E-11	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	Am-241	9.37E-09	1.61E-10	1.38E-10	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	C-14	1.17E-09	1.73E-10	1.15E-10	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	Cs-137	4.54E-10	4.45E-11	2.92E-11	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	H-3	1.77E-05	2.59E-06	1.72E-06	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	I-129	2.51E-08	2.1E-09	2.14E-10	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	I-131	0.000136	1.34E-05	1.38E-06	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	Pu-238	3.64E-06	1.75E-07	1.56E-07	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	Pu-239	1.26E-05	5.78E-07	5.07E-07	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	Ru-106	2.12E-07	3.85E-08	3.28E-08	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	Sr-89	3.64E-10	6.94E-11	5.79E-11	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	Sr-90	7.96E-08	9.78E-09	8.85E-09	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	U-234	1.86E-07	2.58E-08	2.44E-08	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	U-235	7.66E-09	1.12E-09	1.05E-09	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	U-236	1.21E-08	1.67E-09	1.58E-09	Air	0
Rural Family #2	Child born 1955	Inhalation	Air Inhalation	U-238	3.21E-07	4.83E-08	4.56E-08	Air	0

Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	Am-241	4.04E-09	6.92E-11	5.94E-11	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	Cs-137	1.92E-10	1.88E-11	1.23E-11	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	I-129	4.45E-09	3.72E-10	3.78E-11	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	I-131	1.97E-06	1.93E-07	2E-08	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	Pu-238	1.56E-06	7.51E-08	6.68E-08	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	Pu-239	5.41E-06	2.49E-07	2.18E-07	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	Ru-106	7.26E-08	1.32E-08	1.13E-08	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	Sr-89	5E-11	9.57E-12	7.97E-12	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	Sr-90	3.63E-08	4.66E-09	4.08E-09	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	U-234	7.98E-08	1.11E-08	1.05E-08	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	U-235	3.3E-09	4.81E-10	4.53E-10	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	U-236	5.2E-09	7.19E-10	6.79E-10	Air	0
Rural Family #2	Child born 1955	Inhalation	Resuspended Soil	U-238	1.38E-07	2.08E-08	1.96E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	Am-241	1.29E-10	3.17E-12	2.21E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	C-14	5.78E-08	9.24E-09	6.13E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	Cs-137	2.29E-09	3.1E-10	2.09E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	H-3	1.55E-06	2.26E-07	1.51E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	I-129	2.68E-08	2.36E-09	2.41E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	I-131	2.98E-07	2.69E-08	2.81E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	Pu-238	4.19E-08	1.46E-09	1.04E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	Pu-239	8.08E-09	3.12E-10	2.22E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	Ru-106	8.83E-08	4.02E-08	2.25E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	Sr-89	1.27E-10	3.08E-11	1.79E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	Sr-90	1.23E-09	1.33E-10	9.14E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	U-234	1.21E-09	1.12E-10	6.89E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	U-235	7.83E-11	7.58E-12	4.64E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	U-236	8.06E-11	7.43E-12	4.6E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Leafy Vegetables	U-238	4.27E-09	4.41E-10	2.68E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	Am-241	6.87E-11	1.74E-12	1.21E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	C-14	3.08E-07	5.07E-08	3.36E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	Cs-137	1.2E-09	1.62E-10	1.09E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	H-3	8.11E-06	1.18E-06	7.88E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	I-129	1.5E-08	1.38E-09	1.41E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	I-131	5.42E-08	5.53E-09	5.77E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	Pu-238	1.43E-08	4.98E-10	3.56E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	Pu-239	4.24E-09	1.64E-10	1.16E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	Ru-106	4.9E-08	2.32E-08	1.3E-08	Air	0

Rural Family #2	Child born 1964	Ingestion	Root Vegetables	Sr-89	6.01E-11	1.4E-11	8.14E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	Sr-90	1.18E-09	1.18E-10	7.88E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	U-234	7.96E-10	6.61E-11	4.05E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	U-235	5.51E-11	4.93E-12	3E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	U-236	5.3E-11	4.4E-12	2.7E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Root Vegetables	U-238	3.15E-09	3.18E-10	1.91E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	Am-241	5.1E-11	1.31E-12	9.07E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	C-14	3.8E-07	6.48E-08	4.27E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	Cs-137	8.97E-10	1.25E-10	8.36E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	H-3	1.04E-05	1.56E-06	1.03E-06	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	I-129	2.03E-08	2.01E-09	2.06E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	I-131	2.96E-07	2.96E-08	3.09E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	Pu-238	2.66E-08	9.28E-10	6.61E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	Pu-239	7.6E-09	2.82E-10	1.99E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	Ru-106	7.64E-08	3.22E-08	1.81E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	Sr-89	1.25E-10	2.76E-11	1.61E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	Sr-90	1.82E-09	1.64E-10	1.1E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	U-234	1.54E-09	1.21E-10	7.37E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	U-235	9.82E-11	8.46E-12	5.13E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	U-236	1.02E-10	8.03E-12	4.92E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Fruit	U-238	5.34E-09	4.99E-10	3E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	Am-241	6.19E-12	1.58E-13	1.1E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	C-14	1.73E-07	2.91E-08	1.92E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	Cs-137	9.96E-11	1.4E-11	9.36E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	H-3	1.1E-06	1.75E-07	1.16E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	I-129	2.05E-09	1.95E-10	1.99E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	I-131	2.82E-08	2.72E-09	2.84E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	Pu-238	3.36E-09	1.17E-10	8.35E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	Pu-239	7.32E-10	2.96E-11	2.1E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	Ru-106	7.61E-09	3.34E-09	1.87E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	Sr-89	1.18E-11	2.86E-12	1.66E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	Sr-90	1.35E-10	1.46E-11	9.88E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	U-234	1.14E-10	1.07E-11	6.55E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	U-235	7.18E-12	7.3E-13	4.44E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	U-236	7.58E-12	7.1E-13	4.36E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Grain	U-238	3.89E-10	4.29E-11	2.59E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	Am-241	2.44E-12	6.34E-14	4.38E-14	Air	0

Rural Family #2	Child born 1964	Ingestion	Beef	C-14	1.94E-06	3.2E-07	2.12E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	Cs-137	4.61E-08	6.31E-09	4.23E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	H-3	1.21E-05	1.83E-06	1.22E-06	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	I-129	5.91E-07	5.44E-08	5.55E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	I-131	6.66E-06	6.21E-07	6.49E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	Pu-238	2.12E-10	7.35E-12	5.26E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	Pu-239	4.64E-11	1.74E-12	1.23E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	Ru-106	2.6E-06	1.18E-06	6.59E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	Sr-89	6.24E-10	1.44E-10	8.39E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	Sr-90	6.96E-09	6.61E-10	4.52E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	U-234	2.44E-10	2.06E-11	1.26E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	U-235	1.55E-11	1.41E-12	8.57E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	U-236	1.62E-11	1.37E-12	8.41E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Beef	U-238	8.14E-10	7.34E-11	4.49E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	Am-241	1.24E-15	3.25E-17	2.25E-17	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	C-14	6.4E-08	1.08E-08	7.12E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	Cs-137	2.88E-11	4.01E-12	2.69E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	H-3	1.62E-06	2.53E-07	1.68E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	I-129	5.48E-13	5.08E-14	5.18E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	I-131	7.54E-19	7.42E-20	7.75E-21	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	Pu-238	2.24E-13	7.79E-15	5.57E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	Pu-239	4.95E-14	2.07E-15	1.47E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	Ru-106	1.08E-09	5.08E-10	2.85E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	Sr-89	1.83E-15	4.6E-16	2.67E-16	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	Sr-90	2.92E-13	3.32E-14	2.26E-14	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	U-234	2.43E-12	2.4E-13	1.48E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	U-235	1.6E-13	1.69E-14	1.03E-14	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	U-236	1.62E-13	1.6E-14	9.82E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Poultry	U-238	8.48E-12	8.85E-13	5.41E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	Am-241	1.68E-13	4.73E-15	3.24E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	C-14	2.36E-06	4.11E-07	2.71E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	Cs-137	1.04E-08	1.54E-09	1.02E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	H-3	4.36E-05	6.79E-06	4.48E-06	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	I-129	4.6E-07	4.56E-08	4.66E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	I-131	6.9E-06	6.8E-07	7.11E-08	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	Pu-238	7.15E-11	2.49E-12	1.78E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	Pu-239	1.87E-11	7.11E-13	5.03E-13	Air	0

Rural Family #2	Child born 1964	Ingestion	Milk	Ru-106	5.98E-10	2.6E-10	1.46E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	Sr-89	8.13E-10	1.85E-10	1.07E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	Sr-90	1E-08	8.34E-10	5.77E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	U-234	1.3E-09	1.06E-10	6.51E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	U-235	8.14E-11	7.31E-12	4.44E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	U-236	8.65E-11	7.07E-12	4.34E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Milk	U-238	4.19E-09	3.66E-10	2.23E-10	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	Am-241	1.37E-15	3.47E-17	2.41E-17	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	C-14	8.32E-08	1.39E-08	9.19E-09	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	Cs-137	2.24E-12	3.09E-13	2.07E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	H-3	2.83E-06	4.38E-07	2.91E-07	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	I-129	2.79E-10	2.59E-11	2.65E-12	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	I-131	6.13E-16	6.21E-17	6.48E-18	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	Pu-238	5.96E-14	2.07E-15	1.48E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	Pu-239	1.43E-14	6.08E-16	4.31E-16	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	Ru-106	1.15E-12	5.36E-13	3.01E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	Sr-89	8.21E-15	2.09E-15	1.22E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	Sr-90	1.18E-12	1.08E-13	7.9E-14	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	U-234	4.16E-12	4.18E-13	2.57E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	U-235	2.81E-13	2.96E-14	1.81E-14	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	U-236	2.77E-13	2.78E-14	1.71E-14	Air	0
Rural Family #2	Child born 1964	Ingestion	Eggs	U-238	1.49E-11	1.5E-12	9.21E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	Am-241	4.31E-14	1.2E-15	8.22E-16	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	Cs-137	5.26E-13	7.82E-14	5.16E-14	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	I-129	1.55E-11	1.55E-12	1.59E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	I-131	6.13E-11	6.16E-12	6.43E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	Pu-238	2.79E-11	9.68E-13	6.93E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	Pu-239	7.73E-12	2.98E-13	2.1E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	Ru-106	6.78E-11	2.92E-11	1.64E-11	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	Sr-89	5.57E-14	1.26E-14	7.34E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	Sr-90	1.73E-12	1.69E-13	1.12E-13	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	U-234	1.49E-12	1.22E-13	7.47E-14	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	U-235	9.42E-14	8.54E-15	5.17E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	U-236	9.9E-14	8.13E-15	4.98E-15	Air	0
Rural Family #2	Child born 1964	Ingestion	Soil	U-238	5.36E-12	5.87E-13	3.49E-13	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Am-241	8.63E-16	1.1E-16	7.11E-17	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Ar-41	3.87E-05	6.61E-06	4.35E-06	Air	0

Rural Family #2	Child born 1964	External	Air Immersion	C-14	2.02E-12	5.36E-14	4.62E-14	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Cs-137	8.1E-12	1.17E-12	7.78E-13	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	I-129	3.21E-13	4.48E-14	2.73E-14	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	I-131	1.34E-09	2.39E-10	1.56E-10	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Pu-238	1.58E-15	2.37E-16	1.35E-16	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Pu-239	3.18E-16	5.2E-17	3.23E-17	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Ru-106	2.19E-10	3.61E-11	2.37E-11	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Sr-89	3.78E-14	1.63E-15	1.27E-15	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	Sr-90	1.21E-14	4.4E-16	3.59E-16	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	U-234	3.37E-16	5.37E-17	3.31E-17	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	U-235	2.37E-14	3.94E-15	2.58E-15	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	U-236	1.49E-17	2.34E-18	1.4E-18	Air	0
Rural Family #2	Child born 1964	External	Air Immersion	U-238	2.59E-15	3.25E-16	2.11E-16	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	Am-241	9.76E-13	1.21E-13	7.84E-14	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	Cs-137	5.73E-09	8.18E-10	5.43E-10	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	I-129	2.96E-10	4E-11	2.49E-11	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	I-131	3.17E-08	5.69E-09	3.72E-09	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	Pu-238	9.07E-12	1.11E-12	6.38E-13	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	Pu-239	8.35E-13	1.09E-13	6.43E-14	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	Ru-106	1.83E-07	2.09E-08	1.42E-08	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	Sr-89	6.14E-11	1.44E-12	1.32E-12	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	Sr-90	2.82E-10	7.38E-12	6.61E-12	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	U-234	1.03E-12	1.32E-13	7.83E-14	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	U-235	1.82E-11	3.04E-12	1.98E-12	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	U-236	6.25E-14	7.76E-15	4.54E-15	Air	0
Rural Family #2	Child born 1964	External	Ground Contamina	U-238	6.48E-10	3.42E-11	2.56E-11	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	Am-241	9.52E-09	2.86E-10	2.48E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	C-14	9.34E-10	1.57E-10	1.04E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	Cs-137	2.32E-10	3.18E-11	2.12E-11	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	H-3	1.36E-05	2.09E-06	1.38E-06	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	I-129	1.63E-08	1.54E-09	1.57E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	I-131	6.38E-07	6.05E-08	6.26E-09	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	Pu-238	3.5E-06	1.36E-07	1.22E-07	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	Pu-239	6.82E-07	2.77E-08	2.45E-08	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	Ru-106	1.31E-07	3.1E-08	2.63E-08	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	Sr-89	1.31E-10	2.53E-11	2.13E-11	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	Sr-90	6.65E-10	9.46E-11	8.61E-11	Air	0

Rural Family #2	Child born 1964	Inhalation	Air Inhalation	U-234	4.46E-08	6.89E-09	6.51E-09	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	U-235	2.59E-09	3.96E-10	3.74E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	U-236	2.91E-09	4.49E-10	4.24E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Air Inhalation	U-238	1.31E-07	2E-08	1.88E-08	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	Am-241	4.1E-09	1.23E-10	1.07E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	Cs-137	9.81E-11	1.34E-11	8.97E-12	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	I-129	2.89E-09	2.72E-10	2.77E-11	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	I-131	9.36E-09	8.87E-10	9.18E-11	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	Pu-238	1.5E-06	5.84E-08	5.2E-08	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	Pu-239	2.93E-07	1.19E-08	1.05E-08	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	Ru-106	4.49E-08	1.06E-08	9.05E-09	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	Sr-89	1.8E-11	3.48E-12	2.94E-12	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	Sr-90	2.93E-10	4.35E-11	3.84E-11	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	U-234	1.92E-08	2.97E-09	2.8E-09	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	U-235	1.11E-09	1.7E-10	1.61E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	U-236	1.25E-09	1.92E-10	1.82E-10	Air	0
Rural Family #2	Child born 1964	Inhalation	Resuspended Soil	U-238	5.65E-08	8.6E-09	8.12E-09	Air	0

APPENDIX L VARIANCE CALCULATION SIMPLIFICATION

L.1 Calculation Simplification

The Savannah River Site (SRS) dose for releases in a particular medium (air or water) may be represented by the following sum:

$$D = \sum_{1954}^{1992} \sum_{1}^{N} \sum_{1}^{M} D_{ijk} \qquad \text{(L.1)}$$

Where,

D	=	the dose to a particular receptor
D_{ijk}	=	the incremental dose (by year, nuclide, and pathway)
i	=	the index by year, from 1954-1992
j	=	the index by radionuclide, with upper limit N equal to 16 for air and 22 for water
k	=	the index by exposure pathway, with upper limit M equal to 13 for air and 5 for water

(Note there are no pathways in common for both air and water).

The point estimate for D is calculated by substituting in the point estimates for a number of input variables. This also generates the point estimates for the component doses from each radionuclide and pathway, D_{ijk}. Denote these point estimates of dose by $\check{D}$ and $\check{D}_{ijk}$, respectively. Based on these values the fraction of the total dose due to various factors is computed. For example:

$$\check{E}_{ijk} = \check{D}_{ijk}/\check{D}$$

Using shorthand notation, if an index is omitted from a fraction or a dose, then summation over the omitted indexes is assumed. For example,

$$\check{E}_j = \frac{\sum_{1954}^{1992} \sum_{1}^{M} \check{D}_{ijk}}{\check{D}} = \frac{\check{D}_j}{\check{D}} \qquad \text{(L.2)}$$

When the Monte Carlo analysis is performed, an assumption is made that the doses are random variables. A set of realizations is computed leading to a sample of doses; each of these randomly generated doses can be partitioned and indexed as with the point estimate dose (i.e., as indexed in Equation (L.1)). However, an additional index, l, representing the realization is needed to completely characterize the set of numbers; the index l has a range of 1 to L, where L is the total number of realizations. What is being sought is the population mean and variance. As usual, the population mean and variance is estimated by using the sample mean and variance.

Because the input variable distributions will be chosen to be centered on the point estimate values, it is expected that the sample mean, μ, will be close to the point estimate of dose, $\check{D}$. A similar relationship is expected to hold for any subset of doses or even the $\check{D}_{ijk}$. Then by extending the notation used before:

$$\mu_{ijk} = \frac{\sum_{1}^{L} D_{ijkl}}{L} \qquad \text{(L.3)}$$

That is, μ_{ijk} is the mean value of the dose realizations for a particular year, radionuclide, and pathway.

$$E_{ijk} = \mu_{ijk}/\check{D} = [\check{D}_{ijk}/\check{D}][\mu_{ijk}/\check{D}_{ijk}] = \check{E}_{ijk}\cdot[\mu_{ijk}/\check{D}_{ijk}] \qquad \text{(L.4)}$$

That is, E_{ijk} is μ_{ijk} divided by the total point-estimate dose, $\check{D}$.

However, for a well-behaved problem in which the point-estimate dose is close to the mean dose, the second factor ≈ 1. If both sides of (L.4) are summed with respect to all indices, then:

$$E = 1 \cong \sum_{1954}^{1992}\sum_{1}^{N}\sum_{1}^{M} E_{ijk}\cdot 1 \qquad \text{(L.5)}$$

In other words, the result is that the estimate of mean dose can be obtained if elements of the sum are omitted, but only if the <u>aggregate</u> sum of the E_{ijk} for those elements is a suitable small percentage of unity. However, if the interest is in characterizing the variability, more elements of the sum may be omitted, provided the missing dose is added back in at the end. That is:

$$\mu = \mu_v + \mu_f \qquad \text{(L.6)}$$

Where μ_v is a partial mean calculated based on Monte Carlo sampling and μ_f is a partial mean calculated based on the point estimate calculation, where the partition is on any basis that is convenient.

To estimate the variance, rather than the mean, the situation is quite different. Although it is expected that the point-estimate total dose will be close to the mean of the total dose from the Monte Carlo sampling, the point estimate provides no information on the variance of the dose distribution. This information must come from the Monte Carlo simulation. To simplify the analysis, consider the sum over time indicated in Equation (L.1). Because the adults and child born in 1955 experience large releases early in the history of the site, the doses for these receptors are dominated by the first 20 years of releases. However, the child born in 1964 misses most of these large doses, so the cumulative releases over a 20 year period are important. If both time ranges are to be studied, then, because of the calculation approach adopted for the project, the doses for the entire 39 year period of the study might as well be calculated. Because simplification by eliminating certain years does not seem feasible, the index related to summing over years will be dropped and the summation will be assumed. Then Equation (L.1) becomes:

$$D = \sum_{1}^{N}\sum_{1}^{M} D_{jk} \qquad \text{(L.7)}$$

where the summation over time is understood, but will not be used to simplify the variance calculation. In other words, D_{jk} should be read as the dose for a particular radionuclide and pathway summed over 39 years. Furthermore, it should now be understood that D is a random variable; in practice a sample of this random variable of size L will be created.

To facilitate the analysis, transform both the doses and the independent variables by their point estimate values; i.e.,

$$Z = X/\breve{X} \qquad \text{(L.8)}$$

where,

Z = the normalized input variable or dose;

X = the lth realization of the input variable or dose;
$\breve{X}$ = the point estimate value of the input variable or dose.

Then Equation (L.7) becomes:

$$F = \frac{D}{\breve{D}} = \sum_{1}^{N}\sum_{1}^{M}\frac{D_{jk}}{\breve{D}} \qquad \text{(L.9)}$$

where D_{jk}, D, and F are all random variables.

This can be rearranged into a slightly more convenient form (similar to what was done in Equation (L.4)):

$$F = \sum_{1}^{N}\sum_{1}^{M}\frac{D_{jk}}{\breve{D}_{jk}}\cdot\frac{\breve{D}_{jk}}{\breve{D}} \qquad \text{(L.10)}$$

Note the variance of a random variable, X, by $\sigma^2\{X\}$. Then some useful relationships are:

$$\sigma^2\{cX\} = c^2\sigma^2\{X\} \qquad \text{(L.11a)}$$

and

$$\sigma^2\{X + Y\} = \sigma^2\{X\} + \sigma^2\{Y\} \qquad \text{(L.11b)}$$

where,
c = a constant
X and Y = independent random variables.

Note that the term $\breve{D}_{jk}/\breve{D}$ in Equation (L.9) is the fractional contribution to total dose by pathway and radionuclide based on the point estimate calculation, i.e., E_{jk}. This quantity is a constant for each choice of j and k. The variance of the normalized total dose can be found by determining the variance of each of the contributing terms in Equation (L.10) and then using the rules in Equations (L.11) to combine them. This procedure yields:

$$\sigma^2\{F\} = \sum_{1}^{N}\sum_{1}^{M}\sigma^2\left\{\frac{D_{jk}}{\breve{D}_{jk}}\cdot\frac{\breve{D}_{jk}}{\breve{D}}\right\} = \sum_{1}^{N}\sum_{1}^{M}\sigma^2\left\{\frac{D_{jk}}{\breve{D}_{jk}}\right\}E_{jk}^2 \qquad \text{(L.12)}$$

In other words, the variance of the dose is equal to the variance of the normalized dose contributors by radionuclide and exposure pathway, multiplied by the square of the contribution of that radionuclide and exposure pathway to the point estimate dose. If the variance of each normalized contributor to dose, $\sigma^2\{D_{ij}/\breve{D}_{ij}\}$, is bounded by some quantity, say Q^2, then the sum can be approximated by eliminating any terms for which:

$$E_{ij}^2 / \max\{E_{ij}^2\} << 1 \qquad \text{(L.13)}$$

and where max $\{x_{ij}\}$ is the maximum value of the indexed variable. In other words, if the variances of the normalized contributors to dose are bounded, only the terms with a large fractional contribution to the point estimate dose (E^2_{ij}) will be important. Based on the results of the point estimate runs, the ratios indicated by Equation (L.13) can be calculated. For example, the results for the adult female in Rural Family 2 are given in Table L-1. Table L-2 shows the reduced renormalized set after some nuclides and pathways were eliminated because they had only a minor contribution to dose. Table L-3 shows the

values indicated in Equation (L.12) and demonstrates that only four values account for over 98% of the total. This clearly highlights four nuclide/pathway pairs that are candidates to account for most of the variance in the dose. Table L-4 shows the equivalent of Table L-3, but for the child born in 1964. This shows more and different pathways and nuclides, primarily those involving tritium.

To reach this point, however, it was assumed the variance of each normalized contributor to dose is bounded. Consider the variance of each normalized contributor to dose, denoted in Equation (L.12) by the term:

$$\sigma^2\left\{\frac{D_{jk}}{\breve{D}_{jk}}\right\}.$$

To simplify the notation for the upcoming derivation, denote D_{jk} by u. Then the normalized contributor to dose is u/ŭ. Suppose this contributor to dose is expanded in a Taylor series of the variables involved in calculating this aspect of dose; note that this set of variables may include variables unique to this nuclide and pathway, such as the uptake of iodine by milk from animal feed, but it may also include variables common to many pathways and radionuclides, such as the particle diameter used to determine deposition velocity. We can then write:

$$u(z_1,z_2,\ldots,z_n) = a_0 + a_1z_1 + a_2z_2 + \ldots + a_nz_n \qquad \text{(L.14)}$$

If the variance of both sides of (L.14) are taken and the relationships in equations (L.11a) and (L.11b) are applied, then:

$$\sigma^2\{u\} = \sum a_m{}^2\sigma^2\{z_m\} \qquad \text{(L.15)}$$

where m is the index for the n independent variables. Note also that the variance of a constant (a_0) is zero.

Similar to Equation (L.5) an expression for the variance of u/ŭ can be written as:

$$\sigma^2\{u/\breve{u}\} = \sigma^2\{u\}/\breve{u}^2 = \sum_1^n \frac{a_m^2\sigma^2\{z_m\}}{\breve{u}^2} = \sum_1^n \frac{a_m^2\breve{z}_m^2}{\breve{u}^2}\frac{\sigma^2\{z_m\}}{\breve{z}_m^2} \qquad \text{(L.16)}$$

But, from the definition of the Taylor series,

$$a_m = \left(\frac{\partial u}{\partial z_m}\right)_{z_m=\breve{z}_m} \qquad \text{(L.17)}$$

Furthermore, the definition of the dimensionless sensitivity coefficient, S_m, is given by:

$$S_m = \left(\frac{\breve{z}_m}{\breve{u}}\frac{\partial u}{\partial z_m}\right)_{z_m=\breve{z}_m} \qquad \text{(L.18)}$$

Then combining (L.16), (L.17), and (L.18) yields:

$$\frac{\sigma^2\{u\}}{\breve{u}^2} = \sum_1^n S_l^2 \cdot \frac{\sigma^2\{z_m\}}{\breve{z}_m^2} = \sum_l S_m^2 \cdot V_m^2 \qquad \text{(L.19)}$$

Where the term, V_m, denotes the coefficient of variation for variable z_m; i.e., the standard deviation of z_m divided by its mean. However, this requires that the mean value of the random variable is approximately equal to the point-estimate value of the same variable. This can be achieved by "anchoring" the distribution of the random variable, by making its mean (or possibly its median for a log-normal distribution) to the point estimate value for that variable. If the means of the independent random variables are equal to their point estimate values, it would be expected that the mean of the dose to be approximately equal to its point estimate value.

Although this may seem to be a lot of mathematical manipulation, the result summarized by Equation (L.19) is quite useful. Essentially the square of the coefficient of variation of u, (recall that u is another name for D_{jk}, the contribution to dose from a particular radionuclide and pathway) is equal to the sum over all variables of the square of the product of the sensitivity coefficient for the variable z_m and the coefficient of variation for that same variable. This is an approximate relationship, because it was assumed that the mean of the random variables is approximately equal to the point estimate value of the variable (including the dose). Although this is an approximate relationship, depending on the degree of fit of the Taylor series expansion, it provides a means to determine which variables contribute substantially to the variance of the incremental dose.

Equation (L.18) can be simplified further, by noting the following. Many of the equations used to estimate dose are of the form:

$$u = Az_1z_2z_3 \qquad \text{(L.20)}$$

Where A is a constant and the z_m's are variables. Then,

$$\frac{\partial u}{\partial z_1} = Az_2z_3 \qquad \text{(L.21)}$$

and

$$S_1 = \frac{\breve{z}_1}{\breve{u}} \frac{\partial u}{\partial z_1}_{z_m=\breve{z}_m} = \frac{\breve{z}_1}{A\breve{z}_1\breve{z}_2\breve{z}_3} A\breve{z}_2\breve{z}_3 = 1 \qquad \text{(L.22)}$$

If the equation is of the form:

$$u = Az_2z_3/z_1 \qquad \text{(L.23)}$$

then,

$$\frac{\partial u}{\partial z_1} = -Az_2z_3/z_1^2 \qquad \text{(L.24)}$$

and

$$S_1 = \frac{\breve{z}_1}{\breve{u}} \frac{\partial u}{\partial z_1}_{z_m = \breve{z}_{m1}} = \frac{\breve{z}_1}{(A\breve{z}_2\breve{z}_3 / \breve{z}_1)}(-A\breve{z}_2\breve{z}_3 / \breve{z}_1^2) = -1 \qquad \text{(L.25)}$$

Since many of the dose equations are of the form in Equation (L.20) or (L.23) the value to be used for S_m becomes either +1 or -1 in these cases. Since S_m is squared in Equation (L.19), the squared value, in many cases, will be unity. On this basis Equations (L.18) and (L.11) can be combined to yield:

$$\frac{\sigma^2\{D\}}{\breve{D}^2} = \sum_1^N \sum_1^M E_{jk}^2 \sigma^2 \left\{ \frac{D_{jk}}{\breve{D}_{jk}} \right\} = \sum_1^N \sum_1^M E_{jk}^2 \sum_1^n S_{jkm}^2 V_m^2 \qquad \text{(L.26)}$$

Note that now the sensitivity coefficient depends on the independent variable, m, as well as the Taylor series representation for the particular contributor to dose, jk. If the m ranges over all variables, then S_{jkm} will be approximately unity if the variable enters into the dose equation for that nuclide and pathway, otherwise it will be zero.

In evaluating this expression to determine which variables to include in the variance estimation, there are two distinct cases: (1) a variable enters into only one increment of dose, E_{jk}, and (2) a variable enters into two or more increments of dose. An example of case 1 is the uptake factor for ruthenium-106 from animal feed to milk. This variable enters only into the dose from the milk pathway for the isotope ruthenium-106. An example of case 2 is the absolute humidity variable that affects all food-chain pathways involving tritium. For case 1 the contribution to the normalized variance by variable l is given simply by:

$$V_m^2 E_{jk}^2 \qquad \text{(L.27)}$$

where the E_{jk} is defined as before as the value associated with the pathway and nuclide in which the variable l plays a role. For case 2 the contribution to the normalized variance by variable l is given by:

$$\sum_{j'} \sum_{k'} V_m^2 E_{jk}^2 \qquad \text{(L.28)}$$

where the summation is over all nuclides, j', and pathways, k', involving variable m. However, because V_m is frequently unity, then V_m^2 will be unity, and a good approximation to Equation (L.28) will usually be:

$$\sum_{j'} \sum_{k'} E_{jk}^2 \qquad \text{(L.29)}$$

where again the summation is over all nuclides, j', and pathways, k', involving variable m. The types of functional dependence that will make the sensitivity coefficient substantially different from unity are exponential, logarithmic, and power functions of the variables. This type of functional dependence in dose assessment does occur, but infrequently.

L.2 Summary of Implementation Approach

1. Take the entire set of about 350 input variables and eliminate from consideration any variables solely associated with the following pathways and radionuclides:

   a. Air Release:
      i. Radionuclides: ^{241}Am, ^{137}Cs, ^{129}I, ^{89}Sr, ^{90}Sr, all isotopes of U
      ii. Pathways: ground contamination, grain, and soil ingestion

   b. Water Release:
      i. Radionuclides: ^{129}I, ^{95}Nb, ^{89}Sr, all isotopes of U.
      ii. Pathways: Boating, swimming immersion, swimming inadvertent ingestion.

These radionuclides and pathways were eliminated from the dose assessment model used for the uncertainty analysis, because their cumulative contribution to the dose of all receptors was less than 5%.

2. Eliminate categories of variables not considered suitable for inclusion in the uncertainty analysis. For example, dose and risk coefficients, although uncertain, were considered to be certain variables. These variables, whose nominal values are established by national and international standards organizations, have less uncertainty than many other variables in the study; furthermore, incorporating their variability would confound the results from other variables. Variables specified by scenarios, e.g. consumption values such as breathing rate and quantities of food ingested, were considered to be certain. The variability in these variables was considered to be addressed by the creation and use of the scenarios; incorporating variability for these variables would confound the effects of the various scenarios and blur their differences.

3. Develop Tables of the E^2jk based on a couple of representative receptors for air and water (e.g., Rural Family 2, the adult female and child born in 1964).

4. Use the results of Step 3 to focus on a few key pathways and radionuclides. Identify the variables involved in those pathways and radionuclides. Then develop the distributions describing the uncertainty in those variables. Form the products indicated in Equation (L.27). If any product is noticeably small, eliminate that variable from further consideration. In the case that a variable is used for all pathways, but a single radionuclide, an appropriate sum based on Equation (L.29) can be used instead of Equation (L.27);

5. Look at the entire list (singleton variables) and the approximate contribution to variance computed for each. Order according to expected importance and draw an appropriate line for inclusion/elimination.

6. Evaluate the eliminated variables to make sure consideration of multiple radionuclides or pathways would not cause it to be included; include if appropriate.

L.3 Tables

Table L-1 presents the contribution to total dose by pathway and radionuclide. The contribution of some radionuclides has been eliminated (^{241}Am, ^{137}Cs, ^{129}I, ^{89}Sr, ^{90}Sr, all isotopes of U), as has the contribution of some pathways (ground contamination, grain, and soil ingestion). These numbers are the D_{jk} in the notation of this Appendix. Note that the maximum value is 3.48E-04 for ^{131}I and beef ingestion.

Table L-2 identifies the reduced renormalized matrix. For this matrix, we have eliminated the noncontributing pathways and radionuclides and renormalized by the total dose based on those pathways and nuclides included. The highlighted cell indicates the maximum contributor to dose (^{131}I through beef ingestion). The entries in this table are approximately equal to E_{jk}/E_{total}.

Table L-3 matrix is the square of the normalized contribution to dose (E^2jk in my notation) divided by the maximum value of these numbers. The highlighted terms contribute at least 1% of the maximum value. The sum of these four terms constitutes over 98% of the sum over all terms.

The matrix presented in Table L-4 is the square of the normalized contribution to dose (E^2jk in my notation) divided by the maximum value of these numbers. The highlighted terms contribute at least 1% of the maximum value. The sum of these four terms constitutes over 98% of the sum over all terms.

Table L-1 Contribution to Total Dose by Pathway and Radionuclide

	Am-241	Ar-41	C-14	Cs-137	H-3	I-129	I-131	Pu-238	Pu-239	Ru-106	Sr-89	Sr-90	U-234	U-235	U-236	U-238	Sum Over
Air Immers	0.00E+00	5.39E-05	2.55E-12	0.00E+00	0.00E+00	0.00E+00	2.30E-07	1.58E-15	1.00E-14	3.63E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.41E-05
Ground Co	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	1.74E-06	0.00E+00	1.14E-05	0.00E+00	3.48E-04	1.56E-10	1.31E-09	1.83E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-04
Eggs	0.00E+00	0.00E+00	7.13E-08	0.00E+00	2.60E-06	0.00E+00	2.44E-14	4.69E-14	3.30E-13	7.44E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.67E-06
Fruit	0.00E+00	0.00E+00	3.72E-07	0.00E+00	9.70E-06	0.00E+00	1.28E-05	2.20E-08	1.84E-07	5.12E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.31E-05
Grain	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Leafy Vege	0.00E+00	0.00E+00	1.10E-07	0.00E+00	3.10E-06	0.00E+00	3.77E-05	6.50E-08	5.42E-07	1.51E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.17E-05
Milk	0.00E+00	0.00E+00	8.80E-07	0.00E+00	1.63E-05	0.00E+00	9.45E-05	2.06E-11	1.45E-10	1.37E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E-04
Poultry	0.00E+00	0.00E+00	6.66E-08	0.00E+00	1.85E-06	0.00E+00	4.26E-17	1.92E-13	1.60E-12	8.42E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.91E-06
Root Veget	0.00E+00	0.00E+00	3.76E-07	0.00E+00	9.81E-06	0.00E+00	4.21E-06	2.22E-08	1.86E-07	5.05E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.47E-05
Soil	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Air Inhalati	0.00E+00	0.00E+00	8.04E-10	0.00E+00	1.30E-05	0.00E+00	2.75E-05	2.72E-06	1.89E-05	1.25E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.23E-05
Resuspend	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.98E-07	1.17E-06	8.13E-06	4.30E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.74E-06
Total Over	0.00E+00	5.39E-05	3.62E-06	0.00E+00	6.78E-05	0.00E+00	5.26E-04	4.00E-06	2.79E-05	2.25E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.85E-04
Total Dose	6.96E-04																

Table L-2 Reduced Renormalized Matrix

REDUCED RENORMALIZED MATRIX
Rural Family #2
Adult Female

	Ar-41	C-14	H-3	I-131	Pu-238	Pu-239	Ru-106	Sum Over Pathway
Air Immersion	7.86E-02	3.73E-09	0.00E+00	3.36E-04	2.31E-12	1.46E-11	5.30E-07	7.90E-02
Beef	0.00E+00	2.54E-03	1.66E-02	5.08E-01	2.27E-07	1.91E-06	2.67E-03	5.30E-01
Eggs	0.00E+00	1.04E-04	3.79E-03	3.56E-11	6.85E-11	4.82E-10	1.09E-09	3.89E-03
Fruit	0.00E+00	5.44E-04	1.42E-02	1.87E-02	3.21E-05	2.68E-04	7.47E-05	3.37E-02
Leafy Vegetables	0.00E+00	1.60E-04	4.52E-03	5.51E-02	9.48E-05	7.91E-04	2.20E-04	6.09E-02
Milk	0.00E+00	1.28E-03	2.38E-02	1.38E-01	3.00E-08	2.11E-07	2.01E-07	1.63E-01
Poultry	0.00E+00	9.71E-05	2.70E-03	6.22E-14	2.80E-10	2.34E-09	1.23E-06	2.79E-03
Root Vegetables	0.00E+00	5.49E-04	1.43E-02	6.14E-03	3.23E-05	2.71E-04	7.36E-05	2.14E-02
Air Inhalation	0.00E+00	1.17E-06	1.90E-02	4.02E-02	3.98E-03	2.76E-02	1.83E-04	9.09E-02
Resuspended Soil	0.00E+00	0.00E+00	0.00E+00	5.81E-04	1.70E-03	1.19E-02	6.27E-05	1.42E-02
Total Over Isotope	7.86E-02	5.28E-03	9.89E-02	7.67E-01	5.84E-03	4.08E-02	3.28E-03	1.00E+00

Table L-3 Eij^2/max Eij^2

Eij^2 / max Eij^2
Rural Family #2
Adult Female

	Ar-41	C-14	H-3	I-131	Pu-238	Pu-239	Ru-106	Sum Over Pathway
Air Immersion	2.39E-02	5.38E-17	0.00E+00	4.38E-07	2.06E-23	8.29E-22	1.09E-12	2.39E-02
Beef	0.00E+00	2.50E-05	1.06E-03	1.00E+00	2.00E-13	1.41E-11	2.75E-05	1.00E+00
Eggs	0.00E+00	4.19E-08	5.56E-05	4.92E-21	1.82E-20	8.99E-19	4.56E-18	5.56E-05
Fruit	0.00E+00	1.14E-06	7.75E-04	1.35E-03	3.99E-09	2.78E-07	2.16E-08	2.12E-03
Leafy Vegetables	0.00E+00	9.96E-08	7.91E-05	1.17E-02	3.48E-08	2.42E-06	1.87E-07	1.18E-02
Milk	0.00E+00	6.38E-06	2.20E-03	7.36E-02	3.49E-15	1.73E-13	1.56E-13	7.58E-02
Poultry	0.00E+00	3.65E-08	2.81E-05	1.49E-26	3.03E-19	2.11E-17	5.85E-12	2.82E-05
Root Vegetables	0.00E+00	1.17E-06	7.94E-04	1.46E-04	4.04E-09	2.84E-07	2.10E-08	9.41E-04
Air Inhalation	0.00E+00	5.33E-12	1.40E-03	6.24E-03	6.11E-05	2.94E-03	1.29E-07	1.06E-02
Resuspended Soil	0.00E+00	0.00E+00	0.00E+00	1.30E-06	1.12E-05	5.45E-04	1.52E-08	5.57E-04
Total Over Isotope	2.39E-02	3.38E-05	6.39E-03	1.09E+00	7.24E-05	3.49E-03	2.79E-05	1.13E+00

Table L-4 Child Born in 1964

Eij^2 / max Eij^2
Rural Family #2
Child born 1964

	Ar-41	C-14	H-3	I-131	Pu-238	Pu-239	Ru-106	Sum Over Pathway
Air Immersion	4.62E-01	1.88E-15	0.00E+00	1.17E-09	1.69E-21	6.85E-23	3.25E-11	4.62E-01
Beef	0.00E+00	1.74E-03	7.68E-02	2.83E-02	3.03E-11	1.46E-12	4.58E-03	1.11E-01
Eggs	0.00E+00	3.21E-06	4.24E-03	2.42E-22	2.40E-18	1.37E-19	8.93E-16	4.24E-03
Fruit	0.00E+00	6.71E-05	5.76E-02	5.70E-05	4.79E-07	3.91E-08	3.95E-06	5.77E-02
Leafy Vegetables	0.00E+00	1.53E-06	1.25E-03	5.72E-05	1.19E-06	4.41E-08	5.27E-06	1.31E-03
Milk	0.00E+00	2.57E-03	1.00E+00	3.03E-02	3.46E-12	2.36E-13	2.42E-10	1.03E+00
Poultry	0.00E+00	1.89E-06	1.38E-03	3.67E-28	3.41E-17	1.66E-18	7.94E-10	1.38E-03
Root Vegetables	0.00E+00	4.41E-05	3.46E-02	1.91E-06	1.39E-07	1.22E-08	1.62E-06	3.46E-02
Air Inhalation	0.00E+00	4.02E-10	9.47E-02	2.63E-04	8.29E-03	3.15E-04	1.16E-05	1.04E-01
Resuspended Soil	0.00E+00	0.00E+00	0.00E+00	5.66E-08	1.52E-03	5.80E-05	1.36E-06	1.58E-03
Total Over Isotope	4.62E-01	4.43E-03	1.27E+00	5.90E-02	9.81E-03	3.73E-04	4.61E-03	1.81E+00

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APPENDIX M PROBABILITY DISTRIBUTIONS FOR UNCERTAIN VARIABLES

This appendix provides a brief discussion on how a probability distribution for each of the 21 uncertain variables was determined. The type of distribution and its parameters, e.g., mean and standard deviation, are briefly discussed.

Lognormal distribution was assumed for all, except two, of the 21 uncertain variables. Normal distribution was assumed for ABSHUM and CONSUM, 5. Assumptions regarding probability distributions were based on literature survey, including studies similar to the ones provided in the main report.

While the spreadsheets provided in this appendix may have long names for detailed identification purposes, they are also identified as Spreadsheet M1, M2, through M11…to make the task of referencing easier.

It should be noted that for each lognormal distribution assumed, the log mean value is the natural logarithm of the point estimate value of the variable under consideration. In other words, the point estimate value is the geometric mean (or the arithmetic median) of the distribution.

M.1 Probability Distribution and its Parameters for the Release Factor F (Variable 21)

M.1.1 F, Release Factor (Variable 21)

Spreadsheet M1 provides the following information on the isotopes of interest in air and water:

- Isotopes in air (^{3}H, ^{131}I, Pu, U).
- Isotopes in water (^{137}Cs, ^{90}Sr, ^{3}H).
- Sources involved in releasing the isotopes.
- Sigma Y bar (log standard deviations averaged over all years) for each isotope.
- The total release for each isotope.
- Weighted average of Sigma Y bars (weighting done with respect to the total releases).
- Overall weighted average of Sigma Y bars.

The overall weighted averages for air and water isotopes were determined as 0.2310, and 0.2034, respectively.

The steps and formulas that were followed to compute values reflected in Spreadsheet M1 (“Sigmas and Totals”) are provided below.

Sigma Y (Log standard deviation) for each year, and the average (over all years) Sigma Y, referred to as Sigma Y bar, were calculated in the right most block (or at the bottom) of Spreadsheets M2 through M7 with the following titles respectively (the string “ASM122903” has been added to each file name for identification purposes only):

- Annual_reactor_releasesASM122903.
- Annual_Tritium_Facility_releasesASM122903.
- Est_I-131_Releases_(Reactors)ASM122903.
- Revised_I-131_Releases_(F,H)ASM122903.

- Estimated_Source_TermASM122903.
- Water_ReleasesASM122903.

Within each spreadsheet, for each isotope of interest, and for each release year, the value of Sigma Y has been calculated in three steps (columns). In some cases, geometric standard deviation (GSD) has been computed too (Step 4). The averages (arithmetic means) of the computed values over all years are provided at the bottom of the columns within the spreadsheet. The total release (over all years) was also calculated (to the left of the spreadsheet). The steps and formulas used are as follows:

1. Find the ratio of the 95th percentile (95%) over the 5th percentile (5%).
2. Take the natural log of the ratio obtained in step 1.
3. Divide the result of step 2 by 3.29.
4. GSD = EXP(Sigma Y).

It should be noted that in the spreadsheet "Revised_I-131_Releases_(F,H)ASM122903," M5, a weighted average (considering the weights in columns O and P) has been calculated for Sigma Y in each row. And, within "Water_ReleasesASM122903," M7, it should be noted that the sheets/tabs named "Cs annual," "Sr-annual," and "Tritium-annual" have been considered.

The following three spreadsheets (M8 through M10) provided the total releases used in computing the weighted averages (the string "ASM122903-Totals" has been added to each name for identification purposes only):

- Air Master Templete_Revised_Uncertainty4ASM 122903-Total
- SR Liquid Release Cat 13 Master_Revised_Total_110703_Uncertainty2ASM 122903-Totals
- Sr-89_Sr-90_Sr-8990_UN BetaGamma_Cat 13_Revised_Uncertainty1ASM 122903-Totals

The Sigma Y bar values and the total releases obtained from Spreadsheets M2 through M10 have been reflected in Spreadsheet M1, where the overall weighted averages of Sigma Y bars (with respect to total releases) have been computed.

It should be noted that for ^{3}H from facility releases, the total releases have been obtained from the same spreadsheet that the Sigma Y bar values come from ("Annual_Tritium_Facility_releasesASM122903," M3), and the total value of 17820415 has not been used.

Each weighted average has been obtained by considering the following steps:

1. Adding up the product of each Sigma Y bar and its associated total release
2. Dividing the value obtained in Step 1 by the grand total release.

Considering the calculated values of the weighted averages of Sigma Y Bars for water and air, an overall log Standard Deviation of 0.2 was chosen to accompany a log mean value of 0.

Tab 21 of Spreadsheet M11, provided below, contains more details regarding the release factor F than Spreadsheet M1.

M1	M2	M3	M4	M5
Sigmas and Totals1.xls	Annual Reactor Releases.xls	Annual Tritium Releases.xls	EST I-131.xls	Revised I-131.xls

M6
Estimated Source Terms.xls

M7
Water Releases.xls

M8
Air Master.xls

M9
SR Liquid Releases.xls

M10
SR-89 SR-90.xls

M.2 Probability Distributions and Their Parameters for Uncertain Variables

The natural logarithm of the point estimate for each lognormally distributed variable was considered to be the log mean of the distribution. In other words, the point estimate of each lognormally distributed variable was treated as the geometric mean or the arithmetic median.

Spreadsheet M11, provided below, and the following paragraphs provide the values, the references, and the resulting statistics leading to the identification of the log mean (log of point estimate) and log standard deviation, or arithmetic mean and arithmetic standard deviation of the probability distribution of the uncertain variables considered in the uncertainty analysis.

The numbered tabs in Spreadsheet M11 correspond to the uncertain variables with the same numbers. Tab "A" provides more details regarding variables number 1, 2, and 3 than Tab "1-6" does.

M11
UV502.xls

M.2.1 CLBFF, ^{137}Cs; CLBFF, ^{90}Sr; and CLBFF, ^{32}P (Variables 1, 2, and 3)

Tab "A" of Spreadsheet M11 provides the detailed information, references, and the computation leading to the parameters of the lognormal distributions for the bioconcentration in fish.

CLBFF, ^{137}Cs was assumed to be lognormally distributed. The log standard deviation was computed based on the three mean values obtained from Friday 1996 (1) and the expected value was obtained from IAEA Technical Report No. 364 (2).

CLBFF, ^{90}Sr was assumed to be lognormally distributed. The standard deviation was computed based on the two maximum values obtained from Friday 1996 (1), and the expected value was obtained from IAEA Technical Report No. 364 (2).

CLBFF, ^{32}P was assumed to be lognormally distributed. The standard deviation was computed based on the natural log of the ratio of maximum over minimum divided by 3.92. The data used were from IAEA Technical Report No. 364 (2).

M.2.2 CLFMK, ^{131}I; CLFMT, ^{131}I (Variables 4 and 5)

In addition to providing a summary of information on Variables 1, 2, and 3, Tab "1-6" of Spreadsheet M11 shows how the parameters for the lognormally distributed CLFMK, ^{131}I and CLFMT, ^{131}I (Variables 4 and 5, respectively) were found.

Page 35 of IAEA Technical Report No. 364 provides the following information for CLFMK (2), ^{131}I:

- Expected value (point estimate) = 0.01 d/L
- 95% confidence interval: 0.001 - 0.035 days/Liter (d/L)

The log mean was determined as Ln (0.01) = 4.60517 and the log standard deviation was determined as the natural logarithm of the ratio of upper bound over lower bound of the confidence interval divided by 3.92 = 0.90698

Page 37 of IAEA Technical Report No. 364 provides the following information for CLFMT (2), ^{131}I:

- Expected value (point estimate) = 0.04 d/L
- 95% confidence interval: 0.007 - 0.05 d/L

The log mean was determined as Ln (0.04) = -3.21888 and the log standard deviation was determined as the natural logarithm of the ration of upper bound over lower bound of the confidence interval divided by 3.92 = -0.50156

M.2.3 ABSHUM (Variable 6)

A normal probability distribution was assumed for ABSHUM (Variable 6) with an arithmetic mean of 0.01125 kg/m^3 and a standard deviation of 0.00053 kg/m^3 (3). Tab "1-6" of Spreadsheet M11 reflects the said values in their corresponding columns.

M.2.4 BIOMA2, 5&6 (Variable 7)

Tab "7" of Spreadsheet M11 provides the information used, along with its corresponding reference (NUREG/CR-5512, Vol. 3, Table 6.56), to determine the lognormal distribution for BIOMA2, 5&6 (Variable 7). The log mean (-1.203973) was determined as the natural log of the point estimate. The log standard deviation was calculated as 0.081393.

M.2.5 BIOMA2, 3 (Variable 8)

Tab "8" of Spreadsheet M11 provides the information used, along with its corresponding reference (NUREG/CR-5512, Vol. 3, Table 6.52), to determine the lognormal distribution for BIOMA2, 3 (Variable 8). It is noted that the arithmetic mean and the arithmetic standard deviation of the lognormal distribution are provided as 1.43156 and 0.02909, respectively.

M.2.6 BIOMAS, 1 (Variable 9)

As indicated in Tab "9" of Spreadsheet M11, the ratio of standard deviation over mean (ASD/AM) has been calculated for each row, then, the arithmetic mean of the ratios has been found as 0.034859. As explained in the main report, rations like the one found for BIOMAS, 1 were found for all of the 21 uncertain variables. The ratio was used as a factor contributing to the determination of the variable's rank, which, in turn, helped the analysts consider 7 of the 21 variables as "certain" variables.

M.2.7 WTIM, (Variable 10)

Tab "10" of Spreadsheet M11 shows how the log standard deviation for WTIM (1.403107) was computed from the minimum, maximum, and mode values obtained from page 6-16 of Attachment C of NUREG/CR 6697. Like any other lognormally distributed variable discussed before, The log mean was considered to be the natural log of the point estimate of the variable (WTIM).

M.2.8 CONSUM 5 (Variable 11)

Tab "11-12" of Spreadsheet M11 shows how a normal distribution was assumed for CONSUM, which had a gamma distribution with the given parameters (NUREG/CR-5512, Vol. 3, Table 6.69). Because of the similarity between Gamma and normal distributions, through scaling and the use of the point estimate value, the standard deviation of the normal distribution was calculated as 8.63005. The mean value was considered to be the same as the point estimate value.

M.2.9 CONSUM, 3 (Variable 12)

As indicated in Tab "13" of Spreadsheet M11, the arithmetic mean and arithmetic standard deviation of CONSUM, 3 were provided by Table 6.69 of NUREG/CR-5512, Vol. 3 as 1.71, and 0.262, respectively.

M.2.10 DRYFAC, 1 (Variable 13)

Tab "11-12" of Spreadsheet L12 shows how a lognormal distribution was obtained for DRYFAC, 1 from the gamma distribution parameters provided by NUREG/CR-5512, Table 6.79. The arithmetic mean and arithmetic standard deviation were determined as 0.108753 and 0.002175, respectively.

M.2.11 GRWP, 1 (Variable 14)

Tobacco was used as a surrogate for Variable 14. The usual planting and harvesting dates for states of Georgia and South Carolina were considered for this variable. The duration between each planting date and its corresponding harvesting date was computed for each state. The mean and standard deviation of the computed durations were calculated for each state along with their ratio. These values were 110, 18.27567, and 0.166142 for GA, respectively; and 108, 18.51801, and 0.171067 for SC, respectively. The average ratio (0.168605) was considered to be the ratio of standard deviation over mean for GRWP, 1. The data used were from Usual Planting and Harvesting Dates for U.S. Field Crops December 1997; USDA Handbook Number 628 (4).

M.2.12 GRWPA, 5&6 (Variable 15)

According to personal communication from Dr. Bruce Pinkerton, Clemson University Extension Station, to Norman A. Eisenberg, February 3, 2004, harvesting times for bermuda grass are 3 weeks at the smallest, 6 weeks on average, and 3 months at most. The log standard deviation for GRWPA, 5&6 (0.442337) was calculated by following the steps provided below.

1. Calculating the ratio of the maximum harvesting time (considered as the 95th percentile) over the minimum harvesting time (considered as the 5th percentile).
2. Taking the natural logarithm of the ratio obtained in Step 1.
3. Dividing the results obtained in Step 2 by 3.29.

M.2.13 GRWPA, 3 (Variable 16)

Corn was considered as the milk animal feed (Variable 16). The usual planting and harvesting dates for states of Georgia and South Carolina were considered for this variable. The duration between each planting date and its corresponding harvesting date was computed for each state. The mean and standard deviation of the computed durations were calculated for each state along with their ratio. These values were 146, 6.377042, and 0.043678 for GA, respectively; and 146, 8.539126, and 0.058387 for SC, respectively. The average ratio (0.051033) was considered to be the ratio of standard deviation over mean

for GRWPA, 3. The data used were from Usual Planting and Harvesting Dates for U.S. Field Crops December 1997; USDA Handbook Number 628 (4).

M.2.14 DEPFR1,2 (Variable 17)

Ali A. Simpkins, "Uncertainty in Transport Factors Used to Calculate Dose from ^{131}I Releases at SRS for Period of 1955-1961," provides the range for DEPFR1and DEPFR2 as 0.09 to 0.9. Considering the given values as the bounds for 95 percent confidence interval, and assuming a lognormal distribution, the log standard deviation is obtained as the natural log of the ratio of upper bound over lower bound divided by 3.92. The value obtained is 0.587394.

M.2.15 LEAFRS, RESFAC;1 (Variable 18)

The resuspension factors associated with seven different activities are obtained from Atmospheric Science and Power Production, 1984, DOE/TIC-27601, Table 12.9, p. 567. A lognormal distribution is assumed for Variable 18. The log standard deviation for the assumed lognormal distribution is calculated as the standard deviation of the natural logarithm of the seven resuspension factors considered. The log standard deviation was determined to be 2.621412906.

M.2.16 DPVRES (Variable 19)

Table F.1 of the source given below provides a default value and a range for the deposition velocity. The sources indicated in that table are Peterson (1983) and NCRP (1989).

Source: Risk Assessment Information System (RAIS), Appendix F (Food Chain Models for Risk Assessment); Website: http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml (5)

A lognormal distribution was assumed for this variable, and the given range was considered to be the 95 percent confidence interval. The log standard deviation was determined by

1. Finding the ratio of the upper limit of the interval by the lower limit of the interval
2. Taking the natural log of the ratio obtained in step 1
3. Dividing the value obtained in Step 2 by 3.92.

The value obtained for the log standard deviation was 1.255534931.

It is noted that the point estimate value used for Variable 19 was 0.001, whose natural logarithm was considered to be the log mean value.

M.2.17 Radius (Variable 20)

Phase II, Chapter 4, p. 4.4-14, Table 4-4.3 provides the geometric mean and geometric standard deviation of the mean. Natural logarithm of the geometric standard deviation provided the log standard deviation for the lognormally distributed radius. The value calculated was 0.405465.

M.3 References

1. Friday GP, Cummins CL, Schwartzman AL. Radiological bioconcentration factors for aquatic, terrestrial, and wetland ecosystems at the Savannah River Site (U). WSRC-TR-96-0231. Westinghouse Savannah River Company. Aiken, South Carolina. 1996.

2. International Atomic Energy Agency (IAEA). Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments. Safety Reports Series No. 364. IAEA. Vienna, Austria. 1994

3. Hamby DM. A probabilistic estimation of atmospheric tritium dose. Health Physics 65(1):33-40. July 1993.

4. U.S. Department of Agriculture. Usual planting and harvesting dates for U.S. field crops. National Agricultural Statistics Service. Agricultural Handbook No. 628. December 1997.

5. Oak Ridge National Laboratory. Food chain models for risk assessment, Appendix F. Risk Assessment Information System. 2002 Jul 1. *http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml*.

APPENDIX N INPUT DATA FOR LJS AND GEN II COMPUTER CODES

The input data provided to the GEN II computer code for stochastic analysis are provided in this appendix. These input data are shown in Table N2 provided below, as a 40 by 14 matrix. These data, in turn, are the output of the LHS code whose input data are provided below in Table N1.

Each row of the input data matrix (Table N2) is one realization (one computer run), resulting in one total dose value (a total of 40 dose values corresponding to 40 realizations) for each receptor. The 14 columns of the input data matrix correspond to the 14 uncertain variables involved in the stochastic analysis. In other words, Variable numbers 1 through 14 in the left column of Table N1 correspond to the column labels X(1) through X(14) in Table N2, respectively.

N1

Document.txt

N2

srs3output.txt

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VARIABLE	DISTRIBUTION	RANGE			LABEL
1	LOGNORMAL	116.	TO	1.902E+05	CLBFF--Cs-137
2	LOGNORMAL	0.849	TO	2.386E+05	CLBFF--Sr-90
3	LOGNORMAL	3.151E+03	TO	7.934E+05	CLBFF--P-32
4	LOGNORMAL	3.033E-09	TO	3.297E-02	LEAFRS/RESFAC--Urban
5	LOGNORMAL	0.143	TO	1.75	RADIUS
6	LOGNORMAL	0.183	TO	1.070E+03	WTIM
7	LOGNORMAL	2.065E-05	TO	4.842E-02	DPVRES
8	LOGNORMAL	4.070E-02	TO	1.54	DEPFR--1&2
9	LOGNORMAL	7.65	TO	118.	GRWPA--5&6
10	LOGNORMAL	8.490E-03	TO	0.188	CLFMT--I-131
11	LOGNORMAL	0.539	TO	1.86	F
12	NORMAL	9.33	TO	62.7	CONSUM--5
13	LOGNORMAL	6.064E-04	TO	0.165	CLFMK--I-131
14	LOGNORMAL	0.233	TO	0.386	BIOMA2--5&6

Appendix N PKG350

RUN NO.	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)	X(7)	X(8)	X(9)	X(10)	X(11)	X(12)	X(13)	X(14)
1	4.645E+03	436.	1.003E+05	1.134E-04	0.779	32.1	6.987E-04	0.268	16.7	6.812E-02	0.911	32.8	1.778E-02	0.322
2	1.362E+04	113.	4.265E+04	1.899E-04	0.571	38.9	6.136E-04	0.222	28.6	9.061E-02	0.972	35.9	1.527E-02	0.300
3	1.294E+03	1.523E+04	3.163E+04	1.284E-04	0.997	27.0	2.347E-03	0.720	64.2	5.643E-02	0.887	33.3	4.345E-02	0.308
4	2.109E+04	3.272E+03	1.080E+05	2.479E-05	0.367	2.93	4.138E-03	0.259	35.3	2.231E-02	0.562	28.3	2.761E-03	0.305
5	3.507E+03	924.	1.242E+05	2.372E-07	0.470	18.2	4.641E-04	0.329	21.8	5.429E-02	1.08	41.3	1.280E-02	0.280
6	2.785E+03	58.5	1.669E+05	8.949E-06	0.672	176.	1.129E-03	0.112	41.4	3.524E-02	0.899	26.7	6.935E-03	0.272
7	9.469E+03	459.	2.685E+04	4.670E-05	1.19	9.80	2.301E-04	0.381	18.4	2.667E-02	0.816	18.1	2.445E-02	0.319
8	3.013E+03	136.	3.792E+04	6.507E-05	0.415	5.29	1.364E-04	0.464	30.9	2.368E-02	0.791	42.7	2.564E-02	0.298
9	1.744E+03	160.	8.498E+04	7.883E-07	0.882	4.09	3.110E-05	0.176	33.0	3.851E-02	1.00	31.9	5.491E-03	0.273
10	1.704E+03	1.202E+03	2.399E+05	5.331E-05	0.494	140.	2.136E-03	0.146	31.9	3.981E-02	1.19	43.8	2.216E-02	0.288
11	3.254E+03	36.9	4.063E+04	5.140E-07	0.505	85.6	2.798E-03	0.277	25.6	3.384E-02	0.722	32.5	8.070E-03	0.383
12	5.036E+03	1.487E+03	2.115E+04	8.674E-07	0.425	7.13	3.546E-03	0.286	22.4	3.286E-02	1.24	36.1	6.238E-02	0.286
13	2.065E+03	20.3	3.712E+04	2.752E-05	0.799	1.02	1.773E-03	0.425	21.4	2.889E-02	1.07	40.3	1.354E-02	0.309
14	1.603E+04	1.577E+03	2.948E+04	4.734E-07	0.735	46.4	6.265E-04	4.070E-02	29.4	1.424E-02	1.65	40.5	1.004E-02	0.318
15	2.205E+04	5.810E+03	7.606E+04	8.658E-08	0.390	8.34	1.612E-03	0.506	37.8	4.793E-02	1.22	25.4	4.104E-03	0.333
16	1.674E+04	545.	1.643E+04	7.122E-06	0.690	1.94	1.042E-03	0.163	17.5	0.117	1.02	51.7	1.084E-02	0.300
17	2.796E+04	1.930E+03	8.917E+04	6.313E-04	0.338	1.61	8.347E-04	0.131	57.5	7.926E-02	0.962	31.2	5.099E-02	0.296
18	1.260E+04	5.32	1.350E+04	2.450E-06	0.308	58.8	1.482E-03	9.736E-02	46.5	5.190E-02	0.926	30.0	3.427E-02	0.330
19	5.682E+04	731.	1.489E+05	2.168E-05	0.649	21.7	1.200E-03	0.344	23.2	4.421E-02	1.03	47.3	3.834E-03	0.294
20	3.896E+03	183.	7.348E+04	3.125E-08	0.524	33.9	3.077E-02	0.294	34.2	6.621E-02	0.761	34.1	2.095E-02	0.285
21	2.155E+03	2.608E+04	8.633E+03	4.488E-06	0.295	44.5	1.650E-03	0.204	19.0	2.579E-02	0.682	38.3	1.128E-02	0.264
22	1.377E+03	2.239E+03	4.957E+04	1.574E-06	0.721	15.0	4.246E-04	0.123	28.2	5.376E-02	0.994	37.2	6.128E-03	0.350
23	1.039E+04	626.	6.198E+04	3.574E-04	0.353	10.5	9.950E-03	0.584	39.8	4.376E-02	1.13	46.8	7.788E-03	0.311

24	6.223E+03	319.	2.011E+05	3.310E-03	0.318	24.8	1.693E-04	0.225	26.1	2.996E-02	1.05	29.1	4.600E-03	0.302
25	1.027E+03	1.143E+04	6.589E+04	3.357E-06	0.547	0.812	5.120E-03	8.349E-02	24.5	4.189E-02	1.06	35.4	7.258E-03	0.295
26	491.	72.4	1.291E+05	2.930E-06	0.242	2.70	3.267E-04	0.156	54.4	4.110E-02	1.10	44.6	1.864E-02	0.315
27	431.	117.	5.298E+04	2.036E-06	0.200	11.0	4.989E-04	0.902	13.7	6.055E-02	1.16	19.1	6.535E-03	0.312
28	2.522E+03	1.045E+03	1.441E+04	1.235E-05	0.376	12.8	2.471E-04	0.234	30.7	3.474E-02	0.840	48.9	3.282E-03	0.290
29	4.251E+03	272.	5.081E+04	1.130E-06	0.480	13.4	9.869E-04	0.401	118.	2.833E-02	1.17	30.5	1.423E-02	0.235
30	821.	396.	1.144E+04	9.511E-04	0.630	6.07	2.946E-03	0.144	43.4	1.888E-02	1.13	27.8	1.839E-03	0.313
31	8.625E+03	4.037E+03	1.975E+04	3.796E-05	0.443	15.5	3.021E-04	0.214	36.4	0.102	1.37	23.8	9.127E-03	0.326
32	5.865E+03	2.943E+03	2.388E+04	1.126E-05	0.455	71.4	1.046E-04	0.568	44.1	3.643E-02	0.863	39.1	8.741E-03	0.281
33	1.109E+04	213.	9.716E+04	1.741E-07	0.560	5.95	3.513E-04	0.309	50.7	1.943E-02	0.807	45.7	5.353E-03	0.338
34	5.156E+03	96.7	5.709E+04	8.412E-06	0.924	3.34	6.589E-03	0.457	25.1	2.433E-02	1.29	34.8	1.204E-02	0.276
35	985.	15.1	2.888E+04	2.153E-04	0.530	23.8	2.008E-03	0.316	49.1	4.633E-02	0.945	53.3	4.763E-03	0.305
36	7.035E+03	254.	2.173E+04	5.708E-06	0.602	257.	5.215E-04	0.361	38.1	6.263E-02	1.45	36.7	2.702E-03	0.282
37	3.796E+04	29.3	3.440E+04	1.615E-05	0.404	4.36	8.838E-04	0.176	27.2	3.076E-02	0.920	38.1	1.619E-02	0.257
38	2.487E+03	6.931E+03	6.991E+05	4.139E-06	0.592	19.7	7.531E-04	0.190	20.5	4.853E-02	0.851	42.2	9.757E-03	0.292
39	6.399E+03	50.7	4.605E+04	1.867E-05	0.430	7.43	4.557E-03	0.195	15.1	7.535E-02	0.987	23.3	1.049E-03	0.269
40	7.513E+03	847.	6.799E+04	8.174E-05	0.261	62.2	1.339E-03	0.246	12.5	1.512E-02	1.28	39.4	2.902E-02	0.329

APPENDIX O TOTAL 39-YEAR DOSE FOR EACH RECEPTOR

The results of computer runs (based on the GEN II computer code and post processing) for the seven hypothetical four-member families (a total of 28 receptors) are provided in this appendix. Each family was subjected to a different exposure scenario. Forty one total dose values are listed for each receptor. Each total dose value is the result of a realization (a computer run). Run 0 is a run based on the simplified model (reduced pathways and isotopes) that used the point estimate values. Run 0 results were compared with the results obtained for the point estimate (non-simplified model) run. This comparison showed the impact of the model simplification (pathway and isotope reduction) on the point estimate results.

The results contained in the following seven spreadsheets are discussed in details in Chapter 12.

O1
Delivery Family Sensitivity

O2
Migrant Family Sensitivity

O3
Near Water Sensitivity

O4
Outdoor Family Sensitivity

O5
Rural Family One Sensitivity

O6
Rural Family Two Sensitivity

O7
Urban Family Sensitivity

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Location	Receptor	CurrYear	FacilityID	RunNum	Isotope	Pathway	Route	TEDE	TRCI	TRCF
Delivery Family	Adult Female	ALL	ALL	0	ALL	ALL	ALL	0.006091	0	0
Delivery Family	Adult Female	ALL	ALL	1	ALL	ALL	ALL	0.005875	0	0
Delivery Family	Adult Female	ALL	ALL	2	ALL	ALL	ALL	0.014356	0	0
Delivery Family	Adult Female	ALL	ALL	3	ALL	ALL	ALL	0.020796	0	0
Delivery Family	Adult Female	ALL	ALL	4	ALL	ALL	ALL	0.014775	0	0
Delivery Family	Adult Female	ALL	ALL	5	ALL	ALL	ALL	0.006672	0	0
Delivery Family	Adult Female	ALL	ALL	6	ALL	ALL	ALL	0.003741	0	0
Delivery Family	Adult Female	ALL	ALL	7	ALL	ALL	ALL	0.008736	0	0
Delivery Family	Adult Female	ALL	ALL	8	ALL	ALL	ALL	0.003234	0	0
Delivery Family	Adult Female	ALL	ALL	9	ALL	ALL	ALL	0.002796	0	0
Delivery Family	Adult Female	ALL	ALL	10	ALL	ALL	ALL	0.006163	0	0
Delivery Family	Adult Female	ALL	ALL	11	ALL	ALL	ALL	0.002919	0	0
Delivery Family	Adult Female	ALL	ALL	12	ALL	ALL	ALL	0.009796	0	0
Delivery Family	Adult Female	ALL	ALL	13	ALL	ALL	ALL	0.00288	0	0
Delivery Family	Adult Female	ALL	ALL	14	ALL	ALL	ALL	0.030629	0	0
Delivery Family	Adult Female	ALL	ALL	15	ALL	ALL	ALL	0.037362	0	0
Delivery Family	Adult Female	ALL	ALL	16	ALL	ALL	ALL	0.018348	0	0
Delivery Family	Adult Female	ALL	ALL	17	ALL	ALL	ALL	0.030122	0	0
Delivery Family	Adult Female	ALL	ALL	18	ALL	ALL	ALL	0.012164	0	0
Delivery Family	Adult Female	ALL	ALL	19	ALL	ALL	ALL	0.060911	0	0
Delivery Family	Adult Female	ALL	ALL	20	ALL	ALL	ALL	0.004117	0	0
Delivery Family	Adult Female	ALL	ALL	21	ALL	ALL	ALL	0.025256	0	0
Delivery Family	Adult Female	ALL	ALL	22	ALL	ALL	ALL	0.00498	0	0
Delivery Family	Adult Female	ALL	ALL	23	ALL	ALL	ALL	0.014064	0	0
Delivery Family	Adult Female	ALL	ALL	24	ALL	ALL	ALL	0.008572	0	0
Delivery Family	Adult Female	ALL	ALL	25	ALL	ALL	ALL	0.017738	0	0
Delivery Family	Adult Female	ALL	ALL	26	ALL	ALL	ALL	0.001845	0	0
Delivery Family	Adult Female	ALL	ALL	27	ALL	ALL	ALL	0.001988	0	0
Delivery Family	Adult Female	ALL	ALL	28	ALL	ALL	ALL	0.003765	0	0
Delivery Family	Adult Female	ALL	ALL	29	ALL	ALL	ALL	0.006502	0	0
Delivery Family	Adult Female	ALL	ALL	30	ALL	ALL	ALL	0.001987	0	0
Delivery Family	Adult Female	ALL	ALL	31	ALL	ALL	ALL	0.020012	0	0
Delivery Family	Adult Female	ALL	ALL	32	ALL	ALL	ALL	0.009408	0	0
Delivery Family	Adult Female	ALL	ALL	33	ALL	ALL	ALL	0.00992	0	0
Delivery Family	Adult Female	ALL	ALL	34	ALL	ALL	ALL	0.007832	0	0
Delivery Family	Adult Female	ALL	ALL	35	ALL	ALL	ALL	0.001813	0	0

Delivery Family	Adult Female	ALL	ALL	36	ALL	ALL	ALL	0.01215	0	0
Delivery Family	Adult Female	ALL	ALL	37	ALL	ALL	ALL	0.03545	0	0
Delivery Family	Adult Female	ALL	ALL	38	ALL	ALL	ALL	0.013492	0	0
Delivery Family	Adult Female	ALL	ALL	39	ALL	ALL	ALL	0.007066	0	0
Delivery Family	Adult Female	ALL	ALL	40	ALL	ALL	ALL	0.012236	0	0
Delivery Family	Adult Male	ALL	ALL	0	ALL	ALL	ALL	0.006266	0	0
Delivery Family	Adult Male	ALL	ALL	1	ALL	ALL	ALL	0.006101	0	0
Delivery Family	Adult Male	ALL	ALL	2	ALL	ALL	ALL	0.014523	0	0
Delivery Family	Adult Male	ALL	ALL	3	ALL	ALL	ALL	0.021457	0	0
Delivery Family	Adult Male	ALL	ALL	4	ALL	ALL	ALL	0.014827	0	0
Delivery Family	Adult Male	ALL	ALL	5	ALL	ALL	ALL	0.006993	0	0
Delivery Family	Adult Male	ALL	ALL	6	ALL	ALL	ALL	0.003846	0	0
Delivery Family	Adult Male	ALL	ALL	7	ALL	ALL	ALL	0.0088	0	0
Delivery Family	Adult Male	ALL	ALL	8	ALL	ALL	ALL	0.003409	0	0
Delivery Family	Adult Male	ALL	ALL	9	ALL	ALL	ALL	0.002905	0	0
Delivery Family	Adult Male	ALL	ALL	10	ALL	ALL	ALL	0.006404	0	0
Delivery Family	Adult Male	ALL	ALL	11	ALL	ALL	ALL	0.003038	0	0
Delivery Family	Adult Male	ALL	ALL	12	ALL	ALL	ALL	0.010109	0	0
Delivery Family	Adult Male	ALL	ALL	13	ALL	ALL	ALL	0.003001	0	0
Delivery Family	Adult Male	ALL	ALL	14	ALL	ALL	ALL	0.030763	0	0
Delivery Family	Adult Male	ALL	ALL	15	ALL	ALL	ALL	0.037607	0	0
Delivery Family	Adult Male	ALL	ALL	16	ALL	ALL	ALL	0.018514	0	0
Delivery Family	Adult Male	ALL	ALL	17	ALL	ALL	ALL	0.030234	0	0
Delivery Family	Adult Male	ALL	ALL	18	ALL	ALL	ALL	0.012298	0	0
Delivery Family	Adult Male	ALL	ALL	19	ALL	ALL	ALL	0.061183	0	0
Delivery Family	Adult Male	ALL	ALL	20	ALL	ALL	ALL	0.004372	0	0
Delivery Family	Adult Male	ALL	ALL	21	ALL	ALL	ALL	0.025363	0	0
Delivery Family	Adult Male	ALL	ALL	22	ALL	ALL	ALL	0.005106	0	0
Delivery Family	Adult Male	ALL	ALL	23	ALL	ALL	ALL	0.014475	0	0
Delivery Family	Adult Male	ALL	ALL	24	ALL	ALL	ALL	0.008718	0	0
Delivery Family	Adult Male	ALL	ALL	25	ALL	ALL	ALL	0.017822	0	0
Delivery Family	Adult Male	ALL	ALL	26	ALL	ALL	ALL	0.001968	0	0
Delivery Family	Adult Male	ALL	ALL	27	ALL	ALL	ALL	0.001737	0	0
Delivery Family	Adult Male	ALL	ALL	28	ALL	ALL	ALL	0.003906	0	0
Delivery Family	Adult Male	ALL	ALL	29	ALL	ALL	ALL	0.006736	0	0
Delivery Family	Adult Male	ALL	ALL	30	ALL	ALL	ALL	0.002086	0	0
Delivery Family	Adult Male	ALL	ALL	31	ALL	ALL	ALL	0.020297	0	0

Delivery Family	Adult Male	ALL	ALL	32	ALL	ALL	ALL	0.009762	0	0
Delivery Family	Adult Male	ALL	ALL	33	ALL	ALL	ALL	0.010014	0	0
Delivery Family	Adult Male	ALL	ALL	34	ALL	ALL	ALL	0.008024	0	0
Delivery Family	Adult Male	ALL	ALL	35	ALL	ALL	ALL	0.002089	0	0
Delivery Family	Adult Male	ALL	ALL	36	ALL	ALL	ALL	0.012692	0	0
Delivery Family	Adult Male	ALL	ALL	37	ALL	ALL	ALL	0.035561	0	0
Delivery Family	Adult Male	ALL	ALL	38	ALL	ALL	ALL	0.013648	0	0
Delivery Family	Adult Male	ALL	ALL	39	ALL	ALL	ALL	0.007209	0	0
Delivery Family	Adult Male	ALL	ALL	40	ALL	ALL	ALL	0.012444	0	0
Delivery Family	Child born 1955	ALL	ALL	0	ALL	ALL	ALL	0.00518	0	0
Delivery Family	Child born 1955	ALL	ALL	1	ALL	ALL	ALL	0.006122	0	0
Delivery Family	Child born 1955	ALL	ALL	2	ALL	ALL	ALL	0.010084	0	0
Delivery Family	Child born 1955	ALL	ALL	3	ALL	ALL	ALL	0.03501	0	0
Delivery Family	Child born 1955	ALL	ALL	4	ALL	ALL	ALL	0.008321	0	0
Delivery Family	Child born 1955	ALL	ALL	5	ALL	ALL	ALL	0.008411	0	0
Delivery Family	Child born 1955	ALL	ALL	6	ALL	ALL	ALL	0.00309	0	0
Delivery Family	Child born 1955	ALL	ALL	7	ALL	ALL	ALL	0.006001	0	0
Delivery Family	Child born 1955	ALL	ALL	8	ALL	ALL	ALL	0.005347	0	0
Delivery Family	Child born 1955	ALL	ALL	9	ALL	ALL	ALL	0.002397	0	0
Delivery Family	Child born 1955	ALL	ALL	10	ALL	ALL	ALL	0.008763	0	0
Delivery Family	Child born 1955	ALL	ALL	11	ALL	ALL	ALL	0.002732	0	0
Delivery Family	Child born 1955	ALL	ALL	12	ALL	ALL	ALL	0.01407	0	0
Delivery Family	Child born 1955	ALL	ALL	13	ALL	ALL	ALL	0.002518	0	0
Delivery Family	Child born 1955	ALL	ALL	14	ALL	ALL	ALL	0.016434	0	0
Delivery Family	Child born 1955	ALL	ALL	15	ALL	ALL	ALL	0.023874	0	0
Delivery Family	Child born 1955	ALL	ALL	16	ALL	ALL	ALL	0.009794	0	0
Delivery Family	Child born 1955	ALL	ALL	17	ALL	ALL	ALL	0.015993	0	0
Delivery Family	Child born 1955	ALL	ALL	18	ALL	ALL	ALL	0.007372	0	0
Delivery Family	Child born 1955	ALL	ALL	19	ALL	ALL	ALL	0.030356	0	0
Delivery Family	Child born 1955	ALL	ALL	20	ALL	ALL	ALL	0.005983	0	0
Delivery Family	Child born 1955	ALL	ALL	21	ALL	ALL	ALL	0.025276	0	0
Delivery Family	Child born 1955	ALL	ALL	22	ALL	ALL	ALL	0.004904	0	0
Delivery Family	Child born 1955	ALL	ALL	23	ALL	ALL	ALL	0.011976	0	0
Delivery Family	Child born 1955	ALL	ALL	24	ALL	ALL	ALL	0.005913	0	0
Delivery Family	Child born 1955	ALL	ALL	25	ALL	ALL	ALL	0.017074	0	0
Delivery Family	Child born 1955	ALL	ALL	26	ALL	ALL	ALL	0.002559	0	0
Delivery Family	Child born 1955	ALL	ALL	27	ALL	ALL	ALL	0.004868	0	0

Delivery Family	Child born 1955	ALL	ALL	28	ALL	ALL	ALL	0.003519	0	0
Delivery Family	Child born 1955	ALL	ALL	29	ALL	ALL	ALL	0.007666	0	0
Delivery Family	Child born 1955	ALL	ALL	30	ALL	ALL	ALL	0.001767	0	0
Delivery Family	Child born 1955	ALL	ALL	31	ALL	ALL	ALL	0.015285	0	0
Delivery Family	Child born 1955	ALL	ALL	32	ALL	ALL	ALL	0.011107	0	0
Delivery Family	Child born 1955	ALL	ALL	33	ALL	ALL	ALL	0.00568	0	0
Delivery Family	Child born 1955	ALL	ALL	34	ALL	ALL	ALL	0.006209	0	0
Delivery Family	Child born 1955	ALL	ALL	35	ALL	ALL	ALL	0.003675	0	0
Delivery Family	Child born 1955	ALL	ALL	36	ALL	ALL	ALL	0.010333	0	0
Delivery Family	Child born 1955	ALL	ALL	37	ALL	ALL	ALL	0.016981	0	0
Delivery Family	Child born 1955	ALL	ALL	38	ALL	ALL	ALL	0.013816	0	0
Delivery Family	Child born 1955	ALL	ALL	39	ALL	ALL	ALL	0.004179	0	0
Delivery Family	Child born 1955	ALL	ALL	40	ALL	ALL	ALL	0.011086	0	0
Delivery Family	Child born 1964	ALL	ALL	0	ALL	ALL	ALL	0.002081	0	0
Delivery Family	Child born 1964	ALL	ALL	1	ALL	ALL	ALL	0.002361	0	0
Delivery Family	Child born 1964	ALL	ALL	2	ALL	ALL	ALL	0.003629	0	0
Delivery Family	Child born 1964	ALL	ALL	3	ALL	ALL	ALL	0.010181	0	0
Delivery Family	Child born 1964	ALL	ALL	4	ALL	ALL	ALL	0.004621	0	0
Delivery Family	Child born 1964	ALL	ALL	5	ALL	ALL	ALL	0.003171	0	0
Delivery Family	Child born 1964	ALL	ALL	6	ALL	ALL	ALL	0.002343	0	0
Delivery Family	Child born 1964	ALL	ALL	7	ALL	ALL	ALL	0.002357	0	0
Delivery Family	Child born 1964	ALL	ALL	8	ALL	ALL	ALL	0.001092	0	0
Delivery Family	Child born 1964	ALL	ALL	9	ALL	ALL	ALL	0.001594	0	0
Delivery Family	Child born 1964	ALL	ALL	10	ALL	ALL	ALL	0.004688	0	0
Delivery Family	Child born 1964	ALL	ALL	11	ALL	ALL	ALL	0.000995	0	0
Delivery Family	Child born 1964	ALL	ALL	12	ALL	ALL	ALL	0.003213	0	0
Delivery Family	Child born 1964	ALL	ALL	13	ALL	ALL	ALL	0.00114	0	0
Delivery Family	Child born 1964	ALL	ALL	14	ALL	ALL	ALL	0.008438	0	0
Delivery Family	Child born 1964	ALL	ALL	15	ALL	ALL	ALL	0.012023	0	0
Delivery Family	Child born 1964	ALL	ALL	16	ALL	ALL	ALL	0.004508	0	0
Delivery Family	Child born 1964	ALL	ALL	17	ALL	ALL	ALL	0.008264	0	0
Delivery Family	Child born 1964	ALL	ALL	18	ALL	ALL	ALL	0.002886	0	0
Delivery Family	Child born 1964	ALL	ALL	19	ALL	ALL	ALL	0.015146	0	0
Delivery Family	Child born 1964	ALL	ALL	20	ALL	ALL	ALL	0.001509	0	0
Delivery Family	Child born 1964	ALL	ALL	21	ALL	ALL	ALL	0.012878	0	0
Delivery Family	Child born 1964	ALL	ALL	22	ALL	ALL	ALL	0.002568	0	0
Delivery Family	Child born 1964	ALL	ALL	23	ALL	ALL	ALL	0.004054	0	0

Delivery Family	Child born 1964	ALL	ALL	24	ALL	ALL	ALL	0.004098	0	0
Delivery Family	Child born 1964	ALL	ALL	25	ALL	ALL	ALL	0.009577	0	0
Delivery Family	Child born 1964	ALL	ALL	26	ALL	ALL	ALL	0.001892	0	0
Delivery Family	Child born 1964	ALL	ALL	27	ALL	ALL	ALL	0.00111	0	0
Delivery Family	Child born 1964	ALL	ALL	28	ALL	ALL	ALL	0.001378	0	0
Delivery Family	Child born 1964	ALL	ALL	29	ALL	ALL	ALL	0.002195	0	0
Delivery Family	Child born 1964	ALL	ALL	30	ALL	ALL	ALL	0.000885	0	0
Delivery Family	Child born 1964	ALL	ALL	31	ALL	ALL	ALL	0.007002	0	0
Delivery Family	Child born 1964	ALL	ALL	32	ALL	ALL	ALL	0.003292	0	0
Delivery Family	Child born 1964	ALL	ALL	33	ALL	ALL	ALL	0.00307	0	0
Delivery Family	Child born 1964	ALL	ALL	34	ALL	ALL	ALL	0.002592	0	0
Delivery Family	Child born 1964	ALL	ALL	35	ALL	ALL	ALL	0.000712	0	0
Delivery Family	Child born 1964	ALL	ALL	36	ALL	ALL	ALL	0.003148	0	0
Delivery Family	Child born 1964	ALL	ALL	37	ALL	ALL	ALL	0.008187	0	0
Delivery Family	Child born 1964	ALL	ALL	38	ALL	ALL	ALL	0.010973	0	0
Delivery Family	Child born 1964	ALL	ALL	39	ALL	ALL	ALL	0.0021	0	0
Delivery Family	Child born 1964	ALL	ALL	40	ALL	ALL	ALL	0.004053	0	0

Location	Receptor	CurrYear	FacilityID	RunNum	Isotope	Pathway	Route	TEDE	TRCI	TRCF
Migrant Family	Adult Female	ALL	ALL	0	ALL	ALL	ALL	0.000438		
Migrant Family	Adult Female	ALL	ALL	1	ALL	ALL	ALL	0.000709		
Migrant Family	Adult Female	ALL	ALL	2	ALL	ALL	ALL	0.000994		
Migrant Family	Adult Female	ALL	ALL	3	ALL	ALL	ALL	0.002211		
Migrant Family	Adult Female	ALL	ALL	4	ALL	ALL	ALL	0.000138		
Migrant Family	Adult Female	ALL	ALL	5	ALL	ALL	ALL	0.000803		
Migrant Family	Adult Female	ALL	ALL	6	ALL	ALL	ALL	0.000248		
Migrant Family	Adult Female	ALL	ALL	7	ALL	ALL	ALL	0.000338		
Migrant Family	Adult Female	ALL	ALL	8	ALL	ALL	ALL	0.000471		
Migrant Family	Adult Female	ALL	ALL	9	ALL	ALL	ALL	0.000247		
Migrant Family	Adult Female	ALL	ALL	10	ALL	ALL	ALL	0.000658		
Migrant Family	Adult Female	ALL	ALL	11	ALL	ALL	ALL	0.000303		
Migrant Family	Adult Female	ALL	ALL	12	ALL	ALL	ALL	0.000721		
Migrant Family	Adult Female	ALL	ALL	13	ALL	ALL	ALL	0.000331		
Migrant Family	Adult Female	ALL	ALL	14	ALL	ALL	ALL	0.000261		
Migrant Family	Adult Female	ALL	ALL	15	ALL	ALL	ALL	0.000684		
Migrant Family	Adult Female	ALL	ALL	16	ALL	ALL	ALL	0.000422		
Migrant Family	Adult Female	ALL	ALL	17	ALL	ALL	ALL	0.000909		
Migrant Family	Adult Female	ALL	ALL	18	ALL	ALL	ALL	0.000301		
Migrant Family	Adult Female	ALL	ALL	19	ALL	ALL	ALL	0.000717		
Migrant Family	Adult Female	ALL	ALL	20	ALL	ALL	ALL	0.000628		
Migrant Family	Adult Female	ALL	ALL	21	ALL	ALL	ALL	0.000257		
Migrant Family	Adult Female	ALL	ALL	22	ALL	ALL	ALL	0.000289		
Migrant Family	Adult Female	ALL	ALL	23	ALL	ALL	ALL	0.004615		
Migrant Family	Adult Female	ALL	ALL	24	ALL	ALL	ALL	0.003807		
Migrant Family	Adult Female	ALL	ALL	25	ALL	ALL	ALL	0.000171		
Migrant Family	Adult Female	ALL	ALL	26	ALL	ALL	ALL	0.000276		
Migrant Family	Adult Female	ALL	ALL	27	ALL	ALL	ALL	0.001162		
Migrant Family	Adult Female	ALL	ALL	28	ALL	ALL	ALL	0.000346		
Migrant Family	Adult Female	ALL	ALL	29	ALL	ALL	ALL	0.000654		
Migrant Family	Adult Female	ALL	ALL	30	ALL	ALL	ALL	0.00143		
Migrant Family	Adult Female	ALL	ALL	31	ALL	ALL	ALL	0.000795		
Migrant Family	Adult Female	ALL	ALL	32	ALL	ALL	ALL	0.000919		
Migrant Family	Adult Female	ALL	ALL	33	ALL	ALL	ALL	0.000232		
Migrant Family	Adult Female	ALL	ALL	34	ALL	ALL	ALL	0.000495		
Migrant Family	Adult Female	ALL	ALL	35	ALL	ALL	ALL	0.001123		

Migrant Family	Adult Female	ALL	ALL	36	ALL	ALL	ALL	0.001392
Migrant Family	Adult Female	ALL	ALL	37	ALL	ALL	ALL	0.000262
Migrant Family	Adult Female	ALL	ALL	38	ALL	ALL	ALL	0.000375
Migrant Family	Adult Female	ALL	ALL	39	ALL	ALL	ALL	0.000397
Migrant Family	Adult Female	ALL	ALL	40	ALL	ALL	ALL	0.00063
Migrant Family	Adult Male	ALL	ALL	0	ALL	ALL	ALL	0.000614
Migrant Family	Adult Male	ALL	ALL	1	ALL	ALL	ALL	0.001008
Migrant Family	Adult Male	ALL	ALL	2	ALL	ALL	ALL	0.001435
Migrant Family	Adult Male	ALL	ALL	3	ALL	ALL	ALL	0.003155
Migrant Family	Adult Male	ALL	ALL	4	ALL	ALL	ALL	0.000184
Migrant Family	Adult Male	ALL	ALL	5	ALL	ALL	ALL	0.00116
Migrant Family	Adult Male	ALL	ALL	6	ALL	ALL	ALL	0.000335
Migrant Family	Adult Male	ALL	ALL	7	ALL	ALL	ALL	0.000454
Migrant Family	Adult Male	ALL	ALL	8	ALL	ALL	ALL	0.000646
Migrant Family	Adult Male	ALL	ALL	9	ALL	ALL	ALL	0.000336
Migrant Family	Adult Male	ALL	ALL	10	ALL	ALL	ALL	0.000913
Migrant Family	Adult Male	ALL	ALL	11	ALL	ALL	ALL	0.000416
Migrant Family	Adult Male	ALL	ALL	12	ALL	ALL	ALL	0.000984
Migrant Family	Adult Male	ALL	ALL	13	ALL	ALL	ALL	0.000457
Migrant Family	Adult Male	ALL	ALL	14	ALL	ALL	ALL	0.000329
Migrant Family	Adult Male	ALL	ALL	15	ALL	ALL	ALL	0.000979
Migrant Family	Adult Male	ALL	ALL	16	ALL	ALL	ALL	0.000612
Migrant Family	Adult Male	ALL	ALL	17	ALL	ALL	ALL	0.001241
Migrant Family	Adult Male	ALL	ALL	18	ALL	ALL	ALL	0.00041
Migrant Family	Adult Male	ALL	ALL	19	ALL	ALL	ALL	0.001037
Migrant Family	Adult Male	ALL	ALL	20	ALL	ALL	ALL	0.000907
Migrant Family	Adult Male	ALL	ALL	21	ALL	ALL	ALL	0.00035
Migrant Family	Adult Male	ALL	ALL	22	ALL	ALL	ALL	0.0004
Migrant Family	Adult Male	ALL	ALL	23	ALL	ALL	ALL	0.00677
Migrant Family	Adult Male	ALL	ALL	24	ALL	ALL	ALL	0.005136
Migrant Family	Adult Male	ALL	ALL	25	ALL	ALL	ALL	0.000223
Migrant Family	Adult Male	ALL	ALL	26	ALL	ALL	ALL	0.000374
Migrant Family	Adult Male	ALL	ALL	27	ALL	ALL	ALL	0.001691
Migrant Family	Adult Male	ALL	ALL	28	ALL	ALL	ALL	0.000488
Migrant Family	Adult Male	ALL	ALL	29	ALL	ALL	ALL	0.000911
Migrant Family	Adult Male	ALL	ALL	30	ALL	ALL	ALL	0.001928
Migrant Family	Adult Male	ALL	ALL	31	ALL	ALL	ALL	0.001149

Migrant Family	Adult Male	ALL	ALL	32	ALL	ALL	ALL	0.00132
Migrant Family	Adult Male	ALL	ALL	33	ALL	ALL	ALL	0.000313
Migrant Family	Adult Male	ALL	ALL	34	ALL	ALL	ALL	0.000683
Migrant Family	Adult Male	ALL	ALL	35	ALL	ALL	ALL	0.001622
Migrant Family	Adult Male	ALL	ALL	36	ALL	ALL	ALL	0.002051
Migrant Family	Adult Male	ALL	ALL	37	ALL	ALL	ALL	0.000355
Migrant Family	Adult Male	ALL	ALL	38	ALL	ALL	ALL	0.000531
Migrant Family	Adult Male	ALL	ALL	39	ALL	ALL	ALL	0.000565
Migrant Family	Adult Male	ALL	ALL	40	ALL	ALL	ALL	0.000829
Migrant Family	Child born 1955	ALL	ALL	0	ALL	ALL	ALL	0.00216
Migrant Family	Child born 1955	ALL	ALL	1	ALL	ALL	ALL	0.00347
Migrant Family	Child born 1955	ALL	ALL	2	ALL	ALL	ALL	0.004555
Migrant Family	Child born 1955	ALL	ALL	3	ALL	ALL	ALL	0.018042
Migrant Family	Child born 1955	ALL	ALL	4	ALL	ALL	ALL	0.000417
Migrant Family	Child born 1955	ALL	ALL	5	ALL	ALL	ALL	0.004552
Migrant Family	Child born 1955	ALL	ALL	6	ALL	ALL	ALL	0.000979
Migrant Family	Child born 1955	ALL	ALL	7	ALL	ALL	ALL	0.00177
Migrant Family	Child born 1955	ALL	ALL	8	ALL	ALL	ALL	0.003271
Migrant Family	Child born 1955	ALL	ALL	9	ALL	ALL	ALL	0.0009
Migrant Family	Child born 1955	ALL	ALL	10	ALL	ALL	ALL	0.00406
Migrant Family	Child born 1955	ALL	ALL	11	ALL	ALL	ALL	0.001432
Migrant Family	Child born 1955	ALL	ALL	12	ALL	ALL	ALL	0.006697
Migrant Family	Child born 1955	ALL	ALL	13	ALL	ALL	ALL	0.001333
Migrant Family	Child born 1955	ALL	ALL	14	ALL	ALL	ALL	0.00084
Migrant Family	Child born 1955	ALL	ALL	15	ALL	ALL	ALL	0.00294
Migrant Family	Child born 1955	ALL	ALL	16	ALL	ALL	ALL	0.001758
Migrant Family	Child born 1955	ALL	ALL	17	ALL	ALL	ALL	0.002199
Migrant Family	Child born 1955	ALL	ALL	18	ALL	ALL	ALL	0.00177
Migrant Family	Child born 1955	ALL	ALL	19	ALL	ALL	ALL	0.003251
Migrant Family	Child born 1955	ALL	ALL	20	ALL	ALL	ALL	0.003896
Migrant Family	Child born 1955	ALL	ALL	21	ALL	ALL	ALL	0.001399
Migrant Family	Child born 1955	ALL	ALL	22	ALL	ALL	ALL	0.001125
Migrant Family	Child born 1955	ALL	ALL	23	ALL	ALL	ALL	0.024269
Migrant Family	Child born 1955	ALL	ALL	24	ALL	ALL	ALL	0.005082
Migrant Family	Child born 1955	ALL	ALL	25	ALL	ALL	ALL	0.000446
Migrant Family	Child born 1955	ALL	ALL	26	ALL	ALL	ALL	0.001218
Migrant Family	Child born 1955	ALL	ALL	27	ALL	ALL	ALL	0.005397

Migrant Family	Child born 1955	ALL	ALL	28	ALL	ALL	ALL	0.001438
Migrant Family	Child born 1955	ALL	ALL	29	ALL	ALL	ALL	0.004127
Migrant Family	Child born 1955	ALL	ALL	30	ALL	ALL	ALL	0.002401
Migrant Family	Child born 1955	ALL	ALL	31	ALL	ALL	ALL	0.00335
Migrant Family	Child born 1955	ALL	ALL	32	ALL	ALL	ALL	0.005331
Migrant Family	Child born 1955	ALL	ALL	33	ALL	ALL	ALL	0.000994
Migrant Family	Child born 1955	ALL	ALL	34	ALL	ALL	ALL	0.002576
Migrant Family	Child born 1955	ALL	ALL	35	ALL	ALL	ALL	0.004781
Migrant Family	Child born 1955	ALL	ALL	36	ALL	ALL	ALL	0.006257
Migrant Family	Child born 1955	ALL	ALL	37	ALL	ALL	ALL	0.001241
Migrant Family	Child born 1955	ALL	ALL	38	ALL	ALL	ALL	0.00184
Migrant Family	Child born 1955	ALL	ALL	39	ALL	ALL	ALL	0.001432
Migrant Family	Child born 1955	ALL	ALL	40	ALL	ALL	ALL	0.004222
Migrant Family	Child born 1964	ALL	ALL	0	ALL	ALL	ALL	8.09E-05
Migrant Family	Child born 1964	ALL	ALL	1	ALL	ALL	ALL	9.89E-05
Migrant Family	Child born 1964	ALL	ALL	2	ALL	ALL	ALL	0.000125
Migrant Family	Child born 1964	ALL	ALL	3	ALL	ALL	ALL	0.000198
Migrant Family	Child born 1964	ALL	ALL	4	ALL	ALL	ALL	4.31E-05
Migrant Family	Child born 1964	ALL	ALL	5	ALL	ALL	ALL	9.62E-05
Migrant Family	Child born 1964	ALL	ALL	6	ALL	ALL	ALL	6.8E-05
Migrant Family	Child born 1964	ALL	ALL	7	ALL	ALL	ALL	7.06E-05
Migrant Family	Child born 1964	ALL	ALL	8	ALL	ALL	ALL	7.85E-05
Migrant Family	Child born 1964	ALL	ALL	9	ALL	ALL	ALL	7.2E-05
Migrant Family	Child born 1964	ALL	ALL	10	ALL	ALL	ALL	0.000117
Migrant Family	Child born 1964	ALL	ALL	11	ALL	ALL	ALL	5.7E-05
Migrant Family	Child born 1964	ALL	ALL	12	ALL	ALL	ALL	0.000114
Migrant Family	Child born 1964	ALL	ALL	13	ALL	ALL	ALL	8.46E-05
Migrant Family	Child born 1964	ALL	ALL	14	ALL	ALL	ALL	0.000116
Migrant Family	Child born 1964	ALL	ALL	15	ALL	ALL	ALL	9.82E-05
Migrant Family	Child born 1964	ALL	ALL	16	ALL	ALL	ALL	7.84E-05
Migrant Family	Child born 1964	ALL	ALL	17	ALL	ALL	ALL	0.000186
Migrant Family	Child born 1964	ALL	ALL	18	ALL	ALL	ALL	7.16E-05
Migrant Family	Child born 1964	ALL	ALL	19	ALL	ALL	ALL	9.32E-05
Migrant Family	Child born 1964	ALL	ALL	20	ALL	ALL	ALL	7.1E-05
Migrant Family	Child born 1964	ALL	ALL	21	ALL	ALL	ALL	5.41E-05
Migrant Family	Child born 1964	ALL	ALL	22	ALL	ALL	ALL	7.31E-05
Migrant Family	Child born 1964	ALL	ALL	23	ALL	ALL	ALL	0.000521

Migrant Family	Child born 1964	ALL	ALL	24	ALL	ALL	ALL	0.000732
Migrant Family	Child born 1964	ALL	ALL	25	ALL	ALL	ALL	7.41E-05
Migrant Family	Child born 1964	ALL	ALL	26	ALL	ALL	ALL	8.05E-05
Migrant Family	Child born 1964	ALL	ALL	27	ALL	ALL	ALL	0.000107
Migrant Family	Child born 1964	ALL	ALL	28	ALL	ALL	ALL	6.69E-05
Migrant Family	Child born 1964	ALL	ALL	29	ALL	ALL	ALL	0.000102
Migrant Family	Child born 1964	ALL	ALL	30	ALL	ALL	ALL	0.000305
Migrant Family	Child born 1964	ALL	ALL	31	ALL	ALL	ALL	0.000119
Migrant Family	Child born 1964	ALL	ALL	32	ALL	ALL	ALL	9.28E-05
Migrant Family	Child born 1964	ALL	ALL	33	ALL	ALL	ALL	6E-05
Migrant Family	Child born 1964	ALL	ALL	34	ALL	ALL	ALL	0.000103
Migrant Family	Child born 1964	ALL	ALL	35	ALL	ALL	ALL	0.000154
Migrant Family	Child born 1964	ALL	ALL	36	ALL	ALL	ALL	0.000138
Migrant Family	Child born 1964	ALL	ALL	37	ALL	ALL	ALL	7.08E-05
Migrant Family	Child born 1964	ALL	ALL	38	ALL	ALL	ALL	6.76E-05
Migrant Family	Child born 1964	ALL	ALL	39	ALL	ALL	ALL	7.78E-05
Migrant Family	Child born 1964	ALL	ALL	40	ALL	ALL	ALL	0.000129

Location	Receptor	CurrYear	FacilityID	RunNum	Isotope	Pathway	Route	TEDE	TRCI	TRCF
Near Water Family	Adult Female	ALL	ALL	0	ALL	ALL	ALL	0.002057	0	0
Near Water Family	Adult Female	ALL	ALL	1	ALL	ALL	ALL	0.00247	0	0
Near Water Family	Adult Female	ALL	ALL	2	ALL	ALL	ALL	0.003088	0	0
Near Water Family	Adult Female	ALL	ALL	3	ALL	ALL	ALL	0.005908	0	0
Near Water Family	Adult Female	ALL	ALL	4	ALL	ALL	ALL	0.002972	0	0
Near Water Family	Adult Female	ALL	ALL	5	ALL	ALL	ALL	0.00328	0	0
Near Water Family	Adult Female	ALL	ALL	6	ALL	ALL	ALL	0.00256	0	0
Near Water Family	Adult Female	ALL	ALL	7	ALL	ALL	ALL	0.001934	0	0
Near Water Family	Adult Female	ALL	ALL	8	ALL	ALL	ALL	0.001394	0	0
Near Water Family	Adult Female	ALL	ALL	9	ALL	ALL	ALL	0.00187	0	0
Near Water Family	Adult Female	ALL	ALL	10	ALL	ALL	ALL	0.004718	0	0
Near Water Family	Adult Female	ALL	ALL	11	ALL	ALL	ALL	0.001198	0	0
Near Water Family	Adult Female	ALL	ALL	12	ALL	ALL	ALL	0.002824	0	0
Near Water Family	Adult Female	ALL	ALL	13	ALL	ALL	ALL	0.001481	0	0
Near Water Family	Adult Female	ALL	ALL	14	ALL	ALL	ALL	0.005524	0	0
Near Water Family	Adult Female	ALL	ALL	15	ALL	ALL	ALL	0.007281	0	0
Near Water Family	Adult Female	ALL	ALL	16	ALL	ALL	ALL	0.003213	0	0
Near Water Family	Adult Female	ALL	ALL	17	ALL	ALL	ALL	0.00538	0	0
Near Water Family	Adult Female	ALL	ALL	18	ALL	ALL	ALL	0.002272	0	0
Near Water Family	Adult Female	ALL	ALL	19	ALL	ALL	ALL	0.009896	0	0
Near Water Family	Adult Female	ALL	ALL	20	ALL	ALL	ALL	0.001836	0	0
Near Water Family	Adult Female	ALL	ALL	21	ALL	ALL	ALL	0.005688	0	0
Near Water Family	Adult Female	ALL	ALL	22	ALL	ALL	ALL	0.002037	0	0
Near Water Family	Adult Female	ALL	ALL	23	ALL	ALL	ALL	0.003659	0	0
Near Water Family	Adult Female	ALL	ALL	24	ALL	ALL	ALL	0.003934	0	0
Near Water Family	Adult Female	ALL	ALL	25	ALL	ALL	ALL	0.004906	0	0
Near Water Family	Adult Female	ALL	ALL	26	ALL	ALL	ALL	0.002386	0	0
Near Water Family	Adult Female	ALL	ALL	27	ALL	ALL	ALL	0.002094	0	0
Near Water Family	Adult Female	ALL	ALL	28	ALL	ALL	ALL	0.001302	0	0
Near Water Family	Adult Female	ALL	ALL	29	ALL	ALL	ALL	0.002424	0	0
Near Water Family	Adult Female	ALL	ALL	30	ALL	ALL	ALL	0.001138	0	0
Near Water Family	Adult Female	ALL	ALL	31	ALL	ALL	ALL	0.004452	0	0
Near Water Family	Adult Female	ALL	ALL	32	ALL	ALL	ALL	0.002603	0	0
Near Water Family	Adult Female	ALL	ALL	33	ALL	ALL	ALL	0.00256	0	0
Near Water Family	Adult Female	ALL	ALL	34	ALL	ALL	ALL	0.002653	0	0
Near Water Family	Adult Female	ALL	ALL	35	ALL	ALL	ALL	0.001352	0	0

Near Water Family	Adult Female	ALL	ALL	36	ALL	ALL	ALL	0.003297	0	0
Near Water Family	Adult Female	ALL	ALL	37	ALL	ALL	ALL	0.005243	0	0
Near Water Family	Adult Female	ALL	ALL	38	ALL	ALL	ALL	0.008901	0	0
Near Water Family	Adult Female	ALL	ALL	39	ALL	ALL	ALL	0.002024	0	0
Near Water Family	Adult Female	ALL	ALL	40	ALL	ALL	ALL	0.003478	0	0
Near Water Family	Adult Male	ALL	ALL	0	ALL	ALL	ALL	0.00217	0	0
Near Water Family	Adult Male	ALL	ALL	1	ALL	ALL	ALL	0.002631	0	0
Near Water Family	Adult Male	ALL	ALL	2	ALL	ALL	ALL	0.003306	0	0
Near Water Family	Adult Male	ALL	ALL	3	ALL	ALL	ALL	0.006418	0	0
Near Water Family	Adult Male	ALL	ALL	4	ALL	ALL	ALL	0.002999	0	0
Near Water Family	Adult Male	ALL	ALL	5	ALL	ALL	ALL	0.003511	0	0
Near Water Family	Adult Male	ALL	ALL	6	ALL	ALL	ALL	0.002617	0	0
Near Water Family	Adult Male	ALL	ALL	7	ALL	ALL	ALL	0.002009	0	0
Near Water Family	Adult Male	ALL	ALL	8	ALL	ALL	ALL	0.001513	0	0
Near Water Family	Adult Male	ALL	ALL	9	ALL	ALL	ALL	0.001931	0	0
Near Water Family	Adult Male	ALL	ALL	10	ALL	ALL	ALL	0.004871	0	0
Near Water Family	Adult Male	ALL	ALL	11	ALL	ALL	ALL	0.001273	0	0
Near Water Family	Adult Male	ALL	ALL	12	ALL	ALL	ALL	0.003039	0	0
Near Water Family	Adult Male	ALL	ALL	13	ALL	ALL	ALL	0.001558	0	0
Near Water Family	Adult Male	ALL	ALL	14	ALL	ALL	ALL	0.00558	0	0
Near Water Family	Adult Male	ALL	ALL	15	ALL	ALL	ALL	0.007462	0	0
Near Water Family	Adult Male	ALL	ALL	16	ALL	ALL	ALL	0.003329	0	0
Near Water Family	Adult Male	ALL	ALL	17	ALL	ALL	ALL	0.005449	0	0
Near Water Family	Adult Male	ALL	ALL	18	ALL	ALL	ALL	0.002351	0	0
Near Water Family	Adult Male	ALL	ALL	19	ALL	ALL	ALL	0.010084	0	0
Near Water Family	Adult Male	ALL	ALL	20	ALL	ALL	ALL	0.002019	0	0
Near Water Family	Adult Male	ALL	ALL	21	ALL	ALL	ALL	0.005753	0	0
Near Water Family	Adult Male	ALL	ALL	22	ALL	ALL	ALL	0.002109	0	0
Near Water Family	Adult Male	ALL	ALL	23	ALL	ALL	ALL	0.003962	0	0
Near Water Family	Adult Male	ALL	ALL	24	ALL	ALL	ALL	0.004022	0	0
Near Water Family	Adult Male	ALL	ALL	25	ALL	ALL	ALL	0.004944	0	0
Near Water Family	Adult Male	ALL	ALL	26	ALL	ALL	ALL	0.002456	0	0
Near Water Family	Adult Male	ALL	ALL	27	ALL	ALL	ALL	0.002411	0	0
Near Water Family	Adult Male	ALL	ALL	28	ALL	ALL	ALL	0.00139	0	0
Near Water Family	Adult Male	ALL	ALL	29	ALL	ALL	ALL	0.002602	0	0
Near Water Family	Adult Male	ALL	ALL	30	ALL	ALL	ALL	0.001183	0	0
Near Water Family	Adult Male	ALL	ALL	31	ALL	ALL	ALL	0.004658	0	0

Near Water Family	Adult Male	ALL	ALL	32	ALL	ALL	ALL	0.002859	0	0
Near Water Family	Adult Male	ALL	ALL	33	ALL	ALL	ALL	0.002616	0	0
Near Water Family	Adult Male	ALL	ALL	34	ALL	ALL	ALL	0.002775	0	0
Near Water Family	Adult Male	ALL	ALL	35	ALL	ALL	ALL	0.001544	0	0
Near Water Family	Adult Male	ALL	ALL	36	ALL	ALL	ALL	0.003688	0	0
Near Water Family	Adult Male	ALL	ALL	37	ALL	ALL	ALL	0.005306	0	0
Near Water Family	Adult Male	ALL	ALL	38	ALL	ALL	ALL	0.009001	0	0
Near Water Family	Adult Male	ALL	ALL	39	ALL	ALL	ALL	0.002119	0	0
Near Water Family	Adult Male	ALL	ALL	40	ALL	ALL	ALL	0.003605	0	0
Near Water Family	Child born 1955	ALL	ALL	0	ALL	ALL	ALL	0.003099	0	0
Near Water Family	Child born 1955	ALL	ALL	1	ALL	ALL	ALL	0.004301	0	0
Near Water Family	Child born 1955	ALL	ALL	2	ALL	ALL	ALL	0.004626	0	0
Near Water Family	Child born 1955	ALL	ALL	3	ALL	ALL	ALL	0.018333	0	0
Near Water Family	Child born 1955	ALL	ALL	4	ALL	ALL	ALL	0.002387	0	0
Near Water Family	Child born 1955	ALL	ALL	5	ALL	ALL	ALL	0.006145	0	0
Near Water Family	Child born 1955	ALL	ALL	6	ALL	ALL	ALL	0.002996	0	0
Near Water Family	Child born 1955	ALL	ALL	7	ALL	ALL	ALL	0.002664	0	0
Near Water Family	Child born 1955	ALL	ALL	8	ALL	ALL	ALL	0.003931	0	0
Near Water Family	Child born 1955	ALL	ALL	9	ALL	ALL	ALL	0.002223	0	0
Near Water Family	Child born 1955	ALL	ALL	10	ALL	ALL	ALL	0.007635	0	0
Near Water Family	Child born 1955	ALL	ALL	11	ALL	ALL	ALL	0.001905	0	0
Near Water Family	Child born 1955	ALL	ALL	12	ALL	ALL	ALL	0.008542	0	0
Near Water Family	Child born 1955	ALL	ALL	13	ALL	ALL	ALL	0.002051	0	0
Near Water Family	Child born 1955	ALL	ALL	14	ALL	ALL	ALL	0.004184	0	0
Near Water Family	Child born 1955	ALL	ALL	15	ALL	ALL	ALL	0.007142	0	0
Near Water Family	Child born 1955	ALL	ALL	16	ALL	ALL	ALL	0.002864	0	0
Near Water Family	Child born 1955	ALL	ALL	17	ALL	ALL	ALL	0.004322	0	0
Near Water Family	Child born 1955	ALL	ALL	18	ALL	ALL	ALL	0.002761	0	0
Near Water Family	Child born 1955	ALL	ALL	19	ALL	ALL	ALL	0.007512	0	0
Near Water Family	Child born 1955	ALL	ALL	20	ALL	ALL	ALL	0.00442	0	0
Near Water Family	Child born 1955	ALL	ALL	21	ALL	ALL	ALL	0.007282	0	0
Near Water Family	Child born 1955	ALL	ALL	22	ALL	ALL	ALL	0.002605	0	0
Near Water Family	Child born 1955	ALL	ALL	23	ALL	ALL	ALL	0.006446	0	0
Near Water Family	Child born 1955	ALL	ALL	24	ALL	ALL	ALL	0.004327	0	0
Near Water Family	Child born 1955	ALL	ALL	25	ALL	ALL	ALL	0.005504	0	0
Near Water Family	Child born 1955	ALL	ALL	26	ALL	ALL	ALL	0.003183	0	0
Near Water Family	Child born 1955	ALL	ALL	27	ALL	ALL	ALL	0.004895	0	0

Near Water Family	Child born 1955	ALL	ALL	28	ALL	ALL	ALL	0.001918	0	0
Near Water Family	Child born 1955	ALL	ALL	29	ALL	ALL	ALL	0.005189	0	0
Near Water Family	Child born 1955	ALL	ALL	30	ALL	ALL	ALL	0.001293	0	0
Near Water Family	Child born 1955	ALL	ALL	31	ALL	ALL	ALL	0.005504	0	0
Near Water Family	Child born 1955	ALL	ALL	32	ALL	ALL	ALL	0.005941	0	0
Near Water Family	Child born 1955	ALL	ALL	33	ALL	ALL	ALL	0.002543	0	0
Near Water Family	Child born 1955	ALL	ALL	34	ALL	ALL	ALL	0.003867	0	0
Near Water Family	Child born 1955	ALL	ALL	35	ALL	ALL	ALL	0.00314	0	0
Near Water Family	Child born 1955	ALL	ALL	36	ALL	ALL	ALL	0.005655	0	0
Near Water Family	Child born 1955	ALL	ALL	37	ALL	ALL	ALL	0.003568	0	0
Near Water Family	Child born 1955	ALL	ALL	38	ALL	ALL	ALL	0.010509	0	0
Near Water Family	Child born 1955	ALL	ALL	39	ALL	ALL	ALL	0.00213	0	0
Near Water Family	Child born 1955	ALL	ALL	40	ALL	ALL	ALL	0.006149	0	0
Near Water Family	Child born 1964	ALL	ALL	0	ALL	ALL	ALL	0.001734	0	0
Near Water Family	Child born 1964	ALL	ALL	1	ALL	ALL	ALL	0.002537	0	0
Near Water Family	Child born 1964	ALL	ALL	2	ALL	ALL	ALL	0.001765	0	0
Near Water Family	Child born 1964	ALL	ALL	3	ALL	ALL	ALL	0.003787	0	0
Near Water Family	Child born 1964	ALL	ALL	4	ALL	ALL	ALL	0.002274	0	0
Near Water Family	Child born 1964	ALL	ALL	5	ALL	ALL	ALL	0.003619	0	0
Near Water Family	Child born 1964	ALL	ALL	6	ALL	ALL	ALL	0.003623	0	0
Near Water Family	Child born 1964	ALL	ALL	7	ALL	ALL	ALL	0.00115	0	0
Near Water Family	Child born 1964	ALL	ALL	8	ALL	ALL	ALL	0.001085	0	0
Near Water Family	Child born 1964	ALL	ALL	9	ALL	ALL	ALL	0.002307	0	0
Near Water Family	Child born 1964	ALL	ALL	10	ALL	ALL	ALL	0.006856	0	0
Near Water Family	Child born 1964	ALL	ALL	11	ALL	ALL	ALL	0.001014	0	0
Near Water Family	Child born 1964	ALL	ALL	12	ALL	ALL	ALL	0.001693	0	0
Near Water Family	Child born 1964	ALL	ALL	13	ALL	ALL	ALL	0.001375	0	0
Near Water Family	Child born 1964	ALL	ALL	14	ALL	ALL	ALL	0.00313	0	0
Near Water Family	Child born 1964	ALL	ALL	15	ALL	ALL	ALL	0.004792	0	0
Near Water Family	Child born 1964	ALL	ALL	16	ALL	ALL	ALL	0.001471	0	0
Near Water Family	Child born 1964	ALL	ALL	17	ALL	ALL	ALL	0.003476	0	0
Near Water Family	Child born 1964	ALL	ALL	18	ALL	ALL	ALL	0.001055	0	0
Near Water Family	Child born 1964	ALL	ALL	19	ALL	ALL	ALL	0.00576	0	0
Near Water Family	Child born 1964	ALL	ALL	20	ALL	ALL	ALL	0.001643	0	0
Near Water Family	Child born 1964	ALL	ALL	21	ALL	ALL	ALL	0.004037	0	0
Near Water Family	Child born 1964	ALL	ALL	22	ALL	ALL	ALL	0.001958	0	0
Near Water Family	Child born 1964	ALL	ALL	23	ALL	ALL	ALL	0.00251	0	0

Near Water Family	Child born 1964	ALL	ALL	24	ALL	ALL	ALL	0.005166	0	0
Near Water Family	Child born 1964	ALL	ALL	25	ALL	ALL	ALL	0.004387	0	0
Near Water Family	Child born 1964	ALL	ALL	26	ALL	ALL	ALL	0.003486	0	0
Near Water Family	Child born 1964	ALL	ALL	27	ALL	ALL	ALL	0.001855	0	0
Near Water Family	Child born 1964	ALL	ALL	28	ALL	ALL	ALL	0.000867	0	0
Near Water Family	Child born 1964	ALL	ALL	29	ALL	ALL	ALL	0.001998	0	0
Near Water Family	Child born 1964	ALL	ALL	30	ALL	ALL	ALL	0.000881	0	0
Near Water Family	Child born 1964	ALL	ALL	31	ALL	ALL	ALL	0.002668	0	0
Near Water Family	Child born 1964	ALL	ALL	32	ALL	ALL	ALL	0.001505	0	0
Near Water Family	Child born 1964	ALL	ALL	33	ALL	ALL	ALL	0.002326	0	0
Near Water Family	Child born 1964	ALL	ALL	34	ALL	ALL	ALL	0.002356	0	0
Near Water Family	Child born 1964	ALL	ALL	35	ALL	ALL	ALL	0.001028	0	0
Near Water Family	Child born 1964	ALL	ALL	36	ALL	ALL	ALL	0.001722	0	0
Near Water Family	Child born 1964	ALL	ALL	37	ALL	ALL	ALL	0.002223	0	0
Near Water Family	Child born 1964	ALL	ALL	38	ALL	ALL	ALL	0.01409	0	0
Near Water Family	Child born 1964	ALL	ALL	39	ALL	ALL	ALL	0.001601	0	0
Near Water Family	Child born 1964	ALL	ALL	40	ALL	ALL	ALL	0.002926	0	0

Location	Receptor	CurrYear	FacilityID	RunNum	Isotope	Pathway	Route	TEDE	TRCI	TRCF
Outdoor Family	Adult Female	ALL	ALL	0	ALL	ALL	ALL	0.003001	0	0
Outdoor Family	Adult Female	ALL	ALL	1	ALL	ALL	ALL	0.00398	0	0
Outdoor Family	Adult Female	ALL	ALL	2	ALL	ALL	ALL	0.005229	0	0
Outdoor Family	Adult Female	ALL	ALL	3	ALL	ALL	ALL	0.01086	0	0
Outdoor Family	Adult Female	ALL	ALL	4	ALL	ALL	ALL	0.003096	0	0
Outdoor Family	Adult Female	ALL	ALL	5	ALL	ALL	ALL	0.005512	0	0
Outdoor Family	Adult Female	ALL	ALL	6	ALL	ALL	ALL	0.002912	0	0
Outdoor Family	Adult Female	ALL	ALL	7	ALL	ALL	ALL	0.002484	0	0
Outdoor Family	Adult Female	ALL	ALL	8	ALL	ALL	ALL	0.002348	0	0
Outdoor Family	Adult Female	ALL	ALL	9	ALL	ALL	ALL	0.002222	0	0
Outdoor Family	Adult Female	ALL	ALL	10	ALL	ALL	ALL	0.005944	0	0
Outdoor Family	Adult Female	ALL	ALL	11	ALL	ALL	ALL	0.001828	0	0
Outdoor Family	Adult Female	ALL	ALL	12	ALL	ALL	ALL	0.004477	0	0
Outdoor Family	Adult Female	ALL	ALL	13	ALL	ALL	ALL	0.001972	0	0
Outdoor Family	Adult Female	ALL	ALL	14	ALL	ALL	ALL	0.005565	0	0
Outdoor Family	Adult Female	ALL	ALL	15	ALL	ALL	ALL	0.009022	0	0
Outdoor Family	Adult Female	ALL	ALL	16	ALL	ALL	ALL	0.004198	0	0
Outdoor Family	Adult Female	ALL	ALL	17	ALL	ALL	ALL	0.005795	0	0
Outdoor Family	Adult Female	ALL	ALL	18	ALL	ALL	ALL	0.0028	0	0
Outdoor Family	Adult Female	ALL	ALL	19	ALL	ALL	ALL	0.011751	0	0
Outdoor Family	Adult Female	ALL	ALL	20	ALL	ALL	ALL	0.003608	0	0
Outdoor Family	Adult Female	ALL	ALL	21	ALL	ALL	ALL	0.006172	0	0
Outdoor Family	Adult Female	ALL	ALL	22	ALL	ALL	ALL	0.002536	0	0
Outdoor Family	Adult Female	ALL	ALL	23	ALL	ALL	ALL	0.006769	0	0
Outdoor Family	Adult Female	ALL	ALL	24	ALL	ALL	ALL	0.004575	0	0
Outdoor Family	Adult Female	ALL	ALL	25	ALL	ALL	ALL	0.00496	0	0
Outdoor Family	Adult Female	ALL	ALL	26	ALL	ALL	ALL	0.002771	0	0
Outdoor Family	Adult Female	ALL	ALL	27	ALL	ALL	ALL	0.005503	0	0
Outdoor Family	Adult Female	ALL	ALL	28	ALL	ALL	ALL	0.002044	0	0
Outdoor Family	Adult Female	ALL	ALL	29	ALL	ALL	ALL	0.003979	0	0
Outdoor Family	Adult Female	ALL	ALL	30	ALL	ALL	ALL	0.001272	0	0
Outdoor Family	Adult Female	ALL	ALL	31	ALL	ALL	ALL	0.006388	0	0
Outdoor Family	Adult Female	ALL	ALL	32	ALL	ALL	ALL	0.00522	0	0
Outdoor Family	Adult Female	ALL	ALL	33	ALL	ALL	ALL	0.002928	0	0
Outdoor Family	Adult Female	ALL	ALL	34	ALL	ALL	ALL	0.003574	0	0
Outdoor Family	Adult Female	ALL	ALL	35	ALL	ALL	ALL	0.003256	0	0

Outdoor Family	Adult Female	ALL	ALL	36	ALL	ALL	ALL	0.00745	0	0
Outdoor Family	Adult Female	ALL	ALL	37	ALL	ALL	ALL	0.005614	0	0
Outdoor Family	Adult Female	ALL	ALL	38	ALL	ALL	ALL	0.009752	0	0
Outdoor Family	Adult Female	ALL	ALL	39	ALL	ALL	ALL	0.002803	0	0
Outdoor Family	Adult Female	ALL	ALL	40	ALL	ALL	ALL	0.004327	0	0
Outdoor Family	Adult Male	ALL	ALL	0	ALL	ALL	ALL	0.004169	0	0
Outdoor Family	Adult Male	ALL	ALL	1	ALL	ALL	ALL	0.005444	0	0
Outdoor Family	Adult Male	ALL	ALL	2	ALL	ALL	ALL	0.007145	0	0
Outdoor Family	Adult Male	ALL	ALL	3	ALL	ALL	ALL	0.014246	0	0
Outdoor Family	Adult Male	ALL	ALL	4	ALL	ALL	ALL	0.003508	0	0
Outdoor Family	Adult Male	ALL	ALL	5	ALL	ALL	ALL	0.007524	0	0
Outdoor Family	Adult Male	ALL	ALL	6	ALL	ALL	ALL	0.003661	0	0
Outdoor Family	Adult Male	ALL	ALL	7	ALL	ALL	ALL	0.003275	0	0
Outdoor Family	Adult Male	ALL	ALL	8	ALL	ALL	ALL	0.003354	0	0
Outdoor Family	Adult Male	ALL	ALL	9	ALL	ALL	ALL	0.003041	0	0
Outdoor Family	Adult Male	ALL	ALL	10	ALL	ALL	ALL	0.007367	0	0
Outdoor Family	Adult Male	ALL	ALL	11	ALL	ALL	ALL	0.002626	0	0
Outdoor Family	Adult Male	ALL	ALL	12	ALL	ALL	ALL	0.00611	0	0
Outdoor Family	Adult Male	ALL	ALL	13	ALL	ALL	ALL	0.002918	0	0
Outdoor Family	Adult Male	ALL	ALL	14	ALL	ALL	ALL	0.006568	0	0
Outdoor Family	Adult Male	ALL	ALL	15	ALL	ALL	ALL	0.010828	0	0
Outdoor Family	Adult Male	ALL	ALL	16	ALL	ALL	ALL	0.005447	0	0
Outdoor Family	Adult Male	ALL	ALL	17	ALL	ALL	ALL	0.006629	0	0
Outdoor Family	Adult Male	ALL	ALL	18	ALL	ALL	ALL	0.003658	0	0
Outdoor Family	Adult Male	ALL	ALL	19	ALL	ALL	ALL	0.01352	0	0
Outdoor Family	Adult Male	ALL	ALL	20	ALL	ALL	ALL	0.005138	0	0
Outdoor Family	Adult Male	ALL	ALL	21	ALL	ALL	ALL	0.006857	0	0
Outdoor Family	Adult Male	ALL	ALL	22	ALL	ALL	ALL	0.003441	0	0
Outdoor Family	Adult Male	ALL	ALL	23	ALL	ALL	ALL	0.009358	0	0
Outdoor Family	Adult Male	ALL	ALL	24	ALL	ALL	ALL	0.00558	0	0
Outdoor Family	Adult Male	ALL	ALL	25	ALL	ALL	ALL	0.005633	0	0
Outdoor Family	Adult Male	ALL	ALL	26	ALL	ALL	ALL	0.003665	0	0
Outdoor Family	Adult Male	ALL	ALL	27	ALL	ALL	ALL	0.008295	0	0
Outdoor Family	Adult Male	ALL	ALL	28	ALL	ALL	ALL	0.003006	0	0
Outdoor Family	Adult Male	ALL	ALL	29	ALL	ALL	ALL	0.00558	0	0
Outdoor Family	Adult Male	ALL	ALL	30	ALL	ALL	ALL	0.002026	0	0
Outdoor Family	Adult Male	ALL	ALL	31	ALL	ALL	ALL	0.008431	0	0

Outdoor Family	Adult Male	ALL	ALL	32	ALL	ALL	ALL	0.007303	0	0
Outdoor Family	Adult Male	ALL	ALL	33	ALL	ALL	ALL	0.003627	0	0
Outdoor Family	Adult Male	ALL	ALL	34	ALL	ALL	ALL	0.00489	0	0
Outdoor Family	Adult Male	ALL	ALL	35	ALL	ALL	ALL	0.005008	0	0
Outdoor Family	Adult Male	ALL	ALL	36	ALL	ALL	ALL	0.010927	0	0
Outdoor Family	Adult Male	ALL	ALL	37	ALL	ALL	ALL	0.006384	0	0
Outdoor Family	Adult Male	ALL	ALL	38	ALL	ALL	ALL	0.010783	0	0
Outdoor Family	Adult Male	ALL	ALL	39	ALL	ALL	ALL	0.00389	0	0
Outdoor Family	Adult Male	ALL	ALL	40	ALL	ALL	ALL	0.005513	0	0
Outdoor Family	Child born 1955	ALL	ALL	0	ALL	ALL	ALL	0.009383	0	0
Outdoor Family	Child born 1955	ALL	ALL	1	ALL	ALL	ALL	0.013977	0	0
Outdoor Family	Child born 1955	ALL	ALL	2	ALL	ALL	ALL	0.017291	0	0
Outdoor Family	Child born 1955	ALL	ALL	3	ALL	ALL	ALL	0.06027	0	0
Outdoor Family	Child born 1955	ALL	ALL	4	ALL	ALL	ALL	0.003314	0	0
Outdoor Family	Child born 1955	ALL	ALL	5	ALL	ALL	ALL	0.020307	0	0
Outdoor Family	Child born 1955	ALL	ALL	6	ALL	ALL	ALL	0.005563	0	0
Outdoor Family	Child born 1955	ALL	ALL	7	ALL	ALL	ALL	0.007387	0	0
Outdoor Family	Child born 1955	ALL	ALL	8	ALL	ALL	ALL	0.013032	0	0
Outdoor Family	Child born 1955	ALL	ALL	9	ALL	ALL	ALL	0.004649	0	0
Outdoor Family	Child born 1955	ALL	ALL	10	ALL	ALL	ALL	0.018077	0	0
Outdoor Family	Child born 1955	ALL	ALL	11	ALL	ALL	ALL	0.006	0	0
Outdoor Family	Child born 1955	ALL	ALL	12	ALL	ALL	ALL	0.027366	0	0
Outdoor Family	Child born 1955	ALL	ALL	13	ALL	ALL	ALL	0.005574	0	0
Outdoor Family	Child born 1955	ALL	ALL	14	ALL	ALL	ALL	0.00582	0	0
Outdoor Family	Child born 1955	ALL	ALL	15	ALL	ALL	ALL	0.01633	0	0
Outdoor Family	Child born 1955	ALL	ALL	16	ALL	ALL	ALL	0.008346	0	0
Outdoor Family	Child born 1955	ALL	ALL	17	ALL	ALL	ALL	0.007627	0	0
Outdoor Family	Child born 1955	ALL	ALL	18	ALL	ALL	ALL	0.007641	0	0
Outdoor Family	Child born 1955	ALL	ALL	19	ALL	ALL	ALL	0.01754	0	0
Outdoor Family	Child born 1955	ALL	ALL	20	ALL	ALL	ALL	0.01641	0	0
Outdoor Family	Child born 1955	ALL	ALL	21	ALL	ALL	ALL	0.011152	0	0
Outdoor Family	Child born 1955	ALL	ALL	22	ALL	ALL	ALL	0.005781	0	0
Outdoor Family	Child born 1955	ALL	ALL	23	ALL	ALL	ALL	0.024632	0	0
Outdoor Family	Child born 1955	ALL	ALL	24	ALL	ALL	ALL	0.00816	0	0
Outdoor Family	Child born 1955	ALL	ALL	25	ALL	ALL	ALL	0.006509	0	0
Outdoor Family	Child born 1955	ALL	ALL	26	ALL	ALL	ALL	0.006443	0	0
Outdoor Family	Child born 1955	ALL	ALL	27	ALL	ALL	ALL	0.022374	0	0

Outdoor Family	Child born 1955	ALL	ALL	28	ALL	ALL	ALL	0.006298	0	0
Outdoor Family	Child born 1955	ALL	ALL	29	ALL	ALL	ALL	0.017195	0	0
Outdoor Family	Child born 1955	ALL	ALL	30	ALL	ALL	ALL	0.002529	0	0
Outdoor Family	Child born 1955	ALL	ALL	31	ALL	ALL	ALL	0.015955	0	0
Outdoor Family	Child born 1955	ALL	ALL	32	ALL	ALL	ALL	0.02237	0	0
Outdoor Family	Child born 1955	ALL	ALL	33	ALL	ALL	ALL	0.005232	0	0
Outdoor Family	Child born 1955	ALL	ALL	34	ALL	ALL	ALL	0.010824	0	0
Outdoor Family	Child born 1955	ALL	ALL	35	ALL	ALL	ALL	0.013654	0	0
Outdoor Family	Child born 1955	ALL	ALL	36	ALL	ALL	ALL	0.026341	0	0
Outdoor Family	Child born 1955	ALL	ALL	37	ALL	ALL	ALL	0.006846	0	0
Outdoor Family	Child born 1955	ALL	ALL	38	ALL	ALL	ALL	0.01599	0	0
Outdoor Family	Child born 1955	ALL	ALL	39	ALL	ALL	ALL	0.0062	0	0
Outdoor Family	Child born 1955	ALL	ALL	40	ALL	ALL	ALL	0.016214	0	0
Outdoor Family	Child born 1964	ALL	ALL	0	ALL	ALL	ALL	0.00181	0	0
Outdoor Family	Child born 1964	ALL	ALL	1	ALL	ALL	ALL	0.002655	0	0
Outdoor Family	Child born 1964	ALL	ALL	2	ALL	ALL	ALL	0.001935	0	0
Outdoor Family	Child born 1964	ALL	ALL	3	ALL	ALL	ALL	0.004167	0	0
Outdoor Family	Child born 1964	ALL	ALL	4	ALL	ALL	ALL	0.002284	0	0
Outdoor Family	Child born 1964	ALL	ALL	5	ALL	ALL	ALL	0.003797	0	0
Outdoor Family	Child born 1964	ALL	ALL	6	ALL	ALL	ALL	0.003652	0	0
Outdoor Family	Child born 1964	ALL	ALL	7	ALL	ALL	ALL	0.001191	0	0
Outdoor Family	Child born 1964	ALL	ALL	8	ALL	ALL	ALL	0.001161	0	0
Outdoor Family	Child born 1964	ALL	ALL	9	ALL	ALL	ALL	0.002334	0	0
Outdoor Family	Child born 1964	ALL	ALL	10	ALL	ALL	ALL	0.006957	0	0
Outdoor Family	Child born 1964	ALL	ALL	11	ALL	ALL	ALL	0.001064	0	0
Outdoor Family	Child born 1964	ALL	ALL	12	ALL	ALL	ALL	0.001822	0	0
Outdoor Family	Child born 1964	ALL	ALL	13	ALL	ALL	ALL	0.001414	0	0
Outdoor Family	Child born 1964	ALL	ALL	14	ALL	ALL	ALL	0.003133	0	0
Outdoor Family	Child born 1964	ALL	ALL	15	ALL	ALL	ALL	0.004929	0	0
Outdoor Family	Child born 1964	ALL	ALL	16	ALL	ALL	ALL	0.001548	0	0
Outdoor Family	Child born 1964	ALL	ALL	17	ALL	ALL	ALL	0.003509	0	0
Outdoor Family	Child born 1964	ALL	ALL	18	ALL	ALL	ALL	0.001097	0	0
Outdoor Family	Child born 1964	ALL	ALL	19	ALL	ALL	ALL	0.00591	0	0
Outdoor Family	Child born 1964	ALL	ALL	20	ALL	ALL	ALL	0.001785	0	0
Outdoor Family	Child born 1964	ALL	ALL	21	ALL	ALL	ALL	0.004076	0	0
Outdoor Family	Child born 1964	ALL	ALL	22	ALL	ALL	ALL	0.001997	0	0
Outdoor Family	Child born 1964	ALL	ALL	23	ALL	ALL	ALL	0.00277	0	0

Outdoor Family	Child born 1964	ALL	ALL	24	ALL	ALL	ALL	0.005232	0	0
Outdoor Family	Child born 1964	ALL	ALL	25	ALL	ALL	ALL	0.00439	0	0
Outdoor Family	Child born 1964	ALL	ALL	26	ALL	ALL	ALL	0.003514	0	0
Outdoor Family	Child born 1964	ALL	ALL	27	ALL	ALL	ALL	0.002111	0	0
Outdoor Family	Child born 1964	ALL	ALL	28	ALL	ALL	ALL	0.000936	0	0
Outdoor Family	Child born 1964	ALL	ALL	29	ALL	ALL	ALL	0.002118	0	0
Outdoor Family	Child born 1964	ALL	ALL	30	ALL	ALL	ALL	0.000893	0	0
Outdoor Family	Child born 1964	ALL	ALL	31	ALL	ALL	ALL	0.002819	0	0
Outdoor Family	Child born 1964	ALL	ALL	32	ALL	ALL	ALL	0.001727	0	0
Outdoor Family	Child born 1964	ALL	ALL	33	ALL	ALL	ALL	0.002356	0	0
Outdoor Family	Child born 1964	ALL	ALL	34	ALL	ALL	ALL	0.002429	0	0
Outdoor Family	Child born 1964	ALL	ALL	35	ALL	ALL	ALL	0.001188	0	0
Outdoor Family	Child born 1964	ALL	ALL	36	ALL	ALL	ALL	0.002065	0	0
Outdoor Family	Child born 1964	ALL	ALL	37	ALL	ALL	ALL	0.002252	0	0
Outdoor Family	Child born 1964	ALL	ALL	38	ALL	ALL	ALL	0.014158	0	0
Outdoor Family	Child born 1964	ALL	ALL	39	ALL	ALL	ALL	0.00166	0	0
Outdoor Family	Child born 1964	ALL	ALL	40	ALL	ALL	ALL	0.002992	0	0

Location	Receptor	CurrYear	FacilityID	RunNum	Isotope	Pathway	Route	TEDE	TRCI	TRCF
Rural Family #1	Adult Female	ALL	ALL	0	ALL	ALL	ALL	0.000299		
Rural Family #1	Adult Female	ALL	ALL	1	ALL	ALL	ALL	0.000461		
Rural Family #1	Adult Female	ALL	ALL	2	ALL	ALL	ALL	0.00063		
Rural Family #1	Adult Female	ALL	ALL	3	ALL	ALL	ALL	0.001584		
Rural Family #1	Adult Female	ALL	ALL	4	ALL	ALL	ALL	9.01E-05		
Rural Family #1	Adult Female	ALL	ALL	5	ALL	ALL	ALL	0.000553		
Rural Family #1	Adult Female	ALL	ALL	6	ALL	ALL	ALL	0.000168		
Rural Family #1	Adult Female	ALL	ALL	7	ALL	ALL	ALL	0.000229		
Rural Family #1	Adult Female	ALL	ALL	8	ALL	ALL	ALL	0.000328		
Rural Family #1	Adult Female	ALL	ALL	9	ALL	ALL	ALL	0.000169		
Rural Family #1	Adult Female	ALL	ALL	10	ALL	ALL	ALL	0.000451		
Rural Family #1	Adult Female	ALL	ALL	11	ALL	ALL	ALL	0.000208		
Rural Family #1	Adult Female	ALL	ALL	12	ALL	ALL	ALL	0.000546		
Rural Family #1	Adult Female	ALL	ALL	13	ALL	ALL	ALL	0.00022		
Rural Family #1	Adult Female	ALL	ALL	14	ALL	ALL	ALL	0.000182		
Rural Family #1	Adult Female	ALL	ALL	15	ALL	ALL	ALL	0.000458		
Rural Family #1	Adult Female	ALL	ALL	16	ALL	ALL	ALL	0.000282		
Rural Family #1	Adult Female	ALL	ALL	17	ALL	ALL	ALL	0.000465		
Rural Family #1	Adult Female	ALL	ALL	18	ALL	ALL	ALL	0.000214		
Rural Family #1	Adult Female	ALL	ALL	19	ALL	ALL	ALL	0.000476		
Rural Family #1	Adult Female	ALL	ALL	20	ALL	ALL	ALL	0.000437		
Rural Family #1	Adult Female	ALL	ALL	21	ALL	ALL	ALL	0.000179		
Rural Family #1	Adult Female	ALL	ALL	22	ALL	ALL	ALL	0.000196		
Rural Family #1	Adult Female	ALL	ALL	23	ALL	ALL	ALL	0.003005		
Rural Family #1	Adult Female	ALL	ALL	24	ALL	ALL	ALL	0.001685		
Rural Family #1	Adult Female	ALL	ALL	25	ALL	ALL	ALL	0.000117		
Rural Family #1	Adult Female	ALL	ALL	26	ALL	ALL	ALL	0.000191		
Rural Family #1	Adult Female	ALL	ALL	27	ALL	ALL	ALL	0.000774		
Rural Family #1	Adult Female	ALL	ALL	28	ALL	ALL	ALL	0.000232		
Rural Family #1	Adult Female	ALL	ALL	29	ALL	ALL	ALL	0.000461		
Rural Family #1	Adult Female	ALL	ALL	30	ALL	ALL	ALL	0.00069		
Rural Family #1	Adult Female	ALL	ALL	31	ALL	ALL	ALL	0.000521		
Rural Family #1	Adult Female	ALL	ALL	32	ALL	ALL	ALL	0.000631		
Rural Family #1	Adult Female	ALL	ALL	33	ALL	ALL	ALL	0.00016		
Rural Family #1	Adult Female	ALL	ALL	34	ALL	ALL	ALL	0.000342		
Rural Family #1	Adult Female	ALL	ALL	35	ALL	ALL	ALL	0.000702		

Rural Family #1	Adult Female	ALL	ALL	36	ALL	ALL	ALL	0.000922
Rural Family #1	Adult Female	ALL	ALL	37	ALL	ALL	ALL	0.00018
Rural Family #1	Adult Female	ALL	ALL	38	ALL	ALL	ALL	0.000257
Rural Family #1	Adult Female	ALL	ALL	39	ALL	ALL	ALL	0.00026
Rural Family #1	Adult Female	ALL	ALL	40	ALL	ALL	ALL	0.000433
Rural Family #1	Adult Male	ALL	ALL	0	ALL	ALL	ALL	0.000418
Rural Family #1	Adult Male	ALL	ALL	1	ALL	ALL	ALL	0.000656
Rural Family #1	Adult Male	ALL	ALL	2	ALL	ALL	ALL	0.000912
Rural Family #1	Adult Male	ALL	ALL	3	ALL	ALL	ALL	0.00206
Rural Family #1	Adult Male	ALL	ALL	4	ALL	ALL	ALL	0.00012
Rural Family #1	Adult Male	ALL	ALL	5	ALL	ALL	ALL	0.000797
Rural Family #1	Adult Male	ALL	ALL	6	ALL	ALL	ALL	0.000227
Rural Family #1	Adult Male	ALL	ALL	7	ALL	ALL	ALL	0.000308
Rural Family #1	Adult Male	ALL	ALL	8	ALL	ALL	ALL	0.00045
Rural Family #1	Adult Male	ALL	ALL	9	ALL	ALL	ALL	0.00023
Rural Family #1	Adult Male	ALL	ALL	10	ALL	ALL	ALL	0.000625
Rural Family #1	Adult Male	ALL	ALL	11	ALL	ALL	ALL	0.000322
Rural Family #1	Adult Male	ALL	ALL	12	ALL	ALL	ALL	0.000743
Rural Family #1	Adult Male	ALL	ALL	13	ALL	ALL	ALL	0.000304
Rural Family #1	Adult Male	ALL	ALL	14	ALL	ALL	ALL	0.000231
Rural Family #1	Adult Male	ALL	ALL	15	ALL	ALL	ALL	0.000655
Rural Family #1	Adult Male	ALL	ALL	16	ALL	ALL	ALL	0.000409
Rural Family #1	Adult Male	ALL	ALL	17	ALL	ALL	ALL	0.000638
Rural Family #1	Adult Male	ALL	ALL	18	ALL	ALL	ALL	0.000291
Rural Family #1	Adult Male	ALL	ALL	19	ALL	ALL	ALL	0.000688
Rural Family #1	Adult Male	ALL	ALL	20	ALL	ALL	ALL	0.000629
Rural Family #1	Adult Male	ALL	ALL	21	ALL	ALL	ALL	0.000505
Rural Family #1	Adult Male	ALL	ALL	22	ALL	ALL	ALL	0.000272
Rural Family #1	Adult Male	ALL	ALL	23	ALL	ALL	ALL	0.004406
Rural Family #1	Adult Male	ALL	ALL	24	ALL	ALL	ALL	0.002276
Rural Family #1	Adult Male	ALL	ALL	25	ALL	ALL	ALL	0.000153
Rural Family #1	Adult Male	ALL	ALL	26	ALL	ALL	ALL	0.000259
Rural Family #1	Adult Male	ALL	ALL	27	ALL	ALL	ALL	0.001124
Rural Family #1	Adult Male	ALL	ALL	28	ALL	ALL	ALL	0.000327
Rural Family #1	Adult Male	ALL	ALL	29	ALL	ALL	ALL	0.000637
Rural Family #1	Adult Male	ALL	ALL	30	ALL	ALL	ALL	0.000931
Rural Family #1	Adult Male	ALL	ALL	31	ALL	ALL	ALL	0.000753

Rural Family #1	Adult Male	ALL	ALL	32	ALL	ALL	ALL	0.000903
Rural Family #1	Adult Male	ALL	ALL	33	ALL	ALL	ALL	0.000216
Rural Family #1	Adult Male	ALL	ALL	34	ALL	ALL	ALL	0.000471
Rural Family #1	Adult Male	ALL	ALL	35	ALL	ALL	ALL	0.001018
Rural Family #1	Adult Male	ALL	ALL	36	ALL	ALL	ALL	0.001358
Rural Family #1	Adult Male	ALL	ALL	37	ALL	ALL	ALL	0.000281
Rural Family #1	Adult Male	ALL	ALL	38	ALL	ALL	ALL	0.000362
Rural Family #1	Adult Male	ALL	ALL	39	ALL	ALL	ALL	0.000371
Rural Family #1	Adult Male	ALL	ALL	40	ALL	ALL	ALL	0.00057
Rural Family #1	Child born 1955	ALL	ALL	0	ALL	ALL	ALL	0.00158
Rural Family #1	Child born 1955	ALL	ALL	1	ALL	ALL	ALL	0.002536
Rural Family #1	Child born 1955	ALL	ALL	2	ALL	ALL	ALL	0.003254
Rural Family #1	Child born 1955	ALL	ALL	3	ALL	ALL	ALL	0.014487
Rural Family #1	Child born 1955	ALL	ALL	4	ALL	ALL	ALL	0.000281
Rural Family #1	Child born 1955	ALL	ALL	5	ALL	ALL	ALL	0.003366
Rural Family #1	Child born 1955	ALL	ALL	6	ALL	ALL	ALL	0.000699
Rural Family #1	Child born 1955	ALL	ALL	7	ALL	ALL	ALL	0.001358
Rural Family #1	Child born 1955	ALL	ALL	8	ALL	ALL	ALL	0.002613
Rural Family #1	Child born 1955	ALL	ALL	9	ALL	ALL	ALL	0.000628
Rural Family #1	Child born 1955	ALL	ALL	10	ALL	ALL	ALL	0.003158
Rural Family #1	Child born 1955	ALL	ALL	11	ALL	ALL	ALL	0.001043
Rural Family #1	Child born 1955	ALL	ALL	12	ALL	ALL	ALL	0.005541
Rural Family #1	Child born 1955	ALL	ALL	13	ALL	ALL	ALL	0.000954
Rural Family #1	Child born 1955	ALL	ALL	14	ALL	ALL	ALL	0.000617
Rural Family #1	Child born 1955	ALL	ALL	15	ALL	ALL	ALL	0.002009
Rural Family #1	Child born 1955	ALL	ALL	16	ALL	ALL	ALL	0.001203
Rural Family #1	Child born 1955	ALL	ALL	17	ALL	ALL	ALL	0.001459
Rural Family #1	Child born 1955	ALL	ALL	18	ALL	ALL	ALL	0.001383
Rural Family #1	Child born 1955	ALL	ALL	19	ALL	ALL	ALL	0.002255
Rural Family #1	Child born 1955	ALL	ALL	20	ALL	ALL	ALL	0.002941
Rural Family #1	Child born 1955	ALL	ALL	21	ALL	ALL	ALL	0.001063
Rural Family #1	Child born 1955	ALL	ALL	22	ALL	ALL	ALL	0.000783
Rural Family #1	Child born 1955	ALL	ALL	23	ALL	ALL	ALL	0.01741
Rural Family #1	Child born 1955	ALL	ALL	24	ALL	ALL	ALL	0.002655
Rural Family #1	Child born 1955	ALL	ALL	25	ALL	ALL	ALL	0.000301
Rural Family #1	Child born 1955	ALL	ALL	26	ALL	ALL	ALL	0.000901
Rural Family #1	Child born 1955	ALL	ALL	27	ALL	ALL	ALL	0.003703

Rural Family #1	Child born 1955	ALL	ALL	28	ALL	ALL	ALL	0.001003
Rural Family #1	Child born 1955	ALL	ALL	29	ALL	ALL	ALL	0.003187
Rural Family #1	Child born 1955	ALL	ALL	30	ALL	ALL	ALL	0.001367
Rural Family #1	Child born 1955	ALL	ALL	31	ALL	ALL	ALL	0.002296
Rural Family #1	Child born 1955	ALL	ALL	32	ALL	ALL	ALL	0.003963
Rural Family #1	Child born 1955	ALL	ALL	33	ALL	ALL	ALL	0.000722
Rural Family #1	Child born 1955	ALL	ALL	34	ALL	ALL	ALL	0.001934
Rural Family #1	Child born 1955	ALL	ALL	35	ALL	ALL	ALL	0.003305
Rural Family #1	Child born 1955	ALL	ALL	36	ALL	ALL	ALL	0.004234
Rural Family #1	Child born 1955	ALL	ALL	37	ALL	ALL	ALL	0.000935
Rural Family #1	Child born 1955	ALL	ALL	38	ALL	ALL	ALL	0.001338
Rural Family #1	Child born 1955	ALL	ALL	39	ALL	ALL	ALL	0.00094
Rural Family #1	Child born 1955	ALL	ALL	40	ALL	ALL	ALL	0.003414
Rural Family #1	Child born 1964	ALL	ALL	0	ALL	ALL	ALL	7.07E-05
Rural Family #1	Child born 1964	ALL	ALL	1	ALL	ALL	ALL	7.71E-05
Rural Family #1	Child born 1964	ALL	ALL	2	ALL	ALL	ALL	9.14E-05
Rural Family #1	Child born 1964	ALL	ALL	3	ALL	ALL	ALL	0.000151
Rural Family #1	Child born 1964	ALL	ALL	4	ALL	ALL	ALL	3.74E-05
Rural Family #1	Child born 1964	ALL	ALL	5	ALL	ALL	ALL	8.36E-05
Rural Family #1	Child born 1964	ALL	ALL	6	ALL	ALL	ALL	6E-05
Rural Family #1	Child born 1964	ALL	ALL	7	ALL	ALL	ALL	6E-05
Rural Family #1	Child born 1964	ALL	ALL	8	ALL	ALL	ALL	6.56E-05
Rural Family #1	Child born 1964	ALL	ALL	9	ALL	ALL	ALL	6.48E-05
Rural Family #1	Child born 1964	ALL	ALL	10	ALL	ALL	ALL	9.65E-05
Rural Family #1	Child born 1964	ALL	ALL	11	ALL	ALL	ALL	5.02E-05
Rural Family #1	Child born 1964	ALL	ALL	12	ALL	ALL	ALL	0.000103
Rural Family #1	Child born 1964	ALL	ALL	13	ALL	ALL	ALL	7.31E-05
Rural Family #1	Child born 1964	ALL	ALL	14	ALL	ALL	ALL	0.000105
Rural Family #1	Child born 1964	ALL	ALL	15	ALL	ALL	ALL	8.55E-05
Rural Family #1	Child born 1964	ALL	ALL	16	ALL	ALL	ALL	6.91E-05
Rural Family #1	Child born 1964	ALL	ALL	17	ALL	ALL	ALL	0.000112
Rural Family #1	Child born 1964	ALL	ALL	18	ALL	ALL	ALL	6.42E-05
Rural Family #1	Child born 1964	ALL	ALL	19	ALL	ALL	ALL	7.79E-05
Rural Family #1	Child born 1964	ALL	ALL	20	ALL	ALL	ALL	6.17E-05
Rural Family #1	Child born 1964	ALL	ALL	21	ALL	ALL	ALL	4.79E-05
Rural Family #1	Child born 1964	ALL	ALL	22	ALL	ALL	ALL	6.54E-05
Rural Family #1	Child born 1964	ALL	ALL	23	ALL	ALL	ALL	0.000313

Rural Family #1	Child born 1964	ALL	ALL	24	ALL	ALL	ALL	0.00034
Rural Family #1	Child born 1964	ALL	ALL	25	ALL	ALL	ALL	6.7E-05
Rural Family #1	Child born 1964	ALL	ALL	26	ALL	ALL	ALL	7.24E-05
Rural Family #1	Child born 1964	ALL	ALL	27	ALL	ALL	ALL	9.03E-05
Rural Family #1	Child born 1964	ALL	ALL	28	ALL	ALL	ALL	5.81E-05
Rural Family #1	Child born 1964	ALL	ALL	29	ALL	ALL	ALL	8.91E-05
Rural Family #1	Child born 1964	ALL	ALL	30	ALL	ALL	ALL	0.000167
Rural Family #1	Child born 1964	ALL	ALL	31	ALL	ALL	ALL	9.96E-05
Rural Family #1	Child born 1964	ALL	ALL	32	ALL	ALL	ALL	7.67E-05
Rural Family #1	Child born 1964	ALL	ALL	33	ALL	ALL	ALL	5.37E-05
Rural Family #1	Child born 1964	ALL	ALL	34	ALL	ALL	ALL	9.09E-05
Rural Family #1	Child born 1964	ALL	ALL	35	ALL	ALL	ALL	0.000105
Rural Family #1	Child born 1964	ALL	ALL	36	ALL	ALL	ALL	0.000114
Rural Family #1	Child born 1964	ALL	ALL	37	ALL	ALL	ALL	6.25E-05
Rural Family #1	Child born 1964	ALL	ALL	38	ALL	ALL	ALL	5.95E-05
Rural Family #1	Child born 1964	ALL	ALL	39	ALL	ALL	ALL	6.72E-05
Rural Family #1	Child born 1964	ALL	ALL	40	ALL	ALL	ALL	0.000105

Location	Receptor	CurrYear	FacilityID	RunNum	Isotope	Pathway	Route	TEDE	TRCI	TRCF
Rural Family #2	Adult Female	ALL	ALL	0	ALL	ALL	ALL	0.000685		
Rural Family #2	Adult Female	ALL	ALL	1	ALL	ALL	ALL	0.001078		
Rural Family #2	Adult Female	ALL	ALL	2	ALL	ALL	ALL	0.00148		
Rural Family #2	Adult Female	ALL	ALL	3	ALL	ALL	ALL	0.003755		
Rural Family #2	Adult Female	ALL	ALL	4	ALL	ALL	ALL	0.000199		
Rural Family #2	Adult Female	ALL	ALL	5	ALL	ALL	ALL	0.00129		
Rural Family #2	Adult Female	ALL	ALL	6	ALL	ALL	ALL	0.000376		
Rural Family #2	Adult Female	ALL	ALL	7	ALL	ALL	ALL	0.000522		
Rural Family #2	Adult Female	ALL	ALL	8	ALL	ALL	ALL	0.000762		
Rural Family #2	Adult Female	ALL	ALL	9	ALL	ALL	ALL	0.000373		
Rural Family #2	Adult Female	ALL	ALL	10	ALL	ALL	ALL	0.001045		
Rural Family #2	Adult Female	ALL	ALL	11	ALL	ALL	ALL	0.000474		
Rural Family #2	Adult Female	ALL	ALL	12	ALL	ALL	ALL	0.001267		
Rural Family #2	Adult Female	ALL	ALL	13	ALL	ALL	ALL	0.000494		
Rural Family #2	Adult Female	ALL	ALL	14	ALL	ALL	ALL	0.000386		
Rural Family #2	Adult Female	ALL	ALL	15	ALL	ALL	ALL	0.001056		
Rural Family #2	Adult Female	ALL	ALL	16	ALL	ALL	ALL	0.000646		
Rural Family #2	Adult Female	ALL	ALL	17	ALL	ALL	ALL	0.001096		
Rural Family #2	Adult Female	ALL	ALL	18	ALL	ALL	ALL	0.000484		
Rural Family #2	Adult Female	ALL	ALL	19	ALL	ALL	ALL	0.001107		
Rural Family #2	Adult Female	ALL	ALL	20	ALL	ALL	ALL	0.001022		
Rural Family #2	Adult Female	ALL	ALL	21	ALL	ALL	ALL	0.000409		
Rural Family #2	Adult Female	ALL	ALL	22	ALL	ALL	ALL	0.00044		
Rural Family #2	Adult Female	ALL	ALL	23	ALL	ALL	ALL	0.007162		
Rural Family #2	Adult Female	ALL	ALL	24	ALL	ALL	ALL	0.004098		
Rural Family #2	Adult Female	ALL	ALL	25	ALL	ALL	ALL	0.000248		
Rural Family #2	Adult Female	ALL	ALL	26	ALL	ALL	ALL	0.000423		
Rural Family #2	Adult Female	ALL	ALL	27	ALL	ALL	ALL	0.001818		
Rural Family #2	Adult Female	ALL	ALL	28	ALL	ALL	ALL	0.000529		
Rural Family #2	Adult Female	ALL	ALL	29	ALL	ALL	ALL	0.001068		
Rural Family #2	Adult Female	ALL	ALL	30	ALL	ALL	ALL	0.001641		
Rural Family #2	Adult Female	ALL	ALL	31	ALL	ALL	ALL	0.001208		
Rural Family #2	Adult Female	ALL	ALL	32	ALL	ALL	ALL	0.00148		
Rural Family #2	Adult Female	ALL	ALL	33	ALL	ALL	ALL	0.000358		
Rural Family #2	Adult Female	ALL	ALL	34	ALL	ALL	ALL	0.000779		
Rural Family #2	Adult Female	ALL	ALL	35	ALL	ALL	ALL	0.001656		

Rural Family #2	Adult Female	ALL	ALL	36	ALL	ALL	ALL	0.00216
Rural Family #2	Adult Female	ALL	ALL	37	ALL	ALL	ALL	0.000403
Rural Family #2	Adult Female	ALL	ALL	38	ALL	ALL	ALL	0.000588
Rural Family #2	Adult Female	ALL	ALL	39	ALL	ALL	ALL	0.000593
Rural Family #2	Adult Female	ALL	ALL	40	ALL	ALL	ALL	0.001
Rural Family #2	Adult Male	ALL	ALL	0	ALL	ALL	ALL	0.000961
Rural Family #2	Adult Male	ALL	ALL	1	ALL	ALL	ALL	0.001537
Rural Family #2	Adult Male	ALL	ALL	2	ALL	ALL	ALL	0.002146
Rural Family #2	Adult Male	ALL	ALL	3	ALL	ALL	ALL	0.00533
Rural Family #2	Adult Male	ALL	ALL	4	ALL	ALL	ALL	0.000267
Rural Family #2	Adult Male	ALL	ALL	5	ALL	ALL	ALL	0.001863
Rural Family #2	Adult Male	ALL	ALL	6	ALL	ALL	ALL	0.000508
Rural Family #2	Adult Male	ALL	ALL	7	ALL	ALL	ALL	0.000703
Rural Family #2	Adult Male	ALL	ALL	8	ALL	ALL	ALL	0.000819
Rural Family #2	Adult Male	ALL	ALL	9	ALL	ALL	ALL	0.000511
Rural Family #2	Adult Male	ALL	ALL	10	ALL	ALL	ALL	0.00145
Rural Family #2	Adult Male	ALL	ALL	11	ALL	ALL	ALL	0.000653
Rural Family #2	Adult Male	ALL	ALL	12	ALL	ALL	ALL	0.001728
Rural Family #2	Adult Male	ALL	ALL	13	ALL	ALL	ALL	0.000686
Rural Family #2	Adult Male	ALL	ALL	14	ALL	ALL	ALL	0.000489
Rural Family #2	Adult Male	ALL	ALL	15	ALL	ALL	ALL	0.001516
Rural Family #2	Adult Male	ALL	ALL	16	ALL	ALL	ALL	0.000939
Rural Family #2	Adult Male	ALL	ALL	17	ALL	ALL	ALL	0.001506
Rural Family #2	Adult Male	ALL	ALL	18	ALL	ALL	ALL	0.00066
Rural Family #2	Adult Male	ALL	ALL	19	ALL	ALL	ALL	0.001603
Rural Family #2	Adult Male	ALL	ALL	20	ALL	ALL	ALL	0.001472
Rural Family #2	Adult Male	ALL	ALL	21	ALL	ALL	ALL	0.000583
Rural Family #2	Adult Male	ALL	ALL	22	ALL	ALL	ALL	0.000612
Rural Family #2	Adult Male	ALL	ALL	23	ALL	ALL	ALL	0.010502
Rural Family #2	Adult Male	ALL	ALL	24	ALL	ALL	ALL	0.005538
Rural Family #2	Adult Male	ALL	ALL	25	ALL	ALL	ALL	0.000324
Rural Family #2	Adult Male	ALL	ALL	26	ALL	ALL	ALL	0.000577
Rural Family #2	Adult Male	ALL	ALL	27	ALL	ALL	ALL	0.002648
Rural Family #2	Adult Male	ALL	ALL	28	ALL	ALL	ALL	0.000749
Rural Family #2	Adult Male	ALL	ALL	29	ALL	ALL	ALL	0.001487
Rural Family #2	Adult Male	ALL	ALL	30	ALL	ALL	ALL	0.002214
Rural Family #2	Adult Male	ALL	ALL	31	ALL	ALL	ALL	0.001753

Rural Family #2	Adult Male	ALL	ALL	32	ALL	ALL	ALL	0.002122
Rural Family #2	Adult Male	ALL	ALL	33	ALL	ALL	ALL	0.000485
Rural Family #2	Adult Male	ALL	ALL	34	ALL	ALL	ALL	0.001078
Rural Family #2	Adult Male	ALL	ALL	35	ALL	ALL	ALL	0.002404
Rural Family #2	Adult Male	ALL	ALL	36	ALL	ALL	ALL	0.003187
Rural Family #2	Adult Male	ALL	ALL	37	ALL	ALL	ALL	0.000548
Rural Family #2	Adult Male	ALL	ALL	38	ALL	ALL	ALL	0.000833
Rural Family #2	Adult Male	ALL	ALL	39	ALL	ALL	ALL	0.000849
Rural Family #2	Adult Male	ALL	ALL	40	ALL	ALL	ALL	0.001319
Rural Family #2	Child born 1955	ALL	ALL	0	ALL	ALL	ALL	0.003729
Rural Family #2	Child born 1955	ALL	ALL	1	ALL	ALL	ALL	0.006024
Rural Family #2	Child born 1955	ALL	ALL	2	ALL	ALL	ALL	0.007726
Rural Family #2	Child born 1955	ALL	ALL	3	ALL	ALL	ALL	0.034526
Rural Family #2	Child born 1955	ALL	ALL	4	ALL	ALL	ALL	0.000642
Rural Family #2	Child born 1955	ALL	ALL	5	ALL	ALL	ALL	0.008003
Rural Family #2	Child born 1955	ALL	ALL	6	ALL	ALL	ALL	0.001619
Rural Family #2	Child born 1955	ALL	ALL	7	ALL	ALL	ALL	0.003199
Rural Family #2	Child born 1955	ALL	ALL	8	ALL	ALL	ALL	0.006206
Rural Family #2	Child born 1955	ALL	ALL	9	ALL	ALL	ALL	0.001444
Rural Family #2	Child born 1955	ALL	ALL	10	ALL	ALL	ALL	0.007492
Rural Family #2	Child born 1955	ALL	ALL	11	ALL	ALL	ALL	0.00245
Rural Family #2	Child born 1955	ALL	ALL	12	ALL	ALL	ALL	0.013187
Rural Family #2	Child born 1955	ALL	ALL	13	ALL	ALL	ALL	0.002221
Rural Family #2	Child born 1955	ALL	ALL	14	ALL	ALL	ALL	0.001385
Rural Family #2	Child born 1955	ALL	ALL	15	ALL	ALL	ALL	0.004732
Rural Family #2	Child born 1955	ALL	ALL	16	ALL	ALL	ALL	0.002825
Rural Family #2	Child born 1955	ALL	ALL	17	ALL	ALL	ALL	0.003461
Rural Family #2	Child born 1955	ALL	ALL	18	ALL	ALL	ALL	0.003257
Rural Family #2	Child born 1955	ALL	ALL	19	ALL	ALL	ALL	0.005334
Rural Family #2	Child born 1955	ALL	ALL	20	ALL	ALL	ALL	0.006997
Rural Family #2	Child born 1955	ALL	ALL	21	ALL	ALL	ALL	0.002512
Rural Family #2	Child born 1955	ALL	ALL	22	ALL	ALL	ALL	0.00182
Rural Family #2	Child born 1955	ALL	ALL	23	ALL	ALL	ALL	0.041579
Rural Family #2	Child born 1955	ALL	ALL	24	ALL	ALL	ALL	0.006459
Rural Family #2	Child born 1955	ALL	ALL	25	ALL	ALL	ALL	0.000663
Rural Family #2	Child born 1955	ALL	ALL	26	ALL	ALL	ALL	0.002096
Rural Family #2	Child born 1955	ALL	ALL	27	ALL	ALL	ALL	0.008811

Rural Family #2	Child born 1955	ALL	ALL	28	ALL	ALL	ALL	0.002345
Rural Family #2	Child born 1955	ALL	ALL	29	ALL	ALL	ALL	0.007554
Rural Family #2	Child born 1955	ALL	ALL	30	ALL	ALL	ALL	0.003254
Rural Family #2	Child born 1955	ALL	ALL	31	ALL	ALL	ALL	0.00543
Rural Family #2	Child born 1955	ALL	ALL	32	ALL	ALL	ALL	0.009419
Rural Family #2	Child born 1955	ALL	ALL	33	ALL	ALL	ALL	0.00168
Rural Family #2	Child born 1955	ALL	ALL	34	ALL	ALL	ALL	0.004552
Rural Family #2	Child born 1955	ALL	ALL	35	ALL	ALL	ALL	0.007869
Rural Family #2	Child born 1955	ALL	ALL	36	ALL	ALL	ALL	0.010042
Rural Family #2	Child born 1955	ALL	ALL	37	ALL	ALL	ALL	0.002191
Rural Family #2	Child born 1955	ALL	ALL	38	ALL	ALL	ALL	0.003154
Rural Family #2	Child born 1955	ALL	ALL	39	ALL	ALL	ALL	0.002196
Rural Family #2	Child born 1955	ALL	ALL	40	ALL	ALL	ALL	0.008107
Rural Family #2	Child born 1964	ALL	ALL	0	ALL	ALL	ALL	0.000137
Rural Family #2	Child born 1964	ALL	ALL	1	ALL	ALL	ALL	0.000154
Rural Family #2	Child born 1964	ALL	ALL	2	ALL	ALL	ALL	0.000186
Rural Family #2	Child born 1964	ALL	ALL	3	ALL	ALL	ALL	0.000319
Rural Family #2	Child born 1964	ALL	ALL	4	ALL	ALL	ALL	7.18E-05
Rural Family #2	Child born 1964	ALL	ALL	5	ALL	ALL	ALL	0.000163
Rural Family #2	Child born 1964	ALL	ALL	6	ALL	ALL	ALL	0.000115
Rural Family #2	Child born 1964	ALL	ALL	7	ALL	ALL	ALL	0.000117
Rural Family #2	Child born 1964	ALL	ALL	8	ALL	ALL	ALL	0.00013
Rural Family #2	Child born 1964	ALL	ALL	9	ALL	ALL	ALL	0.000123
Rural Family #2	Child born 1964	ALL	ALL	10	ALL	ALL	ALL	0.000191
Rural Family #2	Child born 1964	ALL	ALL	11	ALL	ALL	ALL	9.67E-05
Rural Family #2	Child born 1964	ALL	ALL	12	ALL	ALL	ALL	0.000202
Rural Family #2	Child born 1964	ALL	ALL	13	ALL	ALL	ALL	0.000141
Rural Family #2	Child born 1964	ALL	ALL	14	ALL	ALL	ALL	0.000199
Rural Family #2	Child born 1964	ALL	ALL	15	ALL	ALL	ALL	0.000165
Rural Family #2	Child born 1964	ALL	ALL	16	ALL	ALL	ALL	0.000132
Rural Family #2	Child born 1964	ALL	ALL	17	ALL	ALL	ALL	0.000239
Rural Family #2	Child born 1964	ALL	ALL	18	ALL	ALL	ALL	0.000124
Rural Family #2	Child born 1964	ALL	ALL	19	ALL	ALL	ALL	0.000152
Rural Family #2	Child born 1964	ALL	ALL	20	ALL	ALL	ALL	0.000121
Rural Family #2	Child born 1964	ALL	ALL	21	ALL	ALL	ALL	9.25E-05
Rural Family #2	Child born 1964	ALL	ALL	22	ALL	ALL	ALL	0.000125
Rural Family #2	Child born 1964	ALL	ALL	23	ALL	ALL	ALL	0.000706

Rural Family #2	Child born 1964	ALL	ALL	24	ALL	ALL	ALL	0.000796
Rural Family #2	Child born 1964	ALL	ALL	25	ALL	ALL	ALL	0.000127
Rural Family #2	Child born 1964	ALL	ALL	26	ALL	ALL	ALL	0.000138
Rural Family #2	Child born 1964	ALL	ALL	27	ALL	ALL	ALL	0.000176
Rural Family #2	Child born 1964	ALL	ALL	28	ALL	ALL	ALL	0.000112
Rural Family #2	Child born 1964	ALL	ALL	29	ALL	ALL	ALL	0.000174
Rural Family #2	Child born 1964	ALL	ALL	30	ALL	ALL	ALL	0.000371
Rural Family #2	Child born 1964	ALL	ALL	31	ALL	ALL	ALL	0.000194
Rural Family #2	Child born 1964	ALL	ALL	32	ALL	ALL	ALL	0.000153
Rural Family #2	Child born 1964	ALL	ALL	33	ALL	ALL	ALL	0.000103
Rural Family #2	Child born 1964	ALL	ALL	34	ALL	ALL	ALL	0.000175
Rural Family #2	Child born 1964	ALL	ALL	35	ALL	ALL	ALL	0.00022
Rural Family #2	Child born 1964	ALL	ALL	36	ALL	ALL	ALL	0.000224
Rural Family #2	Child born 1964	ALL	ALL	37	ALL	ALL	ALL	0.00012
Rural Family #2	Child born 1964	ALL	ALL	38	ALL	ALL	ALL	0.000115
Rural Family #2	Child born 1964	ALL	ALL	39	ALL	ALL	ALL	0.000129
Rural Family #2	Child born 1964	ALL	ALL	40	ALL	ALL	ALL	0.000209

Location	Receptor	CurrYear	FacilityID	RunNum	Isotope	Pathway	Route	TEDE	TRCI	TRCF
Urban Family	Adult Female	ALL	ALL	0	ALL	ALL	ALL	0.000325	0	0
Urban Family	Adult Female	ALL	ALL	1	ALL	ALL	ALL	0.000453	0	0
Urban Family	Adult Female	ALL	ALL	2	ALL	ALL	ALL	0.000552	0	0
Urban Family	Adult Female	ALL	ALL	3	ALL	ALL	ALL	0.002204	0	0
Urban Family	Adult Female	ALL	ALL	4	ALL	ALL	ALL	8.34E-05	0	0
Urban Family	Adult Female	ALL	ALL	5	ALL	ALL	ALL	0.000623	0	0
Urban Family	Adult Female	ALL	ALL	6	ALL	ALL	ALL	0.000175	0	0
Urban Family	Adult Female	ALL	ALL	7	ALL	ALL	ALL	0.000275	0	0
Urban Family	Adult Female	ALL	ALL	8	ALL	ALL	ALL	0.000481	0	0
Urban Family	Adult Female	ALL	ALL	9	ALL	ALL	ALL	0.00017	0	0
Urban Family	Adult Female	ALL	ALL	10	ALL	ALL	ALL	0.000577	0	0
Urban Family	Adult Female	ALL	ALL	11	ALL	ALL	ALL	0.000219	0	0
Urban Family	Adult Female	ALL	ALL	12	ALL	ALL	ALL	0.001	0	0
Urban Family	Adult Female	ALL	ALL	13	ALL	ALL	ALL	0.000224	0	0
Urban Family	Adult Female	ALL	ALL	14	ALL	ALL	ALL	0.000216	0	0
Urban Family	Adult Female	ALL	ALL	15	ALL	ALL	ALL	0.000408	0	0
Urban Family	Adult Female	ALL	ALL	16	ALL	ALL	ALL	0.000264	0	0
Urban Family	Adult Female	ALL	ALL	17	ALL	ALL	ALL	0.00024	0	0
Urban Family	Adult Female	ALL	ALL	18	ALL	ALL	ALL	0.000291	0	0
Urban Family	Adult Female	ALL	ALL	19	ALL	ALL	ALL	0.000427	0	0
Urban Family	Adult Female	ALL	ALL	20	ALL	ALL	ALL	0.000533	0	0
Urban Family	Adult Female	ALL	ALL	21	ALL	ALL	ALL	0.000221	0	0
Urban Family	Adult Female	ALL	ALL	22	ALL	ALL	ALL	0.000196	0	0
Urban Family	Adult Female	ALL	ALL	23	ALL	ALL	ALL	0.00144	0	0
Urban Family	Adult Female	ALL	ALL	24	ALL	ALL	ALL	0.000264	0	0
Urban Family	Adult Female	ALL	ALL	25	ALL	ALL	ALL	0.000122	0	0
Urban Family	Adult Female	ALL	ALL	26	ALL	ALL	ALL	0.000224	0	0
Urban Family	Adult Female	ALL	ALL	27	ALL	ALL	ALL	0.000678	0	0
Urban Family	Adult Female	ALL	ALL	28	ALL	ALL	ALL	0.000219	0	0
Urban Family	Adult Female	ALL	ALL	29	ALL	ALL	ALL	0.000603	0	0
Urban Family	Adult Female	ALL	ALL	30	ALL	ALL	ALL	0.000161	0	0
Urban Family	Adult Female	ALL	ALL	31	ALL	ALL	ALL	0.00046	0	0
Urban Family	Adult Female	ALL	ALL	32	ALL	ALL	ALL	0.000703	0	0
Urban Family	Adult Female	ALL	ALL	33	ALL	ALL	ALL	0.000173	0	0
Urban Family	Adult Female	ALL	ALL	34	ALL	ALL	ALL	0.000396	0	0
Urban Family	Adult Female	ALL	ALL	35	ALL	ALL	ALL	0.000477	0	0

Urban Family	Adult Female	ALL	ALL	36	ALL	ALL	ALL	0.000781	0	0
Urban Family	Adult Female	ALL	ALL	37	ALL	ALL	ALL	0.000216	0	0
Urban Family	Adult Female	ALL	ALL	38	ALL	ALL	ALL	0.000276	0	0
Urban Family	Adult Female	ALL	ALL	39	ALL	ALL	ALL	0.000209	0	0
Urban Family	Adult Female	ALL	ALL	40	ALL	ALL	ALL	0.00063	0	0
Urban Family	Adult Male	ALL	ALL	0	ALL	ALL	ALL	0.000723	0	0
Urban Family	Adult Male	ALL	ALL	1	ALL	ALL	ALL	0.000883	0	0
Urban Family	Adult Male	ALL	ALL	2	ALL	ALL	ALL	0.001051	0	0
Urban Family	Adult Male	ALL	ALL	3	ALL	ALL	ALL	0.003276	0	0
Urban Family	Adult Male	ALL	ALL	4	ALL	ALL	ALL	0.000263	0	0
Urban Family	Adult Male	ALL	ALL	5	ALL	ALL	ALL	0.001172	0	0
Urban Family	Adult Male	ALL	ALL	6	ALL	ALL	ALL	0.000482	0	0
Urban Family	Adult Male	ALL	ALL	7	ALL	ALL	ALL	0.000593	0	0
Urban Family	Adult Male	ALL	ALL	8	ALL	ALL	ALL	0.000867	0	0
Urban Family	Adult Male	ALL	ALL	9	ALL	ALL	ALL	0.000505	0	0
Urban Family	Adult Male	ALL	ALL	10	ALL	ALL	ALL	0.001111	0	0
Urban Family	Adult Male	ALL	ALL	11	ALL	ALL	ALL	0.000498	0	0
Urban Family	Adult Male	ALL	ALL	12	ALL	ALL	ALL	0.001685	0	0
Urban Family	Adult Male	ALL	ALL	13	ALL	ALL	ALL	0.000599	0	0
Urban Family	Adult Male	ALL	ALL	14	ALL	ALL	ALL	0.000731	0	0
Urban Family	Adult Male	ALL	ALL	15	ALL	ALL	ALL	0.000915	0	0
Urban Family	Adult Male	ALL	ALL	16	ALL	ALL	ALL	0.000654	0	0
Urban Family	Adult Male	ALL	ALL	17	ALL	ALL	ALL	0.000592	0	0
Urban Family	Adult Male	ALL	ALL	18	ALL	ALL	ALL	0.000646	0	0
Urban Family	Adult Male	ALL	ALL	19	ALL	ALL	ALL	0.000893	0	0
Urban Family	Adult Male	ALL	ALL	20	ALL	ALL	ALL	0.000954	0	0
Urban Family	Adult Male	ALL	ALL	21	ALL	ALL	ALL	0.000486	0	0
Urban Family	Adult Male	ALL	ALL	22	ALL	ALL	ALL	0.00054	0	0
Urban Family	Adult Male	ALL	ALL	23	ALL	ALL	ALL	0.002295	0	0
Urban Family	Adult Male	ALL	ALL	24	ALL	ALL	ALL	0.000664	0	0
Urban Family	Adult Male	ALL	ALL	25	ALL	ALL	ALL	0.00045	0	0
Urban Family	Adult Male	ALL	ALL	26	ALL	ALL	ALL	0.000508	0	0
Urban Family	Adult Male	ALL	ALL	27	ALL	ALL	ALL	0.001298	0	0
Urban Family	Adult Male	ALL	ALL	28	ALL	ALL	ALL	0.000536	0	0
Urban Family	Adult Male	ALL	ALL	29	ALL	ALL	ALL	0.001139	0	0
Urban Family	Adult Male	ALL	ALL	30	ALL	ALL	ALL	0.000527	0	0
Urban Family	Adult Male	ALL	ALL	31	ALL	ALL	ALL	0.001033	0	0

Urban Family	Adult Male	ALL	ALL	32	ALL	ALL	ALL	0.001225	0	0
Urban Family	Adult Male	ALL	ALL	33	ALL	ALL	ALL	0.000455	0	0
Urban Family	Adult Male	ALL	ALL	34	ALL	ALL	ALL	0.000893	0	0
Urban Family	Adult Male	ALL	ALL	35	ALL	ALL	ALL	0.000939	0	0
Urban Family	Adult Male	ALL	ALL	36	ALL	ALL	ALL	0.001538	0	0
Urban Family	Adult Male	ALL	ALL	37	ALL	ALL	ALL	0.000542	0	0
Urban Family	Adult Male	ALL	ALL	38	ALL	ALL	ALL	0.000617	0	0
Urban Family	Adult Male	ALL	ALL	39	ALL	ALL	ALL	0.000567	0	0
Urban Family	Adult Male	ALL	ALL	40	ALL	ALL	ALL	0.001187	0	0
Urban Family	Child born 1955	ALL	ALL	0	ALL	ALL	ALL	0.002675	0	0
Urban Family	Child born 1955	ALL	ALL	1	ALL	ALL	ALL	0.004187	0	0
Urban Family	Child born 1955	ALL	ALL	2	ALL	ALL	ALL	0.004808	0	0
Urban Family	Child born 1955	ALL	ALL	3	ALL	ALL	ALL	0.03082	0	0
Urban Family	Child born 1955	ALL	ALL	4	ALL	ALL	ALL	0.000345	0	0
Urban Family	Child born 1955	ALL	ALL	5	ALL	ALL	ALL	0.005826	0	0
Urban Family	Child born 1955	ALL	ALL	6	ALL	ALL	ALL	0.001099	0	0
Urban Family	Child born 1955	ALL	ALL	7	ALL	ALL	ALL	0.002758	0	0
Urban Family	Child born 1955	ALL	ALL	8	ALL	ALL	ALL	0.005987	0	0
Urban Family	Child born 1955	ALL	ALL	9	ALL	ALL	ALL	0.000873	0	0
Urban Family	Child born 1955	ALL	ALL	10	ALL	ALL	ALL	0.00657	0	0
Urban Family	Child born 1955	ALL	ALL	11	ALL	ALL	ALL	0.001688	0	0
Urban Family	Child born 1955	ALL	ALL	12	ALL	ALL	ALL	0.013851	0	0
Urban Family	Child born 1955	ALL	ALL	13	ALL	ALL	ALL	0.001519	0	0
Urban Family	Child born 1955	ALL	ALL	14	ALL	ALL	ALL	0.001188	0	0
Urban Family	Child born 1955	ALL	ALL	15	ALL	ALL	ALL	0.002344	0	0
Urban Family	Child born 1955	ALL	ALL	16	ALL	ALL	ALL	0.001466	0	0
Urban Family	Child born 1955	ALL	ALL	17	ALL	ALL	ALL	0.002072	0	0
Urban Family	Child born 1955	ALL	ALL	18	ALL	ALL	ALL	0.002944	0	0
Urban Family	Child born 1955	ALL	ALL	19	ALL	ALL	ALL	0.002865	0	0
Urban Family	Child born 1955	ALL	ALL	20	ALL	ALL	ALL	0.005532	0	0
Urban Family	Child born 1955	ALL	ALL	21	ALL	ALL	ALL	0.002092	0	0
Urban Family	Child born 1955	ALL	ALL	22	ALL	ALL	ALL	0.001078	0	0
Urban Family	Child born 1955	ALL	ALL	23	ALL	ALL	ALL	0.018203	0	0
Urban Family	Child born 1955	ALL	ALL	24	ALL	ALL	ALL	0.001721	0	0
Urban Family	Child born 1955	ALL	ALL	25	ALL	ALL	ALL	0.000416	0	0
Urban Family	Child born 1955	ALL	ALL	26	ALL	ALL	ALL	0.001653	0	0
Urban Family	Child born 1955	ALL	ALL	27	ALL	ALL	ALL	0.004393	0	0

Urban Family	Child born 1955	ALL	ALL	28	ALL	ALL	ALL	0.001323	0	0
Urban Family	Child born 1955	ALL	ALL	29	ALL	ALL	ALL	0.00649	0	0
Urban Family	Child born 1955	ALL	ALL	30	ALL	ALL	ALL	0.000769	0	0
Urban Family	Child born 1955	ALL	ALL	31	ALL	ALL	ALL	0.002788	0	0
Urban Family	Child born 1955	ALL	ALL	32	ALL	ALL	ALL	0.0069	0	0
Urban Family	Child born 1955	ALL	ALL	33	ALL	ALL	ALL	0.001198	0	0
Urban Family	Child born 1955	ALL	ALL	34	ALL	ALL	ALL	0.003573	0	0
Urban Family	Child born 1955	ALL	ALL	35	ALL	ALL	ALL	0.0038	0	0
Urban Family	Child born 1955	ALL	ALL	36	ALL	ALL	ALL	0.004544	0	0
Urban Family	Child born 1955	ALL	ALL	37	ALL	ALL	ALL	0.001825	0	0
Urban Family	Child born 1955	ALL	ALL	38	ALL	ALL	ALL	0.00219	0	0
Urban Family	Child born 1955	ALL	ALL	39	ALL	ALL	ALL	0.000833	0	0
Urban Family	Child born 1955	ALL	ALL	40	ALL	ALL	ALL	0.008025	0	0
Urban Family	Child born 1964	ALL	ALL	0	ALL	ALL	ALL	0.000106	0	0
Urban Family	Child born 1964	ALL	ALL	1	ALL	ALL	ALL	0.000104	0	0
Urban Family	Child born 1964	ALL	ALL	2	ALL	ALL	ALL	0.000113	0	0
Urban Family	Child born 1964	ALL	ALL	3	ALL	ALL	ALL	0.000215	0	0
Urban Family	Child born 1964	ALL	ALL	4	ALL	ALL	ALL	5.41E-05	0	0
Urban Family	Child born 1964	ALL	ALL	5	ALL	ALL	ALL	0.000127	0	0
Urban Family	Child born 1964	ALL	ALL	6	ALL	ALL	ALL	8.92E-05	0	0
Urban Family	Child born 1964	ALL	ALL	7	ALL	ALL	ALL	8.8E-05	0	0
Urban Family	Child born 1964	ALL	ALL	8	ALL	ALL	ALL	9.95E-05	0	0
Urban Family	Child born 1964	ALL	ALL	9	ALL	ALL	ALL	9.72E-05	0	0
Urban Family	Child born 1964	ALL	ALL	10	ALL	ALL	ALL	0.00014	0	0
Urban Family	Child born 1964	ALL	ALL	11	ALL	ALL	ALL	7.54E-05	0	0
Urban Family	Child born 1964	ALL	ALL	12	ALL	ALL	ALL	0.000174	0	0
Urban Family	Child born 1964	ALL	ALL	13	ALL	ALL	ALL	0.000107	0	0
Urban Family	Child born 1964	ALL	ALL	14	ALL	ALL	ALL	0.000159	0	0
Urban Family	Child born 1964	ALL	ALL	15	ALL	ALL	ALL	0.000125	0	0
Urban Family	Child born 1964	ALL	ALL	16	ALL	ALL	ALL	0.000102	0	0
Urban Family	Child born 1964	ALL	ALL	17	ALL	ALL	ALL	9.9E-05	0	0
Urban Family	Child born 1964	ALL	ALL	18	ALL	ALL	ALL	9.92E-05	0	0
Urban Family	Child born 1964	ALL	ALL	19	ALL	ALL	ALL	0.00011	0	0
Urban Family	Child born 1964	ALL	ALL	20	ALL	ALL	ALL	9.56E-05	0	0
Urban Family	Child born 1964	ALL	ALL	21	ALL	ALL	ALL	7.3E-05	0	0
Urban Family	Child born 1964	ALL	ALL	22	ALL	ALL	ALL	9.78E-05	0	0
Urban Family	Child born 1964	ALL	ALL	23	ALL	ALL	ALL	0.000186	0	0

Urban Family	Child born 1964	ALL	ALL	24	ALL	ALL	ALL	0.000109	0	0
Urban Family	Child born 1964	ALL	ALL	25	ALL	ALL	ALL	0.000101	0	0
Urban Family	Child born 1964	ALL	ALL	26	ALL	ALL	ALL	0.00011	0	0
Urban Family	Child born 1964	ALL	ALL	27	ALL	ALL	ALL	0.00013	0	0
Urban Family	Child born 1964	ALL	ALL	28	ALL	ALL	ALL	8.5E-05	0	0
Urban Family	Child born 1964	ALL	ALL	29	ALL	ALL	ALL	0.000138	0	0
Urban Family	Child born 1964	ALL	ALL	30	ALL	ALL	ALL	0.00011	0	0
Urban Family	Child born 1964	ALL	ALL	31	ALL	ALL	ALL	0.000141	0	0
Urban Family	Child born 1964	ALL	ALL	32	ALL	ALL	ALL	0.000114	0	0
Urban Family	Child born 1964	ALL	ALL	33	ALL	ALL	ALL	8.09E-05	0	0
Urban Family	Child born 1964	ALL	ALL	34	ALL	ALL	ALL	0.000136	0	0
Urban Family	Child born 1964	ALL	ALL	35	ALL	ALL	ALL	0.000107	0	0
Urban Family	Child born 1964	ALL	ALL	36	ALL	ALL	ALL	0.00016	0	0
Urban Family	Child born 1964	ALL	ALL	37	ALL	ALL	ALL	9.37E-05	0	0
Urban Family	Child born 1964	ALL	ALL	38	ALL	ALL	ALL	8.93E-05	0	0
Urban Family	Child born 1964	ALL	ALL	39	ALL	ALL	ALL	9.62E-05	0	0
Urban Family	Child born 1964	ALL	ALL	40	ALL	ALL	ALL	0.000154	0	0

APPENDIX P QUALITY ASSURANCE/QUALITY CONTROL

The work performed for the Savannah River Site Dose Reconstruction Project (SRS DRP) was done in accordance with the following Quality Assurance Procedures:

- QAP 1 – Work Process Controls
- QAP 2 – QA Training Procedure
- QAP 3 – Work Product Review
- QAP 4 – Records Management
- QAP 5 – Assessment
- QAP 6 – Information Control

Additionally, other tiered procedures were used including:

- QAP 4.2 - Production of Electronic Records from Hardcopy Documents
- QAP 4.3 - Quality Assurance Review of Scanned Documents

Prior to initiation of any work activities on the project, a Work Plan was developed by the Project Director in accordance with QAP 1. This Work Plan detailed project description, project schedule, project budget, project personnel, applicable technical standards and regulations, training requirements, subcontractor QA requirements, and technical review requirements. This plan was maintained electronically and was available to all project personnel.

All data used in this project was quality checked. Quality checks include verifying that original data from source documents were properly copied, all calculations and manipulations done to original data were performed correctly, and that revised data was entered into computer files correctly. All quality checks were documented on the form available in QAP 3.0. The forms, along with a copy of the data that was checked and any pertinent formulas that were used for calculations, were provided to the Project QA Manager. The forms were sequentially numbered and information from the forms was input into the QA Tracking Database. The forms and associated data are maintained in the QA project files.

P.1 Quality Control (QC) Activities

There were several activities that were performed in support of the SRSDRP that required extensive quality control reviews to assure the accuracy and defensibility of the work product. These activities were source term development; transfer, exposure, usage, and transportation factor development, software development, and output from the computer code. The QC activities associated with each of these work activities is described below:

P.1.1 Source Term Development

The process used in developing the air and liquid source terms is presented in Figure P-1.

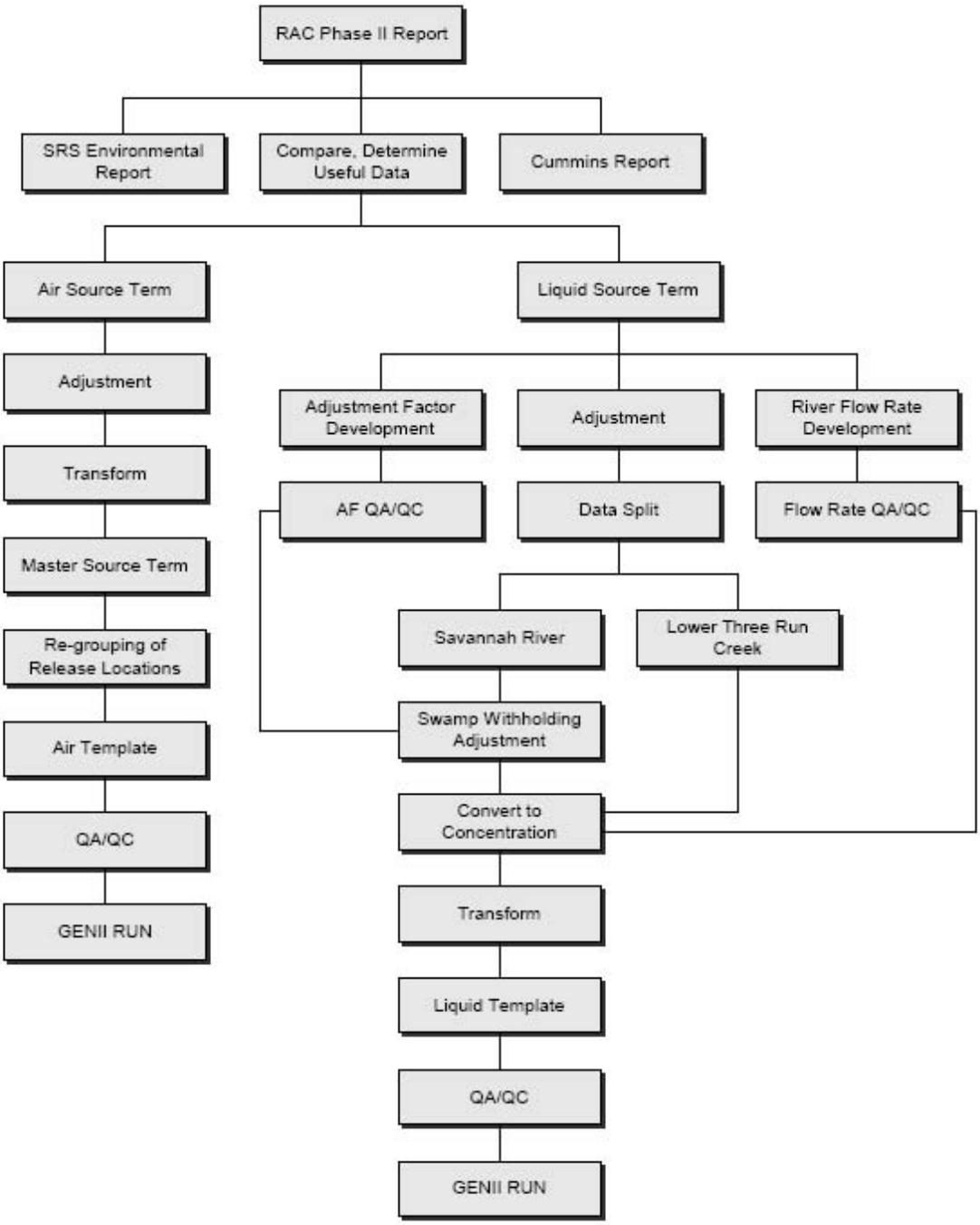

Figure P-1 Source Term Development Process

The development of source term information required two quality control processes; review of source term data to determine if the data was traceable back to an original source document after any

manipulations or calculations, and a review of the inputted data files to determine if any errors arose during the data input process.

Original source term data for air and liquid releases was derived from SRS Environmental Reports and from the Phase II report as detailed in Chapters 5 and 7. For air releases, these data were adjusted to account for modifications to the original data used in the Phase II report. The data that resulted from the adjustment process was quality checked and the reviews documented. Any errors found during the quality review were noted and the data returned to the author(s) for correction. Also, in order for the computer code to proper read the data input files, the input files that to be transformed into a specific file structure. This process did not involve any data calculations but entailed transferring data within an Excel spreadsheet. The data spreadsheets that resulted from this transformation process were quality checked and the review documented. Any errors found during the quality review were noted and the data returned to the author(s) for correction. For liquid releases, the source term data for radionuclide concentrations in the Savannah River was based on direct releases to onsite streams and direct releases to seepage and containment basins.

Data that was input into files for processing by the pre-processor were quality checked to ensure that no errors occurred during the input activity. All input files were quality checked and any errors or inconsistent data were returned to the author(s) for correction. Documentation of the source term data quality checks is maintained in the QA project files.

P.1.2 Transfer, Exposure, Usage, and Transportation Variable Quality Reviews

Approximately 109 radionuclide transfer, exposure, usage, and transportation variables had to be defined prior to running the computer model. The majority of the variables used in the modeling for this project consist of default values incorporated into the GENII code. Transfer variables not available in GENII were derived from *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments, Technical Reports Series No.364, International Atomic Energy Agency, Vienna, Austria, 1994* and numerous other documents that are referenced in the applicable Chapters.

The factors that were input into the computer files were quality checked against the original source documents. Any errors found during the quality review were noted and the data returned to the author(s) for correction.

P.1.3 Software Development

Two major software efforts were completed for the SRS DRP. The first was the development, testing and implementation of the pre-processor code and the second was the development, testing, and implementation of the post-processor code. A description of how these codes functioned is included in Appendix G. The quality assurance activities for the development and testing of these two codes included:

- Preparation of the software selection decision document
- Preparation of software requirements documents for the pre- and post-processor,
- Detailed design requirements documents for the pre- and post-processor, and
- Preparation and execution of the Quality Assurance Application Test Plan for the Pre- and Post-Processors to GENII-V2.

The Software Selection Document (SSD) details the basis for selecting the computational code to be used for the dose calculation. One of the selection criteria was the capability to calculate dose and risks for individuals. Additionally, the code needed to have the versatility to accept a pre- and post-processor in

order to perform all the required calculations. The SSD was reviewed by The GENII Version 2 code was selected based on these requirements.

Once the modeling software was selected, the requirements for the pre- and post-processors had to be developed so that the software designers would have a design structure. Software Requirements Documents for the Pre- and Post-processors were developed and quality reviewed to ensure that all the elements needed to perform the dose calculation for the SRS were adequately addressed. Comments from the technical reviewers were provided back to the authors of the requirements documents for responses and revising the documents if necessary.

When the requirements for the pre- and post-processors were considered adequate for the all the planned dose and risk calculations, detailed design documents were developed to guide the software designers. These detailed design documents were also reviewed to ensure that they addressed all the elements required for the calculations. Comments from the technical reviewers were provided back to the authors of the requirements documents for responses and revising the documents if necessary.

After the software design for the pre- and post-processors was completed, a Quality Assurance (QA) Application plan was developed. The purpose of the QA Application Plan was to assess the accuracy and completeness of the pre- and post-processor applications. The projected boundaries of the planned tests included limiting test data to a base case of input values with discrete scenario modifications that contained minimal attribute changes. These modifications satisfied the data permutations necessary to test the functional capabilities of the software design without creating unmanageable volumes of test data. The Quality Assurance Applications Test Plan is included in Attachment A to this Appendix.

After performing the testing as required by the QA Application Test Plan, all identified errors or faults detected in the pre- and port-processor software were documented and fully addressed. This documentation is maintained in the QA project files.

P.1.4 GENII V2 Output

After the pre- and post-processors were verified as functioning properly with the GENII V2 model, the actual dose and risk computer calculations were performed. A copy of each of the thousands of computer code runs that were done in support of the SRS DRP was electronically stored as a QA record. These files were reviewed by project staff for any obvious anomalies in the output data. When an anomaly was suspected, the computer code run was performed repeated and corrective actions were determined as a result of the second run. The QA records for the computer code runs are maintained in the QA project files.

P.1.5 Document Scanning

A part of the SRS DRP was to scan over 140 boxes of documents, reports, and pages of information. The goal of this process is to accurately duplicate the information into an electronic format so that the images could be uploaded to the appropriate CDC website and made available to the public. QAP 4.2 was followed to ensure that all documents were visually inspected prior to the scanning process to assess the physical integrity of the documents, if the document pages were in sequential order, and if the document identification number was on the first page of the document. The procedures also details activities for scanning preparation and operations to ensure that the scanned documents are properly identified, oriented on the image, and that the size of the document doesn’t exceed the capacity of the scanner.

QAP 4.3 was followed to ensure that the scanning process was performed correctly, that the scan image is readable, properly labeled and identified, and retrievable from the electronic storage media, i.e. compact disc.

An assessment by a person independent of the scanning process was performed to determine if any errors or problems existed with the scanned images. Assessment of every page of every document contained in over 140 boxes was not feasible but one document from every two boxes was reviewed. No errors or problems were detected during the assessment. The assessment results were documented and maintained in the QA project files.

ATTACHMENT A

Quality Assurance Application Test Plan for the Pre- and Post-Processors to GENII-V2 For the Generation of the Dose Reconstruction at the Savannah River Plant

Date: September 22, 2003

Revision 4

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1. PURPOSE

The purpose of this QA test plan is to assess the accuracy and completeness of the Pre- and Post-Processor applications that have been developed to utilize the GENII-V2 dose calculation software. The overall goal of systems integrated testing is to confirm that the working applications, or groups of components, can be fully integrated and satisfy functional and technical requirements.

2. BACKGROUND

Two applications (a Pre-Processor and a Post-Processor) have been developed to help automate the dosage analysis process using the GENII-V2 dose calculation software as a primary component. The pre-processor has been designed take a standardized GENII-V2 input file (GID file) and make changes in the standardized GID to account for varying facilities with releases by isotope, year of operation and receptor combination. In addition, for each facility and year and receptor combination, there could be up to 101 GID files generated as required by the uncertainty analysis (one for the point estimate data and 100 for the uncertainty data). The post-processor will use a two-step process to create the input files for the uncertainty/sensitivity analysis software. The post-processor will first read a set of GENII-V2 output files (HIF files) for a given facility and prepare a set of dose/risk results for the receptors designated in the scenario requirements for that facility. It will then combine the facility based results to form results for the entire site once all the facility results are available.

3. SCOPE

The projected boundaries of the planned tests include limiting test data to a base case of input values with discrete scenario modifications that contain minimal attribute changes. These modifications will satisfy the data permutations necessary to test the functional capabilities of the software design without creating unmanageable volumes of test output.

While actual input data could have variations that yield potentially millions of output data points from the Pre-Processor alone, it is obviously unfeasible to test every possible permutation within a reasonable time-frame and completely unnecessary based on the objectives of the testing. Given that initial input data varies primarily on facility, year and uncertainty, these are the major areas that will be used to group variations in the test scenario data.

4. LIMITATIONS AND TRACEABILITY

4.1 Limitations

4.1.1 Pre-Processor

General limitations for the Pre-Processor will be that Media, Isotopes and Exposure Locations will remain constant while data test scenarios will be grouped and generated as a function of facility, year and uncertainty combinations. More specific limitations to the Pre-Processor are as follows:

4.1.1.1 Media

Media will be limited to atmospheric, while liquid and soil will not be addressed by this QA test since there are still outstanding requirement questions surrounding those two media as of the writing of this document.

4.1.1.2 Isotopes

Since isotopes are limited by release facility, the subset of isotopes corresponding to selected facility data will be tracked for correct values while the remaining isotopes not available in the facility data will be checked to confirm zero values.

4.1.1.3 Exposure Locations

All exposure location data available within the subset of the standard GID template containing the first 10 locations will be tracked to provide confirmation of distance values both near and far from chosen Facilities.

4.1.1.4 Facilities

Three facilities (one centralized for control and two in opposing directions) will be used to capture and confirm changes in distance and direction. A fourth facility will be used to distinguish filenames for error trapping. The same source term data will be used for all facilities to maintain a control constant.

4.1.1.5 Years

Two specific years will be used to capture changes in source term release amounts for a given facility over time.

4.1.1.6 Uncertainty

A total of three uncertainty runs (one point estimate baseline and two uncertainty sets) will be tracked to confirm uncertainty values, while all 101 runs will actually need to be executed to confirm the uncertainty execution process.

4.1.1.7 Source Term Uncertainty

All facility source term data will be checked for uncertainty factor calculations and compared to the point estimate baseline values for accuracy.

4.1.1.8 Parameter Uncertainty

A discrete subset of parameter variables will be checked for value replacement and will include isotope independent variables, isotope dependent variables and exposure location dependent variables for the selected uncertainty runs.

4.1.2 Post-Processor

All of the limitations for the Pre-Processor input data will also apply to the Post-Processor with the following exceptions:

4.1.2.1 Facilities

Only one facility will be used since risk and dose output files are facility specific.

4.1.2.2 Years

Five years will be used to allow risk and dose factor differences to be seen for receptors across all factor groupings based on age.

Limitations specific only to the Post-Processor are as follows:

4.1.2.3 Location

All seven locations will be selected crossing different age groups to account for all receptor age group combinations.

4.1.2.4 Receptor

Ten receptors will be selected, one for each combination of age group.

4.1.2.5 Pathway

All pathways for all available isotopes will be reviewed for one particular receptor during one particular year.

4.1.2.6 Risk by Organ

All risk by organs will be accounted for one receptor and pathway.

4.1.2.7 Dose by Organ

All dose organs will be accounted for one receptor and pathway.

4.1.2.8 Total Risk

Total risk will be reviewed in all comparison scenarios.

4.1.2.9 Total Dose

Total dose will be reviewed in all comparison scenarios.

4.2 Traceability

Traceability of test scenarios to individual requirements will be maintained through a functional requirements traceability matrix. The requirements will be obtained directly from the detailed design documentation. Each requirement will be numbered based on the outline paragraph number within the detailed design. If paragraphs contain more than one potential requirement a sub paragraph number will be assigned. There will be separate spreadsheet tabs within the RTM for the Pre-Processor and for the Post-Processor as well as associated Failed History. The Requirements Traceability Matrix spreadsheet document will contain the following columns:

Column Name	Column Description
Paragraph #	Outline number of the requirement from the detailed design.
Sub Paragraph #	A more detailed number indicating that the paragraph contains more than one discrete requirement and must be broken down into individual test scenarios.
Requirement Description	Actual requirement text from the detailed design.
Requirement Section	Outline title of the requirement section.

Column Name	Column Description
Requirement Sub Section(s) [x3]	Outline titles of the requirement sub sections.
Test Run #	Number of the execution run for the given test input data set.
Test Scenario	Title of the scenario that distinguishes the various test cases within the given Test Run.
Test Sub Scenario(s) [x2]	A more detailed title indicating that the scenario must be broken down into more discrete sub scenarios.
Verification	Flag indicating results of the comparison between actual output data and expected values (passed, failed, n/a).
File Name	Name of the file containing the output data being compared if applicable.
Row #	Number of the row within the output file containing the data being compared.
GID Row Values (Pre-Processor only)	The following columns are only on the Pre-Processor RTM spreadsheet and apply to the GID input file.
Field Name	Name of the field in the row within the GID file being compared.
1, 2, 3, 4, 5, 6, 7	Indices for the given row within the GID file having various meanings (see detailed design).
Text 1, Text 2	Unit of measure used for the row within the GID file.
Dose and Risk Row Values (Post-Processor only)	The following columns are only on the Post-Processor RTM spreadsheet and apply to the Dose and Risk results TXT file.
Organ Name	Name of the Organ column within the Dose and Risk file being compared.
Location	Receptor Location for the row within the Dose and Risk file being compared.
Receptor	Receptor Name for the row within the Dose and Risk file being compared.
CurrYear	Current Year (1954-1992) for the row within the Dose and Risk file being compared.
RunNum	Uncertainty Run Number (000-100) for the row within the Dose and Risk file being compared.
Isotope	Isotope value for the row within the Dose and Risk file being compared.
Pathway	Pathway value for the row within the Dose and Risk file being compared.
Route	Route value for the row within the Dose and Risk file being compared.
Comparison Values (Pre and Post Processor)	The following columns are on both Pre- and Post-Processor RTM spreadsheets.

Column Name	Column Description
Actual	Output value of the test scenario to be compared with expected value (corresponds to Field Name for Pre-Processor and Organ Name for Post-Processor).
Expected	Expected value of the test scenario to be compared with actual value.
Tolerance %	Percent difference between actual and expected values (for value comparison test cases where null or zero constitutes a passed test, very small values indicate differences due to acceptable rounding or truncation and large values or "#DIV/0!" errors indicate a failed test).
Notes	Additional detail that provides indication of duplicate requirements (e.g. "duplicate of n.n.n"), indication of general requirements confirmed by more specific requirements (e.g. "see n.n.n through n.n.n."), exact text within a message or QA file, or why a test scenario passed or failed.

5. TEST PLANS

5.1 Test Levels

5.1.1.1 Subsystem Integration Test

The Pre-Processor and Post-Processor will be tested as individual subsystems. Execution of each application is manually driven and requires human intervention to select the setup criteria at each stage. There will be no automated end-to-end integration test. The Pre-Processor will be used to generate upstream test files that will process through GENII-V2 prior to being used as input for the Post-Processor testing.

5.2 User Acceptance Test

These applications are designed to be run only once for all data, not as an ongoing end-user-driven process. The production-level execution will be performed by the QA team. Since there is no end-user involvement, no user acceptance test will be necessary.

5.3 Test Methods and Evaluation

Testing will be accomplished through multiple execution runs of the application using a variety of input data sets. The requirements traceability matrix will be the solitary driver for all test scenarios. Test data sets will be created for each scenario to meet the needs of the requirements as defined in the detailed design documentation.

5.3.1 Pre-Processor

5.3.1.1 Input Data Creation

The test data for the Pre-Processor will be set up to address specific test scenarios and will be contained in a combination of standard GID templates for given exposure location sets and facility specific source term data files. Reference data will be contained in pre-defined isotope description files, dispersion factor

files, exposure description files, facility description files, parameter uncertainty files and source term uncertainty files. The appropriate combination of input files will be set up for each execution run as they pertain to the test scenarios within that particular run. Many input reference files will remain constant across test scenarios and will be re-used by multiple test runs as necessary. Any variation of input files will be documented and kept for reference.

5.3.1.2 Expected Results Calculation

Expected results for each test scenario will be determined through both manual calculations and other tool-assisted methods. In the most basic scenario, the application obtains data directly from a source term file for a given media and facility, then multiplies by a unit conversion factor and places the data in a specific row within the GID output file based on corresponding variable names and row indices for a given isotope or exposure location. These calculations are relatively simple, self-explanatory and will not require additional explanation beyond referencing the detailed design requirement. Distance calculations are slightly more complex and a separate tool will be developed using Microsoft Excel to determine values for expected results. Since user interface requirements typically affect all test runs and only occur during execution setup, they have no particular test scenarios and no specific expected results to compare. Visual verification will suffice to confirm application functionality for most user interface requirements.

5.3.1.3 Error Messages Confirmation

Error message functionality will be confirmed by setting up various error scenarios within the input files and capturing output text within message files. Since the same message output filename may be used for several error scenarios, the message output files will be re-named after each error run to include the corresponding scenario for easy traceability.

5.3.1.4 Output Data Comparison Analysis

Once each test execution run has completed successfully, the output files for each run will be captured and analyzed using a text editor or Microsoft Excel to assist in the analysis.

For each test scenario within the corresponding GID output file, the specific field name and index values will be matched to find the actual quantity, distance or setup values. The row number will be noted and the entire row of data will be captured and the actual values will be placed in the traceability matrix for comparison with the expected values.

If the actual value matches expected results within acceptable tolerances, the scenario is marked as passed in the verification column. If the value does not match the expected results, the scenario is marked as failed in the verification column and placed in the failed history. Failed scenarios must be retested as fixes are made available.

5.3.2 Post-Processor

5.3.2.1 Input Data Creation

The test data for the Post-Processor will need to be generated by the GEN-II V2 dose calculation software and will be contained in a combination of HIF files based on selected media, facility, year range and uncertainty criteria. Reference data will be contained in pre-defined receptor description files, isotope description files, risk factor files, dose factor files and behavior pathway usage files. The appropriate combination of input files will be set up for each execution run as they pertain to the test scenarios within that particular run.

5.3.2.2 Expected Results Calculation

Expected results for each test scenario will be determined through both manual calculations and other tool-assisted methods. In the most basic scenario, the application obtains data directly from an HIF file for a given media, exposure set, facility, year and uncertainty, then multiplies by a series of risk, dose and usage factors and places the data by organ and total in a specific row within the XLS output file based on corresponding row indices for a given location, receptor, year, uncertainty, pathway and isotope. These calculations are relatively simple, self-explanatory and will not require additional explanation beyond referencing the detailed design requirement. A tool will be developed using Microsoft Excel to determine risk and dose values for expected results.

5.3.2.3 Error Messages Confirmation

[TBD]

5.3.2.4 Output Data Comparison Analysis

Once each test execution run has completed successfully, the output files for each run will be captured and analyzed using a text editor or Microsoft Excel to assist in the analysis.

For each test scenario within the corresponding XLS output file, the index values will be matched to find the actual risk and dose values for specific organ name or total. The row number will be noted and the index portion of the row of data will captured including the organ name or total and the actual risk or dose values will be placed in the traceability matrix for comparison with the expected values.

If the actual value matches expected results within acceptable tolerances, the scenario is marked as passed in the verification column. If the value does not match the expected results, the scenario is marked as failed in the verification column and placed in the failed history. Failed scenarios must be retested as fixes are made available.

6. TEST DESCRIPTION

6.1 Pre-Processor

There will be a total of 6 execution runs setup for particular sets of test scenarios. Each Pre-Processor run will create the necessary permutations of data output to allow confirmation of the particular requirements that correspond to the given test scenarios. The runs will be as follows:

- Run 0.000: Baseline Facility (F Canyon 1954)
- Run 1.000-.100: Point Estimate & Uncertainty (F Canyon 1954)
- Run 2.000: Alternate Facility 2 (A Area 1954)
- Run 3.000: Alternate Facility 3 (L Reactor 1954)
- Run 4.000: Alternate Year 2 (F Canyon 1955)
- Run 5.000: Error Messages (C Area 1954)

Reference and Input files will be labeled as version Q for control setup values and as version X for error message setup values.

6.1.1 Run 0.000: Baseline Facility

6.1.1.1 Test Description

Test Run 0.000 will be the testing baseline and be used to confirm that a single point estimate can be executed successfully with multiple exposure location sets using no uncertainty. No additional data confirmation will be addressed by this run. Setup will be as follows:

6.1.1.2 Inputs

Media: Atmospheric
Facility: F Canyon
Year: 1954
Uncertainty: No
Exposure Location Sets: A1STANDQ.txt and A2STANDQ.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.1.1.3 Outputs

Output files: A1F54000.GID and A2F540000.GID

6.1.1.4 Procedures

Input files will be developed for the baseline with dummy data as specified by the detailed design. The application will be started and execution will be setup by selecting the input files with the user interface. Media will be set to Atmospheric, facility will be set to F Canyon and year will be set to 1954. Uncertainty will not be selected. The run will be executed to create the GID(s). Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios.

6.1.1.5 Scenarios

- Run 0.000 (Baseline Facility F)

  Baseline: A single point estimate will be executed successfully with multiple exposure location sets using no uncertainty.

6.1.2 Run 1.000-.100: Point Estimate & Uncertainty

6.1.2.1 Test Description

Test Run 1 is actually 3 runs in one. Test Run 1.000 will be used to confirm that the point estimate can be executed successfully during an uncertainty run. It will also be used to confirm all data values for the point estimate. Setup and execution will also create files for 100 uncertainty test runs. Two of these uncertainty runs (1.001 and 1.100) will be used to confirm source term uncertainty factors and parameter uncertainty values. Setup will be as follows:

6.1.2.2 Inputs

Media: Atmospheric
Facility: F Canyon
Year: 1954
Uncertainty: Yes
Exposure Location Set: A1STANDQ.txt and A2STANDQ.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.1.2.3 Outputs

Output files: A1F54000.GID, A1F54001.GID through A1F54100.GID

6.1.2.4 Procedures

Original input files developed for the baseline will be used. The application will be started and execution will be setup by selecting the input files with the user interface. Media will be set to Atmospheric, facility will be set to F Canyon and year will be set to 1954. Uncertainty will be selected. The run will be executed to create the GID(s). Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios

6.1.2.5 Scenarios

- Run 1.000 (Point Estimate)

  General Setup: Basic setup procedures will be reviewed for accuracy of the user interface, reading standard files and generating the GID file(s).

  F Canyon: Reading facility description and exposure location description files will be confirmed. Release height and distance calculations for baseline facility will be confirmed.

  Source Term Point Estimate: Correct values for cflux lines will be confirmed for all isotopes as defined in the source term file for the given year. It will also be confirmed that no cflux lines are written for daughter isotopes.

  Parameter Point Estimate: Correct values for three types of parameters will be confirmed. The Isotope Independent variable checked will be BIOMA2 (Animal feed standing biomass (wet)). The Isotope Dependent variable checked will be CLBFF (Bioaccumulation in Freshwater Fish) which applies to AM241 and I131. Both BIOMA2 and BIOMAS (Standing biomass (wet)) will be checked as the Exposure Location Dependent variable.

  1954: The correct directory path and file name of the Meteorological file will be checked.

  Exposure Set 1: Values will be checked for correct exposure name and label.

Exposure Set 2: The second exposure set will generate GID files and the values for unused exposure locations remain unchanged from the template.

Model State: Correct values will be checked for "xxxModelStat" and "ModState". All values should be "1" except for Con1 which should be "2".

QA File: Confirm that the QA file is created and contains correct information.

Batch File: Confirm that the Batch file is created and contains correct information.

Informational Messages: Confirm that the Message file is created and contains correct information for non-error messages that occur during normal execution without aborting, such as an isotope not included in the Facility Release File.

- Run 1.001 (Uncertainty 001)

Source Term Uncertainty 001: New values for cflux lines will be confirmed for all isotopes to ensure application of the source term uncertainty factor.

Parameter Uncertainty 001: New values for three types of parameters will be confirmed to ensure application of the parameter uncertainty values.

- Run 1.100 (Uncertainty 100)

Source Term Uncertainty 100: Correct values for cflux lines will be confirmed for all isotopes including the application of the source term uncertainty factor.

Parameter Uncertainty 100: New values for three types of parameters will be confirmed to ensure application of the parameter uncertainty values.

6.1.3 Run 2.000: Alternate Facility 2

6.1.3.1 Test Description

Test Run 2.000 will be used to confirm distance calculations for a second facility. Setup will be as follows:

6.1.3.2 Inputs

Media: Atmosphere
Facility: A Area
Year: 1954
Uncertainty: No
Exposure Location Set: A1STANDQ.txt
Pre-Processor Input files: AA5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.1.3.3 Outputs

Output files: A1A54000.GID

6.1.3.4 Procedures

Original input files developed for the baseline will be used except a copy of Facility F Canyon data will be created and labeled as A Area with appropriate file name that matches naming standards. The application will be started and execution will be setup by selecting the input files with the user interface. Media will be set to Atmospheric, facility will be set to A Area and year will be set to 1954. Uncertainty will not be selected. The run will be executed to create the GID(s). Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios

Scenarios

- Run 2.000 (Alternate Facility 2)

  A Area: New values will be confirmed for release height, distance to each exposure location, northing and easting. New Sitename value will also be confirmed.

6.1.4 Run 3.000: Alternate Facility 3

6.1.4.1 Test Description

Test Run 3.000 will be used to confirm distance calculations for a third facility. Setup will be as follows:

Inputs

Media: Atmospheric
Facility: L Reactor
Year: 1954
Uncertainty: No
Exposure Location Set: A1STANDQ.txt
Pre-Processor Input files: AL5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.1.4.2 Outputs

Output files: A1L54000.GID

6.1.4.3 Procedures

Original input files developed for the baseline will be used except a copy of Facility F Canyon data will be created and labeled as L Reactor with appropriate file name that matches naming standards. The application will be started and execution will be setup by selecting the input files with the user interface. Media will be set to Atmospheric, facility will be set to L Reactor and year will be set to 1954. Uncertainty will not be selected. The run will be executed to create the GID(s). Output files will be

identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios.

Scenarios

- Run 3.000 (Alternate Facility 3)

  L Reactor: New values will be confirmed for release height, distance to each exposure location, northing and easting. New Sitename value will also be confirmed.

6.1.5 Run 4.000: Alternate Year 2

6.1.5.1 Test Description

Test Run 4.000 will be used to confirm source term data changes for a given year. Setup will be as follows:

6.1.5.2 Inputs

Media: Atmospheric
Facility: F Canyon
Year: 1955
Uncertainty: No
Exposure Location Set: A1STANDQ.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.1.5.3 Outputs

Output files: A1F55000.GID

6.1.5.4 Procedures

Original input files developed for the baseline will be used. The application will be started and execution will be setup by selecting the input files with the user interface. Media will be set to Atmospheric, facility will be set to F Canyon and year will be set to 1955. Uncertainty will not be selected. The run will be executed to create the GID(s). Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios.

6.1.5.5 Scenarios

- Run 4.000 (Alternate Year 2)

  1955: New Sitename value will be confirmed to include alternate year. Different value will be confirmed for Meteorological file name. New cflux values will be confirmed as indicated by the alternate year column in the original source term file.

6.1.6 Run 5.000: Error Messages

6.1.6.1 Test Description

Test Run 5.000 will actually be a series of unique runs that will designed to correspond to specific error message scenarios. Setup will be as follows:

6.1.6.2 Inputs

Media: Atmospheric
Facility: C Area or D Area
Year: 1954 or 1993
Uncertainty: No or Yes
Exposure Location Set: A1STANDX.txt
Pre-Processor Input files: AC5492X.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACX.xls, EXPDESCX.xls, FACDESX.xls, PAUNCERX.xls, STUNCERX.xls

Note: Input files for version X will only be used for specific test scenarios where applicable, otherwise control files for version Q will be used.

6.1.6.3 Outputs

Output files: AC1954Q.MES, AC1954X.MES, AC1993Q.MES, AD1954Q.MES, and AF1955Q.MES

6.1.6.4 Procedures

Procedures will vary greatly since each scenario requires a different setup. In general the original input files developed for the baseline will be used. However, each error scenario may require a modification to an input file. In general, media will be set to Atmospheric, facility will be set to C Area and year will be set to 1955. Uncertainty will not be selected. Each run will be executed to create the GID(s). Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios. Any variation from this procedure will be listed in the scenarios.

Scenarios

- Run 5.000 (Error Messages)

  No C Area Facility: The facility description file will be modified to remove the C Area facility line. A run will be setup to utilize this file and should abort.

  No D Area File: A run will be setup to utilize the D Area facility without a release file. More specifically, a dummy release file will be created to be selected during the setup, but removed from the directory just prior to execution. The process should abort and write an error.

  Bad 1993 Year: A run will be setup to select 1993 which is outside the range of the standard release file. The process should abort and write an error.

  Empty GID File: The standard GID file will be modified to be empty prior to a run. The process should abort and write an error.

Blank Air3: The Air3 section within the standard GID file will be removed prior to a run. The process should abort and write an error.

Bad Facility Isotope: A dummy isotope "BADISO" will be placed in the facility source term file. The process should abort and write an error.

Mismatch Uncertainty: The source term uncertainty file will be modified to contain less that the typical 100 uncertainty rows. This will be run simultaneously with a parameter uncertainty file with the typical 100 rows. Uncertainty must be selected. The process should abort and write an error.

Bad Parameter Isotope: A dummy isotope "BADISO" will be placed in the parameter uncertainty file. The process should abort and write an error.

Parameter Not Used: A dummy parameter "NOTUSED" will be placed in the parameter uncertainty file. The process should abort and write an error.

No Exp4: The exposure location description file will be modified to remove exposure location 4, (Jackson, SC). The process should abort and write an error.

Blank C Data: The facility source term data file for C Area will be modified to be empty prior to a run. The process should abort and write an error.

No MET File: The dispersion facility file will be modified to contain an invalid Meteorological file. The process should abort and write an error.

6.2 Post-Processor

There will be 4 Pre-Processor execution runs setup to feed GENII-V2 the Post-Processor as follows:

- Run 1.000: Point Estimate Multi-Year (F Canyon 1964-1966)
- Run 2.000: Point Estimate Single Year (F Canyon 1969)
- Run 3.000: Point Estimate Multi-Year Gender Assignment (F Canyon 1972-73, 1981-82, 1989)
- Run 4.000: Liquid Pathways and Isotope Decay Products
- Run 5.000: Facility Identification

This will generate a series of GID files that will feed the GENII-V2 dose calculation software. GENII-V2 will then be used to generate the corresponding HIF files to be used as input for all Post-Processor test scenarios.

There will be 4 Post-Processor execution runs that will create the necessary permutations of data output to allow confirmation of the particular requirements that correspond to the given test scenarios. These runs will contain the following receptors:

- Run 1.000: Point Estimate Multi-Year (F Canyon 1964-1966)
  - Rural Family #1 Child born 1964
  - Rural Family #2 Child born 1964
  - Urban Family Child born 1964
  - Delivery Family Child born 1954
  - Outdoor Family Child born 1954
  - Migrant Family Adult Male
  - Near Water Family Adult Female

- Run 2.000: Point Estimate Single Year (F Canyon 1969)
  - Rural Family #1 Child born 1964
  - Rural Family #2 Child born 1954
- Run 3.000: Point Estimate (F Canyon 1971-72, 1981-82, 1989)
  - Urban Family Child born 1955
  - Urban Family Child born 1964
- Run 4.000: Liquid Pathways and Isotope Decay Products
  - Urban Family Child born 1964
- Run 5.000: Facility Identification

Reference files are static and will remain constant.

6.2.1 Setup Run 1.000: Point Estimate Multi-Year

6.2.1.1 Inputs

Media: Atmospheric
Facility: F Canyon
Year Range: 1964-1966
Uncertainty: No
Exposure Location Set: A1STANDA.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.2.1.2 Outputs

Pre-Processor Output files (GENII-V2 Input files): A1B64000.GID, A1B65000.GID, and A1B66000.GID

GENII-V2 Output files (Post-Processor Input files): A1B64000.HIF, A1B65000.HIF, and A1B66000.HIF

6.2.2 Setup Run 2.000: Point Estimate Single-Year

6.2.2.1 Inputs

Media: Atmospheric
Facility: F Canyon
Year Range: 1969
Uncertainty: No
Exposure Location Set: A1STANDA.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls,

FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.2.2.2 Outputs

Pre-Processor Output files (GENII-V2 Input files): A1B69000.GID

GENII-V2 Output files (Post-Processor Input files): A1B69000.HIF

6.2.3 Setup Run 3.000: Point Estimate Multi-Year Gender-Assignment

6.2.3.1 Inputs

Media: Atmospheric
Facility: F Canyon
Year Range: 1972-73, 1981-82, 1989
Uncertainty: Yes
Exposure Location Set: A1STANDA.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.2.3.2 Outputs

Pre-Processor Output files (GENII-V2 Input files): A1B72000.GID, A1B73000.GID, A1B81000.GID, A1B82000.GID, A1B89000.GID.

GENII-V2 Output files (Post-Processor Input files): A1B72000.HIF, A1B73000.HIF, A1B81000.HIF, A1B82000.HIF, A1B89000.HIF

6.2.4 Setup Run 4.000: Liquid Pathways and Decay Products

6.2.4.1 Inputs

Media: Atmospheric
Facility: F Canyon
Year Range: 1972-73, 1981-82, 1989
Uncertainty: Yes
Exposure Location Set: A1STANDA.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.2.4.2 Outputs

Pre-Processor Output files (GENII-V2 Input files): LZ65000.GID

GENII-V2 Output files (Post-Processor Input files): LZ65000.HIF

6.2.5 Setup Run 5.000: Facility Identification

6.2.5.1 Inputs

Media: Atmospheric
Facility: F Canyon, B
Year Range: 1964-1965
Uncertainty: No
Exposure Location Set: A1STANDA.txt
Pre-Processor Input files: AF5492Q.xls
Pre-Processor Reference files: AISOTDEQ.xls, DISPFACQ.xls, EXPDESCQ.xls, FACDESQ.xls, PAUNCERQ.xls, STUNCERQ.xls

6.2.5.2 Outputs

Pre-Processor Output files (GENII-V2 Input files): A1B64000.GID, A1B65000.GID

GENII-V2 Output files (Post-Processor Input files): A1B64000.HIF, A1B65000.HIF

6.2.6 Run 1.000: Point Estimate Multi-Year

6.2.6.1 Test Description

Test Run 1.000 will be used to confirm point estimate values for the given receptors in the scenario over a period of years. Receptors have been selected to capture the largest portion of possible age factor group permutations within the shortest range of years.

6.2.6.2 Inputs

Media: Atmospheric
Facility: F Canyon
Year Range: 1964-1965
Dose: by Organs (All)
Risk: by Organs (All)
Pathways: by Pathway (All)
Isotope: by Isotope (All)

Receptors: Rural Family #1 Child born 1964 Rural Family #2 Child born 1964 Urban Family Child born 1964 Delivery Family Child born 1954 Outdoor Family Child born 1954 Migrant Family Adult Male Near Water Family Adult Female
Post-Processor Input files: A1B64000.HIF, A1B65000.HIF, and A1B66000.HIF
Post-Processor Reference files: pathways.xls

6.2.6.3 Outputs

Post-Processor Output files: A1B(year)(receptor name).XLS

6.2.6.4 Procedures

3 HIF files resulting from previous execution of the GENII-V2 application will be used as input for the Post Processor. The application will be started and execution will be setup by selecting the pathways reference file with the user interface. Media will be set to Atmospheric, facility will be set to F Canyon and year will be set to range of 1964-1966. Dose will be by Organs, selecting all. Risk will be with cancer results including Cancer Incidents by Organs, selecting all, and Cancer Fatalities by Organs, selecting all. Pathway will be by Exposure Pathways, selecting all. Isotopes will be by Isotope, selecting all. Receptors will be selected as identified in the Input matrix. The run will be executed to create the XLS files. Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios.

6.2.6.5 Scenarios

Scenarios have been identified to capture combinations of Risk factors, Dose factors and Usage factors based on Receptor age. The following table illustrates the scenarios that will be tested with this run.

Risk Factor	Dose Factor	Behavior Pathways (Usage)	Receptor	Run Year	Age
0-5 y	Infant	Infant	Rural Family #1 Child born 1964	1964	0
0-5 y	1 y old	Pre-school Child	Rural Family #2 Child born 1964	1965	1
0-5 y	5 y old	Pre-school Child	Urban Family Child born 1964	1966	2
5-15 y	10 y old	School Child	Delivery Family Child born 1954	1964	10
5-15 y	15 y old	Teenager	Outdoor Family Child born 1954	1966	12
25-70 y	Adult	Adult Male	Migrant Family Adult Male	1964	35
25-70 y	Adult	Adult Female	Near Water Family Adult Female	1964	35

6.2.7 Run 2.000: Point Estimate Single-Year

6.2.7.1 Test Description

Test Run 2.000 will be used to confirm point estimate values for the given receptors in the scenario within the specific year and will account for additional factor combinations.

6.2.7.2 Inputs

Media: Atmospheric
Facility: F Canyon
Year Range: 1969
Dose: by Organs (All)
Risk: by Organs (All)
Pathways: by Pathway (All)
Isotope: by Isotope (All)
Receptors: Rural Family #1 Child born 1964 Rural Family #2 Child born 1954
Post-Processor Input files: A1B69000.HIF
Post-Processor Reference files: pathways.xls

6.2.7.3 Outputs

Post-Processor Output files: A1B(year)(receptor name).XLS

6.2.7.4 Procedures

1 HIF file resulting from previous execution of the GENII-V2 application will be used as input for the Post Processor. The application will be started and execution will be setup by selecting the pathways reference file with the user interface. Media will be set to Atmospheric, facility will be set to F Canyon and year will be set to 1969. Dose will be by Organs, selecting all. Risk will be with cancer results including Cancer Incidents by Organs, selecting all, and Cancer Fatalities by Organs, selecting all. Pathway will be by Exposure Pathways, selecting all. Isotopes will be by Isotope, selecting all. Receptors will be selected as identified in the Input matrix. The run will be executed to create the XLS files. Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios.

6.2.7.5 Scenarios

Scenarios have been identified to capture combinations of Risk factors, Dose factors and Usage factors based on Receptor age. The following table illustrates the scenarios that will be tested with this run.

Risk Factor	Dose Factor	Behavior Pathways (Usage)	Receptor	Run Year	Age
5-15 y	5 y old	School Child	Rural Family #1 Child born 1964	1969	5
5-15 y	15 y old	Teenager	Rural Family #2 Child born 1954	1969	15

6.2.8 Run 3.000: Point Estimate Multi-Year Gender-Assignment

6.2.8.1 Test Description

Test Run 3.000 will be used to confirm point estimate for the given receptors in the scenarios as they age from teenagers to adults. Setup will be as follows:

6.2.8.2 Inputs

Media: Atmospheric
Facility: F Canyon
Year Range: 1972,-73, 1981-82, 1989
Dose: by Organs (All)
Risk: by Organs (All)
Pathways: by Pathway (All)
Isotope: by Isotope (All)
Receptors: Urban Family Child born 1954, Urban Family Child born 1955, Urban Family Child born 1964
Post-Processor Input files: A1B72000.HIF, A1B73000.HIF, A1B81000.HIF, A1B82000.HIF, A1B89000.HIF
Post-Processor Reference files: pathways.xls

6.2.8.3 Outputs

Post-Processor Output files: AB(year)(receptor name).XLS

6.2.8.4 Procedures

HIF files resulting from previous execution of the GENII-V2 application will be used as input for the Post Processor. The application will be started and execution will be setup by selecting the pathways reference file with the user interface. Media will be set to Atmospheric, facility will be set to F Canyon and year will be set to 1972-1973, 1981-1982, or 1989 depending on the scenario. Dose will be by Organs, selecting all. Risk will be with cancer results including Cancer Incidents by Organs, selecting all, and Cancer Fatalities by Organs, selecting all. Pathway will be by Exposure Pathways, selecting all. Isotopes will be by Isotope, selecting all. Receptors will be selected as identified in the Input matrix. The run will be executed to create the XLS files. Output files will be identified and confirmed. Content of each output file will be reviewed and analyzed as needed to confirm specific scenarios.

6.2.8.5 Scenarios

Scenarios have been identified to capture combinations of Risk factors, Dose factors and Usage factors based on Receptors aging from teenagers to adults when a gender is assigned based on their birth year. The following table illustrates the scenarios that will be tested with this run.

Risk Factor	Dose Factor	Behavior Pathways (Usage)	Receptor	Run Year	Age
15-25	Adult	Adult Female	Urban Family Child born 1964	1982	18
15-25	15 y old	Teenager	Urban Family Child born 1964	1981	17
15-25	Adult	Adult Male	Urban Family Child born 1955	1972	18
15-25	15 y old	Teenager	Urban Family Child born 1955	1973	17
25-70	Adult	Adult Male	Urban Family Child born 1954	1989	35

6.2.9 Run 4.000: Liquid Pathways and Decay Products

6.2.9.1 Test Description

Test Run 4.000 will be used to confirm the Liquid Media and isotope decay product calculations.

6.2.9.2 Inputs

Media: Liquid
Facility: F Canyon
Year Range: 1965
Dose: by Organs (All)
Risk: by Organs (All)
Pathways: by Pathway (All)
Isotope: by Isotope (All)
Receptors: Urban Family Child born 1964
Post-Processor Input files:LZ65000.HIF
Post-Processor Reference files: pathways.xls

6.2.9.3 Outputs

Post-Processor Output files: LZ(year receptor name).XLS

6.2.9.4 Procedures

The HIF file resulting from a previous execution of the GENII-V2 application will be used as input for the Post Processor. The application will be started and execution will be setup by selecting the pathways reference file with the user interface. Media will be set to Liquid, facility will be set to F Canyon and year

will be set to 1965. Dose will be by Organs, selecting all. Risk will be with cancer results including Cancer Incidents by Organs, selecting all, and Cancer Fatalities by Organs, selecting all. Pathway will be by Exposure Pathways, selecting all. Isotopes will be by Isotope, selecting all. Receptors will be selected as identified in the Input matrix. The run will be executed to create the XLS file. The output file will be identified and confirmed. The content of the output file will be reviewed and analyzed as needed to confirm the specific scenario.

6.2.9.5 Scenarios

The scenario was identified to capture combinations of isotopes and their decay products in addition to utilizing the Liquid pathways. The following table illustrates the scenario that will be tested with this run.

Risk Factor	Dose Factor	Behavior Pathways (Usage)	Receptor	Run Year	Age
0-5 y	1 y old	Pre-school Child	Urban Family Child born 1964	1965	1

6.2.10 Run 5.000: Facility Identification

6.2.10.1 Test Description

Test Run 5.000 will be used to confirm the facility identified in the GENII-V2 output file is correctly output in the Post-Processor output file.

6.2.10.2 Inputs

Media: Atmospheric

Facility: F Canyon, B

Post-Processor Input files:A1B64000.HIF, A1B65000.HIF, A1F64000.HIF A1F65000.HIF

6.2.10.3 Outputs

Post-Processor Output files: A1(facility)(year)(receptor name).XLS

6.2.10.4 Procedures

The HIF file resulting from a previous execution of the GENII-V2 application will be used as input for the Post Processor. The application will be started and execution will be setup by selecting the pathways reference file with the user interface. Media will be set to Liquid, facility will be set to F Canyon or B and year will be set to 1964 or 1965. Pathway will be by Exposure Pathways, selecting all. Isotopes will be by Isotope, selecting all. The run will be executed to create the XLS files. The output files will be identified and confirmed. The content of the output files will be reviewed and analyzed as needed to confirm the specific scenario.

6.2.10.5 Scenarios

The scenario was identified to confirm that the Facility identifier located in the GENII-V2 output file is correctly inserted in the Post-Processor output file. Multiple years and facilities will be used and the Post-Processor output file and GENII-V2 facility identifier values will be compared.

APPENDIX Q INHALATION AND EXTERNAL EXPOSURE DATA TABLES

The inhalation and external exposure rates that were used in the GENII V2 model are provided in this appendix.

Inhalation And External Tables

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Inhalation Rates For Each Age Group (m^3/year breathed)

Inhalation - Exposure Factors Handbook Table 5-23

Age/Gender Group	Long-Term Mean Recommended Value m3/d	m3/yr	GENII Categories	Weighted Average m3/yr		x 0.0119				
Infants <1	4.5	1642.5	Infant	1,643	0.0119	20	1,623			
Children 1-2	6.8	2482	Preschool 1-5	2,811	0.0119	33	2,777			
Children 3-5	8.3	3029.5			0.0119	-	-			
Children 6-8	10	3650	Schoolchild 6-12	4,380	0.0119	52	4,328			
Children 9-11 Male	14	5110			0.0119	-	-			
Children 12-14 Male	15	5475	Teen	5,892	0.0119	70	5,822			
Children 15-18 Male	17	6205			0.0119	-	-			
Adults 19-65+ Male	15.2	5548	Adult Male	5,548	0.0119	66	5,482	0.73214286	4,062	1,486
Adults 19-65+ Female	11.3	4124.5	Adult Female	4,125	0.0119	49	4,075			

Receptor Group	Family Member	Location	m^3 of air breathed per member per location
Rural Family #1	Infant	Girard	1643
	Preschooler	Girard	2811
	Schoolchild	Girard	4380
	Teenager	Girard	5045
	Teenager	Waynesboro	848
	Adult Male	Girard	5548
	Adult Female	Girard	4125
Rural Family #2	Infant	Williston	1643
	Preschooler	Williston	2811
	Schoolchild	Williston	4380
	Teenager	Williston	5892
	Adult Male	Williston	5548

	Adult Female	Williston	4125
Urban/Suburban Family	Infant	Augusta	1643
	Preschooler	Augusta	2811
	Schoolchild	Augusta	4380
	Teenager	Augusta	5892
	Adult Male	Augusta	4281
	Adult Male	Onsite SRS	1267
	Adult Female	Augusta	4125
Delivery Person	Infant	Martin	57
	Infant	Barnwell	1585
	Preschooler	Martin	98
	Preschooler	Barnwell	2712
	Schoolchild	Martin	153
	Schoolchild	Barnwell	4227
	Teenager	Martin	206
	Teenager	Barnwell	5686
	Adult Male	Martin	194
	Adult Male	Barnwell	4088
	Adult Male	Onsite SRS	253
	Adult Male	Allendale	1013
	Adult Female	Martin	144
	Adult Female	Barnwell	3980
Outdoors Person	Infant	Jackson	1643
	Preschooler	Jackson	2811
	Schoolchild	Jackson	4380
	Teenager	Jackson	5892
	Adult Male	Jackson	4281
	Adult Male	Onsite SRS	1267
	Adult Female	Jackson	4125
Family Living Near River	Infant	Martin	1643
	Preschooler	Martin	2811
	Schoolchild	Martin	4380
	Teenager	Martin	5892
	Adult Male	Martin	5548
	Adult Female	Martin	4125
	Infant	New Ellenton	821
	Preschooler	New Ellenton	1405

Migrant Family	Schoolchild	New Ellenton	2190
	Teenager	New Ellenton	2946
	Adult Male	New Ellenton	2774
	Adult Female	New Ellenton	2062

Inhalation Rates For Each Age Group (m^3/year breathed)

Inhalation - Exposure Factors Handbook Table 5-23

Age/Gender Group	Long-Term Mean Recommended Value m3/d	m3/yr	GENII Categories	Weighted Average m3/yr		x 0.0119				
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Children 1-2	6.8	2482	Preschool 1-5	2,811	0.0119	33	2,777			
Children 3-5	8.3	3029.5			0.0119	-	-			
Children 6-8	10	3650	Schoolchild 6-12	4,380	0.0119	52	4,328			
Children 9-11 Male	14	5110			0.0119	-	-			
Children 12-14 Male	15	5475	Teen	5,892	0.0119	70	5,822			
Children 15-18 Male	17	6205			0.0119	-	-			
Adults 19-65+ Male	15.2	5548	Adult Male	5,548	0.0119	66	5,482	0.73214286	4,062	1,486
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	Adult Male	Augusta	4281
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	Teenager	Martin	206
	Teenager	Barnwell	5686
	Adult Male	Martin	194
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Outdoors Person	Infant	Jackson	1643
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Family Living Near River	Infant	Martin	1643
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	Schoolchild	Martin	4380
	Teenager	Martin	5892
	Adult Male	Martin	5548
	Adult Female	Martin	4125
	Infant	New Ellenton	821
	Preschooler	New Ellenton	1405

Migrant Family	Schoolchild	New Ellenton	2190
	Teenager	New Ellenton	2946
	Adult Male	New Ellenton	2774
	Adult Female	New Ellenton	2062

APPENDIX R BASIS FOR DETERMINING ISOTOPIC FRACTIONS FROM SRS ENVIRONMENTAL REPORTS FOR PERFORMING RADIOLOGICAL DOSE ASSESSMENTS

The quantification of environmental releases on an isotopic basis is needed to perform radiological dose assessments. Each isotope has a different half-life, thus making its contribution to the total radioactivity released from the site different from other isotopes. Each isotope also has a unique dose conversion factor, making it important to know the specific isotopes released to conduct the radiological dose assessments. Because a number of constituents are not delineated by isotope in environmental release reports, assumptions need to be developed based on nuclear physics and knowledge of the process history of the SRS facilities.

Throughout much of the history of the Savannah River Site (SRS), technology and programmatic limitations have restricted the ability to differentiate environmental releases on an isotopic basis. Gross alpha (α) and gross beta + gamma ($\beta + \gamma$) measurements were primarily used to measure radioactive releases (1) to the air, seepage basins, and surface waters in many facilities. SRS has historically had a practice of reporting specific isotopes from the gross alpha/beta/gamma measurements if the isotopes are known to be in the effluent (2).

This appendix provides the technical basis and assumptions for quantifying environmental releases by isotopes that have not been specifically identified in SRS environmental reports.

R.1 Constituents

As stated above, the environmental release reports being used for the radiological dose assessments do not, in some cases, delineate individual isotopes but instead show total radioactivity for a combination of isotopes (or constituent). Constituents shown in various SRS environmental reports whose total radioactivity needs to be fractioned into individual isotopes include:

- ^{89}Sr, ^{90}Sr
- ^{95}Zr, ^{95}Nb
- ^{134}Cs, ^{137}Cs
- Uranium
- Plutonium
- Unidentified alpha
- Unidentified beta + gamma

Technical information and general assumptions for determining the fraction an individual isotope contributes to the total radioactivity of the constituent are described below with more detailed application to site facilities as applicable. When appropriate, each of the above constituents is analyzed on the basis of the process to which it is related to determine the fraction of the activity to be designated to individual isotopes. Table R-1 summarizes how the radioactivity of each constituent should be fractioned for the applicable SRS site areas.

Table R-1 Summary of Assumed Isotopic Distributions

Constituent	SRS Area	Isotopic Distribution (by Curies)
$^{89, 90}$Sr	F&H Areas	75% ^{89}Sr; 25% ^{90}Sr
	A Area	100% ^{90}Sr
	D Area	100% ^{90}Sr
	Central Shops	100% ^{90}Sr
^{95}Zr, ^{95}Nb	Reactor Areas	35% ^{95}Zr; 65% ^{95}Nb
	F, H, and D Areas	31% ^{95}Zr; 69% ^{95}Nb
$^{134, 137}$Cs	D Area	100% ^{137}Cs
Uranium	Reactor Areas	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	F Area	1.27% ^{235}U; 98.73% ^{238}U
	H Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
	M Area	Air emissions: 49.49% ^{234}U; 2.25% ^{235}U; 48.26% ^{238}U Liquid emissions: 1.27% ^{235}U; 98.73% ^{238}U
	A Area (SRL)	91.44% ^{234}U; 1.8% ^{235}U; 6.4% ^{236}U; 0.36% ^{238}U
	CMX/TNX	49.49% ^{234}U; 2.25% ^{235}U; 48.26% ^{238}U
	D Area	91.73% ^{234}U; 1.79% ^{235}U; 6.45% ^{236}U; 0.03% ^{238}U
Total Plutonium	All Areas	100% ^{239}Pu
Unidentified Alpha	All Areas	100% ^{239}Pu
Unidentified Beta + Gamma	All Areas	100% ^{90}Sr

R.2 Isotopic Fraction Evaluation

R.2.1 $^{89, 90}$Strontium ($^{89, 90}$Sr)

^{89}Sr and ^{90}Sr are shown together in the Cummins et al. historical report as a single constituent (1) for liquid releases from SRL to seepage basins, liquid releases from D Area to streams, atmospheric releases in F and H Areas, and liquid releases to seepage basins in Central Shops. It is necessary to determine what curie fraction contributes to the total value reported for each of these facilities and environmental pathways.

^{89}Sr and ^{90}Sr are fission products generated from the bombardment of ^{235}U, ^{238}U, and ^{239}Pu with neutrons. Carlton et al. calculated the number of curies related to the generation of ^{89}Sr and ^{90}Sr in the production reactors, assuming a typical fuel element composition. The number of curies associated with each of these strontium isotopes is summarized in Table R-2.

Based on Table R-2, the percentage of curies of $^{89, 90}$Sr associated with ^{89}Sr is calculated and presented in Table R-3.

Table R-2 Accumulated Fission Yields (3)

Isotope	Half-Life	Curies Remaining at Various Times After End of Irradiation				
		0 seconds	24 hours	100 days	200 days	2 years
^{89}Sr	53.21 days	9.080E7	8.962E7	2.468E7	6.707E6	6.685E3
^{90}Sr	28.28 years	2.219E6	2.219E6	2.204E6	2.189E6	2.113E6

Table R-3 Percentage of ^{89}Sr to the Total Curies Associated with ^{89}Sr, ^{90}Sr

Isotope	0 seconds	24 hours	100 days	200 days	2 years
^{89}Sr	98%	98%	92%	75%	0.3%

The percentages in Table R-3 are used to determine the fraction of ^{89}Sr and ^{90}Sr assumed to be released for the situations in which releases are shown for the combined ^{89}Sr, 90 data as following:

Separations Areas: Fuel and target elements were stored in the reactor basins for a nominal period of 200 days after completion of irradiation before being processed in F and H Areas (3). For F and H Areas, it should be assumed that the environmental releases to the atmosphere occur 200 days after completion of irradiation in the reactors. $^{89, 90}$Sr atmospheric releases should therefore be fractioned to 75% ^{89}Sr and 25% ^{90}Sr for these releases.

Administration Area (A): Environmental releases of $^{89, 90}$Sr in A Area are attributed to releases from SRL to the SRL seepage basins. SRL conducted research using various forms of uranium and plutonium. Strontium isotopes were generated as a result. SRL also worked with Cf-252 for several years, and ^{90}Sr is daughter product of this isotope. It cannot be determined to what proportion ^{89}Sr to ^{90}Sr was generated by operations at SRL; therefore it should be assumed that all of the environmental releases attributed to ^{89}Sr, 90 are attributed to ^{90}Sr for conservatism in dose calculations since ^{90}Sr has higher inhalation and ingestion dose conversion factors than ^{89}Sr.

D Area: D Area was used to separate light water from used moderator from the reactors (3). This process can be assumed to occur within one year after receipt of the moderator from the reactors. It is unclear as to how long the moderator was typically removed from the reactor before it was processed in D Area; therefore it should be assumed that all of the environmental releases attributed to $^{89, 90}$Sr are attributed to ^{90}Sr for conservatism in dose calculations since ^{90}Sr has higher inhalation and ingestion dose conversion factors than ^{89}Sr.

Central Shops: The Central Shops (CS) were used for repairing equipment from the reactors and separations areas. Prior to repair of the equipment, the equipment was cleaned with water. The discharge water was discharged to seepage basins. The discharge of the water is assumed to occur approximately 2 years after the $^{89, 90}$Sr contained in the discharge water was originally generated. The curie content of $^{89, 90}$Sr from Central Shops should therefore be attributed to ^{90}Sr for conservatism in dose calculations.

R.2.2 Zirconium-95, Niobium-95 (^{95}Zr, ^{95}Nb)

^{95}Zr and ^{95}Nb are fission products. ^{95}Nb is also the only daughter product of ^{95}Zr. ^{95}Zr has a half-life of 64.02 days and ^{95}Nb has a half-life of 34.975 days. Table R-4 shows that these isotopes are initially generated as fission products in equal mass amounts (4).

Table R-4 Accumulated Fission Yields

Fissile with Neutron Energy	Accumulated Yield	
	^{95}Zr	^{95}Nb
^{235}U with 0.0253 eV	0.06	0.06
^{235}U with 1.0 MeV	0.06	0.06
^{238}U with 1.0 MeV	0.05	0.05
^{239}Pu with 0.0253 eV	0.05	0.05
^{239}Pu with 1.0 MeV	0.05	0.05

Equation 1 can be used to determine the initial curie content in the production reactors assuming equal masses of ^{95}Zr and ^{95}Nb are produced in the reactors and assuming the reactors operate with neutron thermal energies shown in Table R-4:

$$A = \lambda N \qquad \text{(Eq. 1; (5))}$$

at t (time) = 0; A is the activity; λ is the radioactive decay constant; and N is the number of atoms. At any time t greater than 0, equation 2 applies:

$$A(t) = A_0 e^{-\lambda t} \qquad \text{(Eq. 2; (5))}$$

Since the fission yields (the number of atoms emitted) of ^{95}Zr and ^{95}Nb are equal, their contribution to the gross activity of ^{95}Zr, ^{95}Nb is calculated to be 35% for ^{95}Zr and 65% for ^{95}Nb immediately upon their generation in the reactor.

The half-life of the daughter is less than (but not much less than) the half-life of the parent isotope. The time (t_{max}) at which the maximum activity of ^{95}Nb will occur, based on its production from the decay of ^{95}Zr, is 67 days, calculated from the following equation ((5)):

$$t_{max} = \frac{\ln \frac{\lambda_{Nb}}{\lambda_{Zr}}}{\lambda_{Nb} - \lambda_{Zr}} \qquad \text{(Eq. 3; (5))}$$

After 67 days, the activity of ^{95}Nb begins to decline at the same rate as the decline in activity of ^{95}Zr (this is called transient equilibrium). This ratio can be calculated by the following ((5)):

$$\frac{A_{Nb}}{A_{Zr}} = \frac{\lambda_{Nb}}{\lambda_{Nb} - \lambda_{Zr}} = 2.2 \qquad \text{(Eq. 4; (5))}$$

Based on the decay chain and the calculated ratio after the 67 day maximum, the ratio of isotopic activity approaches a constant value where 31% of the total activity is due to ^{95}Zr and 69% of the activity is due to ^{95}Nb. These percentages are appropriate for operations which would occur after the removal of the fuel and targets from the reactors. By SRS process area, then, the following isotopic fractions can be used:

Reactor Areas:	35% ^{95}Zr	65% ^{95}Nb
All other areas:	31% ^{95}Zr	69% ^{95}Nb

These assumed values are based on assumptions that are meant to best reflect actual operating conditions and environmental releases. Carlton and Denham, in determining the potential dose to individuals from these same isotopes, used more conservative assumptions that are based on the impact on dose (6).

R.2.3 $^{134, 137}$Cesium ($^{134, 137}$Cs)

The cesium isotopes were generated at SRS as fission products and, in the case of ^{137}Cs, was at times isolated for further use as an energy source. The combined constituent $^{134, 137}$Cs is shown (1) in environmental releases in D-Area. ^{134}Cs has a half-life of 2.06 years while ^{137}Cs has a half-life of 30.07 years. Table R-5 shows the yield of ^{134}Cs and ^{137}Cs that is assumed for reactor operations (4).

Table R-5 Accumulated Fission Yields

Fissile with Neutron Energy	Accumulated Yield	
	^{134}Cs	^{137}Cs
^{235}U with 0.0253 eV	0.0000001	0.06
^{235}U with 1.0 MeV	0.0000005	0.06
^{238}U with 1.0 MeV	0.000000003	0.06
^{239}Pu with 0.0253 eV	0.00001	0.07
^{239}Pu with 1.0 MeV	0.00001	0.07

Because the fraction of ^{134}Cs is so small, ^{137}Cs is expected to contribute to nearly 100% of the activity of the combined constituent $^{134, 137}$Cs. The activity measured for this constituent should therefore be attributed to ^{137}Cs.

R.2.4 Uranium ("U-Nat", or "$^{235, 238}$U")

The relative abundance of the various uranium isotopes in air and water releases from SRS facilities is dependent on a number of factors. The primary factor is the enrichment level of the uranium being handled at the facilities. Enrichment increases the relative abundance of the lower weight isotopes (^{234}U and ^{235}U) and decreases the proportion of the higher weight isotopes (^{238}U). A second factor is whether the uranium has been subjected to neutron radiation (in a reactor). Reactor irradiation would result in the production of ^{236}U. While it is fairly certain that the uranium at SRS facilities, in particular the reactors and separations facilities, were irradiated in reactors, there is only limited information on the enrichment levels of uranium in these and other facilities. Therefore, the analysis of the isotopic composition of uranium found in air and water discharges is largely based on general assumptions. However, due to two key properties of the various uranium isotopes, changes to the composition will not have a substantive effect on the results of the SRS dose reconstruction. The first key property is half-life. All of the uranium isotopes have very long half-lives (240,000 years and longer) in comparison to the period being studied (~40 years). Therefore, radioactive decay will not have a significant effect on the relative abundance of the isotopes after they are released. The second key property is the dose conversion factor. The dose conversion factors for the uranium isotopes fall within a ~15% range; therefore, the doses received from equal amounts of the different isotopes will be about the same (+/- ~15%).

Until the mid-1990s, alpha-emitting radioisotopes were detected using instrumentation that measured gross alpha. This gross alpha count was attributed to a combination of primarily uranium and plutonium. The fraction of the gross alpha assigned to each of these elements varied depending on the facility or process emitting the alpha radioactivity. In M Area where reactor fuel was manufactured, alpha radioactivity was solely attributed to uranium. When dose calculations were conducted, assumptions were

made as to the type of uranium present (natural, enriched, or depleted), with the corresponding isotopic fractions used (7). This approach is used below to estimate the curie fraction of each uranium isotope for the applicable SRS facilities.

In Cummins report, "U-Nat" (natural uranium) represents "$^{235, 238}$U" (1). ^{235}U and ^{238}U represent the majority of the mass of naturally occurring uranium. It should not be assumed, however, that all uranium measured in environmental releases at SRS is natural uranium. Despite the nomenclature being used in Cummins report, uranium actually occurs in three basic forms in the SRS environment: natural, depleted, and enriched. Natural uranium is processed to remove ^{238}U so that a higher concentration of ^{235}U is achieved, thus creating enriched uranium. The enrichment process creates a byproduct called depleted uranium. Depleted uranium is either disposed as a waste or reused in target materials for producing plutonium isotopes. Evans et al. provides approximate isotopic compositions for each of these waste forms, shown in Table R-6 (2). Note that for enriched uranium, two basic types of fuel were manufactured and used at SRS: Type M and Type F. Since it is unclear as to how much Type M fuel versus Type F fuel was used, Table R-6 shows an average isotopic composition for enriched fuel, assuming the same mass of Type M and Type F fuel. Note that these compositions include ^{234}U and ^{236}U. While the original data sources only reference ^{235}U /^{238}U, it is assumed that these other uranium isotopes are also present.

Table R-6 Isotopic Composition of Savannah River Uranium Wastes (2)

Isotope	Isotopic Composition (wt %)**			
	^{234}U	^{235}U	^{236}U	^{238}U
Half-Life (years)*	2.45E+5	7.03E+8	2.34E+7	4.47E+9
Natural	0.0055	0.7200	n/a	99.2745
Depleted	n/a	0.2	n/a	99.8
Enriched***	1.45	81.55	9.8	7.2

* Source [KAERI, 2003], (4).
** Source Evans et al., (2)
*** Average of Isotopic Composition for Type M and Type F fuels

Using the above weight percentages, the contribution to the activity for each isotope is calculated using Equation 1 and presented in Table R-7.

Table R-7 Activity Fraction for Specific Isotopes in Uranium Wastes

Isotope	Activity Fraction (%)			
	^{234}U	^{235}U	^{236}U	^{238}U
Natural	49.49	2.25	n/a	48.26
Depleted	n/a	1.27	n/a	98.73
Enriched	91.73	1.79	6.45	0.03

These activity fractions can be used in the dose assessments, taking into account the prevalent form of uranium in each process area at SRS at the time of release, as presented below.

Reactor Areas: Any environmental releases of uranium in the reactor areas to streams and seepage basins are assumed to occur after the storage of spent fuel (containing enriched uranium) and target materials (containing depleted uranium) in spent fuel basins and disassembly basins (2). Basin purge water was normally discharged to the plant streams and seepage basins along with the reactor secondary cooling water. Uranium releases from the reactors to the atmosphere occurred due to the venting of

"harps" (storage containers located underwater in the reactor basin which contained failed fuel and target elements) to the reactor stack (6). The ratio of enriched to depleted uranium that was used in the production reactors is not known and cannot be calculated. Since it can be assumed that there was most likely more enriched uranium, on a mass basis, than depleted uranium that was used in the reactors, the fraction of uranium isotopes in Table R-7 for enriched uranium should be used for environmental releases from the reactors.

Separations Areas: Based on Evans et al., the F Area facilities primarily isolated ^{239}Pu from ^{238}U target material comprised of depleted uranium. The curie fraction in Table R-7 associated with depleted uranium should therefore be used for environmental releases from F Area. In H Area, ^{235}U was recovered from enriched fuels. According to Evans et al., enriched fuel in H Area could contain from 1.1% to 94% ^{235}U (2). The curie fraction in Table R-7 associated with enriched uranium should therefore be used for environmental releases from H Area.

M-Area: The fuel and target materials used in the reactors were fabricated in M-Area. Atmospheric releases of uranium were very small compared to the releases in F Area. Based on Evans et al., these releases were in the form of natural and depleted uranium, although it is unclear to what proportion these two forms of uranium were released (2). For the purposes of this study, natural uranium fractions from Table R-7 should be assumed for atmospheric releases since ^{234}U is known to have been emitted and is present in natural uranium in measurable quantities. Depleted uranium has been found in stream sediments (2), so curie fractions for depleted uranium from Table R-7 should be used for all liquid releases.

A Area (SRL): SRL worked with all forms of uranium and there is no method for determining the quantity of each form used; therefore an average of the activity fractions for all three forms of uranium may be used, assuming an equal mass of natural, depleted, and enriched uranium was released. This assumption results in the following percentages of uranium isotopic activity: 91.44% for ^{234}U; 1.8% for ^{235}U; 6.4% for ^{236}U; and 0.36% for ^{238}U.

CMX/TNX: Some natural uranium was used in fuel and target development at TNX (2). Activity fractions from Table R-7 for natural uranium should therefore be used.

D Area: The rework of degraded moderator from reactor areas was the most likely source of alpha activity, which is assumed to be uranium (2). The moderator most likely contained a mixture of uranium isotopes representing both depleted and enriched uranium. To be consistent with the assumptions for the reactor areas, activity fractions from Table R-7 for enriched uranium should be used for environmental releases in D Area.

R.2.5 Plutonium

^{238}Pu, ^{239}Pu and ^{240}Pu were the primary plutonium isotopes of interest in environmental releases at SRS. ^{239}Pu and ^{240}Pu were often reported as ^{239}Pu since these two isotopes are indistinguishable in alpha spectroscopy measurements (8). All three of these isotopes were produced by the reactors and were present in the F and H Area processes. The most common form of plutonium produced at SRS was weapons-grade plutonium. Weapons-grade plutonium had an isotopic composition similar to that shown in Table R-8.

Table R-8 Isotopic Composition of Weapons-Grade Plutonium (9)

	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu*	^{242}Pu
Mass Fraction (9)	0.00012	0.938	0.58	0.0035	0.00022
Activity Fraction (using Equation 1)	0.0047	0.1337	0.0302	0.8313	0.0000

* ^{241}Pu plus ^{241}Am

Despite comprising a very small mass fraction of weapons-grade plutonium, ^{241}Pu (plus its daughter product ^{241}Am) contributes approximately 83% to the curie content. ^{241}Am is addressed as a separate constituent; therefore ^{241}Pu is indirectly addressed in the dose assessments. Also, the dose contribution of ^{241}Pu is approximately 100 times less than ^{238}Pu, ^{239}Pu and ^{240}Pu. Since ^{239}Pu was the primary plutonium product at SRS and it has nearly identical dose conversion factors with ^{238}Pu and ^{240}Pu, all "Total Plutonium" releases to the environment can be assumed to be ^{239}Pu.

R.2.6 Unidentified α/Unidentified β + γ

As mentioned in the beginning of this appendix, many of the radioactive releases at SRS were detected with gross α and gross β + γ measurements. If the isotopes were known due to process knowledge, then the measurements were assigned to the isotopes in the environmental release reports. If the isotopes were not known, then the environmental release reports reflected unidentified α and unidentified β + γ measurements (2). The unknown constituents comprising unidentified α and unidentified β + γ measurements most likely were a combination of several isotopes.

Since SRS could not assign the unidentified α and unidentified β + γ measurements to specific isotopes, it is not possible to proportion these measurements among several isotopes for this effort. These unidentified measurements can be attributed, however, to a single isotope to allow for a conservative estimate. In the case of unknown α, the unidentified α will be assigned to ^{239}Pu. ^{239}Pu has greater dose conversion factors than the uranium isotopes for many of the exposure pathways. ^{239}Pu is also one of the more prevalent plutonium isotopes at SRS. Other transuranic isotopes have been produced and used at the SRS (such as ^{237}Np, ^{244}Cm and ^{252}Cf) that have contributed to the measurement of unidentified α, but these isotopes were primarily produced during brief periods and have dose conversion factors 100 to 1000 times less than ^{239}Pu. Using ^{239}Pu for unidentified alpha values therefore is the most conservative assumption.

Many isotopes could contribute to the unidentified β + γ measurements. For conservatism, the unidentified β + γ measurements will be attributed to ^{90}Sr. Commonly found in environmental releases throughout the facilities at SRS, ^{90}Sr has dose conversion factor values 10 to 100 times higher than the other beta and gamma emitting isotopes of concern. With a half-life of 28 years, ^{90}Sr will also remain in the environment longer than most of the other beta and gamma emitting isotopes of concern.

R.3 References

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APPENDIX S ESTIMATION OF RIVER FLOW RATE FOR LOWER THREE RUNS CREEK AT MARTIN, SOUTH CAROLINA

S.1 Background

As part of CDC's SRS Dose Reconstruction Project, ATL has included exposure pathways to surface water contaminated with water discharges from SRS. One of the CDC-specified exposure locations occurs on Lower Three Runs Creek at the town of Martin, South Carolina (LTRC-Martin). To calculate exposure, data are needed in two areas: (1) the flowrate of the creek at LTRC-Martin and (2) the quantities of radionuclides discharged. This analysis addresses the approach for determining flowrates at LTRC-Martin and presents the methodology, assumptions, and analytical results (1).[1]

The modeling approach for this project requires the use of constant annual creek flowrates and constant annual releases. Therefore, an average annual creek flowrate value is needed for each year of modeled releases, from 1954 to 1992. Because direct measured flowrate data for LTRC-Martin do not appear to be available, ATL estimated flowrates based on other available flowrate measurements (2) (3).[2]

S.2 Analysis

ATL identified two sets of data usable in estimating 1954-1992 LTRC-Martin average flowrate values:

- LTRC-Snelling monthly flowrate data for 1974 – 2001 (4).
- LTRC-Martin monthly flowrate data for 1998 – 2001 (2).

USGS flowrate monitoring station at LTRC-Snelling is located approximately 6 miles downstream of the Par Pond dam and 8 miles upstream of the LTRC-Martin flowrate monitoring station (See Figures 1 and 2).

When comparing the monthly flowrate data from LTRC-Martin to LTRC-Snelling for 1998 to 2001, it was observed that the flowrate at Martin was generally twice the flowrate at Snelling. This ratio can be used to estimate the flowrate of LTRC-Martin based upon the data obtained for the LTRC-Snelling using the following basic formula:

[LTRC-Martin Flowrate] = [LTRC-Snelling Flowrate] x [Martin-to-Snelling Ratio]

The ratios calculated by comparing the monthly flowrate at LTRC-Martin and LTRC-Snelling are shown in Attachment 2. In calculating the Martin-to-Snelling ratio, only data from 1998 to 2000 is considered since no data is available at Martin for October, November, and December, 2001, omitting an entire season of data. However, a review of the 2001 LTRC-Martin monthly flowrates shows them to be comparable to those for 1998 to 2000. The calculated ratios are summarized in Table S-1.

The standard deviation and corresponding percent error show that the average ratio is relatively consistent over the 1998 – 2000 period, taking into account possible seasonal and annual fluctuations for this time period.

[1] Data on the quantities of discharged radionuclides used in this analysis are based on Risk Assessment Corporation 2001 and supporting references.
[2] USGS monitoring data for LTRC-Martin for 1954-1992 are not available (2). SRS also does not have LTRC-Martin flowrate data (3).

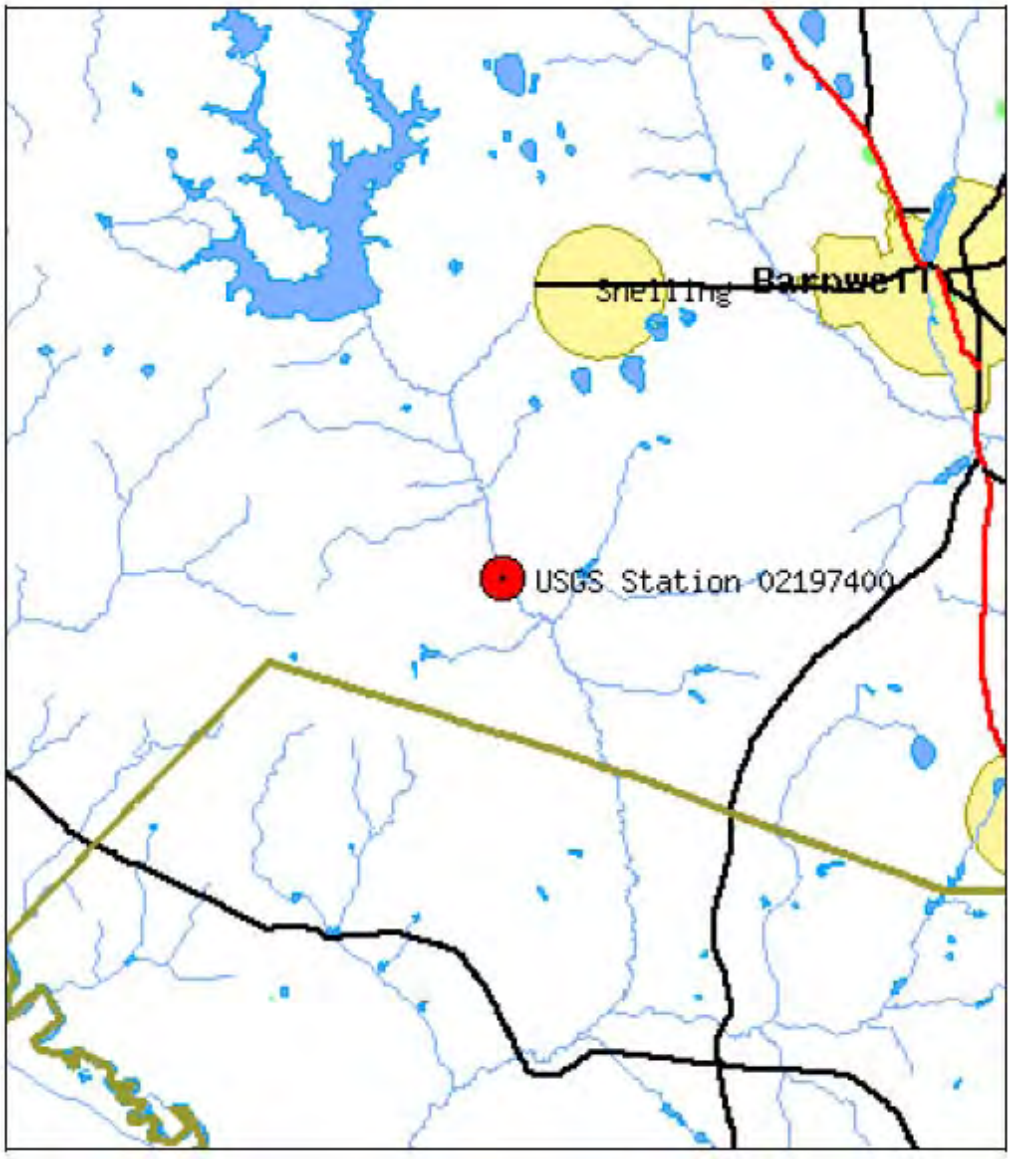

Figure S-1 LRTC-Snelling Monitoring Station Location

Figure S-2 LRTC-Martin Monitoring Station Location

Table S-1 Average Ratio of Monthly Flowrate Data

Martin:Snelling from 1998 to 2000	Standard Deviation	Percent Error
2.2	0.3	16.0%

1974 – 1992 Flowrates. For the purposes of dose reconstruction, it is assumed that the average Martin-to-Snelling ratio is applicable for the entire project study period. Attachment 3 shows the calculated monthly and annual flowrates at LTRC-Martin for the 1974 – 1992 period, based on the measured monthly flowrates at LTRC-Snelling during the 1974 – 1992 period and the average Martin-to-Snelling ratio. The calculated annual flowrate value is used as the LTRC-Martin flowrate in the dose reconstruction modeling calculations.

1954 – 1973 Flowrates. The approach described above was suitable for the 1974 – 1992 period because flowrate measurements for LTRC-Snelling were available for this period. To estimate flowrates for the first part of the modeled period (no flowrate measurement data for the 1954 – 1973 period are available), this approach had to be adjusted.

For this calculation, , it was assumed that the monthly flowrate at LTRC-Snelling during the 1954 – 1973 period was equal to the average monthly flowrate during the 1974 – 1992 period (calculated in Attachment 1). LTRC-Martin flowrates for this period were then calculated using the 1974 – 1992 average monthly flowrate and the previously calculated Martin-to-Snelling ratio. The resulting LTRC-Martin monthly and annual flowrates for the 1954 – 1973 period are shown in Attachment 3.

Data Gaps. In applying the approaches described above, two minor data gaps had to be addressed. Flowrate measurements for LTRC-Snelling were not available for January, February, and March of 1974, and October of 1984, as shown by shaded cells in Attachment 1. For the 1974 data gap, it was assumed that the average monthly flowrates for the corresponding months for the period 1975 to 1992 could be applied to 1974. For the 1984 data gap, it was assumed that the October 1984 flowrate is the average of the flowrate of September and November for that year. Data gaps for January through May of 1997, and October through December of 2001 are not addressed because flowrates are not required for these time periods to determine flowrates at LTRC-Martin from 1954 through 1992.

S.3 References

1. RAC, 2001. Risk Assessment Corporation. Final Report, Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released from Savannah River Site. U.S. Centers for Disease Control and Prevention. April 30, 2001.

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4. USGS, 2003b. Monthly Streamflow Statistics for South Carolina, USGS 02197400 Lower Three Runs near Snelling, SC [online]. 2003b. [cited 2003 March 28]. Available from URL: *http://waterdata.usgs.gov/sc/nwis/monthly/?site_no=02197400*

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APPENDIX T DECISION DOCUMENTS

The following decision documents present the rationale and bases for decisions and processes used in the development of the doses and risks calculated for each of the four hypothetical individuals (family members) comprising each of the seven exposure scenarios:

- Attachment A - Adjustment of Dose Conversion Factors and Risk Factors
- Attachment B - An Approach to Source Terms for the Surface Water Pathway
- Attachment C - Base Case Values for Exposure Activity and Usage Factors for the CDC SRS Dose Reconstruction Project
- Attachment D - Comparison of Phase II and Phase III Source Terms for Water Releases
- Attachment E - Basis for Determining Isotopic Fractions from SRS Environmental Reports for Performing Radiological Dose Assessments
- Attachment F - Soil-to-Water Distribution Coefficients for Radionuclides Considered in the Dose Reconstruction of Savannah River Site
- Attachment G - Documentation for GENII Model Parameters Used in SRS Base Case Calculation
- Attachment H - Base Case Values for Receptor Activity and Usage Factors for the CDC SRS Dose Reconstruction Project
- Attachment I - Proposed Values of Transfer, Bioconcentration, and Bioaccumulation Factors Used for Modeling Dose Reconstruction for Historical Releases from the U.S. Department of Energy Savannah River Site
- Attachment J - Treatment of Radionuclide Concentrations in Wild Game in Dose Reconstruction Modeling

Attachment A - Adjustment of Dose Conversion Factors and Risk Factors

The following describes the appropriate factors to correct the doses and risks contained in the GENII-V2 output files. The GENII-V2 output files were generated assuming an adult. Therefore the calculated doses and risk results have to be corrected for the receptor's current age. The Federal Guidance 13 dose and risk factors are divided into three groups of factors by isotope: external, ingestion and inhalation. Each of these groups is further divided into several groups. The external is divided into submersion in the cloud (Sv per Bq-s/m3), exposure to ground plane (Sv per Bq-s/m2) and exposure to soil volume (Sv per Bq-s/m3). Data is presented by isotope and by organ but only for the adult. The ingestion factors for each isotope and organ are divided into drinking water and dietary intakes and are presented by age group ({0 – 5 yr}, {5 – 15yr}, {15 - 25yr}, and {25 - 70yr}). The generally, the inhalation factors for each isotope and organ are divided into three particulate inhalation classes (F, M, and S) by organ and by age group. The inhalation class used is based on the class selected for that isotope in the HEI modules.

It should be noted that several isotopes have more than one chemical form. Tritium has particulate, water vapor, elemental and organic bound. Carbon has particulate, monoxide, and dioxide. Sulfur has particulate, dioxide and Carbon disulfide. Iodine has a particulate, vapor form and methyl iodide. For tritium, the chemical forms other than the particulate are differentiated in GENII-V2 (H3 is tritium oxide, H3EL is elemental tritium and OBT is organic bound tritium).

The receptor age groups will be matched to the FGR-13 age groups as follows:

Receptor Age Group	FRG-13 Age Group
Infant	0 – 5 year
Preschooler	0 – 5 year
School Age child	5 – 15 year
Teenager	15 – 25 year
Adult	25 – 70 year

The procedure to adjust the dose and risk factors will be discussed by pathway and by isotope, if necessary.

External Exposure--Air Submersion

For air submersion doses there is no correction factor since FGR-13 only provides adult dose factors. For the air submersion risks, the GENII-V2 risks by isotope and by organ will be corrected by age groups (receptor age risk factor for external submersion divided by the adult risk factor for external submersion.) Note for all forms of tritium the air submersion dose and risk factors are zero.

External Exposure--Ground Plane

For the ground plane dose there is no correction factor since FGR-13 only provides adult dose factors. For risk, the GENII-V2 ground plane risks by isotope and by organ will be corrected by age groups (receptor age risk factor for ground plane divided by the adult risk factor for the ground plane.) Note for all forms of tritium the air submersion dose and risk factors are zero.

Ingestion

For all ingestion doses, the GENII-V2 doses by isotope and by organ will be corrected by age groups (receptor age dose factor divided by the adult dose factor.) For risks from drinking water, the GENII-V2 risks by isotope and by organ will be corrected by age groups (receptor age risk factor for drinking water divided by the adult risk factor for drinking water.) For risk from all other ingestion pathways, the GENII-V2 risks by isotope and by organ will be corrected by age groups (receptor age risk factor for dietary divided by the adult risk factor for dietary.) Note for Ar-41, the ingestion doses and risk factors are zero. For S-35, GENII-V2 uses the inorganic dose and risk factors

Inhalation

For the inhalation pathway, the doses and risks factors in FRG-13 are presented by lung inhalation classes of F, M or S. In addition, for some isotopes addition classes for gas or vapor are provided. For the inhalation doses, the GENII-V2 doses by isotope and by organ will be corrected by age groups (receptor age dose factor for lung class divided by the adult dose factor for lung class.) The lung class will be provided by a file relating the isotope name and lung class.

For C-14, if the class is “Gas”, GENII-V2 uses the dose and risk factors associated with monoxide. For I-131, if the class is “Vapor”, GENII-V2 uses elemental iodine factors. For S-35, if the class is “Vapor”, GENII-V2 uses sulfur dioxide factors.

FGR-13 Factors

The FGR-13 dose and risk factors will be contained in supplement files provided as input. The files will contain only data for the isotopes that could be used in the GENII-V2 (only about 30 isotopes out of more than 800 isotopes presented in FGR-13.)

Attachment B - An Approach to Source Terms for the Surface Water Pathway

1.0 INTRODUCTION

This paper describes a method by which ATL proposes to make adjustments to source term data to reflect uncertainties and loss mechanisms associated with transport in surface water at the SRS. The Phase II Report gives adjusted source term estimates for H-3, Sr-90, and Cs-137 which take into account uncertainties associated with a variety of parameters and processes that can affect the release and transport of the contaminants across the site and into the Savannah River. This paper proposes a method by which the results of the Phase II model for three radionuclides can be extrapolated to the other radionuclides of interest in the dose reconstruction.

Chapter 5 of the Phase II Report discussed how the accounting of releases to the surface water pathway ***at the point of release*** is not an accurate estimate of the actual releases from the SRS site to the Savannah River. In addition to direct releases to on-site streams, waters were released to seepage basins, which held the waste for some period of time. These waste waters would seep into the soil, and would eventually reach the surface at the nearby streams. The southwestern edge of the SRS site, along the Savannah River, consists of a wetland, which slows the flow of water to the Savannah River, as well as acting as a sink for dissolved constituents that are sorbed or taken up by minerals, sediments, plants and other biota in the swamp. In addition to these physicochemical means of reducing the releases to the Savannah River, radioactive decay also affects the concentration of constituents that would reach the Savannah River.

As described in Chapter 5 of the Phase II Report a relatively simple model was used to estimate the releases to the Savannah River as affected by the various sinks, delay mechanisms, and uncertainties in the transport parameters. A sequence of Monte Carlo-style analyses developed ranges of annual releases for H-3, Sr-90, and Cs-137, based on concentrations of constituents measured at the sampling stations along Road A, the sampling point closest to the river. The effects of the various physical and chemical interactions of released radionuclides with the soil, biota, and other features of the SRS are expected to generally decrease the amount of radionuclides released to the Savannah River; on-the-other-hand, many of the uncertainties in measuring the releases, when incorporated into the Phase II model, increase the amount released. The Phase II model explicitly considers effects of the following factors:

1. Measurement uncertainty;

2. Retention of radionuclides in the swamp by sorption;

3. Release of previously retained radionuclides by periodic flooding of the swamp.

ATL has used the resultant medians (50th percentile) from the Phase II uncertainty analyses as representative of the results of the modeling and as a means for extrapolating the uncertainty analysis to those releases of radionuclides not modeled in Phase II. These adjusted releases will be used in the dose reconstruction analysis. Adjustment factors are developed for each year for three classes of radionuclides. These radionuclide classes encompass different ranges of K_D. The adjustment factors are the ratio of (1) the median of the Phase II modeling results for each year, respectively for H-3, Sr-90, and Cs-137 to (2) the total releases from the site for each year, respectively for each of these three radionuclides. The adjustment factors are applied to the annual releases of radionuclides for the liquid pathway; these annual releases are the sum of direct facility releases and migration from seepage basins. These annual releases have been derived from fundamental data (Cummins et al., 1991), but are consistent with the Phase II report. Different adjustment factors are used, depending on the radionuclide. The medians calculated in

Phase II Monte Carlo analysis for H-3and Cs-137 will be used directly for those nuclides. Since Sr-90 is being used to represent the health effects from annual releases of unidentified beta-gamma emitters, an additional adjustment is needed for releases of Sr-90. The adjustment factor derived for Sr-90 will be applied to the sum of (1) annual unidentified beta-gamma inventory plus (2) the annual Sr-90 releases. For all other radionuclides, the adjustment factor will be applied to the annual liquid-pathway release; adjustment factors derived for H-3, Sr-90, or Cs-137 will be used, depending on the K_D range most appropriate to the particular radionuclide.

2.0 COMPARISON OF UNCERTAINTY ESTIMATES WITH TOTAL RELEASES

ATL compared the annual median releases estimated by uncertainty analysis of surface water transport for H-3, Sr-90, and C-137 (from the Water_Releases.xls (RAC, 2001)) with the total releases from the facilities (Cummins et al., 1991). The results are presented in Appendix A. Part of the rationale for doing this comparison was to check whether the releases estimated by RAC were close in value to the total releases from the facilities. It was expected that the median values estimated by Phase II surface water uncertainty analysis model should be approximately equal to, or less than the total releases reported by SRS. With a few exceptions, this was the case. An example exception is that of the 1954 ratio of the estimated median release to the total reported for tritium. The ratio is 20.88. RAC stated in the Phase II report that it adjusted the releases if it believed that reported releases were too low. This extremely high ratio is probably a reflection of such an adjustment, since reporting of releases in the early years of operations was not as accurate as in later years.

The results of the comparison of the Phase II uncertainty analysis median values with the total release values are summarized in Table 1.

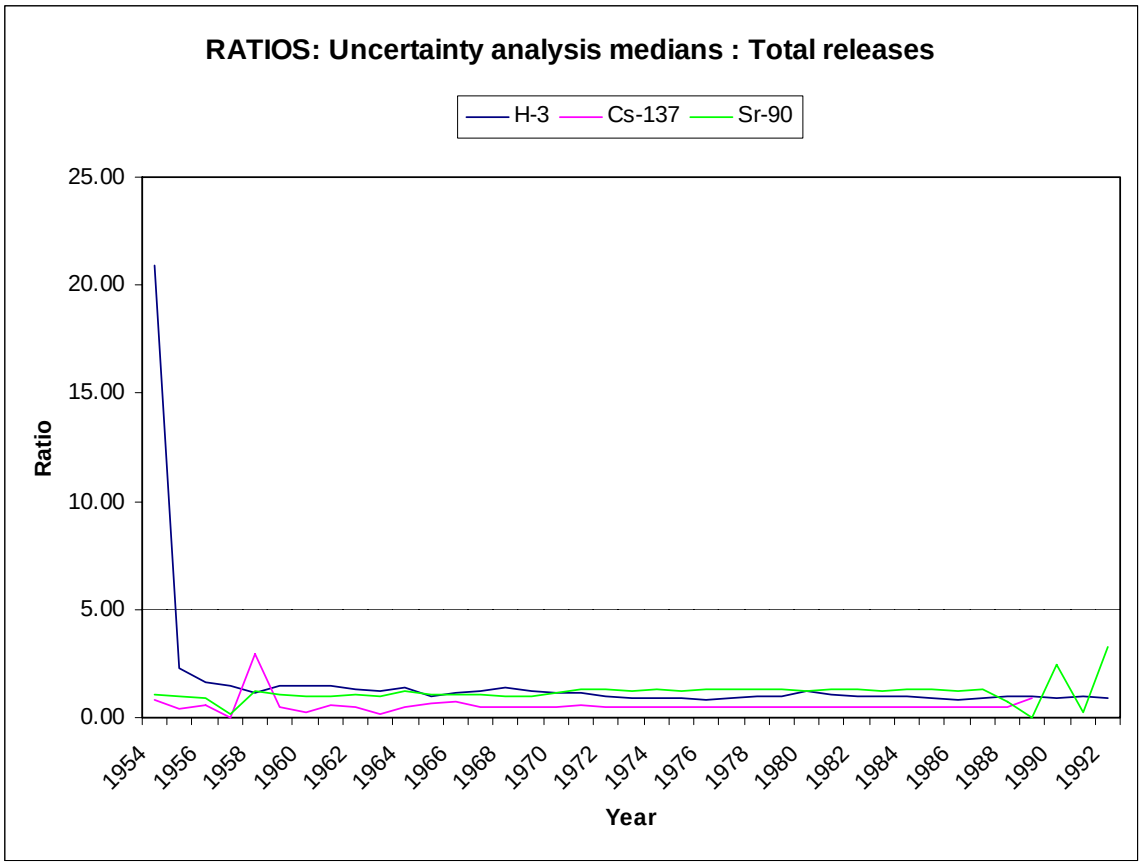
Table 1. Results of Comparison of the Median Values from the Phase II Uncertainty Analysis with the Total Releases from the SRS.

Radionuclide	Range of Median/Total Release Ratios	Mean Ratio
Median/Total Release		
H-3	0.78 – 20.88	1.13
Sr-90	0.02 – 3.25	1.16
Cs-137	0.02 – 2.95	0.57

If one considers the effect of mineralogy of SRS area soils, and the K_D for these species, the average ratio for Sr-90 appears to be "too low," while that for Cs-137 appears to be "too high." K_D values used in the Phase II modeling were orders of magnitude different from site-specific values recently reported by SRS (Kaplan, 2003 etc.; see ATL, 2003). Specifically, range of K_Ds with a median value of 10,000 were used for Cs, whereas the range of values of Sr had a median value of 100. Median K_Ds reported by Kaplan et al. for agricultural soils are 59 for Cs, and 3041 for Sr, respectively. However, another report by Kaplan reports K_D values that appear to be more appropriate for the swampy soils at issue in the holdup of radionuclides released from the SRS. For example, a "reasonably conservative" value for the K_D for Sr in the swamp is 1676. But, without further explanation of and examination of the Phase II model, it is difficult to say that the "apparent reversal" of Cs and Sr is due entirely to the use of inappropriate K_D values. Other uncertainties, such as measurement uncertainty and uncertainty in the release from the swamp during flooding were also considered in the estimation of releases for H-3, Sr-90, and Cs-137. These uncertainties are not the same from one radionuclide to another.

The ratios as a function of time are presented in Figure 1. Note that the ratios are dramatically higher during the early and last years of operations. The early years ratios may reflect inaccurate record keeping. The late years may reflect that operations in general were reduced, but there were still releases from the site. Note that the variations in time are significant. This is due, in part, to the model that increased releases in years with large spring floods to account for the remobilization of radionuclides stored in previous years in the sediments and biota of the swamp. For this reason, ATL has concluded that annual adjustment factors are required, rather than an average adjustment factor for all years.

Figure 1. Ratios of Uncertainty Median to Total Release for H-3, Sr-90, and Cs-137. Medians are estimated based on results provided in Phase II; Total releases are from Cummins et al. (1991). This graph does not include 1954 data for H-3.



3.0 THE EFFECT OF THE DISTRIBUTION COEFFICIENT K_D ON RELEASE

The distribution coefficient, or K_D, is a measure of the partitioning between solid and liquid phases that a particular nuclide experiences as it passes through geologic media. As radioactive contaminants move through the soils, sediments in surface water, and swamp at the SRS site, they will be attracted to various mineral surfaces. This attraction results in a delay (retardation) of the transport of the contaminant through the system, relative to the flow of water. The amount of a particular radionuclide that will reach the Savannah River will be in part, a reflection of this retardation phenomenon.

ATL has used the Phase II uncertainty analysis to estimate an adjustment factor for each year for each of the radionuclides modeled, tritium, Sr-90, Cs-137. ATL proposes to apply these annual adjustment factors to release values of other radionuclides, based on their K_D. Since the modeling was performed for

three radionuclides, with substantially different K_D values, the adjustment factor for each radionuclide modeled can be applied to radionuclides with similar K_D, values.

Figure 2 is a plot of the median/total ratios versus the median K_D used to characterize the appropriate releases; note this does not reflect the annual variations, but characterizes the overall 39-year historical trend.

Figure 2. Ratios of Uncertainty Analysis Median to Total Release vs. K_Ds

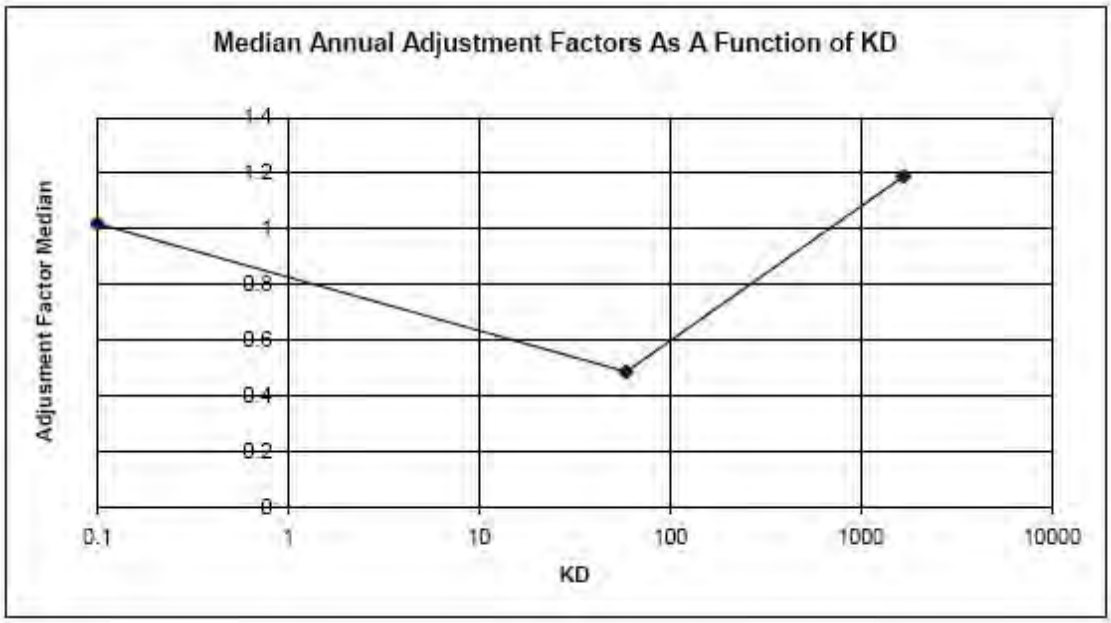


Table 2. Grouping of Radionuclides According to K_D Values; Identification of Annual Adjustment Ratios Used to Modify Release Data

Radionuclide	K_D (Values use to determine the K_D group are shown in bold)			Adjustment Factor (applied on an annual basis) [1]
	Phase II Value	Soil Value[2]	Swamp Value[3] (Reasonably conservative)	
H-3	**0**	0		H-3
I-129, 131		**1.55**		H-3
Tc-99		**2.49**		H-3
S-35		**7.5**		H-3
Ru-103, 106		**55**		Sr-90
Co-60		**60**		Sr-90
Sr-89, 90	**100**[4]	3040	1676	Sr-90
Nb-95		**160**		Sr-90
P-32		**173**		Sr-90
Zn-65		**200**		Sr-90
Ce-141, 144		490	**255**	Sr-90
Zr-95		**600**		Sr-90
U		1000	**170**	Sr-90
Pu		**4100**		Cs-137
Cs-134, 137	**10,000**[4]	59		Cs-137

1The annual adjustment ratios are provided in Appendix A.
2Kaplan et al., 2003
3Kaplan and Serkiz, 2000
4These values are problematic. They are significantly different from values measured for the SRS. The Sr-90 value is 1/10 that of the median for the reported range. The median value of 10,000 for Cs-137 is 1/10 that reportedly used in the Phase II uncertainty modeling.

4.0 COMPARISON OF MODELED TO MEASURED CONCENTRATIONS

Up to this point the discussion has compared modeled releases of radionuclides to the Savannah River versus measured releases from facilities. However, the important variable for dose reconstruction is the concentration of the radionuclides in the River. As part of developing an approach to dose reconstruction, ATL compared different methods for estimating the annual concentrations of radionuclides in the Savannah River to concentrations measured in the River. Such comparisons are not definitive for several reasons:

1. The measured concentrations are highly variable in time and may not be representative of an annual mean value;

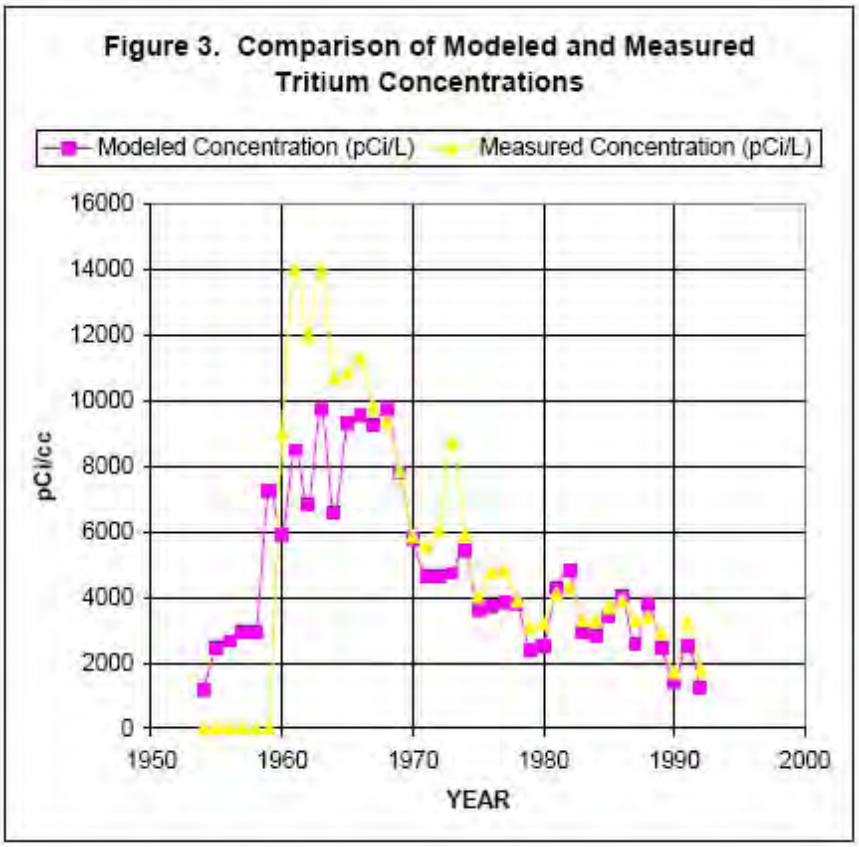
2. The measured concentrations were frequently made at or near the limits of detection for the instruments used;

3. The limits of detection changed in time;

4. Only a few radionuclides were measurable for a significant portion of the 39-year study period;

5. As described in the Phase II Report, the modeled releases are uncertain, because the exact behavior of the sediment, swamp, river, streams, and biota has not been precisely modeled and probably cannot be precisely modeled.

Nevertheless, it is instructive to compare the modeled and measured concentrations in the Savannah River. To obtain the modeled concentration, the median value of the modeled release for each year was divided by the flow rate measured by the USGS for that year in the Savannah River. This quotient is an estimate of the annual average concentration for each year. The measured concentrations were obtained from the annual Environmental Reports. Figures 3, 4, and 5 portray the comparison of modeled and measured concentrations for tritium, Cs, and Sr. Given all the uncertainties mentioned above, the agreement between modeled and measured concentrations is good. The significant deviation between modeled and measured concentrations for Sr from 1954-1963 results from recording the detection limit as the measured concentration for those years. It is difficult to identify the exact reasons for other significant deviations, without examination of the Monte Carlo modeling runs.



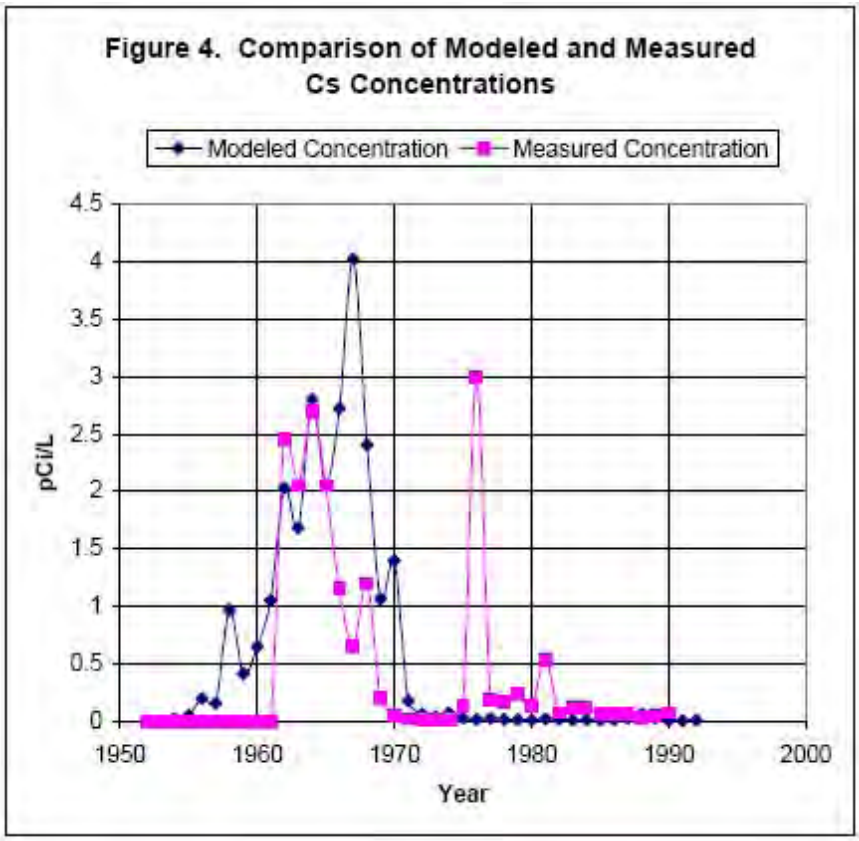
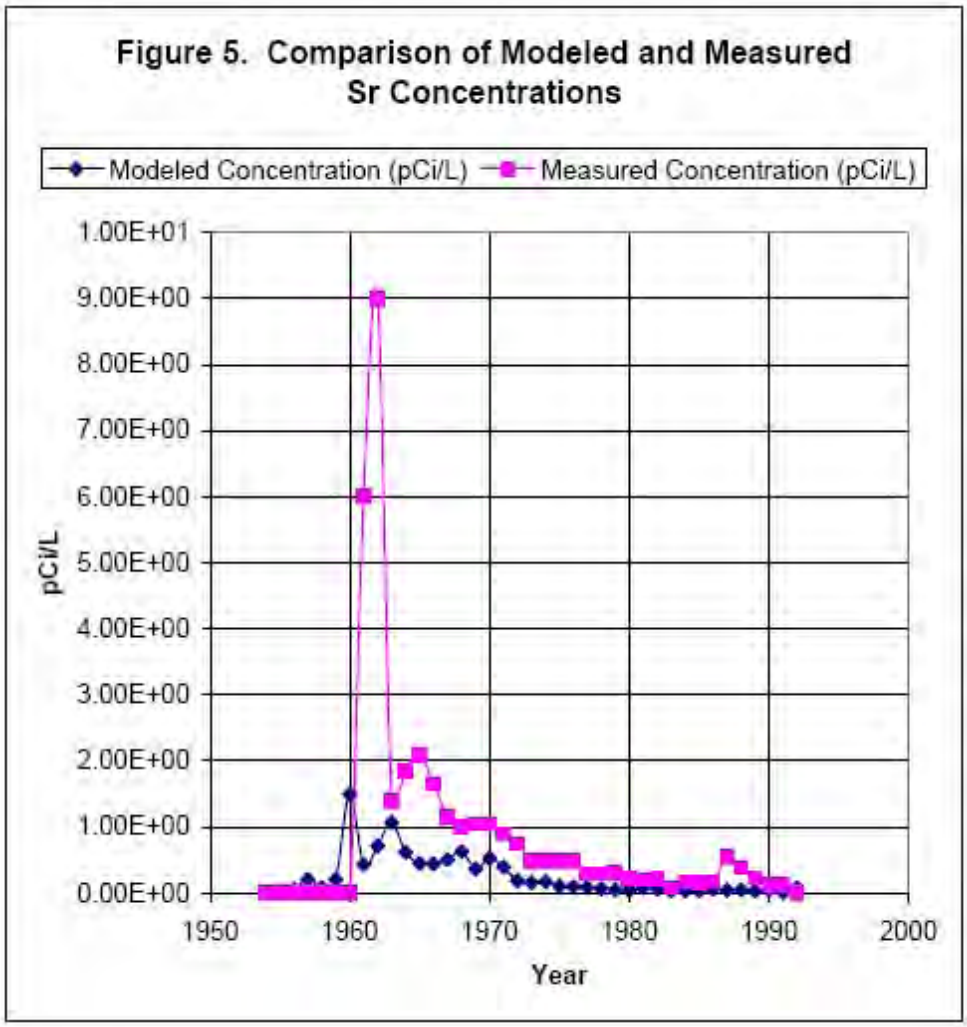


Figure 4. Comparison of Modeled and Measured Cs Concentrations
Modeled Concentration
Measured Concentration
pCi/L
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1950
1960
1970
1980
1990
2000
Year



5.0 SUMMARY

The adjustment factors that can be applied to total releases from the SRS to the surface water pathway are only a gross estimate of the loss of contamination during the transport process. Because of differences in the chemistry and the half-lives of each of the radioelement, the use of a K_D-based adjustment to the releases can result in over-estimation as well as underestimation of the releases to the Savannah River.

Two other alternatives to consider for adjusting the releases for use in the dose reconstruction computation are:

1) Do nothing; use the total releases as reported by Cummins et al. (1991), and supplemented by the annual SRS environmental reports. This approach will give concentrations in the Savannah River that are generally higher than were actually the case. It would be a conservative approach, but not appropriate for a site-specific analysis. The storage of radionuclides in the swamp and their release during flood will not be represented. The uncertainty in measurement will not be represented.

2) Reconstruct the model outlined in Chapter 5 of the Phase II report and do the analysis separately for each radionuclide of interest. This would give more accurate ratios because the individual K_Ds and decay rates would be accounted for. This approach would also require an evaluation of measurement

and reporting uncertainty for each radionuclide. Developing the model would require extensive resources. Table 5-9 in the Phase II report outlines how some of the factors in the model were varied for the uncertainty analyses. To reconstruct a similar model, however, would require extensive work to determine exactly how parameters were varied, etc.

6.0 CITED REFERENCES

ATL (Advanced Technologies and Laboratories International, Inc.), 2003. *Distribution Coefficients for Radionuclides Considered in the Dose Reconstruction of Savannah River Site.*

Cummins, C.L., C.S. Hetrick, and D.K. Martin, 1991. *Radioactive Releases from the Savannah River Pland 1954-1989, Environmental Protection Department Summary.* WSRC-RP-91-684, SRS Phase II Database MOL199401111.

Kaplan, D., 2003. Personal Communication.

RAC (Risk Assessment Corporation), 2001. *Savannah River Site Environmental Dose Reconstruction Project—Phase II: Source Term Calculation and Ingestion Pathway Dose Retrieval Evaluation of Materials Released from the Savannah River Site.* RAC Report No. 1-CDC-SRS-1999-Final, April 30, 2001.

APPENDIX A

Adjustment factors are based on the ratio of the median of the uncertainty analysis to the total releases. H-3 factors are to be applied to I-129, I-131, Tc-99, and S-35; Cs-137 factors are to be applied to U and Pu; Sr-90 factors are to be applied to Co-60, Ru-103, Ru-106,Sr-89, Sr-90 (augmented by unidentified beta-gamma releases), Nb-95, P32, Zn-65, Ce-141, Ce-144, and Zr-95.

Ratios of uncertainty analysis median releases to total releases.							
	H-3	Cs-137	Sr-90		H-3	Cs-137	Sr-90
1954	20.881	0.781	1.058	1976	0.779	0.482	1.274
1955	2.248	0.394	0.993	1977	0.920	0.481	1.295
1956	1.602	0.608	0.914	1978	0.944	0.486	1.273
1957	1.439	0.023	0.141	1979	0.966	0.488	1.298
1958	1.180	2.953	1.189	1980	1.217	0.481	1.263
1959	1.500	0.452	1.047	1981	1.054	0.519	1.325
1960	1.438	0.218	0.957	1982	0.950	0.520	1.275
1961	1.482	0.542	0.996	1983	0.951	0.523	1.257
1962	1.337	0.511	1.034	1984	0.985	0.514	1.278
1963	1.252	0.172	1.014	1985	0.884	0.519	1.278
1964	1.415	0.474	1.185	1986	0.795	0.523	1.257
1965	1.021	0.694	1.050	1987	0.903	0.520	1.276
1966	1.168	0.741	1.032	1988	0.940	0.517	0.765
1967	1.258	0.482	1.052	1989	1.003	0.888	0.022
1968	1.363	0.478	0.969	1990	0.933		2.473
1969	1.189	0.475	0.942	1991	0.951		0.214
1970	1.154	0.482	1.132	1992	0.936		3.250
1971	1.170	0.552	1.296				
1972	1.018	0.482	1.346	Mean	1.131	0.567	1.158
1973	0.862	0.484	1.242	Median	1.019	0.487	1.189
1974	0.902	0.468	1.290	Max	20.881	2.953	3.250
1975	0.887	0.476	1.224	Min	0.779	0.023	0.022

Attachment C - Base Case Values for Exposure Activity and Usage Factors for the CDC SRS Dose Reconstruction Project

1. Introduction

This document describes in detail the characteristics of the hypothetical receptor groups modeled in the SRS Dose Reconstruction. The specific characteristics of the receptor families are used in the model to calculate the nature of radioactive exposure to each individual in the families for each of the potential exposure pathways being modeled. Some pathways occur for airborne releases of contaminants, and others occur for waterborne releases. The pathways being modeled are listed below in Table 1.

Table 1. Pathways Modeled in SRS Dose Reconstruction.

Pathway Category	Pathway	Air Release	Water Release
External Exposure	Finite Plume and External Air	X	
	Shoreline External		X
	Swimming Water External		X
	Boating Water External		X
	External Soil	X	[a]
Inhalation	Air	X	
	Resuspended Soil	X	[a]
Ingestion	Beef	X	[a]
	Poultry	X	[a]
	Milk	X	[a]
	Eggs	X	[a]
	Leafy Vegetables	X	[a]
	Root Vegetables	X	[a]
	Fruit	X	[a]
	Grains	X	[a]
	Fish		X
	Inadvertent Soil	X	[a]
	Swimming Water		X

[a] These water release pathways represent exposures that would result from irrigation using contaminated river water. For the Base Case calculation, research efforts determined that, at least by 1990, the Savannah River immediately downstream (~20 miles or less) of the site was not used for irrigation, and no irrigation pathways were modeled.

1.1 CDC Receptor Family Scenarios

Seven hypothetical receptor families are modeled. The composition and characteristics of each family are based on direction from the CDC, with additional input from the Health Effects Workgroup (primarily Lockridge 2002). Information from this briefing was evaluated and augmented, as necessary, with more detailed assumptions to define the receptors to be modeled. Attachment 1 presents the scenario description information in Lockridge 2002 and summarizes how the receptor scenarios were developed based on that information. The seven receptor families and the composition of each family were given the same standard composition:

- A male who was an adult (over age 18) in 1954.
- A female who was an adult (over age 18) in 1954.
- A male born in 1955.
- A male born in 1964.

This family composition would allow infant exposure to be modeled for the years 1955 and 1964, two years with large radionuclide releases. While input from CDC's SRS Health Effects Workgroup indicated an interest in adding additional children for certain scenarios (see Lockridge 2002), the standard family composition approach was used because limited additional information about these doses to hypothetical individuals would be gained by modeling infants born in other years. Furthermore, maintaining a consistent family composition will facilitate comparisons across scenarios. Male children were selected because males have slightly higher exposure factors for some pathways (e.g., food ingestion rates), allowing a more conservative estimation of dose. For the children, in utero doses were not assessed.

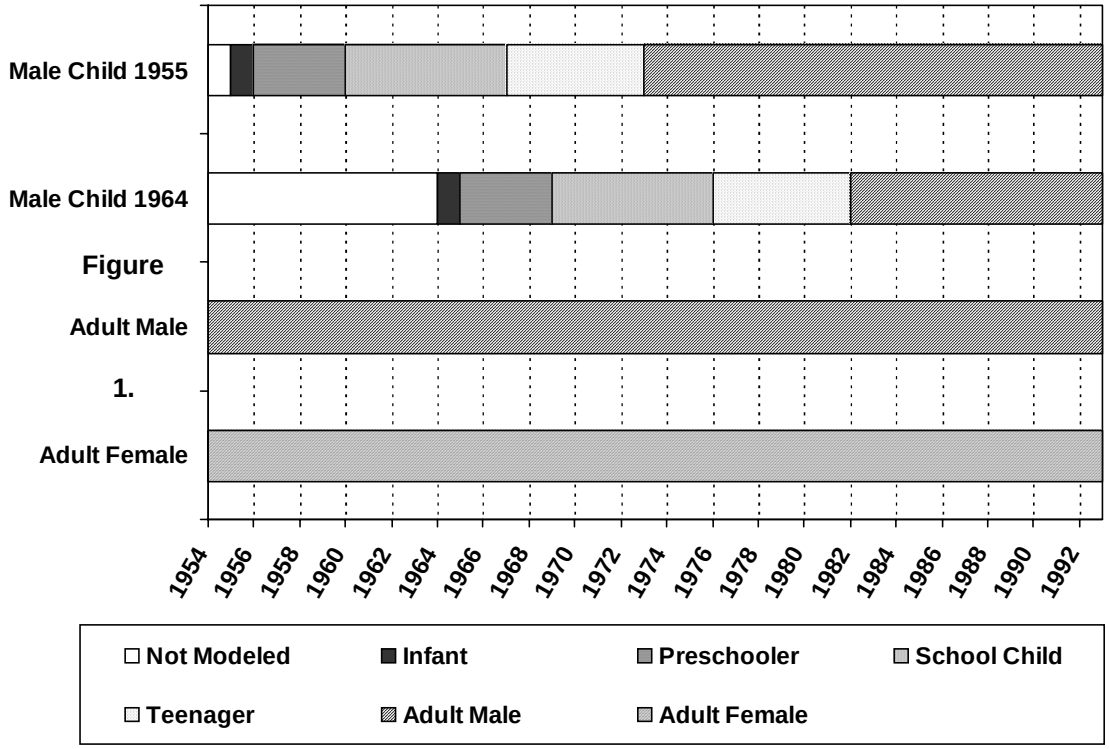
The information on the age and gender of each individual in the receptor families is used in this analysis to help calculate radioactive doses and cancer risks. Certain activities, such as food consumption, are quantified based on exposure factors or contact rates (e.g., ingestion of certain foods). Radioactive exposures are calculated in GENII, a computer program for calculating radiation dose and risk from radionuclides released to the environment, and other computer models in direct proportion to such activity levels. Studies (e.g., EPA's Exposure Factors Handbooks) quantify levels of activity according to the age and gender of the individual using usage factors or activity factors that specify the amount of activity performed on an annual or daily basis. For example, ingestion usage factors specify the kilograms of various foodstuffs consumed each day or year, and inhalation usage factors specify the cubic meters of air breathed each day or year. Gender-specific exposure factor data is available for certain pathways beginning at different ages (depending on the data source consulted).

Information about each individual's age and gender is also used to convert exposure levels to lifetime dose and risk (i.e., carcinogenic effect). Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report (FGR) No. 13 (EPA 1999), specifies dose factors and risk factors according to certain age categories. To model the behavior and levels of exposure of individuals in the CDC-specified receptors, exposure factors were determined for six different age and gender groups. Table 2 lists the six exposure factor groups, identifies the individual age and gender characteristics for each group, and identifies the corresponding dose and risk groups from FGR 13. Table 2 also specifies the duration (in years) of the period an individual spends in each exposure factor group. Figure 1 presents the age and gender of each receptor individual for each year of exposure. The period being modeled is 39 years long; it starts at the beginning of 1954 and ends at the end of 1992. It should be noted that the receptor scenarios developed by CDC assume that the children do not move out of the area or out of their childhood residence for the entire 39-year modeling period. At the end of the modeling period, the children are aged 38 and 29.

Table 2. Exposure Factor Groupings and Corresponding FGR Dose and Risk Factor Age Groups.

Age/Gender	Exposure Factor Group [Duration (years)]	FGR 13 Dose and Risk Factor Age Group
<1 male	Infant (male only) [1]	0 – 5
1 – 4 male	Preschool (male only) [4]	
5 – 11 male	Schoolage (male only) [7]	5 – 15
12 – 17 male	Teenage (male only) [6]	
		15 – 25
18 – 70 male	Adult male [varies] [a]	25 – 70
18 – 70 female	Adult female [varies] [a]	

[a] The exposure duration of the adult age groups depends on which year the an individual reaches age 18. The exposure duration lasts from year of the 18th birthday until the end of the modeling period (i.e., the end of 1992).



Age/Gender Categories of Modeled Individuals (by Year).

The geographic locations where each family resided and performed various activities (e.g., school, work, recreation) are used to specify the scenarios and pathways in the model. Locations are specified for exposure to air-released and water-released contamination. For activities involving exposure to air-released contamination, these locations are identified in the February 26, 2003, memorandum from Vern McDougall (ATL International) to C.M. Wood (CDC) (McDougall 2003). These locations, which are shown in Figure 2, as well as the activity locations for exposure to water-released contamination, are summarized in Tables 3 and 4 below. Table 5 lists exposure locations for the air releases by receptor, individual, and pathway. Table 6 lists exposure locations for water releases by receptors

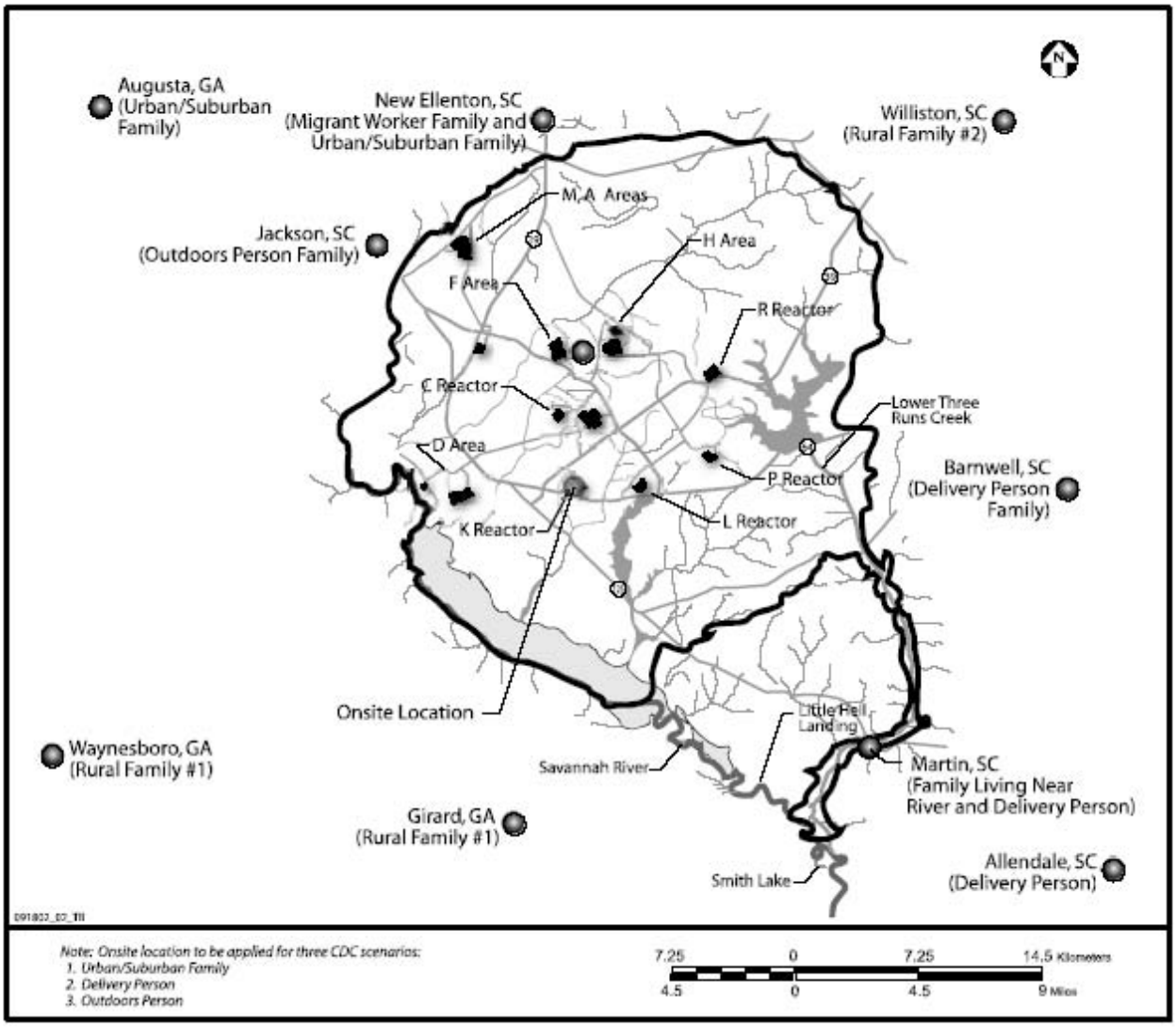


Figure 2. Exposure Locations of CDC Receptor Scenarios (Air Releases).

Table 3. Summary of Proposed Exposure Locations for SRS Air Releases.*

CDC Scenario	Activity [a]	Proposed Location									
		Girard, GA	Waynesboro, GA	Martin, SC	Augusta, GA	Williston, SC	SRS Onsite Location	Barnwell, SC	Allendale, SC	Jackson, SC	New Ellenton, SC
Rural Family #1	All except those noted below	X									
	High school		X								
Rural Family #2	All activities					X					
Urban/Suburban Family	All except those noted below				X						
	Employment						X				
	Dairy				X						X
Delivery Person	All except those noted below							X			
	Employment								X		
	Employment						X				
	Church, grocery (partial), swimming, boating, camping, hunting, fishing			X							
Outdoors Person	All except those noted below									X	
	Employment, hunting, trapping						X				
Family Living Near the River	All activities			X							
Migrant Worker Family	All activities										X

[a] Activities include school, work, recreation, church, production of foodstuffs, indoor and outdoor activities in and around the home.

* For all receptor groups, excluding Rural Family #1, the children are assumed to attend school at a location nearby the residence so the same exposure location is used.

Table 4. Summary of Proposed Exposure Locations for SRS Water Releases.

CDC Scenario	Activities / Pathways	Downstream Savannah River	Lower Three Runs Creek	No Exposure to Affected Water[a]
Rural Family #1	All activities[b]			X
Rural Family #2	All activities[b]			X
Urban/Suburban Family	All activities[b]			X
Delivery Person	Fishing, swimming, shoreline		X	
	Boating	X		
Outdoors Person	Fishing, shoreline	X		
	Swimming, boating			X
Family Living Near the River	All activities[b]	X		
Migrant Worker Family	All activities[b]			X

[a] For some scenarios, the activity is assumed to occur in un-affected water. In other scenarios, the activity is assumed to not occur.
[b] "All activities" includes fishing, boating, swimming, and shoreline

Table 5. Exposure Locations for Air Releases by Receptor, Individual, and Pathway.

CDC Scenario	Individual	Pathway												
		External Exposure		Inhalation		Ingestion								
		Air	Soil	Air	Resuspen-ded Soil	Beef	Poultry	Milk	Eggs	Leafy Veg	Root Veg	Fruit	Grain	Soil
Rural Family #1	Adult Male	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
	Adult Female	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
	Child Born 1955	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
	Child Born 1964	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard, Waynesboro	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard	Girard
Rural Family #2	Adult Male	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
	Adult Female	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
	Child Born 1955	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
	Child Born 1964	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston	Williston
Urban/ Suburb Family	Adult Male	Augusta, Onsite SRS	Augusta, Onsite SRS	Augusta, Onsite SRS	Augusta, Onsite SRS	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
	Adult Female	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
	Child Born 1955	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
	Child Born 1964	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta, New Ellenton	Augusta	Augusta	Augusta	Augusta	Augusta	Augusta
Delivery Person	Adult Male	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin, Allendale, Onsite SRS	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin
	Adult Female	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin
	Child Born 1955	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin
	Child Born 1964	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin	Barnwell, Martin
Outdoors Person	Adult Male	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson

CDC Scenario	Individual	Pathway												
		External Exposure		Inhalation		Ingestion								
		Air	Soil	Air	Resuspen-ded Soil	Beef	Poultry	Milk	Eggs	Leafy Veg	Root Veg	Fruit	Grain	Soil
	Adult Female	Jackson	Jackson	Jackson	Jackson	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
	Child Born 1955	Jackson	Jackson	Jackson	Jackson	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
	Child Born 1964	Jackson	Jackson	Jackson	Jackson	Jackson, Onsite SRS	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson	Jackson
Family Living Near the River	Adult Male	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
	Adult Female	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
	Child Born 1955	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
	Child Born 1964	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin	Martin
Migrant Worker Family	Adult Male	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton
	Adult Female	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton
	Child Born 1955	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton
	Child Born 1964	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton	New Ellenton

Table 6. Exposure Locations for Water Releases by Receptor, Individual, and Pathway.

CDC Scenario	Individual	Pathway				
		External Exposure			Ingestion	
		Shoreline	Swimming	Boating	Fish	Swimming Water
Rural Family #1	Adult Male	None				
	Adult Female					
	Child Born 1955					
	Child Born 1964					
Rural Family #2	Adult Male	None				
	Adult Female					
	Child Born 1955					
	Child Born 1964					
Urban/ Suburb Family	Adult Male	None				
	Adult Female					
	Child Born 1955					
	Child Born 1964					
Delivery Person	Adult Male	LTRC & Savannah R	LTRC	Savannah R	LTRC	
	Adult Female					
	Child Born 1955					
	Child Born 1964					
Outdoors Person	Adult Male	Savannah R	None	Savannah R	Savannah R	None
	Adult Female	None				
	Child Born 1955					
	Child Born 1964					
Family Living Near the River	Adult Male	Savannah R				
	Adult Female					
	Child Born 1955					
	Child Born 1964					
Migrant Worker Family	Adult Male	None				
	Adult Female					
	Child Born 1955					
	Child Born 1964					

Representative locations for where these activities are performed were determined for dose modeling purposes. These locations were picked using information on recreational water usage from Lockridge 2002. The Lower Three Runs Creek (LTRC) location corresponds to exposure in and around Martin, SC. The downstream Savannah River (SR) location corresponds to multiple locations downstream from the site, including onsite (e.g., fishing for the Outdoors Person), above the LTRC-SR confluence (e.g., Little Hell Landing swimming for the Delivery Person), and below the LTRC-SR confluence (e.g., Smith Lake fishing for the Delivery Person).

The following sections describe the activities and potential exposures for each of the CDC scenario families and individuals as they are modeled across the CDC-specified 39-year period of analysis, from 1954 to 1992. Except where noted, the activity rates are the same from year to year. Some year-to-year changes result from activity changes over time which occur as an individual grows older. For example, for many ingestion pathways, food consumption increases as a child ages. In a limited number of other cases, activity patterns change due to lifestyle changes.

The activity and usage rates are expressed in units that are compatible with GENII input requirements. For many pathways, the rates were expressed in units that required conversions or other adjustments to allow their use in GENII. Table 7 summarizes the units for the various exposure pathways.

Table 7. GENII-Compatible Units of Activity and Usage Rates.

Pathways	Units
Direct Exposure	Hours/year
Inhalation	Cubic meters/year[a]
Ingestion	Kilograms/year and Liters/year

[a] The amount of air inhaled for each individual in a specified location is a function of an hourly or daily inhalation rate and is directly proportional to the amount of time spent in the specified location.

For each pathway, GENII requires certain variables to be specified in order to quantify the level of exposure for a given individual at a given location each year. These variables and the data entry points appear in the receptor module of the FRAMES user interface used with GENII. In the Base Case analysis, the GENII model will be run with all of the variable values set at unit levels (e.g., =1), and the values will be entered into the calculations through a post-processor program that takes the results from each GENII run and calculates final dose and risk results using separate arrays of receptor variable values, dose factors, and risk factors. Table 8 lists, by pathway, the variables used in the GENII receptor module that are considered when entering in data through the post-processor. The post processor has been configured to group the variables used within each pathway as exposure factors.

Table 8. GENII Receptor Module Variables By Pathway.

Pathway Category	Pathway	Air Release	Water Release	GENII Variables
External Exposure	Finite Plume and External Air	X		▪ Daily plume immersion exposure time (hours) ▪ Year plume immersion exposure time (days)
	Shoreline External		X	▪ Frequency of shoreline use (evt/day) ▪ Duration of shoreline use events (hours) ▪ Shoreline days (days) ▪ Shoreline width factor (unitless)
	Swimming Water External		X	▪ Frequency of swimming use (evt/day) ▪ Duration of swimming events (hours) ▪ Swimming days (days) ▪ Immersion in water while swimming (hr/yr)
	Boating Water External		X	▪ Shielding factor (unitless) ▪ Frequency of boating event (evt/day) ▪ Duration of boating event (hours) ▪ Boating days (days)
	External Ground	X	[a]	▪ Indoor shielding factor (unitless) ▪ Outdoor shielding factor (unitless) ▪ Daily external ground exposure time (hours) ▪ Yearly external ground exposure time (days) ▪ Fraction of time spent indoors (unitless) ▪ Fraction of time spent outdoors (unitless)
Inhalation	Air	X		▪ Air inhalation rate (m3/day) ▪ Air inhalation period (days/year) ▪ Fraction of a day outdoor inhalation occurs (unitless)
	Resuspended Soil	X	[a]	▪ Resuspended soil inhalation rate (m3/day) ▪ Resuspended soil inhalation period (days/year) ▪ Fraction of a day inhalation of resuspension occurs (unitless)
	Indoor or Showering		X	▪ Indoor inhalation rate (m3/day) ▪ Indoor inhalation period (days/year) ▪ Fraction of a day indoor inhalation occurs (unitless)
Ingestion	Beef	X	[a]	▪ Beef consumption rate (kg/day) ▪ Beef consumption period (day/yr)
	Poultry	X	[a]	▪ Poultry consumption rate (kg/day) ▪ Poultry consumption period (day/yr)
	Milk	X	[a]	▪ Milk consumption rate (kg/day) ▪ Milk consumption period (day/yr)
	Eggs	X	[a]	▪ Eggs consumption rate (kg/day) ▪ Eggs consumption period (day/yr)
	Leafy Vegetables	X	[a]	▪ Leafy vegetables consumption rate (kg/day) ▪ Leafy vegetables consumption period (day/yr)
	Root Vegetables	X	[a]	▪ Root vegetables consumption rate (kg/day) ▪ Root vegetables consumption period (day/yr)

Pathway Category	Pathway	Air Release	Water Release	GENII Variables
	Fruit	X	[a]	▪ Fruit consumption rate (kg/day) ▪ Fruit consumption period (day/yr)
	Grains	X	[a]	▪ Grains consumption rate (kg/day) ▪ Grains consumption period (day/yr)
	Fish		[a]	▪ Fish consumption rate (kg/day) ▪ Fish consumption period
	Inadvertent Soil	X	[a]	▪ Soil contact days (days) ▪ Inadvertent soil ingestion rate (kg/day)
	Swimming Water		X	▪ Frequency of swimming event (evt/day) ▪ Duration of swimming event (hours) ▪ Swimming days (days) ▪ Ingestion rate of water while swimming (L/hour)

[a] These water release pathways represent exposures that would result from irrigation using contaminated river water. For the Base Case calculation, research efforts determined that, at least by 1990, the Savannah River immediately downstream (~20 miles or less) of the site was not used for irrigation, and no irrigation pathways were modeled.

2 Determining Activity and Usage Rates

This section presents the data analysis, assumptions, calculations, and rationale for determining the activity and usage rates for each exposure pathway modeled in the "Base Case" of the SRS dose reconstruction. The usage rates (also referred to as exposure factors or contact rates) are organized by pathway category (i.e., external exposure, ingestion, and inhalation) and pathway

2.1 External Exposure Pathways

2.1.1 Finite Plume (Air) and External Air

This pathway accounts for exposure to contaminated air. It affects all individuals of all receptor scenarios and individuals. The GENII variables for this pathway are:

- Daily plume immersion exposure time (hours) (i.e., hours/day)
- Yearly plume immersion exposure time (days) (i.e., days/year)

Exposure Factor. The combination of these two variables results in an exposure factor represented in hours/year. The general assumption is that for each individual for each year, 8,760 hours of potential exposure are accounted for (i.e., 365 days/year x 24 hours/day = 8,760 hours/year). The GENII model assumes no adjustments in exposure factors for individuals being indoors for a portion of each day. That is, indoor air concentrations are equal to outdoor air concentrations. Since indoor air concentrations would likely contain lower concentrations of airborne radioactivity, this assumption contributes to conservative (i.e., increased) estimates of dose and risk.

Table 9. Finite Plume and External Air Exposure Pathway, Exposure Factors

<table>
<tr><th>Scenario Family</th><th>Discussion</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>Girard. The adult male and female are exposed full-time (8,760 hours/year) at the Girard location for all years. With the exception of high school, the two children are also exposed full-time at the Girard location for all years beginning with their birth year. During the high school years (1967-72 and 1976-81), exposure for the children is reduced to 7,500 hours/year.

Waynesboro. High school exposures occur at Waynesboro over six years for 180 days/year x 7 hours/day = 1,260 hours/year. The 7 hour/day value assumes 1 hour of transport between home and school and 6 hours at school. The high school exposure occurs for each child aged 12 to 17 (1967-72 for a child born in 1955, and 1976-1981 for a child born in 1964).</td><td>Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>Girard</th><th>Waynesboro</th></tr>
<tr><td>Adult M</td><td>8,760</td><td>0</td></tr>
<tr><td>Adult F</td><td>8,760</td><td>0</td></tr>
<tr><td>Child 1955</td><td>7,500 for 1967-72; 8,760 for other years</td><td>1,260 for 1967-72; 0 for other years</td></tr>
<tr><td>Child 1964</td><td>7,500 for 1976-81; 8,760 for other years</td><td>1,260 for 1976-81; 0 for other years</td></tr>
</table>
Notes:

1. Child exposures start in 1955 and 1964.

2. During the indicated years (1967-72 for Child-1955, and 1976-81 for Child-1964), Child-1955 and Child-1964 are classified as teenagers.</td></tr>
<tr><td>Rural Family #2</td><td>Williston. All individuals are exposed full time (8,760 hours/year) at Williston for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>Girard</th></tr>
<tr><td>Adult M</td><td>8,760</td></tr>
<tr><td>Adult F</td><td>8,760</td></tr>
<tr><td>Child 1955</td><td>8,760</td></tr>
<tr><td>Child 1964</td><td>8,760</td></tr>
</table>
Notes: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Urban/Suburban Family</td><td>Onsite SRS. The adult male is exposed at this location during full-time employment (250 days/year x 8 hours/day = 2,000 hours/year) for all years.

Augusta. The adult female and two children are exposed full time (8,760 hours/year) at Augusta for all years. The adult male is exposed at Augusta except when at the place of employment (Onsite SRS). This amounts to 6,510 hours/year in Augusta for the adult male.</td><td>Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>Augusta</th><th>Onsite SRS</th></tr>
<tr><td>Adult M</td><td>6,760</td><td>2,000</td></tr>
<tr><td>Adult F</td><td>8,760</td><td>0</td></tr>
<tr><td>Child 1955</td><td>8,760</td><td>0</td></tr>
<tr><td>Child 1964</td><td>8,760</td><td>0</td></tr>
</table>
Notes:

Child exposures start in 1955 and 1964.</td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Discussion</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Delivery Person</td><td>Martin. All individuals attend church in Martin for 52 days/year x 2 hours/day = 104 hours/year. Children begin church attendance immediately beginning in their birth year.

Onsite SRS. The adult male is exposed at this location during onsite beverage deliveries for 8 hours/week x 50 weeks/year = 400 hours/year.

Allendale. The adult male is exposed at this location during the balance of his full-time employment, equal to 1,600 hours/year (250 days/year x 8 hours/day - 400 hours/year = 1,600 hours/year).

Barnwell. All individuals spend the remainder of their time, excluding church and employment, in Barnwell for all years. For the adult female and the two children, the amount of time in Barnwell is 8,656 hours/year (8,760 – 104 = 8,656). For the adult male, the amount of time in Barnwell is 6,656 hours/year (8,760 – 104 – 400 – 1,600 = 6,656).</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>Martin</td><td>Onsite SRS</td></tr>
<tr><td>Adult M</td><td>104</td><td>400</td></tr>
<tr><td>Adult F</td><td>104</td><td>0</td></tr>
<tr><td>Child 1955</td><td>104</td><td>0</td></tr>
<tr><td>Child 1964</td><td>104</td><td>0</td></tr>
</table>
<table>
<tr><td>Individual</td><td>Allendale</td><td>Barnwell</td></tr>
<tr><td>Adult M</td><td>1,600</td><td>6,656</td></tr>
<tr><td>Adult F</td><td>0</td><td>8,656</td></tr>
<tr><td>Child 1955</td><td>0</td><td>8,656</td></tr>
<tr><td>Child 1964</td><td>0</td><td>8,656</td></tr>
</table>
Notes: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Outdoors Person</td><td>Onsite SRS. The adult male is exposed at this location during full-time employment (250 days/year x 8 hours/day = 2,000 hours/year) for all years.

Jackson. All individuals spend the remainder of their time, excluding employment, in Jackson. For the adult female and the two children, the amount of time in Jackson is 8,760 hours/year. For the adult male, the amount of time in Jackson is 6,760 hours/year (8,760 – 2,000 = 6,760).</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>Onsite SRS</td><td>Jackson</td></tr>
<tr><td>Adult M</td><td>2,000</td><td>6,760</td></tr>
<tr><td>Adult F</td><td>0</td><td>8,760</td></tr>
<tr><td>Child 1955</td><td>0</td><td>8,760</td></tr>
<tr><td>Child 1964</td><td>0</td><td>8,760</td></tr>
</table>
Notes: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Family Living Near the River</td><td>Martin. All individuals are exposed full time (8,760 hours/year) at (or near) Martin for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>Martin</td></tr>
<tr><td>Adult M</td><td>8,760</td></tr>
<tr><td>Adult F</td><td>8,760</td></tr>
<tr><td>Child 1955</td><td>8,760</td></tr>
<tr><td>Child 1964</td><td>8,760</td></tr>
</table>
Notes: Child exposures start in 1955 and 1964.</td></tr>
</table>

Scenario Family	Discussion	Values for Exposure and Adjustment Factors
Migrant Worker Family	New Ellenton. The family is assumed to be away from the SRS region half the year, in all years. All individuals are exposed 8,760 hours/year x 0.5 = 4,380 hours/year at New Ellenton. For the remainder of the time, the individuals are present in areas outside the region potentially affected by air released contamination from SRS.	Exposure Factors (hours/year) Individual: New Ellenton Adult M: 4,380 Adult F: 4,380 Child 1955: 4,380 Child 1964: 4,380 Note: Child exposures start in 1955 and 1964.

2.1.2 Shoreline External Pathway

This pathway accounts for direct radiation exposure that results from standing on the shoreline containing radioactivity deposited by contaminated water. The GENII variables for this pathway are:

- Frequency of shoreline use (event/day)
- Duration of shoreline use events (hours) (i.e., hours/event)
- Shoreline days (days) (i.e., days/year)
- Shoreline width factor (unitless)

Exposure Factors. The exposure factor takes into account the first three variables which, when combined, result in an hours/year exposure rate. Shoreline exposure rates are assumed to be zero for the receptors listed in Table 10 because any shoreline activity is assumed to occur along waters that are hydrologically upgradient or crossgradient from the site and are unaffected by site releases. This is due to the assumption made that these sites aren't affected by liquid releases from the Savannah River Site. The locations cited in Table 10 are based on information presented in Lockridge 2002.

Table 10. Receptors Without Shoreline External Exposure.

Receptor Family	Shoreline Usage Location
Rural Family #1	Briar Creek
Rural Family #2	Farm ponds around Williston, SC
Urban/Suburban Family	Savannah River upstream of the site
Outdoors Person	Savannah River upstream of the site (excluding adult male)
Migrant Family	Savannah River upstream of site and farm ponds around New Ellenton

For the remaining receptors, the exposure rate is determined as follows: the Delivery Person Family uses the shoreline on Lower Three Runs Creek near Martin and the shoreline of the Savannah River, and the Family Living Near the River and the Outdoors Person (adult male only) use the shoreline on the Savannah River downstream of SRS. As stated before, these locations are surrogates for dose modeling purposes that were chosen from Lockridge 2002. As discussed below, a different approach is used to develop exposure rates for each of these receptors.

Delivery Person Family. For this receptor, Lockridge 2002 does not give specific information on the level of exposure. Shoreline exposure rates are estimated using the following factors based on South Carolina recreational patterns cited in Hamby 1991 (p.6 and 24):

- Average number of shoreline usage events/year – 19.15
- Average hours/shoreline usage event – 4.44

This results in an exposure rate of 85 hours/year, which was applied to all individuals in the Delivery Person Family. The Hamby values are based on "Outdoor Recreation Assessment and Policy Plan 1989," in the Georgia Recreation Planning Process, GA, Department of Natural Resources, J.L. Ledbetter, Commissioner, Atlanta, GA, 1990. The numbers apply to all age groups and represent warm water fishing activity. This exposure value is higher than default values cited in NRC 1977 for a maximum exposed individual (MEI). NRC MEI exposure values for adults, teens, and children are 12, 67, and 14 hours/year, respectively. Hamby 1991 calculated MEI values for population doses in the area around SRS using local data and assumptions. The Hamby 1991 MEI numbers for adults, teens, and children are 23, 128, and 27 hours/year, respectively.

Family Living Near the River. For this receptor, Lockridge 2002 states “Assume they were always outdoors in contact with the Savannah River,” but it does not provide specific information on the amount of shoreline activity. However, it was assumed that the shoreline use exposure rate corresponded to a family that used the river for fishing to supply a significant portion of the family diet. This level would be well above the values cited in statistical studies. An average daily exposure level over the course of a year of 1 hour/day (365 hours/year) was assumed for each individual.

Outdoors Person. The adult male is the only individual in this receptor family that was engaged in shoreline use along a body of contaminated water. For this receptor, it was assumed the adult male was present in shoreline areas along the Savannah River onsite at SRS as part of his job. This time includes time spent fishing and hunting. The exposure level assumes the adult male was “on the river” 8 hours/day (40 hours/week) during the summer (13 weeks), as cited in Lockridge 2002. It further assumes that half the time spent “on the river” was spent on the shoreline, and the other half was spent on a boat. This results in an exposure factor of 260 hours/year on the shoreline for the adult male. The other individuals in this family, according to Lockridge 2002, are exposed at the Jackson, SC, boat ramp, which is upstream from site discharges.

EPA 1997 data for time spent outdoors at a pool/river/lake was also considered for this pathway. EPA 1997 data provided exposure rates specific to individual age categories, but it was not used in the analysis because it was not possible to separate the total time spent at a pool/river/lake into separate categories for swimming, boating, and shoreline use.

The shoreline external exposure rates for the CDC scenarios are summarized in Table 11.

Table 11. Shoreline External Exposure Pathway, Exposure and Adjustment Factors.

<table>
<tr><th>Scenario Family</th><th>Shoreline External Pathway</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>No shoreline external exposure. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Rural Family #2</td><td>No shoreline external exposure. Exposure locations (Farm ponds around Williston) are not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Urban/Suburban Family</td><td>No shoreline external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Delivery Person</td><td>Lower Three Runs Creek at Martin (50%) and the Savannah River (50%). All individuals exposed for a total of 85 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>LTRC-Martin</th><th>Savannah Rv</th></tr>
<tr><td>Adult M</td><td>42.5</td><td>42.5</td></tr>
<tr><td>Adult F</td><td>42.5</td><td>42.5</td></tr>
<tr><td>Child 1955</td><td>42.5</td><td>42.5</td></tr>
<tr><td>Child 1964</td><td>42.5</td><td>42.5</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Outdoors Person</td><td>No shoreline external exposure for the adult female and children. The exposure location (Savannah River upstream of SRS) is not hydrologically downgradient from release points.

Savannah River Downstream of SRS. The adult male is exposed for 260 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>Savannah Rv</th></tr>
<tr><td>Adult M</td><td>260</td></tr>
<tr><td>Adult F</td><td>0</td></tr>
<tr><td>Child 1955</td><td>0</td></tr>
<tr><td>Child 1964</td><td>0</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Family Living Near the River</td><td>Savannah River Downstream of SRS. All individuals are exposed for 365 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>Savannah Rv</th></tr>
<tr><td>Adult M</td><td>365</td></tr>
<tr><td>Adult F</td><td>365</td></tr>
<tr><td>Child 1955</td><td>365</td></tr>
<tr><td>Child 1964</td><td>365</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Migrant Worker Family</td><td>No shoreline external exposure. Exposure locations (Savannah River upstream of SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
</table>

2.1.3 Swimming Water External Pathway

This pathway accounts for direct external radiation exposure that results from swimming in contaminated water. The GENII variables for this pathway are:

- Frequency of swimming use (event/day)
- Duration of swimming events (hours) (i.e., hours/event)
- Swimming days (days) (i.e., days/year)

Exposure Factors. The exposure factor takes into account these three variables which, when combined, result in an hours/year exposure rate. Swimming exposure rates are assumed to be zero for the receptors listed in Table 12 because any swimming is assumed to occur in uncontaminated water; water that is hydrologically upgradient or crossgradient from the site. The locations cited in Table 12 are based on information presented in Lockridge 2002.

Table 12. Receptors Without Swimming Water External Exposure.

Receptor Family	Swimming Location
Rural Family #1	Briar Creek
Rural Family #2	Farm ponds around Williston, SC
Urban/Suburban Family	Savannah River upstream of the site
Outdoors Person	Savannah River upstream of the site
Migrant Family	Savannah River upstream of site and farm ponds around New Ellenton

For the remaining two receptors, the Delivery Person Family swims on Lower Three Runs Creek near Martin, and the Family Living Near the River swims on the Savannah River downstream of SRS. For the Delivery Person Family receptor, Lockridge 2002 does not provide specific information on the amount of swimming. Swimming water exposure rates are estimated using the following factors based on South Carolina recreational patterns cited in Hamby 1991 (p.6 and 24). The Hamby values are based on "Outdoor Recreation Assessment and Policy Plan 1989," in the Georgia Recreation Planning Process, GA Department of Natural Resources, J.L. Ledbetter, Commissioner, Atlanta, GA, 1990. The numbers apply to all age groups and represent warmwater fishing activity:

- Average number of lake swimming events/year – 8.12
- Average hours/lake swimming event – 2.61

This results in an exposure rate of 21.2 hours/year for the Delivery Person Family. For the Family Living Near the River receptor, it is stated in Lockridge 2002 to “Assume they were always outdoors in contact with the Savannah River.” During the summer a swimming rate of 1 hour/day is assumed, leading to an exposure rate of 91 hrs/yr for that receptor group.

As discussed above, EPA 1997 data for time spent outdoors at a pool/river/lake was also considered for this pathway. EPA 1997 data provided exposure rates specific to individual age categories, but this data was not used because it was not possible to separate the total time between swimming, boating, and shoreline activities.

The swimming water exposure rates for the CDC scenarios are specified in Table 13.

Table 13. Swimming External Exposure Pathway, Exposure Factors.

<table>
<tr><th>Scenario Family</th><th>Swimming Water External Pathway</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>No swimming water external exposure. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Rural Family #2</td><td>No swimming water external exposure. Exposure locations (Farm ponds around Williston) are not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Urban/Suburban Family</td><td>No swimming water external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Delivery Person</td><td>Lower Three Runs Creek at Martin. All individuals exposed for 21.2 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>LTRC</td></tr>
<tr><td>Adult M</td><td>21.2</td></tr>
<tr><td>Adult F</td><td>21.2</td></tr>
<tr><td>Child 1955</td><td>21.2</td></tr>
<tr><td>Child 1964</td><td>21.2</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Outdoors Person</td><td>No swimming water external exposure. Exposure location (Savannah River upstream of SRS) is not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Family Living Near the River</td><td>Savannah River Downstream of SRS. All individuals exposed for 91 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>Savannah Rv</td></tr>
<tr><td>Adult M</td><td>91</td></tr>
<tr><td>Adult F</td><td>91</td></tr>
<tr><td>Child 1955</td><td>91</td></tr>
<tr><td>Child 1964</td><td>91</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Migrant Worker Family</td><td>No swimming water external exposure. Exposure locations (Savannah River upstream of SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
</table>

2.1.4 Boating Water External Pathway

This pathway accounts for direct radiation exposure that results from boating in a body of contaminated water. The GENII variables for this pathway are:

- Shielding factor (unitless)
- Frequency of boating event (event/day)

- Duration of boating event (hours) (i.e., hours/event)
- Boating days (days) (i.e., days/year)

Exposure Factors. The exposure factor takes into account these last three variables which, when combined, result in an hours/year exposure rate. Boating exposure rates are assumed to be zero for the four receptors listed in Table 14 because any boating is assumed to occur in waters that are hydrologically upgradient or crossgradient from the site and are unaffected by site releases.

Table 14. Receptors Without Boating External Exposure.

Receptor Family	Swimming Location
Rural Family #1	No boating
Rural Family #2	No boating
Urban/Suburban Family	Savannah River upstream of the site
Migrant Family	No boating

For the remaining three receptors—the Delivery Person Family, the Family Living Near the River, and the Outdoors Person—boating occurs on Savannah River downstream of SRS. These locations and the locations cited above in Table 13 are based on information in Lockridge 2002. The approach used to develop exposure rates for each of these receptors is discussed below.

Delivery Person Family. For this receptor, Lockridge 2002 does not provide specific information on the amount of time spent boating. Boating exposure rates are estimated using the factors for boating based on South Carolina recreational patterns cited in Hamby 1991 (p. 6 and 24) and shown below in Table 15. These values are based on "Outdoor Recreation Assessment and Policy Plan 1989," in the Georgia Recreation Planning Process, GA Department of Natural Resources, J.L. Ledbetter, Commissioner, Atlanta, GA, 1990. The numbers apply to all age groups and include two categories – canoeing and boating/sailing.

Table 15. South Carolina Boating Usage Rates (adapted from Hamby 1991).

Boating Usage	Canoe Trails	Boating / Sailing
Events / Year (average)	6.13	18.77
Hours / Event (average)	2.25	4.38
Hours / Year	13.8	82.2
Total	96 hours/year	

The total rate (96 hours/year) was applied to all individuals in the Delivery Person Family.

Family Living Near the River. For this receptor, Lockridge 2002 states “Assume they were always in contact with the Savannah River.” It was assumed that the amount of time spent boating corresponded to a family that used the river for periods significantly longer the values cited in statistical studies. An average exposure level over the course of a year of twice the rates cited in Hamby 1991 (192 hours/year) was assumed for each individual.

Outdoors Person. For this receptor, the adult male is exposed at a different rate than the other family members. For the adult male, the exposure rate includes two components, one for work and one for recreation. For work, the rate for the adult male was calculated to be 260 hours/year based on the amount

of time spent "on the river" as cited in Lockridge 2002. The amount of time spent boating was assumed to be half the time spent "on the river," and the time spent "on the river" was cited in Lockridge 2002 as 8 hours/day (i.e., 40 hours/week) during the summer (i.e., 13 weeks) (0.5 x 40 x 130 = 260 hours/year). For recreational boating, the same rate (i.e., the 96 hours/year rate adapted from Hamby 1991) was applied to all individuals in the family.

As discussed above, EPA1997 data for time spent outdoors at a pool/river/lake was also considered for this pathway. EPA 1997 data provided exposure rates specific to individual age categories, but this data was not used because it was not possible to separate the total time between swimming, boating, and shoreline activities.

The boating exposure rates for the CDC scenarios are specified in Table 16.

Table 16. Boating External Exposure Pathway, Exposure and Adjustment Factors.

<table>
<tr><th>Scenario Family</th><th>Boating External Pathway</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>No boating external exposure. No boating performed by receptor.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Rural Family #2</td><td>No boating external exposure. No boating performed by receptor.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Urban/Suburban Family</td><td>No boating external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
<tr><td>Delivery Person</td><td>Savannah River Downstream of SRS. All individuals exposed for 96 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>Savannah Rv</td></tr>
<tr><td>Adult M</td><td>96</td></tr>
<tr><td>Adult F</td><td>96</td></tr>
<tr><td>Child 1955</td><td>96</td></tr>
<tr><td>Child 1964</td><td>96</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Outdoors Person</td><td>Savannah River Downstream of SRS. The adult male is exposed 356 hours/year for all years, including 260 hours for work and 96 hours for recreation. Boating exposure for all other individuals is 96 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>Savannah Rv</td></tr>
<tr><td>Adult M</td><td>356</td></tr>
<tr><td>Adult F</td><td>96</td></tr>
<tr><td>Child 1955</td><td>96</td></tr>
<tr><td>Child 1964</td><td>96</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Boating External Pathway</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Family Living Near the River</td><td>Savannah River Downstream of SRS. All individuals exposed for 192 hours/year for all years.</td><td>Exposure Factors (hours/year)
<table>
<tr><td>Individual</td><td>Savannah Rv</td></tr>
<tr><td>Adult M</td><td>192</td></tr>
<tr><td>Adult F</td><td>192</td></tr>
<tr><td>Child 1955</td><td>192</td></tr>
<tr><td>Child 1964</td><td>192</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Migrant Worker Family</td><td>No boating external exposure. No boating performed by receptor.</td><td>Exposure Factors (hours/year) = 0 (all years and individuals)</td></tr>
</table>

2.1.5 External Soil Pathway

This pathway accounts for direct radiation exposure that results from standing on the ground at a specified location contaminated by deposition of airborne contamination. The amount of time spent exposed to direct radiation at each location is equal to the amount of time individuals are exposed to the inhalation of airborne contamination at the specified location. This pathway accounts for exposure that occurs either indoors or outdoors. The GENII variables for this pathway are:

- S_i Indoor shielding factor (unitless)
- S_o Outdoor shielding factor (unitless)
- T_i Daily external ground exposure time (hours) (i.e., hours/day)
- T_o Yearly external ground exposure time (days) (i.e., days/year)
- F_i Fraction of time spent indoors (unitless)
- F_o Fraction of time spent outdoors (unitless)

For each exposure location, the exposure factor equals TiTo (hours/year), and the external soil adjustment factor equals ($S_iF_i + S_oF_o$) (unitless).

Exposure factor and time spent outdoors/indoors. The exposure factor (hours/year) must total 8,760 hours/year for each individual of each scenario, except for the migrant family individuals. The 8,760 hours/year value corresponds to the total amount of time each individual is present at the receptor locations. For the migrant family, half of this value (4,380 hours/year) is used because the family is present in the SRS region for only half of the year. The amounts of time spent outdoors are based on data from two sources: Lockridge 2002, and EPA 1997, and are shown below in Table 17. The values in EPA 1997 correspond to the mean averages for time spent outdoors/indoors for the different age groups.

Table 17. Time Spent Outdoors – EPA 1997 Age/Gender Categories and Rate Data, and Corresponding Modeled Age/Gender Categories and Calculated Rates.

EPA 1997 Data, Mean Values(Table 15-132)					
Age/Gender Categories	**Corresponding Modeled Age/Gender Categories**	**Time Spent Outdoors (minutes/day)**	**Calculated Time Spent Outdoors (hours/year)**	**Time Spent Indoors (minutes/day)**	**Calculated Time Spent Indoors (hours/year)**
1 – 4	Infant (<1)	196	1190	1212	7371
1 – 4	Pre-School (1 – 7)	196	1190	1212	7371
5 – 11	Child (<7 – 12)	188	1141	1005	6115
12 – 17	Teenager (<12 – 17)	135	823	970	5898
18 – 64	Adult Male (>17)	144	877	948	5766
18 - 64	Adult Female (>17)	144	877	948	5766

The data in the above table has to be adjusted as the calculated times spent indoors and outdoors do not add up to 8760 hours per year for any of the different family members. To do this, the indoor and outdoor hours per year were summed and subtracted from 8760 to find the hours of the year "unaccounted for". An indoor hours ratio and outdoor hours ratio was then determined by dividing the calculated time spent outdoors/indoors by the summed indoor/outdoor amount. The formula is as follows: Calculated Time Spent Indoors(Outdoors) (hours/year) /(Calculated Time Spent Outdoors (hours/year)+(Calculated Time Spent Indoors (hours/year) = Indoor(Outdoor) hours ratio. That ratio is then multiplied by the "unaccounted for" hours in the year to determine how many of those remaining hours will be counted as indoor(outdoor) hours. The approach for applying the calculated rates for external soil exposure to the CDC scenarios is described below in Table 18.

External Soil Adjustment Factor. The value of the So, the outdoor shielding factor, is set at 1.0 for all scenarios, exposure locations, individuals, and years. The value of the Si, the indoor shielding factor, is based on EPA's October 2000 Soil Screening Guidance for Radionuclides Technical Background Document (EPA 2000) , p. 2-18, which specifies a default indoor shielding factor (gamma shielding factor) value of 0.7. This value for S_i is applied for all scenarios, exposure locations, individuals, and years. As stated above, the external soil adjustment factor is ($S_iF_i + S_oF_o$).

Table 18. External Soil Exposure Pathway, Exposure and Adjustment Factors.

<table>
<tr><th>Scenario Family</th><th>External Soil Exposure</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr>
<td>Rural Family #1</td>
<td>
Girard. The adult male and female are exposed at the Girard location for all years. With the exception of high school, the three children are also exposed at the Girard location for all years beginning with their birth year. During high school, there are indoor and outdoor rates at both Girard and Waynesboro.

Waynesboro. High school exposures occur at Waynesboro over six years for 180 days/year x 7 hours/day = 1,260 hours/year. The high school exposure occurs for each child aged 12 to 17 (1967-72 for a child born in 1955, and 1976-81 for a child born in 1964). Fi and Fo values during high school are based on 2 hour/day outdoors (360 hours/year) and 5 hours/day indoors (900 hours/year).

Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>Year</th><th>Girard</th><th>Waynes-boro</th></tr>
<tr><td>Adult M</td><td>All Years</td><td>8,760</td><td>0</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>8,760</td><td>0</td></tr>
<tr><td rowspan="2">Child 1955</td><td>1967-72</td><td>7,500</td><td>1,260</td></tr>
<tr><td>All other years</td><td>8,760</td><td>0</td></tr>
<tr><td rowspan="2">Child 1964</td><td>1976-82</td><td>7,500</td><td>1,260</td></tr>
<tr><td>All other years</td><td>8,760</td><td>0</td></tr>
</table>
Note: Child exposures start in 1955 and 1964
</td>
<td>
Exposure Factors Girard
<table>
<tr><th>Individ-ual</th><th>Year</th><th>F_i</th><th>F_o</th><th>Ext. Soil Adj. Factor</th></tr>
<tr><td>Adult M</td><td>All Years</td><td>0.6910</td><td>0.3090</td><td>0.7927</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>0.8611</td><td>0.1389</td><td>0.7417</td></tr>
<tr><td rowspan="4">Child 1955</td><td>Infant&Preschl 1955-59</td><td>0.8543</td><td>0.1457</td><td>0.7437</td></tr>
<tr><td>Schoolchild 1960-66</td><td>0.8179</td><td>0.1821</td><td>0.7546</td></tr>
<tr><td>Teen 1967-72</td><td>0.8692</td><td>0.1308</td><td>0.7392</td></tr>
<tr><td>Adult M 1973-92</td><td>0.6910</td><td>0.3090</td><td>0.7927</td></tr>
<tr><td rowspan="4">Child 1964</td><td>Infant&Preschl 1964-68</td><td>0.8543</td><td>0.1457</td><td>0.7437</td></tr>
<tr><td>Schoolchild 1969-75</td><td>0.8179</td><td>0.1821</td><td>0.7546</td></tr>
<tr><td>Teen 1976-81</td><td>0.8692</td><td>0.1308</td><td>0.7392</td></tr>
<tr><td>Adult M 1982-92</td><td>0.6910</td><td>0.3090</td><td>0.7927</td></tr>
</table>
Exposure Factors Waynesboro
<table>
<tr><th>Individual</th><th>Year</th><th>F_i</th><th>F_o</th><th>Ext. Soil Adj. Factor</th></tr>
<tr><td>Adult M</td><td>All Years</td><td>na</td><td>na</td><td>na</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>na</td><td>na</td><td>na</td></tr>
<tr><td>Child 1955</td><td>Teen 1967-72</td><td>0.7143</td><td>0.2857</td><td>0.7857</td></tr>
<tr><td></td><td>All other years</td><td>na</td><td>na</td><td>na</td></tr>
<tr><td>Child 1964</td><td>Teen 1976-81</td><td>0.7143</td><td>0.2857</td><td>0.7857</td></tr>
<tr><td></td><td>All other years</td><td>na</td><td>na</td><td>na</td></tr>
</table>
na = Not applicable because the exposure rate is zero at this location for this individual in this year.
</td>
</tr>
</table>

Rural Family #2

Williston. All individuals are exposed at the Williston location for all years.

Exposure Factors (hours/year)

Individual	Year	Williston
Adult M	All Years	8,760
Adult F	All Years	8,760
Child 1955	All Years	8,760
Child 1964	All Years	8,760

Note: Child exposures start in 1955 and 1964

Exposure Factors Williston

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.6910	0.3090	0.7927
Adult F	All Years	0.8611	0.1389	0.7417
Child 1955	Infant&Preschl 1955-59	0.8543	0.1457	0.7437
	Schoolchild 1960-66	0.8179	0.1821	0.7546
	Teen 1967-72	0.8469	0.1531	0.7459
	Adult M 1973-92	0.6910	0.3090	0.7927
Child 1964	Infant&Preschl 1964-68	0.8543	0.1457	0.7437
	Schoolchild 1969-75	0.8179	0.1821	0.7546
	Teen 1976-81	0.8469	0.1531	0.7459
	Adult M 1982-92	0.6910	0.3090	0.7927

Urban/Suburban Family

Onsite SRS. The adult male is exposed at this location during full-time employment, 2000 hours, for all years. Adjustment factors for the adult male at this location are based on 1 hour/day outdoors (250 hours/year) and 8 hours/day indoors (1635 hours/year).

Augusta. All individuals except the adult male are exposed at the Augusta location for all years. The adult male exposure at Augusta corresponds to the recommended value rates, minus 2000 hours of outdoor and indoor exposure while at the onsite SRS location.

Exposure Factors (hours/year)

Individual	Augusta	Onsite SRS
Adult M	6,760	2,000
Adult F	8,760	0
Child 1955	8,760	0
Child 1964	8,760	0

Note: Child exposures start in 1955 and 1964

Exposure Factors Augusta

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.8714	0.1286	0.7386
Adult F	All Years	0.8706	0.1294	0.7388
Child 1955	Infant&Preschl 1955-59	0.8638	0.1362	0.7409
	Schoolchild 1960-66	0.8270	0.1730	0.7519
	Teen 1967-72	0.8563	0.1437	0.7431
	Adult M 1973-92	0.8714	0.1286	0.7386
Child 1964	Infant&Preschl 1964-68	0.8638	0.1362	0.7409
	Schoolchild 1969-75	0.8270	0.1730	0.7519
	Teen 1976-81	0.8563	0.1437	0.7431
	Adult M 1982-92	0.8714	0.1286	0.7386

Exposure Factors Onsite SRS

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.8750	0.1250	0.7375
Adult F	All Years	na	na	na
Child 1955	All Years	na	na	na
Child 1964	All Years	na	na	na

na = Not applicable because the exposure rate is zero at this location for this individual in this year.

Delivery Person

Martin. All individuals attend church in Martin for 52 days/year x 2 hours/day = 104 hours/year. Children begin church attendance immediately beginning in their birth year. All exposures at this location are indoors.

Onsite SRS. The adult male is exposed at this location during onsite beverage deliveries for 8 hours/week x 50 weeks/year = 400 hours/year. Adjustment factors are based on 200 hours/year outdoors and 200 hours/year indoors.

Allendale. The adult male is exposed at this location during the balance of his full-time employment, equal to 1600 hours/year (250 days/year x 8 hours/day - 400 hours/year = 1,600 hours/year).

Barnwell. All individuals spend the remainder of their time, excluding church and employment, in Barnwell.

Exposure Factors (hours/year)

Individual	Martin	Onsite SRS
Adult M	104	400
Adult F	104	0
Child 1955	104	0
Child 1964	104	0
Individual	Allendale	Barnwell
Adult M	1,600	6,660
Adult F	0	8,660
Child 1955	0	8,660
Child 1964	0	8,660

Notes: Child exposures start in 1955 and 1964.

Exposure Factors Martin

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.5503	0.4497	0.8349
Adult F	All Years	0.5503	0.4497	0.8349
Child 1955	Infant&Preschl 1955-59	0.5503	0.4497	0.8349
	Schoolchild 1960-66	0.5503	0.4497	0.8349
	Teen 1967-72	0.5503	0.4497	0.8349
	Adult M 1973-92	0.5503	0.4497	0.8349
Child 1964	Infant&Preschl 1964-68	0.5503	0.4497	0.8349
	1969-75	0.5503	0.4497	0.8349
	Teen 1976-81	0.5503	0.4497	0.8349
	Adult M 1982-92	0.5503	0.4497	0.8349

Exposure Factors Onsite SRS

Individual	Year	Fi	Fo	Ext. Soil Adj. Factor
Adult M	All Years	0.5000	0.5000	0.8500
Adult F	All Years	na	na	na
Child 1955	All Years	na	na	na
Child 1964	All Years	na	na	na

na = Not applicable because the exposure rate is zero at this location for this individual in this year.

Exposure Factors Allendale

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.8438	0.1563	0.7469
Adult F	All Years	na	na	na
Child 1955	All Years	na	na	na
Child 1964	All Years	na	na	na

na = Not applicable because the exposure rate is zero at this location for this individual in this year.

Exposure Factors Barnwell

Individual	Year	F_i	F_o	ESAF
Adult M	All Years	0.8680	0.1320	0.7396
Adult F	All Years	0.8680	0.1320	0.7396
Child 1955	Infant&Preschl 1955-59	0.8610	0.1390	0.7417
	Schoolchild 1960-66	0.8236	0.1764	0.7529
	Teen 1967-72	0.8532	0.1468	0.7440
	Adult M 1973-92	0.8680	0.1320	0.7396
Child 1964	Infant&Preschl 1964-68	0.8610	0.1390	0.7417
	Schoolchild 1969-75	0.8236	0.1764	0.7529
	Teen 1976-81	0.8532	0.1468	0.7440
	Adult M 1982-92	0.8680	0.1320	0.7396

Outdoors Person

Onsite SRS. The adult male is exposed at this location during full-time employment (250 days/year x 8 hours/day = 2,000 hours/year) for all years. All exposure for the adult male at this location is outdoors.

Jackson. All individuals spend the remainder of their time, excluding employment, in Jackson.

Exposure Factors (hours/year)

Individual	Onsite SRS	Jackson
Adult M	2,000	6,760
Adult F	0	8,760
Child 1955	0	8,760
Child 1964	0	8,760

Notes: Child exposures start in 1955 and 1964.

Exposure Factors Jackson

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.8589	0.1411	0.7423
Adult F	All Years	0.8610	0.1390	0.7417
Child 1955	Infant&Preschl 1955-59	0.8542	0.1458	0.7437
	Schoolchild 1960-66	0.8177	0.1823	0.7547
	Teen 1967-72	0.8466	0.1534	0.7460
	Adult M 1973-92	0.8589	0.1411	0.7423
Child 1964	Infant&Preschl 1964-68	0.8542	0.1458	0.7437
	Schoolchild 1969-75	0.8177	0.1823	0.7547
	Teen 1976-81	0.8466	0.1534	0.7460
	Adult M 1982-92	0.8589	0.1411	0.7423

Exposure Factors Onsite SRS

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.0000	1.0000	1.0000
Adult F	All Years	na	na	na
Child 1955	All Years	na	na	na
Child 1964	All Years	na	na	na

Family Living Near the River

Martin. All individuals are exposed at the Martin location for all years.

Exposure Factors (hours/year)

Individual	Martin
Adult M	8,760
Adult F	8,760
Child 1955	8,760
Child 1964	8,760

Notes: Child exposures start in 1955 and 1964.

Exposure Factors Martin

Individual	Year	F_i	F_o	Ext. Soil Adj. Factor
Adult M	All Years	0.8698	0.1302	0.7391
Adult F	All Years	0.8681	0.1319	0.7396
Child 1955	Infant&Preschl 1955-59	0.8612	0.1388	0.7417
	Schoolchild 1960-66	0.8241	0.1759	0.7528
	Teen 1967-72	0.8532	0.1468	0.7440
	Adult M 1973-92	0.8698	0.1302	0.7391
Child 1964	Infant&Preschl 1964-68	0.8612	0.1388	0.7417
	Schoolchild 1969-75	0.8241	0.1759	0.7528
	Teen 1976-81	0.8532	0.1468	0.7440
	Adult M 1982-92	0.8698	0.1302	0.7391

<table>
<tr>
<td>Migrant Worker Family</td>
<td>New Ellenton. All individuals are exposed at the New Ellenton location for all years. This family is assumed to be present in potentially affected areas 50 percent of the time for all years. The schoolchild and the teenager do not go to school in this scenario, and the teenager works out in the fields with the father. For the remainder of the time, the individuals are present in areas outside the region potentially affected by air released contamination from SRS.

Exposure Factors (hours/year)
<table>
<tr><th>Individual</th><th>New Ellenton</th></tr>
<tr><td>Adult M</td><td>4,380</td></tr>
<tr><td>Adult F</td><td>4,380</td></tr>
<tr><td>Child 1955</td><td>4,380</td></tr>
<tr><td>Child 1964</td><td>4,380</td></tr>
</table>
Notes: Child exposures start in 1955 and 1964.</td>
<td>Exposure Factors New Ellenton
<table>
<tr><th>Individual</th><th>Year</th><th>F_i</th><th>F_o</th><th>Ext. Soil Adj. Factor</th></tr>
<tr><td>Adult M</td><td>All Years</td><td>0.6909</td><td>0.3091</td><td>0.7927</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>0.8610</td><td>0.1390</td><td>0.7417</td></tr>
<tr><td rowspan="4">Child 1955</td><td>Infant&Preschl 1955-59</td><td>0.8543</td><td>0.1457</td><td>0.7437</td></tr>
<tr><td>Schoolchild 1960-66</td><td>0.8177</td><td>0.1823</td><td>0.7547</td></tr>
<tr><td>Teen 1967-72</td><td>0.8468</td><td>0.1532</td><td>0.7460</td></tr>
<tr><td>Adult M 1973-92</td><td>0.6909</td><td>0.3091</td><td>0.7927</td></tr>
<tr><td rowspan="4">Child 1964</td><td>Infant&Preschl 1964-68</td><td>0.8543</td><td>0.1457</td><td>0.7437</td></tr>
<tr><td>Schoolchild 1969-75</td><td>0.8177</td><td>0.1823</td><td>0.7547</td></tr>
<tr><td>Teen 1976-81</td><td>0.8468</td><td>0.1532</td><td>0.7460</td></tr>
<tr><td>Adult M 1982-92</td><td>0.6909</td><td>0.3091</td><td>0.7927</td></tr>
</table></td>
</tr>
</table>

2.2 Inhalation Pathways

2.2.1 Air Inhalation

This pathway accounts for radiation exposure that results from inhalation of airborne contaminants. The amount of time spent at each location coincides with the specified amounts of time individuals spend at specified exposure locations. These periods of time are documented above for the external air and external soil exposure pathways. This pathway accounts for exposure that occurs either indoors or outdoors. The GENII variables for this pathway are:

- Air inhalation rate (m^3/day)
- Air inhalation period (days/year)
- Fraction of a day outdoor inhalation occurs (unitless)

Exposure Rates. For each exposure location, the exposure factor is based on the first two variables, resulting in a rate expressed in m^3/year of inhalation. Air Inhalation rates were based on Recommended Values from EPA 1997 (Table 5-26). The age/gender categories in this reference were averaged together to align with the modeled categories. Table 19 specifies the categories and data from EPA 1997 and the corresponding modeled categories and rates.

Table 19. EPA 1997 Air Inhalation Age/Gender Categories and Rates, and Corresponding GENII-Modeled Air Inhalation Age/Gender Categories and Calculated Rates.

EPA 1997 Data (Table 5-26)		Corresponding Modeled Exposure Rate Values	
Age/Gender Categories	**Air Inhalation (m^3/day)**	**Modeled Age/Gender Categories**	**Air Inhalation (m^3/year) [a]**
Infants (<1)	4.5	Infant (<1)	1,643
1 – 2	6.8	Pre-School (1 – 4)	2,811b
3 – 5	8.3		
6 – 8	10	Child (5 – 11)	4,380[b]
9 – 11 Male	14		
9 – 11 Female	13		
12 – 14 Male	15	Teenager (12 – 17)	5,892[b]
12 – 14 Female	12		
15 – 18 Male	17		
15 – 18 Female	12		
Adult Male 19 – 65+	15.2	Adult Male (>18)	5,548
Adult Female 19 – 65+	11.3	Adult Female (>18)	4,125

[a] Calculated rates are based on 365 days/year of inhalation.
[b] These inhalation rates are a time-weighted average of the different age categories.

For the CDC scenarios, these rates were apportioned between the receptor locations according to the amount of time each individual receptor spent at each location, as indicated below. The inhalation volumes for each receptor at each location are directly proportional to the amount of time present at each location (see the External Air Exposure pathway). The GENII model assumes no adjustments in exposure factors for individuals being indoors for a portion of each day. For a lot of constituents, like fine particulate matter and gasses, the indoor concentration would be roughly equal to the outdoor concentration. This is due to the assumption of people at the receptor locations having windows open and/or not having completely sealed living structures.

Table 20. Air Inhalation Exposure Pathway, Exposure Factors.

<table>
<tr><th>Scenario Family</th><th>Air Inhalation</th><th>Values for Exposure Factors</th></tr>
<tr><td>Rural Family #1</td><td>Girard. The adult male and female reside full-time in the area around Girard and inhale 100% of the adult rates at the Girard location for all years. With the exception of high school, the three children inhale 100% of the applicable rates the Girard location for all years beginning with their birth year. During high school, the children inhalation rates in Girard are 85.6% (7,500/8,760) of the applicable rates. The high school exposure occurs for each child aged 12 to 17 (1967-72 for a child born in 1955, and 1976-81 for a child born in 1964).

Waynesboro. During high school, the children inhalation rates in Waynesboro are 14.4% (1,260/8,760) of the applicable rates.</td><td>Exposure Factors (m^3/year)
<table>
<tr><th>Individual</th><th>Year</th><th>Girard</th><th>Waynesboro</th></tr>
<tr><td>Adult M</td><td>All years</td><td>5,548</td><td>0</td></tr>
<tr><td>Adult F</td><td>All years</td><td>4,125</td><td>0</td></tr>
<tr><td>Child 1955</td><td>Infant 1955</td><td>1,643</td><td>0</td></tr>
<tr><td></td><td>Preschl 1956-59</td><td>2,811</td><td>0</td></tr>
<tr><td></td><td>Schoolchild 1960-66</td><td>4,380</td><td>0</td></tr>
<tr><td></td><td>Teen 1967-72</td><td>5,045</td><td>848</td></tr>
<tr><td></td><td>Adult M 1973-92</td><td>5,548</td><td>0</td></tr>
<tr><td>Child 1964</td><td>Infant 1964</td><td>1,643</td><td>0</td></tr>
<tr><td></td><td>Preschl 1965-68</td><td>2,811</td><td>0</td></tr>
<tr><td></td><td>Schoolchild 1969-75</td><td>4,380</td><td>0</td></tr>
<tr><td></td><td>Teen 1976-81</td><td>5,045</td><td>848</td></tr>
<tr><td></td><td>Adult M 1982-92</td><td>5,548</td><td>0</td></tr>
</table>
Notes:

1. Child exposures start in 1955 and 1964.

2. During the indicated years (1967-72 for Child-1955, and 1976-81 for Child-1964), Child-1955 and Child-1964 are in high school.</td></tr>
<tr><td>Rural Family #2</td><td>Williston. All individuals inhale 100% of the applicable rates at Williston for all years.</td><td>Exposure Factors (m^3/year)
<table>
<tr><th>Individual</th><th>Year</th><th>Williston</th></tr>
<tr><td>Adult M</td><td>All years</td><td>5,548</td></tr>
<tr><td>Adult F</td><td>All years</td><td>4,125</td></tr>
<tr><td>Child 1955</td><td>Infant 1955</td><td>1,643</td></tr>
<tr><td></td><td>Preschl 1956-59</td><td>2,811</td></tr>
<tr><td></td><td>Schoolchild 1960-66</td><td>4,380</td></tr>
<tr><td></td><td>Teen 1967-72</td><td>5,892</td></tr>
<tr><td></td><td>Adult M 1973-92</td><td>5,548</td></tr>
<tr><td>Child 1964</td><td>Infant 1964</td><td>1,643</td></tr>
<tr><td></td><td>Preschl 1965-68</td><td>2,811</td></tr>
<tr><td></td><td>Schoolchild 1969-75</td><td>4,380</td></tr>
<tr><td></td><td>Teen 1976-81</td><td>5,892</td></tr>
<tr><td></td><td>Adult M 1982-92</td><td>5,548</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Air Inhalation</th><th>Values for Exposure Factors</th></tr>
<tr><td>Urban/Suburban Family</td><td>Onsite SRS. The adult male inhales ~23% (2,000/8,760) of the applicable rate at the Onsite SRS location, representing full-time employment for all years.

Augusta. All individuals except the adult male inhale 100% of the applicable rates at Augusta for all years. The adult male inhales ~77% (6,760/8,760) of the applicable rate at the Augusta location.</td><td>Exposure Factors (m^3/year)
<table>
<tr><th>Individual</th><th>Year</th><th>Augusta</th><th>Onsite SRS</th></tr>
<tr><td>Adult M</td><td>All years</td><td>4,281</td><td>1,267</td></tr>
<tr><td>Adult F</td><td>All years</td><td>4,125</td><td>0</td></tr>
<tr><td rowspan="5">Child 1955</td><td>Infant 1955</td><td>1,643</td><td>0</td></tr>
<tr><td>Preschl 1956-59</td><td>2,811</td><td>0</td></tr>
<tr><td>Schoolchild 1960-66</td><td>4,380</td><td>0</td></tr>
<tr><td>Teen 1967-72</td><td>5,892</td><td>0</td></tr>
<tr><td>Adult M 1973-92</td><td>5,548</td><td>0</td></tr>
<tr><td rowspan="5">Child 1964</td><td>Infant 1964</td><td>1,643</td><td>0</td></tr>
<tr><td>Preschl 1965-68</td><td>2,811</td><td>0</td></tr>
<tr><td>Schoolchild 1969-75</td><td>4,380</td><td>0</td></tr>
<tr><td>Teen 1976-81</td><td>5,892</td><td>0</td></tr>
<tr><td>Adult M 1982-92</td><td>5,548</td><td>0</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Air Inhalation</th><th>Values for Exposure Factors</th></tr>
<tr><td>Delivery Person</td><td>Martin. All individuals inhale ~1.2% (104/8,760) of the applicable rates at the Martin location for all years, representing 104 hours/year of church attendance. Children begin church attendance immediately beginning in their birth year.

Onsite SRS. The adult male inhales ~4.6% (400/8,760) of the applicable rate at the Onsite SRS location for all years, representing 400 hours/year of onsite beverage deliveries.

Allendale. The adult male inhales ~18% (1,600/8,760) of the applicable rate at the Allendale location for all years, representing the balance of his full-time employment.

Barnwell. All individuals inhale for the remainder of their time at the Barnwell location. For all individuals except the adult male, this amount is 99% (8,656/8,760) of the applicable rates. For the adult male, the amount is 76% (6,656/8,760) of the applicable rate.</td><td>Exposure Factors (m^3/year)
<table>
<tr><th>Individual</th><th>Year</th><th>Martin</th><th>Onsite SRS</th></tr>
<tr><td>Adult M</td><td>All years</td><td>194</td><td>253</td></tr>
<tr><td>Adult F</td><td>All years</td><td>144</td><td>0</td></tr>
<tr><td rowspan="5">Child 1955</td><td>Infant 1955</td><td>57</td><td>0</td></tr>
<tr><td>Preschl 1956-59</td><td>98</td><td>0</td></tr>
<tr><td>Schoolchild 1960-66</td><td>153</td><td>0</td></tr>
<tr><td>Teen 1967-72</td><td>206</td><td>0</td></tr>
<tr><td>Adult M 1973-92</td><td>66</td><td>0</td></tr>
<tr><td rowspan="5">Child 1964</td><td>Infant 1964</td><td>57</td><td>0</td></tr>
<tr><td>Preschl 1965-68</td><td>98</td><td>0</td></tr>
<tr><td>Schoolchild 1969-75</td><td>153</td><td>0</td></tr>
<tr><td>Teen 1976-81</td><td>206</td><td>0</td></tr>
<tr><td>Adult M 1982-92</td><td>66</td><td>0</td></tr>
</table>
<table>
<tr><th>Individual</th><th>Year</th><th>Allendale</th><th>Barnwell</th></tr>
<tr><td>Adult M</td><td>All years</td><td>1,013</td><td>4088</td></tr>
<tr><td>Adult F</td><td>All years</td><td>0</td><td>3,980</td></tr>
<tr><td rowspan="5">Child 1955</td><td>Infant 1955</td><td>0</td><td>1,585</td></tr>
<tr><td>Preschl 1956-59</td><td>0</td><td>2,712</td></tr>
<tr><td>Schoolchild 1960-66</td><td>0</td><td>4,227</td></tr>
<tr><td>Teen 1967-72</td><td>0</td><td>5,686</td></tr>
<tr><td>Adult M 1973-92</td><td>0</td><td>5,482</td></tr>
<tr><td rowspan="5">Child 1964</td><td>Infant 1964</td><td>0</td><td>1,585</td></tr>
<tr><td>Preschl 1965-68</td><td>0</td><td>2,712</td></tr>
<tr><td>Schoolchild 1969-75</td><td>0</td><td>4,227</td></tr>
<tr><td>Teen 1976-81</td><td>0</td><td>5,686</td></tr>
<tr><td>Adult M 1982-92</td><td>0</td><td>5,482</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Air Inhalation</th><th>Values for Exposure Factors</th></tr>
<tr><td>Outdoors Person</td><td>Onsite SRS. The adult male inhales 23% (2,000/8,760) of the applicable rate at the Onsite SRS location, representing full-time employment for all years.

Jackson. All individuals inhale for the remainder of their time at the Jackson location. For all individuals except the adult male, this amount is 100% of the applicable rates. For the adult male, the amount is ~77% (6,760/8,760) of the applicable rate.</td><td>Exposure Factors (m^3/year)
<table>
<tr><th>Individual</th><th>Year</th><th>Onsite SRS</th><th>Jackson</th></tr>
<tr><td>Adult M</td><td>All years</td><td>1,267</td><td>4,281</td></tr>
<tr><td>Adult F</td><td>All years</td><td>0</td><td>4,125</td></tr>
<tr><td rowspan="5">Child 1955</td><td>Infant 1955</td><td>0</td><td>1,643</td></tr>
<tr><td>Preschl 1956-59</td><td>0</td><td>2,811</td></tr>
<tr><td>Schoolchild 1960-66</td><td>0</td><td>4,380</td></tr>
<tr><td>Teen 1967-72</td><td>0</td><td>5,892</td></tr>
<tr><td>Adult M 1973-92</td><td>0</td><td>5,548</td></tr>
<tr><td rowspan="5">Child 1964</td><td>Infant 1964</td><td>0</td><td>1,643</td></tr>
<tr><td>Preschl 1965-68</td><td>0</td><td>2,811</td></tr>
<tr><td>Schoolchild 1969-75</td><td>0</td><td>4,380</td></tr>
<tr><td>Teen 1976-81</td><td>0</td><td>5,892</td></tr>
<tr><td>Adult M 1982-92</td><td>0</td><td>5,548</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
<tr><td>Family Living Near the River</td><td>Martin. All individuals inhale 100% of the applicable rates at Martin for all years.</td><td>Exposure Factors (m^3/year)
<table>
<tr><th>Individual</th><th>Year</th><th>Martin</th></tr>
<tr><td>Adult M</td><td>All years</td><td>5,548</td></tr>
<tr><td>Adult F</td><td>All years</td><td>4,125</td></tr>
<tr><td rowspan="5">Child 1955</td><td>Infant 1955</td><td>1,643</td></tr>
<tr><td>Preschl 1956-59</td><td>2,811</td></tr>
<tr><td>Schoolchild 1960-66</td><td>4,380</td></tr>
<tr><td>Teen 1967-72</td><td>5,892</td></tr>
<tr><td>Adult M 1973-92</td><td>5,548</td></tr>
<tr><td rowspan="5">Child 1964</td><td>Infant 1964</td><td>1,643</td></tr>
<tr><td>Preschl 1965-68</td><td>2,811</td></tr>
<tr><td>Schoolchild 1969-75</td><td>4,380</td></tr>
<tr><td>Teen 1976-81</td><td>5,892</td></tr>
<tr><td>Adult M 1982-92</td><td>5,548</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Air Inhalation</th><th>Values for Exposure Factors</th></tr>
<tr><td>Migrant Worker Family</td><td>New Ellenton. All individuals inhale 50% of the applicable rates at New Ellenton for all years. The remainder of their inhalation occurs in areas outside the region potentially affected by air-released contamination from SRS. This leads to an exposure rate of (m^3/yr) x 0.5 being the exposure factor for dose modeling.</td><td>Exposure Factors (m^3/year)
<table>
<tr><th>Individual</th><th>Year</th><th>New Ellenton</th></tr>
<tr><td>Adult M</td><td>All years</td><td>2,774</td></tr>
<tr><td>Adult F</td><td>All years</td><td>2,062</td></tr>
<tr><td rowspan="5">Child 1955</td><td>Infant 1955</td><td>821</td></tr>
<tr><td>Preschl 1956-59</td><td>1,405</td></tr>
<tr><td>Schoolchild 1960-66</td><td>2,190</td></tr>
<tr><td>Teen 1967-72</td><td>2,946</td></tr>
<tr><td>Adult M 1973-92</td><td>2,774</td></tr>
<tr><td rowspan="5">Child 1964</td><td>Infant 1964</td><td>821</td></tr>
<tr><td>Preschl 1965-68</td><td>1,405</td></tr>
<tr><td>Schoolchild 1969-75</td><td>2,190</td></tr>
<tr><td>Teen 1976-81</td><td>2,946</td></tr>
<tr><td>Adult M 1982-92</td><td>2,774</td></tr>
</table>
Note: Child exposures start in 1955 and 1964.</td></tr>
</table>

2.2.2 Resuspended Soil Inhalation

This pathway represents inhalation of soil. The assumption made here is that an individual is exposed to resuspended soil when both indoors and outdoors. Indoor exposure can be assumed due to individuals having windows and doors of living structures open for ventilation, and/or not having a perfectly sealed living structure. The GENII variables for this pathway are:

- Resuspended soil inhalation rate (m^3/day)
- Resuspended soil inhalation period (days/year)
- Fraction of a day inhalation of resuspension occurs (unitless)

Exposure Factors. The three GENII variables are multiplied together to produce an exposure factor expressed in m^3/year. Table 20, Air Inhalation Exposure Pathway, Exposure Factors will be used for the exposure factors for resuspended soil. Since people are assumed to be exposed to soil indoors and outdoors, total volume of air breathed is used to calculate the resuspended soil exposure factors.

2.3 Ingestion Pathways

2.3.1 Beef Ingestion Pathway

GENII allows for two separate meat ingestion pathways, identified in the model as beef and poultry. In this assessment, the GENII beef pathway is used to represent all non-poultry and non-fish meat that is potentially affected by SRS releases. This includes beef, but also serves as a surrogate for wild game, pork, and other non-poultry meats. Several sets of data were evaluated to develop values for meat consumption. The principal source was the EPA 1997, which provided values for national averages for adult and child meat and beef consumption. Also considered were values for beef consumption referenced in Hamby 1991. Both sources are secondary references that provide analysis of consumption

data originally compiled by USDA in periodic National Food Consumption Surveys (NFCS) and Continuing Surveys of Food Intakes by Individuals (CSFII). Neither of these sources provides values that align exactly with the CDC scenarios or the age group categories of GENII. Additionally, neither source is based on local (e.g., county- or state-level) data. Therefore, some adjustment of the raw data was necessary to develop values that better correspond with the CDC and GENII specifications. EPA 1997 was selected as a better source because it provided separate categories for adult males and females and multiple categories identifying different meat types. Tables 21 and 22 below present the categories of data included in each of the sources.

Table 21. Ingestion Categories in EPA 1997 Meat Consumption Data.

1987-88 NFCS and 1994/1995 CSFII		1977-78 NFCS	
Age and Gender Categories	**Meat Categories**	**Age and Gender Categories**	**Meat Categories**
<5	Total Meat, Poultry and Fish	<1	Total Meat, Poultry and Fish
6 – 11 male / female	Beef	1 – 2	Beef
12 – 19 male / female	Pork	3 – 5	Pork
>20 male / female	Lamb, Veal, Game	6 – 8	Lamb, Veal, Game
All individuals	Frankfurters, sausages, luncheon meats	9 – 11 male / female	Frankfurters, sausages, luncheon meats
	Total Poultry	12 – 14 male / female	Total Poultry
	Chicken Only	15 – 18 male / female	Chicken Only
	Meat Mixtures	19 – 22 male / female	Meat Mixtures
		23 – 34 male / female	
		35 – 50 male / female	
		51 – 64 male / female	
		65 – 74 male / female	
		>75 male / female	
		All individuals	

Table 22. Ingestion Categories in Hamby 1991 Meat Consumption Data.[a]

Age and Gender Categories	Meat Categories
Infant	
Child	Beef (households in the south only)
Teen	All meat (nationwide only)
Adult	

[a] Hamby 1991 provides 2 sets of data, NFCS 1977-78 data for households in the south, and NRC defaults.

The meat consumption values used in the model were derived primarily from EPA 1997 data derived from the 1977-78 NFCS. This data set was selected for four reasons:

- This data set includes values for a broad range of individual meat categories.

- The time period covered by this data set (1977-1978) is closer to the midpoint of the 1954-1992 period being modeled than the other data sets, which occur near or after 1992.
- This data set provides numerous age/gender categories that can be more easily aligned with the CDC and GENII age/gender categories.
- This data set is expressed in units that more easily convert to units required by GENII (g/day to kg/year). Additional conversions considering consumption rate variations by body weight were not needed.

To calculate input consumption quantities for GENII "Beef" (i.e., meat that is not poultry and not fish), EPA 1997 values for intake of beef, pork, lamb/veal/game, meat mixtures, and processed meats (frankfurters, sausages, luncheon meats, spreads) were added together. For non-adult age/gender categories, male and female values were averaged. Table 23 shows the modeled age/gender categories, the corresponding age/gender categories from EPA 1997 that were averaged together to calculate a comparable input value, and the calculated value was converted to units used by the GENII model (i.e., g/day to kg/year).

Table 23. Alignment between GENII-Modeled Age/Gender Categories for "Beef"a, Poultry, Milk, and Eggs, Corresponding EPA 1997 Age/Gender Categories, and Calculated Rates.

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged	Calculated Value – Average Consumption (kg/yr or L/yr)			
		"Beef" [a]	Poultry	Milk	Eggs
Infant (<1)	<1	25.2	1.5	131.8	1.8
Pre-School (1 – 4)	1 – 2 3 – 5	31.4	6.5	130.2	7.7
Child (5 – 11)	6 – 8 9 – 11 male	50.6	8.0	146.5	8.0
Teenager (12 – 17)	12 – 14 male 15 – 18 male	75.6	11.9	169.5	10.8
Adult Male (>18)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	78.1	11.3	73.7	13.9
Adult Female (>18)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	49.7	9.1	55.5	8.4

[a] The beef ingestion pathway in the GENII model is being used to model consumption of potentially all affected meat that is not fish or poultry.

The approach for applying these rates to the CDC scenarios is described in Table 24.

Table 24. Beef Ingestion Exposure Pathway, Exposure and Adjustment Factors

<table>
<tr><th>Scenario Family</th><th>Beef Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>Girard. For all individuals, during the 1950's, 50% of the beef is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 50% of the beef comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources. Beginning in 1960, 25% of the beef is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 75% of the beef comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources.

In Lockridge 2002, it is stated that 50% of the meat is grown on the farm for the 1950's, while 25% of the meat is grown from the 1960's on. It is also stated that there is a significant amount of hunting for wild game.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Girard</th><th>Contaminated Fraction</th></tr>
<tr><td rowspan="2">Adult M</td><td>Up to 1960</td><td>78.1</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>78.1</td><td>0.625</td></tr>
<tr><td rowspan="2">Adult F</td><td>Up to 1960</td><td>49.7</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>49.7</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>25.2</td><td>0.75</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>31.4</td><td>0.75</td></tr>
<tr><td>1960-66</td><td>School</td><td>50.6</td><td>0.625</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>75.6</td><td>0.625</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>78.1</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>25.2</td><td>0.625</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>31.4</td><td>0.625</td></tr>
<tr><td>1969-75</td><td>School</td><td>50.6</td><td>0.625</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>75.6</td><td>0.625</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>78.1</td><td>0.625</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Beef Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Rural Family #2</td><td>Williston. For all individuals, during the 1950's, 50% of the beef is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 50% of the beef comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources. Beginning in 1960, 25% of the beef is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 75% of the beef comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources.

In Lockridge 2002, it is stated that 50% of the meat is grown on the farm for the 1950's, while 25% of the meat is grown from the 1960's on. It is also stated that there is a significant amount of hunting for wild game.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2">Individual</th><th>Williston</th><th>Contaminated Fraction</th></tr>
<tr><td rowspan="2">Adult M</td><td>Up to 1960</td><td>78.1</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>78.1</td><td>0.625</td></tr>
<tr><td rowspan="2">Adult F</td><td>Up to 1960</td><td>49.7</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>49.7</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2"></td></tr>
<tr><td>1955</td><td>Infant</td><td>25.2</td><td>0.75</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>31.4</td><td>0.75</td></tr>
<tr><td>1960-66</td><td>School</td><td>50.6</td><td>0.625</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>75.6</td><td>0.625</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>78.1</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2"></td></tr>
<tr><td>1964</td><td>Infant</td><td>25.2</td><td>0.625</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>31.4</td><td>0.625</td></tr>
<tr><td>1969-75</td><td>School</td><td>50.6</td><td>0.625</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>75.6</td><td>0.625</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>78.1</td><td>0.625</td></tr>
</table></td></tr>
<tr><td>Urban/Suburban Family</td><td>Augusta For all individuals, 100% of the beef comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources.

There is no direct mention of beef for this family in Lockridge 2002, just the statement that food was obtained from local grocery stores in Augusta GA. It was also stated that there was no hunting for wild game.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2">Individual</th><th>Augusta</th><th>Contaminated Fraction</th></tr>
<tr><td>Adult M</td><td>All Years</td><td>78.1</td><td>0.5</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>49.7</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2"></td></tr>
<tr><td>1955</td><td>Infant</td><td>25.2</td><td>0.5</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>31.4</td><td>0.5</td></tr>
<tr><td>1960-66</td><td>School</td><td>50.6</td><td>0.5</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>75.6</td><td>0.5</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>78.1</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2"></td></tr>
<tr><td>1964</td><td>Infant</td><td>25.2</td><td>0.5</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>31.4</td><td>0.5</td></tr>
<tr><td>1969-75</td><td>School</td><td>50.6</td><td>0.5</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>75.6</td><td>0.5</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>78.1</td><td>0.5</td></tr>
</table></td></tr>
</table>

Scenario Family	Beef Ingestion Pathway	Values For Exposure And Adjustment Factors
Delivery Person	Martin and Barnwell. For all individuals, half of the beef comes from Martin. 25% of the beef comes from the local grocery store, and is considered to be 50% contaminated. The other 25% of the meat from Martin comes from hunting of wild game in the LTRC area. The other 50% of the beef is from a local grocery store in Barnwell and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources. There is no direct mention of beef for this family in Lockridge 2002, just the statement that food was obtained from local grocery stores in Barnwell and Martin SC. It was also stated that there was some hunting for wild game in the Lower Three Runs Creek area.	Exposure Factors (kg/yr)

Individual		Martin		Barnwell	
		Amount	C.F.	Amount	C.F.
Adult M		39.05	0.625	39.05	0.50
Adult F		24.85	0.625	24.85	0.50
Child 1955					
1955	Infant	12.6	0.625	12.6	0.50
1956-59	Pre-school	15.7	0.625	15.7	0.50
1960-66	School	25.3	0.625	25.3	0.50
1967-73	Teen	37.8	0.625	37.8	0.50
1974-92	Adult	39.05	0.625	39.05	0.50
Child 1964					
1964	Infant	12.6	0.625	12.6	0.50
1965-68	Pre-school	15.7	0.625	15.7	0.50
1969-75	School	25.3	0.625	25.3	0.50
1976-82	Teen	37.8	0.625	37.8	0.50
1983-92	Adult	39.05	0.625	39.05	0.50

Scenario Family	Beef Ingestion Pathway	Values For Exposure And Adjustment Factors
Outdoors Person	Onsite SRS and Jackson. For all individuals, 75% of the beef comes from Onsite SRS, and is considered to be 100% contaminated. The other 25% of the meat comes from local grocery stores in Jackson, and is considered to be 50% contaminate d. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources. In Lockridge 2002 it is stated that 75% of meat is obtained from wild game on the SRS.	Exposure Factors (kg/yr)

Individual		Onsite SRS		Jackson	
		Amount	C.F.	Amount	C.F.
Adult M		58.58	1.00	19.52	0.50
Adult F		37.28	1.00	12.42	0.50
Child 1955					
1955	Infant	18.9	1.00	6.3	0.50
1956-59	Pre-school	23.55	1.00	7.85	0.50
1960-66	School	37.95	1.00	12.65	0.50
1967-73	Teen	56.7	1.00	18.9	0.50
1974-92	Adult	58.58	1.00	19.52	0.50
Child 1964					
1964	Infant	18.9	1.00	6.3	0.50
1965-68	Pre-school	23.55	1.00	7.85	0.50
1969-75	School	37.95	1.00	12.65	0.50
1976-82	Teen	56.7	1.00	18.9	0.50
1983-92	Adult	58.58	1.00	19.52	0.50

<table>
<tr><th>Scenario Family</th><th>Beef Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Family Living Near the River</td><td>Martin. For all individuals, 100% of the beef comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources

There is no direct mention of beef in Lockridge 2002 for this family, just that food comes from local grocery stores.</td><td>Exposure Factors (kg/yr)
<table>
<tr><td colspan="2">Individual</td><td>Martin</td><td>Contaminated Fraction</td></tr>
<tr><td>Adult M</td><td>All Years</td><td>78.1</td><td>0.5</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>49.7</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>25.2</td><td>0.5</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>31.4</td><td>0.5</td></tr>
<tr><td>1960-66</td><td>School</td><td>50.6</td><td>0.5</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>75.6</td><td>0.5</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>78.1</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>25.2</td><td>0.5</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>31.4</td><td>0.5</td></tr>
<tr><td>1969-75</td><td>School</td><td>50.6</td><td>0.5</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>75.6</td><td>0.5</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>78.1</td><td>0.5</td></tr>
</table></td></tr>
<tr><td>Migrant Worker Family</td><td>New Ellenton. For all individuals, 100% of the beef comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the beef at the local grocery store comes from the local farms, and half from outside sources. Since this family is in the area for half of the year, they are assigned half of the consumption rates of the other scenario groups.

In Lockridge 2002 there is no direct mention of beef, only that the family obtained their food from local grocery stores.</td><td>Exposure Factors (kg/yr)
<table>
<tr><td colspan="2">Individual</td><td>New Ellenton</td><td>Contaminated Fraction</td></tr>
<tr><td>Adult M</td><td>All Years</td><td>39.05</td><td>0.5</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>24.85</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>12.6</td><td>0.5</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>15.7</td><td>0.5</td></tr>
<tr><td>1960-66</td><td>School</td><td>25.3</td><td>0.5</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>37.8</td><td>0.5</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>39.05</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>12.6</td><td>0.5</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>15.7</td><td>0.5</td></tr>
<tr><td>1969-75</td><td>School</td><td>25.3</td><td>0.5</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>37.8</td><td>0.5</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>39.05</td><td>0.5</td></tr>
</table></td></tr>
</table>

2.3.2 Poultry Ingestion

For the poultry ingestion pathway, consumption rates for specific age/gender categories from EPA 1997 (Table 11-10) from the 1977-78 NFCS were adapted to the age/gender categories used in the model using the same approach used for beef. This alignment and the subsequent calculated rates are presented in Table 25. The approach for applying these rates to the CDC scenarios is described below.

Table 25. Poultry Ingestion Exposure Pathway, Exposure and Adjustment Factors

<table>
<tr><th>Scenario Family</th><th>Poultry Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>Girard. For all individuals, during the 1950's, 50% of the poultry is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 50% of the poultry comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources. Beginning in 1960, 25% of the poultry is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 75% of the poultry comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources.

In Lockridge 2002, it is stated that 50% of the meat is grown on the farm for the 1950's, while 25% of the meat is grown from the 1960's on. It is stated to assume family chickens. It is also stated that there is a significant amount of hunting for wild game.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2">Individual</th><th>Girard</th><th>Contaminated Fraction</th></tr>
<tr><td rowspan="2">Adult M</td><td>Up to 1960</td><td>11.3</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>11.3</td><td>0.625</td></tr>
<tr><td rowspan="2">Adult F</td><td>Up to 1960</td><td>9.1</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>9.1</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.5</td><td>0.75</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>6.5</td><td>0.75</td></tr>
<tr><td>1960-66</td><td>School</td><td>8.0</td><td>0.625</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>11.9</td><td>0.625</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>11.3</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.5</td><td>0.625</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>6.5</td><td>0.625</td></tr>
<tr><td>1969-75</td><td>School</td><td>8.0</td><td>0.625</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>11.9</td><td>0.625</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>11.3</td><td>0.625</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Poultry Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Rural Family #2</td><td>Williston. For all individuals, during the 1950's, 50% of the poultry is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 50% of the poultry comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources. Beginning in 1960, 25% of the poultry is grown on the farm (including wild game), and is considered to be 100% contaminated. The other 75% of the poultry comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources.

In Lockridge 2002, it is stated that 50% of the meat is grown on the farm for the 1950's, while 25% of the meat is grown from the 1960's on. It is stated to assume family chickens. It is also stated that there is a significant amount of hunting for wild game.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2">Individual</th><th>Williston</th><th>Contaminated Fraction</th></tr>
<tr><td rowspan="2">Adult M</td><td>Up to 1960</td><td>11.3</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>11.3</td><td>0.625</td></tr>
<tr><td rowspan="2">Adult F</td><td>Up to 1960</td><td>9.1</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>9.1</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.5</td><td>0.75</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>6.5</td><td>0.75</td></tr>
<tr><td>1960-66</td><td>School</td><td>8.0</td><td>0.625</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>11.9</td><td>0.625</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>11.3</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.5</td><td>0.625</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>6.5</td><td>0.625</td></tr>
<tr><td>1969-75</td><td>School</td><td>8.0</td><td>0.625</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>11.9</td><td>0.625</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>11.3</td><td>0.625</td></tr>
</table></td></tr>
<tr><td>Urban/Suburban Family</td><td>Augusta For all individuals, 100% of the poultry comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources.

There is no direct mention of poultry for this family in Lockridge 2002, just the statement that food was obtained from local grocery stores in Augusta GA. It was also stated that there was no hunting for wild game.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2">Individual</th><th>Augusta</th><th>Contaminated Fraction</th></tr>
<tr><td>Adult M</td><td>Up to 1960</td><td>11.3</td><td>0.5</td></tr>
<tr><td>Adult F</td><td>Up to 1960</td><td>9.1</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.5</td><td>0.5</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>6.5</td><td>0.5</td></tr>
<tr><td>1960-66</td><td>School</td><td>8.0</td><td>0.5</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>11.9</td><td>0.5</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>11.3</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.5</td><td>0.5</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>6.5</td><td>0.5</td></tr>
<tr><td>1969-75</td><td>School</td><td>8.0</td><td>0.5</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>11.9</td><td>0.5</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>11.3</td><td>0.5</td></tr>
</table></td></tr>
</table>

Scenario Family	Poultry Ingestion Pathway	Values For Exposure And Adjustment Factors
Delivery Person	Martin and Barnwell. For all individuals, half of the poultry comes from Martin. 25% of the poultry comes from the local grocery store and is considered to be 50% contaminated. The other 25% of the poultry from Martin comes from hunting of wild game in the LTRC area. The other 50% of the poultry is from a local grocery store in Barnwell and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources Lockridge 2002 states an assumption of backyard chickens and hunting for wild game at Lower Three Runs Creek area.	Exposure Factors (kg/yr)

Individual		Martin		Barnwell	
		Amount	C.F.	Amount	C.F.
Adult M		5.65	0.625	5.65	0.50
Adult F		4.55	0.625	4.55	0.50
Child 1955					
1955	Infant	0.75	0.625	0.75	0.50
1956-59	Pre-school	3.25	0.625	3.25	0.50
1960-66	School	4.0	0.625	4.0	0.50
1967-73	Teen	5.95	0.625	5.95	0.50
1974-92	Adult	5.65	0.625	5.65	0.50
Child 1964					
1964	Infant	0.75	0.625	0.75	0.50
1965-68	Pre-school	3.25	0.625	3.25	0.50
1969-75	School	4.0	0.625	4.0	0.50
1976-82	Teen	5.95	0.625	5.95	0.50
1983-92	Adult	5.65	0.625	5.65	0.50

Outdoors Person	Onsite SRS and Jackson. For all individuals, 75% of the poultry comes from Onsite SRS, and is considered to be 100% contaminated. The other 25% of the poultry comes from local grocery stores in Jackson, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources In Lockridge 2002 it is stated that 75% of meat is obtained from the SRS. Wild game is also stated to be trapped on the SRS.	Exposure Factors (kg/yr)

Individual		Onsite SRS		Jackson	
		Amount	C.F.	Amount	C.F.
Adult M		8.475	1.00	2.825	0.50
Adult F		6.825	1.00	2.275	0.50
Child 1955					
1955	Infant	1.125	1.00	0.375	0.50
1956-59	Pre-school	4.875	1.00	1.625	0.50
1960-66	School	6.0	1.00	2.0	0.50
1967-73	Teen	8.925	1.00	2.975	0.50
1974-92	Adult	8.475	1.00	2.825	0.50
Child 1964					
1964	Infant	1.125	1.00	1.125	0.50
1965-68	Pre-school	4.875	1.00	4.875	0.50
1969-75	School	6.0	1.00	6.0	0.50
1976-82	Teen	8.925	1.00	8.925	0.50
1983-92	Adult	8.475	1.00	8.475	0.50

<table>
<tr><th>Scenario Family</th><th>Poultry Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Family Living Near the River</td><td>Martin. For all individuals, 100% of the poultry comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources

There is no direct mention of poultry in Lockridge 2002 for this family, just that food comes from local grocery stores.</td><td>Exposure Factors (kg/yr)
<table>
<tr><td colspan="2">Individual</td><td>Martin</td><td>Contaminated Fraction</td></tr>
<tr><td>Adult M</td><td>All Years</td><td>11.3</td><td>0.5</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>9.1</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.5</td><td>0.5</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>6.5</td><td>0.5</td></tr>
<tr><td>1960-66</td><td>School</td><td>8.0</td><td>0.5</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>11.9</td><td>0.5</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>11.3</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.5</td><td>0.5</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>6.5</td><td>0.5</td></tr>
<tr><td>1969-75</td><td>School</td><td>8.0</td><td>0.5</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>11.9</td><td>0.5</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>11.3</td><td>0.5</td></tr>
</table></td></tr>
<tr><td>Migrant Worker Family</td><td>New Ellenton. For all individuals, 100% of the poultry comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the poultry at the local grocery store comes from the local farms, and half from outside sources. Since this family is in the area for half of the year, they are assigned half of the consumption rates of the other scenario groups.

In Lockridge 2002 there is no direct mention of poultry, only that the family obtained their food from local farms and grocery stores.</td><td>Exposure Factors (kg/yr)
<table>
<tr><td colspan="2">Individual</td><td>New Ellenton</td><td>Contaminated Fraction</td></tr>
<tr><td>Adult M</td><td>All Years</td><td>5.65</td><td>0.5</td></tr>
<tr><td>Adult F</td><td>All Years</td><td>4.55</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>0.75</td><td>0.5</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>3.25</td><td>0.5</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.0</td><td>0.5</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>5.95</td><td>0.5</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>5.65</td><td>0.5</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>0.75</td><td>0.5</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>3.25</td><td>0.5</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.0</td><td>0.5</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>5.95</td><td>0.5</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>5.65</td><td>0.5</td></tr>
</table></td></tr>
</table>

2.3.3 Milk and Egg Ingestion

For the milk and egg ingestion pathways, consumption rates for specific age/gender categories from EPA 1997 (Table 11.12) from the 1977-78 NFCS were adapted to the age/gender categories used in the model using the same approach used for beef and poultry. This alignment and the subsequent calculated rates are presented in Table 26.

Table 26. Milk and Egg Ingestion Exposure Pathway, Exposure and Adjustment Factors

Scenario Family	Milk and Egg Ingestion Pathways	Values For Exposure And Adjustment Factors
Rural Family #1	Girard. All individuals consume locally produced milk and eggs. It is assumed that these local products are 100% contaminated. It is stated in Lockridge 2002 that "the milk source was most likely the local dairies near Girard, but not to the exclusion of a backyard cow." It is also assumed that the family had chickens.	Exposure Factors (kg/yr)

Individual		Girard			
		Milk	C.F.	Eggs	C.F.
Adult M		73.7	1.00	13.9	1.00
Adult F		55.5	1.00	8.4	1.00
Child 1955		[redacted]			
1955	Infant	131.8	1.00	1.8	1.00
1956-59	Pre-school	130.2	1.00	7.7	1.00
1960-66	School	146.5	1.00	8.0	1.00
1967-73	Teen	169.5	1.00	10.8	1.00
1974-92	Adult	73.7	1.00	13.9	1.00
Child 1964		[redacted]			
1964	Infant	131.8	1.00	1.8	1.00
1965-68	Pre-school	130.2	1.00	7.7	1.00
1969-75	School	146.5	1.00	8.0	1.00
1976-82	Teen	169.5	1.00	10.8	1.00
1983-92	Adult	73.7	1.00	13.9	1.00

Scenario Family	Milk and Egg Ingestion Pathways	Values For Exposure And Adjustment Factors
Rural Family #2	Williston. All individuals consume locally produced milk and eggs. It is assumed that these local products are 100% contaminated. It is stated in Lockridge 2002 that "the milk source was most likely the local dairies near (Williston), but not to the exclusion of a backyard cow." It is also assumed that the family had chickens.	Exposure Factors (kg/yr)

Individual		Williston			
		Milk	C.F.	Eggs	C.F.
Adult M		73.7	1.00	13.9	1.00
Adult F		55.5	1.00	8.4	1.00
Child 1955		[redacted]			
1955	Infant	131.8	1.00	1.8	1.00
1956-59	Pre-school	130.2	1.00	7.7	1.00
1960-66	School	146.5	1.00	8.0	1.00
1967-73	Teen	169.5	1.00	10.8	1.00
1974-92	Adult	73.7	1.00	13.9	1.00
Child 1964		[redacted]			
1964	Infant	131.8	1.00	1.8	1.00
1965-68	Pre-school	130.2	1.00	7.7	1.00
1969-75	School	146.5	1.00	8.0	1.00
1976-82	Teen	169.5	1.00	10.8	1.00
1983-92	Adult	73.7	1.00	13.9	1.00

Urban/ Suburban Family

Augusta and New Ellenton. All individuals consume locally produced milk and eggs. Half of the milk comes from dairies in Augusta and the other half comes from dairies in New Ellenton. All eggs come from Augusta. It is assumed that these local products are 100% contaminated.

It is stated in Lockridge 2002 that food and milk supplied by local dairies in Aiken and Augusta was obtained from local grocery stores in the Augusta area. McDougall 2003 adds the dairy in New Ellenton. It is also stated that the backyard cow is also included for the purposes of dose modeling.

Exposure Factors (kg/yr)

Individual		Augusta				New Ellenton	
		Milk	C.F.	Eggs	C.F.	Milk	C.F.
Adult M		36.85	1.00	13.9	1.00	36.85	1.00
Adult F		27.75	1.00	8.4	1.00	27.75	1.00
Child 1955							
1955	Infant	65.9	1.00	1.8	1.00	65.9	1.00
1956-59	Pre-school	65.1	1.00	7.7	1.00	65.1	1.00
1960-66	School	73.25	1.00	8.0	1.00	73.25	1.00
1967-73	Teen	84.75	1.00	10.8	1.00	84.75	1.00
1974-92	Adult	36.85	1.00	13.9	1.00	36.85	1.00
Child 1964							
1964	Infant	65.9	1.00	1.8	1.00	65.9	1.00
1965-68	Pre-school	65.1	1.00	7.7	1.00	65.1	1.00
1969-75	School	73.25	1.00	8.0	1.00	73.25	1.00
1976-82	Teen	84.75	1.00	10.8	1.00	84.75	1.00
1983-92	Adult	36.85	1.00	13.9	1.00	36.85	1.00

Delivery Person

Barnwell and Martin. All individuals consume locally produced milk and eggs. Half of the milk and half of the eggs come from Martin, and the other half comes from Barnwell. It is assumed that these local products are 100% contaminated .

It is stated in Lockridge 2002 that the family consumed milk from the nearest dairy or local farmer and that they kept backyard chickens.

Exposure Factors (kg/yr)

Individual		Barnwell				Martin			
		Milk	C.F.	Eggs	C.F.	Milk	C.F.	Eggs	C.F.
Adult M		36.85	1.00	6.95	1.00	36.85	1.00	6.95	1.00
Adult F		27.75	1.00	4.2	1.00	27.75	1.00	4.2	1.00
Child 1955									
1955	Infant	65.9	1.00	0.90	1.00	65.9	1.00	0.90	1.00
1956-59	Pre-school	65.1	1.00	3.85	1.00	65.1	1.00	3.85	1.00
1960-66	School	73.25	1.00	4.0	1.00	73.25	1.00	4.0	1.00
1967-73	Teen	84.75	1.00	5.4	1.00	84.75	1.00	5.4	1.00
1974-92	Adult	36.85	1.00	6.95	1.00	36.85	1.00	6.95	1.00
Child 1964									
1964	Infant	65.9	1.00	0.90	1.00	65.9	1.00	0.90	1.00
1965-68	Pre-school	65.1	1.00	3.85	1.00	65.1	1.00	3.85	1.00
1969-75	School	73.25	1.00	4.0	1.00	73.25	1.00	4.0	1.00
1976-82	Teen	84.75	1.00	5.4	1.00	84.75	1.00	5.4	1.00
1983-92	Adult	36.85	1.00	6.95	1.00	36.85	1.00	6.95	1.00

<table>
<tr>
<td>Outdoors Person</td>
<td>Jackson. All individuals consume locally produced milk and eggs. It is assumed that these local products are 100% contaminated.

Lockridge 2002 provides no data for the source of any milk or eggs.</td>
<td>Exposure Factors (kg/yr)
<table>
<tr><td colspan="2" rowspan="2">Individual</td><td colspan="4">Jackson</td></tr>
<tr><td>Milk</td><td>C.F.</td><td>Eggs</td><td>C.F.</td></tr>
<tr><td colspan="2">Adult M</td><td>73.7</td><td>1.00</td><td>13.9</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>55.5</td><td>1.00</td><td>8.4</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>131.8</td><td>1.00</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>130.2</td><td>1.00</td><td>7.7</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>146.5</td><td>1.00</td><td>8.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>169.5</td><td>1.00</td><td>10.8</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>73.7</td><td>1.00</td><td>13.9</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>131.8</td><td>1.00</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>130.2</td><td>1.00</td><td>7.7</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>146.5</td><td>1.00</td><td>8.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>169.5</td><td>1.00</td><td>10.8</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>73.7</td><td>1.00</td><td>13.9</td><td>1.00</td></tr>
</table></td>
</tr>
<tr>
<td>Family Living Near the River</td>
<td>Martin. All individuals consume locally produced milk and eggs. It is assumed that these local products are 100% contaminated.

In Lockridge 2002 there is no direct mention of milk or egg sources, but states that the family obtained their food from local grocery stores.</td>
<td>Exposure Factors (kg/yr)
<table>
<tr><td colspan="2" rowspan="2">Individual</td><td colspan="4">Martin</td></tr>
<tr><td>Milk</td><td>C.F.</td><td>Eggs</td><td>C.F.</td></tr>
<tr><td colspan="2">Adult M</td><td>73.7</td><td>1.00</td><td>13.9</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>55.5</td><td>1.00</td><td>8.4</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>131.8</td><td>1.00</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>130.2</td><td>1.00</td><td>7.7</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>146.5</td><td>1.00</td><td>8.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>169.5</td><td>1.00</td><td>10.8</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>73.7</td><td>1.00</td><td>13.9</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>131.8</td><td>1.00</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>130.2</td><td>1.00</td><td>7.7</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>146.5</td><td>1.00</td><td>8.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>169.5</td><td>1.00</td><td>10.8</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>73.7</td><td>1.00</td><td>13.9</td><td>1.00</td></tr>
</table></td>
</tr>
</table>

<table>
<tr>
<td>Migrant Worker Family</td>
<td>New Ellenton. All individuals consume locally produced milk and eggs. It is assumed that these local products are 100% contaminated.

The individuals are outside of the affected area 50% of the time.

In Lockridge 2002 there is no direct mention of milk or egg sources, but states that the family obtained their food from local grocery stores.</td>
<td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2" rowspan="2">Individual</th><th colspan="4">New Elleton</th></tr>
<tr><th>Milk</th><th>C.F.</th><th>Eggs</th><th>C.F.</th></tr>
<tr><td colspan="2">Adult M</td><td>36.85</td><td>1.00</td><td>6.95</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>27.75</td><td>1.00</td><td>4.2</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>65.9</td><td>1.00</td><td>0.90</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>65.1</td><td>1.00</td><td>3.85</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>73.25</td><td>1.00</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>84.75</td><td>1.00</td><td>5.4</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>36.85</td><td>1.00</td><td>6.95</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>65.9</td><td>1.00</td><td>0.90</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>65.1</td><td>1.00</td><td>3.85</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>73.25</td><td>1.00</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>84.75</td><td>1.00</td><td>5.4</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>36.85</td><td>1.00</td><td>6.95</td><td>1.00</td></tr>
</table>
</td>
</tr>
</table>

2.3.4 Produce Ingestion – Leafy Vegetables, Root Vegetables, and Fruit

For the GENII produce ingestion pathways, which include leafy vegetables, root/other vegetables, and fruit, consumption rate data from EPA 1997 and Hamby 1991 were considered. Both of these references are secondary sources that cite data from USDA studies, including the NFCS and CSFII. Consumption rates are specified in these references for specific age/gender categories and produce categories, as shown below in Table 27. EPA 1997 also presents consumption rates based on other factors (Table 27). However, age and gender differentiations were not specified under these other categorizations, so these other factors were not considered.

Table 27. Categories of Produce Consumption Data.

Study [rate units]	Age and Gender Categories	Produce Categories[a]	Other Categories[b]
1989-91 CSFII (EPA 1997) [grams / kilogram-day]	<5 6 – 11 male / female 12 – 19 male / female >20 male / female All individuals	Total vegetables Individual fruits and vegetables (28 types) Exposed fruits Protected fruits Exposed vegetables Protected vegetables Root vegetables	Geographic region (northeast, midwest, south, west) Urbanization (central city, suburban, nonmetropolitan) Season (spring, summer, fall, winter) Race (white, black, asian, native american, other)

Study [rate units]	Age and Gender Categories	Produce Categories[a]	Other Categories[b]
1977-78 NFCS (EPA 1997) [g / d] Data Set #1	<1 1 – 2 3 – 5 6 – 8 9 – 11 male / female 12 – 14 male / female 15 – 18 male / female 19 – 22 male / female 23 – 34 male / female 35 – 50 male / female 51 – 64 male / female 65 – 74 male / female >75 male / female All individuals	Total fruits Total vegetables Total produce	Geographic region (northeast, north central, south, west)
1977-78 NFCS (EPA 1997) [g / d] Data Set #2	<1 1 – 4 5 – 9 10 – 14 15 – 19 20 – 24 25 – 29 30 – 39 40 – 59 >60	Leafy produce Exposed produce Protected produce Other produce	Geographic region (northeast, north central, south, west)
1987-88 NFCS (EPA 1997) [g / d]	<6 6 – 11 male / female 12 – 19 male / female >19 male / female All individuals	Total fruits Total vegetables	None reported
1994-95 CSFII (EPA 1997) [g / d]	<6 6 – 11 male / female 12 – 19 male / female >19 male / female All individuals	Total fruits Total vegetables	None reported
Hamby 1991 Regional estimates [kg / yr]	Infant Child Teen Adult	Leafy vegetables Other vegetables	None reported
NRC Defaults (Hamby 1991) [kg / yr]	Infant Child Teen Adult	Other vegetables	None reported

[a] Data for the listed produce categories are reported by age and gender categories.
[b] Data for these other categories are not reported by age and gender categories.

The data distinguishing between geographic regions, which was not presented in EPA 1997 by age/gender categories, showed that regional differences in consumption rates were small (<10%). EPA 1997 also compared consumption rates over time. Table 28 compares rates for all individuals over time. The data indicate that fruit consumption has gradually increased over time, and that vegetable consumption has fluctuated over time but overall has decreased.

Table 28. Comparison of Produce Consumption Rates Over Time (EPA 1997).

Produce Category	1977-78 NFCS (g/d)	1987-88 NFCS (g/d)	1989-91 CSFII (g/d)	1995 CSFII (g/d)
Fruits	142	142	156	173
Vegetables	201	182	179	188

Source: EPA 1997, Tables 9-12

The data sets from 1977-78 NFCS were selected as the primary basis for the quantities of produce consumed by the CDC receptors for the following reasons:

- The time period covered by this data set (1977-1978) is closer to the midpoint of the 1954-1992 period being modeled than the other data sets, which occur near or after 1992.
- This data set provides numerous age/gender categories that can be more easily aligned with the CDC and GENII age/gender categories.
- This data set is expressed in units that more easily convert to units required by GENII (g/day to kg/year). Additional conversions considering consumption rate variations by body weight were not needed.

Consumption rates for the three different produce categories (leafy vegetables, root vegetables, and fruit) and six different age/gender-specific categories modeled in GENII were derived from the NFCS data in the following manner:

- **Leafy Vegetables.** GENII-input age/gender-specific rates were calculated by averaging the NFCS age-specific categories for leafy vegetables in the NFCS Data Set #2 using an approach similar to that used for meat consumption. The data did not provide a distinction between male and female consumption
- **Root Vegetables.** GENII-input age/gender-specific rates using a two-step calculation. First, age/gender-specific rates were calculated by averaging the NFCS age/gender categories for total vegetables in the NFCS Data Set #1 using an approach similar to that used for meat ingestion. Second, the calculated leafy vegetable rates were subtracted from the total vegetable rates to yield age/gender specific rates for root vegetables.
- **Fruit.** GENII-input age/gender-specific rates were calculated by averaging the NFCS age/gender categories for fruit in the NFCS Data Set #1 using an approach similar to that used for meat consumption.

In all three cases, the calculated rates were converted from g/day to kg/yr units needed for GENII input. Table 29 presents the results of these calculations and the categories that were used for averaging.

Table 29. GENII-Modeled Age/Gender Categories for Leafy Vegetables, Root Vegetables, and Fruit, Corresponding EPA 1997 Age/Gender Categories, and Calculated Rates.

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged		Calculated Value – Average Consumption (kg/year)			
	Data Set #1 (used for total vegetables and fruit)	Data Set #2 (used for leafy vegetables)	Leafy Vegetables	Total Vegetables	Root Vegetables[a]	Fruit
Infant (<1)	<1	<1	1.2	27.7	26.6	61.7
Pre-School (1 – 4)	1 – 2 3 – 5	1 – 4	4.1	35.2	31.1	50.7
Child (5 – 11)	6 – 8 9 – 11 male	5 – 9 10 – 14	8.1	50.0	41.9	52.0
Teenager (12 – 17)	12 – 14 male 15 – 18 male	15 – 19	10.6	73.8	63.2	49.4
Adult Male (>18)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	20 – 24 25 – 29 30 – 34 40 – 59 >=60	16.7	95.9	79.2	55.2
Adult Female (>18)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	20 – 24 25 – 29 30 – 34 40 – 59 >=60	16.7	73.9	57.2	56.6

[a] Root vegetables are calculated by difference (total vegetables – leafy vegetables = root vegetables).
Source: Data adapted from EPA 1997, Tables 9-14, 9-16, and 9-22.

These calculated rates for produce are applied in the following manner to the CDC scenarios.

Table 30. Produce Ingestion Exposure Pathway, Exposure and Adjustment Factors

<table>
<tr><th>Scenario Family</th><th>Produce Ingestion Pathways [Leafy Vegetables (LV), Root Vegetables (RV), and Fruit (F)]</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>Girard. For all individuals, during the 1950's, 50% of the vegetables and fruit are grown on the farm and are considered to be 100% contaminated. The other 50% of the vegetables and fruit come from the local grocery store, and are considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources. Beginning in 1960, 25% of the vegetables and fruit are grown on the farm and are considered to be 100% contaminated. The other 75% of the vegetables and fruit comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources.

In Lockridge 2002, it is stated that 50% of the vegetables are grown on the farm for the 1950's, while 25% of the vegetables are grown from the 1960's b on.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2" rowspan="2">Individual</th><th colspan="6">Girard</th></tr>
<tr><th>LV</th><th>C.F.</th><th>RV</th><th>C.F.</th><th>F</th><th>C.F.</th></tr>
<tr><td rowspan="2">Adult M</td><td>Up to 1960</td><td>16.7</td><td>0.75</td><td>79.2</td><td>0.75</td><td>55.2</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>16.7</td><td>0.625</td><td>79.2</td><td>0.625</td><td>55.2</td><td>0.625</td></tr>
<tr><td rowspan="2">Adult F</td><td>Up to 1960</td><td>16.7</td><td>0.75</td><td>57.2</td><td>0.75</td><td>56.6</td><td>0.75</td></tr>
<tr><td>1960 on</td><td>16.7</td><td>0.625</td><td>57.2</td><td>0.625</td><td>56.6</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="6">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>0.75</td><td>26.6</td><td>0.75</td><td>61.7</td><td>0.75</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.1</td><td>0.75</td><td>31.1</td><td>0.75</td><td>50.7</td><td>0.75</td></tr>
<tr><td>1960-66</td><td>School</td><td>8.1</td><td>0.625</td><td>41.9</td><td>0.625</td><td>52.0</td><td>0.625</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>10.6</td><td>0.625</td><td>63.2</td><td>0.625</td><td>49.4</td><td>0.625</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>16.7</td><td>0.625</td><td>79.2</td><td>0.625</td><td>55.2</td><td>0.625</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="6">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>0.75</td><td>26.6</td><td>0.75</td><td>61.7</td><td>0.75</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.1</td><td>0.75</td><td>31.1</td><td>0.75</td><td>50.7</td><td>0.75</td></tr>
<tr><td>1969-75</td><td>School</td><td>8.1</td><td>0.625</td><td>41.9</td><td>0.625</td><td>52.0</td><td>0.625</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>10.6</td><td>0.625</td><td>63.2</td><td>0.625</td><td>49.4</td><td>0.625</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>16.7</td><td>0.625</td><td>79.2</td><td>0.625</td><td>55.2</td><td>0.625</td></tr>
</table></td></tr>
</table>

Scenario Family	Produce Ingestion Pathways [Leafy Vegetables (LV), Root Vegetables (RV), and Fruit (F)]	Values For Exposure And Adjustment Factors
Rural Family #2	Williston. For all individuals, during the 1950's, 50% of the vegetables and fruit are grown on the farm and are considered to be 100% contaminated. The other 50% of the vegetables and fruit come from the local grocery store, and are considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources. Beginning in 1960, 25% of the vegetables and fruit are grown on the farm and are considered to be 100% contaminated. The other 75% of the vegetables and fruit comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources. In Lockridge 2002, it is stated that 50% of the vegetables are grown on the farm for the 1950's, while 25% of the vegetables are grown from the 1960's on.	Exposure Factors (kg/yr)

Individual		Williston					
		LV	C.F.	RV	C.F.	F	C.F.
Adult M	Up to 1960	16.7	0.75	79.2	0.75	55.2	0.75
	1960 on	16.7	0.625	79.2	0.625	55.2	0.625
Adult F	Up to 1960	16.7	0.75	57.2	0.75	56.6	0.75
	1960 on	16.7	0.625	57.2	0.625	56.6	0.625
Child 1955		[redacted]					
1955	Infant	1.2	0.75	26.6	0.75	61.7	0.75
1956-59	Pre-school	4.1	0.75	31.1	0.75	50.7	0.75
1960-66	School	8.1	0.625	41.9	0.625	52.0	0.625
1967-73	Teen	10.6	0.625	63.2	0.625	49.4	0.625
1974-92	Adult	16.7	0.625	79.2	0.625	55.2	0.625
Child 1964		[redacted]					
1964	Infant	1.2	0.75	26.6	0.75	61.7	0.75
1965-68	Pre-school	4.1	0.75	31.1	0.75	50.7	0.75
1969-75	School	8.1	0.625	41.9	0.625	52.0	0.625
1976-82	Teen	10.6	0.625	63.2	0.625	49.4	0.625
1983-92	Adult	16.7	0.625	79.2	0.625	55.2	0.625

Scenario Family	Produce Ingestion Pathways [Leafy Vegetables (LV), Root Vegetables (RV), and Fruit (F)]	Values For Exposure And Adjustment Factors
Urban/Suburban Family	Augusta For all individuals, 100% of the vegetables and fruit comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources. There is no direct mention of vegetable sources in Lockridge 2002, but it is stated that the family obtains its food from local grocery stores in the Augusta area.	Exposure Factors (kg/yr)

Individual		Augusta					
		LV	C.F.	RV	C.F.	F	C.F.
Adult Male		16.7	0.50	79.2	0.50	55.2	0.50
Adult Female		16.7	0.50	57.2	0.50	56.6	0.50
Child 1955		[redacted]					
1955	Infant	1.2	0.50	26.6	0.50	61.7	0.50
1956-59	Pre-school	4.1	0.50	31.1	0.50	50.7	0.50
1960-66	School	8.1	0.50	41.9	0.50	52.0	0.50
1967-73	Teen	10.6	0.50	63.2	0.50	49.4	0.50
1974-92	Adult	16.7	0.50	79.2	0.50	55.2	0.50
Child 1964		[redacted]					
1964	Infant	1.2	0.50	26.6	0.50	61.7	0.50
1965-68	Pre-school	4.1	0.50	31.1	0.50	50.7	0.50
1969-75	School	8.1	0.50	41.9	0.50	52.0	0.50
1976-82	Teen	10.6	0.50	63.2	0.50	49.4	0.50
1983-92	Adult	16.7	0.50	79.2	0.50	55.2	0.50

Scenario Family	Produce Ingestion Pathways [Leafy Vegetables (LV), Root Vegetables (RV), and Fruit (F)]	Values For Exposure And Adjustment Factors
Delivery Person	Barnwell and Martin. For all individuals, 50% of the fruits and vegetables come from local grocery stores in Martin, and the other half comes from grocery stores in Barnwell. All produce is considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources. There is no direct mention of vegetable sources in Lockridge 2002, but it is stated that the family obtains its food from local grocery stores in the Martin and Barnwell areas.	Exposure Factors (kg/yr)

Individual		Martin					
		LV	C.F.	RV	C.F.	F	C.F.
Adult Male		8.35	0.50	39.6	0.50	27.6	0.50
Adult Female		8.35	0.50	28.6	0.50	28.3	0.50
Child 1955		[redacted]					
1955	Infant	0.6	0.50	13.3	0.50	30.85	0.50
1956-59	Pre-school	2.05	0.50	15.55	0.50	25.35	0.50
1960-66	School	4.05	0.50	20.95	0.50	26.0	0.50
1967-73	Teen	5.3	0.50	31.6	0.50	24.7	0.50
1974-92	Adult	8.35	0.50	39.6	0.50	27.6	0.50
Child 1964		[redacted]					
1964	Infant	0.6	0.50	13.3	0.50	30.85	0.50
1965-68	Pre-school	2.05	0.50	15.55	0.50	25.35	0.50
1969-75	School	4.05	0.50	20.95	0.50	26.0	0.50
1976-82	Teen	5.3	0.50	31.6	0.50	24.7	0.50
1983-92	Adult	8.35	0.50	39.6	0.50	27.6	0.50

Individual		Barnwell					
		LV	C.F.	RV	C.F.	F	C.F.
Adult Male		8.35	0.50	39.6	0.50	27.6	0.50
Adult Female		8.35	0.50	28.6	0.50	28.3	0.50
Child 1955		[redacted]					
1955	Infant	0.6	0.50	13.3	0.50	30.85	0.50
1956-59	Pre-school	2.05	0.50	15.55	0.50	25.35	0.50
1960-66	School	4.05	0.50	20.95	0.50	26.0	0.50
1967-73	Teen	5.3	0.50	31.6	0.50	24.7	0.50
1974-92	Adult	8.35	0.50	39.6	0.50	27.6	0.50
Child 1964		[redacted]					
1964	Infant	0.6	0.50	13.3	0.50	30.85	0.50
1965-68	Pre-school	2.05	0.50	15.55	0.50	25.35	0.50
1969-75	School	4.05	0.50	20.95	0.50	26.0	0.50
1976-82	Teen	5.3	0.50	31.6	0.50	24.7	0.50
1983-92	Adult	8.35	0.50	39.6	0.50	27.6	0.50

<table>
<tr><th>Scenario Family</th><th>Produce Ingestion Pathways [Leafy Vegetables (LV), Root Vegetables (RV), and Fruit (F)]</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Outdoors Person</td><td>Jackson. For all individuals, 100% of the vegetables and fruit comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources.

In Lockridge 2002 it is stated that 50% of the vegetables are grown locally and irrigated from a surface creek.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2" rowspan="2">Individual</th><th colspan="6">Jackson</th></tr>
<tr><th>LV</th><th>C.F.</th><th>RV</th><th>C.F.</th><th>F</th><th>C.F.</th></tr>
<tr><td colspan="2">Adult Male</td><td>16.7</td><td>0.50</td><td>79.2</td><td>0.50</td><td>55.2</td><td>0.50</td></tr>
<tr><td colspan="2">Adult Female</td><td>16.7</td><td>0.50</td><td>57.2</td><td>0.50</td><td>56.6</td><td>0.50</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="6">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>0.50</td><td>26.6</td><td>0.50</td><td>61.7</td><td>0.50</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.1</td><td>0.50</td><td>31.1</td><td>0.50</td><td>50.7</td><td>0.50</td></tr>
<tr><td>1960-66</td><td>School</td><td>8.1</td><td>0.50</td><td>41.9</td><td>0.50</td><td>52.0</td><td>0.50</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>10.6</td><td>0.50</td><td>63.2</td><td>0.50</td><td>49.4</td><td>0.50</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>16.7</td><td>0.50</td><td>79.2</td><td>0.50</td><td>55.2</td><td>0.50</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="6">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>0.50</td><td>26.6</td><td>0.50</td><td>61.7</td><td>0.50</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.1</td><td>0.50</td><td>31.1</td><td>0.50</td><td>50.7</td><td>0.50</td></tr>
<tr><td>1969-75</td><td>School</td><td>8.1</td><td>0.50</td><td>41.9</td><td>0.50</td><td>52.0</td><td>0.50</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>10.6</td><td>0.50</td><td>63.2</td><td>0.50</td><td>49.4</td><td>0.50</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>16.7</td><td>0.50</td><td>79.2</td><td>0.50</td><td>55.2</td><td>0.50</td></tr>
</table></td></tr>
<tr><td>Family Living Near the River</td><td>Martin. For all individuals, 100% of the vegetables and fruit comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources.

There is no direct mention of vegetable sources in Lockridge 2002, but it is stated that the family obtains its food from local grocery stores in the Martin area.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2" rowspan="2">Individual</th><th colspan="6">Martin</th></tr>
<tr><th>LV</th><th>C.F.</th><th>RV</th><th>C.F.</th><th>F</th><th>C.F.</th></tr>
<tr><td colspan="2">Adult Male</td><td>16.7</td><td>0.50</td><td>79.2</td><td>0.50</td><td>55.2</td><td>0.50</td></tr>
<tr><td colspan="2">Adult Female</td><td>16.7</td><td>0.50</td><td>57.2</td><td>0.50</td><td>56.6</td><td>0.50</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="6">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>0.50</td><td>26.6</td><td>0.50</td><td>61.7</td><td>0.50</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.1</td><td>0.50</td><td>31.1</td><td>0.50</td><td>50.7</td><td>0.50</td></tr>
<tr><td>1960-66</td><td>School</td><td>8.1</td><td>0.50</td><td>41.9</td><td>0.50</td><td>52.0</td><td>0.50</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>10.6</td><td>0.50</td><td>63.2</td><td>0.50</td><td>49.4</td><td>0.50</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>16.7</td><td>0.50</td><td>79.2</td><td>0.50</td><td>55.2</td><td>0.50</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="6">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>0.50</td><td>26.6</td><td>0.50</td><td>61.7</td><td>0.50</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.1</td><td>0.50</td><td>31.1</td><td>0.50</td><td>50.7</td><td>0.50</td></tr>
<tr><td>1969-75</td><td>School</td><td>8.1</td><td>0.50</td><td>41.9</td><td>0.50</td><td>52.0</td><td>0.50</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>10.6</td><td>0.50</td><td>63.2</td><td>0.50</td><td>49.4</td><td>0.50</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>16.7</td><td>0.50</td><td>79.2</td><td>0.50</td><td>55.2</td><td>0.50</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Produce Ingestion Pathways [Leafy Vegetables (LV), Root Vegetables (RV), and Fruit (F)]</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Migrant Worker Family</td><td>New Ellenton. For all individuals, 100% of the vegetables and fruit comes from the local grocery store, and is considered to be 50% contaminated. This is due to the assumption that half of the produce at the local grocery store comes from the local farms, and half from outside sources. This family is only in the area for half of the year, so they have half of the normal consumption values.

There is no direct mention of vegetable sources in Lockridge 2002, but it is stated that the family obtains its food from local grocery stores in the Martin area.</td><td>Exposure and Adjustment Factors (kg/yr)
<table>
<tr><th colspan="2" rowspan="2">Individual</th><th colspan="6">New Ellenton</th></tr>
<tr><th>LV</th><th>C.F.</th><th>RV</th><th>C.F.</th><th>F</th><th>C.F.</th></tr>
<tr><td colspan="2">Adult Male</td><td>8.35</td><td>0.50</td><td>39.6</td><td>0.50</td><td>27.6</td><td>0.50</td></tr>
<tr><td colspan="2">Adult Female</td><td>8.35</td><td>0.50</td><td>28.6</td><td>0.50</td><td>28.3</td><td>0.50</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>0.6</td><td>0.50</td><td>13.3</td><td>0.50</td><td>30.85</td><td>0.50</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>2.05</td><td>0.50</td><td>15.55</td><td>0.50</td><td>25.35</td><td>0.50</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.05</td><td>0.50</td><td>20.95</td><td>0.50</td><td>26.0</td><td>0.50</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>5.3</td><td>0.50</td><td>31.6</td><td>0.50</td><td>24.7</td><td>0.50</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>8.35</td><td>0.50</td><td>39.6</td><td>0.50</td><td>27.6</td><td>0.50</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>0.6</td><td>0.50</td><td>13.3</td><td>0.50</td><td>30.85</td><td>0.50</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>2.05</td><td>0.50</td><td>15.55</td><td>0.50</td><td>25.35</td><td>0.50</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.05</td><td>0.50</td><td>20.95</td><td>0.50</td><td>26.0</td><td>0.50</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>5.3</td><td>0.50</td><td>31.6</td><td>0.50</td><td>24.7</td><td>0.50</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>8.35</td><td>0.50</td><td>39.6</td><td>0.50</td><td>27.6</td><td>0.50</td></tr>
</table></td></tr>
</table>

2.3.5 Grain Ingestion

For the GENII grain ingestion pathways, consumption rate data from EPA 1997 were considered. No data on local consumption was identified. EPA 1997 is a secondary source that cites data from USDA studies, including the NFCS and CSFII. Of the several data sets presented in EPA 1997, per-capita intake of corn data from Table 9-5 was used as a basis for the GENII grain consumption input values. This data was chosen due to the assumptions that most grain products that an individual in the area would consume, (i.e. breads, pastas, flours, etc.), would come from sources that did not use local grains, but that individuals would use locally produced corn. In this case, corn is considered a grain rather than a vegetable. The data is presented in g/kg-day of consumption, and was converted into kg/day by using Tables 7-2 and 7-3 from EPA 1997 which gives mean body mass in kg/yr of age. Consumption rates for specific age/gender categories in this data set were combined and averaged as shown below in Table 31. EPA 1997 also presents consumption rates based on geographic region. However, age and gender differentiations were not specified by geographic region, and differences between regions were small, so regional data were not considered.

Table 31. GENII-Modeled Age/Gender Categories for Grains, Corresponding EPA 1997 Age/Gender Categories, and Calculated Rates.

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged	Calculated Value – Average Consumption (kg/yr)
Infant (<1)	<1	1.2
Pre-School (1 – 4)	1 – 2 3 – 5	2.9
Child (5 – 11)	6 – 8 9 – 11 male	4.0
Teenager (12 – 17)	12 – 14 male 15 – 18 male	3.6
Adult Male (>18)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	4.1
Adult Female (>18)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	3.4

These calculated rates for grain ingestion are applied in the same manner as for the produce ingestion rates pathways. The approach for applying these rates to the CDC scenarios is described in Table 32.

Table 32. Grain Ingestion Exposure Pathway, Exposure and Adjustment Factors

<table>
<tr><th>Scenario Family</th><th>Grain Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>Girard. For all individuals, the grain is assumed to come from local sources, and is assumed to be 100% contaminated.

Lockridge 2002 contains no specific information on consumption of locally produced grain.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Girard</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>3.4</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
</table></td></tr>
<tr><td>Rural Family #2</td><td>Williston. For all individuals, the grain is assumed to come from local sources, and is assumed to be 100% contaminated.

Lockridge 2002 contains no specific information on consumption of locally produced grain.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Williston</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>3.4</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2">[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2">[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Grain Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Urban/ Suburban Family</td><td>Augusta. For all individuals, the grain is assumed to come from local sources, and is assumed to be 100% contaminated.

Lockridge 2002 contains no specific information on consumption of locally produced grain.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Augusta</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>3.4</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
</table></td></tr>
<tr><td>Delivery Person</td><td>Barnwell and Martin. For all individuals, half of the grain comes from Martin, and the other half of the grain comes from Barnwell. All is assumed to come from local sources, and is assumed to be 100% contaminated.

Lockridge 2002 states that the family obtains its food from local grocery stores in the Augusta and Barnwell areas.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2">Individual</th><th>Barnwell</th><th>C.F.</th><th>Martin</th><th>C.F.</th></tr>
<tr><td colspan="2">Adult M</td><td>2.05</td><td>1.00</td><td>2.05</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>1.7</td><td>1.00</td><td>1.7</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>0.6</td><td>1.00</td><td>0.6</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>1.45</td><td>1.00</td><td>1.45</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>2.0</td><td>1.00</td><td>2.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>1.8</td><td>1.00</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>2.05</td><td>1.00</td><td>2.05</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>0.6</td><td>1.00</td><td>0.6</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>1.45</td><td>1.00</td><td>1.45</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>2.0</td><td>1.00</td><td>2.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>1.8</td><td>1.00</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>2.05</td><td>1.00</td><td>2.05</td><td>1.00</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Grain Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Outdoors Person</td><td>Jackson. For all individuals, the grain is assumed to come from local sources, and is assumed to be 100% contaminated.

Lockridge 2002 contains no specific information on consumption of locally produced grain.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Jackson</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>3.4</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
</table></td></tr>
<tr><td>Family Living Near the River</td><td>Martin. For all individuals, the grain is assumed to come from local sources, and is assumed to be 100% contaminated.

Lockridge 2002 contains no specific information on consumption of locally produced grain. However, it does state that the family obtains its food from local grocery stores in the Martin area.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Martin</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>3.4</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.2</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>2.9</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>3.6</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>4.1</td><td>1.00</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Grain Ingestion Pathway</th><th>Values For Exposure And Adjustment Factors</th></tr>
<tr><td>Migrant Worker Family</td><td>New Ellenton. For all individuals, the grain is assumed to come from local sources, and is assumed to be 100% contaminated. This family is only in the area for half of the year, so the consumption values are half of the normal rates.

Lockridge 2002 contains no specific information on consumption of locally produced grain. However, it does state that the family obtains its food from local grocery stores.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>New Ellenton</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>2.05</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>1.7</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td>[redacted]</td><td>[redacted]</td></tr>
<tr><td>1955</td><td>Infant</td><td>0.6</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>1.45</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>2.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>2.05</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td>[redacted]</td><td>[redacted]</td></tr>
<tr><td>1964</td><td>Infant</td><td>0.6</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>1.45</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>2.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>1.8</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>2.05</td><td>1.00</td></tr>
</table></td></tr>
</table>

2.3.6 Fish Ingestion

For the GENII fish ingestion pathways, consumption rate data from several sources were considered. References included EPA 1997, Hamby 1991, EPA 2002, EPA 1994, and EPA 1991. These sources generally are secondary references that cite data from several studies, including the USDA NFCS and CSFII studies and several state-level studies, but no studies local to South Carolina and Georgia. Hamby 1991 is a secondary source that cites data from the 1977-78 NFCS and NRC default values. EPA 1997 values were ultimately used for the calculations, and shown below in Table 33.

Table 33. GENII-Modeled Age/Gender Categories and Calculated Rates for Fish.

Modeled Age Categories	Fish Consumption (kg/yr)
Infant (<1)	4.2
Pre-School (1 – 4)	4.2
Child (5 – 11)	5.0
Teenager (12 – 17)	4.5
Adult Male (>18)	9.9
Adult Female (>18)	9.9

The approach for applying these rates to the CDC scenarios is described in Table 34.

Table 32. Fish Ingestion Exposure Pathway, Exposure and Adjustment Factors

<table>
<tr><th>Scenario Family</th><th>Fish Ingestion Pathways</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>For all individuals, no contamination because the fishing location (Briar Creek) is not hydrologically downstream from SRS.

There is no fish data in Lockridge 2002 for this family scenario.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Girard</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>9.9</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>9.9</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>4.2</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.2</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>5.0</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>4.5</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>9.9</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>4.2</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.2</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>5.0</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>4.5</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>9.9</td><td>0</td></tr>
</table></td></tr>
<tr><td>Rural Family #2</td><td>For all individuals, no contamination because the fishing locations (local farm ponds near Williston) are not hydrologically downstream from SRS.

There is no fish data in Lockridge 2002 for this family scenario.</td><td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Williston</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>9.9</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>9.9</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>4.2</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.2</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>5.0</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>4.5</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>9.9</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>4.2</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.2</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>5.0</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>4.5</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>9.9</td><td>0</td></tr>
</table></td></tr>
</table>

Urban/ Suburban Family

For all individuals, no contamination because the fishing location (Savannah River upstream of site) is not hydrologically downstream from SRS.

There is no fish data in Lockridge 2002 for this family scenario.

Exposure Factors (kg/year)

Individual		Augusta	Contamination Fraction
Adult M		9.9	0
Adult F		9.9	0
Child 1955		[redacted]	
1955	Infant	4.2	0
1956-59	Pre-school	4.2	0
1960-66	School	5.0	0
1967-73	Teen	4.5	0
1974-92	Adult	9.9	0
Child 1964		[redacted]	
1964	Infant	4.2	0
1965-68	Pre-school	4.2	0
1969-75	School	5.0	0
1976-82	Teen	4.5	0
1983-92	Adult	9.9	0

Delivery Person

Lower Three Runs Creek and Savannah River. For all individuals, consumption is 50% for LTRC and 50% for the Savannah River. 100% contamination is assumed due to being downstream of the SRS.

It is stated in Lockridge 2002 that fishing is done at Lower Three Runs Creek and also at Savannah River's Smith Lake.

Exposure Factors (kg/yr)

Individual		LTRC	C.F.	Savannah River	C.F.
Adult M		4.95	1.00	4.95	1.00
Adult F		4.95	1.00	4.95	1.00
Child 1955		[redacted]			
1955	Infant	2.1	1.00	2.1	1.00
1956-59	Pre-school	2.1	1.00	2.1	1.00
1960-66	School	2.5	1.00	2.5	1.00
1967-73	Teen	2.25	1.00	2.25	1.00
1974-92	Adult	4.95	1.00	4.95	1.00
Child 1964		[redacted]			
1964	Infant	2.1	1.00	2.1	1.00
1965-68	Pre-school	2.1	1.00	2.1	1.00
1969-75	School	2.5	1.00	2.5	1.00
1976-82	Teen	2.25	1.00	2.25	1.00
1983-92	Adult	4.95	1.00	4.95	1.00

<table>
<tr>
<td>Outdoors Person</td>
<td>Savannah River. For all individuals, 100% of the fish comes from the SRS, and is 100% contaminated.

It is stated in Lockridge 2002 that fish meat is obtained by fishing on site.</td>
<td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Savannah River</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>9.9</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>9.9</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>5.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>4.5</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>9.9</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>5.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>4.5</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>9.9</td><td>1.00</td></tr>
</table></td>
</tr>
<tr>
<td>Family Living Near the River</td>
<td>Savannah River. For all individuals, 100% of the fish comes from the Savannah River, and is 100% contaminated.

It is stated in Lockridge 2002 that one of the food sources for this family scenario is fishing.</td>
<td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>Savannah River</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>9.9</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>9.9</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>5.0</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>4.5</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>9.9</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.2</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>5.0</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>4.5</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>9.9</td><td>1.00</td></tr>
</table></td>
</tr>
</table>

<table>
<tr>
<td>Migrant Worker Family</td>
<td>For all individuals, consumption is 0 because the fishing locations (Savannah River upstream of site and local farm ponds near New Ellenton) are not hydrologically downstream from SRS.

There is no fish data in Lockridge 2002 for this family scenario.</td>
<td>Exposure Factors (kg/year)
<table>
<tr><th colspan="2">Individual</th><th>New Ellenton</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>4.95</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>4.95</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>2.1</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>2.1</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>2.5</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>2.25</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>4.95</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>2.1</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>2.1</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>2.5</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>2.25</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>4.95</td><td>0</td></tr>
</table>
</td>
</tr>
</table>

2.3.7 Inadvertent Soil Ingestion

Soil ingestion rates used for this project are based on EPA 1997, Table 4-23. Daily rates of 100 mg/day for children and 50 mg/day for adults were converted to annual rates (Table 35).

Table 35. GENII-Modeled Age/Gender Categories and Calculated Rates for Soil Ingestion.

Modeled Age Categories	Soil Ingestion (kg/yr)
Infant (<1)	0.0365
Pre-School (1 – 4)	0.0365
Child (5 – 11)	0.0365
Teenager (12 – 17)	0.0365
Adult Male (>18)	0.01825
Adult Female (>18)	0.01825

For the CDC scenarios, these rates were apportioned between the receptor locations according to the amount of time each individual receptor spent at each location, as indicated in Table 36.

Table 36. Soil Ingestion Exposure Pathway, Exposure and Adjustment Factors

Scenario Family	Soil Ingestion	Values for Exposure and Adjustment Factors
Rural Family #1	Girard. All members except the teenager ingest 100% at this location, with an assumed contamination rate of 100%. Waynesboro. During the specified high school years, teens ingest 85% of the calculated rates. The high school exposure occurs for each child aged 12 to 17 (1967-72 for a child born in 1955, and 1976-1981 for a child born in 1964).	Exposure Factors (kg/yr)

Individual		Girard	C.F.	Waynes-boro	C.F.
Adult M		0.0183	1.00	0	1.00
Adult F		0.0183	1.00	0	1.00
Child 1955		[redacted]			
1955	Infant	0.0365	1.00	0	1.00
1956-59	Pre-school	0.0365	1.00	0	1.00
1960-66	School	0.0365	1.00	0	1.00
1967-73	Teen	0.0313	1.00	0.00525	1.00
1974-92	Adult	0.0183	1.00	0	1.00
Child 1964		[redacted]			
1964	Infant	0.0365	1.00	0	1.00
1965-68	Pre-school	0.0365	1.00	0	1.00
1969-75	School	0.0365	1.00	0	1.00
1976-82	Teen	0.0313	1.00	0.00525	1.00
1983-92	Adult	0.0183	1.00	0	1.00

Rural Family #2	Williston. All members ingest 100% at this location, with an assumed contamination rate of 100%.	Exposure Factors (kg/yr)

Individual		Williston	Contamination Fraction
Adult M		0.0183	1.00
Adult F		0.0183	1.00
Child 1955		[redacted]	
1955	Infant	0.0365	1.00
1956-59	Pre-school	0.0365	1.00
1960-66	School	0.0365	1.00
1967-73	Teen	0.0365	1.00
1974-92	Adult	0.0183	1.00
Child 1964		[redacted]	
1964	Infant	0.0365	1.00
1965-68	Pre-school	0.0365	1.00
1969-75	School	0.0365	1.00
1976-82	Teen	0.0365	1.00
1983-92	Adult	0.0183	1.00

Scenario Family	Soil Ingestion	Values for Exposure and Adjustment Factors
Urban/Suburban Family	Onsite SRS. The adult male ingests 23% of the calculated rate for all years. It is assumed to be 100% contaminated. Augusta. All individuals except the adult male ingest 100% of the calculated rates. The adult male ingests 77% of the calculated rate. It is assumed to be 100% contaminated	Exposure Factors (kg/yr)

Individual		Augusta	C.F.	Onsite SRS	C.F.
Adult M		0.0141	1.00	0.00418	1.00
Adult F		0.0183	1.00	0	1.00
Child 1955		[redacted]			
1955	Infant	0.0365	1.00	0	1.00
1956-59	Pre-school	0.0365	1.00	0	1.00
1960-66	School	0.0365	1.00	0	1.00
1967-73	Teen	0.0365	1.00	0	1.00
1974-92	Adult	0.0183	1.00	0	1.00
Child 1964		[redacted]			
1964	Infant	0.0365	1.00	0	1.00
1965-68	Pre-school	0.0365	1.00	0	1.00
1969-75	School	0.0365	1.00	0	1.00
1976-82	Teen	0.0365	1.00	0	1.00
1983-92	Adult	0.0183	1.00	0	1.00

Scenario Family	Soil Ingestion	Values for Exposure and Adjustment Factors
Delivery Person	Martin. All individuals ingest 1% of the calculated rates for all years. It is assumed to be 100% contaminated. Onsite SRS. The adult male ingests 5% of the calculated rate for all years. It is assumed to be 100% contaminated. Allendale. The adult male ingests 18% of the calculated rate for all years. It is assumed to be 100% contaminated Barnwell. All individuals except the adult male ingest 99% of the calculated rates for all years. The adult male ingests 76% of the calculated rate for all years. It is assumed to be 100% contaminated	Exposure Factors (kg/yr)

Individual		Martin	C.F.	Onsite SRS
Adult M		0.000693	1.00	0.000836
Adult F		0.000693	1.00	0
Child 1955		[redacted]		
1955	Infant	0.00128	1.00	0
1956-59	Pre-school	0.00128	1.00	0
1960-66	School	0.00128	1.00	0
1967-73	Teen	0.00128	1.00	0
1974-92	Adult	0.000693	1.00	0
Child 1964		[redacted]		
1964	Infant	0.00128	1.00	0
1965-68	Pre-school	0.00128	1.00	0
1969-75	School	0.00128	1.00	0
1976-82	Teen	0.00128	1.00	0
1983-92	Adult	0.000693	1.00	0

Individual		Allen dale	C.F.	Barnw ell	C.F.
Adult M		0.00334	1.00	0.0135	1.00
Adult F		0	1.00	0.0177	1.00
Child 1955		[redacted]			
1955	Infant	0	1.00	0.0352	1.00
1956-59	Pre-school	0	1.00	0.0352	1.00
1960-66	School	0	1.00	0.0352	1.00
1967-73	Teen	0	1.00	0.0352	1.00
1974-92	Adult	0	1.00	0.0177	1.00
Child 1964		[redacted]			
1964	Infant	0	1.00	0.0352	1.00
1965-68	Pre-school	0	1.00	0.0352	1.00
1969-75	School	0	1.00	0.0352	1.00
1976-82	Teen	0	1.00	0.0352	1.00
1983-92	Adult	0	1.00	0.0177	1.00

Scenario Family	Soil Ingestion	Values for Exposure and Adjustment Factors
Outdoors Person	Onsite SRS. The adult male ingests 23% of the calculated rate for all years. It is assumed to be 100% contaminated. Jackson. All individuals excluding the adult male ingest 100% of the calculated rates for all years. The adult male ingests 77% of the calculated rate for all years. It is assumed to be 100% contaminated.	Exposure Factors (kg/yr)

Individual		Jackson	C.F.	Onsite SRS	C.F.
Adult M		0.0141	1.00	0.00418	1.00
Adult F		0.0183	1.00	0	1.00
Child 1955		[redacted]			
1955	Infant	0.0365	1.00	0	1.00
1956-59	Pre-school	0.0365	1.00	0	1.00
1960-66	School	0.0365	1.00	0	1.00
1967-73	Teen	0.0365	1.00	0	1.00
1974-92	Adult	0.0183	1.00	0	1.00
Child 1964		[redacted]			
1964	Infant	0.036	1.00	0	1.00
1965-68	Pre-school	0.036	1.00	0	1.00
1969-75	School	0.036	1.00	0	1.00
1976-82	Teen	0.036	1.00	0	1.00
1983-92	Adult	0.0183	1.00	0	1.00

Scenario Family	Soil Ingestion	Values for Exposure and Adjustment Factors
Family Living Near the River	Martin. All individuals ingest 100% of the calculated rates for all years. It is assumed to be 100% contaminated.	Exposure Factors (kg/yr)

Individual		Martin	Contamination Fraction
Adult M		0.018	1.00
Adult F		0.018	1.00
Child 1955		[redacted]	
1955	Infant	0.036	1.00
1956-59	Pre-school	0.036	1.00
1960-66	School	0.036	1.00
1967-73	Teen	0.036	1.00
1974-92	Adult	0.018	1.00
Child 1964		[redacted]	
1964	Infant	0.036	1.00
1965-68	Pre-school	0.036	1.00
1969-75	School	0.036	1.00
1976-82	Teen	0.036	1.00
1983-92	Adult	0.018	1.00

<table>
<tr><th>Scenario Family</th><th>Soil Ingestion</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Migrant Worker Family</td><td>New Ellenton. All soil consumption is done in New Ellenton. It is assumed to be 100% contaminated. Since this family is in the area for only half of the year, their ingestion values are half of the normal ones.</td><td>Exposure Factors (kg/yr)
<table>
<tr><th colspan="2">Individual</th><th>New Ellenton</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>0.009125</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>0.009125</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>0.009125</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>0.01825</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>0.009125</td><td>1.00</td></tr>
</table></td></tr>
</table>

2.3.8 Swimming Water Ingestion

This pathway accounts for ingestion of contaminated water that occurs when an individual swims in contaminated water. Swimming water ingestion rates are assumed to be zero for the receptors listed in Table 37 because any swimming is assumed to occur in water that is hydrologically upgradient or crossgradient from the site.

Table 37. Receptors Without Swimming Water External Exposure.

Receptor Family	Swimming Location
Rural Family #1	Briar Creek
Rural Family #2	Farm ponds around Williston, SC
Urban/Suburban Family	Savannah River upstream of the site
Outdoors Person	Savannah River upstream of the site
Migrant Family	Savannah River upstream of site and farm ponds around New Ellenton

For the remaining two receptors, the Delivery Person swims on Lower Three Runs Creek near Martin, and the Family Living Near the River swims on the Savannah River downstream of the site at a location near Martin. For these receptors, swimming water ingestion rates are estimated based on the time spent swimming (21.2 hours/year, as calculated in the discussion of the swimming water external exposure pathway using the factors based on South Carolina recreational patterns cited in Hamby 1991 (p.24)) and EPA's default rate of water ingestion while swimming, equal to 0.05 Liters/hour. These factors result in an annual ingestion rate of 1.0 L/year. This rate was applied to all individuals in the Delivery Person Family and the Family Living Near the River.

For the CDC scenarios, the rates used for the swimming water ingestion pathway are summarized in Table 38.

Table 38. Swimming Water Ingestion Exposure Pathway, Exposure and Adjustment Factors

<table>
<tr><th>Scenario Family</th><th>Swimming Water Ingestion</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Rural Family #1</td><td>No contaminated swimming water ingestion. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.

Lockridge 2002 states that there was “some swimming”</td><td>Exposure Factors (L/yr)
<table>
<tr><th colspan="2">Individual</th><th>Girard</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2"></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2"></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
</table></td></tr>
<tr><td>Rural Family #2</td><td>No contaminated swimming water ingestion. Exposure locations (farm ponds around Williston) are not hydrologically downgradient from release points.

Lockridge 2002 states that there was “some swimming”</td><td>Exposure Factors (L/yr)
<table>
<tr><th colspan="2">Individual</th><th>Williston</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2"></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2"></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Swimming Water Ingestion</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Urban/Suburban Family</td><td>No contaminated swimming water ingestion. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.

Lockridge 2002 states that there is occasional swimming in the Clark's Hill Lake, later called Thurman Reservoir.</td><td>Exposure Factors (L/yr)
<table>
<tr><th colspan="2">Individual</th><th>Augusta</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
</table></td></tr>
<tr><td>Delivery Person</td><td>Lower Three Runs Creek at Martin. All individuals ingest 1.0 L/year of contaminated water for all years.

Lockridge 2002 states that there is swimming in Lower Three Runs Creek in Martin, SC, and also at Little Hell Landing on the Savannah River, which is on the south border of the SRS.</td><td>Exposure Factors (L/yr)
<table>
<tr><th colspan="2">Individual</th><th>LTRC</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>1.06</td><td>1.00</td></tr>
<tr><td colspan="2">Adult F</td><td>1.06</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1960-66</td><td>School</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>1.06</td><td>1.00</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1969-75</td><td>School</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>1.06</td><td>1.00</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>1.06</td><td>1.00</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Swimming Water Ingestion</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Outdoors Person</td><td>No contaminated swimming water ingestion. Exposure location (Savannah River upstream of SRS) is not hydrologically downgradient from release points.

Lockridge 2002 states swimming in Savannah River.</td><td>Exposure Factors (L/yr)
<table>
<tr><th colspan="2">Individual</th><th>Jackson</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>1.06</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>1.06</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>1.06</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>1.06</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>1.06</td><td>0</td></tr>
</table></td></tr>
<tr><td>Family Living Near the River</td><td>Savannah River. All individuals ingest 4.55 L/year of contaminated water for all years.

Lockridge 2002 does not state anything about swimming .</td><td>Exposure Factors (L/yr)
<table>
<tr><th colspan="2">Individual</th><th>Savannah River</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>4.55</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>4.55</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td></td><td></td></tr>
<tr><td>1955</td><td>Infant</td><td>4.55</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>4.55</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>4.55</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>4.55</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>4.55</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td></td><td></td></tr>
<tr><td>1964</td><td>Infant</td><td>4.55</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>4.55</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>4.55</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>4.55</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>4.55</td><td>0</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Scenario Family</th><th>Swimming Water Ingestion</th><th>Values for Exposure and Adjustment Factors</th></tr>
<tr><td>Migrant Worker Family</td><td>No contaminated swimming water ingestion. Exposure locations (Savannah River upstream of SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points. This family is only in the area for half of the year, so they get half of the normal values.

Lockridge 2002 does not state anything about swimming .</td><td>Exposure Factors (L/yr)
<table>
<tr><th colspan="2">Individual</th><th>Savannah River</th><th>Contamination Fraction</th></tr>
<tr><td colspan="2">Adult M</td><td>0.53</td><td>0</td></tr>
<tr><td colspan="2">Adult F</td><td>0.53</td><td>0</td></tr>
<tr><td colspan="2">Child 1955</td><td colspan="2"></td></tr>
<tr><td>1955</td><td>Infant</td><td>0.53</td><td>0</td></tr>
<tr><td>1956-59</td><td>Pre-school</td><td>0.53</td><td>0</td></tr>
<tr><td>1960-66</td><td>School</td><td>0.53</td><td>0</td></tr>
<tr><td>1967-73</td><td>Teen</td><td>0.53</td><td>0</td></tr>
<tr><td>1974-92</td><td>Adult</td><td>0.53</td><td>0</td></tr>
<tr><td colspan="2">Child 1964</td><td colspan="2"></td></tr>
<tr><td>1964</td><td>Infant</td><td>0.53</td><td>0</td></tr>
<tr><td>1965-68</td><td>Pre-school</td><td>0.53</td><td>0</td></tr>
<tr><td>1969-75</td><td>School</td><td>0.53</td><td>0</td></tr>
<tr><td>1976-82</td><td>Teen</td><td>0.53</td><td>0</td></tr>
<tr><td>1983-92</td><td>Adult</td><td>0.53</td><td>0</td></tr>
</table></td></tr>
</table>

3 References

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Attachment 1 - Scenario Descriptions

The SRS Dose Reconstruction includes seven scenarios to represent potential receptors. The general characteristics of the scenarios were developed by CDC with input from the SRS Site-Specific Advisory Board, Health Effects Subcommittee Scenario Work Group. Information on the general scenario characteristics was provided primarily from CDC briefings, including Lockridge 2002 and Donnelly 2002. These references also provided some of the detailed information needed to model the scenarios. For the actual modeling of the scenarios, however, additional detailed characteristics needed to be specified. This document describes the general and detailed characteristics upon which define the scenarios and which were used in the modeling.

The seven scenarios are:

1. Rural Family #1 in Girard, GA
2. Rural Family #2 in Williston, SC
3. Urban/Suburban Family in Augusta, GA
4. Delivery Person Family in Barnwell, SC
5. Outdoors Person Family in Jackson, SC
6. Family Living Near the River in Martin, SC
7. Migrant Worker Family in New Ellenton, SC

Lockridge 2002 and Donnelly 2002 contained six scenarios. However, these scenarios did not include any locations northeast of the site. Joint frequency distribution meteorological data for SRS (include reference) indicate that local wind direction may result in significant SRS contamination dispersing to the northeast. Therefore, a seventh scenario, Rural Family #2 in Williston, SC, was added in McDougall 2003 to ensure that potential exposures northeast of the site would be estimated in the dose reconstruction.

While nearly all information provided by CDC in Lockridge 2002 and Donnelly 2002 was used to develop the detailed characteristics of the scenarios, some information had to be adapted or was not used. In these cases, comparable substitute information was specified wherever possible to ensure that the intent of the initial characteristics was respected. Information was adapted or not used for the following three reasons:

1. There is no established modeling approach which would allow the exposure to be modeled.

2. The characteristic of the scenario, if modeled, would not substantially affect the results of the analysis.

3. The exposure pathway described does not result in any additional exposure of significance. All characteristics falling into this category also fall into category (2) above.

The information provided in Lockridge 2002 and Donnelly 2002 falls into three categories:

- Initial Assumptions (initially specified in Donnelly 2002 and repeated in Lockridge 2002);
- Working Group Comments (presented in Lockridge 2002); and
- New Scenario Modifications (presented in Lockridge 2002)

Following are descriptions of the seven scenarios, including the information supporting the scenarios from Lockridge 2002 and Donnelly 2002.

No. 1 – Rural Family #1 in Girard, GA

CDC Information	Scenario Description
Initial Assumptions 1. Use the closest downwind location where there could have been farms in 1955. 2. Consider an adult, an infant born in 1955 and an infant born in 1964 (year of highest radioiodine releases). Use default consumption values. 3. Assume they spent a lot of time outdoors and working in soil. 4. Assume they drank milk from a backyard cow. 5. Assume the crops were irrigated from the Savannah River. 6. Assumption of "working in soil" also included re-suspension of soil contaminants in the breathing zone (1/20/02) 7. In addition to inclusion of two infants, also included mother nursing at least one of the infants. (1/20/02)	This family consisted of an adult male, adult female, a male child born in 1955 and a female child born in 1964 (2) . As a rural family, all family members spent a large portion of their work, home activities, and recreation time outdoors (3). The adult male worked as a farmer, and the adult female worked at home. The family participated in hunting, fishing, camping, trapping, and other outdoor activities around the Girard area and in the nearby area of Briar Creek (14,15). The children stayed at home until of school age, attended schools in Girard, and attended high school in Waynesboro, GA (10). When not attending school, the children remained in the Girard area and, when they grew up, they assumed lifestyles similar to their parents. With the exception of high school the family lived, recreated, and worked in and around Girard, GA. The only exposure outside of the Girard area was for the children to attend high school. All milk, eggs and fish consumed by the family was produced or collected in or near Girard. Because the Briar Creek is not located hydrologically downstream from SRS, none of the fish consumed by the family is assumed to be affected by SRS releases. During the 1950s, half of most other food consumed by the family, including meat (poultry, beef, and wild game), vegetables (leafy and root), and fruit, was produced or collected locally in the Girard area, with the remainder produced outside the SRS area (13). Beginning in 1960, the locally produced/collected portion fell to 25 percent of total consumption (13). Any irrigation used to produce the food consumed by the family and drinking water consumed by the family is assumed to come from local groundwater or surface water sources unaffected by SRS releases.
Working Group Comments 1. Scenario Location: Farm in rural GA, Burke County. Girard, GA - 3 miles west of the Savannah River, SW from SRS. Population approximately 200 in 1950's. Located in SRS plume path. 2. Family: 2 parents, 5 children (1950's); 2 parents, 3 children (1960s) 3. Schools: Girard Elementary, Waynesboro High School 4. Work: Farming. Cash crops were peanuts, corn, cotton. Vegetables grown for family consumption. 5. Religion: Methodist 6. Food Sources: (1950's) 50% of meat & vegetables grown on farm; (1960s) 25% grown on farm; most milk from one of two local dairies in Girard. Family had a few dairy cows. 7. Swimming, Boating & Camping: Some swimming, but minimal camping. No recreational boating. 8. Hunting & Fishing: Lot of fishing from Briar Creek, 2 miles east of Girard. Significant amount of hunting for deer, quail and dove. Limited trapping.	**Adapted / Excluded Information [& Substituted Data]** Assume the crops were irrigated from the Savannah River. [Irrigation pathways were excluded from the analysis.] In addition to inclusion of two infants, also included mother nursing at least one of the infants. [No exposure through nursing modeled.] Family: 2 parents, 5 children (1950's); 2 parents, 3 children (1960s). [2 parents and 2 children modeled.] Cash crops were peanuts, corn, cotton. [Crops immaterial to model.] Religion: Methodist . [Religion immaterial to model.[Assume family had dogs for pets. [Pets immaterial to model.]
New Scenario Modifications 1. Milk source was most likely the local dairies near Girard, but not to the exclusion of the backyard cow. 2. Assume family had dogs for pets. 3. Assume family chickens.	

No. 2 – Rural Family #2 in Williston, SC

CDC Information	Scenario Description
Initial Assumptions • See Initial Assumptions for Rural Family #1 in Girard, GA.	This family was defined to be substantially similar to the Rural Family #1, except in its location. The family is resides and spends all time in Williston, SC, instead of Girard and Waynesboro. The family consisted of an adult male, adult female, a male child born in 1955 and a female child born in 1964. As a rural family, all family members spent a large portion of their work, home activities, and recreation time outdoors. The adult male worked as a farmer, and the adult female worked at home. The family participated in hunting, fishing, camping, trapping, and other outdoor activities around the Williston area. The children stayed at home until of school age, then attended schools in Williston. When not attending school, the children remained in the Williston area and, when they grew up, they assumed lifestyles similar to their parents. The family lived, recreated, and worked in and around Williston, SC. All milk, eggs, and fish consumed by the family was produced or collected in or near Williston. Because the streams and ponds around Williston are not located hydrologically downstream from SRS, none of the fish consumed by the family is assumed to be affected by SRS releases. During the 1950s, half of most other food consumed by the family, including meat (poultry, beef, and wild game), vegetables (leafy and root), and fruit, was produced or collected locally in the Williston area, with the remainder produced outside the SRS area (13). Beginning in 1960, the locally produced/collected portion fell to 25 percent of total consumption (13). Any irrigation used to produce the food consumed by the family and drinking water consumed by the family is assumed to come from local groundwater or surface water sources unaffected by SRS releases. **Adapted / Excluded Information** • Similar to Rural Family #1.
Working Group Comments • See Working Group Comments for Rural Family #1 in Girard, GA.	
New Scenario Modifications • See New Scenario Modifications for Rural Family #1 in Girard, GA.	

No. 3 – Urban/Suburban Family in Augusta, GA

CDC Information	Scenario Description
Initial Assumptions 1. Use the closest downwind location where urban or suburban families could have lived in 1955. 2. Consider an adult, an infant born in 1955 and an infant born in 1964 (year of highest radioiodine releases). 3. Use default consumption values 4. Assume the adult worked at the nearest industrial location downwind in 1955. 5. Assume they drank milk from the nearest dairy or rural neighbor. 6. Assume the adult worked on-site at SRS in lieu of the "nearest industrial location" (1/20/03 change) 7. Assume the onsite work location was associated with higher radiological exposures, e.g. SRS Canyons (1/20/03 change)	The family consisted of an adult male, adult female, a male child born in 1955 and a female child born in 1964. The family resided in Augusta, GA, and all family members were present there for most activities, including school and church. When the children grew up, they continued to reside in the Augusta area. Periods where family members were not present in Augusta include employment and some recreation. For employment, the adult male worked onsite at SRS for the duration of the study period, and the adult female worked onsite during 1954. For recreation, all family members swim, boat, and fish in the Augusta area rather than at Clark Hill Lake specified by CDC. This location was selected in order to reduce the number of receptor locations for the air pathway (to 10). The Augusta location is closer to SRS than Clark Hill Lake and on the same or nearly the same compass heading from SRS. Therefore, changing the location from Clark Hill Lake to Augusta should slightly increase the inhalation doses associated with the recreational activities. Because Clark Hill Lake is hydrologically upstream from the site, no doses would be estimated for swimming, boating, and fish consumption. For food consumption pathways, all milk is assumed to come from cows residing in Augusta. For most other foods, (meat, poultry, leafy and root vegetables, and fruit) half is assumed to come from local sources produced in Augusta, and half comes from unaffected non-local sources. Fish are assumed to come from unaffected sources.
Working Group Comments 1. Scenario Location: Family residence Augusta, GA (Region of Broad and Greene Streets) 2. Family: 2 parents, 2 children varying ages (1950's); 2 parents, 3 children (1960s) 3. Schools: Augusta neighborhood schools 4. Work: Father is assumed to have worked in the SRS F-Area Canyon Building from 1955 to 1992. The mother is assumed to have stayed home to raise the children. Mother worked on site until well into her pregnancy. 5. Religion: Attended local church in Augusta, GA 6. Food Sources: Food and milk were obtained from local grocery stores in Augusta, GA . Milk was supplied to local stores from dairies in the Aiken and Augusta area. 7. Swimming, Boating & Camping: Occasion swimming and boating in Clark's Hill Lake (later named Thurman Reservoir). 8. Hunting & Fishing: No hunting, but fishing in Clark's Hill Reservoir. Fishing two weekends per month.	**Adapted / Excluded Information** • Added that the mother also worked at the site during the early months of her first pregnancy (actual anecdotal). Stayed home after birth of her first child.
New Scenario Modifications 1. Milk was obtained from a local grocery in Augusta and in New Ellenton, and not the"nearest diary or a rural neighbor". Backyard cow is also included for the purpose of dose modeling. 2. Include a family pet.	

No. 4 – Delivery Person Family in Barnwell, SC

CDC Information	Scenario Description
Initial Assumptions 1. Same as Urban/Suburban Family 2. Use the closest downwind location where urban or suburban families could have lived in 1955. 3. Consider an adult, an infant born in 1955 and an infant born in 1964 (year of highest radio-iodine releases). 4. Use default consumption values 5. Assume the adult worked at the nearest industrial location downwind in 1955. 6. Assume they drank milk from the nearest dairy or rural neighbor. 7. Also assume that the person spent 8 hours per week on site.	This family consisted of an adult male, adult female, a male child born in 1955 and a female child born in 1964 (3). The family resided in Barnwell, SC, and all family members were present there for most activities, including school. When the children grew up, they continued to reside in the Barnwell area. Periods where family members were not present in Barnwell include employment for the adult male, religious services, and some recreation. For employment, the adult male worked as a delivery driver for a bottling plant located in Allendale, SC, and was assumed to spend a portion of his time in Allendale and onsite at SRS, where periodic deliveries occurred. For religious services, all family members were present in Martin, SC, for a few hours each week. For recreation, all family members swam and fished at on Lower Three Runs Creek (LTRC) at Martin, and the adult male hunted at the Martin location. Additionally, all family members boated and fished on the Savannah River (SR) at Little Hell Landing (upstream of the SR-LTRC confluence) and also some fishing on Smith Lake, a small lake in Georgia adjacent to the SR at the 127 mile point (downstream of the SR-LTRC confluence). For purposes of modeling exposure to liquid releases, both Little Hell Landing and Smith Lake were assigned the same contaminant concentrations. Similarly, for air releases, these locations were collocated with the Martin, SC, location, which is approximately the same distance and a similar general direction (south) from release points at the site, in order to model the inhalation and air plume immersion pathways for. For food consumption pathways, all milk and eggs are assumed to come from cows residing in Barnwell and martin.. For other foods (meat, poultry, leafy and root vegetables, and fruit), one quarter is assumed to be produced in Barnwell (including backyard chickens), one quarter is assumed to be produced in Martin (including local hunting of deer), and half is assumed to come from non-local sources. Half of the fish are assumed to come from LTRC at Martin, and half is assumed to come from the SR.
Working Group Comments 1. Scenario Location: Family resides in Barnwell, SC. Father provides weekly beverage deliveries to SRS. 2. Family: 2 parents, 2 children varying ages (1950's); 2 parents, 3 children (1960s) 3. Schools: Barnwell, SC school system 4. Work: Assumes the delivery person worked at the Allendale Coca Cola Bottling Plant in Allendale, SC. and made routine deliveries to SRS (various locations), spending 8 hours per week on-site. 5. Religion: Attended Mount Hope Baptist Church, Martin, SC. 6Food Sources: Barnwell, SC grocery stores, and Furses' Grocery Store, Martin, SC 7 Swimming, Boating & Camping: Swimming in Lower Three Runs Creek (outside Martin, SC). Boating and camping at Little Hell Landing on the Savannah River (South boundary of SRS). 8 Hunting & Fishing: Hunting at Lower Three Runs Creek area (known for poaching). Fishing at Lower Three Runs Creek, and Savannah River's Smith Lake. 9 Family drank a lot of carbonated beverages (including beer) through the years.	**Adapted / Excluded Information** • Family: 2 parents, 2 children (1950's); 2 parents, 3 children (1960s). (2 parents and 2 children modeled.) • Family drank a lot of carbonated beverages (including beer) through the years. (Beverages immaterial to model because no contaminated beverage consumption is modeled.)
New Scenario Modifications 1. No dosimetry issued for this person. 2 Consider backyard chickens and or rabbits at residence.	

No. 5 – Outdoors Person Family in Jackson, SC

CDC Information	Scenario Description
Initial Assumptions 1. Assume that the person camped at the nearest downwind location that would make sense with the season (hunting, fishing, etc.) 2. Assume that the person was always outdoors. 3. Use default consumption values 4. Assume the person spent 8 hours per day on the Savannah River in the summer. 5. Assume that the person spent 8 hours per week on site hunting or fishing (in season). 6. Assume that the person obtained their food from nearby groceries. 7. Delete the assumption that the person obtained their food from nearby grocery store, and replace with the person obtaining fish and meat (deer, game birds, and turtles) from hunting and fishing onsite (some authorized, some not).(1/20/02) 8. New scenario incorporates the "poacher" assumption.	This family consisted of an adult male, adult female, a male child born in 1955 and a female child born in 1964 (3). The family resided in Jackson, SC, and all family members were present there for most activities, including school and religious services (9,11,13). When the children grew up, they continued to reside in the Jackson area. Periods where family members were not present in Jackson are hunting and fishing for the adult male. For employment, the adult male worked onsite at SRS as a hunter (5,12,17). For recreation, all family members swam, boated, camped, and fished on the Savannah River at Jackson (upstream of the site) (15). The adult male also fished, boated, hunted, and trapped onsite along the SR and in the area downstream of the site (4,5,12,16,17,19). For food consumption pathways, all milk and eggs are assumed to come from cows residing in Jackson. For leafy and root vegetables and fruit), half is assumed to be produced in and around Jackson, and half is assumed to come from non-local sources (14). . Venison from deer harvested onsite is used to represent all wild game (7,14). Except for hunting, other meat (beef and poultry) is assumed to come from Jackson sources (14). All fish are assumed to come from local sources (14). **Adapted / Excluded Information** • Hunting dogs were also family pets (18). (Pets immaterial to model.)
Working Group Comments 1. Scenario Location: Family resides in Jackson, SC 2. Family: 2 parents, 2 children varying ages (1950's); 2 parents, 3 children (1960s) 3. Schools: (1950) Jackson Elementary (29831). (1986) Redcliff Elementary (29803). Jackson High School. 4. Work: Works as a hunter/trapper subcontractor to the primary SRS Contractor (DuPont, WSRC, etc.) or the US Forest Service. 5. Religion: First Baptist Church, Jackson, SC 6. Food Sources: 50% of vegetables locally grown and irrigated from a surface creek. 75% of meat obtained from SRS. Fish obtained from Savannah River. Water obtained from well on home property. 7. Swimming, Boating & Camping: Boating in Savannah River from Jackson, SC boat ramp. 8. Hunting & Fishing: Obtained deer, hogs from work at SRS trapping. Fished in Savannah River.	
New Scenario Modifications 1. Scenario also includes the hypothetical poacher. 2. Hunting dogs were also family pets. 3. Some potential onsite exposure from trapping activities, streams, ponds, etc.	

No. 6 – Family Living Near the River in Martin, SC

CDC Information	Scenario Description
Initial Assumptions 1. Use the nearest docking location downwind where people could have lived on the house boats in 1955. 2. Consider an adult, an infant born in 1955 and an infant born in 1964 (year of highest radioiodine releases. 3. Use default consumption values 4. Assume they were always outdoors in contact with the Savannah River 5. Assume they obtained their food from the nearest local farm or grocery store. 6. Validate with the CAB that the boat scenario is plausible, and if so define a location.(1/20/02) 7. If not plausible, replace the boat scenario with a new scenario of a site construction worker living in a trailer. (1/20/02)	This family consisted of an adult male, adult female, a male child born in 1955 and a female child born in 1964 (2) . As a rural family, all family members spent a large portion of their work, home activities, and recreation time outdoors (4). The adult male worked as a farmer, and the adult female worked at home. The family lived, worked, and went to school in the Martin, SC, area, and participated in hunting, trapping, and other outdoor activities around Martin (8) and fishing in the Savannah River. When the children grew up, they continued to reside in the Martin area. All milk and eggs consumed by the family was produced or collected in or near Martin (5). For most other foods, (meat, poultry, leafy and root vegetables, and fruit) half is assumed to come from local sources produced in Martin, and half comes from unaffected non-local sources. All fish consumed by the family were caught in the Savannah River downstream of the site at or near the Little Hell Landing. For grain, it was assumed that 25% of the consumed grain was produced locally until 1970, and the remainder came from unaffected non-local sources. Any irrigation used to produce the food consumed by the family and drinking water consumed by the family is assumed to come from local groundwater unaffected by SRS releases. **Adapted / Excluded Information**
Working Group Comments 1. Scenario Location: Consider Martin-Millet area 2. Family: TBD 3. Schools: TBD 4. Work: TBD 5. Religion: TBD 6. Food Sources: Shell fishing, shrimping, crabbing 7. Swimming, Boating & Camping: TBD. 8. Hunting & Fishing: TBD	
New Scenario Modifications 1. TBD	

No. 7 – Migrant Worker Family in New Ellenton, SC

CDC Information	Scenario Description
Initial Assumptions 1. Use the closest downwind location where urban or suburban families could have been farms in 1955. 2. Consider an adult, an infant born in 1955 and an infant born in 1964 (year of highest radioiodine releases. 3. Use default consumption values 4. Assume they were always outdoors in contact with the soil. 5. Assume that the crops were irrigated by the Savannah River. 6. Assume they obtained their food from the nearest local farm or grocery store.	This family consisted of an adult male, adult female, a male child born in 1955 and a female child born in 1964 (2) . As a rural family, all family members spent a large portion of their work, home activities, and recreation time outdoors (4). The adult male and female worked as migrant farm workers. The family participated in hunting, fishing, trapping, and other outdoor activities around the New Ellenton area and in the nearby area of Briar Creek (14,15). The children stayed at home until of school age, attended schools in New Ellenton. When not attending school, the children remained in the New Ellenton area and, when they grew up, they assumed lifestyles similar to their parents. The family lived, recreated, and worked in and around New Ellenton, GA. All milk, eggs, and fish consumed by the family was produced or collected in or near New Ellenton. For most other foods, (meat, poultry, leafy and root vegetables, and fruit) half is assumed to come from local sources produced in New Ellenton, and half comes from unaffected non-local sources. Because the Briar Creek is not located hydrologically downstream from SRS, none of the fish consumed by the family is assumed to be affected by SRS releases. Any irrigation used to produce the food consumed by the family and drinking water consumed by the family is assumed to come from local groundwater or surface water sources unaffected by SRS releases. **Adapted / Excluded Information**
Working Group Comments 1. Scenario Location: TBD 2. Family: 2 parents, 2 children varying ages (1950's); 2 parents, 3 children (1960s) 3. Schools: TBD 4. Work: TBD 5. Religion: TBD 6. Food Sources: TBD 7. Swimming, Boating & Camping: TBD 8. Hunting & Fishing: TBD	
New Scenario Modifications 1. TBD	

Attachment D - Comparison of Phase II and Phase III Source Terms for Water Releases

The purpose of this document is to record the similarities and differences between the Phase II source term values for water releases and the Phase III values used for the dose reconstruction. Also, where there are significant differences, the rationale for those differences are stated.

The Phase II report presents data on releases at several levels of detail. For example, total releases for a 36-year period of operation are considered for the screening analysis described in Chapter 3; annual values for a particular isotope and facility are presented in Chapter 5; in addition, some of the spreadsheets in the supplementary data provide releases by facility on a weekly or monthly basis. Because of the approach adopted for the Phase III dose reconstruction, the liquid releases to two receiving bodies of water are compiled by isotope, and, for some radionuclides, by chemical form. The two bodies of water represent locations for exposure to water released radionuclides for receptors in various receptor groups (scenarios).

Savannah River Concentrations.

ATL has checked and rechecked the data used as input to the dose reconstruction, through a Quality Assurance Program. However, to assure an appropriate degree of agreement between the Phase II and Phase III reports, the total releases for all significant radionuclides are compared here. Comparison of each year or each facility has been performed to some degree, but as a consistency check, comparison of total releases is considered to be sufficient. Since reconstructed doses are based on the concentrations in the Savannah River and those concentrations are based on the liquid releases from the entire site, a check on total releases serves as direct verification for Savannah River concentrations. The comparison between the Phase II and Phase III analyses is made more difficult by the large amount of data in the Phase II report and the different ways in which it is employed. For example, the total releases used in Chapter 3 to screen radionuclides based on their dose impact are largely raw releases based on primary sources (e.g., Cummins); in Chapter 5 different source terms are developed for releases of H-3, Sr-90, and Cs-137.

These different source terms are based on measurements of radionuclide concentrations in streams near the site boundary; as Chapter 5 states: “For the source term work at SRS, we reasoned that the last measurement point onsite would be the best data to use as the starting point. This location was at Road A where it intersected each stream.” Chapter 5 further states: “However, it was clear that some of the factors that might affect the release estimates that are listed above had not been evaluated quantitatively. The hold-up time in the swamp, and sampling and analytical procedures were the major components of the uncertainty analysis.” The Phase II report then proceeds to develop modified source terms that include the effects of radionuclide holdup in the swamp, release of sequestered radionuclides by large spring floods, and uncertainties in measurement and monitoring. The results of this Monte-Carlo modeling are presented as median results plus additional percentile values for each year, but only for releases of H-3, Sr-90, and Cs-137.

The complex nature of radionuclide transport by surface water at the SRS requires consideration of the loss mechanisms, time delays, and uncertainties that influence concentrations produced by releases in the Savannah River. Transport of released radionuclides across the SRS into the Savannah River was neither simple, nor direct. Direct releases from SRS facilities to the five major on-site streams (Upper Three Runs Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek) caused dissolved radionuclides to travel some distance (~ 10 km) to the Savannah River; during that journey, the radionuclides were subject to sorption on sediment and soil, uptake by biota, and dilution by inflows of

uncontaminated water. The southwestern edge of the SRS site, along the Savannah River, consists of a wetland, which slows the flow of water in the five on-site streams to the Savannah River, as well as acting as a sink for dissolved constituents that are sorbed or taken up by minerals, sediments, plants and other biota in the swamp. To further confound the surface water transport of radionuclides, facilities released radionuclides to seepage basins, which held the waste for some period of time; these facility releases were often in addition to releases directly to surface waters. These impounded, waste-contaminated waters would seep into the soil, and would eventually reach the surface waters of nearby streams. In addition to these various physicochemical means of reducing the releases to the Savannah River, radioactive decay also affected the concentration of constituents that would reach the Savannah River, depending upon radionuclide half-life and hold-up time. Because of this complex array of processes and multiple pathways, Chapter 5 of the Phase II Report concludes: "For the source term work at SRS, we reasoned that the last measurement point onsite would be the best data to use as the starting point. This location was at Road A where it intersected each stream." Because accounting for releases to the surface water pathway at the facility point of release is not an accurate estimate of the actual releases from the SRS site to the Savannah River, the Phase II Report takes the following steps:

1. Releases were estimated based on concentrations and flow rates measured at sampling points where Road A intersected the on-site streams;

2. A physically based, quantitative model was used to estimate retention of radionuclides in the swamp and their subsequent release during heavy floods.

As described in Chapter 5 of the Phase II Report a relatively simple model was used to estimate the releases to the Savannah River as affected by the various sinks, delay mechanisms, and uncertainties in the transport parameters. A sequence of Monte Carlo-style analyses developed ranges of annual releases for H-3, Sr-90, and Cs-137, based on concentrations of constituents measured at the sampling stations along Road A, the sampling point closest to the river. The effects of the various physical and chemical interactions of released radionuclides with the soil, biota, and other features of the SRS are expected to generally decrease the amount of radionuclides released to the Savannah River. On the other hand, many of the uncertainties in measuring the releases, when incorporated into the Phase II model, increase the amount released. The Phase II model explicitly considers effects of the following factors:

1. Measurement uncertainty;

2. Retention of radionuclides in the swamp by sorption;

3. Release of previously retained radionuclides by periodic flooding of the swamp.

Because ATL wished to model more than the three nuclides that had been modeled in Phase II, Chapter 5, a means to extend those considerations to additional radionuclides was sought. ATL considers the base-case analysis in Phase III as a refinement of the Phase II screening analysis. The Phase III base-case analysis considers the impacts of environmental dispersion and transport on the concentration of radionuclides in media to which hypothetical receptors are exposed; the Phase II screening analysis did not consider these environmental dilution phenomena. Direct modeling similar to that performed in Chapter 5 was not possible, because most nuclides were below detectable concentration limits at the Road A intersections and, therefore, the basis for the Chapter 5 modeling was unavailable. Instead of direct modeling, ATL has extrapolated these Phase II modeling results for three radionuclides to additional radionuclides. Since the Chapter 5 modeling essentially factors in environmental depletion and delay, as well as measurement uncertainty, the ratio of the **modeled annual releases from the site** to the **measured annual releases from all the facilities**, represents the net effect of the modeled factors. ATL has used the resultant medians (50th percentile) from the Phase II uncertainty analyses as representative

of the results of the modeling and as a means for extrapolating the uncertainty analysis to those releases of radionuclides not modeled explicitly in Phase II. These adjusted releases will be used in the dose reconstruction analysis. Adjustment factors are developed for each year for three classes of radionuclides. These radionuclide classes encompass different ranges of Kd.

The adjustment factors are the ratio of (1) the median of the Phase II modeling results for each year, respectively for H-3, Sr-90, and Cs-137 to (2) the Category 1 plus Category 3 releases from the site for each year, respectively for each of these three radionuclides. Liquid releases from the site have been placed into three categories:

1. Category 1 - Direct releases to onsite streams

2. Category 2 - Migration from seepage basins into onsite streams

3. Category 3 - Direct releases to seepage basins.

Although one would think that the total releases to site streams would be the sum of Categories 1 and 2, the Phase II report generally uses the sum of Categories 1 and 3 to represent the liquid source terms (e.g., in the screening analysis), except for two special cases. There appear to be at least two reasons for this choice: (1) Migration from the seepage basins is distributed in time and space, so measurements of concentrations immediately downstream of the seepage basins may under-represent the total flux from the seepage basins to the streams; and (2) The sum of Categories 1 and 3 should be a conservative estimate of liquid releases to site streams. For these reasons, ATL has chosen the annual sum of Categories 1 and 3 as representative of SRS releases to site streams. This has two implications: (1) the adjustment factors based on modeled releases of H-3, Sr-90, and Cs-137 should use the sum of Categories 1 and 3 as the denominator of the adjustment factor and (2) these adjustment factors should be applied to the sum of Categories 1 and 3 for radionuclides with similar Kd's.

Although these annual liquid releases for Categories 1 and 3 have been derived from fundamental data (e.g., Cummins et al., 1991), they are consistent with the Phase II report. Different adjustment factors are used, depending on the radionuclide. The medians calculated in Phase II Monte Carlo analysis for H-3 and Cs-137 will be used directly for those nuclides. Since Sr-90 is being used to represent the health effects from annual releases of unidentified beta-gamma emitters, an additional adjustment is needed for releases of Sr-90. The adjustment factor derived for Sr-90 will be applied to the sum of (1) annual unidentified beta-gamma inventory plus (2) the annual Sr-90 releases. For all other radionuclides, the adjustment factor will be applied to the annual liquid-pathway release; adjustment factors derived for H-3, Sr-90, or Cs-137 will be used, depending on the KD range most appropriate to the particular radionuclide.

Confirmatory Checks.

There are two desirable confirmatory checks that also place the Phase III analysis in context. These checks are: (1) comparison of the un-extrapolated releases used in Phase III to the screening values used in Phase II and (2) comparison of the extrapolated releases used in Phase III to the screening values used in Phase II. The following Table 1 makes these comparisons.

The column headed "Eval." compares the unadjusted Phase III values to the Phase II screening values. A green notation indicates agreement without any explanation required. A red notation indicates a difference that cannot be resolved. A yellow notation indicates agreement with an explanation.

Releases from Water-Step 1 Screening		Sum of all years releases from Cummins data - basis for modification			Sum of all years releases from GENII input spreadsheet	
Symbol	Surface Water Release Rate from SRS	Cat. 1 + Cat. 3, unles noted otherwise	Ratio Phase II basis to screening	Eval.	Adjusted releases for Phase III - GENII input	Ratio GENII input to screening
0	(Ci/36 yr)					
Ce-141,144	7.00E+02	7.05E+02	0.99		4.58E+02	6.54E-01
Cs-134	1.35E+01	1.35E+01	1.00		2.87E+00	2.13E-01
Cs-137	1.95E+03	1.95E+03	1.00		2.57E+02	1.32E-01
Co-60	8.40E+01	8.42E+01	1.00		5.40E+01	6.43E-01
H-3	1.50E+06	1.53E+06	0.98		1.73E+06	1.16E+00
I-131	3.03E+02	3.02E+02	1.00		2.88E+02	9.50E-01
I-129	1.20E+00	3.00E+00	see note		2.71E+00	2.26E+00
P-32	1.96E+02	1.96E+02	1.00		1.29E+02	6.60E-01
Pu-239, 240	8.00E+00	7.91E+00	1.01		2.02E+00	2.52E-01
Pu-238	4.00E+00	4.07E+00	0.98		7.08E-01	1.77E-01
Ru-103,106	1.80E+03	1.68E+03	1.07		1.30E+03	7.25E-01
Sr-89,90	6.20E+02	7.23E+02	0.86		2.99E+02	4.82E-01
S-35	1.75E+03	1.75E+03	1.00		1.53E+03	8.77E-01
Tc-99	5.30E+01	5.30E+01	1.00		5.47E+01	1.03E+00
U-235,238	4.20E+01	4.15E+01	1.01		1.19E+01	2.83E-01
Zn-65	1.50E+02	1.50E+02	1.00		9.64E+01	6.43E-01
Zr,Nb-95	1.45E+02	9.64E+02	0.15		8.23E+02	5.67E+00

Yellow – Agreement with an explanation.

H-3. The value listed in the Table for "Cat. 1 + Cat. 3" is essentially Category 1 only for tritium; i.e., releases to the streams only, not to streams and seepage basins. This may be reasonable, because a large amount of the tritium in the seepage basins may migrate to the atmosphere and therefore be unavailable for the Savannah River.

I-131. This entry is the Category 1 release only, i.e., release to streams only, not to streams and seepage basins. This appears to be appropriate because of the short, 8-day half-life of I-131. Any substantial holdup duration will cause the seepage basin inventory to decay away.

I-129. In the Phase II report, the 1.2 Ci entry for I-129 in the table for the screening calculation, was obtained by assuming that 3 Ci entered the seepage basin and 40% of that inventory was released from the basin to the stream (3 Ci * 0.4 = 1.2 Ci). Since Phase III is modifying all of the other gross inventories with an adjustment factor, we used this 3 Ci basis. The sum of Category 1 and Category 3 releases, based on the Cummins report, is 0.358 Ci.

Sr-89,90. Although the Phase II screening value and the Phase III base value are different by about 15%, this appears to be due to an addition error in the Phase II report. The screening spreadsheet value should have been about 720 Ci, based on the note in the spreadsheet indicating how the entry was obtained. However, this difference is not important. When the Sr-89,90 releases are applied in the dose reconstruction, ATL adds the unidentified beta-gamma releases to the Sr-90 inventory in the amount of XXXX Ci, which dwarfs the Sr-89,90 releases, and any differences between the Phase III basis and screening values.

Red – Unable to reconcile differences.

Zr,Nb-95. We have rechecked our numbers and those in the Phase II report, but cannot explain why our value is about 6.6 times that used in the Phase II screening. Since we could find no explanation in Phase II for the reduction, we will use the larger value, which will be either more conservative or more accurate or both.

Ru-103,106. We have been unable to resolve the 7% difference in the liquid release values in Phase II and Phase III for these isotopes; however, the difference is not expected to produce substantially different results.

Comparison of Adjusted Releases to Screening Values.

The adjustment factors, applied on the basis of Kd, appears to be reflected in the ratios of the adjusted releases (Phase III) to the screening releases (Phase II). On average the ratios for the three groups are given in the following Table 2.

	Average Ratio
H-3 Scaled: I-129, 131, Tc-99, S-35	1.28E+00
Sr Scaled:Ru-103,106, Co-60, Sr-89,90, Nb/Zr-95, P-32, Zn-65, Ce-141, 144, U	5.84E-01 *
Cs Scaled:Pu, Cs-134, 137	1.93E-01

*Does not include Zr/Nb-95, since our source was much higher than the screening value.

In other words, the H-3 scaled nuclides have increased values on average (+28%); the Sr scaled nuclides have on average 60% of the screening value; the Cs-scaled nuclides have about 20% of the screening values. This is due to hold-up in the environment, based on the increasing value of Kd. These values compare, in general, with the adjustment factor values for each scaling group averaged over all the years, which are respectively: 0.749, 0.711, and 0.232. Since the ratio for each nuclide depends on applying the annual adjustment factor for the group to the annual releases for the radionuclide, the sum of the products depends upon the release history of the radionuclide. This accounts for the variability of the ratios within each group.

Attachment E - Basis for Determining Isotopic Fractions from SRS Environmental Reports for Performing Radiological Dose Assessments

The quantification of environmental releases on an isotopic basis is needed to perform radiological dose assessments. Each isotope has a different half-life, thus making its contribution to the total radioactivity released from the site different from other isotopes. Each isotope also has a unique dose conversion factor, making it important to know the specific isotopes released to conduct the radiological dose assessments. Because a number of constituents are not delineated by isotope in environmental release reports, assumptions need to be developed based on nuclear physics and knowledge of the process history of the SRS facilities.

Throughout much of the history of the Savannah River Site (SRS), technology and programmatic limitations have restricted the ability to differentiate environmental releases on an isotopic basis. Gross alpha (α) and gross beta + gamma ($\beta+\gamma$) measurements were primarily used to measure radioactive releases (Cummins et al., 1991) to the air, seepage basins, and surface waters in many facilities. SRS has historically had a practice of reporting specific isotopes from the gross alpha/beta/gamma measurements if the isotopes are known to be in the effluent (Evans et al., 1992).

This appendix provides the technical basis and assumptions for quantifying environmental releases by isotopes that have not been specifically identified in SRS environmental reports.

Constituents

As stated above, the environmental release reports being used for the radiological dose assessments do not, in some cases, delineate individual isotopes but instead show total radioactivity for a combination of isotopes (or constituent). Constituents shown in various SRS environmental reports whose total radioactivity needs to be fractioned into individual isotopes include:

- Sr-89, Sr-90
- Zr-95, Nb-95
- Cs-134, Cs-137
- Uranium
- Plutonium
- Unidentified alpha
- Unidentified beta + gamma

Technical information and general assumptions for determining the fraction an individual isotope contributes to the total radioactivity of the constituent are described below with more detailed application to site facilities as applicable. When appropriate, each of the above constituents is analyzed on the basis of the process to which it is related to determine the fraction of the activity to be designated to individual isotopes. Table A-1 summarizes how the radioactivity of each constituent should be fractioned for the applicable SRS site areas.

Table A-1 Summary of Assumed Isotopic Distributions

Constituent	SRS Area	Isotopic Distribution (by Curies)
Sr-89, 90	F&H Areas	75% Sr-89; 25% Sr-90
	A Area	100% Sr-90
	D Area	100% Sr-90
	Central Shops	100% Sr-90
Zr, Nb-95	Reactor Areas	35% Zr-95; 65% Nb-95
	F, H, and D Areas	31% Zr-95; 69% Nb-95
Cs-134, 137	D Area	100% Cs-137
Uranium	Reactor Areas	91.73% U-234; 1.79% U-235; 6.45% U-236; 0.03% U-238
	F Area	1.27% U-235; 98.73% U-238
	H Area	91.73% U-234; 1.79% U-235; 6.45% U-236; 0.03% U-238
	M Area	Air emissions: 49.49% U-234; 2.25% U-235; 48.26% U-238
Liquid emissions: 1.27% U-235; 98.73% U-238		
	A Area (SRL)	91.44% U-234; 1.8% U-235; 6.4% U-236; 0.36% U-238
	CMX/TNX	49.49% U-234; 2.25% U-235; 48.26% U-238
	D Area	91.73% U-234; 1.79% U-235; 6.45% U-236; 0.03% U-238
Total Plutonium	All Areas	100% Pu-239
Unidentified Alpha	All Areas	100% Pu-239
Unidentified Beta + Gamma	All Areas	100% Sr-90

Isotopic Fraction Evaluation

Strontium-89, 90 (Sr-89, 90)

Sr-89 and Sr-90 are shown together in the Cummins et al. historical report as a single constituent (Cummins, 1991) for liquid releases from SRL to seepage basins, liquid releases from D Area to streams, atmospheric releases in F and H Areas, and liquid releases to seepage basins in Central Shops. It is necessary to determine what curie fraction contributes to the total value reported for each of these facilities and environmental pathways.

Sr-89 and Sr-90 are fission products generated from the bombardment of U-235, U-238, and Pu-239 with neutrons. Carlton et al. calculated the number of curies related to the generation of Sr-89 and Sr-90 in the

production reactors, assuming a typical fuel element composition. The number of curies associated with each of these strontium isotopes is summarized in Table A-2.

Table A-2 Accumulated Fission Yields (Carlton et al., 1994a)

		Curies Remaining at Various Times After End of Irradiation				
Isotope	Half-Life	0 seconds	24 hours	100 days	200 days	2 years
Sr-89	53.21 days	9.080E7	8.962E7	2.468E7	6.707E6	6.685E3
Sr-90	28.28 years	2.219E6	2.219E6	2.204E6	2.189E6	2.113E6

Based on Table A-2, the percentage of curies of Sr-89, 90 associated with Sr-89 is calculated and presented in Table A-3.

Table A-3 Percentage of Sr-89 to the Total Curies Associated with Sr-89, Sr90

Isotope	0 seconds	24 hours	100 days	200 days	2 years
Sr-89	98%	98%	92%	75%	0.3%

The percentages in Table A-3 are used to determine the fraction of Sr-89 and Sr-90 assumed to be released for the situations in which releases are shown for the combined Sr-89, 90 data as following:

Separations Areas: Fuel and target elements were stored in the reactor basins for a nominal period of 200 days after completion of irradiation before being processed in F and H Areas (Carlton et al., 1994a). For F and H Areas, it should be assumed that the environmental releases to the atmosphere occur 200 days after completion of irradiation in the reactors. Sr-89, 90 atmospheric releases should therefore be fractioned to 75% Sr-89 and 25% Sr-90 for these releases.

Administration Area (A): Environmental releases of Sr-89, 90 in A Area are attributed to releases from SRL to the SRL seepage basins. SRL conducted research using various forms of uranium and plutonium. Strontium isotopes were generated as a result. SRL also worked with Cf-252 for several years, and Sr-90 is daughter product of this isotope. It cannot be determined to what proportion Sr-89 to Sr-90 was generated by operations at SRL; therefore it should be assumed that all of the environmental releases attributed to Sr-89, 90 are attributed to Sr-90 for conservatism in dose calculations since Sr-90 has higher inhalation and ingestion dose conversion factors than Sr-89.

D Area: D Area was used to separate light water from used moderator from the reactors (Carlton et al., 1994a). This process can be assumed to occur within one year after receipt of the moderator from the reactors. It is unclear as to how long the moderator was typically removed from the reactor before it was processed in D Area; therefore it should be assumed that all of the environmental releases attributed to Sr-89, 90 are attributed to Sr-90 for conservatism in dose calculations since Sr-90 has higher inhalation and ingestion dose conversion factors than Sr-89.

Central Shops: The Central Shops (CS) were used for repairing equipment from the reactors and separations areas. Prior to repair of the equipment, the equipment was cleaned with water. The discharge water was discharged to seepage basins. The discharge of the water is assumed to occur approximately 2 years after the Sr-89, 90 contained in the discharge water was originally generated. The curie content of Sr-89, 90 from Central Shops should therefore be attributed to Sr-90 for conservatism in dose calculations.

Zirconium-95, Niobium-95 (Zr, Nb-95)

Zr-95 and Nb-95 are fission products. Nb-95 is also the only daughter product of Zr-95. Zr-95 has a half-life of 64.02 days and Nb-95 has a half-life of 34.975 days. Table A-4 shows that these isotopes are initially generated as fission products in equal mass amounts (KAERI, 2003).

Table A-4 Accumulated Fission Yields

	Accumulated Yield	
Fissile with Neutron Energy	**Zr-95**	**Nb-95**
U-235 with 0.0253 eV	0.06	0.06
U-235 with 1.0 MeV	0.06	0.06
U-238 with 1.0 MeV	0.05	0.05
Pu-239 with 0.0253 eV	0.05	0.05
Pu-239 with 1.0 MeV	0.05	0.05

Equation 1 can be used to determine the initial curie content in the production reactors assuming equal masses of Zr-95 and Nb-95 are produced in the reactors and assuming the reactors operate with neutron thermal energies shown in Table A-4:

$$A = \lambda N \qquad \text{(Eq. 1; Hankins, 1988)}$$

at t (time) = 0; A is the activity; λ is the radioactive decay constant; and N is the number of atoms. At any time t greater than 0, equation 2 applies:

$$A(t) = A_0 e^{-\lambda t} \qquad \text{(Eq. 2; Hankins, 1988)}$$

Since the fission yields (the number of atoms emitted) of Zr-95 and Nb-95 are equal, their contribution to the gross activity of Zr-95, Nb-95 is calculated to be 35% for Zr-95 and 65% for Nb-95 immediately upon their generation in the reactor.

The half-life of the daughter is less than (but not much less than) the half-life of the parent isotope. The time (t_{max}) at which the maximum activity of Nb-95 will occur, based on its production from the decay of Zr-95, is 67 days, calculated from the following equation (Hankins, 1988):

$$t_{max} = \frac{\ln \frac{\lambda_{Nb}}{\lambda_{Zr}}}{\lambda_{Nb} - \lambda_{Zr}} \qquad \text{(Eq. 3; Hankins, 1988)}$$

After 67 days, the activity of Nb-95 begins to decline at the same rate as the decline in activity of Zr-95 (this is called transient equilibrium). This ratio can be calculated by the following (Hankins, 1988):

$$\frac{A_{Nb}}{A_{Zr}} = \frac{\lambda_{Nb}}{\lambda_{Nb} - \lambda_{Zr}} = 2.2 \qquad \text{(Eq. 4; Hankins, 1988)}$$

Based on the decay chain and the calculated ratio after the 67 day maximum, the ratio of isotopic activity approaches a constant value where 31% of the total activity is due to Zr-95 and 69% of the activity is due to Nb-95. These percentages are appropriate for operations which would occur after the removal of the fuel and targets from the reactors. By SRS process area, then, the following isotopic fractions can be used:

Reactor Areas: 35% Zr-95 65% Nb-95

All other areas: 31% Zr-95 69% Nb-95

These assumed values are based on assumptions that are meant to best reflect actual operating conditions and environmental releases. Carlton and Denham, in determining the potential dose to individuals from these same isotopes, used more conservative assumptions that are based on the impact on dose (Carlton and Denham, 1997).

Cesium-134, 137 (Cs-134, 137)

The cesium isotopes were generated at SRS as fission products and, in the case of Cs-137, was at times isolated for further use as an energy source. The combined constituent Cs-134, 137 is shown (Cummins et al., 1991) in environmental releases in D-Area. Cs-134 has a half-life of 2.06 years while Cs-137 has a half-life of 30.07 years. Table A-5 shows the yield of Cs-134 and Cs-137 that is assumed for reactor operations (KAERI, 2003).

Table A-5 Accumulated Fission Yields

	Accumulated Yield	
Fissile with Neutron Energy	**Cs-134**	**Cs-137**
U-235 with 0.0253 eV	0.0000001	0.06
U-235 with 1.0 MeV	0.0000005	0.06
U-238 with 1.0 MeV	0.000000003	0.06
Pu-239 with 0.0253 eV	0.00001	0.07
Pu-239 with 1.0 MeV	0.00001	0.07

Because the fraction of Cs-134 is so small, Cs-137 is expected to contribute to nearly 100% of the activity of the combined constituent Cs-134, 137. The activity measured for this constituent should therefore be attributed to Cs-137.

Uranium (“U-Nat”, or “U-235, 238”)

The relative abundance of the various uranium isotopes in air and water releases from SRS facilities is dependent on a number of factors. The primary factor is the enrichment level of the uranium being handled at the facilities. Enrichment increases the relative abundance of the lower weight isotopes (U-234 and U-235) and decreases the proportion of the higher weight isotopes (U-238). A second factor is whether the uranium has been subjected to neutron radiation (in a reactor). Reactor irradiation would result in the production of U-236. While it is fairly certain that the uranium at SRS facilities, in particular the reactors and separations facilities, were irradiated in reactors, there is only limited information on the enrichment levels of uranium in these and other facilities. Therefore, the analysis of the isotopic composition of uranium found in air and water discharges is largely based on general assumptions. However, due to two key properties of the various uranium isotopes, changes to the composition will not have a substantive effect on the results of the SRS dose reconstruction. The first key property is half-life. All of the uranium isotopes have very long half-lives (240,000 years and longer) in comparison to the period being studied (~40 years). Therefore, radioactive decay will not have a significant effect on the relative abundance of the isotopes after they are released. The second key property is the dose conversion factor. The dose conversion factors for the uranium isotopes fall within a ~15% range; therefore, the doses received from equal amounts of the different isotopes will be about the same (+/- ~15%).

Until the mid-1990s, alpha-emitting radioisotopes were detected using instrumentation that measured gross alpha. This gross alpha count was attributed to a combination of primarily uranium and plutonium. The fraction of the gross alpha assigned to each of these elements varied depending on the facility or process emitting the alpha radioactivity. In M Area where reactor fuel was manufactured, alpha radioactivity was solely attributed to uranium. When dose calculations were conducted, assumptions were made as to the type of uranium present (natural, enriched, or depleted), with the corresponding isotopic fractions used (Hefner, 2003). This approach is used below to estimate the curie fraction of each uranium isotope for the applicable SRS facilities.

In Cummins report, "U-Nat" (natural uranium) represents "U-235, 238" (Cummins et al., 1991). U-235 and U-238 represent the majority of the mass of naturally occurring uranium. It should not be assumed, however, that all uranium measured in environmental releases at SRS is natural uranium. Despite the nomenclature being used in Cummins report, uranium actually occurs in three basic forms in the SRS environment: natural, depleted, and enriched. Natural uranium is processed to remove U-238 so that a higher concentration of U-235 is achieved, thus creating enriched uranium. The enrichment process creates a byproduct called depleted uranium. Depleted uranium is either disposed as a waste or reused in target materials for producing plutonium isotopes. Evans et al. provides approximate isotopic compositions for each of these waste forms, shown in Table A-6 (Evans et al., 1992). Note that for enriched uranium, two basic types of fuel were manufactured and used at SRS: Type M and Type F. Since it is unclear as to how much Type M fuel versus Type F fuel was used, Table A-6 shows an average isotopic composition for enriched fuel, assuming the same mass of Type M and Type F fuel. Note that these compositions include U-234 and U-236. While the original data sources only reference U-235/U-238, it is assumed that these other uranium isotopes are also present.

Table A-6 Isotopic Composition of Savannah River Uranium Wastes (Evans et al., 1992)

	Isotopic Composition (wt %)**			
Isotope	U-234	U-235	U-236	U-238
Half-Life (years)*	2.45E+5	7.03E+8	2.34E+7	4.47E+9
Natural	0.0055	0.7200	n/a	99.2745
Depleted	n/a	0.2	n/a	99.8
Enriched***	1.45	81.55	9.8	7.2

* (KAERI, 2003).
** Evans et al.
*** Average of Isotopic Composition for Type M and Type F fuels

Using the above weight percentages, the contribution to the activity for each isotope is calculated using Equation 1 and presented in Table A-7.

Table A-7 Activity Fraction for Specific Isotopes in Uranium Wastes

	Activity Fraction (%)			
Isotope	U-234	U-235	U-236	U-238
Natural	49.49	2.25	n/a	48.26
Depleted	n/a	1.27	n/a	98.73
Enriched	91.73	1.79	6.45	0.03

These activity fractions can be used in the dose assessments, taking into account the prevalent form of uranium in each process area at SRS at the time of release, as presented below.

Reactor Areas: Any environmental releases of uranium in the reactor areas to streams and seepage basins are assumed to occur after the storage of spent fuel (containing enriched uranium) and target materials (containing depleted uranium) in spent fuel basins and disassembly basins (Evans et al., 1992). Basin purge water was normally discharged to the plant streams and seepage basins along with the reactor secondary cooling water. Uranium releases from the reactors to the atmosphere occurred due to the venting of "harps" (storage containers located underwater in the reactor basin which contained failed fuel and target elements) to the reactor stack (Carlton and Denham, 1997). The ratio of enriched to depleted uranium that was used in the production reactors is not known and cannot be calculated. Since it can be assumed that there was most likely more enriched uranium, on a mass basis, than depleted uranium that was used in the reactors, the fraction of uranium isotopes in Table A-7 for enriched uranium should be used for environmental releases from the reactors.

Separations Areas: Based on Evans et al., the F Area facilities primarily isolated Pu-239 from U-238 target material comprised of depleted uranium. The curie fraction in Table A-7 associated with depleted uranium should therefore be used for environmental releases from F Area. In H Area, U-235 was recovered from enriched fuels. According to Evans et al., enriched fuel in H Area could contain from 1.1% to 94% U-235 (Evans et al., 1992). The curie fraction in Table A-7 associated with enriched uranium should therefore be used for environmental releases from H Area.

M-Area: The fuel and target materials used in the reactors were fabricated in M-Area. Atmospheric releases of uranium were very small compared to the releases in F Area. Based on Evans et al., these releases were in the form of natural and depleted uranium, although it is unclear to what proportion these two forms of uranium were released (Evans et al., 1992). For the purposes of this study, natural uranium fractions from Table A-7 should be assumed for atmospheric releases since U-234 is known to have been emitted and is present in natural uranium in measurable quantities. Depleted uranium has been found in stream sediments (Evans et al, 1992), so curie fractions for depleted uranium from Table A-7 should be used for all liquid releases.

A Area (SRL): SRL worked with all forms of uranium and there is no method for determining the quantity of each form used; therefore an average of the activity fractions for all three forms of uranium may be used, assuming an equal mass of natural, depleted, and enriched uranium was released. This assumption results in the following percentages of uranium isotopic activity: 91.44% for U-234; 1.8% for U-235; 6.4% for U-236; and 0.36% for U-238.

CMX/TNX: Some natural uranium was used in fuel and target development at TNX (Evans et al, 1992). Activity fractions from Table A-7 for natural uranium should therefore be used.

D Area: The rework of degraded moderator from reactor areas was the most likely source of alpha activity, which is assumed to be uranium (Evans et al, 1992). The moderator most likely contained a mixture of uranium isotopes representing both depleted and enriched uranium. To be consistent with the assumptions for the reactor areas, activity fractions from Table A-7 for enriched uranium should be used for environmental releases in D Area.

Plutonium

Pu-238, Pu-239 and Pu-240 were the primary plutonium isotopes of interest in environmental releases at SRS. Pu-239 and Pu-240 were often reported as Pu-239 since these two isotopes are indistinguishable in alpha spectroscopy measurements (Carlton et al., 1994b). All three of these isotopes were produced by the

reactors and were present in the F and H Area processes. The most common form of plutonium produced at SRS was weapons-grade plutonium. Weapons-grade plutonium had an isotopic composition similar to that shown in Table A-8.

Table A-8 Isotopic Composition of Weapons-Grade Plutonium (Mark, 1993)

	Pu-238	**Pu-239**	**Pu-240**	**Pu-241***	**Pu-242**
Mass Fraction (Mark, 1993)	0.00012	0.938	0.58	0.0035	0.00022
Activity Fraction (using Equation 1)	0.0047	0.1337	0.0302	0.8313	0.0000

* Pu-241 plus Am-241

Despite comprising a very small mass fraction of weapons-grade plutonium, Pu-241 (plus its daughter product Am-241) contributes approximately 83% to the curie content. Am-241 is addressed as a separate constituent; therefore Pu-241 is indirectly addressed in the dose assessments. Also, the dose contribution of Pu-241 is approximately 100 times less than Pu-238, Pu-239 and Pu-240. Since Pu-239 was the primary plutonium product at SRS and it has nearly identical dose conversion factors with Pu-238 and Pu-240, all “Total Plutonium” releases to the environment can be assumed to be Pu-239.

Unidentified α/Unidentified $\beta + \gamma$

As mentioned in the beginning of this appendix, many of the radioactive releases at SRS were detected with gross α and gross $\beta + \gamma$ measurements. If the isotopes were known due to process knowledge, then the measurements were assigned to the isotopes in the environmental release reports. If the isotopes were not known, then the environmental release reports reflected unidentified α and unidentified $\beta + \gamma$ measurements (Evans et al.). The unknown constituents comprising unidentified α and unidentified $\beta + \gamma$ measurements most likely were a combination of several isotopes.

Since SRS could not assign the unidentified α and unidentified $\beta + \gamma$ measurements to specific isotopes, it is not possible to proportion these measurements among several isotopes for this effort. These unidentified measurements can be attributed, however, to a single isotope to allow for a conservative estimate. In the case of unknown α, the unidentified α will be assigned to Pu-239. Pu-239 has greater dose conversion factors than the uranium isotopes for many of the exposure pathways. Pu-239 is also one of the more prevalent plutonium isotopes at SRS. Other transuranic isotopes have been produced and used at the SRS (such as Neptunium-237, Curium-244 and Californium-252) that have contributed to the measurement of unidentified α, but these isotopes were primarily produced during brief periods and have dose conversion factors 100 to 1000 times less than Pu-239. Using Pu-239 for unidentified alpha values therefore is the most conservative assumption.

Many isotopes could contribute to the unidentified $\beta + \gamma$ measurements. For conservatism, the unidentified $\beta + \gamma$ measurements will be attributed to Sr-90. Commonly found in environmental releases throughout the facilities at SRS, Sr-90 has dose conversion factor values 10 to 100 times higher than the other beta and gamma emitting isotopes of concern. With a half-life of 28 years, Sr-90 will also remain in the environment longer than most of the other beta and gamma emitting isotopes of concern.

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Attachment F - Soil-to-Water Distribution Coefficients for Radionuclides Considered in the Dose Reconstruction of Savannah River Site

1.0 INTRODUCTION

This document describes the distribution coefficients selected for evaluating potential doses and health risks to individuals residing in the vicinity of the Savannah River Site (SRS) during the period of concern (1954-1992). The principal application of these distribution coefficients is to model leaching of radionuclides from soil. For the SRS dose reconstruction, the major source of radionuclides in soil is deposition of radionuclides released into the air from the SRS. Radionuclides leached from the soil are moved from the root zone deeper into the subsurface, where they become generally unavailable for uptake by crops and subsequent incorporation into the human food chain. These distribution coefficients are used in the soil leaching models, used for chronic exposure, incorporated in the GENII v.2 radiation dose assessment code (Napier et al., 2002).

The distribution coefficients presented below have been gathered from a variety of sources. They were chosen based on the criteria that they reflect the mineralogical and chemical conditions of the soils in the SRS vicinity and are generally unbiased.

2.0 DISTRIBUTION COEFFICIENT

Distribution coefficients, Kds, are a measure of the retention/retardation of dissolved constituents by sorption on the solid phases in soils and sediments during environmental transport. The Kd may be defined as:

$$K_d = C_{sorb} / C_{aq}, \qquad (1)$$

Where Csorb is the concentration [Mass/Mass] of the constituent of interest sorbed on the solid phase and Caq is the concentration [Mass/Length3 or Volume] in the aqueous phase. The Kd is generally expressed in mL/g or its equivalent, L/kg . The former will be used in this report. Equation (1) is a special case of the more general expression:

$$C_{sorb} = K_f \cdot (C_{aq})^n \qquad (2)$$

which is known as the Freundlich isotherm (Hemond and Fechner-Levy, 2000). If Csorb is linearly proportional to Caq then n = 1, the isotherm is referred to as a linear isotherm (Freeze and Cherry, 1979), and the Freundlich constant, Kf, becomes the Kd, the distribution coefficient.

Distribution coefficients are generally determined empirically. The Kd reflects a variety of physicochemical processes that may be involved in sorption. It varies with the type of surfaces available for sorption, as reflected in the mineralogy. It varies with the Eh and pH of the solutions in contact with the solid phases, reflected in the oxidation state of dissolved phases. It varies with the amount of organic carbon in the soil/sediment and the concentration of the constituent of interest. The Kd may vary over many orders of magnitude for any given metal or organic compound of interest. Kds can also vary in space and time for the same medium. Kds can be determined by either sorption or desorption experiments. Sorption Kds often tend to be smaller than their desorption counterparts. This is because the aging of mineral surfaces tends to “fix” sorbed materials, making them less capable of exchange or removal.

Kds are used to represent the partitioning of contaminants between liquid and solid phases of a system. This is based on the assumption that sorption of constituents onto solid phases along the flow path is reversible and occurs much more rapidly than the rate of flow (Freeze and Cherry, 1979). Even though the distribution of contaminants between solid and liquid phases may be affected by the many phenomena described above, the Freundlich isotherm may be applied to a broad range of natural systems. The GENII code being used in the SRS dose reconstruction assumes linear sorption as described by Kds.

Removal of sorbed radionuclides from the soil in the root zones decreases the concentrations available for uptake by plants and subsequent exposure through various terrestrial food pathways. High Kd values may be considered as "conservative" for some exposure pathways, such as external exposure from contaminated ground, because more contaminant is retained in the soil for potential exposure. However, higher soil retention (high Kds) competes with plant uptake (Baes et al. 1984) and, consequently, grazing animal intake, and may result in lower doses from the food chain; however, the models for plant uptake implemented in the GENII code do not explicitly account for this phenomenon. Since the GENII model (see equation 7.8 in the GENII v.2 Software Design Document) decreases the amount of soil radionuclides removed by leaching with a higher value of Kd, higher values of soil Kds are conservative for all exposure pathways, as modeled in the GENII code.

In this analysis, Kd values will be used for evaluating leaching of radionuclides from soil (Napier et al., 2002). They are also considered in the evaluation of removal mechanisms during surface water transport (ATL, 2003).

3.0 SAVANNAH RIVER SITE SOIL

The soils in the vicinity of the Savannah River Site are quite sandy, with less than 20% clay content (Table 1; Kaplan and Serkiz, 2000). The clays in the Savannah River Site soils are rich in kaolinite (~70%), hydroxy-interlayered vermiculite (20%), and less than 0.1% iron oxides (Table 2). The soils contain approximately 1% organic carbon. The pH is generally less than 5.

This soil composition is not conducive to adsorption and retention of dissolved contaminants:

1. Quartz and kaolinite have low cation and anion exchange capacities (less the 10 meq/100g).

2. Hydroxy-interlayered vermiculite has a reduced exchange capacity because of the hydroxyls occupying the interlayer region.

3. Low organic carbon and iron oxide contents indicate that sorption by organic material or iron oxy-hydroxides will be limited.

4. Low pH values (and oxidizing conditions) indicate that metals such as plutonium will exist as cationic species. Non-metals will exist as anionic oxygen-complex (e.g., PO43-). These forms of radionuclides tend to make them more soluble and mobile.

Given the composition and the low pH conditions, the sorption capacity of the soils would be expected to be relatively low. The sorptive properties of the soil should be similar to the sediments (Table1) since the sediments are primarily derived from soil runoff.

Table 1. Average characteristics of sediments TNX Outfall Delta, SRS (after Kaplan and Serkiz, 2000)

>2 mm (% wt)	5.4
Sand (% wt)	61.1
Silt (%wt)	22.7
Clay (%wt)	10.8
PH	4.67
Org. C (mg/kg)	1315
CEC* mmol(+) / 100g	7.52
AEC mmol(-) / 100g**	1.68
Fe-oxides (% wt)	0.06

*CEC = Cation Exchange Capacity
**AEC = Anion Exchange Capacity

Table 2. Average Mineralogy for the <2 µm clay fraction in sediments, TNX Outfall Delta, SRS (after Kaplan and Serkiz, 2000)

Mineral	**<2 µm %wt**
Kaolinite	73
Quartz	0.6
HIV[a]	20.5
Illite	3.3
Gibbsite	2.25
Fe-oxides	0.065

[a]HIV = hydroxyl-interlayered vermiculite

4.0 Kds FOR USE IN THE DOSE RECONSTRUCTION CALCULATIONS USING GENII V. 2

As described in this Section, Kds specific to the SRS area soils have been derived for the most significant radionuclides released during the SRS operations: H-3, Sr-89, Sr-90, Tc-99, I-131, Cs-137, U and Pu. For those radionuclides not directly measured at the Savannah River Site, there are several compilations of distribution coefficients that provide default values or other information that can be used in selecting an appropriate value (IAEA, 1994; Baes et al., 1984; EPA, 1999).

Table 3 contains point-estimates of Kds for those radionuclides to be considered in the dose reconstruction. The Kds presented in Table 3 were selected in the following manner:

1. The median of the range of values provided for the SRS (Kaplan, 2003; Kaplan and Serkiz, 2000) was used;

2. If Kds were not available for the SRS, the median of the range provided for sandy soils in the IAEA Handbook of Parameter Values (IAEA, 1994) was selected.

3. If Kds for sandy soils were not available for the radionuclides of interest in the IAEA Handbook of Parameter Values, then the median of the range from the compilation by Baes et al. (1984) was used.

4. In several instances, where only a single value was available, this value was selected.

Table 3. Selected Point-Estimates of Kd for Radionuclides Released from the Savannah River Site Nuclear Facility

Nuclide	K_d (mL/g)	SRS Specific	Source
H-3	0	✔	Kaplan, 2003
P-32	173 *	✔	Kaplan, 2003
S-35	7.5		Baes et al, 1984
Co-60	60		IAEA, 1994
Zn-65	200		IAEA, 1994
Sr-89,90	3041*	✔	Kaplan and Serkiz, 2000
Y-90d	510		Baes et al, 1984
Zr-95	600		IAEA, 1994
Nb-95	160		IAEA, 1994
Tc-99	2.49	✔	Kaplan and Serkiz, 2000
Ru-103, Ru-106	55		IAEA,1994
I-131, I-129	1.55	✔	Kaplan, 2003
Cs-134, Cs-137	59	✔	Goto, 2001
Ce-141,144	490		IAEA, 1994
Th-231,234d	3000		IAEA,1994
U (all isotopes)	1000	✔	Serkiz and Johnson, 1994
Pu (all isotopes)	4100	✔	Powell, 2003
Am-241	2000		IAEA, 1994

* Generally, for any numerical value documented, only the first two digits should be considered significant. Some values reported here might have more significant digits than are appropriate given the lack of precision in data and models. However, these additional significant digits are included to reduce the round-off error in the subsequent computer calculations and to help readers and reviewers trace these values to the original data sources.
d denotes a daughter-product

5.0 COMPARISON OF Kds WITH THOSE USED IN THE PHASE II REPORT

The Phase II Report provides two lists of Kd values that were considered in evaluating the SRS source term to the surface water pathway. Table 4 presents those values. There are inconsistencies in some of the values due to different procedures used for deriving the values from the literature.

Table 4. Comparison of Distribution Coefficients

Phase II Report (Jirka et al., 1983)			This Report (Table 3)	
Radionuclide	**K_d at pH = 1 (mL/g)[a]**	**K_d in Freshwater (mL/g)[b]**	**Radionuclide**	**K_d Value (mL/g)[c]**
H-3	0	0	H-3	0
Co-60	100	5000	Co-60	60
Sr-90	50	100	Sr-89,90	3041
Ru-106	800	--	Ru-103,106	55
I-131	--	10	I-131 and I-129	1.55
Cs-134, Cs-137	1000	10,000	Cs-134 and Cs-137	59
Pu-239	10,000	100,000	Pu (all isotopes)	4100

[a] From Table 5-7 (RAC, 2001) K_d at pH = 1 (mL/g). This applies to acidic releases from the reprocessing facilities to the seepage basins.
[b] Median Values From Table 5-8 (RAC, 2001) K_d in freshwater (mL/g). Used for estimating surface water source term.

It should be noted that some of the Kd values considered in the Phase II analysis differed considerably from those reported recently by SRS investigators. This is due in part to the fact that sorption and desorption Kd isotherms are different. Much of the recent work concerning distribution coefficients for radionuclides and SRS soils has been done using desorption experiments, to better reflect release of material to the environment over time (Kaplan, 2003; personal communication).

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Powell BA, Fjeld RA, Coates JT, Kaplan DI, Serkiz SM. Plutonium oxidation state geochemistry in the SRS subsurface environment. WSRC-TR-2003-00035 Rev. 0. Westinghouse Savannah River Company, Aiken, SC; 2003.

Serkiz SM, Johnson WH. Uranium geochemistry in soil and groundwater at the F and H seepage basins. EPD-SGS-94-307. Westinghouse Savannah River Company, Aiken, SC; 1994.

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Winberg MR, Garcia RS. National low-level waste management program radionuclide report series. Vol. 14: Americium-241. Idaho National Engineering Laboratory, Idaho Falls, ID, DOE/LLW-130; 1995.

Attachment G - Documentation for GENII Model Parameters Used in SRS Base Case Calculation

This document identifies the source, transport, and exposure variables used in the SRS Base Case GENII model runs, indicates the GENII module and the section and subsection of FRAMES where the variable is used (this corresponds to the dialog boxes contained in the FRAMES user interface), states the units and input value(s) of each variable, and describes how each value was determined. Supporting references are also identified.

In addition to the variables addressed herein, two specific subsets of the source, transport, and exposure variables are not addressed in this document but instead are addressed in separate documents. The first subset not addressed includes variables considered transfer, bioconcentration, and bioaccumulation factors, and the second subset not addressed includes other food chain variables. In addition, another set of variables, receptor factors, is discussed in a separate document. For the Base Case analysis, the receptor factors are input into a custom post-processor unit rather than input into GENII using the FRAMES interface.

The variables discussed here are organized according to the following GENII modules and FRAMES sections and subsections:

GENII Module	FRAMES Section and Subsection
Source	Atmospheric Flux
	Atmospheric Flux – Flux Types
Air	Model Information – Meteorological Files
	Model Information – Default Parameters
	Model Information – Model Parameters
	Model Information – Radial Grid Definition
Constituent Database	Partitioning
	Toxicity Parameters – Exposure Factors
Exposure	Agriculture – General
	Controls
	Soil – Leaching
	Soil – Resuspension
	Soil – Surface Soil
Water	General
Health Impacts	Constituent Parameters
River	Surface Water

The following notes apply to the discussions of variables and input values in this document:

Significant Figures. Generally, for any numerical value documented, only the first two digits should be considered significant. Some values reported here are shown with more significant digits than are appropriate given the lack of precision in data and models. In these cases, the additional significant digits are included to reduce the round-off error in the subsequent computer calculations and to help readers and reviewers trace these values to the original data sources. For example, the value used for relative humidity, 0.01125 kg/m^3 is a 42-year average with a standard deviation of 0.00053 kg/m^3. This clearly implies the last two digits in the cited value are in doubt, but they are included so the value may be more easily traced through the computer calculation.

Stochastic Analysis. A final list of the variables selected for stochastic analysis had not been completed at the time this document was prepared, in part, because the selection of which variables to include depends on the results of the Base Case analysis. Some variable are clearly so important or so highly uncertain that they have been identified in these tables as "selected for stochastic analysis". Based on the evaluation of the base case and other considerations, other variables are expected to be included.

The following references were used to support the selected values:

Citation	**Reference**	**Variables Supported**
ATL 2003a	White Paper, Combining Sources of Air Releases for the SRS Dose Reconstruction ATL June 5, 2003.	Flux type, Two, ARRADVAL
ATL 2003b	Source Term Analysis (under preparation)	CFLUX
ATL 2003c	Distribution Coefficients for Radionuclides Considered in the Dose Reconstruction of Savannah River Site. ATL September, 2003.	CLKD, SOILKD
Chaki 2000	Chaki S, Parks B. CAP88-PC Version 2.1 Updated Users Guide (Beta Version), Ch.12, p.8. September 2000.	ABSHUM
DOE 2002	Savannah River Site High-Level Waste Tank Closure Final Environmental Impact Statement. U.S. Department of Energy. DOE/EIS-0303. May 2002.	SLDN, BULKD, SSLDN
EPA 2000	EPA Soil Screening Guidance for Radionuclides, Users Guide. EPA/540-R-00-007. October 2000.	MOISTC
EPA 2001	Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments), Final. U.S. Environmental Protection Agency. Publication 9285.7-47. December 2001.	SHOUT
EPA 2003	Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors, (Federal Guidance Report No.13, Morbidity Risk Coefficients, in Units of Picocuries). U.S. Environmental Protection Agency. http://www.epa.gov/radiation/heast/docs/heast2_table_4-d2_0401.pdf . 2003.	SOLUBIL
Cook 2002a	JR Cook, MA Phifer, EL Wilhite, KE Young. Closure Plant for the E-Area Low-Level Waste Facility, Rev. 2. WSRC-RP-2000-00425. WSRC, SRS, September 2, 2002.	VLEACH

Citation	Reference	Variables Supported
Cook 2002b	JR Cook and EL Wilhite. Analysis of Disposal of Lead in the E-Area Low-Level Waste Facility. WSRC-TR-2002-00101. WSRC, SRS. February 20, 2002.	VLEACH
Hamby 1991	Hamby DM. Land and Water Use Characteristics in the Vicinity of the Savannah River Site. WSRC-RP-91-17. Westinghouse Savannah River Company, Aiken, SC. March 1, 1991.	VLEACH
Hamby 1993	Hamby DM. A Probabilistic Estimation of Atmospheric Tritium Dose. Health Physics; 65(1):33-40. July 1993.	ABSHUM
Hubbard 1987	Hubbard JE and Engelhardt M. Calculation of Groundwater Recharge at the Old SRP Burial Ground Using the CREAMS Model (1961-1986). Memorandum. July 31, 1987	RAIN, VLEACH
Johnson 1962	Johnson JE. Sulfur-35 Releases from Reactor Areas. Dupont Interoffice Memorandum to CM Patterson. Savannah River Plant. RAC reference no. SKR1994020129. July 19, 1962.	SOLUBIL
Kennedy 1992	WE Kennedy and DL Strenge. Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Final Report. NUREG/CR-5512, PNL-7994. October 1992.	LEAFRS, RESFAC
Moore 2002	Moore MS. Critical Pathway Assessment of the Savannah River Site, Aiken, South Carolina. South Carolina Department of Health and Environmental Control. May 2002.	VLEACH
Napier 2003a	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. March 4, 2003.	Radius, Density
Napier 2003b	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. June 9, 2003.	Density
Napier 2003c	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. March 31, 2003.	DEPFR1, DEPFR2
Napier 2003d	Personal communication. Napier BA, PNNL, to WE Joyce, ATL International. February 12, 2003.	ANDKR
NCDC 2003	2002 Local Climatological Data (LCD) Annual Summary with Comparative Data, Augusta, GA. ISSN 0198-1587. National Oceanic and Atmospheric Administration. National Climactic Data Center. 2003.	RAIN
NRC 1977	Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I. Revision 1. U.S. Nuclear Regulatory Commission. October 1977.	WTIM, SLDN, SEDDN, SOILT
ORNL 2003	Food Chain Models for Risk Assessment, Appendix F. Risk Assessment Information System. Oak Ridge National Laboratory. http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml. July 1, 2002.	DEPFR1, DPVRES

Citation	Reference	Variables Supported
Phifer 2003	M.A Phifer and L.B. Collard. Unreviewed Disposal Question Evaluation: Backfill Soil Compaction Requirements. WSRC-TR-2003-00081. WSRC, SRS. February 6, 2003.	VLEACH
PNNL 2002	Napier, BA, Strenge DL, Ramsdell JV, Eslinger PW, and Fosmire C. GENII Version 2 Software Design Document. Pacific Northwest National Laboratory (PNNL). November 2002.	[numerous]
Simpkins 2002	Ali A. Simpkins. Estimating Derived Response Levels at the Savannah River Site for Use with Emergency Response Models. WSRC-MS-2002-00596. Westinghouse Savannah River Company. 2002.	SLDN, SEDDN
Till 1983	Till JE, Meyer HR, Peterson, HT. Radiological Assessment, A Textbook on Environmental Dose Analysis. NUREG/CR-3332, ORNL-5968. September 1983.	WTIM, LEAFRS, DPVRES, RESFAC
Till 2001	Till JE. FINAL REPORT, Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released from the Savannah River Site. Risk Assessment Corporation, Neeses, SC. April 30, 2001.	Radius, Density
Wild 2003	Wild EW, Brigmon RL, Berry CJ, Altman DJ, Rossabi J, Looney BB, and Harris SP. D-Area Drip Irrigation-Phytoremediation Project: SRTC Final Report. WSRC-TR-2002-00080. Westinghouse Savannah River Company, Aiken, SC. January 2003.	VLEACH
WSRC 1991	Savannah River Site Environmental Report for 1990. WSRC-IM-91-28. Westinghouse Savannah River Company, Aiken, SC. 1991.	SHIN, SWFAC
WSRC 1992	Savannah River Site Environmental Report for 1991. Westinghouse Savannah River Company, Aiken, SC. 1992.	SHIN, SWFAC
WSRC 1993	Savannah River Site Environmental Report for 1992. WSRC-TR-93-075 and -077. Westinghouse Savannah River Company, Aiken, SC. 1993.	SHIN, SWFAC

GENII Model Parameters Used in SRS Base Case Calculation

<table>
<tr><th>GENII Module</th><th>Module Section-Subsection</th><th>Variable</th><th>Variable Name (Units)</th><th>Indices</th><th>Value and Basis</th></tr>
<tr><td>Source</td><td>Atmospheric Flux</td><td>Flux Type</td><td>(none)</td><td>By source</td><td>Value = Point source (for offsite exposure locations)

For air releases, all sources will be defined as point sources (as opposed to area sources). The rationale is as follows: The four defined model sources are virtual sources representing several (~2 to ~5) actual sources. Most of the nuclide releases come from elevated sources (typically 61 meters). GENII can only model an elevated source if it is a point source; area sources cannot be elevated. The selection of point or area has an effect on air concentrations very close to the release location, but would not have a substantive effect on concentrations that are far (several miles) from the release location (see PNNL 2002, p43, and ATL 2003a). In this study, the offsite exposure locations are far enough away from the sources that using the simpler point source flux type is not expected to substantively affect the results.</td></tr>
<tr><td>Source</td><td>Atmospheric Flux</td><td>Exit height of source (m)</td><td>Two (m)</td><td>By media type (3=Air)</td><td>Value = [see table below]

This variable is established for each of several (~3 to 5) distinct “virtual sources,” each of which represents several actual sources. Each virtual source will represent the combined releases from several physical sources such as stacks or basin evaporation. The exit height for each virtual source is based on the heights of the individual physical sources that it represents. The process under which these sources is defined is described in White Paper, Combining Sources of Air Releases for the SRS Dose Reconstruction [ATL 2003a]. The source heights are specified there as follows:
<table>
<tr><th>Virtual Source Group</th><th>Height (m)</th><th>Actual Sources Represented</th></tr>
<tr><td>1</td><td>10</td><td>A Area, M Area, SRL</td></tr>
<tr><td>2</td><td>61</td><td>F Canyon, H Canyon, H Area Tritium Stack (includes stacks and basin evaporation)</td></tr>
<tr><td>3</td><td>61</td><td>C, K, and L Reactors (includes stacks and basin evaporation)</td></tr>
<tr><td>4</td><td>61</td><td>P and R Reactors (includes stacks and basin evaporation)</td></tr>
</table></td></tr>
</table>

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Source	Atmospheric Flux	Release Rate	CFLUX (pCi, pCi/kg, pCi/l)	By Media Type and Isotope	Value = [see separate source term analysis (ATL 2003b)] The release rate is the Base Case source term data. For air and water releases, the release rate is entered in the GID file (and the FRAMES interface) in units of pCi for each nuclide over a 1 year period (corresponding to pCi/year) for each release point. Note: This variable is included in the stochastic analysis.
Source	Atmospheric Flux – Flux Types	Particle radius (um)	Radius (um)	By flux type	Value = 0.5 um Particle radius is used to characterize the source release for the air pathway. The particle radius value is used in the model to determine the rate of deposition (PNNL 2002, p. 73-75). The user can specify multiple flux types, including up to three particle types (defined by their radii and density) and a gas fraction for each nuclide. For this analysis, all nuclides except the following were modeled as particles. The following nuclides were modeled as gases, based on their physical properties: H-3 (both as HT or HTO), Ar-41, I-129, I-131 (Napier 2003a). Part of the iodine source terms will also be modeled as a particulate release. Limited data on particle size is available (see Till 2001, p.4.4-12-15), and an analysis of this data did not yield a meaningful single value or range of values to be used for particle diameter. The limited available data focused on stack measurements of particle size. However, as used in the model, particle size after the time of release (i.e., at the time of deposition) is more relevant. The stack measurements do not account for the particle agglomeration and other physiochemical changes that would be expected to occur after the particles are released. A radius value of 0.5 micron (i.e., 1.0 micron diameter) was selected to model particle deposition. At this size, depletion of the air concentration by gravitational deposition should be minimal, resulting in conservative (high) air concentrations at the exposure locations. In the absence of applicable data and with many factors causing variation over time, choice of a standard value is justified. Particle size will be considered in the stochastic analysis.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Source	Atmospheric Flux – Flux Types	Particle density (g/cm^3)	Density (g/cm^3)	By Particle Size	Value = 2.0 g/cm^3 Particle density is used with particle radius in the model to determine the rate of dry deposition (see PNNL 2002, p.73-75). Previous SRS studies identified in the RAC Phase 2 report (Till 2001, p.4.4-13) have assumed particle densities of 1 and 2 g/cm^3. However, there is no available data that characterizes particle density for SRS air releases. Since the emissions at SRS may be particulates, as well as, dehydrated solutions, a density between water (1.0) and soil (~2.5) has some appeal. Particle density will be considered in the stochastic analysis.
Source	Atmospheric Flux – Flux Types	Nonreactive fraction if gas	Density (fraction)	None	Value = 0.5 (Iodine isotopes) This variable is used when a nuclide source term air release is specified as a gas rather than a particle. The non-reactive fraction represents the proportion of the release quantity that is not reduced through degradation, except for iodine, which uses a special model (the reactive fraction is converted to a particle), forms of tritium, and noble gases. For forms of tritium and noble gases, GENII automatically assigns a nonreactive gas fraction of 1.0. For other gaseous nuclides, GENII allows a single nonreactive gas fraction to be specified. For iodine, a value of 0.5 is assumed, based on the assumption that the release will eventually reach equilibrium at 40% particle, 30% reactive gas, and 30% nonreactive gas (see Napier 2003a and Napier 2003b).
Air	Model Information – Meteorological Files	Name of met file	ARMETFILE (met file name)	None	The name of the file containing met data to be read into GENII is determined according to the pre-processor design document.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Air	Model Information – Default Parameters	Transfer resistance for Iodine	ARTRANS RESIST (s/m)	None	Value = 10 s/m Transfer resistance is used in the GENII air deposition model as a mathematical device to establish an upper limit on the deposition velocity of contaminants depositing on the soil and foliage. The deposition velocity is the factor relating the concentration of contaminants in the air and the flux rate of the contamination depositing on the ground. High transfer resistance reduces the deposition velocity and the amount of contamination deposited. As transfer resistance is decreased, deposition velocities and contaminant fluxes increase until transfer resistance becomes small in comparison to aerodynamic and surface resistances (which are calculated from near surface wind data), at which point these other resistances dominate dry deposition velocity. The GENII default for gases (iodine) is 10 s/m (PNNL 2002, p.75). The Base Case analysis adopted the GENII default value (10 s/m). This variable has not been selected for stochastic analysis.
Air	Model Information – Default Parameters	Transfer resistance for particulates	ARTRANS RESIST (s/m)	None	Value = 100 s/m The transfer resistance for particulates is used in the GENII air deposition model in the same manner as the transfer resistance for iodine. The SRS Base Case analysis adopted the GENII default value of 100 s/m (PNNL 2002, p.75) This variable has not been selected for stochastic analysis.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Air	Model Information – Model Parameters	Sigma Paramaterization Usage	ARSIGPARM (none)	None	Value = Pasquill-Gifford (NRC) This variable is used in the GENII air dispersion module chronic plume model. This variable is used to specify the approach to calculate plume diffusion coefficients which are used to describe the spread of effluents in plumes. These coefficients are related to atmospheric turbulence and the time since release. Most of the schemes used to estimate diffusion coefficients are based on atmospheric stability classes and distance from the source (see PNNL 2002, p. 59-67). The following five options available in GENII: ▪ Brigg's Open Country (Default) ▪ Pasquill-Gifford (ISC3) ▪ Pasquill-Gifford (NRC) ▪ Brigg's Urban Condition, and ▪ Turbulence Statistics. Note: For each option, it is possible to select a user-supplied calm wind distribution, which includes the fraction of time the wind blows in each given direction during calm periods. (See GENII FRAMES User Interface, air dispersion module, Model Parameters tab.) The Pasquill-Gifford (NRC) was selected because it is consistent with how SRS meteorological data is collected and stability classes determined.
Air	Model Information – Radial Grid Definition	Ring Distance	ARRADVAL (m)	By Ring Index	Value = [see separate air release analysis (ATL 2003a)] This variable is the radii of the rings used in the sector-based air dispersion analysis. When GENII determines air concentrations at various locations, the locations are moved to the closest calculation point on a grid formed by user-defined ring distances and 16 established compass headings. The ring diameters will be set so as to minimize the distance a exposure location must be moved to get to a grid point. The radii value of each ring is set so that it coincides with the distance between the source and exposure locations. A separate set of ring distances is calculated for each source. Since there are 4 sources and up to 10 distances can be calculated for each source, up to (4 x 10) 40 ring distances are calculated.. The actual distances will be determined in the analysis of source collocation. This variable is not selected for stochastic analysis

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Constit Database	Partitioning	Soil-water Partition Coefficient	CLKD (ml/g)	By Isotope and Daughter	This is the same as the soil adsorption coefficient (SOILKD), which is addressed in the Exposure-Soil-Leaching GENII module.
Constit Database	Toxicity Parameters – Exposure Factors	Water Purification Factor	CLWPF (none)	By isotope and daughters	Value = 1.0 This variable is used in drinking water/showering pathways. In the SRS Base Case, only the family living on the river uses the contaminated water for indoor uses. Members of the family living on the river are assumed to use untreated river water for all purposes except drinking. It is reasonable and conservative to assume that the water is not treated and the value for the Water Purification Factor = 1.0 for all isotopes. Usage of this variable is documented in the PNNL 2002, p. 156.
Exposure	Agriculture – General	Weathering rate constant from plants	WTIM (days)	None	Value = 14 days This variable is the weathering half-life of nuclides that have been deposited on plant surfaces. It used in calculations of contaminant levels on foliage that is consumed by humans or by animals that are subsequently consumed by humans (PNNL 2002, p. 155). NRC 1977, p.69, recommends a value of 14 days (this is also the GENII default value). Till 1983 includes a range of values (4 days to 300 days) and recognizes how the value can be affected by different seasons and different plant species. Most cited values are in the 10 to 30 day range (Till 1983, p. 5-33 to 5-38). The default value (14 days) is therefore reasonable.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Agriculture – General	Dry deposition retention fraction to plants	DEPFR1 (fraction)	None	Value = 0.25 This variable represents the fraction of dry-deposited contamination that is retained on plant surfaces. It is also considered the interception fraction. [see Napier 2003c]. The GENII default value is 0.20. The selected value of 0.25 is considered a reasonable value, based on the following analysis cited by Oak Ridge 2003 (http://risk.lsd.ornl.gov/homepage/bjcor271/appf.shtml): " . . . The interception fraction accounts for the proportion of aerial deposition that is intercepted by plant surfaces. The interception fraction varies with plant type and density of vegetation. NRC (1977) and NCRP (1984) use a default value of 0.25 for pasture grasses and 0.2 for vegetable crops. NCRP (1989) used 0.25 as the default for both vegetables and pasture. However, Miller (1980) reviewed a number of studies and reported a range of 0.02-0.82 for various grasses. The midpoint of this range (0.42) is suggested as the default value for use in the pasture plant models in this report. Interception fractions for vegetable crops ranged from 0.06-1.2 (Miller 1980), but 10 of 13 values were less than 0.49. The value of 0.42 used for pasture grasses is also suggested as the default for vegetable crops. Breshears et al. (1992) examined a number of values and determined that the geometric mean for the interception fraction was 0.39. The reader should note that there is considerable variability in the interception fraction values. Iodines exhibit a greater tendency to be retained on vegetation. The default iodine value of 1.0 from NRC (1977) is recommended in this white paper for both pasture and vegetable crops. The recommended value for interception of particles deposited by spray irrigation is 0.25; this is the default value used by NRC (1977) and is within the range reported by Miller (1980)."
Exposure	Agriculture – General	Wet deposition retention fraction to plant surfaces	DEPFR2 (fraction)	None	Value = 0.25 This variable represents the fraction of wet-deposited contamination that is retained on plant surfaces. It is also considered the interception fraction. [see Napier 2003c] The GENII default value is 0.25. The rationale for selecting 0.25 is the same as described above for DEPFR1.
Exposure	Agriculture – General	Resuspension factor from soil to plant surfaces	LEAFRS (1/m)	None	Value = 10e-5 & 10e-7 (depending on location) The values used for this variable are the same as those used for soil resuspension for use in the soil inhalation pathway (see RESFAC, below). These values are 10e-5/m for the Girard(1), New Ellenton(5), and Williston(9) locations, and 10e-7/m for all other locations.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Agriculture – General	Deposition velocity from soil to plant surfaces	DPVRES (m/s)	None	Value = 0.001 m/s. The selected value of 0.001 m/s is based on a review of Till 1983, p.5-16 through 5-21. Limited data is available, most of it for iodine deposition. Values tend to cover a range between 0.01 and 0.00001 m/s. The GENII Default = 0.001 m/s, and [NCRP 1989] (as cited in ORNL 2003) recommends a value of 1000 m/d (roughly equal to 0.01 m/s). GENII requires a single value be used for all nuclides.
Exposure	Agriculture – General	Radionuclide removal due to harvesting	HARVST (on/off)	None	Value = FALSE (OFF) This variable is an on/off switch used to account for reductions in soil contamination levels resulting when contaminated plants are harvested and removed from the area (PNNL 2002, p.143). To be conservative, the switch will be OFF in the Base Case scenario. OFF means that the soil contamination levels will not be automatically reduced to account for contamination removed from the field when crops are harvested.

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Controls	Absolute humidity, used only for tritium model	ABSHUM (kg/m^3)	None	Value = 0.01125 kg/m^3 The absolute humidity parameter is used only in the tritium model of the GENII exposure module (PNNL 2002, p.161). Only a single value is needed to model the Base Case scenario. The following two candidate values were identified: The value selected for the Base Case scenario is a site-specific value (0.01125 kg/m^3). According to Hamby 1993, weekly averages at SRS over a two-year period ranged from 0.0032 to 0.0244 kg/m^3 (Hamby and Jumper 1990, cited in Hamby 1993, p.34). Annual averages, however, are less variable. A database of average daily temperature and average daily wet-bulb temperature from the Columbia, SC, National Weather Service station were analyzed to generate a distribution of annual average absolute humidity values for SRS. The database includes the 42-year period from 1949 to 1990 and provides the basis for the selected value of the absolute humidity parameter. The mean value of the distribution of the 42 data points is 0.01125 kg/m^3, with a standard deviation of 0.00053 kg/m^3 (Hamby 1993, p.34). An alternative, non-site-specific default value (not used) of 0.008 kg/m^3 is proposed in the documentation for EPA's CAP88-PC computer model for estimating dose and risk for radionuclide emissions to air. The 0.008 kg/m^3 value is proposed for use with the CAP-88 tritium module (Chaki 2000.) The GENII default value = 0.008. This parameter was selected for stochastic analysis because it is used in the tritium dose calculation, and tritium is believed to be a potentially significant contributor to dose.
Exposure	Controls	Average daily rain rate	RAIN (mm/d)	None	Value = 11.4mm/d This is the average daily rain rate, when it is raining. It is used in the calculation of wet deposition (PNNL 2002, p.76). A value of 11.4 mm/d was calculated using data in two references, NCDC 2003 and Hubbard 1987. Hubbard 1987 presents annual rainfall data for F-Area at SRS for the 1961-1986 period and calculates an average value of 48.51 inches. This value is slightly higher than the "normal" annual rainfall reported for Augusta on NCDC 2003, p. 3 (44.66 inches/year). NCDC 2003, p.3, also reports 108.2 days/year with precipitation of at least 0.01 inches (normal long-term average). Using this data, the average daily rain rate is calculated as follows: (48.51 in/yr) * (25.4 mm/in) / (108.2 d/yr) = 11.4 mm/d

<table>
<tr><th>GENII Module</th><th>Module Section-Subsection</th><th>Variable</th><th>Variable Name (Units)</th><th>Indices</th><th>Value and Basis</th></tr>
<tr><td>Exposure</td><td>Soil – Leaching</td><td>Surface soil moisture content</td><td>MOISTC (fraction)</td><td>None</td><td>
Value = 0.22
This variable is used in the GENII leach rate calculations. GENII offers 3 options for getting leach rates:
1. Use GENII Default leach rates (Not Used)
2. Use leach rates calculated from user input. For this option, the user must specify the following variables:
- Surface Soil Thickness
- Surf. Soil Moisture Content (fraction)
- Surf. Soil Bulk Density
- Total Infiltration Rate
- Soil Adsorption Coefficient (Kd), which is specific for each nuclide
3. Use User-provided leach rate constants. (Not Used)
In this study, leach rates are determined using option (2), above. See formulas in PNNL 2002, p.101, 104, and 143. Using the formulas and values in [EPA 2000], p. A-5 and A-6, the following soil moisture values can be calculated using the local 40 cm/year infiltration rate and the following formula:
Soil Moisture (unitless fraction) = n * (I / Ks)e, where:
n = total soil porosity (unitless fraction) [value = 0.4 (see below)]
I = infiltration rate (m/yr) [local value =0.373 m/yr]
Ks = saturated hydraulic conductivity (m/yr)
e = soil-specific exponential parameter (unitless)
Values for Ks and e are provided by EPA 2000 for different soil types (below). For total soil porosity (n), n = (1 – (dry soil bulk density / soil particle density)) Using EPA’s recommended soil particle density value of 2.65 g/cm^3 and the local soil bulk density of 1.59 g/cm3, n = 0.4
<table>
<tr><th>Soil Type</th><th>I (m/yr)</th><th>K_s (m/yr)</th><th>e</th><th>(I/Ks)e</th><th>BulkSoil Porosity</th><th>Soil Moist</th></tr>
<tr><td>Sand</td><td>0.373</td><td>1830</td><td>0.09</td><td>0.47</td><td>0.4</td><td>0.19</td></tr>
<tr><td>Loamy Sand</td><td>0.373</td><td>540</td><td>0.085</td><td>0.54</td><td>0.4</td><td>0.22</td></tr>
<tr><td>Sandy Loam</td><td>0.373</td><td>230</td><td>0.08</td><td>0.60</td><td>0.4</td><td>0.24</td></tr>
<tr><td>Silt Loam</td><td>0.373</td><td>120</td><td>0.074</td><td>0.66</td><td>0.4</td><td>0.26</td></tr>
<tr><td>Loam</td><td>0.373</td><td>60</td><td>0.073</td><td>0.69</td><td>0.4</td><td>0.28</td></tr>
<tr><td>Sandy Clay Loam</td><td>0.373</td><td>40</td><td>0.058</td><td>0.77</td><td>0.4</td><td>0.30</td></tr>
<tr><td>Silt Clay Loam</td><td>0.373</td><td>13</td><td>0.054</td><td>0.83</td><td>0.4</td><td>0.33</td></tr>
<tr><td>Clay Loam</td><td>0.373</td><td>20</td><td>0.05</td><td>0.82</td><td>0.4</td><td>0.33</td></tr>
<tr><td>Sandy Clay</td><td>0.373</td><td>10</td><td>0.042</td><td>0.87</td><td>0.4</td><td>0.35</td></tr>
<tr><td>Silt Clay</td><td>0.373</td><td>8</td><td>0.042</td><td>0.88</td><td>0.4</td><td>0.35</td></tr>
<tr><td>Clay</td><td>0.373</td><td>5</td><td>0.039</td><td>0.90</td><td>0.4</td><td>0.36</td></tr>
</table>
The soil type at SRS was taken to be loamy sand, and a soil moisture value of 0.22 was selected.
</td></tr>
</table>

<table>
<tr><th>GENII Module</th><th>Module Section-Subsection</th><th>Variable</th><th>Variable Name (Units)</th><th>Indices</th><th>Value and Basis</th></tr>
<tr><td>Exposure</td><td>Soil - Leaching</td><td>Surface soil thickness</td><td>THICK (cm)</td><td>None</td><td>GENII Default = 15 cm.

Used in direct exposure and leach rate calculations - See PNNL 2002, p. 186. (same as SURCM). This is a standard value widely used.</td></tr>
<tr><td>Exposure</td><td>Soil – Leaching</td><td>Total infiltration rate</td><td>VLEACH (cm/yr)</td><td>None</td><td>Value = 37.3 cm/yr

This value is based on a study conducted at SRS [Hubbard 1987] which calculated groundwater recharge rates at SRS in the vicinity of the Old SRP Burial Ground from 1961 to 1986. Several other SRS and local studies have cited a local value of about 40 cm/yr. Phifer 2003, p.5, cites an infiltration rate of 40 cm/year based on “past infiltration studies conducted at SRS.” Other references citing a 40 cm/yr infiltration rate are Cook 2002a (p.4) and Cook 2002b, p.6. Wild 2003, p.17, cites an infiltration rate of “1/6th to 1/3 of rainfall” which, when combined with the 1961-86 average precipitation rate at F-Area (48.51 inches/year [Hubbard 1987]) yields an infiltration rate of 20 to 41 cm/year.

These studies use values that do not consider additional infiltration resulting from irrigation. In this analysis, irrigation is assumed to be zero [see Moore 2002, p. 17-18, and Hamby 1991].</td></tr>
<tr><td>Exposure</td><td>Soil – Leaching</td><td>Soil adsorption coefficient</td><td>SOILKD (ml/g)</td><td>By Isotope Index</td><td>This variable is also known the Kd or distribution coefficient. The Kd is used in the soil model to calculate leaching of contaminants from the surface soil to deeper soil (PNNL 2002, p.105 & 143). Higher Kds result in the contaminant remaining in the surface soil longer and resulting in higher availability of the contaminant to transfer to the air (resuspension) or to plants (for ingestion).

An analysis of available Kd data from several sources for the purpose of this model is presented in ATL 2003c. The Kd values resulting from the analysis are as follows:
<table>
<tr><th>Nuc.</th><th>Value</th></tr>
<tr><td>Am</td><td>2000</td></tr>
<tr><td>Ar</td><td>Not Applic</td></tr>
<tr><td>C</td><td>Not Applic</td></tr>
<tr><td>Ce</td><td>490</td></tr>
<tr><td>Co</td><td>60</td></tr>
<tr><td>Cs</td><td>59</td></tr>
<tr><td>H3</td><td>0</td></tr>
<tr><td>I</td><td>1.55</td></tr>
<tr><td>Nb</td><td>160</td></tr>
<tr><td>P</td><td>173</td></tr>
</table>
<table>
<tr><th>Nuc.</th><th>Value</th></tr>
<tr><td>Pu</td><td>4100</td></tr>
<tr><td>Ru</td><td>55</td></tr>
<tr><td>S</td><td>7.5</td></tr>
<tr><td>Sr</td><td>3041</td></tr>
<tr><td>Tc</td><td>2.49</td></tr>
<tr><td>Th</td><td>3000</td></tr>
<tr><td>U</td><td>1000</td></tr>
<tr><td>Y</td><td>510</td></tr>
<tr><td>Zn</td><td>200</td></tr>
<tr><td>Zr</td><td>600</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>GENII Module</th><th>Module Section-Subsection</th><th>Variable</th><th>Variable Name (Units)</th><th>Indices</th><th>Value and Basis</th></tr>
<tr><td>Exposure</td><td>Soil – Resuspension</td><td>Resuspension factor</td><td>RESFAC (1/m)</td><td>None</td><td>
Value = 10e-5/m and 10e-7/m, depending on location
GENII offers 3 different ways to calculate a soil resuspension factor (1/m), which is multiplied by the areal soil concentration (Bq/m2) to calculate an air concentration (Bq/m3) (PNNL 2002, p. 159):
1. Mass loading model. This method requires a Mass Loading Factor [GENII Default = 5.00e-5 g/m3] to calculate a resuspension factor (1/m). [Not Used]
2. Anspaugh model. This is a time-dependent approach that is independent of soil characteristics. It calculates a resuspension factor that is exponential with time. It requires a top soil depth [GENII Default = 1 cm]. [Not Used]
3. User input of resuspension factor, GENII default = 1.0e-9/m
The third option, which allows the user to input a resuspension factor, was selected for this analysis.
Two values are selected for this variable. A higher value (10e-5/m) is assigned to exposure locations around agricultural areas where there is a relatively higher level of soil disturbance. A lower value (10e-7/m) is assigned to exposure locations in areas where there is comparatively less soil disturbance. In each case, the available literature does not identify a single preferred value for this variable. However, recommended values occur over a range [see Kennedy 1992, Table 6-4, and Till 1983, Sect 5.2.2.6 (p.5-30) and Table 5.8.
Exposure Locations, CDC Scenarios, (Location Index Numbers), and Assigned Values for Resuspension Factor
<table>
<tr><th>10e-5/m (More Disturbed Exposure Locations)</th><th>10e-7/m (Less Disturbed Exposure Locations)</th></tr>
<tr><td>Girard – Rural Family #1 (1)
New Ellenton – Migrant Family (5)
Williston – Rural Family #2 (9)</td><td>Waynesboro – Rural Family#1 (2)
Augusta – Urban Family (3)
Jackson – Outdoors Family(4)
Barnwell – Delivery Person (6)
Martin/LTRC – River Family, Delivery Person (7 and 21)
Allendale – Delivery Person (8)
Onsite Location – Urban Family, Delivery Person, Outdoors Family (10)
SR Downstream (22)</td></tr>
</table>
</td></tr>
</table>

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Exposure	Soil – Surface Soil	Surface soil areal density	SLDN (kg/m^2)	None	Value = 240 kg/m2 This variable is used in calculating soil concentrations for use in food chain pathways. It represents the bulk mass of soil into which air-deposited contamination is mixed. The selected value of is consistent with a soil thickness of 15 cm and the site-specific soil density of 1,600 kg/m3. This value is also equal to the default value (240 kg/m3) recommended by the NRC [NRC 1977, p.68]. SRS adopted the same NRC default value in a dose modeling study [Simpkins 2002]. The 240 kg/m2 value is also the GENII default value (PNNL 2002, p.290). The basis for the soil thickness and density values cited above is explained below.
Exposure	Soil – Surface Soil	GENII soil layer thickness used for density	SURCM (cm)	None	Value = 15cm This variable is used in calculating direct exposure from contaminated soil [PNNL 2002, p. 186]. GENII Default = 15 cm.
Exposure	Soil – Surface Soil	Surface soil bulk density	BULKD (g/cm^3)	None	Value 1.60 g/cm3 This variable is used in connection with SURCM in the calculation of the direct exposure pathway (PNNL 2002, p.186). The selected value of 1.60 g/cm3 is based on the bulk density of soil of the vadose zone at H and F areas used in DOE 2002, p.C-22 (the value was rounded from 1.59 g/cm3).
Exposure	Water - General	Delay time in water distribution system	HOLDDW (days)	None	Value = 0 days This variable will only be used in the drinking water and shower inhalation pathways. It is reasonable to assume that any river water used by the family would have minimal holdup time between when it is removed from the river and used in the household. Therefore, a value of zero (0) is assumed for the Base Case Scenario.
Exposure	Water – General	Shoreline sediment density	SEDDN (kg/m^2)	None	Value = 240 kg/m2 This variable is used in determining the direct exposure rate resulting from contaminant deposition along the shoreline. Neither default nor site-specific data for sediment density was found. The selected value is based on the value selected for the surface soil areal density (SLDN).

<table>
<tr><th>GENII Module</th><th>Module Section-Subsection</th><th>Variable</th><th>Variable Name (Units)</th><th>Indices</th><th>Value and Basis</th></tr>
<tr><td>Exposure</td><td>Water - General</td><td>Indoor volatilization factor for radionuclides</td><td>ANDKR (l/m^3)</td><td>None</td><td>Value = 0 l/m3

This variable is used in determining the amount of nuclides in water that volatilize into indoor breathing air. The variable is not contaminant specific. Because the nuclides in the water pathway are generally nonvolatile, this variable should always be set to 0 [Napier 2003d].</td></tr>
<tr><td>Health Impacts</td><td>Constituent Parameters</td><td>Lung Transfer Inhalation Class for each isotope</td><td>SOLUBIL (none)</td><td>By Isotope Index</td><td>This variable is the ICRP lung transfer class (Fast, Medium, or Slow, Vapor, or Gas, based on the nuclide and its chemical form). The selected values are based on the presumed physical forms of each nuclide and the EPA recommended lung class for that form and nuclide. See PNNL 2002, p. 239, & FRG-13 Radionuclide Table (EPA 2003):
<table>
<tr><th>Nuc.</th><th>Value</th></tr>
<tr><td>Am241</td><td>M</td></tr>
<tr><td>Ar41</td><td>G</td></tr>
<tr><td>C14-CO2</td><td>G</td></tr>
<tr><td>Ce *</td><td>M</td></tr>
<tr><td>Co60 *</td><td>M</td></tr>
<tr><td>Cs</td><td>F</td></tr>
<tr><td>H3el</td><td>G</td></tr>
</table>
<table>
<tr><th>Nuc.</th><th>Value</th></tr>
<tr><td>HTO</td><td>V</td></tr>
<tr><td>I</td><td>G</td></tr>
<tr><td>Nb *</td><td>M</td></tr>
<tr><td>P32 *</td><td>M</td></tr>
<tr><td>Pu</td><td>M</td></tr>
<tr><td>Ru-part *</td><td>M</td></tr>
<tr><td>S *</td><td>V</td></tr>
</table>
<table>
<tr><th>Nuc.</th><th>Value</th></tr>
<tr><td>Sr</td><td>M</td></tr>
<tr><td>Tc99 *</td><td>M</td></tr>
<tr><td>Th</td><td>S</td></tr>
<tr><td>U</td><td>M</td></tr>
<tr><td>Xe</td><td>G</td></tr>
<tr><td>Y90</td><td>S</td></tr>
<tr><td>Zn65 *</td><td>M</td></tr>
<tr><td>Zr95 *</td><td>M</td></tr>
</table>
The *-designated nuclides are released in the liquid pathway only, which for this analysis does not include an inhalation pathway. GENII requires lung factor values for these nuclides to be entered, but the values are not used in the dose calculations.

For 4 elements (C, I, Ru, and S), different EPA-recommended lung transfer classes may be appropriate depending on the physical form of the element. The selected classes are rationalized below:

C-14. A value of G was selected. This is EPA’s recommended value for CO2, which is considered the most expected form of SRS-released carbon that receptors would inhale because it is the most chemically stable, oxidized form of carbon.

Iodine (I). A value of G was selected. This is EPA’s recommended value for organic iodine. Iodine is believed to have been released in several forms, including organic gas (nonreactive gas), elemental iodine (reactive gas), and particulate. The value for an organic gas was selected because it provides dose values that are intermediate between particulate and elemental iodine.</td></tr>
</table>

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
					Ru. A value of M was selected. This is EPA's recommended value for particulates and also is an intermediate value. S. A value of V is selected. This is EPA's recommended value for sulfur dioxide. Limited data on the chemical form suggested an oxide was more likely than the other choice of chemical form, carbon disulfide (Johnson 1962), at least from reactor areas. Additionally, it was believed that the oxide form would be more stable in a liquid release.
Health	Method Parameters	Density of contaminated soil/sediment layer	SSLDN (kg/m^3)	None	Value = 1,600 kg/m3 This variable is used in direct exposure calculation - See PNNL 2002, p. 189. The value was selected to be consistent with the BULKD variable (density of surface soil) and comes from the DOE 2002, Appx C, p. C-22, which cites a bulk density of soil of vadose zone at H and F areas of 1.59 g/cm3 (value rounded from 1,590 kg/m3).
Health Impacts	Method Parameters	Thickness of contaminated soil/sediment layer	SOILT (m)	None	Value = 0.15m This variable is used in direct exposure calculation - See PNNL 2002, p. 189. The selected value is based on the value recommended in NRC 1977, p.68 (15 cm).
Receptor	External Ground Exposure	Indoor shielding factor	SHIN (none)	None	Value = 0.7 A value of 0.7 is assumed. Values of 0.5, 0.7 and 0.8 were found in the literature. EPA recommends a value of 0.8 for Reasonable Max Exposure in an example screening scenario (EPA 2001, Example Scenario 11, Table 4.3). Values 0.7 and 0.5 are used by SRS in population dose modeling (WSRC 1991, p.A-48, WSRC 1992, p.115, and WSRC 1993, p.133).
Receptor	External Ground Exposure	Outdoor shielding factor	SHOUT (none)	None	Value = 1.0 A value of 1.0 is assumed. The GENII default value = 1.0 (PNNL 2002, p.300). No shielding would be expected in outdoor situations. A value of 1.0 is specified by EPA for Reasonable Max Exposure (EPA 2001).

GENII Module	Module Section-Subsection	Variable	Variable Name (Units)	Indices	Value and Basis
Receptor	External Exposure to Shoreline	Shoreline width factor	SWFAC (none)	None	Value = 0.2 The shore width factor is a factor for reduction of the external dose rate factor for exposure to the shoreline. The external dose rate factors are based on exposure to an infinite flat plane of contamination. Because most shorelines do not represent an infinite plane, a reduction is allowed to address this difference in geometry. A value of 0.2 was selected based on its use in SRS analyses and use as a GENII default value (PNNL 2002, p.300, WSRC 1991, p.A-56, WSRC 1992, p.123, WSRC 1992, p. 138). A value of 0.2 accounts for the shoreline being a narrow strip rather than an infinite plane.
River	Surface Water	Concentration	CVAL	pCi/ml	This variable represents the concentration of each contaminant at a specified exposure location. The values for this variable differ based on the year of release, the nuclide of interest, and the specified exposure location. Values for this variable are determined through a separate ATL analysis of releases, water flowrates, and holdup/loss between the release and exposure locations.

Attachment H - Base Case Values for Receptor Activity and Usage Factors for the CDC SRS Dose Reconstruction Project

1 Introduction

This document describes in detail the characteristics of the hypothetical receptor families modeled in the SRS Dose Reconstruction. The specific characteristics of the receptor families are used in the model to calculate the nature of radioactive exposure to each individual in the families for each of the potential exposure pathways being modeled. Some pathways occur for airborne releases of contaminants, and others occur for waterborne releases. The pathways being modeled are listed below in Table 1.

Table 1. Pathways Modeled in SRS Dose Reconstruction.

Pathway Category	Pathway	Air Release	Water Release
External Exposure	Finite Plume and External Air	X	
	Shoreline External		X
	Swimming Water External		X
	Boating Water External		X
	External Soil	X	
Inhalation	Air	X	
	Resuspended Soil	X	
	Indoor or Showering		X
Ingestion	Beef	X	Xa
	Poultry	X	Xa
	Milk	X	Xa
	Eggs	X	Xa
	Leafy Vegetables	X	Xa
	Root Vegetables	X	Xa
	Fruit	X	Xa
	Grains	X	Xa
	Fish		Xa
	Shellfish[b]		X[a]
	Inadvertent Soil	X	
	Drinking Water		X
	Shower Water		X
	Swimming Water		X

[a] These pathways modeled for water releases represent exposures that would result from irrigation using contaminated river water.
[b] The shellfish ingestion pathway includes mollusk and crustacea.

1.1 CDC Receptor Family Scenarios

Seven hypothetical receptor families are modeled. The composition and characteristics of each family are based on direction from the CDC, primarily on the September 6, 2002, briefing by Jim Lockridge, Chairperson of the CDC-sponsored Scenario Work Group of the SRS Health Effects Site Specific Advisory Board. Information from this briefing was evaluated and augmented with more detailed assumptions needed to define the receptors to be modeled. The seven receptor families and the composition of each family are specified below in Table 2.

Table 2. Composition of Scenario Families.

Composition	Rural Family #1	Rural Family #2	Urban Family	Delivery Person Family	Outdoors Person Family	Family Living Near the River	Migrant Family
Adult Male	X	X	X	X	X	X	X
Adult Female	X	X	X	X	X	X	X
Child #1 Birth Year (Male)	1955	1955	1955	1955	1955	1955	1955
Child #2 Birth Year (Female)	1955	1955	1955	1955	1955	1964	1955
Child #3 Birth Year (Male)	1964	1964	1964	1964	1964	1964	1964

The information on the age and gender of each individual in the receptor families is used in this analysis to help calculate radioactive dose. Certain activities, such as food consumption, are quantified based on levels of activity (e.g., ingestion of certain foods). Radioactive exposures are calculated in GENII and other computer models in direct proportion to such activity levels. Studies (e.g., EPA's Exposure Factors Handbooks) quantify levels of activity according to the age and gender of the individual using usage factors or activity factors that specify the amount of activity performed on an annual or daily basis. For example, ingestion usage factors specify the kilograms of various foodstuffs consumed each day or year, and inhalation usage factors specify the cubic meters of air breathed each day or year.

Information about each individual's age and gender is also used to convert exposure levels to lifetime dose and risk (i.e., carcinogenic effect). Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13 (EPA 1999), specifies dose factors and risk factors according to certain age and gender categories. The age and gender categories used by GENII, which are consistent with EPA Federal Radiation Guidance age/gender categories, are listed below in Table 3. Figure 1 presents the age and gender of each receptor individual for each year of exposure. The period being modeled starts at the beginning of 1954 and ends at the end of 1992.

Table 3. GENII Defined Age and Gender Groups

GENII-Defined Age Groups (PNL 2002, p. 182)		Duration (Years)
<1	(Infant)	1
1 – 2	(Pre-school)	2
<2 – 7	(Pre-school)	5
<7 – 12	(Child)	5
<12 – 17	(Teen)	5
>17 male	(Adult Male)	Varies[a]
>17 female	(Adult Female)	Varies[a]

[a] The exposure duration of the adult age groups depends on which year the an individual reaches age 18. The exposure duration lasts from year of the 18th birthday until the end of the modeling period (i.e., the end of 1992).

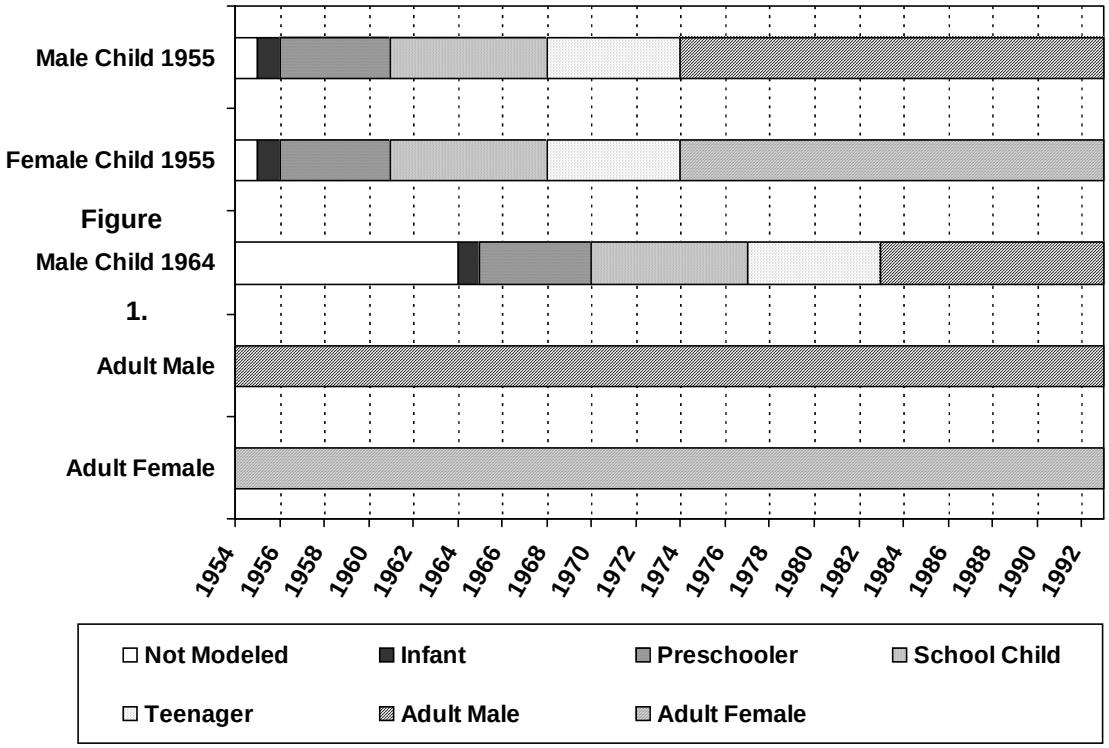

Figure 1. Age/Gender Categories of Modeled Individuals (by Year).

The geographic locations where each family resided and performed various activities (e.g., school, work, recreation) are used to specify the scenarios in the model. Locations are specified for exposure to air-released and water-released contamination. For activities involving exposure to air-released contamination, these locations are identified in the February 26, 2003, memorandum from Vern McDougall (ATL International) to C.M. Wood (CDC) (McDougall 2003). These locations, as well as the activity locations for exposure to water-released contamination, are summarized in Tables 4 and 5 below.

Table 4. Summary of Proposed Receptor Locations for SRS Air Releases.

CDC Scenario	Activity	Proposed Location									
		Girard, GA	Waynesboro, GA	Martin, SC	Augusta, GA	Williston, SC	SRS Onsite	Barnwell, SC	Allendale, SC	Jackson, SC	New Ellenton, SC
Rural Family #1	All except those noted below	X									
	High school		X								
	Briar Creek fishing	X									
Rural Family #2	All activities					X					
Urban/Suburban Family	All except those noted below				X						
	Employment						X				
	Dairy				X						X
Delivery Person	All except those noted below							X			
	Employment								X		
	Employment						X				
	Church, grocery (partial), swimming, boating, camping, hunting, fishing			X							
Outdoors Person	All except those noted below									X	
	Employment, hunting, trapping						X				
Family Living Near the River	All activities			X							
Migrant Worker Family	All activities										X

Table 5. Summary of Proposed Receptor Locations for SRS Water Releases

CDC Scenario	Activities / Pathways	Downstream Savannah River	Lower Three Runs Creek	No Exposure to Affected Water[a]
Rural Family #1	Fishing, boating, shoreline			X
	Swimming	X		
Rural Family #2	All activities[b]			X
Urban/Suburban Family	All activities[b]			X
Delivery Person	Fishing, swimming, shoreline		X	
	Boating			X
Outdoors Person	Fishing, shoreline	X		
	Swimming, boating			X
Family Living Near the River	All activities, plus drinking, shower water inhalation, and irrigation-based pathways	X		
Migrant Worker Family	All activities[b]			X

[a] For some scenarios, the activity is assumed to occur in un-affected water. In other scenarios, the activity is assumed to not occur.
[b] "All activities" includes fishing, boating, swimming, and shoreline

The following narrative describes the activities and potential exposures for each of the CDC scenario families and individuals as they are modeled across the CDC-specified 39-year period of analysis, from 1954 to 1992. Except where noted, the activity rates are the same from year to year. Some year-to-year changes result from activity changes over time which occur as an individual grows older. For example, for many ingestion pathways, food consumption increases as a child ages. In a limited number of other cases, activity patterns change due to lifestyle changes.

The activity and usage rates are expressed in units that are compatible with GENII input requirements. For many pathways, the rates were expressed in units that required conversions or other adjustments to allow their use in GENII. Table 6 summarizes the units for the various exposure pathways.

Table 6. GENII-Compatible Units of Activity and Usage Rates.

Pathways	Units
Direct Exposure	Hours/year
Inhalation	Cubic meters/year[a]
Ingestion	Kilograms/year and Liters/year

[a] The inhalation rate for each individual in a specified location is a function of an hourly or daily inhalation rate and is directly proportional to the amount of time spent in the specified location.

2 Determining Activity and Usage Rates

This section presents the data analysis, assumptions, calculations, and rationale for determining the activity and usage rates for each exposure pathway modeled in the "Base Case" of the SRS dose reconstruction. The usage rates are organized by pathway category (i.e., external exposure, ingestion, and inhalation) and pathway

2.1 External Exposure Pathways

2.1.1 Finite Plume (Air) and External Air

This pathway accounts for exposure to contaminated air. It affects all individuals of all families. The general assumption is that individuals remain within various affected areas at all times (i.e., 365 days/year x 24 hours/day – 8,760 hours/year).

Scenario Family	Finite Plume and External Air Exposure
Rural Family #1	Girard. The adult male and female are exposed full-time (8,760 hours/year) at the Girard location for all years. With the exception of high school, the three children are also exposed full-time at the Girard location for all years beginning with their birth year. Waynesboro. High school exposures occur at Waynesboro over four years for 180 days/year x 6 hours/day = 1,080 hours/year. The high school exposure occurs for each child aged 14 to 17 (1969-72 for a child born in 1955, and 1978-1981 for a child born in 1964).
Rural Family #2	Williston. All individuals are exposed full time (8,760 hours/year) at Williston for all years.
Urban/Suburban Family	Onsite SRS. The adult male is exposed at this location during full-time employment (250 days/year x 8 hours/day = 2,000 hours/year) for all years.
Delivery Person	Martin. All individuals attend church in Martin for 50 days/year x 2 hours/day = 100 hours/year. Children begin church attendance immediately beginning in their birth year. Augusta. All individuals except the adult male are exposed full time (8,760 hours/year) at Augusta for all years. The adult male is exposed at Augusta except when at the place of employment (Onsite SRS). Onsite SRS. The adult male is exposed at this location during onsite beverage deliveries for 8 hours/week x 50 weeks/year = 400 hours/year. Allendale. The adult male is exposed at this location during the balance of his full-time employment, equal to 1,600 hours/year (250 days/year x 8 hours/day - 400 hours/year = 1,600 hours/year). Barnwell. All individuals spend the remainder of their time, excluding church and employment, in Barnwell.

Scenario Family	Finite Plume and External Air Exposure
Outdoors Person	Onsite SRS. The adult male is exposed at this location during full-time employment (250 days/year x 8 hours/day = 2,000 hours/year) for all years. Jackson. All individuals spend the remainder of their time, excluding employment, in Jackson.
Family Living Near the River	Martin. All individuals are exposed full time (8,760 hours/year) at (or near) Martin for all years.
Migrant Worker Family	New Ellenton. This family is assumed to be present in potentially affected areas 50 percent of the time for all years. All individuals are exposed 8,760 hours/year x 0.5 = 4,380 hours/year at New Ellenton. For the remainder of the time, the individuals are present in areas outside the region potentially affected by air released contamination from SRS.

2.1.2 Shoreline External Pathway

This pathway accounts for direct radiation exposure that results from standing on the shoreline of a body of contaminated water. Shoreline exposure rates are assumed to be zero for the receptors listed in Table 7 because any shoreline activity is assumed to occur along waters that are hydrologically upgradient or crossgradient from the site.

Table 7. Receptors Without Shoreline External Exposure.

Receptor Family	Shoreline Usage Location
Rural Family #1	Brier Creek
Rural Family #2	Savannah River upstream of site and farm ponds around Williston, SC
Urban/Suburban Family	Savannah River upstream of the site
Outdoors Person	Savannah River upstream of the site (excluding adult male)
Migrant Family	Savannah River upstream of site and farm ponds around New Ellenton

For the remaining receptors, the Delivery Person Family uses the shoreline on Lower Three Runs Creek near Martin, and the Family Living Near the River and the Outdoors Person (adult male only) use the shoreline on the Savannah River downstream of SRS. As discussed below, a different approach is used to develop exposure rates for each of these receptors.

Delivery Person Family. For this receptor, shoreline exposure rates are estimated using the following factors based on South Carolina recreational patterns cited in Hamby 1991 (p.24):

- Average number of shoreline usage events/year – 19.15
- Average hours/shoreline usage event – 4.44

This results in an exposure rate of 85 hours/year, which was applied to all individuals in the Delivery Person Family.

Family Living Near the River. For this receptor, it was assumed that the shoreline use level corresponded to a family that used the river for fishing to supply a significant portion of the family diet.

This level would be well above the values cited in statistical studies. An average daily exposure level over the course of a year of 1 hour/day (365 hours/year) was assumed for each individual.

Outdoors Person. The adult male is the only individual in this receptor family that was engaged in shoreline use along a body of contaminated water. For this receptor, it was assumed the adult male was present in shoreline areas along the Savannah River onsite at SRS as part of his job. This time includes time spent fishing and hunting. An average weekly exposure level over the course of a year of 4 hours/week (200 hours/year) was assumed for the adult male.

EPA 1997 data for time spent outdoors at a pool/river/lake was also considered for this pathway. EPA 1997 data provided exposure rates specific to individual age categories, but it was not possible to separate the total time between swimming, boating, and shoreline usage categories.

The shoreline external exposure rates for the CDC scenarios are summarized below.

Scenario Family	Shoreline External Pathway
Rural Family #1	No shoreline external exposure. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.
Rural Family #2	No shoreline external exposure. Exposure locations (Savannah River upstream of SRS and farm ponds around Williston) are not hydrologically downgradient from release points.
Urban/Suburban Family	No shoreline external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.
Delivery Person	Lower Three Runs Creek at Martin. All individuals exposed for 21.2 hours/year for all years.
Outdoors Person	No shoreline external exposure except for adult male. For other individuals, exposure location (Savannah River upstream of SRS) is not hydrologically downgradient from release points. Savannah River Downstream of SRS. For adult male is exposed for 200 hours/year for all years.
Family Living Near the River	Savannah River Downstream of SRS. All individuals are exposed for 365 hours/year for all years.
Migrant Worker Family	No shoreline external exposure. Exposure locations (Savannah River upstream of SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points.

2.1.3 Swimming Water External Pathway

This pathway accounts for direct external radiation exposure that results from swimming in contaminated water. Swimming water exposure rates are assumed to be zero for the receptors listed in Table 8 because any swimming is assumed to occur in water that is hydrologically upgradient or crossgradient from the site.

Table 8. Receptors Without Swimming Water External Exposure.

Receptor Family	Swimming Location
Rural Family #1	Brier Creek
Rural Family #2	Savannah River upstream of site and farm ponds around Williston, SC
Urban/Suburban Family	Savannah River upstream of the site
Outdoors Person	Savannah River upstream of the site
Migrant Family	Savannah River upstream of site and farm ponds around New Ellenton

For the remaining two receptors, the Delivery Person Family swims on Lower Three Runs Creek near Martin, and the Family Living Near the River swims on the Savannah River downstream of SRS. For these receptors, swimming water exposure rates are estimated using the following factors based on South Carolina recreational patterns cited in Hamby 1991 (p.24):

- Average number of lake swimming events/year – 8.12
- Average hours/lake swimming event – 2.61

This results in an exposure rate of 21.2 hours/year, which is applied to all individuals in the Delivery Person Family and the Family Living Near the River.

As discussed above, EPA 1997 data for time spent outdoors at a pool/river/lake was also considered for this pathway. EPA 1997 data provided exposure rates specific to individual age categories, but this data was not used because it was not possible to separate the total time between swimming, boating, and shoreline activities.

The swimming water exposure rates for the CDC scenarios are specified below.

Scenario Family	Swimming Water External Pathway
Rural Family #1	No swimming water external exposure. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.
Rural Family #2	No swimming water external exposure. Exposure locations (Savannah River upstream of SRS and farm ponds around Williston) are not hydrologically downgradient from release points.
Urban/Suburban Family	No swimming water external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.
Delivery Person	Lower Three Runs Creek at Martin. All individuals exposed for 21.2 hours/year for all years.
Outdoors Person	No swimming water external exposure. Exposure location (Savannah River upstream of SRS) is not hydrologically downgradient from release points.
Family Living Near the River	Savannah River Downstream of SRS. All individuals exposed for 21.2 hours/year for all years.
Migrant Worker Family	No swimming water external exposure. Exposure locations (Savannah River upstream of SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points.

2.1.4 Boating Water External Pathway

This pathway accounts for direct radiation exposure that results from boating in a body of contaminated water. Boating exposure rates are assumed to be zero for the receptors listed in Table 9 because either no boating is performed by the receptor or any boating is assumed to occur in water that is hydrologically upgradient or crossgradient from the site.

Table 9. Receptors Without Boating External Exposure.

Receptor Family	Swimming Location
Rural Family #1	No boating
Rural Family #2	No boating
Urban/Suburban Family	Savannah River upstream of the site
Outdoors Person	Savannah River upstream of the site
Migrant Family	No boating

For the remaining two receptors, the Delivery Person Family and the Family Living Near the River, boating occurs on Savannah River downstream of SRS. The approach used to develop exposure rates for each of these receptors is discussed below.

Delivery Person Family. For this receptor, shoreline exposure rates are estimated using the factors for boating based on South Carolina recreational patterns cited in Hamby 1991 (p.24) and shown below in Table 10.

Table 10. South Carolina Boating Usage Rates (adapted from Hamby 1991).

Boating Usage	Canoe Trails	Boating / Sailing
Events / Year (average)	6.13	18.77
Hours / Event (average)	2.25	4.38
Hours / Year	13.8	82.2
Total	96 hours/year	

The total rate (96 hours/year) was used for all individuals in the Delivery Person Family.

Family Living Near the River. For this receptor, it was assumed that the boating level corresponded to a family that used the river for periods well above the values cited in statistical studies. An average exposure level over the course of a year of twice the rates cited in Hamby 1991 (192 hours/year) was assumed for each individual.

As discussed above, EPA1997 data for time spent outdoors at a pool/river/lake was also considered for this pathway. EPA 1997 data provided exposure rates specific to individual age categories, but this data was not used because it was not possible to separate the total time between swimming, boating, and shoreline activities.

The swimming water exposure rates for the CDC scenarios are specified below.

Scenario Family	**Boating External Pathway**
Rural Family #1	No boating external exposure. No boating performed by receptor.
Rural Family #2	No boating external exposure. No boating performed by receptor.
Urban/Suburban Family	No boating external exposure. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.
Delivery Person	Savannah River Downstream of SRS. All individuals exposed for 96 hours/year for all years.
Outdoors Person	No boating external exposure. Exposure location (Savannah River upstream of SRS) is not hydrologically downgradient from release points.
Family Living Near the River	Savannah River Downstream of SRS. All individuals exposed for 192 hours/year for all years.
Migrant Worker Family	No boating external exposure. No boating performed by receptor.

2.1.5 External Soil Pathway

This pathway accounts for direct radiation exposure that results from standing on the ground at a specified location contaminated by deposition of airborne contamination. The amount of time spent at each location coincides with the amount of time individuals are exposed to airborne contamination at the specified location. This pathway accounts for exposure that occurs either indoors or outdoors. For this pathway, GENII allows users to specify the fraction of time in spent outdoors and the fraction spent indoors and uses shielding factors to differentiate between indoor and outdoor exposure. The value of the outdoor shielding factor is set as 1.0, and the value of the indoor shielding factor is based on EPA's October 2000 Soil Screening Guidance for Radionuclides Technical Background Document (EPA 2000) , p. 2-18, which specifies a default indoor shielding factor (gamma shielding factor) value of 0.4.

The amounts of time spent outdoors are based on data from EPA 1997, shown below in Table 11. Some of the CDC receptor scenarios represent urban lifestyles that can be modeled using EPA Recommended Values. However, because some of the receptor scenarios correspond to a rural lifestyle thought to have higher levels of outdoor activity, 95th percentile values are also used.

Table 11. Time Spent Outdoors – EPA 1997 Age/Gender Categories and Rate Data, and Corresponding GENII-Modeled Age/Gender Categories and Calculated Rates.

EPA 1997 Data, 95th Percentile Values (Table 15-132), Adapted				
Age/Gender Categories	**Time Spent Outdoors (minutes/day)**	**Corresponding Modeled Age/Gender Categories**	**Calculated Time Spent Outdoors (hours/year)**	**Balance of Time Spent Indoors (hours/year) [Percent Indoors]**
1 – 4	535	Infant (<1)	3,255	5,505 [63%]
1 – 4	535	Pre-School (1 – 7)	3,255	5,505 [63%]
5 – 11	479	Child (<7 – 12)	2,914	5,846 [67%]
12 – 17	452	Teenager (<12 – 17)	2,750	6,010 [69%]
18 – 64	470	Adult Male (>17)	2,860	5,900 [67%]
18 - 64	470	Adult Female (>17)	2,860	5,900 [67%]
EPA 1997 Data Recommended Values (Table 15-176), Adapted				
Age/Gender Categories	**Recommended Value (hours/day)a**	**Corresponding Modeled Age/Gender Categories**	**Calculated Time Spent Outdoors (hours/year)**	**Balance of Time Spent Indoors (hours/year) [Percent Indoors]**
3 – 11	5 , 7 [a]	Infant (<1)	2,034 [b]	6,726 [77%]
3 – 11	5 , 7 [a]	Pre-School (1 – 7)	2,034 [b]	6,726 [77%]
3 – 11	5 , 7 [a]	Child (<7 – 12)	2,034 [b]	6,726 [77%]
12 and older	3 [c]	Teenager (<12 – 17)	1,095 [c]	7,665 [88%]
12 and older	3 [c]	Adult Male (>17)	1,095 [c]	7,665 [88%]
12 and older	3 [c]	Adult Female (>17)	1,095 [c]	7,665 [88%]

[a] The lower value is for weekdays, and the higher value is for weekends.
[b] The weekday and weekend values have been averaged to calculate a single average annual value.
[c] The outdoor value includes all time not spent indoors (e.g., includes time spent in vehicle).

The approach for applying the calculated rates for external soil exposure to the CDC scenarios is described below. The values used are presented in Table 12.

Scenario Family	External Soil Exposure
Rural Family #1	Girard. The adult male and female are exposed at the 95th percentile outdoor and indoor rates at the Girard location for all years. With the exception of high school, the three children are also exposed at the 95th percentile outdoor and indoor rates at the Girard location for all years beginning with their birth year. During high school, the 95th percentile outdoor rate is reduced by 180 hours/year (from 2,750 to 2,570 hours/year), and the indoor rate is reduced by 900 hours/year (from 6,010 to 5,110 hours/year). Waynesboro. High school exposures occur at Waynesboro over four years for 180 days/year x 6 hours/day = 1,080 hours/year. The high school exposure occurs for each child aged 14 to 17 (1969-72 for a child born in 1955, and 1978-1981 for a child born in 1964). The 1,080 hours/year includes 1 hour/day outdoors (180 hours/year) and 5 hours/day indoors (900 hours/year)

Scenario Family	External Soil Exposure
Rural Family #2	Williston. All individuals are exposed at the 95th percentile outdoor and indoor rates at the Williston location for all years.
Urban/Suburban Family	Onsite SRS. The adult male is exposed at this location during full-time employment (250 days/year x 8 hours/day = 2,000 hours/year) for all years. Exposure for the adult male at this location is 1 hour/day outdoors (250 hours/year) and 7 hours/day indoors (1,750 hours/year).
Delivery Person	Martin. All individuals attend church in Martin for 50 days/year x 2 hours/day = 100 hours/year. Children begin church attendance immediately beginning in their birth year. All exposures at this location are indoors. Onsite SRS. The adult male is exposed at this location during onsite beverage deliveries for 8 hours/week x 50 weeks/year = 400 hours/year. This includes 200 hours/year outdoors and 200 hours/year indoors. Allendale. The adult male is exposed at this location during the balance of his full-time employment, equal to 1,600 hours/year (250 days/year x 8 hours/day - 400 hours/year = 1,600 hours/year). This includes 1,200 hours/year outdoors and 400 hours/year indoors. Barnwell. All individuals spend the remainder of their time, excluding church and employment, in Barnwell. Exposure rates for all individuals except the adult male are at the Recommended Values. For the adult male, the rates correspond to the 95th Percentile values minus the 1,400 outdoor and 700 indoor hours/year spent at other locations, leaving 1,460 hours/year outdoors and 5,200 hours/year indoors at the Barnwell location.
Outdoors Person	Onsite SRS. The adult male is exposed at this location during full-time employment (250 days/year x 8 hours/day = 2,000 hours/year) for all years. All exposure for the adult male at this location is outdoors. Jackson. All individuals spend the remainder of their time, excluding employment, in Jackson. Exposure rates for all individuals except the adult male are at the 95th percentile values. For the adult male, the rates correspond to the 95th percentile values minus 2,000 hours of outdoor exposure spent at the Onsite SRS location, leaving 860 hours/year outdoors and 5,900 hours/year indoors.
Family Living Near the River	Martin. All individuals are exposed at the 95th percentile outdoor and indoor rates at the Martin location for all years.
Migrant Worker Family	New Ellenton. All individuals are exposed at ½ of the 95th percentile outdoor and indoor rates at the New Ellenton location for all years. This family is assumed to be present in potentially affected areas 50 percent of the time for all years. For the remainder of the time, the individuals are present in areas outside the region potentially affected by air released contamination from SRS.

Table 12. Indoor and Outdoor Soil Exposure Rates of Receptors by GENII Age/Gender Category and Location.

Receptor Scenario	Individual	Exposure Location	Total Hours/Year	Indoor Hours/Year	Outdoor Hours/Year	Percentage Indoor	Percentage Outdoor
Rural Family #1	Infant	Girard	8,760	5,505	3,255	63%	37%
	Preschooler	Girard	8,760	5,505	3,255	63%	37%
	School Child	Girard	8,760	5,846	2,914	67%	33%
	Teenager	Girard	7,680	5,110	2,570	67%	33%
	Teenager	Waynesboro	1,080	900	180	83%	17%
	Adult Male	Girard	8,760	5,900	2,860	67%	33%
	Adult Female	Girard	8,760	5,900	2,860	67%	33%
Rural Family #2	Infant	Girard	8,760	5,505	3,255	63%	37%
	Preschooler	Girard	8,760	5,505	3,255	63%	37%
	School Child	Girard	8,760	5,846	2,914	67%	33%
	Teenager	Girard	8,760	6,010	2,750	69%	31%
	Adult Male	Girard	8,760	5,900	2,860	67%	33%
	Adult Female	Girard	8,760	5,900	2,860	67%	33%
Urban/Suburban Family	Adult Male	Onsite SRS	2,000	1,750	250	88%	13%
	Adult Male	Augusta	6760	5,915	845	88%	13%
	Adult Female	Augusta	8,760	7,665	1,095	88%	13%
	Infant	Augusta	8,760	6,726	2,034	77%	23%
	Preschooler	Augusta	8,760	6,726	2,034	77%	23%
	School Child	Augusta	8,760	6,726	2,034	77%	23%
	Teenager	Augusta	8,760	7,665	1,095	88%	13%
Delivery Person	Infant	Martin	100	100	0	100%	0%
	Infant	Barnwell	8660	6,626	2,034	77%	23%
	Preschooler	Martin	100	100	0	100%	0%
	Preschooler	Barnwell	8660	6,626	2,034	77%	23%
	School Child	Martin	100	100	0	100%	0%
	School Child	Barnwell	8660	6,626	2,034	77%	23%
	Teenager	Martin	100	100	0	100%	0%
	Teenager	Barnwell	8660	7,565	1,095	87%	13%
	Adult Male	Martin	100	100	0	100%	0%
	Adult Male	Onsite SRS	400	200	200	50%	50%
	Adult Male	Allendale	1600	400	1,200	25%	75%
	Adult Male	Barnwell	6660	5,200	1,460	78%	22%
	Adult Female	Martin	100	100	0	100%	0%
	Adult Female	Barnwell	8660	7,565	1,095	87%	13%

Receptor Scenario	Individual	Exposure Location	Total Hours/Year	Indoor Hours/Year	Outdoor Hours/Year	Percentage Indoor	Percentage Outdoor
Outdoors Person	Infant	Jackson	8,760	6,726	2,034	77%	23%
	Preschooler	Jackson	8,760	6,726	2,034	77%	23%
	School Child	Jackson	8,760	6,726	2,034	77%	23%
	Teenager	Jackson	8,760	7,665	1,095	88%	13%
	Adult Male	Onsite SRS	2,000	0	2,000	0%	100%
	Adult Male	Jackson	6760	860	5,900	13%	87%
	Adult Female	Jackson	8,760	7,665	1,095	88%	13%
Family Living Near the River	Infant	Jackson	8,760	6,726	2,034	77%	23%
	Preschooler	Jackson	8,760	6,726	2,034	77%	23%
	School Child	Jackson	8,760	6,726	2,034	77%	23%
	Teenager	Jackson	8,760	7,665	1,095	88%	13%
	Adult Male	Jackson	8760	7,665	1,095	88%	13%
	Adult Female	Jackson	8,760	7,665	1,095	88%	13%
Migrant Worker Family	Infant	New Ellenton	4,380	3,363	1,017	77%	23%
	Preschooler	New Ellenton	4,380	3,363	1,017	77%	23%
	School Child	New Ellenton	4,380	3,363	1,017	77%	23%
	Teenager	New Ellenton	4,380	3,832	548	87%	13%
	Adult Male	New Ellenton	4,380	3,832	548	87%	13%
	Adult Female	New Ellenton	4,380	3,832	548	87%	13%

2.2 Inhalation Pathways

2.2.1 Air Inhalation

Air Inhalation rates were based on Recommended Values from EPA 1997 (Table 5-26). The age/gender categories in this reference were averaged together to align with the GENII modeled categories. Table 13 specifies the categories and data from EPA 1997 and the corresponding modeled categories and rates.

Table 13. EPA 1997 Air Inhalation Age/Gender Categories and Rates, and Corresponding GENII-Modeled Air Inhalation Age/Gender Categories and Calculated Rates.

EPA 1997 Data (Table 5-26)		Corresponding GENII Modeled Values	
Age/Gender Categories	**Air Inhalation (m3/day)**	**Modeled Age/Gender Categories**	**Air Inhalation (m3/year)**
Infants (<1)	4.5	Infant (<1)	1,643
1 – 2 3 – 5	6.8 8.3	Pre-School (1 – 7)	2,756
6 – 8 9 – 11 Male 9 – 11 Female	10 14 13	Child (<7 – 12)	4,502
12 – 14 Male 12 – 14 Female 15 – 18 Male 15 – 18 Female	15 12 17 12	Teenager (<12 – 17)	5,110
Adult Male 19 – 65+	15.2	Adult Male (>17)	5,548
Adult Female 19 – 65+	11.3	Adult Female (>17)	4,125

For the CDC scenarios, these rates were apportioned between the receptor locations according to the amount of time each individual receptor spent at each location, as indicated below. The inhalation volumes for each receptor at each location are directly proportional to the amount of time present at each location (see the direct exposure to air pathway). For one receptor using contaminated water for showering (the Family Living Near the River), the inhalation volumes have been further adjusted to account for periods of indoor inhalation during which additional exposure resulting from volatilization of nuclides from shower water could occur.

Scenario Family	Air Inhalation
Rural Family #1	Girard. The adult male and female reside full-time in the area around Girard and inhale 100% of the adult rates at the Girard location for all years. With the exception of high school, the three children are inhale 100% of the applicable rates the Girard location for all years beginning with their birth year. During high school, the children inhalation rates in Girard are 88% (7,680/8,760) of the applicable rates. The high school exposure occurs for each child aged 14 to 17 (1969-72 for a child born in 1955, and 1978-1981 for a child born in 1964). Waynesboro. During high school, the children inhalation rates in Waynesboro are 12% (1,080/8,760) of the applicable rates.
Rural Family #2	Williston. All individuals inhale 100% of the applicable rates at Williston for all years.
Urban/Suburban Family	Onsite SRS. The adult male inhales 23% (2,000/8,760) of the applicable rate at the Onsite SRS location, representing full-time employment for all years. Augusta. All individuals except the adult male inhale 100% of the applicable rates at Augusta for all years. The adult male inhales 77% (6,760/8,760) of the applicable rate at the Augusta location.

Scenario Family	Air Inhalation
Delivery Person	Martin. All individuals inhale 1.1% (100/8,760) of the applicable rates at the Martin location for all years, representing 100 hours/year of church attendance. Children begin church attendance immediately beginning in their birth year. Onsite SRS. The adult male inhales 4.6% (400/8,760) of the applicable rate at the Onsite SRS location for all years, representing 400 hours/year of onsite beverage deliveries. Allendale. The adult male inhales 18% (1,600/8,760) of the applicable rate at the Allendale location for all years, representing the balance of his full-time employment. Barnwell. All individuals inhale for the remainder of their time at the Barnwell location. For all individuals except the adult male, this amount is 99% (8,660/8,760) of the applicable rates. For the adult male, the amount is 76% (6,660/8,760) of the applicable rate.
Outdoors Person	Onsite SRS. The adult male inhales 23% (2,000/8,760) of the applicable rate at the Onsite SRS location, representing full-time employment for all years. Martin. All individuals inhale 50% of the applicable rates at Martin for all years, representing the time spent outdoors. The remaining inhalation occurs indoors and is accounted for in the Indoor and Showering Inhalation pathway. Jackson. All individuals inhale for the remainder of their time at the Jackson location. For all individuals except the adult male, this amount is 100% of the applicable rates. For the adult male, the amount is 77% (6,760/8,760) of the applicable rate. Family Living Near the River
Migrant Worker Family	New Ellenton. All individuals inhale 50% of the applicable rates at New Ellenton for all years. The remainder of their inhalation occurs in areas outside the region potentially affected by air-released contamination from SRS.

2.2.2 Resuspended Soil Inhalation

This pathway represents inhalation of soil in areas that are representative of active farming (Napier 2002, p. 155). For the CDC receptor scenarios, this would include the time spent and inhalation occurring while working the soil in farming (adult male), gardening (adult female), or playing outdoors in sand or gravel (all children). Table 14 presents data on the time spent engaging in activities involving resuspended soil, adapted from the EPA 1997 and assumptions, and the resultant inhalation rates. These rates were used for individuals not actively engaged in farming.

Table 14. Time Spent Around Resuspended Soil and Calculated Inhalation Rates for Non-Farmer Individuals.

Source Data and Assumptions			Corresponding GENII-Modeled Values	
Activity (Source)	**Age/Gender Categories**	**Time**	**Modeled Age/Gender Categories**	**Calculated Rate, Resuspended Soil Inhalation (m3/year)**
Playing in sand or gravel, 95th percentile[EPA 1997, Table 15-58]	1 – 4	121 minutes/day[a]	Infant (<1)	138
	1 – 4	121 minutes/day[a]	Pre-School (1 – 7)	232
	5 – 11	121 minutes/day[a]	Child (<7 – 12)	378
	12 – 17	121 minutes/day[a]	Teenager (<12 – 17)	429
Gardening, 95th percentile [EPA 1997, Table 15-62]	Adult 18 – 64	40 hours/month	Adult Male (>17)	304
			Adult Female (>17)	226

[a] The actual value was not reported in EPA 1997, but it is more than 120 minutes/month.

In addition to the rates for non-farmers, shown above and based on data from EPA 1997, assumption-based rates were developed for individuals engaged in farming. The rates were based on 1,000 hours/year of exposure time and previously specified inhalation rates (Table 13). The farmer rates were calculated for the adult male and female, the teenager, and the schoolchild. For the remaining age/gender categories (infant and preschooler) the farmer rates are assumed to be the same as the non-farmer rates. The calculated rates for resuspended soil inhalation for farmers are presented in Table 15.

Table 15. Calculated Resuspended Soil Inhalation Rates for Farmers.

Modeled Age/Gender Categories	Calculated Rate, Resuspended Soil Inhalation (m3/year)
Infant (<1)	138 (same as for non-farmer)
Pre-School (1 – 7)	232 (same as for non-farmer)
Child (<7 – 12)	514
Teenager (<12 – 17)	583
Adult Male (>17)	633
Adult Female (>17)	471

The rates applied to the CDC scenarios for resuspended soil inhalation are summarized below.

Scenario Family	**Resuspended Soil Inhalation**
Rural Family #1	Girard. This receptor family is assumed to be operating a farm. The farmer rate is applied to the adult male at this location for all years. Non-farmer rates are applied to all individuals except the adult male at this location for all years.
Rural Family #2	Williston. This receptor family is assumed to be operating a farm. The farmer rate is applied to the adult male at this location for all years. Non-farmer rates are applied to all individuals except the adult male at this location for all years.
Urban/Suburban Family	Augusta. Non-farmer rates are applied to all individuals at this location for all years. The non-farmer rate is applied to the adult male.
Delivery Person	Barnwell. Non-farmer rates are applied to all individuals at this location for all years. The non-farmer rate is applied to the adult male.
Outdoors Person	Onsite SRS. The non-farmer rate is applied to the adult male. The activity corresponds to hiking and hunting activity (in place of gardening). Jackson. Non-farmer rates are applied to all individuals except the adult male at this location for all years.
Family Living Near the River	Martin. Non-farmer rates are applied to all individuals at this location for all years. The non-farmer rate is applied to the adult male.
Migrant Worker Family	New Ellenton. 50% of the farmer rates are applied to all individuals at this location for all years.

2.2.3 Indoor or Showering Inhalation

This pathway is being modeled only for receptors that use contaminated water for showering. For this analysis, this includes only the Family Living Near the River. It is assumed that all individuals in this category are indoors exposed to contaminants volatilized from shower water (i.e., at home), 50% of the time, and that 50% of their inhalation occurs through this pathway. During this time, inhalation of air-released contaminants (the regular air inhalation pathway) continues to occur. The rates applied to the CDC scenarios for indoor or showering inhalation are summarized below.

Scenario Family	Indoor or Showering Inhalation Pathway
Rural Family #1	For all individuals, inhalation is 0 for all years because contaminated water is not used for showering.
Rural Family #2	For all individuals, inhalation is 0 for all years because contaminated water is not used for showering.
Urban/Suburban Family	For all individuals, inhalation is 0 for all years because contaminated water is not used for showering.
Delivery Person	For all individuals, inhalation is 0 for all years because contaminated water is not used for showering.
Outdoors Person	For all individuals, inhalation is 0 for all years because contaminated water is not used for showering.
Family Living Near the River	Lower Three Runs Creek / Martin. For all individuals, inhalation is 50% of the air inhalation rate for all years, representing the time spent at home exposed to contaminants volatilized from shower water. Exposure to volatilized shower water is based on water contamination levels at the Lower Three Runs Creek exposure location. Exposure to contaminants from other sources (not volatilized from shower water) is based on air contamination levels at the Martin location.
Migrant Worker Family	For all individuals, inhalation is 0 for all years because contaminated water is not used for showering.

2.3 Ingestion Pathways

2.3.1 Beef Ingestion Pathway

GENII allows for two separate meat ingestion pathways, identified in the model as beef and poultry. In this assessment, the GENII beef pathway is used to represent all non-poultry and non-fish meat that is potentially affected by SRS releases. This includes beef, but also serves as a surrogate for wild game, pork, and other non-poultry meats. Several sets of data were evaluated to develop values for meat consumption. The principal source was the EPA 1997, which provided values for national averages adult and child meat and beef consumption. Also considered were values for beef consumption referenced in Hamby 1991. Both sources are secondary references that provide analysis of consumption data originally compiled by USDA in periodic National Food Consumption Surveys (NFCS) and Continuing Surveys of Food Intakes by Individuals (CSFII). Neither of these sources provides values that align exactly with the CDC scenarios or the age group categories of GENII. Additionally, neither source is based on local (e.g., county- or state-level) data. Therefore, some adjustment of the raw data was necessary to develop values that better correspond with the CDC and GENII specifications. EPA 1997 was selected as a better source because it provided separate categories for adult males and females and multiple categories identifying different meat types. Tables 16 and 17 below present the categories of data included in each of the sources.

Table 16. Ingestion Categories in EPA 1997 Meat Consumption Data.

1987-88 NFCS and 1994/1995 CSFII		1977-78 NFCS	
Age and Gender Categories	Meat Categories	Age and Gender Categories	Meat Categories
<5 6 – 11 male / female 12 – 19 male / female >20 male / female All individuals	Total Meat, Poultry and Fish Beef Pork Lamb, Veal, Game Frankfurters, sausages, luncheon meats Total Poultry Chicken Only Meat Mixtures	<1 1 – 2 3 – 5 6 – 8 9 – 11 male / female 12 – 14 male / female 15 – 18 male / female 19 – 22 male / female 23 – 34 male / female 35 – 50 male / female 51 – 64 male / female 65 – 74 male / female >75 male / female All individuals	Total Meat, Poultry and Fish Beef Pork Lamb, Veal, Game Frankfurters, sausages, luncheon meats Total Poultry Chicken Only Meat Mixtures

Table 17. Ingestion Categories in Hamby 1991 Meat Consumption Data.[a]

Age and Gender Categories	**Meat Categories**
Infant	Beef (households in the south only) All meat (nationwide only)
Child	
Teen	
Adult	

[a] Hamby 1991 provides 2 sets of data, NFCS 1977-78 data for households in the south, and NRC defaults.

The meat consumption values used in the model were derived primarily from EPA 1997 data derived from the 1977-78 NFCS. This data set was selected for four reasons:

- This data set includes values for a broad range of individual meat categories.
- The time period covered by this data set (1977-1978) is closer to the midpoint of the 1954-1992 period being modeled than the other data sets, which occur near or after 1992.
- This data set provides numerous age/gender categories that can be more easily aligned with the CDC and GENII age/gender categories.
- This data set is expressed in units that more easily convert to units required by GENII (g/day to kg/year). Additional conversions considering consumption rate variations by body weight were not needed.

To calculate input consumption quantities for GENII "Beef" (i.e., meat that is not poultry and not fish), EPA 1997 values for intake of beef, pork, lamb/veal/game, meat mixtures, and processed meats (frankfurters, sausages, luncheon meats, spreads) were added together. For non-adult age/gender categories, male and female values were averaged. Table 18 shows the modeled age/gender categories, the corresponding age/gender categories from EPA 1997 that were averaged together to calculate a

comparable input value, and the calculated value was converted to units used by the GENII model (i.e., g/day to kg/year).

Table 18. Alignment between GENII-Modeled Age/Gender Categories for "Beef"a, Poultry, Milk, and Eggs, Corresponding EPA 1997 Age/Gender Categories, and Calculated Rates.

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged	Calculated Value – Average Consumption (kg/year or L/yr)			
		"Beef" [a]	Poultry	Milk	Eggs
Infant (<1)	<1	25.2	1.5	132	1.8
Pre-School (1 – 7)	1 – 2 3 – 5	30.5	6.4	133	7.7
Child (<7 – 12)	6 – 8 9 – 11 male 9 – 11 female	49.6	8.6	143	7.1
Teenager (<12 – 17)	12 – 14 male 12 – 14 female 15 – 18 male 15 – 18 female	63.3	10.5	141	9.0
Adult Male (>17)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	78.5	11.9	80	13.6
Adult Female (>17)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	49.7	9.1	59	8.5

[a] The beef ingestion pathway in the GENII model is being used to model consumption of potentially all affected meat that is not fish or poultry.

These calculated values are applied in the following manner to the CDC scenarios.

Scenario Family	Beef Ingestion Pathway
Rural Family #1	Girard. For all individuals, during the 1950's, consumption is 100% of the calculated values, representing 50% farm-raised beef and pork and 50% wild game. Beginning in 1960, consumption is 75% of the calculated values, representing 25% farm-raised beef and pork and 50% wild game. The remaining 25% is presumed to come from clean sources.

Scenario Family	Beef Ingestion Pathway
Rural Family #2	Williston. For all individuals, during the 1950's, consumption is 100% of the calculated values, representing 50% farm-raised beef and pork and 50% wild game. Beginning in 1960, consumption is 75% of the calculated values, representing 25% farm-raised beef and pork and 50% wild game. The remaining 25% is presumed to come from clean sources.
Urban/Suburban Family	Augusta. For all individuals, 100% of the calculated values.
Delivery Person	Martin. For all individuals, 50% of the calculated values representing locally raised beef (25%) and locally hunted wild game (25%) Barnwell. For all individuals, 50% of the calculated values representing locally raised beef.
Outdoors Person	Onsite SRS. For all individuals, 75% of the calculated values representing wild game. Jackson. For all individuals, 25% of the calculated values representing locally raised beef.
Family Living Near the River	Martin. For all individuals, 100% of the calculated values representing locally raised beef.
Migrant Worker Family	New Ellenton. For all individuals, 50% of the calculated values representing locally raised beef. The individuals are outside of the affected area 50% of the time.

2.3.2 Poultry Ingestion

For the poultry ingestion pathway, consumption rates for specific age/gender categories from EPA 1997 (Table 11-10) from the 1977-78 NFCS were adapted to the age/gender categories used in the model using the same approach used for beef. This alignment and the subsequent calculated rates are presented in Table 18. The approach for applying these rates to the CDC scenarios is described below.

Scenario Family	Poultry Ingestion Pathway
Rural Family #1	Girard. For all individuals, during the 1950's, consumption is 100% of the calculated values, representing 50% farm-raised poultry and 50% wild game. Beginning in 1960, consumption is 75% of the calculated values, representing 25% farm-raised poultry and 50% wild game. The remaining 25% is presumed to come from clean sources.
Rural Family #2	Williston. For all individuals, during the 1950's, consumption is 100% of the calculated values, representing 50% farm-raised poultry and 50% wild game. Beginning in 1960, consumption is 75% of the calculated values, representing 25% farm-raised poultry and 50% wild game. The remaining 25% is presumed to come from clean sources.
Urban/Suburban Family	Augusta. For all individuals, 100% of the calculated values, representing locally raised poultry.

Scenario Family	Poultry Ingestion Pathway
Delivery Person	Martin. For all individuals, 50% of the calculated values representing locally raised poultry (25%) and locally hunted wild game (25%) Barnwell. For all individuals, 50% of the calculated values representing locally raised poultry.
Outdoors Person	Onsite SRS. For all individuals, 75% of the calculated values representing wild game. Jackson. For all individuals, 25% of the calculated values representing locally raised poultry.
Family Living Near the River	Martin. For all individuals, 100% of the calculated values representing locally raised poultry.
Migrant Worker Family	New Ellenton. For all individuals, 50% of the calculated values representing locally raised poultry. The individuals are outside of the affected area 50% of the time.

2.3.3 Milk and Egg Ingestion

For the milk and egg ingestion pathways, consumption rates for specific age/gender categories from EPA 1997 (Table 11.12) from the 1977-78 NFCS were adapted to the age/gender categories used in the model using the same approach used for beef and poultry. This alignment and the subsequent calculated rates are presented in Table 18.

Scenario Family	Milk and Egg Ingestion Pathways
Rural Family #1	Girard. For all individuals, consumption is 100% of the calculated values, representing locally produced milk and eggs.
Rural Family #2	Williston. For all individuals, consumption is 100% of the calculated values, representing locally produced milk and eggs.
Urban/Suburban Family	Augusta. For all individuals, consumption is 100% of the calculated valuse, representing locally produced milk and eggs.
Delivery Person	Barnwell. For all individuals, consumption is 100% of the calculated values, representing locally produced milk and eggs.
Outdoors Person	Jackson. For all individuals, consumption is 100% of the calculated values, representing locally produced milk and eggs.
Family Living Near the River	Martin. For all individuals, consumption is 100% of the calculated values, representing locally produced milk and eggs.
Migrant Worker Family	New Ellenton. For all individuals, consumption is 50% of the calculated values, representing locally produced milk and eggs. The individuals are outside of the affected area 50% of the time.

2.3.4 Produce Ingestion – Leafy Vegetables, Root Vegetables, and Fruit

For the GENII produce ingestion pathways, which include leafy vegetables, root/other vegetables, and fruit, consumption rate data from EPA 1997 and Hamby 1991 were considered. Both of these references are secondary sources that cite data from USDA studies, including the NFCS and CSFII. Consumption

rates are specified in these references for specific age/gender categories and produce categories, as shown below in Table 19. EPA 1997 also presents consumption rates based on other factors (Table 19). However, age and gender differentiations were not specified under these other categorizations, so these other factors were not considered.

Table 19. Categories of Produce Consumption Data.

Study [rate units]	Age and Gender Categories	Produce Categories[a]	Other Categories[b]
1989-91 CSFII (EPA 1997) [g/kg-d]	<5 6 – 11 male / female 12 – 19 male / female >20 male / female All individuals	Total fruits Total vegetables Individual fruits and vegetables (28 types) Exposed fruits Protected fruits Exposed vegetables Protected vegetables Root vegetables	Geographic region (northeast, midwest, south, west) Urbanization (central city, suburban, nonmetropolitan) Season (spring, summer, fall, winter) Race (white, black, asian, native american, other)
1977-78 NFCS (EPA 1997) [g/d] Data Set #1	<1 1 – 2 3 – 5 6 – 8 9 – 11 male / female 12 – 14 male / female 15 – 18 male / female 19 – 22 male / female 23 – 34 male / female 35 – 50 male / female 51 – 64 male / female 65 – 74 male / female >75 male / female All individuals	Total fruits Total vegetables Total produce	Geographic region (northeast, north central, south, west)
1977-78 NFCS (EPA 1997) [g/d] Data Set #2	<1 1 – 4 5 – 9 10 – 14 15 – 19 20 – 24 25 – 29 30 – 39 40 – 59 >60	Exposed produce Protected produce Other produce Leafy produce	Geographic region (northeast, north central, south, west)
1987-88 NFCS (EPA 1997) [g/d]	<6 6 – 11 male / female 12 – 19 male / female >19 male / female All individuals	Total fruits Total vegetables	None reported

Study [rate units]	Age and Gender Categories	Produce Categories[a]	Other Categories[b]
1994-95 CSFII (EPA 1997) [g/d]	<6 6 – 11 male / female 12 – 19 male / female >19 male / female All individuals	Total fruits Total vegetables	None reported
Hamby 1991 Regional estimates [kg/yr]	Infant Child Teen Adult	Leafy vegetables Other vegetables	None reported
NRC Defaults (Hamby 1991) [kg/yr]	Infant Child Teen Adult	Other vegetables	None reported

[a] Data for the listed produce categories are reported by age and gender categories.
[b] Data for these other categories are not reported by age and gender categories.

The data distinguishing between geographic regions, which was not presented in EPA 1997 by age/gender categories, showed that regional differences in consumption rates were small (<10%). EPA 1997 also compared consumption rates over time. Table 20 compares rates for all individuals over time. The data indicate that fruit consumption has gradually increased over time, and that vegetable consumption has fluctuated over time but overall has decreased.

Table 20. Comparison of Produce Consumption Rates Over Time (EPA 1997).

Produce Category	1977-78 NFCS	1987-88 NFCS	1989-91 CSFII	1995 CSFII
Fruits	142	142	156	173
Vegetables	201	182	179	188

Source: EPA 1997, Tables 9-12

The data sets from 1977-78 NFCS were selected as the primary basis for the quantities of produce consumed by the CDC receptors for the following reasons:

- The time period covered by this data set (1977-1978) is closer to the midpoint of the 1954-1992 period being modeled than the other data sets, which occur near or after 1992.
- This data set provides numerous age/gender categories that can be more easily aligned with the CDC and GENII age/gender categories.
- This data set is expressed in units that more easily convert to units required by GENII (g/day to kg/year). Additional conversions considering consumption rate variations by body weight were not needed.

Consumption rates for the three different produce categories (leafy vegetables, root vegetables, and fruit) and six different age/gender-specific categories modeled in GENII were derived from the NFCS data in the following manner:

- **Leafy Vegetables.** GENII-input age/gender-specific rates were calculated by averaging the NFCS age-specific categories for leafy vegetables in the NFCS Data Set #2 using an approach similar to that

used for meat consumption. The data did not provide a distinction between male and female consumption

- **Root Vegetables**. GENII-input age/gender-specific rates using a two-step calculation. First, age/gender-specific rates were calculated by averaging the NFCS age/gender categories for total vegetables in the NFCS Data Set #1 using an approach similar to that used for meat ingestion. Second, the calculated leafy vegetable rates were subtracted from the total vegetable rates to yield age/gender specific rates for root vegetables.
- **Fruit.** GENII-input age/gender-specific rates were calculated by averaging the NFCS age/gender categories for fruit in the NFCS Data Set #1 using an approach similar to that used for meat consumption.

In all three cases, the calculated rates were converted from g/day to kg/yr units needed for GENII input. Table 21 presents the results of these calculations and the categories that were used for averaging.

Table 21. GENII-Modeled Age/Gender Categories for Leafy Vegetables, Root Vegetables, and Fruit, Corresponding EPA 1997 Age/Gender Categories, and Calculated Rates.

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged		Calculated Value – Average Consumption (kg/year)			
	Data Set #1 (used for total vegetables and fruit)	Data Set #2 (used for leafy vegetables)	Leafy Vegetables	Total Vegetables	Root Vegetables[a]	Fruit
Infant (<1)	<1	<1	3.2	27.7	24.5	61.7
Pre-School (1 – 7)	1 – 2 3 – 5	1 – 4	9.1	34.9	25.8	51.1
Child (<7 – 12)	6 – 8 9 – 11 male 9 – 11 female	5 – 9 10 – 14	23.1	50.2	27.1	52.7
Teenager (<12 – 17)	12 – 14 male 12 – 14 female 15 – 18 male 15 – 18 female	15 – 19	31.4	66.8	35.4	46.8
Adult Male (>17)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	20 – 24 25 – 29 30 – 34 40 – 59 >=60	43.6	94.2	50.7	54.4
Adult Female (>17)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	20 – 24 25 – 29 30 – 34 40 – 59 >=60	43.6	73.4	29.8	56.4

[a] Root vegetables are calculated by difference (total vegetables – leafy vegetables = root vegetables).
Source: Data adapted from EPA 1997, Tables 9-14, 9-16, and 9-22.

These calculated rates for produce are applied in the following manner to the CDC scenarios.

Scenario Family	**Produce Ingestion Pathways (Leafy Vegetables, Root Vegetables, and Fruit)**
Rural Family #1	Girard. For all individuals, consumption is 50% of the calculated values during the 1950's and 25% of the calculated values beginning in 1960. The remaining consumption is assumed to come from unaffected non-local sources.
Rural Family #2	Williston. For all individuals, consumption is 50% of the calculated values during the 1950's and 25% of the calculated values beginning in 1960. The remaining consumption is assumed to come from unaffected non-local sources.
Urban/Suburban Family	Augusta. For all individuals, consumption is 50% of the calculated values during the 1950's and 25% of the calculated values beginning in 1960. The remaining consumption is assumed to come from unaffected non-local sources.
Delivery Person	Barnwell. For all individuals, consumption is 50% of the calculated values during the 1950's and 25% of the calculated values beginning in 1960. The remaining consumption is assumed to come from unaffected non-local sources.
Outdoors Person	Jackson. For all individuals, consumption is 50% of the calculated for all years. The remaining consumption is assumed to come from unaffected non-local sources.
Family Living Near the River	Martin. For all individuals, consumption is 75% of the calculated for all years. The remaining consumption is assumed to come from unaffected non-local sources.
Migrant Worker Family	New Ellenton. For all individuals, consumption is 38% of the calculated for all years. The remaining consumption is assumed to come from unaffected non-local sources. This assumes that the individuals consume produce within the affected area 50% of the time, and 75% of that produce is affected.

2.3.5 Grain Ingestion

For the GENII grain ingestion pathways, consumption rate data from EPA 1997 were considered. No data on local consumption was identified. EPA 1997 is a secondary source that cites data from USDA studies, including the NFCS and CSFII. Of the several data sets for grain consumption presented in EPA 1997, data from the 1977-78 NFCS was used as a basis for the GENII grain consumption input values. Consumption rates for specific age/gender categories in this data set were combined and averaged as shown below in Table 22. EPA 1997 also presents consumption rates based on geographic region. However, age and gender differentiations were not specified by geographic region, and differences between regions were small, so regional data were not considered.

Table 22. GENII-Modeled Age/Gender Categories for Grains, Corresponding EPA 1997 Age/Gender Categories, and Calculated Rates.

Modeled Age Categories	Corresponding EPA 1997 Categories Averaged	Calculated Value – Average Consumption (kg/year)
Infant (<1)	<1	15.3
Pre-School (1 – 7)	1 – 2 3 - 5	61.9
Child (<7 – 12)	6 – 8 9 – 11 male 9 – 11 female	80.1
Teenager (<12 – 17)	12 – 14 male 12 – 14 female 15 – 18 male 15 – 18 female	93.9
Adult Male (>17)	19 – 22 male 23 – 34 male 35 – 50 male 51 – 64 male 65 – 74 male >75 male	85.3
Adult Female (>17)	19 – 22 female 23 – 34 female 35 – 50 female 51 – 64 female 65 – 74 female >75 female	60.4

These calculated rates for grain ingestion are applied to the CDC scenarios in the same manner as for the produce ingestion rates pathways.

2.3.6 Fish & Invertebrate Ingestion

For the GENII fish and invertebrate ingestion pathways, consumption rate data from several sources were considered. References included EPA 1997, Hamby 1991, EPA 2002, EPA 1994, and EPA 1991. These sources generally are secondary references that cite data from several studies, including the USDA NFCS and CSFII studies and several state-level studies, but no studies local to South Carolina and Georgia. Hamby 1991 is a secondary source that cites data from the 1977-78 NFCS and NRC default values. The Hamby 1991 NFCS data is for the southern region of the United States

Several criteria, listed in Table 23, were considered in identifying the most appropriate data sets for quantifying fish consumption rates. Neither of the references meets all criteria and, as a result, data from multiple sources was used. For adults, EPA 2002 was selected for use in this study because the CDC scenarios correspond to receptors that fish considerably more frequently than the general population or even typical anglers. As a result, data sources directed at the general population would underestimate the fish consumption practices for the CDC receptors. EPA 1991 (p. 7) recommends using 95th-percentile consumption rates to accommodate such receptors, and EPA 2002 contained 95th percentile consumption rate data. However, EPA 2002 data could not be easily adapted to the non-adult age/gender categories

being modeled, and did not have separate rates for finfish and shellfish. Therefore, Hamby 1991 data were used for all shellfish rates and for non-adult finfish rates, and EPA 2002 rates were adapted for adult finfish consumption. Additionally, rates of 0 were assumed for infants. Table 24 summarizes the modeled fish consumption rate data adapted from Hamby 1991 and EPA 2002.

Table 23. Criteria Considered in Identifying Appropriate Data for Fish Consumption.

Factor	EPA 1997	Hamby 1991	EPA 2002
Data should reflect historical practices rather than recent or current ones.	Yes	Yes	No
Data should reflect anglers rather than the general population.	Yes	No	Yes
Data should include age/gender categories and consumption rate units that can be easily converted into GENII-required categories and units.	Yes	Yes	No
Data reflecting local or regional practices is preferred over national or other non-local practices.	No	Yes	No

Table 24. GENII-Modeled Age/Gender Categories and Calculated Rates for Finfish and Shellfish.

Modeled Age Categories	Finfish Consumption[a] (kg/yr)	Shellfish Consumption[b] (kg/yr)
Infant (<1)	0	0
Pre-School (1 – 7)	2.9	0.7
Child (<7 – 12)	2.9	0.7
Teenager (<12 – 17)	6.8	1.5
Adult Male (>17)	20.5[c]	2.0
Adult Female (>17)	12.1[c]	2.0

[a] Cited consumption rates come from Hamby 1991, p.16, except for adult finfish consumption rates.
[b] Shellfish consumption represents the sum of mollusk and crustacean consumption.
[c] Adult finfish rates were calculated using multiple sources, as discussed in this section.

To develop the modeled finfish consumption rates, EPA 2002 rates were adapted using the following three-step process:

1. 95th percentile finfish/shellfish rates for the “14 – 44” and “45 and older” age groups were averaged to generate a single adult male rate and a single adult female rate.
2. The adult male rate and adult female rate calculated in step 1 were converted from g/d to kg/yr.
3. The Hamby adult shellfish rate was subtracted from the adult male rate and the adult female rate.

These rates for fish and shellfish are applied in the following manner to the CDC scenarios.

Scenario Family	Finfish and Shellfish Ingestion Pathways
Rural Family #1	For all individuals, consumption is 0 because the fishing location (Briar Creek) is not hydrologically downstream from SRS.
Rural Family #2	For all individuals, consumption is 0 because the fishing locations (Savannah River upstream of site and local farm ponds near Williston) are not hydrologically downstream from SRS.
Urban/Suburban Family	For all individuals, consumption is 0 because the fishing location (Savannah River upstream of site) is not hydrologically downstream from SRS.
Delivery Person	Lower Three Runs Creek. For all individuals, consumption is 100% of the calculated values.
Outdoors Person	Savannah River. For all individuals, consumption is 100% of the calculated values.
Family Living Near the River	Savannah River. For all individuals, consumption is 100% of the calculated values.
Migrant Worker Family	For all individuals, consumption is 0 because the fishing locations (Savannah River upstream of site and local farm ponds near New Ellenton) are not hydrologically downstream from SRS.

2.3.7 Inadvertent Soil Ingestion

Soil ingestion rates used for this project are based on EPA 1997, Table 4-23. Daily rates of 100 mg/day for children and 50 mg/day for adults were converted to annual rates (Table 25).

Table 25. GENII-Modeled Age/Gender Categories and Calculated Rates for Soil Ingestion.

Modeled Age Categories	Soil Ingestion (kg/yr)
Infant (<1)	36.5
Pre-School (1 – 7)	36.5
Child (<7 – 12)	36.5
Teenager (<12 – 17)	36.5
Adult Male (>17)	18.2
Adult Female (>17)	18.2

For the CDC scenarios, these rates were apportioned between the receptor locations according to the amount of time each individual receptor spent at each location, as indicated below.

Scenario Family	Soil Ingestion
Rural Family #1	Girard. Adults ingest 100% of the calculated rate for all years. Non-adults ingest 100% of the calculated rate for all years except for specified high-school years in Waynesboro. During the specified years, 12% of the calculated rate is ingested. Waynesboro. During the specified high school years, non-adults ingest 88% of the calculated rates. The high school exposure occurs for each child aged 14 to 17 (1969-72 for a child born in 1955, and 1978-1981 for a child born in 1964).
Rural Family #2	Williston. All individuals ingest 100% of the calculated rates for all years.
Urban/Suburban Family	Onsite SRS. The adult male ingests 23% of the calculated rate for all years. Augusta. All individuals except the adult male ingest 100% of the calculated rates. The adult male ingests 77% of the calculated rate.
Delivery Person	Martin. All individuals ingest 1% of the calculated rates for all years. Onsite SRS. The adult male ingests 4% of the calculated rate for all years. Allendale. The adult male ingests 18% of the calculated rate for all years. Barnwell. All individuals except the adult male ingest 99% of the calculated rates for all years. The adult male ingests 77% of the calculated rate for all years.
Outdoors Person	Onsite SRS. The adult male ingests 23% of the calculated rate for all years. Jackson. All individuals excluding the adult male ingest 100% of the calculated rates for all years. The adult male ingests 77% of the calculated rate for all years.
Family Living Near the River	Martin. All individuals ingest 100% of the calculated rates for all years.
Migrant Worker Family	New Ellenton. All individuals ingest 50% of the calculated rates for all years.

2.3.8 Drinking Water

None of the receptor individuals consume drinking water from a contaminated source. Therefore, the ingestion rate is zero for all receptors.

2.3.9 Shower Water Ingestion

The Family Living Near the River is the only receptor using contaminated water for showering. Individuals in all other receptor scenarios have a shower water ingestion rate of zero. For the individuals in the family living near the river, it is assumed that the individuals use untreated river water for bathing/showering. Annual consumption is calculated using the following default rates from GENII and EPA 1997, Table 15-18:

- 365 showering days/year (GENII default)
- 1 shower event / day (GENII default and EPA 1997)
- 0.167 hours / event (GENII default and EPA 1997)
- 0.06 L/hour ingestion (GENII default)

These default rates yield a shower consumption rate of 3.6 L/year, which is applied to the Family Living Near the River for all individuals for all years.

2.3.10 Swimming Water Ingestion

This pathway accounts for ingestion of contaminated water that occurs when an individual swims in contaminated water. Swimming water ingestion rates are assumed to be zero for the receptors listed in Table 26 because any swimming is assumed to occur in water that is hydrologically upgradient or crossgradient from the site.

Table 26. Receptors Without Swimming Water External Exposure.

Receptor Family	Swimming Location
Rural Family #1	Brier Creek
Rural Family #2	Savannah River upstream of site and farm ponds around Williston, SC
Urban/Suburban Family	Savannah River upstream of the site
Outdoors Person	Savannah River upstream of the site
Migrant Family	Savannah River upstream of site and farm ponds around New Ellenton

For the remaining two receptors, the Delivery Person swims on Lower Three Runs Creek near Martin, and the Family Living Near the River swims on the Savannah River downstream of the site at a location near Martin. For these receptors, swimming water ingestion rates are estimated based on the time spent swimming (21.2 hours/year, as calculated in the discussion of the swimming water external exposure pathway using the factors based on South Carolina recreational patterns cited in Hamby 1991 (p.24)) and EPA's default rate of water ingestion while swimming, equal to 0.05 L/hour. These factors result in an annual ingestion rate of 1.0 L/year. This rate was applied to all individuals in the Delivery Person Family and the Family Living Near the River.

For the CDC scenarios, the rates used for the swimming water ingestion pathway are summarized below.

Scenario Family	Swimming Water Ingestion
Rural Family #1	No swimming water ingestion. Exposure location (Briar Creek near Girard) is not hydrologically downgradient from release points.
Rural Family #2	No swimming water ingestion. Exposure locations (Savannah River upstream of SRS and farm ponds around Williston) are not hydrologically downgradient from release points.
Urban/Suburban Family	No swimming water ingestion. Exposure location (Savannah River at Augusta) is not hydrologically downgradient from release points.
Delivery Person	Lower Three Runs Creek at Martin. All individuals ingest 1.0 L/year for all years.
Outdoors Person	No swimming water ingestion. Exposure location (Savannah River upstream of SRS) is not hydrologically downgradient from release points.
Family Living Near the River	Lower Three Runs Creek at Martin. All individuals ingest 1.0 L/year for all years.
Migrant Worker Family	No swimming water ingestion. Exposure locations (Savannah River upstream of SRS and farm ponds around New Ellenton) are not hydrologically downgradient from release points.

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Attachment I - Proposed Values of Transfer, Bioconcentration, and Bioaccumulation Factors Used for Modeling Dose Reconstruction for Historical Releases from the U.S. Department of Energy Savannah River Site

This document describes how values were determined for a set of modeling variables known informally as transfer factors. The transfer factors are used in GENII-V.2 modeling software for modeling food chain transport of radionuclides. Many of these variables describe the ratio (at equilibrium) between contamination levels in two media types; for example, the ratio of contamination levels in soil and in a plant that grows in soil. In other words, these variables are essentially partition coefficients between two environmental compartments. Other variables describe the steady state ratio between contamination levels in plant matter and contamination levels in animal products (meat, eggs, or milk) that is produced from an animal that consumes the plant matter at a unit intake rate. Thus some variables in this group describe bioconcentration (partitioning), while others characterize a bioaccumulation process, for which uptake values must be considered. . Table 1 lists the GENII variables that are transfer factors that are represented in modeling contaminant transport in the SRS food chain, the variable names, and the units.

Table 1. GENII Transfer Factors in Used in SRS Food Chain Modeling

Category	Variable	GENII Variable Name	GENII Units	Complete Units
Soil-to-Plant Concentration Ratios	Soil to Animal Forage	CLBVAF	kg soil/kg dry	(Bq/kg dry plant matter) / (Bq/kg soil)
	Soil to Grain	CLBVAG		
	Soil to Hay	CLBVAH		
	Soil to Cereal	CLBVCL		
	Soil to Fruit	CLBVFR		
	Soil to Leafy Vegetables	CLBVLV		
	Soil to Other Vegetables	CLBVOV		
	Soil to Root Vegetables	CLBVRV		
Animal-Intake-to-Animal-Product Transfer Factor Ratios	Feed to Egg	CLFEG	d/kg	(Bq/kg eggs) / (Bq/day intake)
	Feed to Animal Milk	CLFMK	d/L	(Bq/L milk) / (Bq/day intake)
	Feed to Animal Meat	CLFMT	d/kg	(Bq/kg meat) / (Bq/day intake)
	Feed to Poultry	CLFPL	d/kg	
Water-to-Aquatic-Food Bioaccumulation Factors (Freshwater)	Bioaccumulation in Freshwater Fish	CLBFF	L/kg	(Bq/kg fish) / (Bq/L water)

The units shown in Table 1 include two sets of units. The first set are those specified in the GENII V.2 software, and have been simplified from the complete units by eliminating units that cancel each other out. For example, the units for the soil-to-plant concentration ratio for animal forage (kg soil/kg dry) are actually a reduction of the ratio [Bq/kg dry forage] / [Bq/kg soil]. The second set of units are the complete units of the factor.

In Table 1, the transfer factors are divided into the following three groups based on the type of ratio the represent:

- Soil-to-plant ratios,
- Animal-intake-to-animal-product ratios for unit uptakes, and
- Water-to-aquatic-food ratios for freshwater biota.

Transfer factors in the water-to-aquatic-food group are required for radionuclides released through the liquid pathway. Transfer factors in the soil-to-plant group and animal-intake-to-animal-product are required for radionuclides released for the airborne pathway. Additionally, because farm animals at one or more exposure locations drink river water, animal-intake-to-animal-product factors are required for radionuclides released through the liquid pathway. Finally, while irrigation pathways are not currently planned as part of the dose reconstruction because data cannot confirm that such a pathway exists, soil-to-plant transfer factors for liquid-released radionuclides would be needed to model irrigation pathways. Therefore, soil-to-plant factors for liquid-released radionuclides are included in this analysis.

Another consideration is that a single value for each transfer factor identified for a given element or isotope could be used for all the isotopes of that element. For example, the same value was used for the soil-to-leafy-vegetable transfer factor for all uranium isotopes. For some elements being modeled, notably tritium and argon, no transfer factors were identified because no values were used in GENII. For tritium, GENII uses a special model that assumes fixed values for tritium-to-hydrogen ratios in different media [PNL 2002, p.161-163]. Similarly, GENII also uses a special model to characterize transfer of carbon between certain media. [PNNL 2002, p. 163-165]. For argon (and other noble gases), GENII assumes no transfer into the food chain (the transfer factor equals zero).

Table 2 summarizes the elements, isotopes, and release types for which transfer factors were needed for the SRS dose reconstruction.

Table 2. Elements and Modeled Isotopes Requiring Transfer Factors in SRS Dose Reconstruction

Atmospheric Release		Liquid Release	
C	(C14)	P	(P32)
Sr	(Sr89, Sr90)	S	(S35)
Y	(Y90)	Co	(Co60)
Ru	(Ru103, Ru106)	Zn	(Zn65)
I	(I129, I131 (both elemental and organic)	Sr	(Sr89, Sr90)
Cs	(Cs137)	Y	(Y90) [a]
Th	(Th231, Th234) [a]	Nb	(Nb95, Nb95m)
U	(U234, U235, U236, U238)	Zr	(Zr95)
Pu	(Pu238, Pu239)	Tc	(Tc99)
Am	(Am241)	Ru	(Ru103, Ru106)
		I	(I129, I131)
		Cs	(Cs134, Cs137)
		Ce	(Ce141, Ce144)
		Th	(Th231, Th234) [a]
		U	(U234, U235, U236, U238)
		Pu	(Pu238, Pu239)

[a] Th and Y isotopes are not included in the SRS release inventory being modeled. They are being modeled because they are daughter products of other radionuclides released from SRS.

Default values for all GENII transfer factors are stored in the constituent library of the GENII V.2 software, and the origin of the GENII default values is documented in the GENII V.2 Software Design Document, Appendix D. In addition to the transfer factors listed in Table 1, which represent those needed to model the pathways considered in the SRS study, the GENII constituent library also includes a number of other transfer factors. These other transfer factors are not being analyzed here because the corresponding pathways are not realistic for contaminant transport for the SRS scenarios or because the pathways can be modeled using one of the other existing pathways. For example, transfer factors for saltwater-to-aquatic-food are not used because the nearest source for saltwater biota is outside the region modeled; furthermore, the concentrations of radionuclides in the Savannah River estuary are expected to be so small, that the dose from ingesting seafood originating there is expected to be negligible. Similarly, transfer factors for fresh-water-to-aquatic-plants are not included because the scenarios being modeled do not include a pathway for aquatic plant consumption.

Another limitation on selecting values for transfer factors is that GENII V.2 requires that certain transfer factors be used for multiple pathways [Napier 2003]. For example, the variable used for the soil-to-leafy-vegetable transfer factors (CLBVLV) is used for four different transport pathways (see Table 3). In this case, the FRAMES software that forms the user interface of GENII allows values for three different transfer factor variables to be entered (CLBVLV, CLBVAF, and CLBVAH), but only one transfer factor variable (CLBVLV) is actually read by the model, and it is used for four different pathways. The values entered for the other variables are ignored by GENII.

Table 3. Transfer Factors used in GENII for Multiple Pathways

GENII Transfer Factor	Pathways Covered in GENII
Soil-to-leafy-vegetables (CLBVLV)	▪ Soil-to-leafy-vegetables (for leafy vegetables that are subsequently consumed by humans, CLBVLV) ▪ Soil-to-beef-cattle-forage (for pasture grass that is subsequently consumed by beef cattle, CLBVAF) ▪ Soil-to-milk-cow-forage (for pasture grass that is subsequently consumed by milk cows, CLBVAF) ▪ Soil-to-milk-cow-feed (for hay that is subsequently consumed by milk cows, CLBVAH)
Soil-to-cereal (CLBVCL)	▪ Soil-to-cereal (for cereal that is subsequently consumed by humans, CLBVCL) ▪ Soil-to-beef-cattle-feed (for grain that is subsequently consumed by beef cattle, CLBVAG) ▪ Soil-to-poultry-feed (for grain that is subsequently consumed by poultry, CLBVAG) ▪ Soil-to-egg-animal-feed (for grain that is subsequently consumed by egg-producing chickens, CLBVAG)
Soil-to-other-vegetable (CLBVOV)	▪ Soil-to-other-vegetables (for other vegetables that are subsequently consumed by humans, CLBVOV) ▪ Soil-to-root-vegetables (for root vegetables that are subsequently consumed by humans, CLBVRV)

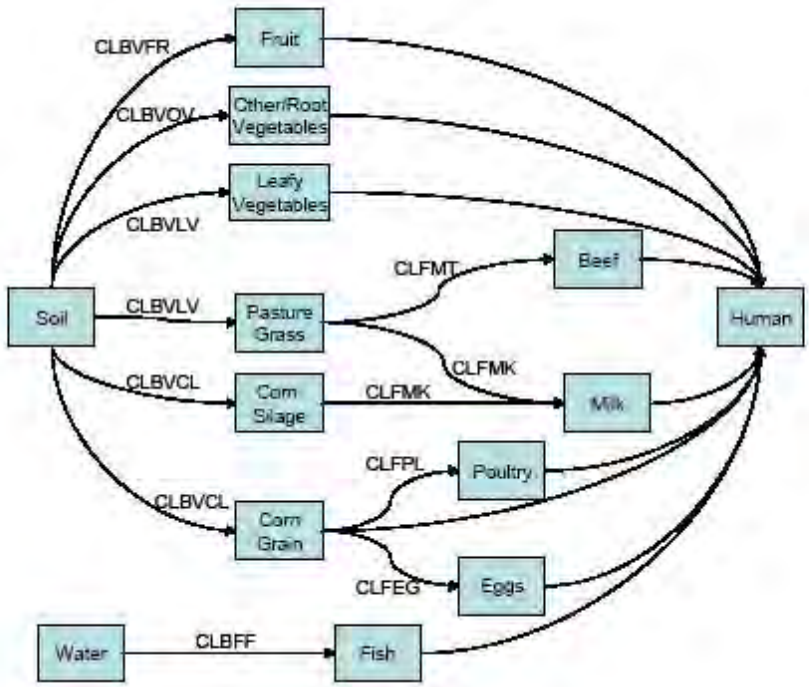
Several pieces of information were considered in determining the value of each transfer factor. One of the primary pieces of information considered in determining the value of each transfer factor was an understanding of the type of crop or food product that was represented in each segment of the food chain involving that transfer factor. For soil-to-plant-matter transfer factors, Table 4 lists the crops or food products to which the transfer factors are applied in the SRS exposure scenarios.

Table 4. Crops or Food Products represented by GENII Transfer Factors in SRS Exposure Scenarios

GENII Variable Used in Calculations	Pathway and GENII Variable	Crop or Food Product
CLBVLV	Soil to Leafy Vegetables (CLBVLV)	Locally produced leafy vegetables
	Soil to Animal Forage (CLBVAF)	Locally grown Bermuda grass used as pasture for beef cattle and milk cows as well as stored Bermuda grass green chop consumed by beef cattle.
	Soil to Hay (CLBVAH)	Locally produced corn silage used as feed for milk cows
CLBVCL	Soil to Grain (CLBVAG)	Locally produced corn grain used as feed for beef cattle, poultry, and egg animals (chickens).
	Soil to Cereal (CLBVCL)	Locally produced corn grain consumed by humans
CLBVFR	Soil to Fruit (CLBVFR)	Locally produced fruit
CLBVOV	Soil to Other Vegetables (CLBVOV)	Locally produced non-leafy vegetables
	Soil to Root Vegetables (CLBVRV)	Locally produced non-leafy vegetables

Figure 1 illustrates the variables used for each of the exposure pathways.

Figure 1. Exposure Pathways of the Food Chain and Corresponding Transfer Factor Variables Used by GENII.



For the CLBVLV variable, three different crops had to be considered in assigning a value to the factor. The approach used to select a value in this instance was to use the most conservative (i.e., highest) value transfer factor of the three pathways. While this approach may contribute to an overestimate of the amount of exposure through the different pathways covered by the CLBVLV variable, implementing this approach is relatively straightforward. In contrast, extensive calculations would be required to determine which of the pathways is the most representative of the total exposure to human receptors, so this approach was not used. Determining which pathway (soil-to-leafy-vegetable, soil-to-beef-animal-forage, soil-to-milk-animal-forage, and soil-to-milk-animal-feed) is most representative would involve comparing the total amount of exposure represented by each pathway, which would be calculated using a pathway-specific transfer factor value. While the amount of exposure through human consumption of leafy vegetables is relatively easy to determine, the amount of exposure through the other pathways would require calculations involving the amount of intake by milk and meat producing animals, the amount of milk and meat consumed by each receptor at each exposure location (including the different amounts consumed by different age groups) and the values of the other transfer factors that form the food chain (the animal-intake-to-milk and animal-intake-to-meat factors).

A similar consideration was used for the soil-to-cereal transfer factor, CLBVCL, which is used to represent corn consumed by humans, poultry, and egg animals, and corn silage consumed by milk cows. In this case, the highest value also was selected.

A substantial body of literature exists for various transfer factors. This literature includes numerous studies that examine radionuclide transport through the food chain. These studies provide experimental results for specific environmental conditions. For example, soil-to-plant factors are typically specified for individual plant species, soil conditions, and growing conditions.

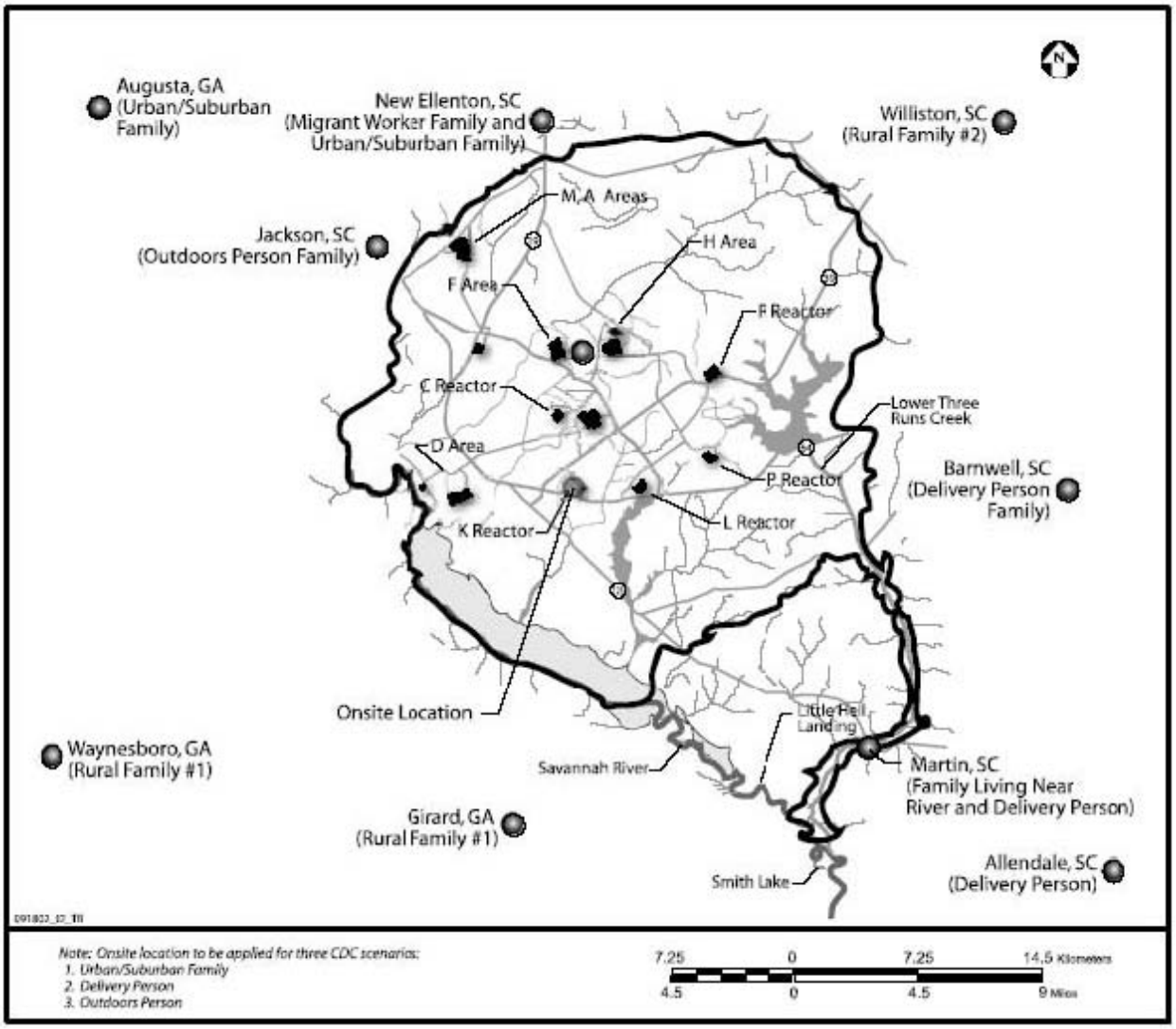


Figure 2. Exposure Locations of CDC Receptor Scenarios (Air Releases).

Table 5. Site-Specific Transfer Factor Values Calculated Using Data from Friday 1996

Pathway	Value and Rationale
Strontium (Sr)	
Water-to-Freshwater-Fish	Value = 450 (Strontium) P. 22 presents two values for piscivores (3,400) and benthic invertebrate and fish feeders (610). The average value is ~2,000. This value is higher than the IAEA default value (60) [IAEA 1994, p.45] by a factor of ~33, and is outside the range of measured values (1 – 1,000) cited in IAEA. Because the values from Friday are so high and represent only two data points, the geometric mean (450) of the site-specific average value (2000) and the generic value (60) is being used.
Soil-to-Cereal	Value = 0.15 (Strontium) P. 23 provides a single value for corn grain of 0.15. Corn grain is consumed by humans and by poultry. This value is lower than the IAEA default value (0.21) [IAEA 1994] by a factor of ~1.4.
Cesium (Cs)	
Water-to-Freshwater-Fish	Value = 4,700 (Cesium) P. 15 presents values for different types of fish muscle. An average of three mean values was taken for surface and midwater insectivores (7,009), insect and bottom invertebrate feeders (911), and piscivores (10,980). The average value (6,300) is higher than the value used by SRS (3,000) [SRS 2002] by a factor of ~2 and the IAEA expected value (2,000) [IAEA 1994, p.45] by a factor of ~3, and is above the 95% confidence range (30 – 3,000) cited in IAEA 1994. The selected value (4,700) is the geometric average of the average of the site-specific values and the IAEA expected value. [Friday 1996] states ". . . the relatively high bioconcentration factors of cesium-137 in fish flesh can be largely explained by the low concentrations of potassium in the water" (p.14). Other SRS studies (Simpkins 2002; Jannik 2002) have recommended a value of 3000 kg/L.
Soil-to-Leafy-Vegetables	Value = 5.31 (Cesium) P. 19 provides a mean value for Bahia Grass of 5.31. Bahia grass is the primary forage for cattle, and the soil-to-leafy vegetable factor is used for soil-to-cattle-forage in GENII (see Table 3). This value is higher than the IAEA default value (0.46) [IAEA 1994] by a factor of ~12. [Friday 1996] states that "The site-specific bioconcentration factors determined for plants and grasses are higher than values reported in the literature and are probably due to the local clay content of the soils at the SRS." (p.18)
Soil-to-Cereal	Value = 0.02 (Cesium) P. 19 provides a single value for corn grain of 0.01. Corn grain is consumed by humans and by poultry. This value is lower than the IAEA default value (0.026) by a factor of ~3 [IAEA 1994, p.20]. However, it is within the 95% confidence range (0.0026 – 0.26) cited in IAEA 1994. The selected value, 0.02, is the geometric mean of the site-specific and IAEA default values.

Pathway	Value and Rationale
Soil-to-Other-Vegetables	Value = 0.9 (Cesium) P. 19 provides a single value for fresh vegetables of 0.9. This value is higher than the IAEA default value (0.46) [IAEA 1994] by a factor of ~2.
Plutonium	
Water-to-Freshwater-Fish	Value = 4,700 (Plutonium) P. 28 provides three values for fish muscle, including two values for piscivores (2,600 and 5,600) and one value for benthic invertebrate and fish feeders (12,000). The average value is ~6,700; the geometric average is 5,600. This value is higher than the IAEA expected value (30) [IAEA 1994, p.45] by a factor of ~190 and is higher than the 95% confidence range (4 – 300) cited in IAEA 1994. The selected value (4,700) is the geometric average of the average of the site-specific values and the IAEA expected value. [Friday 1996] states that "Transuranic elements are known to be fixed by clay minerals and complexed by organic matter which may decrease their availability. Zooplankton and benthic insect larvae have high surface to volume ratios. This allows their surfaces as well as their guts to carry sediment and sestonic particles, which adsorb transuranic particles; thus resulting in higher bioconcentration factors . . . " (p.27). Additionally, for general population dose calculations, SRS uses a value of 3,000 [SRS 2002, p. 76] [Simpkins 2002]
Soil-to-Cereal	Value = 6. e-5 (Plutonium) P. 31 provides a single value for corn grain of 6 e-5. This value is higher than the IAEA default value (8.6 e-6) by a factor of ~7 [IAEA 1994, p.24].
Soil-to-Leafy-Vegetables	Value = 0.0022 (Plutonium) P. 32 provides maximum and minimum values for Bahai grass of 4.4 e-3 and 8.9 e-5. The average of these two values is ~2.2 e-3; the geometric average is 6.3 e-4. The average value is higher than the IAEA default value (3.4 e-4) [IAEA 1994, p.25] by a factor of ~6.5; the geometric average is higher by a factor of ~1.8. Both values are within the 95% confidence range (5. e-5 – 0.65) cited in IAEA 1994. The selected value is the average of the site-specific values .
Americium	
Water-to-Freshwater-Fish	Value = 2,400 (Americium) P. 29 provides two values for fish muscle, including one value for piscivores (2,500) and one value for benthic invertebrate and fish feeders (4,200). The average value is ~3,400; the geometric mean is 3,200. The average value is higher than the IAEA expected value (30) [IAEA 1994, p.45] by a factor of ~140; the geometric mean is higher by a factor of ~110; and both values are higher than the 95% confidence range (30 – 300) cited in IAEA 1994. The selected value (2,400) is the geometric average of the average of the site-specific values and the IAEA expected value. The explanation for the higher site-value for Americium is same as for plutonium (above, see Friday 1996, p.27).

Pathway	Value and Rationale
Soil-to-Leafy-Vegetables	Value = 0.067 (Americium) P. 33 provides a mean value for Bahai grass of 0.067. This value is higher than the IAEA default value (1.2 e-3) [IAEA 1994, p.25] by a factor of ~56.

In selecting values for some variables, the fact was considered that GENII requires the same values to be used for some transfer factors. In particular, for the soil-to-leafy-vegetable transfer factor (which is also used for beef cattle forage, milk cow forage, and milk cow feed), where the approach was to have selected the highest values, only a few values were available, and in no case were values cited for more than one plant species for a given nuclide. For the soil-to-cereal transfer factors, the selected values corresponded to corn grain. This was selected over other crops (wheat, rice, etc.) because corn is grown in the region (USDA 1992, Tables 26 and 29) and would have been consumed by humans as well as poultry.

IAEA Default Values

Default values from IAEA were found for most radionuclides and pathways. In general, only a single value was provided for each animal-intake-to-milk, meat, poultry, and egg pathways. However, for soil-to-plant factors, IAEA 1994 contained multiple values for different plant species and soil conditions. To select from among different plant species, different approaches were used.

- For the soil-to-leafy-vegetable transfer factor, different values were considered for both leafy vegetables and grass forage. The available values in each group were averaged, and the highest calculated average value was used. In some cases, only a single value was available, and in other cases multiple values were considered.
- For the soil-to-cereal transfer factor, values for corn grain were preferred over other values. However, in cases where no value was available for corn grain, other values for grains and corn fodder were averaged.
- For the soil-to-other vegetable transfer factor, available values were averaged.

In addition, to select from among different soil conditions, values for conditions “sand, pH5” were selected because this was judged most similar to the soils surrounding SRS. Other soil conditions (clay, peat) were not considered when data for sandy soil were available. For each of the default value taken from IAEA 1994, the previous reference (generally the primary reference) cited in IAEA 1994 is identified herein. For instances where IAEA 1994 contained multiple values, Table 6 lists the values considered and calculated.

Nuclide and Pathway	Selected Value	Values Cited	
Co – Leafy Vegetables	0.20 (average of cabbage, lettuce, and spinach)	Grass Cabbage Lettuce Spinach	5.4e-02 4.4e-02 2.8e-01 2.9e-01
Co – Other/Root Vegetables	0.11 (average of cited values)	Bean pods Carrot roots Radish roots Potato tubers Mixed green vegetables	3.0e-02 1.3e-01 1.2e-01 6.0e-02 2.0e-01
Zn – Cereals	1.0 (average of cited values)	Barley grain Wheat grain Maize fodder	8.8e-01 1.6e+00 5.6e-01
Zn – Leafy Vegetables	3.3 (highest value)	Grass Spinach	9.9e-01 3.3e+00
Zn – Other/Root Vegetables	12 (average of cited values)	Bean pod Potato tuber Broccoli	7.1e-01 3.5e+01 8.2e-01
Sr – Leafy Vegetables	1.7 (grass in sand pH5)	Grass in sand pH5 Grass in peat pH4	1.7e+00 3.4e-01
Sr – Other/Root Vegetables	1.7 (average of values in sand pH5)	Pea/bean pod in clay loam pH6 Pea/bean pod in sand pH5 Root crops in clay loam pH6 Root crops in sand pH5 Potato tubers in clay loam pH6 Potato tubers in sand pH5, Potato tubers in peat pH4 Green veg exc. spinach in clay loam pH6 Green veg exc. spinach in sand pH5 Green veg exc. spinach in peat pH4	1.3e+00 2.2e+00 1.1e+00 1.4e+00 1.5e-01 2.6e-01 2.0e-02 2.7e+00 3.0e+00 2.6e-01
Tc – Leafy Vegetables	940 (average of cabbage, lettuce, and spinach)	Grass Cabbage Lettuce Spinach	7.6e+01 1.2e+01 2.0e+02 2.6e+03
Tc – Other/Root Vegetables	28 (average of cited values)	Pea/bean pod Turnip root Potato tuber	4.3e+00 7.9e+01 2.4e-01
Th – Other/Root Vegetables	6.9 e-03 (average of cited values)	Bean pod Carrot root Radish root Potato tuber Sweet potato tuber Mixed green vegetables	1.2e-04 3.0e-04 3.9e-02 5.6e-05 2.9e-05 1.8e-03
U – Other/Root Vegetables	0.011 (average of cited values)	Mixed roots Potato tuber Mixed green vegetables	1.4e-02 1.1e-02 8.3e-03
Pu – Other/Root Vegetables	8.2 e-04 (average of cited values)	Bean pod Carrot root Radish root Onion root Mixed roots Potato tuber, swede Cucumber Mixed green vegetables	6.1e-05 4.4e-03 7.7e-04 8.7e-05 9.1e-04 1.5e-04 9.0e-05 7.3e-05

Nuclide and Pathway	Selected Value	Values Cited	
Am – Other/Root Vegetables	8.4 e-04 (average of cited values)	Bean pod	3.9e-04
		Carrot root	2.2e-03
		Radish root	1.4e-03
		Onion root	1.6e-04
		Potato tuber flesh	2.0e-04
		Mixed green vegetables	6.6e-04

GENII Default Values

IAEA 1994 did not specify recommended default values for some radionuclides and pathways. In these cases, the default values specified by GENII were used. The GENII default values are generally specified in both the constituent library included in the GENII V.2 software and in Appendix D of the GENII Software Design Document [PNNL 2002]. A few of the values were only documented in the constituent library. The GENII default values are not specific to plant species, soil types, or growing conditions. With a few exceptions, for each GENII default value taken from PNNL 2002, the previous reference (generally the primary reference) cited in PNNL 2002 is identified herein. However, in a few cases, the previous reference is not indicated.

Table 7 lists the transfer factor values used in this study, which were selected using the process outlined above.

Table 7. Proposed Values for Transfer, Bioconcentration, and Bioaccumulation Factors

Nuclide	Soil-to-Plant Factors (dry kg/dry kg) [ad]				Animal-Intake-to-Animal Product Factors				
	Cereal and Grain (CLBVCL, CLBVAG)	Leafy Vegetables, Animal Forage, and Hay (CLBVLV, CLBVAF, CLBVAH)	Other Vegetables and Root Vegetables (CLBVOV, CLBVRV)	Fruit (CLBVFR)	Animal Milk (CLFMK) p.35, (kg/L)	Animal Meat (CLFMT) (beef) p.37, (kg/kg)	Poultry (CLFPL) p.40, (kg/kg)	Egg (CLFEG) p.41, (kg/kg)	Freshwater Fish (CLBFF) Edible Portions p.45 (L/kg)
P	3.5 [b]	3.5 [b]	3.5 [y]	3.5 [y]	1.6e-02 [j]	5.e-02 [k]	0.19 [a]	1.0 [a]	5 e+04 [i]
S	1.5 [b]	1.5 [b]	1.5 [y]	1.5 [y]	1.6e-02 [j]	2.0 e-01 [l]	2.3 [m]	7.0 [m]	800 [i]
Co	Cereal grain 3.7 e-03 [c]	Average of 3 values 0.20 [c]	Average of 5 values 0.11 [c]	7 e-03 [y]	Organic cobalt 3.e-04 [n]	Organic cobalt 1.e-02 [k]	2 [k]	0.1 [k]	300 [i]
Zn	Wheat grain 1.6 [c]	Spinach 3.3 [c]	Average of 3 values 12 [c]	0.9 [y]	0.01 [p]	0.1 [k]	7 [k]	3 [k]	1,000 [i]
Sr	Site-specific corn grain 0.15 [d]	Grass in sand pH5 1.7 [e]	Average of 4 values 1.7 [e]	Fruit in sand pH5 0.2 [e]	2.8e-03 [o]	8.e-03 [o]	0.08 [o]	0.2 [o]	450 [d]
Y	Not specified 0.01 [f]	Not specified 0.01 [f]	Not specified 0.01 [f]	Not specified 0.01 [f]	2 e-05 [p]	1 e-03 [k]	1 e-02 [k]	2 e-03 [k]	30 [i]
Nb	2.5 e-2 [g]	2.5 e-2 [g]	Bean pod 1.7 e-02 [h]	2.5 e-02 [g]	4.1e-07 [q]	3.e-07 [q]	3.e-04 [r]	1.e-03 [r]	300 [i]
Zr	Not specified 1.0 e-03 [f]	Not specified 1.0 e-03 [f]	Not specified 1.0 e-03 [f]	Not specified 1.0 e-03 [f]	5.5e-07 [q]	1.e-06 [q]	6.e-05 [r]	2.e-04 [r]	300 [i]
Tc	Cereals grain 0.73 [c]	Average of 3 values 940 [c]	Average of 3 values 28 [c]	1.5 [y]	2.3 e-05 [q]	1.e-04 [aa]	0.03 [s]	3 [r]	20 [i]
Ru	Wheat grain 5.0 e-03 [c]	Cabbage 0.2 [c]	Not specified 0.04 [f]	Not specified 0.04 [f]	3.3 e-06 [o]	0.05 [o]	8 [o]	5 e-03 [o]	10 [i]
I	Not specified 2.0 e-02 [f]	Grass 3.4 e-03 [c]	Not specified 0.02 [f]	Not specified 0.02 [f]	0.01 [t]	0.04 [u]	0.01 [r]	3 [r]	40 [i]

Nuclide	Soil-to-Plant Factors (dry kg/dry kg) [ad]				Animal-Intake-to-Animal Product Factors				
	Cereal and Grain (CLBVCL, CLBVAG)	**Leafy Vegetables, Animal Forage, and Hay (CLBVLV, CLBVAF, CLBVAH)**	**Other Vegetables and Root Vegetables (CLBVOV, CLBVRV)**	**Fruit (CLBVFR)**	**Animal Milk (CLFMK)** p.35, (kg/L)	**Animal Meat (CLFMT)** (beef) p.37, (kg/kg)	**Poultry (CLFPL)** p.40, (kg/kg)	**Egg (CLFEG)** p.41, (kg/kg)	**Freshwater Fish (CLBFF)** Edible Portions p.45 (L/kg)
Cs	Corn grain 0.02 [d]	Site-specific Bahai grass 5.31 [d]	Site-specific value 0.9 [d]	Tomato fruit 0.22 [c]	7.9e-03 [o]	0.05 [o]	10 [o]	0.4 [o]	4,700 [d]
Ce	Not specified 3.0 e-02 [f]	Not specified 3.0 e-02 [f]	Not specified 3.0 e-02 [f]	Not specified 3.0 e-02 [f]	3.0 e-05 [v]	2 e-05 [v]	3 e-03 [w]	6.5 e-05 [w]	30 [i]
Th	Maize grain 3.4 e-05 [c]	Grass 1.1 e-02 [c]	Average of 6 values 6.9 e-03 [c]	2.5 e-04 [y]	5 e-06 [p]	4 e-05 [x]	6 e-03 [x]	4 e-03 [ac]	100 [i]
U	Cereals grain 1.3 e-03 [c]	Grass 2.3 e-02 [c]	Average of 3 values 0.011 [c]	4 e-03 [y]	4.0e-04 [z]	3.e-04 [ab]	1 [k]	1 [k]	10 [i]
Pu	Site-specific corn grain 6 e-05 [d]	Site-specific Bahai grass 2.2 e-03 [d]	Average of 8 values 8.2 e-04 [e]	4.5 e-05 [y]	1.1e-06 [o]	1.e-05 [o]	3.e-03 [o]	5.e-04 [k]	4,700 [d]
Am	Cereals grain 2.2 e-05 [e]	Site-specific Bahai grass 0.067 [d]	Average of 6 values 8.4 e-04 [e]	2.5 e-04 [y]	1.5e-06 [o]	4.e-05 [o]	6.e-03 [o]	4.e-03 [k]	2,400 [d]

a GENII default value, PNNL 2002, Appx D, which cites a previous reference of Napier 1988.
b GENII default value, PNNL 2002, Appx D, which cites a previous reference of Kennedy 1992.
c IAEA default value, IAEA 1994, Table VI, p.17-25, which cites a previous reference of Frissel 1989.
d Selected value calculated from data in Friday 1996, or from a combination of data taken from Friday 1996 and IAEA 1994.
e IAEA default value, IAEA 1994, Table VI, p.17-25, which cites a previous reference of Frissel 1992.
f IAEA default value, IAEA 1994, Table VI, p.17-25, which cites a previous reference of Ng 1982a.
g GENII default value, PNNL 2002, Appx D; which cites a previous reference of Coughtrey 1983.
h IAEA default value, IAEA 1994, Table VI, p.17-25, which cites a previous reference of Gerzabek 1993.
i IAEA default value, IAEA 1994, p.45, which cites a several previous references.
j IAEA default value, IAEA 1994, p.35, which cites a previous reference of Ng 1982b.
k IAEA default value, IAEA 1994, p.37, 40, and 41, which cites a previous reference of Ng 1982c.

l GENII default value, PNNL 2002, Appendix D, which cites a previous reference of IAEA 1987.
m GENII default value, GENII V.2 constituent database, unattributed.
n IAEA default value, IAEA 1994, p.35, which cites a previous reference of Baes 1984.
o IAEA default value, IAEA 1994, p.35, 37, 40, and 41, which cites a previous reference of Coughtrey 1990.
p GENII default value, PNNL 2002, Appx D, which cites a previous reference of Ng 1977.
q IAEA default value, IAEA 1994, p.35 and 37, which cites a previous reference of Johnson 1988.
r IAEA default value, IAEA 1994, p.40 and 41, which cites a previous reference of Ennis 1988a.
s IAEA default value, IAEA 1994, p.40 and 41, which cites a previous reference of Ennis 1988b.
t IAEA default value, IAEA 1994, p.35, which cites a previous reference of Hoffman 1988.
u IAEA default value, IAEA 1994, p.37, which cites a previous reference of Handl 1989.
v IAEA default value, IAEA 1994, p.35 and 37, which cites a previous reference of CEC 1987.
w IAEA default value, IAEA 1994, p. 40 and 41, which cites a previous reference of CEC 1987, average of two values for Ce141 and Ce144.
x GENII default value, PNNL 2002, Appx D, which cites a previous reference of Coughtrey 1990.
y GENII default value, PNNL 2002, Appx D, which cites a previous reference of Baes 1984.
z IAEA default value, IAEA 1994, p.35, which cites a previous reference of Morgan 1990.
aa IAEA default value, IAEA 1994, p. 37, which cites a previous reference of Bishop 1989.
ab IAEA default value, IAEA 1994, p. 37, which cites a previous reference of Cramp 1990.
ac GENII default value, PNNL 2002, Appx D, which cites a previous reference of Ng 1982c.
ad GENII requires some of the soil-to-plant bioaccumulation factor variables to have the same value. As noted in Table 3, the values entered for the soil-to-cereal transfer factor (CLBVCL) are also used by GENII for three other soil-to-grain pathways covered by the CLBVAG variable, including soil-to-beef-cattle-feed, soil-to-poultry-feed, and soil-to-egg-animal-feed. Similarly, the values entered for the soil-to-leafy-vegetable transfer factor variable (CLBVLV) are also used by GENII for three other soil-to-plant pathways covered by the CLBVAF and CLBVAH variables, including soil-to-beef-cattle-forage, soil-to-milk-cow-forage, and soil-to-milk-cow-feed (hay). Finally, the values entered for the soil-to-other-vegetable transfer factor variable (CLBVOV) are also used by GENII for the soil-to-root-vegetable transfer factor variable (CLBVRV).

Previous References Cited in IAEA 1994 and PNNL 2002

Table 8 lists references cited in IAEA 1994 and PNNL 2002 as previous or primary references for various transfer factors. The complete citations, listed below, are included for information only. The selection of transfer factors was based on information and recommendations in IAEA 1994 and PNNL 2002. These previous references were not researched under this project.

Table 8. Previous and Primary References Cited in IAEA 1994 and PNNL 2002

Citation	Reference	Application
Baes 1984	Baes, CF, Sharp, RD, Sjoreen, AL, Shor, RW, A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture, Rep ORNL-5786. Oak Ridge National Laboratory, TN. 1984.	Feed-to-Milk
Bishop 1989	Bishop, GP, Beetham CJ, Cuff, YS, Review of Literature for Chlorine, Technetium, Iodine and Neptunium, Nirex Radioactive Waste Disposal Safety Studies, Rep. NSS/R193, UK Nirex Ltd, Harwell, 1989.	Feed-to-Beef
CEC 1987	Commission of the European Communities. 1987. Radionuclide Transfer Factors for Animal Feedingstuffs and Animal Products. Doc. 7682/87. Luxembourg.	Feed-to-Milk
Coughtrey 1983	Coughtrey, PJ, Thorne, MC. 1983. Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems, A Critical Review of Data, Vols. 1 – 6. A.A. Balkema, Rotterdam.	Soil-to-Plant
Coughtrey 1990	Coughtrey, PJ, Radioactivity Transfer to Animal Products, Rep EUR 12608 EN, Commission of the European Communities, Luxembourg. 1990.	Feed-to-Milk, Beef, Poultry, Egg
Cramp 1990	Cramp, TJ, Cuff, YS, Davis, A, Morgan, JE, Review of Data for Uranium, Nickel, and Cobalt, Rep 2150-RI, Associated Nuclear Services Ltd, Epsom 1990.	Feed-to-Beef
Ennis 1988a	Ennis, ME, Jr, Ward, GM, Johnson, JE, Boamah, KN, Transfer Coefficients of Selected Radionuclides to Animal Products. II Hen Eggs and Meat, Health Physics 54 1988 167-170.	Feed-to-Poultry, Egg
Ennis 1988b	Ennis, ME, Johnson, JE, Ward, GM, Voigt, GM, A Specific Activity Effect in the Metabolism of Tc. Health Physics 54 1988. 157-160.	Feed-to-Poultry
Frissel 1989	Frissel, MJ, and van Bergeijk, KE. Mean Transfer Values Derived by Simple Statistical Regression Analysis, Sixth Report of IUR Working Group on Soil-to-Plant Transfer Factors, RIVM Bilthoven. 1989.	Soil-to-Plant
Frissel 1992	Frissel, MJ. An Update of the Recommended Soil-to-Plant Transfer Factors, Eighth Report of the IUR Working Group on Soil-to-Plant Transfer, IUR, Balen, Belgium. 1992	Soil-to-Plant
Gerzabek 1993	Gerzabek, MH, Horak, O., Mohamad, S., and Muck, K. Gefabversuche zum Radionuclidtransfer Boden-Pfanze, Fusionsreaktor – Erste Wand, Rep. OEFZS A-2531, Osterreichisches Forschungszentrum Seibersdorf, 1993, 22-31.	Soil-to-Plant
Handl 1989	Handl, J., Pfau, A., Long-Term Transfer of I-129 into the Food Chain, Sci. Total Environ. 85. 1989. 245-252.	Feed-to-Beef
Hoffman 1988	Hoffman, FO, Amaral, E, Mohrbacher, DA, Deming, E, The Comparison of Generic Model Predictions with Chernobyl Fallout Data on the Transfer of Radioiodine Over the Air-Pasture-Cow-Milk Pathway, J. Environmental Radioactivity 8 1988. 53-71.	Feed-to-Milk

Citation	Reference	Application
Johnson 1988	Johnson, JE, Ward, GM, Ennis, ME, Jr, Boamah KN, Transfer Coefficients of Selected Radionuclides to Animal Products. 1. Comparison of Milk and Meat from Dairy Cows and Goats, Health Physics 54 1988, 161-166.	Feed-to-Milk, Beef
Kennedy 1992	Kennedy, WE Jr, and Strenge, DL. 1992. Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent. Pacific Northwest Laboratory, NUREG/CR-5512. Richland, WA.	Soil-to-Plant
Morgan 1990	Morgan, JE, Beetham, CJ., Review of Literature for Radium, Protactinium, Tin, and Carbon, Nirex Radioactive Waste Disposal Studies, UK Nirex Ltd, Harwell. 1990	Feed-to-Milk
Napier 1988	Napier BA, Peloquin, RA, Strenge, DL, and Ramsdell JV, 1988. GENII – The Hanford Environmental Radiation Dosimetry Software System. Pacific Northwest Laboratory. PNL-6584. Richland, WA.	Soil-to-Plant
Ng 1977	Ng YC, Colsher CS, Quinn DJ, Tompson SE. 1977. Transfer Coefficients for the Prediction of the Dose to Man via the Forage-Cow-Milk Pathway from Radionuclides Released to the Biosphere. UCRL-51939. Lawrence Livermore National Laboratory, California.	Feed-to-Milk
Ng 1982a	Ng, YC, Colsher CS, Thompson, SE, Soil-to-Plant Concentration Factors for Radiological Assessments, Rep. NUREG/CR-2975 UCID-19463, Lawrence Livermore National Laboratory, CA. 1982.	Soil-to-Plant
Ng 1982b	Ng, YC, A Review of Transfer Factors for Assessing the Dose from Radionuclides in Agricultural Products, Nucl. Saf. 23 1982 57-71.	Feed-to-Milk
Ng 1982c	Ng, YC, Colsher, CS, Thompson, SE, Transfer Coefficients for Assessing the Dose from Radionuclides in Meat and Eggs, Final Rep. to USNRC NUREG/CR-2976 UCID-19464 Lawrence Livermore National Laboratory, CA. 1982.	Feed-to-Beef, Poultry, Egg

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Napier BA, Strenge DL, Ramsdell JV, Eslinger PW, and Fosmire C. GENII Version 2 Software Design Document. Richland, Washington, Pacific Northwest National Laboratory. November 2002.

Simpkins AA. Methodology for Estimating Ingestion Dose for Emergency Response at SRS. Aiken, SC, Westinghouse Savannah River Company Report: WSRC- TR-2002-00035; 2002.

1992 Census of Agriculture Volume 1: Part 40, Chapter 2, South Carolina State and County Data, County Data. U.S. Department of Agriculture, National Agricultural Statistics Service. 1993.

Savannah River Site Environmental Report for 2001. Westinghouse Savannah River Company, Airken, SC. WSRC- TR-2001-00474; 2001.

Attachment J - Treatment of Radionuclide Concentrations in Wild Game in Dose Reconstruction Modeling

Background

The SRS Health Effects Subcommittee and other stakeholders are interested in the contribution to radiological dose to community members from consumption of wild game as well as agricultural products that may have been contaminated with radionuclides released by the Savannah River Site during the time period covered by our study. Three scenarios developed by the Health Effects Subcommittee include some consumption of meat from wild game hunted on or near the SRS. These are the Rural, Delivery Person, and Outdoors scenarios.

To model doses from consumption of contaminated wild game, a suitable model and data are required. Three options, discussed below, present themselves for modeling a wild game pathway. Common to all three options is the assumption that only deer (venison) be considered in evaluating wild game consumption.

1. Adapt the beef consumption pathway in GENII to model venison consumption based on calculated meat concentrations.
2. Adapt the beef consumption pathway in GENII to model venison consumption based on measured meat concentrations.
3. Assume venison corresponds to beef, and increase the quantity of locally raised beef consumed by receptors in the GENII model to include the amount of venison consumed.

1. **Adapt the beef consumption pathway in GENII to model venison consumption based on calculated meat concentrations.** While the GENII V.2 computer code does not provide a programmed pathway for evaluating doses from wild game or venison consumption and the published GENII guidance does not address an approach for adapting one of the existing pathways (e.g., beef or poultry consumption) to model wild game consumption, it is conceivable that one of these pathways could be adapted. The actual calculations would be performed in a separate set of GENII runs. To adapt the beef pathway model to venison, transfer coefficients would be required and, depending on the coefficient units, additional data may be required on feeding, drinking, and inhalation behavior of the deer and the growing patterns of ingested forage. Further, this approach requires assuming that deer foraging patterns are understood well enough to be modeled and that supporting data are available. For example, the locations where the deer were hunted would need to be representative of the locations where they were exposed to contamination. If we modeled this pathway, some required data would be available, and some would need to be developed based on assumptions. For example, a transfer coefficient value for Cs-137 to deer is available from IAEA 1994. Transfer factors for other isotopes are not available.

2. **Adapt the beef consumption pathway in GENII to model venison consumption based on measured meat concentrations.** This approach would also require a separate set of GENII runs. Under this approach, required data would include the concentrations of nuclides in vension. For most years, venison data are available for one or a few nuclides (Cs-137 and Sr-90) from SRS annual environmental reports. Concentration data for other nuclides and for missing years would need to be derived or estimated by ATL. In addition, the background concentrations (presumably resulting from nuclear weapons testing) would need to be determined and then subtracted from the measured concentrations. This approach would assume that measured nuclide concentrations in venison from the locations where deer were harvested correspond to the exposure locations established by CDC. A

benefit of this approach is that, except for this assumption, this approach provides a greater certainty since it is based on measured, rather than calculated, vension concentrations.

3. **Assume venison corresponds to beef, and increase the quantity of beef consumed by receptors in the GENII model to include the amount of venison consumed.**. This is the simplest approach. It assumes that venison contamination levels resulting from site releases are similar to those in locally raised beef fed on fresh grass or pasture. No additional GENII runs or data collection would be required. Existing data on the beef consumption pathway will be used, and the total amounts of "beef" consumed by receptors will correspond to the sum totals of venison plus beef in the scenarios.

As discussed in Chapter 11 of the Phase II report by RAC, there is a substantial body of information about the concentrations of cesium in meat from deer killed on the SRS and elsewhere in the region. "In general, 137Cs is the radionuclide of greatest concern because of its relatively long half-life (30 years) and its tendency to accumulate in edible (muscle) tissues."

The Phase II report notes, "Concentrations measured in deer collected from offsite locations give no indication that mean 137Cs burdens in SRS deer are elevated above the expected background concentrations." The Phase II authors describe comparisons between SRS deer and deer taken from other locations in South Carolina and Georgia, and discuss potassium levels in soils as the most likely reason that the mean 137Cs concentrations in the SRS deer are consistently lower. They discuss a study designed to use the fact that the 134Cs/137Cs ratio from SRS releases differs from that in fallout: the cesium ratios in deer in that study "were consistent with global fallout and were comparable to those calculated for offsite deer."

In a brief 1999 report available on the web site of the University of Georgia's Savannah River Ecology Laboratory, Dr. Michael Smith of the University of Georgia and Peter Fledderman of Westinghouse Savannah River Company provide additional information comparing levels of 137Cs found in deer at SRS with those at Fort Jackson, SC, Fort Stewart, Georgia, Cedar Knoll Plantation, SC and Webb Wildlife Center, SC. These authors provide data showing higher average concentrations of 137Cs in deer at the two military bases than at SRS. They describe the soils at the military bases as similar to those at SRS. Deer from the other two locations had much lower concentrations of 137Cs, but the authors maintain that fertilizers with potassium are used at these locations and that this probably reduces the 137Cs levels in the deer. http://www.uga.edu/srel/Graphics/deer_snapshoot.pdf

Discussion

If there were data available that showed radionuclide concentrations in venison from SRS "above background"—higher than the concentrations in other deer—we could use the difference as the SRS contribution of radionuclides—primarily cesium—in venison consumed in certain scenarios. Acknowledging the flaws in the "background" deer populations, the fact remains that there are no data available which show a difference in this way.

If it were possible to discern a difference in the isotopic ratios between the cesium in the SRS deer and the cesium from atmospheric fallout, we could use this to attribute an amount of cesium in the SRS deer to the SRS operations. But this difference cannot be discerned, based on the available literature. In addition, as the Phase II authors note, "radioiodine concentrations measured in deer thyroids have consistently corresponded to periods of weapons testing."

Conclusion and Proposed Path Forward

The Phase II authors suggest how the deer pathway might be further explored in "future phases of the SRS Dose Reconstruction Project." However, Phase II leaves us without usable data that quantifies human exposure via deer to radionuclides released by the SRS.

Therefore, given the current Scope of Work and protocol for this project, ATL proposes to model the wild game consumption pathway as beef consumption (Option 3, above). This approach will yield a calculated concentration of radionuclides per unit of meat consumed. In our analysis, we will compare the calculated concentration with the empirical concentrations found in deer around the SRS. We will discuss, in reports, what this comparison implies for radionuclide exposures that would likely have been experienced by residents of communities surrounding the SRS who consumed venison.

Depending on what our initial analysis shows on this point and on the feedback received from Radiation Studies Branch staff and from the Health Effects Subcommittee, ATL may then propose additional work to further improve our understanding of the contribution of venison and other wild game to human exposure to radionuclides from the SRS.

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