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Environmental Protection Department

Operations and Regulatory Affairs Division

LLNL NESHAPs 1995 Annual Report

Lawrence Livermore National Laboratory
University of California Livermore, California 94550

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LLNL NESHAPs
1995 Annual Report

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U.S. Department of Energy
Radionuclide Air Emission Annual Report
(under Subpart H of 40 CFR Part 61)
Calendar Year 1995

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June 1996

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Lawrence Livermore National Laboratory 1995 NESHAPs Report

This annual report is prepared pursuant to the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) 40 CFR Part 61, Subpart H; Subpart H governs radionuclide emissions to air from Department of Energy (DOE) facilities.

SYNOPSIS

NESHAPs limits the emission of radionuclides to the ambient air from DOE facilities to levels resulting in an annual effective dose equivalent (EDE) of 10 mrem (100 μSv) to any member of the public. The EDEs for the Lawrence Livermore National Laboratory (LLNL) site-wide maximally exposed members of the public from 1995 operations were

- Livermore site: 0.041 mrem (0.41 μSv) (46% from stack emissions, 54% from diffuse-source emissions);
- Site 300: 0.023 mrem (0.23 μSv) (87% due to emissions from explosives experiments, 13% from diffuse-source emissions).

The EDEs were generally calculated using the EPA-approved CAP88-PC air-dispersion/dose-assessment model. The inventory data or continuous-monitoring systems data, stack flow data, and site-specific meteorological data for each modeled source were the specific input to the CAP88-PC model.

SECTION I. Facilities Information

Site Description

The University of California operates LLNL for DOE. LLNL was established in 1952 to conduct weapons research and development. LLNL's current mission is to serve as a national resource in science and engineering, with a focus on national security, energy, the environment, biomedicine, economic competitiveness, and science and mathematics education. LLNL's mission is

dynamic and over the years has been broadened to meet new national needs. LLNL consists of two sites—the main laboratory site located in Livermore, California (Livermore site), and the Experimental Test Facility (Site 300) located near Tracy, California. Figure 1 shows the locations of the sites.

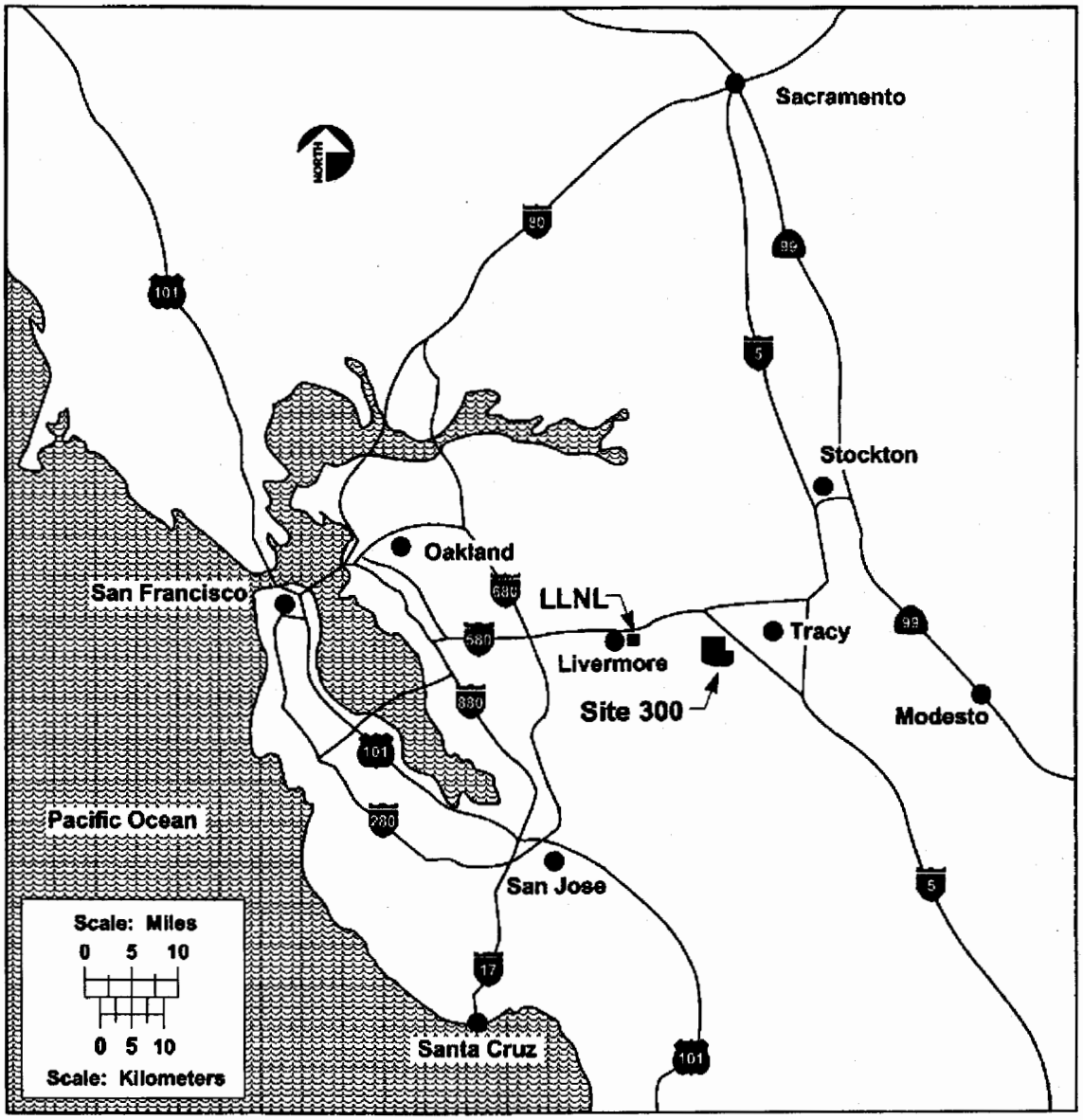

Figure 1. Locations of LLNL Livermore site and Site 300.

Livermore site: LLNL's Livermore site occupies an area of 3.3 km^2 located about 60 km east of San Francisco, California, adjacent to the City of Livermore in the eastern part of Alameda County. More than 6 million people live within 80 km of LLNL; approximately 65,000 of them live in the City of Livermore.

The Livermore site is located in the southeastern portion of the Livermore Valley, a topographical and structural depression oriented east-west within the Diablo Range of the California Coast Range Province. The Livermore Valley forms an irregularly shaped lowland area approximately 26 km long and an average of 11 km wide. The floor of the valley slopes from an elevation of approximately 200 m at the eastern end to approximately 90 m at the southwest corner.

The climate of the Livermore Valley is characterized by mild, rainy winters and warm, dry summers. The mean annual temperature is about 15°C (in 1995, the mean annual temperature was 15.2°C). Temperatures typically range from –5°C during some pre-dawn hours during the winter, to 35°C on a few summer afternoons. The 1995 annual wind data for the Livermore site are shown in Table 1 and displayed as a wind rose in Figure 2. Although winds are variable, the prevailing wind direction is from the southwest, especially during the summer. However, the wind often blows from the northeast, usually during the winter. Most precipitation occurs as rain between October and April with very little rainfall during the summer months. In 1995, the Livermore site received 541 mm of precipitation.

Site 300: Site 300, LLNL's Experimental Test Site, is located 24 km east of the Livermore site in the Altamont Hills of the Diablo Range and occupies an area of 30.3 km^2. It is close to two other explosives-testing facilities; one operated by Physics International, the other by SRI International. A State of California vehicular-recreation area is located nearby, and wind-turbine generators line the surrounding hills. The remainder of the surrounding area is in agricultural use, primarily pasture land for cattle and sheep. The nearest residential area is the City of Tracy (population 40,000), located 10 km to the northeast.

The topography of Site 300 is much more irregular than that of the Livermore site; it consists of a series of steep hills and ridges, which are oriented along a generally northwest/southeast trend, separated by intervening ravines. The elevation ranges from approximately 540 m in the northwestern portion of the site to 150 m at the southeast corner.

Table 1. Wind rose for LLNL's Livermore site during 1995 at the 10-m level. Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding error.

	Wind Speed Range (m/s)					
Direction	0.0-0.4	0.5-2.9	3.0-4.9	5.0-6.9	≥7.0	Total
NNE	1.03	2.71	1.83	0.56	0.12	6.4
NE	1.03	4.16	1.42	0.02	0.00	6.6
ENE	1.03	2.73	0.04	0.00	0.00	3.8
E	1.03	1.64	0.00	0.00	0.00	2.7
ESE	1.03	1.56	0.00	0.00	0.00	2.6
SE	1.03	1.34	0.11	0.00	0.00	2.5
SSE	1.03	1.43	0.34	0.08	0.00	2.9
S	1.03	4.23	0.70	0.41	0.18	6.6
SSW	1.03	6.10	2.01	0.80	0.28	10.2
SW	1.03	7.72	7.65	2.68	0.14	19.2
WSW	1.03	8.06	4.79	0.93	0.12	14.9
W	1.03	4.46	5.57	0.96	0.00	12.0
WNW	1.03	1.88	0.52	0.14	0.00	3.6
NW	1.03	1.03	0.14	0.00	0.00	2.2
NNW	1.03	0.91	0.06	0.04	0.00	2.1
N	1.03	0.71	0.13	0.06	0.04	2.0
Total	**16.4**	**50.7**	**25.3**	**6.7**	**0.9**	**100.0**

Table 2. Wind rose for LLNL's Site 300 at the 10-m level for 1995. Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding error.

	Wind Speed Range (m/s)					
Direction	0.0-0.4	0.5-4.9	5.0-6.9	7.0-10.9	≥11.0	Total
NNE	0.04	1.82	0.05	0.00	0.00	1.9
NE	0.04	2.16	0.10	0.00	0.00	2.3
ENE	0.04	2.00	0.06	0.02	0.00	2.1
E	0.04	1.85	0.13	0.13	0.00	2.2
ESE	0.04	2.21	0.50	0.50	0.12	3.4
SE	0.04	3.09	0.37	0.34	0.16	4.0
SSE	0.04	2.43	0.15	0.17	0.12	2.9
S	0.04	3.43	0.64	0.17	0.05	4.3
SSW	0.04	2.05	0.24	0.12	0.02	2.5
SW	0.04	1.86	0.84	1.59	0.29	4.6
WSW	0.04	3.37	4.71	17.46	5.35	30.9
W	0.04	4.14	4.13	2.18	0.10	10.6
WNW	0.04	4.08	1.03	0.49	0.00	5.6
NW	0.04	5.84	1.62	1.75	0.19	9.4
NNW	0.04	4.25	3.02	1.98	1.06	10.4
N	0.04	1.35	1.14	0.24	0.07	2.8
Total	**0.7**	**45.9**	**18.7**	**27.1**	**7.5**	**100.0**

Table 3. Radionuclides used at LLNL during 1995.

^{3}H	^{57}Co	^{129}I	^{218}Po	^{236}Pu	^{242}Pu
^{13}N	^{59}Ni	^{133}Ba	^{222}Rn	^{236}U	^{243}Am
^{14}C	^{60}Co	^{137}Cs	^{226}Ra	^{237}Np	^{243}Cm
^{15}O	^{63}Ni	^{144}Ce	^{228}Th	^{238}Pu	^{244}Cm
^{22}Na	^{90}Sr	^{152}Eu	^{230}Th	^{238}U	^{244}Pu
^{32}P	^{90}Y	^{154}Eu	^{231}Pa	^{239}Np	^{248}Cm
^{33}P	^{99}Tc	^{155}Eu	^{232}U	^{239}Pu	^{252}Cf
^{35}S	^{106}Ru	^{207}Bi	^{233}U	^{240}Pu	
^{40}K	^{125}I	^{214}Bi	^{234}U	^{241}Am	
^{54}Mn	^{125}Sb	^{214}Pb	^{235}U	^{242}Cm	

SECTION II. Air-Emission Data

Sources

At LLNL, areas where radioactive materials are used or stored, or where activation products occur, are called Radioactive Materials Management Areas (RMMAs). Detailed information is given in Attachment 1 for point-source emissions from the Livermore-site RMMAs in which radiological operations took place during 1995. Building 514 and four other Livermore-site sources external to buildings (including the RMMA at the Building 612 Hazardous Waste Management Yard) are treated as diffuse-area sources.

Similarly, detailed information is given in Attachment 1 for experiments at three Site 300 explosives-testing facilities (Buildings 801, 850, and 851 and their associated firing tables). Six Site 300 sources, including the three firing tables where surface and subsurface contamination exists, are treated as diffuse-area sources.

1995 Inventory Update and Effective Dose Equivalent (EDE) Calculations

For this year's report, covering activities in 1995, we updated the radionuclide inventories in our key facilities, defined as those that accounted for 90% of the 1994 Livermore site radiological dose to members of the public. We also inventoried all RMMAs that began operations in 1995. Radionuclide inventory forms, with detailed guidance for completing them, were sent to the these key unmonitored facilities and new unmonitored facilities having the potential for radionuclide emissions to the air. The forms were completed

by experimenters, and certified by facility managers. Radionuclide inventories for all Site 300 explosives experiments and assessments of source terms for known diffuse sources at both sites were also updated.

Dose-assessment modeling runs were conducted for all diffuse sources and for all point sources using actual radionuclide releases to air, or potential releases based on inventory data completed in 1995. The model used was CAP88-PC (see Section III); we incorporated 1995 on-site meteorological data (wind, precipitation, and temperature) along with the 1995 radionuclide inventory or monitoring data. Annual dose is reported as whole-body EDE expressed in units of mrem (μSv). When reasonable to do so, modeling runs were combined by building, rather than a separate model run for each stack or room. This is permitted by the Memorandum of Understanding between the U.S. EPA and the DOE concerning radionuclide NESHAPs.

A generalized description of each facility and its operations is provided in Attachment 1. The following information is shown for each listed emission point or stack:

- Building and room number(s)
- Specific stack identification code(s)
- Generalized operations in the room(s) or area(s)
- Radionuclides utilized during 1995
- Annual radionuclide inventory with potential for release (by isotope, in curies)
- Physical-state factors (by isotope)
- Stack parameters
- Emission-control devices and emission-control-device abatement factors
- Estimated or measured annual emissions (by isotope)
- Distance and direction to the site-wide maximally exposed individual (SW-MEI)
- Calculated EDE to the SW-MEI
- Distance and direction to the maximally exposed individual for that specific source (MEI)
- Calculated EDE to the MEI (source term not adjusted for emission controls)
- Source category
- Below Appendix E Quantity (Y or N)

A more complete description of these terms is provided in introductory material to the attachment.

emissions by isotopic analysis, so it is possible that these, too, are due to naturally occurring, or background, radioactivity, as discussed above. However, the resulting dose at the SW-MEI for Building 251 was 1.5×10^{-5} mrem/y (1.5×10^{-4} μSv/y) and for Building 419 was 1.6×10^{-4} mrem/y (1.6×10^{-3} μSv/y), well below the NESHAPs limit of 10 mrem/y (1.0×10^{2} μSv/y). In addition, no measured activity concentrations were above facility notification levels, which are designed to trigger investigations of potential releases. These levels are 1×10^{-13} Ci/m^3 (3.7×10^{-3} Bq/m^3) for gross alpha or 1×10^{-11} Ci/m^3 (3.7×10^{-1} Bq/m^3) for gross beta.

SECTION III. Dose Assessment

Description of Dose Model

Estimates of individual and collective radiological doses to the public from all point sources and most diffuse sources at LLNL were obtained using the EPA-developed computer code CAP88-PC. The four principal pathways—internal exposures from inhalation of air and ingestion of foodstuffs and drinking water, and external exposures through irradiation from contaminated ground and immersion in contaminated air—are evaluated by CAP88-PC. The doses are expressed as whole-body effective dose equivalents (EDEs), in units of mrem/y (1 mrem = 10 μSv). Separate doses for the Livermore site and Site 300 from point-source emissions (i.e., stack emissions) and diffuse-source emissions at the two sites are reported.

Three potential doses are emphasized: (1) The dose to the site-wide maximally exposed individual (SW-MEI), which combines the effects of all emission points, for evaluation under the 10 mrem/y (100 μSv/y) standard; (2) the maximum dose to any member of the public (conservatively assumed to be at the LLNL fence line), in any direction, due to each unabated emission point on the site for evaluation of the need to conduct continuous monitoring; and (3) the collective dose to the populations residing within 80 km of the two LLNL sites, adding the products of individual doses received times the number of people receiving them.

Summary of Model Input Parameters

General Model Inputs: Attachment 1 details the key identifiers and input parameters for the CAP88-PC model runs. These include building number; stack ID; isotope(s); emission rate in curies per year (1 Ci = 3.7×10^{10} Bq); and stack parameters, including height, diameter, and emission velocity.

Meteorological Data: All model runs used actual 1995 Livermore-site and Site 300 meteorological data, collected from the meteorological towers for each site. At these towers, wind speed and direction are sampled every few seconds, temperature every minute; and all are averaged into quarter-hour increments, time-tagged, and computer-recorded. The data are converted into a CAP88-PC input wind file using EPA guidelines.

Surrogate Radionuclides: Because the EPA-mandated model CAP88-PC does not contain all the radionuclides in use at LLNL, it was necessary in a few cases to use surrogate radionuclides to estimate EDEs. Attachment 2 shows the surrogate radionuclide lists for CAP88-PC. In selecting the surrogates, the most-restrictive lung class (whether clearance from the lungs takes place in days, weeks, or years) was used. When possible, a surrogate radionuclide with similar chemistry and similar values for "annual limits of intake via inhalation and derived air concentration," as specified in the EPA's Federal Guidance Report No. 11 was used. CAP88-PC contains a library of 265 radionuclides. In some cases, experimenters did not have isotopic analyses of mixtures of radionuclides and could only identify their radionuclide inventory as "gross alpha" or "gross beta." In these cases, ^{239}Pu was used as the surrogate for gross alpha and ^{90}Sr was used as the surrogate for gross beta in modeling efforts to provide conservative dose estimates.

Population Inputs: Population distributions centered on the two LLNL sites were compiled from 1990 census data. The population data files (distribution of population with distance and direction) used in the 1995 modeling effort are described in Section VI under "Collective Effective Dose Equivalent."

Land-Use and Agricultural Inputs: Options for model inputs regarding agricultural characteristics and land use are established by the EPA, and the particular designation selected can strongly influence the ingestion dose received by the population being evaluated. Following investigation into the use of the various options, the "user entered" option was selected for the CAP88-PC modeling effort for 1995. The values entered corresponded to the "local agriculture" option (i.e., everything is home produced), with one exception—all milk consumed was assumed to be imported. The assumption that all milk comes from local cows is not supported by the agricultural activities conducted in the area. The greatest effect of this change is found in the dose from the ingestion pathway attributable to tritium. A detailed discussion of how the dose from tritium is calculated by CAP88-PC is presented in Attachment 3.

At Site 300, the 1995 SW-MEI was located in an experimental area termed "Bunker 2" operated by Physics International. Bunker 2 lies about 300 m outside the east-central boundary of Site 300, as shown in Figure 5. This bunker is 2.4 km east-southeast of the principal firing table at Building 801.

In Attachment 1, the distance and direction to the respective SW-MEI are shown for each facility at each site. Doses to the site-specific SW-MEIs were evaluated for each source and then totaled for site-specific evaluations against the 10 mrem/y dose standard (see "Compliance Assessment" in Section III).

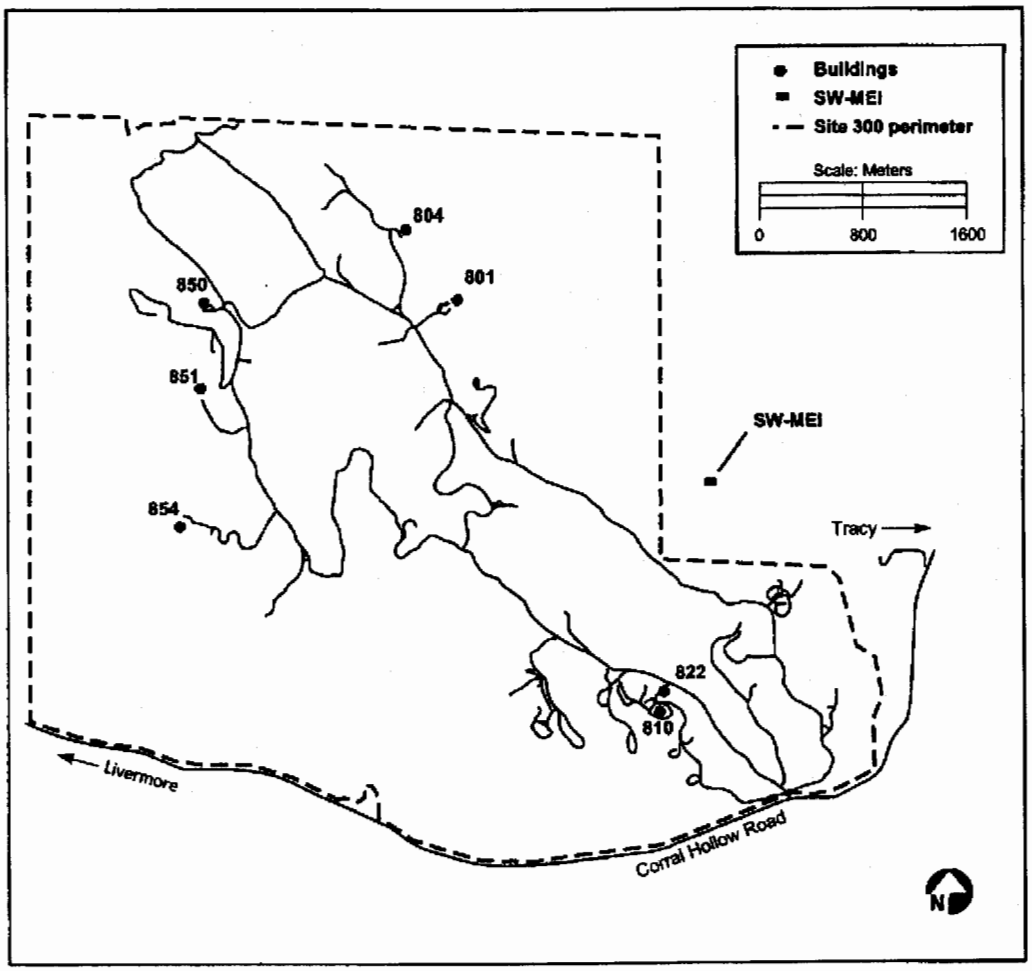

Figure 5. Location of Site-Wide Maximally Exposed Individual (SW-MEI) at Site 300, 1995.

(8.0×10^8 Bq) for 1995. This source term produced a calculated 1995 dose to the SW-MEI of 4.6×10^{-5} mrem (4.6×10^{-4} μSv).

Building 514: Another potential source of diffuse emissions of a variety of radionuclides was HWM waste-storage and treatment operations. Building 514 houses the HWM "tank farm," consisting of six 7,170-liter tanks with ancillary equipment such as pumps, mixers, probes, and a bulking station. The tanks are used to store and treat liquid and solid radioactive and/or mixed wastes. Treatment is performed on a batch basis. Chemicals and waste are added to the tanks to achieve the desired treatment objectives. A 1995 radionuclide inventory was conducted for the facility to determine the diffuse source term (Attachment 1). CAP88-PC modeling gave a 1995 EDE to the SW-MEI of 7.2×10^{-4} mrem (7.2×10^{-3} μSv).

Building 612 Yard: The Building 612 Yard is a potential source of diffuse emissions of tritium. This area is dedicated to hazardous-waste-, radioactive-waste-, and mixed-waste-management activities. The yard consists of several areas where waste containers are stacked outdoors. Many of these containers are not air tight and outgas tritium. A surveillance air monitor has been placed in the Building 612 Yard to provide continuous measurements of tritium near this source. The median annual concentration of tritium in air for 1995 in this area was 0.025 pCi/L (9.3×10^{-4} Bq/L). These data were used to calculate the total tritium emissions from the area, using a conservative approach that assumed the source to be concentrated 120 m south-southwest of the air sampler. With this assumption, CAP88-PC requires a diffuse source emission of 2.1 Ci/y (7.8×10^{10} Bq/y) to produce the concentrations measured at the air sampler. This source term produced a calculated 1995 dose to the SW-MEI from the Building 612 Yard of 1.4×10^{-2} mrem (1.4×10^{-1} μSv).

Southeast Quadrant: The Southeast Quadrant of the Livermore site has elevated levels of ^{239}Pu in the surface soil (from historic waste-management operations) and air (presumably from resuspension). A high-volume air-particulate sampler is located adjacent to the UNCLE Credit Union (the location of the SW-MEI) to monitor the ^{239}Pu levels in this area. Monitoring data from this air sampler were used as a direct measurement of potential dose via the air pathway. The mean annual concentration of ^{239}Pu in air of 2.9×10^{-19} μCi/mL (1.1×10^{-14} Bq/mL), the dose-conversion factor of 3.08×10^5 mrem/μCi (8.33×10^{-5} Sv/Bq) from Federal Guidance Report No. 11, EPA-520/1-88-020, U.S. Environmental Protection Agency (1988) for ^{239}Pu, and the standard-man breathing rates of 1×10^{-10} mL/y were used to calculate the estimated EDE of 9.4×10^{-4} mrem (9.4×10^{-3} μSv) for 1995.

and left to evaporate to the atmosphere before ground water sampling) in this area often contains elevated levels of tritium. During 1995, ground water monitoring operations involved purging three wells with tritium levels above 20,000 pCi/L (740 Bq/L). The evaporation of this water to the atmosphere represents another component of the Pit 7 diffuse emission source term; it was estimated to contribute 1.3×10^8 pCi (4.8×10^6 Bq) during 1995. This emission estimate is based on the total volume of water purged during monitoring activities and the detection levels reported in the 1995 LLNL Site 300 Compliance Monitoring Program Report (UCAR-10191-95-5). The 1995 calculated EDE to the SW-MEI from the combined tritium emissions at the Pit 7 Complex was 3.5×10^{-5} mrem (3.5×10^{-4} μSv).

Well 8 Spring: Tritium released to the soils, and eventually to the ground water, near the Building 850 firing table has been transported to areas where ground water flows near the surface and can evaporate to the atmosphere. Such is the case at the Well 8 Spring, where ground water is very shallow. To estimate tritium flux from this spring, tritium activity data obtained from water samples collected at the spring were used. These data were corrected for radioactive decay, but not for removal by evapotranspiration because the spring was assumed to have a continuous source of tritiated water for the period in question. The affected area of the spring was estimated at 9.3 m^2, and the 1995 source term was estimated to be 2.3×10^{-3} Ci (8.5×10^7 Bq). The 1995 calculated EDE to the SW-MEI from tritium emissions at the Well 8 Spring was 1.4×10^{-7} mrem (1.4×10^{-6} μSv).

Building 802: Tritium in the subsurface soils near the Building 802 firing table may evaporate to the atmosphere. The affected area was estimated to be 900 m^2. Tritium flux was calculated from tritium activity data obtained from subsurface soil samples collected at depths from 0.15 to 3 m. The tritium emission rate from subsurface soils to air was the product of the spatial-average tritium flux, the natural flux of water, the fraction of tritium in the water, and the affected surface area. The 1995 tritium emissions from this source were estimated to be 5.6×10^{-4} Ci (2.1×10^7 Bq). The 1995 calculated EDE to the SW-MEI from tritium emissions at Building 802 was 6.2×10^{-8} mrem (6.2×10^{-7} μSv).

Building 850: Approximately 2.1×10^4 Ci (7.8×10^{14} Bq) of tritium was expended in explosives tests at the Building 850 firing table in the past. Although a significant source of tritium (firing-table gravel) was removed from the area during 1988, tritium remains in subsurface soils beneath the Building 850 firing table, sand pile area, and lower corporation yard. Tritium

NU, and this difference can be used to distinguish between operations-contributed and natural-background-contributed components of the total measured concentration of uranium in air.

Let us denote the fraction (by weight) of uranium contributed by operations as μ and assume the fraction from natural background is then $1 - \mu$ (i.e., we assume these are the only possible sources of uranium at Site 300). Then we can arrive at an expression for μ by writing equations for each uranium isotope as the sum of components from NU and DU. For notation, let M(DU-235) represent the mass, in grams, of the isotope U-235 in DU, M(NU-235) the mass of U-235 in NU, M(CU-235) the mass of U-235 in the composite (measured) uranium, and similarly for U-238 in the three "kinds" of uranium—depleted, natural, and composite. Then

$$M(CU\text{–}235) = \mu \bullet M(DU\text{–}235) + (1\text{-}\mu) \bullet M(NU\text{–}235),$$

and

$$M(CU\text{–}238) = \mu \bullet M(DU\text{–}238) + (1\text{–}\mu) \bullet M(NU\text{–}238).$$

The ratio of these equations is

$$\frac{M(CU-235)}{M(CU-238)} = \frac{\mu \bullet M(DU-235) + (1-\mu) \bullet M(NU-235)}{\mu \bullet M(DU-238) + (1-\mu) \bullet M(NU-238)} .$$

We have available to us the measured CU for ^{235}U and ^{238}U. The apportionment of the CU to NU and DU is calculated on the basis of the weight percents of ^{235}U and ^{238}U for NU and DU as stated above.

Substituting the known fractions contributed by DU–235, DU–238, NU–235, NU–238, yields

$$\frac{M(CU-235)}{M(CU-238)} = \frac{\mu \bullet 0.002 + (1-\mu) \bullet 0.00726}{\mu \bullet 0.998 + (1-\mu) \bullet 0.99274} .$$

After multiplying through and rearranging, we obtain

$$\frac{M(CU-235)}{M(CU-238)} = \frac{0.00726 - 0.00526\mu}{0.99274 + 0.00526\mu} .$$

Finally, solving for μ, we find

$$\mu = \frac{0.00726 - 0.99274\dfrac{M(CU-235)}{M(CU-238)}}{0.00526\dfrac{M(CU-235)}{M(CU-238)} + 0.00526} .$$

This is the desired relation for the fraction of total uranium that is contributed by Lab operations, expressed as a function of the measured (by air sampling) ratio of U-235 to U-238 for total (composite) uranium in air; μ for 1993 is 0.4, for 1994 is 0.5, for 1995 is 0.3.

Using these calculations to apportion the M(CU), we obtain an annual average concentration of DU in air from resuspension of 3.15×10^{-11} g/m^3 for 1993, 4.79×10^{-11} g/m^3 for 1994, and 1.58×10^{-11} g/m^3 for 1995.

Eliminating Double Counting: Our previous estimates of the dose to the SW-MEI from resuspended uranium at Site 300 were unnecessarily conservative for another reason besides our assumption that $\mu = 1$. We engaged in double counting, by allowing the depleted uranium from explosives experiments to contribute to the dose first as a direct release into the air during the detonation and subsequent dispersal in air, and then again as a resuspension product when wind disturbs the soil where this uranium has deposited.

To approximately correct for this double counting, we eliminate, when evaluating the observed U-235 to U-238 ratio, all months in which explosives experiments involving depleted uranium occurred. Thus, for 1993 data the months of April, August, September, and November would be excluded; for 1994, data from the months of April, May, September, October, and December would be excluded; and for 1995, the months of March, April, May, June, and August would be excluded. With these months excluded, μ for 1993 remains 0.4, while for 1994 it is reduced to 0.09, and for 1995 it is reduced to 0.1.

Using these calculations to apportion the M(CU) for 1993, and excluding the appropriate months, we obtain an annual average concentration of DU in air from resuspension of 1.83×10^{-11} g/m^3. Similarly, using these calculations for 1994, and excluding months when experiments involving depleted uranium occurred, we obtain an annual average concentration of DU in air from resuspension of 3.41×10^{-12} g/m^3. Finally, applying these calculations, and excluding the appropriate months, we obtain an annual average concentration of DU in air from resuspension of 7.01×10^{-12} g/m^3.

SECTION V. Certification

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein, and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

Name: James Hirahara
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Signature: James Hirahara **Date:** 6/20/96
James Hirahara

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: Dennis K. Fisher
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Dennis K. Fisher

SECTION VI. Supplemental Information

Collective Effective Dose Equivalent

Population doses, or collective EDEs, for both LLNL sites were calculated out to a distance of 80 km in all directions from the site-centers using CAP88-PC. As noted earlier, CAP88-PC evaluates the four principal exposure pathways: ingestion through food and water consumption, inhalation, air immersion, and irradiation by contaminated ground surface.

Population distributions centered on the two LLNL sites were compiled from 1990 census data. Key population centers affected by LLNL emissions are the relatively nearby communities of Livermore and Tracy, and the more distant metropolitan areas of Oakland, San Francisco, and San Jose, as well as the San Joaquin Valley communities of Modesto and Stockton. Within the 80 km outer distance specified by the EPA, there are 6.3 million residents included for the Livermore site collective dose determination, and 5.4 million for Site 300. Our population data files (distribution of population with distance and direction) are shown in Tables 6 and 7 for the Livermore site and Site 300, respectively.

Table 6. Population distribution for LLNL's Livermore site, based on 1990 census information. Values are population (in thousands) in sector segments bounded by the indicated inner and outer radii, for each of sixteen 22.5-degree-sector directions.

	Range of distance from site (km)					
Direction	0-16	16-32	32-48	48-64	64-80	Total
N	17	15	121	25	15	**193**
NNW	17	16	173	149	46	**401**
NW	17	53	136	291	17	**514**
WNW	27	13	509	715	232	**1496**
W	28	167	146	211	3	**555**
WSW	27	222	319	19	7	**594**
SW	27	58	199	50	49	**383**
SSW	7	44	700	82	99	**932**
S	7	6	7	111	47	**178**
SSE	7	10	7	10	11	**45**
SE	7	7	6	10	18	**48**
ESE	7	9	8	74	145	**243**
E	7	8	82	22	38	**157**
ENE	7	7	48	169	16	**247**
NE	7	11	10	63	78	**169**
NNE	17	22	6	7	74	**126**
Total	**233**	**668**	**2477**	**2008**	**895**	**6281**

length, and relocation of some samplers to meet certain location requirements for sample extraction. The upgrades will ensure the extraction of representative samples as specified by the ANSI N13.1-1969 guidelines called for by 40 CFR 61 Subpart H.

In addition to the sampling system upgrades, anemometer-type, multi-port velocity probes were designed, fabricated, and installed at the sampling locations. These were calibrated using procedures in 40 CFR 60 Appendix A. The velocity probes provide for continuous and near real-time measurement of the exhaust flow from the discharge points. In all, the upgrades involved modifications to 19 aerosol sampling systems and the installation of 21 velocity probes.

These upgrades took three years to complete at a cost of $950,000.

Site Periodic Confirmatory Measurements

LLNL uses a graded approach to determine the required level of periodic confirmatory measurements. The greater the calculated EDE, the more intensive the measurements will be. LLNL invokes a four-tier approach: (1) continuous monitoring at selected facilities, (2) annual effluent sampling, (3) general surveillance monitoring, and (4) site-specific surveillance monitoring, as described below.

Continuous Monitoring: There are currently nine buildings (Buildings 166, 175, 231, 251, 331, 332, 419, 490, and 491) at the LLNL site that have radionuclide air-monitoring systems. These buildings are listed in Table 8, along with the number of samplers, the types of samplers, the analytes of interest, and the number of monitored discharge points at the building. In all, there are 103 samplers operating continuously. Many would operate from emergency power systems if normal power were lost.

In 1995, a new sampling system was installed at Building 166, the Pyrochemistry Demonstration Facility, to continuously sample for potential emissions of uranium particles. Before operations began, a NESHAPs assessment was performed. Results indicated that the MEI resulting from estimated emissions (assuming no control devices) exceeded 0.1 mrem/y (1.0 μSv/y), and therefore required continuous sampling. The sampler was installed in the exhaust from glove boxes where the operations are performed. Operations are HEPA filtered.

the CAM units provide an alarm capability for the facility in the event of a release of alpha activity.

Detection of gross alpha and beta activity resulting from particles collected on the air filters is accomplished using gas-flow-proportional counters. Analysis is delayed for at least four days from sample termination to allow for the decay of naturally occurring radon daughters. For verification of the operation of the counting system, calibration sources, as well as background samples, are intermixed with the sample filters for analysis. Analysis is performed by the Radiological Measurements Laboratory (RML) in the Hazards Control Department (HCD).

Each stack of the Tritium Facility (Building 331) is monitored for tritium release by both a continuous-monitoring alarm system and continuous molecular-sieve samplers. The alarmed samplers, Overhoff ion chambers, provide real-time tritium concentration release levels (HT and HTO). The sieve samplers, which can discriminate between tritiated-water (HTO) vapor and molecular tritium (HT), provide the values used for environmental reporting and are exchanged weekly or bi-weekly depending on the rate of tritium releases expected from planned work. Each sieve sampler (unalarmed) is in parallel with an alarmed monitor and consists of two molecular sieves. The first sieve collects tritiated water vapor; then a palladium-coated catalyst converts molecular tritium to tritiated water, which is then collected on a second sieve. The molecular sieve samples are submitted to the Hazards Control Analytical Laboratory where they are installed into a recovery system for the bake-out of tritiated-water vapor and subsequent condensation and collection of the water. The retrieved tritiated water is analyzed by RML using liquid-scintillation counting techniques. New continuous air-effluent-flow-measurement systems were installed as part of the efforts previously discussed in the stacks of the Tritium Facility.

Data from air-particulate-sampling filter and molecular-sieve analyses are reviewed by the Hazards Control Department Health Physicist responsible for each facility and an Environmental Protection Department Environmental Analyst.

Annual Effluent Sampling: For point sources where the fence line EDE is between 0.1% and 1% of the NESHAPs emission standard of 10 mrem/y (100 μSv/y) (between 0.01 and 0.1 mrem/y or 0.1 and 1.0 μSv/y), and no existing monitoring system is in place, LLNL strives to perform annual confirmatory sampling. Measurements of the effluent from such sources are planned for the year following the annual dose assessment. These

releases. For example, the FSP for the Plutonium Facility (Building 332) describes in detail the procedure for responding to detection of radioactive materials in a release from the stacks. These documents also describe the sample-collection systems for both continuous and passive (i.e., not alarmed) air-monitoring systems (CAM and PAM, respectively), including sampling probes and procedures to be used for measuring flow rates, sampling, and calibration. Similarly, the FSP for the Tritium Facility (Building 331) describes its stack monitoring system, which includes molecular-sieve detectors for tritiated water (HTO) and elemental tritium gas (HT).

The RML Quality Assurance Program describes laboratory-analysis procedures, precision, accuracy and completeness objectives, sample-tracking procedures, quality-control (QC) sampling, sample handling, and data reporting. For example, the Gross Alpha-Beta Procedures Manual of the RML describes operational procedures for analyzing the CAM and PAM filters for radioactivity.

EPD, which is responsible for NESHAPs modeling and reporting, also operates under a Quality Assurance Management Plan and associated procedures. Detailed records are kept of all measurements, model runs, and calculations, and selected model runs are validated. The Terrestrial and Atmospheric Monitoring and Modeling Group (TAMM) of EPD is responsible for modeling and reporting radionuclide emissions for NESHAPs compliance. TAMM members continue to refine mechanisms that ensure they are informed whenever new operations are proposed, significant changes in radionuclide inventories occur, or existing operations are modified so that NESHAPs modeling can be performed and appropriate action taken. All NESHAPs calculations are archived with the supporting information used to make the calculations.

Quality Control (QC) for 1995 Radiological Inventory Update and Modeling

Radiological Inventory Update QC: Approximately 15% of the 21 Livermore-site facilities that completed radiological-inventory updates in 1995 were randomly selected for validation. For this QC check, radiological inventories from four potential emission points were selected for validation: one each in Buildings 222, 253, 327 and 362. An EPD Environmental Analyst contacted the responsible party who signed the NESHAPs Inventory Forms and physically visited and inspected the facilities to verify inventory data. The responsible party was asked to demonstrate how he/she arrived at the data submitted on the original inventory form. Stack parameters also were verified. The QC data

Attachment 1. 1995 LLNL NESHAPs Annual Report Spreadsheet

Guidance for Interpreting Attachment 1

A generalized description of each facility and its operations is provided on the spreadsheet. In addition, the following information is shown for each listed emission point or stack:

- Building and room number(s)
- Specific stack identification code(s)
- Generalized operations in the room(s) or area(s)
- Radionuclides utilized during 1995
- Annual radionuclide inventory with potential for release (by isotope, in curies)
- Physical-state factors (by isotope)
- Stack parameters
- Emission-control devices and emission-control-device abatement factors
- Estimated or measured annual emissions (by isotope)
- Distance and direction to the site-wide maximally exposed individual (SW-MEI)
- Calculated EDE to the SW-MEI
- Distance and direction to the maximally exposed individual for that specific source (MEI)
- Calculated EDE to the MEI (source term not adjusted for emission controls)
- Source category
- Below Appendix E Quantity (Y or N)

Radionuclides: The radionuclides shown in the spreadsheet are those from specific emission points where air emissions were possible. If radionuclides were present, but encapsulated or sealed for the entire year, radionuclides, annual inventories, and emissions are not listed.

For Building 231, Room 1128 (a Materials Management vault that is used for receipt, shipment, and storage of sealed radioactive sources), the variety and turnover of radionuclides makes a listing of individual radionuclides and their inventories impractical. This area is continuously monitored, and emissions are therefore directly determined.

Radionuclide Inventories with Potential for Release: The annual radionuclide inventories for point-source locations are based on data from

Estimated Annual Emissions: For unmonitored and non-continuously monitored sources, estimated annual emissions for each radionuclide are based on the product of (1) inventory data, (2) EPA potential-release fractions (physical-state factors), and (3) applicable emission-control-device abatement factors.

Actual emission measurements are the basis for reported emissions from continuously monitored facilities. LLNL facilities that have continuous monitoring systems are Buildings 166, 175, 231-vault, 251, 331, 332, 419, 490, and 491. See page 9 for a discussion of the use of emissions measurements for monitored sources.

10 mrem/y Site-Wide Dose Requirement: For LLNL to comply with the NESHAPs regulations, the LLNL site-wide maximally exposed individual (SW-MEI; defined as the hypothetical member of the public at a single residence, school, business, or office who receives the greatest LLNL-induced EDE from the combination of all radionuclide source emissions) cannot receive an EDE greater than 10 mrem/y (100 μSv/y).

In Attachment 1, the distance and direction to the respective SW-MEI are shown for each facility at each site. Doses to the site-specific SW-MEIs were evaluated for each source and then totaled for site-specific evaluations against the 10 mrem/y dose standard (see "Compliance Assessment" in Section III).

0.1 mrem/y Monitoring Requirement: To assess compliance with the requirement for continuous monitoring (potential dose greater than 0.1 mrem/y [1.0 μSv/y]), emissions must be individually evaluated from each point source; the location of the maximally exposed public individual (MEI) is generally different for each emission point. The maximum dose at a location of unrestricted public access typically occurs at a point on the site perimeter. Therefore, it is often referred to as the maximum "fence line" dose, although the off-site maximum dose could occur some distance beyond the perimeter. (This could happen, e.g., when the perimeter is close to a stack; however, for all emission points at the Livermore site and Site 300, calculations show that ground-level concentrations of radionuclides decline monotonically beyond LLNL boundaries.) As stipulated by the regulations, modeling for assessment of continuous monitoring requirements assumed unabated emissions (i.e., no credit was taken for emission abatement devices, such as filters), but physical-state factors were applied.

The unabated EDE cannot be calculated for monitored facilities. Because the monitoring equipment is placed after HEPA filtration, there is no way to

obtain an estimate for what the emissions might have been had there been no filtration. It is not reasonable to apply factors for the effects of the HEPA filters on the emission rate because most of what is measured on the HEPA filters is the result of the radioactive decay of radon, which is capable of penetrating the filter. Attachment 1 gives, for each inventoried point source, the dose to the MEI and the distance and direction to the LLNL fence line where the MEI is located. However, for monitored sources, no value is shown.

Source Categories: LLNL radionuclide air-emission sources have been classified into six source categories, indicated by the number in the next to last column of the spreadsheet: (1) Unmonitored or non-continuously monitored Livermore-site facilities that have had a radionuclide-inventory update for 1995; (2) Unmonitored or non-continuously monitored Livermore site facilities with a previous (1994) radionuclide-inventory update; (3) Continuously monitored Livermore-site facilities; (4) Site 300 explosives experiments; (5) Diffuse sources where emissions and subsequent doses were estimated using inventory processes; and (6) Diffuse sources where emission and dose estimates were supported by environmental-surveillance measurements.

Below Appendix E Quantity: In 1995, DOE and EPA entered into a memorandum of understanding that, among other things, made the contents of 40 CFR 61, Appendix E acceptable "other procedures" for DOE facilities to establish compliance with Section 61.93(a) of Subpart H. Part of Appendix E is a list of "Annual Possession Quantities for Environmental Compliance." Facilities having less than these quantities of radionuclides need not report to EPA under NESHAPs. A letter "Y" in this column denotes those inventoried sources at LLNL facilities that contain radionuclides in amounts below the annual possession quantities listed in Appendix E.

Attachment 1 - 1995 LLNL NESHAPs Annual Report Spreadsheet

Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/yr Site-Wide Dose Requirement Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	0.1 mrem/yr Monitoring Requirement Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)	Source Category	Below App. E Quantity
222	1169	FHE-1808	Chemical Analysis	Gross Alpha	1.0E-08	1.0E-03	10.7	0.97	19.4	None	1	1.0E-11	1239	ENE	1.4E-09	253	SW	4.4E-09	2	Y
				Gross Beta	1.0E-08	1.0E-03						1.0E-11								Y
222	1216B	FHE-1808	Chemical Analysis	Gross Alpha	1.0E-06	1.0E-03	10.7	0.97	19.4	None	1	1.0E-09	1239	ENE	1.4E-07	253	SW	4.4E-07	2	Y
				Gross Beta	1.0E-06	1.0E-03						1.0E-09								Y
				Ni-63	7.5E-02	1.0E-06						7.5E-08								Y
222	1223A/B	FHE-1800	No Operations	None	None	NA	10.7	0.97	19.4	HEPA	0.01	0.0E+00	1239	ENE	0.0E+00	NA	NA	0.0E+00	2	Y
222	1228B	FHE-1800	Chemical analysis of waste	Gross Alpha	2.8E-06	1.0E-03	10.7	0.97	19.4	None	1	2.8E-09	1239	ENE	3.4E-07	253	SW	1.1E-06	2	Y
				Gross Beta	2.5E-06	1.0E-03						2.5E-09								Y
222	1316B***	FHE-1808/HDCH-21	Analysis of waste samples	H-3	4.5E-07	1.0E-03	10.7	0.97	19.4	None	1	4.5E-10	1238	ENE	5.2E-08	191	SSW	2.1E-07	1	Y
	1316C***	FHE-67	Sample preparation	Gross Alpha	3.8E-07	1.0E-03	5.0	0.26	4.3	None	1	3.8E-10								Y
				Gross Beta	3.8E-07	1.0E-03						3.8E-10								Y
				Gamma	3.8E-07	1.0E-03						3.8E-10								Y
222	1405	Room Air	Chemical analysis	Gross Alpha	4.9E-07	1.0E-03	NA	NA	NA	None	1	4.9E-10	1239	ENE	1.1E-07	253	SW	3.1E-06	2	Y
				Gross Beta	4.9E-07	1.0E-03						4.9E-10								Y
222	1421	FHE-2060	Chemical analysis	U-234	1.3E-14	1.0E-03	10.7	0.84	13.7	None	1	1.3E-17	1239	ENE	1.4E-15	253	SW	5.6E-15	2	Y
				U-235	1.4E-15	1.0E-03						1.4E-18								Y
				U-238	1.2E-14	1.0E-03						1.2E-17								Y
222	1425	FHE-2060	Chemical analysis	Ni-63	2.8E-02	1.0E+00	10.7	0.84	13.7	None	1	2.8E-02	1239	ENE	1.6E-04	253	SW	6.5E-04	2	Y
223	1506	FHE-106	Gas chromatography	H-3	3.1E-01	1.0E+00	5.0	0.25	9.3	None	1	3.1E-01	1238	ENE	1.7E-04	253	SW	1.6E-03	2	Y
222	1607***	Room Air	Analysis of gravel samples	H-3	1.1E-06	1.0E+00	NA	NA	NA	None	1	1.1E-06	1238	ENE	6.9E-10	253	SW	7.3E-09	1	Y
	1613A***	Room Air	Analysis of samples	Gross Alpha	8.0E-12	1.0E-03	NA	NA	NA	None	1	8.0E-15								Y
	1520B***	Room Air	Uranium oxide dissolution studies	Gross Beta	8.0E-12	1.0E-03	NA	NA	NA	None	1	8.0E-15								Y
				Gamma	8.0E-12	1.0E-03						8.0E-15								Y
				U-238	1.8E-11	1.0E-03						1.8E-14								Y
				U-235	8.8E-11	1.0E-06						8.8E-17								Y
222	1611B	FHE-114	Chemical analysis	U-234	2.6E-12	1.0E-03	6.1	0.36	4.8	None	1	2.6E-15	1239	ENE	3.0E-13	253	SW	9.5E-13	2	Y
				U-235	1.1E-13	1.0E-03						1.1E-16								Y
				U-238	2.4E-12	1.0E-03						2.4E-15								Y
222	1515B	FHE-73	Chemical analysis	Gross Alpha	2.0E-06	1.0E-03	5.0	0.25	9.3	None	1	2.0E-09	1238	ENE	4.4E-07	253	SW	4.2E-06	2	Y
				Gross Beta	2.0E-06	1.0E-03						2.0E-09								Y
222	1520	FHE-118	Optical emission spectroscopy	U-234	3.2E-09	1.0E-06	4.4	0.38	7.4	None	1	3.2E-15	1238	ENE	5.0E-13	263	SW	4.9E-12	2	Y
				U-235	1.4E-10	1.0E-06						1.4E-16								Y
				U-238	3.0E-09	1.0E-06						3.0E-15								Y
222	1520B	FHE-73	Sample preparation	U-234	3.2E-09	1.0E-06	4.9	0.33	6.5	None	1	3.2E-15	1238	ENE	5.0E-13	263	SW	4.9E-12	2	Y
				U-235	1.4E-10	1.0E-06						1.4E-16								Y
				U-238	3.0E-09	1.0E-06						3.0E-15								Y
222	1520C	Room Air	Gravimetric	U-234	3.2E-09	1.0E-06	NA	NA	NA	None	1	3.2E-15	1238	ENE	6.1E-13	253	SW	1.7E-11	2	Y
				U-235	1.4E-10	1.0E-06						1.4E-16								Y
				U-238	3.0E-09	1.0E-06						3.0E-15								Y
222	1523C	FHE-84	Chemical extraction	Gross Alpha	1.2E-06	1.0E-03	6.1	0.23	11.8	None	1	1.2E-09	1238	ENE	2.4E-07	253	SW	2.2E-06	2	Y
				Gross Beta	1.2E-06	1.0E-03						1.2E-09								Y

Attachment 1 - 1995 LLNL NESHAPs Annual Report Spreadsheet

Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10_meaner Rim-Wise Dose Assessment Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	0.1_meaner Monitoring Requirement Distance to MEI (m)	Direction to MEI	Unadjusted EDE (mrem)	Source Category	Below App. E Quantity
Building 224 is operated by the Chemistry and Materials Science Directorate. The facility houses laboratories that perform digestion and analysis of waste samples.																				
224	110	FHE-1000	Sample digestion/ chemical analysis	Gross Alpha Gross Beta	2.5E-04 2.5E-04	1.0E-03 1.0E-03	7.6	0.31	11.0	None	1	2.5E-07 2.5E-07	1170	ENE	4.8E-08	255	SW	3.5E-04	2	Y Y
224	114	FHE-5	Waste collection	Gross Alpha Gross Beta	5.0E-05 5.0E-05	1.0E-03 1.0E-03	5.6	0.41	3.5	None	1	5.0E-08 5.0E-08	1173	ENE	1.3E-08	253	SW	1.1E-04	2	Y Y
224	115	FHE-4	Chemical analysis	Gross Alpha Gross Beta	5.0E-08 5.0E-08	1.0E-03 1.0E-03	6.7	0.33	5.8	None	1	5.0E-11 5.0E-11	1170	ENE	1.1E-08	265	SW	9.0E-08	2	Y Y
224	117	FHE-1	Chemical analysis	Gross Alpha Gross Beta	1.0E-07 1.0E-07	1.0E-03 1.0E-03	5.9	0.25	9.5	None	1	1.0E-10 1.0E-10	1170	ENE	2.2E-08	253	SW	1.0E-07	2	Y Y
Building 226 is operated by the Chemistry and Materials Science Directorate. The facility houses chemistry laboratories that prepare and analyze various media such as soil, vegetation, and waste samples for toxic chemical and radioactivity analysis. Radioactive material can exist in this facility, either in the samples or in the prepared standards.																				
226	108	FE-4	Scintillation counting	Gross Alpha Gross Beta	2.5E-11 2.5E-11	1.0E-03 1.0E-03	6.4	0.10	11.1	None	1	2.5E-14 2.5E-14	1155	ENE	6.3E-12	298	SW	4.3E-11	2	Y Y
226	109	FHE-3	Sample preparation	Gross Alpha Gross Beta	2.5E-09 2.5E-09	1.0E-03 1.0E-03	6.9	0.28	7.6	None	1	2.5E-12 2.5E-12	1156	ENE	5.0E-10	296	SW	4.1E-09	2	Y Y
Building 227 is part of the Chemistry and Material Science Directorate. In room 1063, liquid samples containing very small amounts of depleted uranium are studied to determine the leaching properties of natural waters.																				
227	1028	HDCH-9/FHE-1000	Analysis of waste samples	U-238	6.8E-10	1.0E-03	13.7	1.12	12.8	None	1	5.0E-10	1155	ENE	3.0E-10	292	SSW	7.5E-10	1	Y
227	1038	Room Air	No Operations	None	None	NA	NA	NA	NA	None	1	0.0E+00	1156	ENE	0.0E+00	344	SW	0.0E+00	2	Y
227	1044	Room Air	No Operations	None	None	NA	NA	NA	NA	None	1	0.0E+00	1156	ENE	0.0E+00	344	SW	0.0E+00	2	Y
227	1063	Room Air	Leaching studies	U-234 U-235 U-238	1.1E-06 4.7E-08 1.5E-06	1.0E-03 1.0E-03 1.0E-03	NA	NA	NA	None	1	1.1E-09 4.7E-11 1.0E-09	1155	ENE	2.4E-07	344	SW	3.9E-06	2	Y Y Y
227	1064	Room Air	Leaching studies	U-234 U-235 U-238	3.2E-08 1.4E-09 3.0E-06	1.0E-03 1.0E-03 1.0E-03	NA	NA	NA	None	1	3.2E-11 1.4E-12 3.0E-11	1156	ENE	7.0E-09	344	SW	1.1E-07	2	Y Y Y
The 231 complex houses research and development activities conducted by the Chemistry and Materials Science Directorate, Engineering, Weapons Engineering, and Safeguards and Security Materials Management Division. Management oversight for Building 231 is provided by the Engineering Directorate through the Engineering Sciences Division. *Gross alpha and gross beta emissions are continuously monitored at the stack. Monitoring data, rather than the inventory approach, are used to determine emissions. **Because monitoring takes place after HEPA filtration, an unadjusted EDE cannot be determined (see discussion on page 40)																				
231	1128	FHE-91-1,2	Storage of Radionuclides	Gross Alpha	*	NA	12.2	0.41	12.0	HEPA	0.01	0.0E+00	1197	E	0.0E+00	- -	- -	- -	3	N/A
231	1330	FHE-63/64	Repackaging	U-234 U-235 U-238	9.3E-01 1.3E-01 1.0E+01	1.0E-06 1.0E-06 1.0E-06	10.0	0.56	5.0	HEPA	0.01	9.3E-09 1.3E-09 1.0E-07	1167	ENE	6.7E-06	568	SW	1.8E-03	2	Y Y N
231	1351	FHE-63/64	Verification of packaging	U-234 U-235 U-238	9.3E+00 1.3E+00 1.0E+02	1.0E-06 1.0E-06 1.0E-06	10.0	0.56	5.0	HEPA	0.01	9.3E-08 1.3E-08 1.0E-06	1167	ENE	6.7E-05	568	SW	1.8E-02	2	N Y N
231	1600	Room Air	Tensile testing	U-234 U-235 U-238	1.4E-06 2.0E-08 1.5E-06	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	1.4E-12 2.0E-14 1.5E-12	1167	E	2.5E-19	568 and 671	SW W	1.7E-08 1.7E-08	1	Y Y Y
231	1737	FHE-54	Electron beam welding	Th-232	3.2E-06	1.0E-06	10.5	0.48	2.0	HEPA	0.01	3.2E-14	1167	ENE	6.1E-12	568	SW	1.6E-06	2	Y
231	1737A	FHE-54	No Operations	None	None	NA	10.5	0.48	2.0	None	1	0.0E+00	1167	ENE	0.0E+00	NA	NA	0.0E+00	2	Y
231	1900HB	FOB-7/8	Storage	U-234 U-235 U-238	1.0E-10 2.0E-11 2.0E-09	1.0E-06 1.0E-06 1.0E-06	2.4	0.20	14.4	None	1	1.0E-16 2.0E-17 2.0E-15	1167	ENE	2.0E-13	568	SW	5.5E-13	2	Y Y Y
231	1944	FHE-42	Heat treatment studies	U-234 U-235 U-238	1.0E-10 2.0E-11 2.0E-09	1.0E-06 1.0E-06 1.0E-06	2.4	0.36	10.4	HEPA	0.01	1.0E-18 2.0E-19 2.0E-17	1167	ENE	1.3E-15	568	SW	2.0E-13	2	Y Y Y
231	1945	FHE-40	Sample preparation	U-234 U-235 U-238	1.0E-10 2.0E-11 2.0E-09	1.0E-06 1.0E-06 1.0E-06	18.7	0.36	3.6	None	1	1.0E-16 2.0E-17 2.0E-15	1167	ENE	1.4E-13	680	SW	4.1E-13	2	Y Y Y
231	1945A	Room Air	Scanning electron microscopy	U-234 U-235 U-238	1.0E-13 2.0E-14 2.0E-12	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	1.0E-19 2.0E-20 2.0E-18	1167	ENE	2.3E-16	439	SSW	1.7E-16	2	Y Y Y
231	1945B	FHE-40	Metallography sample preparation	U-234 U-235 U-238	6.0E-03 3.5E-04 1.2E-02	1.0E-03 1.0E-03 1.0E-03	18.7	0.36	3.6	None	1	6.0E-06 3.5E-07 1.2E-05	1167	ENE	1.3E-03	568	SW	3.7E-03	2	Y Y N
231	1945C	Room Air	Microscopy	U-234 U-235 U-238	1.0E-13 2.0E-14 2.0E-12	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	1.0E-19 2.0E-20 2.0E-18	1167	ENE	2.3E-16	439	SSW	1.7E-15	2	Y Y Y
231	1945D	Room Air	Metallographic analysis	U-234 U-235 U-238	1.0E-10 2.0E-11 2.0E-09	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	1.0E-16 2.0E-17 2.0E-15	1167	ENE	2.3E-13	439	SSW	1.7E-12	2	Y Y Y

Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/y Site-Wide Dose Requirement: Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	0.1 mrem/y Monitoring Requirement: Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)	Source Category	Below App. E Quantity
231	1048E	Room Air	Wet grinding/polishing	U-234 U-235 U-238	1.9E-07 2.9E-08 2.9E-06	1.0E-03 1.0E-03 1.0E-03	NA	NA	NA	None	1	1.9E-10 2.9E-11 2.9E-09	1167	ENE	2.3E-07	488	SSW	1.7E-06	2	Y Y Y
231	1056A	FQ08E-7R	Metal casing	U-234 U-235 U-238	9.2E-08 1.3E-08 8.9E-06	1.0E-06 1.0E-06 1.0E-06	2.4	0.20	14.3	None	1	9.2E-12 1.3E-12 8.9E-11	1167	ENE	9.8E-09	568	SW	2.7E-06	2	Y Y Y
231	1056A	FHE-43	Metal casing	U-234 U-235 U-238	9.2E-08 1.3E-08 8.9E-06	1.0E-06 1.0E-06 1.0E-06	8.6	0.60	7.2	HEPA	0.01	9.2E-14 1.3E-14 8.9E-13	1167	ENE	9.8E-11	568	SW	1.9E-06	2	Y Y Y
231	2934	FHE-23	Lapping/cutting/etching	U-234 U-235 U-238	3.7E-07 9.1E-08 4.0E-06	1.0E-03 1.0E-03 1.0E-03	12.8	0.35	1.7	None	1	3.7E-10 9.1E-11 4.0E-09	1167	ENE	2.8E-07	568	SW	7.9E-07	2	Y Y Y
Building 235 is part of the Chemistry and Materials Sciences Directorate. Operations in the facility include examination of material structure, surface, and subsurface; precision milling, ion implanting, and metallurgical studies. Most of the depleted uranium in this building is there for characterization studies; some is used for ion beam implantation experiments. Chemical characterization studies take place in rooms 1190, 1224, and 1229. Up to 500 grams each of depleted uranium and thorium might be present in each of these rooms.																				
235	1190	FHE-2001	No Operations	None	None	NA	11.1	2.30	0.2	HEPA	0.01	0.0E+00	1065	ENE	0.0E+00	NA	NA	0.0E+00	2	Y
235	1121	Room Air	Scanning electron microscopy	U-234 U-235 U-238	1.1E-09 4.7E-10 1.0E-08	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	1.1E-14 4.7E-15 1.0E-14	1065	ENE	2.7E-12	556	SW	1.7E-11	2	Y Y Y
235	1123	Room Air	No Operations	None	None	NA	NA	NA	NA	None	1	0.0E+00	1065	ENE	0.0E+00	NA	NA	0.0E+00	2	Y
235	1128	Room Air	Scanning electron microscopy	U-234 U-235 U-238	5.4E-10 2.9E-11 9.0E-10	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	5.4E-16 2.9E-17 9.0E-16	1066	ENE	1.6E-13	556	SW	1.0E-12	2	Y Y Y
235	1131	FHE-2	Metallographic sample preparation	U-234 U-235 U-238	1.0E-04 7.9E-06 1.7E-04	1.0E-06 1.0E-06 1.0E-06	6.2	0.31	12.3	None	1	1.0E-10 7.9E-12 1.7E-10	1065	ENE	2.7E-08	556	SW	7.8E-08	2	Y Y Y
235	1133	Room Air	Microstructure examination	U-234 U-235 U-238	3.3E-08 2.3E-07 5.0E-06	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	3.3E-12 2.3E-13 5.0E-12	1065	ENE	1.3E-09	556	SW	8.6E-09	2	Y Y Y
235	1135	FHE-1001HO-13	Sample preparation	U-234 U-235 U-238	1.1E-06 4.7E-10< 1.0E-08	1.0E-06 1.0E-06 1.0E-06	9.8	2.30	2.4	HEPA	0.01	1.1E-16 4.7E-18 1.0E-10	1065	ENE	1.6E-14	556	SW	3.5E-12	2	Y Y Y
235	1224	FHE-1001HO-21	Sputter coating	U-234 U-235 U-238	1.7E-06 2.4E-06 1.0E-04	1.0E-06 1.0E-06 1.0E-06	9.8	2.30	2.4	HEPA	0.01	1.7E-13 2.4E-14 1.0E-12	1065	ENE	1.4E-10	556	SW	3.1E-08	2	Y Y Y
235	1226	FHE-1001HO-22	Target cleaning	U-234 U-235 U-238	1.7E-05 2.4E-06 1.0E-04	1.0E-06 1.0E-06 1.0E-06	9.8	2.30	2.4	HEPA	0.01	1.7E-13 2.4E-14 1.0E-12	1065	ENE	1.4E-10	556	SW	3.1E-08	2	Y Y Y
235	1251	FHE-2001	No Operations	None	None	NA	11.1	2.30	0.2	HEPA	0.01	0.0E+00	1065	ENE	0.0E+00	NA	NA	0.0E+00	2	Y

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/y Site-Wide Dose Assessment Distance to SWME (m)	Direction to SWME	EDE (mrem)	0.1 mrem/y Monitoring Assessment Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)	Source Category	Below App. E Quantity
Building 241 is administered by the Chemistry and Material Sciences Directorate for material properties research and testing. Radionuclide emissions result from contamination from past operations that have been discontinued.																				
241	1600	FGBE-44	Oxidation of uranium	U-238	1.0E-09	1.0E-05	12.5	0.30	5.8	HEPA	0.01	1.0E-18	1140	E	6.2E-16	821	SW	1.0E-12	2	Y
241	1629	Room Air	X-ray diffraction analysis	U-238	6.0E-11	1.0E-03	NA	NA	NA	None	1	6.0E-14	1140	E	4.3E-13	897	W	9.6E-11	2	Y
241	1622	Room Air	X-ray diffraction analysis	U-238	2.0E-08	1.0E-05	NA	NA	NA	None	1	2.0E-14	1140	E	1.4E-12	897	W	1.2E-11	2	Y
241	1638	FGBE-9 610	Ceramic waste form research	U-238	6.9E-06	1.0E-03	12.2	0.46	1.8	HEPA	0.01	6.9E-13	1140	E	3.7E-11	661	SSW	9.2E-09	1	Y
241	1641	FHE-53	Reaction of uranium oxide with chlorine	U-238	7.0E-07	1.0E-03	7.0	0.26	11.2	HEPA	0.01	7.0E-12	1140	E	3.0E-10	621	SW	8.7E-09	2	Y
241	1667	FGBE-27	No Operations	None	None	NA	11.3	0.23	21.7	HEPA	0.01	0.0E+00	1140	E	0.0E+00	NA	NA	0.0E+00	2	Y
241	1688	FHE-37	UV spectroscopy	U-238	3.0E-11	1.0E-03	7.0	0.25	14.9	None	1	3.0E-14	1140	E	1.3E-13	621	SW	3.4E-12	2	Y
Building 251, the Heavy Element Facility, is operated by the Defense and Nuclear Technologies Directorate as a facility for handling radioactive materials, especially transuranic isotopes. One area of the facility has been "hardened" to resist damage from earthquakes. Room exhausts from this hardened area are double HEPA filtered, glove box exhausts are triple HEPA filtered. Exhausts from the hardened area are continuously monitored by alpha alarm detectors (CAMs). Exhausts from the unhardened area, also HEPA filtered, are continuously sampled by simple filter systems. *Air exhausts of the Building 251 hardened area are required to have continuous monitoring; measured emissions, rather than the inventory approach, are used to determine annual emissions. **Because monitoring takes place after HEPA filtration, an assisted EDE cannot be determined (see discussion on page 40.) ***Stack emissions have been combined as permitted by the EPA/DOE Memorandum of Understanding.																				
251	Unhardened Area Fume glove box exhaust	FGBE-13,16	General Chemistry	Gross Alpha Gross Beta	*	NA	5.5	0.10	5.9	Double HEPA	0.0001	7.3E-08 6.1E-07	1188	E	1.8E-06	**	**	**	3	N/A
251	Unhardened Area Fume hood and glove box exhaust***	FHE-5	General Chemistry	Gross Alpha Gross Beta	*	NA	4.3	0.20	9.5	Double HEPA	0.0001	0.0E+00 0.0E+00	1188	E	0.0E+00	**	**	**	3	N/A
		FHE-4					4.3	0.27	4.2											
		FHE-6					8.4	0.26	8.0											
		FHE-7					8.4	0.35	4.3											
		FGBE-37,38					5.5	0.76	0.9											
		FHE-10					4.3	0.28	13.7											
		FFE-12					4.3	0.25	7.8											
		FGBE-29,30					5.5	0.13	7.1											
		FFE-14					4.3	0.34	1.9											
		FGBE-31,32					5.0	0.07	0.1											
		FGBE-33,34					8.0	0.15	12.8											
		FHE-13					4.3	0.31	4.9											
		FGBE-42,43					6.6	0.09	12.7											
		FGBE-40,41					5.6	0.29	6.4											
		FGBE-44,46					18.3	0.15	18.2											
		FFE-19					4.3	0.29	8.6											
		FFE-15					4.3	0.31	7.6											
		FHE-9					4.3	0.26	8.1											
		FHE-10					4.3	0.24	4.6											
		FFE-8					4.3	0.31	7.6											
		FGBE-23,25					8.5	0.10	12.8											
		FGBE-21,22					6.9	0.11	7.6											
		FFE-7					8.6	0.33	1.1											
		FHE-8					4.9	0.22	4.1											
		FHE-38,39					7.2	0.13	3.1											
		FFE-9					4.3	0.15	14.7											
		FHE-16					4.3	0.30	5.6											
		FFE-24					4.3	0.46	2.7											
		FHE-14					4.3	0.31	9.1											
		FHE-15					4.3	0.31	8.1											
		FHE-13					4.3	0.40	6.2											
		FFE-21					4.3	0.24	6.1											
		FFE-22					4.3	1.40	1.0											
		FFE-23					4.3	0.34	9.1											
		FGBE-35,36					4.3	0.13	11.2											
		FHE-12					4.3	0.32	9.1											
251	Hardened Area Room Exhaust & Glove Boxes***	FGBE-1000	Transuranic Research	Gross alpha Gross beta	*	NA	7.6	0.30	4.6	Triple HEPA	0.000001	0.0E+00 0.0E+00	1188	E	0.0E+00	**	**	**	3	N/A
		FGBE-3000					7.6	0.30	4.6											
		FFE-1000					7.6	0.50	11.7											
		FFE-2000					7.6	0.30	11.7											

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/y Site-Wide Dose Requirement: Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	0.1 mrem/y Monitoring Requirement: Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)	Source Category	Below App E Quantity
Building 253 houses the Hazards Control Department, and the facility includes laboratories for the chemical analysis and counting of radioactive samples.																				
253	1732A	FHE-24	Liquid scintillation counting	H-3	2.5E-11	1.0E-03	7.9	0.85	8.9	None	1	3.6E-14	1116	E	8.7E-17	1079	NNE	1.0E-16	2	Y
253	1732	FHE-23	HNO3 digestion of samples above 100 deg. C.	Gross Alpha	1.1E-13	1.0E-03	6.1	0.36	7.1	None	1	1.3E-16	1116	E	3.0E-14	600	WSW	8.0E-14	1	Y
				Gross Beta	3.1E-13	1.0E-03						2.1E-16								Y
				Th-230	1.5E-13	1.0E-03						1.5E-16								Y
				Cs-137	6.0E-14	1.0E-03						9.0E-17								Y
253	1734	Room Air	Distillation of spinax and sewer samples	H-3	9.8E-10	1.0E-03	NA	NA	NA	None	1	9.9E-12	1116	E	9.3E-15	736	W	4.7E-12	2	Y
				Pu-238	2.8E-12	1.0E-03						2.8E-16								Y
				Sr-90	1.2E-11	1.0E-03						1.2E-14								Y
253	1734A	F36E-142	Sewer soil samples	Pu-239	3.7E-10	1.0E-06	6.1	0.10	23.6	HEPA	0.01	3.7E-16	1116	E	4.2E-16	1879	NNE	1.1E-15	2	Y
				Sr-90	4.8E-10	1.0E-06						4.8E-16								Y
253	1734B	FHE-2	Samples and standards plated and filmed	Cs-137	1.7E-11	1.0E-03	6.4	0.30	6.7	None	1	1.7E-14	1116	E	2.1E-12	1079	NNE	5.5E-12	2	Y
				Th-230	2.2E-12	1.0E-03						2.2E-15								Y
				Pu-239	1.2E-11	1.0E-03						1.2E-14								Y
				Sr-90	1.7E-12	1.0E-03						1.7E-15								Y
				Y-90	7.5E-13	1.0E-03						7.5E-16								Y
				Np-237	6.4E-13	1.0E-03						6.4E-16								Y
				H-3	4.3E-12	1.0E-03						4.3E-15								Y
253	1734C	FHE-4	Quality control sample aliquoting	H-3	2.2E-14	1.0E-03	6.4	0.30	7.2	None	1	2.2E-17	1116	E	1.9E-12	1079	NNE	3.0E-12	2	Y
				Np-237	3.0E-12	1.0E-03						3.0E-15								Y
				Sr-90	2.5E-12	1.0E-03						2.5E-15								Y
				Y-90	2.6E-12	1.0E-03						2.6E-15								Y
				Cs-137	3.7E-12	1.0E-03						3.7E-15								Y
				Th-230	4.8E-13	1.0E-03						4.8E-16								Y
				Pu-239	7.5E-13	1.0E-03						7.5E-16								Y
253	1734D	FHE-11	Acid digestion for gross alpha/beta	H-3	6.9E-09	1.0E-03	10.4	0.38	12.3	None	1	6.6E-12	1116	E	7.7E-12	1079	NNE	2.0E-11	2	Y
				Pu-239	6.3E-11	1.0E-03						6.3E-14								Y
				Sr-90	2.9E-10	1.0E-03						2.9E-13								Y
				Y-90	2.6E-12	1.0E-03						2.6E-15								Y
				Np-237	3.1E-12	1.0E-03						3.1E-15								Y
253	1806	Room Air	Sample preparation for liquid scintillation counting	H-3	9.0E-09	1.0E-03	NA	NA	NA	None	1	9.0E-12	1116	E	4.9E-15	736	W	2.8E-14	1	Y
253	1907	FHE-10	Assayis of urine for radionuclides	H-3	1.2E-16	1.0E-03	2.1	0.37	5.6	None	1	1.2E-13	1116	E	6.5E-17	890	WSW	2.5E-16	1	Y
				U-234	6.5E-17	1.0E-03						6.3E-20								Y
				U-238	3.7E-18	1.0E-03						3.7E-21								Y
				U-238	7.6E-17	1.0E-03						7.6E-20								Y
253	1913	Room Air	Analysis of radon daughter samples	Po-210	7.0E-07	1.0E-03	NA	NA	NA	None	1	7.0E-10	1116	E	5.3E-10	736	W	4.0E-09	2	N/A
				Pb-214	7.0E-07	1.0E-03						7.0E-10								Y
				Bi-214	7.0E-07	1.0E-03						7.0E-10								Y
				Ra-226	4.0E-06	1.0E-06						4.0E-14								Y
253	1914	FEV-1	Aerosol attachment to radon daughter products	Ra-226	3.5E-06	1.0E-03	9.5	0.21	13.7	4 stage HEPA	0.00000001	3.5E-17	1116	E	2.0E-16	1079	NNE	6.5E-08	2	Y
253	1914A	BLV-1	Aerosol attachment to radon daughter products	Po-218	7.0E-06	1.0E+00	6.4	0.06	3.6	HEPA	0.01	7.0E-07	1116	E	7.3E-18	736	W	2.5E-07	2	N/A
				Pb-214	7.0E-06	1.0E+00						7.0E-07				600	WSW	2.5E-07		Y
				Bi-214	7.0E-06	1.0E+00						7.0E-07								Y
Building 254 is run by Hazards Control for the purpose of conducting bioassays and providing analytical services.																				
254	106	Room Air	Analysis of urine for radionuclides	U-238	5.5E-17	1.0E-03	NA	NA	NA	None	1	5.6E-20	1032	E	1.1E-17	817	W	4.5E-17	2	Y
				U-235	2.0E-18	1.0E-03						2.0E-21								Y
				U-234	5.9E-17	1.0E-03						5.9E-20								Y
254	109	FHE-5	Analysis of urine for radionuclides	U-238	1.3E-16	1.0E-03	6.8	0.36	8.3	None	1	1.3E-19	1032	E	1.0E-17	1070	NNE	3.7E-17	2	Y
				U-235	5.0E-18	1.0E-03						5.0E-21								Y
				U-234	1.4E-16	1.0E-03						1.4E-19								Y
254	113	FHE-2	Analysis of urine for radionuclides	Am-243	1.1E-13	1.0E-03	8.6	0.36	8.3	None	1	1.1E-16	1032	E	2.0E-13	1070	NNE	6.8E-13	2	Y
				Pu-242	1.4E-12	1.0E-03						1.4E-15								Y
				Pu-239	2.3E-13	1.0E-03						2.3E-16								Y
254	113A	FHE-3	Analysis of urine for radionuclides	Am-241	6.8E-14	1.0E-03	8.8	0.30	5.1	None	1	6.6E-17	1032	E	5.8E-12	1070	NNE	1.4E-11	2	Y
				Am-243	2.4E-12	1.0E-03						2.4E-15								Y
				Cm-244	9.1E-13	1.0E-03						9.1E-16								Y
				Np-237	9.0E-12	1.0E-03						9.0E-15								Y
				Th-230	9.4E-12	1.0E-03						9.4E-15								Y
				Cl-252	8.4E-12	1.0E-03						8.4E-15								Y
				U-233	2.8E-14	1.0E-03						2.8E-17								Y
				U-234	1.1E-12	1.0E-03						1.1E-15								Y
				U-235	2.8E-14	1.0E-03						2.8E-17								Y
				U-238	8.8E-12	1.0E-03						8.8E-15								Y
				U-236	6.6E-15	1.0E-03						6.6E-18								Y
254	113B	FHE-4	Analysis of urine for radionuclides	P-32	6.6E-12	1.0E-03	6.6	0.30	8.8	None	1	6.6E-15	1032	E	8.7E-13	1070	NNE	2.1E-12	2	Y
				S-35	1.1E-10	1.0E-03						1.1E-13								Y
				C-14	3.5E-11	1.0E-03						3.5E-14								Y
				P-33	1.1E-09	1.0E-03						1.1E-12								Y

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical Stack Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/yr Site-Wide Dose Requirement: Distance to SWMEI (m)	Direction to SWMEI	CDE (mrem)	0.1 mrem/yr Monitoring Requirement: Distance to MEI (m)	Direction to MEI	Unabated CDE (mrem)	Source Category	Below App. E Quantity
				I-129	1.7E-10	1.0E-03						1.7E-13								Y
				H-3	1.2E-10	1.0E-03						1.2E-13								Y
				Sr-90	2.7E-10	1.0E-03						2.7E-13								Y
				Y-90	2.7E-10	1.0E-03						2.7E-13								Y
Building 255 is operated by Hazards Control and houses a radiation calibration and standards laboratory. Many operations involve the use of sealed sources.																				
255	165	FHE-4	Analysis of urine for radionuclides	Am-241	8.6E-14	1.0E-03	6.8	0.30	6.1	None	1	8.6E-17	1050	E	9.4E-11	858	WSW	2.3E-10	1	Y
				Am-243	2.5E-12	1.0E-03						2.5E-15								Y
				C-14	3.5E-11	1.0E-03						3.5E-14								Y
				Cf-252	8.4E-12	1.0E-03						8.4E-15								Y
				Cm-242	8.1E-13	1.0E-03						8.1E-16								Y
				I-129	1.7E-10	1.0E-03						1.7E-13								Y
				Np-237	1.1E-10	1.0E-03						1.1E-13								Y
				Np-239	1.1E-10	1.0E-03						1.1E-13								Y
				P-32	2.8E-09	1.0E-03						2.8E-12								Y
				Pu-239	2.3E-13	1.0E-03						2.3E-16								Y
				Pu-242	1.4E-12	1.0E-03						1.4E-15								Y
				S-35	1.2E-10	1.0E-03						1.2E-13								Y
				Sr-90	4.9E-14	1.0E-03						4.9E-17								Y
				Th-230	9.4E-12	1.0E-03						9.4E-15								Y
				U-233	2.9E-14	1.0E-03						2.9E-17								Y
				U-234	1.1E-12	1.0E-03						1.1E-15								Y
				U-235	2.8E-14	1.0E-03						2.9E-17								Y
				U-236	8.7E-10	1.0E-03						8.7E-13								Y
				U-238	2.7E-13	1.0E-03						2.7E-16								Y
				Y-90	4.9E-14	1.0E-03						4.9E-17								Y
255	180	FHE-2	H-3 gas monitor calibrations	H-3	2.5E-02	1.0E+00	8.1	0.31	6.2	None	1	2.5E-03	1056	E	1.0E-08	1156	NE	2.3E-06	2	Y
Trailer 2561 is operated by Hazards Control and has no operations in CY94.																				
2561	All	None	No Operations	None	None	NA	3.1	0.24	3.0	HEPA	0.01	0.0E+00	1104	E	0.0E+00	NA	NA	0.0E+00	2	Y
Building 261 is part of the Chemistry and Materials Sciences Directorate. In rooms 1311 and 1319, there are a number of sources, both as solids and in solution, which are kept and used in glove boxes. There are HEPA filters between the glove boxes and the vent stack. Room 1325 is used for collection of Nuclear Test Site groundwater samples. These samples contain some related waste.																				
261	1164	FHE-32	Solution chemistry of the actinides	Pu-242	3.7E-07	1.0E-03	6.7	0.30	7.1	Double HEPA	0.0001	3.7E-14	1332	SSE	4.1E-12	679	NNE	9.2E-07	2	Y
				Am-241	3.7E-07	1.0E-03						3.7E-14								Y
261	1174	FHE-13	Synthesis of expanded porphyrins with actinides	U-238	4.0E-11	1.0E-03	6.7	0.30	5.1	None	1	4.0E-14	1332	SSE	1.1E-12	679	NNE	2.3E-11	2	Y
				Th-232	1.0E-11	1.0E-03						1.0E-14								Y
261	1184	Room Air	No Operations	None	None	NA	NA	NA	NA	None	1	0.0E+00	1332	SSE	0.0E+00	NA	NA	0.0E+00	2	Y
261	1307	FHE-6	Sample preparation for Ni-59 and Ni-63	Ni-59	3.5E-13	1.0E-03	6.4	0.61	2.7	HEPA	0.01	3.5E-16	1332	SSE	3.2E-14	679	NNE	3.4E-11	1	Y
				Ni-63	1.0E-09	1.0E-03						1.0E-11								Y
261	1311	FHE-12	Wet Chemistry Laboratory	U-233	4.6E-11	1.0E-03	6.1	0.41	4.0	None	1	4.6E-14	1332	SSE	8.5E-13	679	NNE	1.8E-11	2	Y
261	1311A	FHE-3	Wet Chemistry Laboratory	Th-232	2.5E-10	1.0E-03	4.9	0.25	10.3	None	1	2.5E-13	1332	SSE	5.0E-10	679	NNE	1.9E-08	2	Y
				Pu-242	1.0E-06	1.0E-03						1.0E-11								Y
261	1311B	FHE-3	Wet Chemistry Laboratory	Pu-242	4.0E-06	1.0E-03	4.9	0.25	10.3	Double HEPA	0.0001	4.0E-13	1332	SSE	1.9E-13	679	NNE	4.9E-08	2	Y
261	1314	FHE-8	Experimental Laboratory with Glove Boxes	Pu-242	2.0E-08	1.0E-03	6.6	0.41	2.5	Double HEPA	0.0001	2.0E-13	1332	SSE	1.3E-13	679	NNE	2.2E-08	2	Y
				U-233	1.0E-06	1.0E-03						1.0E-10								Y
261	1318	FHE-1	Experimental Laboratory with Glove Boxes	Th-232	3.0E-10	1.0E-03	5.2	0.25	9.2	Double HEPA	0.0001	3.0E-17	1332	SSE	4.0E-10	679	NNE	1.3E-04	2	Y
				Np-237	7.0E-08	1.0E-03						7.0E-12								Y
				Pu-242	5.0E-07	1.0E-03						5.0E-14								Y
Building 262 is operated by the Isotope Sciences Division of the Chemistry and Material Sciences Directorate. Experimental work involves neutrino particle mass and related studies. Gaseous tritium is absorbed on a "getter" material to which it is tightly bound at room temperature.																				
262	1000	Room Air	No Operations	None	None	NA	NA	NA	NA	HEPA	0.01	0.0E+00	1332	SSE	0.0E+00	NA	NA	0.0E+00	2	Y
Building 292 is administered by the Physics and Space Technologies Directorate. Residual contamination exists throughout the facility from the past operation of a rotating target neutron source, that is no longer in operation. Also, neutrino mass experiments have not been conducted since 1993.																				
292	1200/1292	Room Air	No Operations	H-3	1.0E+00	1.0E-03	NA	NA	NA	None	1	1.0E-03	1380	SSE	5.7E-07	493	NNE	1.3E-05	2	Y
292	1204	Room Air	No Operations	H-3	2.3E+01	1.0E-03	NA	NA	NA	None	1	2.3E-02	1380	SSE	7.9E-06	493	NNE	1.7E-04	2	Y
292	1402, 1403A 1404, 1405 1407	Room Air	No Operations	H-3	1.0E+00	1.0E-03	NA	NA	NA	None	1	1.0E-03	1380	SSE	5.7E-07	493	NNE	1.3E-05	2	Y
Building 298 is part of the Laser Fusion Program. Small amounts of tritium are used in this facility in conjunction with fusion target research and development.																				
298	109	FHE-14	Laser fusion target research and development	U-238	3.0E-10	1.0E-03	6.4	0.65	15.1	HEPA	0.01	6.0E-15	1386	SE	3.3E-17	344	NE	3.2E-13	2	Y
298	Various	Room Air	Laser fusion target research and development	H-3	3.0E-02	1.0E+00	NA	NA	NA	None	1	3.0E-02	1386	SE	1.3E-05	364	NNE	6.8E-04	2	Y
Buildings 321, 321A, 321B, and 321C are the Material Fabrication Shops and are part of the Mechanical Engineering Department. Operations in this complex include rolling, stamping and machining of depleted uranium. Uranium pieces may be worked on in a single location, or may be moved from machine to machine. In addition, depleted uranium parts occasionally undergo heat treatment. The amount of depleted uranium that is handled depends on programmatic demands and varies from month to month. NOTE: Machining only occurs in 321C.																				

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/y Site-Wide Dose Requirement: Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	0.1 mrem/y Monitoring Requirement: Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)	Source Category	Below App. E Quantity
361	1546	FHE-10	DNA Labeling	S-35 P-32	0.0E+00 4.0E-09	1.0E-03 1.0E-03	1.7	0.41	0.8	None	1	0.0E+00 4.0E-09	918	ESE	1.0E-07	976	W	5.5E-07	2	Y
361	1554	FHE-2000	No Operations	None	None	NA	7.5	0.85	5.8	None	1	0.0E+00	918	ESE	0.0E+00	NA	NA	0.0E+00	2	Y
361	1566	FHE-2000	Biological Dosimetry	P-32 P-33	4.3E-04 1.2E-04	1.0E-03 1.0E-03	1.7	0.41	0.4	None	1	4.3E-07 1.2E-07	918	ESE	1.5E-06	976	W	7.5E-06	2	Y
361	1635	Room Air	DNA Sequencing	P-32	2.0E-04	1.0E-03	NA	NA	NA	None	1	2.0E-07	918	SSE	4.7E-09	976	W	2.3E-08	2	Y
361	1642	FHE-11	DNA/RNA Hybridization	P-32	1.0E-03	1.0E-03	7.0	0.41	4.4	None	1	1.0E-06	918	SSE	8.6E-09	933	NNE	7.4E-08	2	Y
361	1649	FHE-4	Biological Dosimetry	P-33 S-35	3.0E-06 5.0E-04	1.0E-03 1.0E-03	7.0	0.41	4.4	None	1	3.0E-09 5.0E-07	918	ESE	7.5E-08	976	W	4.5E-07	2	Y Y
361	1656	FHE-1000	No Operations	None	None	NA	7.5	0.85	2.8	None	1	0.0E+00	918	ESE	0.0E+00	NA	NA	0.0E+00	2	Y
361	1658C	FHE-1000	Radioactive Probes	P-32	6.0E-03	1.0E-03	7.5	0.85	2.8	None	1	6.0E-06	918	SSE	3.3E-07	976	W	1.2E-06	2	Y
361	1664	FHE-2000	Human Genome	None	None	NA	7.0	0.41	4.4	None	1	0.0E+00	918	SSE	0.0E+00	NA	NA	0.0E+00	2	Y
361	1743	FHE-8	Biological Dosimetry	P-32	2.0E-02	1.0E-03	7.5	0.41	4.4	None	1	2.0E-05	918	ESE	1.3E-07	976	W	2.7E-06	2	Y
361	1745	FHE-7	No Operations	None	None	NA	7.5	0.41	4.4	None	1	0.0E+00	918	ESE	0.0E+00	NA	NA	0.0E+00	2	Y
361	1846	Room Air	Human Genome	P-32 S-35	4.5E-02 2.0E-03	1.0E-03 1.0E-03	NA	NA	NA	None	1	4.5E-05 2.0E-06	918	ESE	9.0E-07	976	W	5.1E-06	2	Y Y
Building 362																				
362	113	Room Air	Dose Preparation	C-14	1.0E-03	1.0E-03	NA	NA	NA	None	1	1.0E-06	960	SSE	2.2E-08	885	W	1.0E-07	2	Y
Building 363																				
363	1009	FHE-3000	Dispensing Samples	H-3	3.0E-03	1.0E-03	1.7	0.41	0.4	HEPA	1	3.0E-06	996	ESE	1.0E-08	952	W	1.5E-07	2	Y
Building 364																				
364	1507	Room Air	DNA Labeling	P-32	3.0E-01	1.0E-03	NA	NA	NA	None	1	3.0E-04	900	SSE	6.3E-08	984	W	4.2E-05	2	Y
364	1510	Room Air	Isolation and Purification	C-14	6.0E-04	1.0E-03	NA	NA	NA	None	1	6.0E-07	900	SSE	1.1E-09	984	W	7.4E-08	2	Y
Building 365																				
365	169	FHE-6	Research Animals Housed	C-14 H-3	1.3E-04 5.0E-07	1.0E-03 1.0E-03	1.7	0.41	0.8	Double HEPA	0.0001 1	1.3E-11 5.0E-10	1002	ESE	8.4E-13	903	W	2.9E-08	2	Y Y
Building 366																				
366	103	FHE-1	Mutation Heterocyclic Amines	H-3	4.0E-03	1.0E-03	1.7	0.41	0.5	None	1	4.0E-06	812	ESE	2.6E-08	988	W	1.4E-06	2	Y
366	111	FHE-1	DNA Sequencing	P-33	5.0E-04	1.0E-03	1.7	0.41	0.4	Blower/HEPA	0.01	5.0E-09	812	ESE	1.3E-10	998	W	6.4E-08	2	Y
Building 377 is operated by the Health and Biological Assessment Division. Activities in this facility were associated with chemical and radiological sample preparation for environmental analysis, and analysis of soil, water, vegetation, etc., samples.																				
377	1003	Stack FHE-9 removed	No Operations	None	None	NA	NA	NA	NA	None	1	0.0E+00	1005	SSE	0.0E+00	NA	NA	0.0E+00	2	Y
377	1005	Stack FHE-1 removed	No Operations	None	None	NA	NA	NA	NA	None	1	0.0E+00	1005	SSE	0.0E+00	NA	NA	0.0E+00	2	Y
377	1028	FHE-1000	No Operations	None	None	NA	8.2	0.23	20.6	None	1	0.0E+00	1005	SSE	0.0E+00	NA	NA	0.0E+00	2	Y
Building 378 is operated by the Health and Ecological Assessment Division. The major activities in this facility are associated with chemical and radiological sample preparation for environmental analysis, and analysis of soil, water, vegetation, etc., samples.																				
378	120	378-120-FHE-1,2,3,4,5,8,9,10	Environmental analysis	Am-241 Pu-238 Pu-242	7.5E-10 3.0E-10 1.5E-09	1.0E-03 1.0E-03 1.0E-03	5.9	0.30	8.9	None	1	7.5E-13 3.0E-13 1.5E-12	889	ESE	1.5E-12	937	NNE	1.5E-09	2	Y Y Y
378	120	378-120-FHE-6,7	Environmental analysis	Am-241 Pu-238 Pu-242	1.5E-10 6.0E-11 4.5E-10	1.0E-03 1.0E-03 1.0E-03	8.5	0.30	9.7	None	1	1.5E-13 6.0E-14 4.5E-13	889	SSE	3.3E-11	957	NNE	3.0E-10	2	Y Y Y
Building 381 is part of the Laser Fusion Program. Small quantities of tritium are handled in support of laser target research and development.																				
381	6100	381-6100-FHE-1	Tritium handling for laser target R&D	H-3	4.0E-04	1.0E-04	11.3	0.30	26.5	None	1	4.0E-04	1092	SE	2.7E-14	680	NNE	8.0E-07	2	Y
Building 391 is part of the Laser Fusion Program. The high energy laser is located in this facility. Small amounts of tritium are handled in support of laser target research and development.																				
391	Target Chamber	391-FHE-1	Fusion Target Irradiation Area	H-3	2.1E-01	1.0E+00	8.1	0.90	9.8	None	1	2.1E-01	1149	SE	2.0E-06	403	NNE	9.0E-04	2	Y
Building 412W R1110 was used by the Health and Ecological Assessment Division for approximately 6 months in 1995.																				
412W	1110	412W-1110-FHE	Sample preparation for measurement of Ni-59 and Ni-63	Ni-59 Ni-63	3.5E-13 1.0E-06	1.0E-03 1.0E-03	11.9	0.25	4.4	HEPA	0.01 0.01	3.5E-16 1.0E-11	762	NE	2.3E-13	158	SSW	5.0E-11	1	Y Y
Building 419 has been used previously for the decontamination of equipment. However, it is now undergoing closure.																				
*Exhausts from the facility are continuously sampled; measured emissions, rather than the inventory approach are used to determine annual emissions.																				
**Because monitoring takes place after HEPA filtration, an unabated EDE cannot be determined (see discussion on page 40.).																				
419	124	FHE-2	Decontamination activities	Gross alpha	-	NA	12.2	0.61	12.5	Double HEPA	0.0001	1.5E-07	886	NE	9.8E-05	- -	- -	- -	3	N/A

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/yr Site-Wide Dose Requirement: Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	0.1 mrem/yr Maximum Requirement: Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)	Source Category	Below App. E Quantity
				U-235	1.0E-06	1.0E-03						1.0E-06								Y
				U-238	6.0E-04	1.0E-03						6.0E-07								Y
The Building 612 Yard is operated by the Hazardous Waste Management Division. The Yard consists of several areas where containers having radioactive wastes are stacked outdoors. The containers, which are not air tight, can outgas tritium.																				
612	Yard	Area Source	Storage of low level waste	H-3	2.1E+00	1.0E+00	NA	NA	NA	None	1	2.1E+00	420	NNE	1.4E-02	283	SW	4.1E-02	E	Y
The Southeast Quadrant of the Livermore Site has slightly elevated levels of Pu-239 in the surface soil and air (presumably from resuspension). The source of the Pu-239 was past waste management operations.																				
Southeast Quadrant		Area Source	Resuspension	Pu-239	NA	NA	NA	NA	NA	None	1	NA	0	NA	8.4E-04	NA	NA	NA	E	Y
SITE 300 DIFFUSE SOURCES																				
Diffuse sources consist of evapotranspiration of tritiated water and resuspension of depleted uranium. Tritiated water sources include land areas where water pumped from wells has been dumped, an open aqueous spring, and evaporation of water from soils due to migration from contaminated ground water.																				
Pit 7 complex		Area Source	Evaporation from Soil and purge water	H-3	9.2E-01	1.0E+00	NA	NA	NA	None	1	9.2E-01	4602	ESE	3.9E-05	853	NNE	7.1E-04	E	Y
802		Area Source	Evaporation from Soil	H-3	6.6E-04	1.0E+00	NA	NA	NA	None	1	6.6E-04	2349	ESE	8.3E-08	1423	NNE	1.8E-07	E	Y
850		Area Source	Evaporation from Soil	H-3	1.1E-01	1.0E+00	NA	NA	NA	None	1	1.1E-01	4206	E	8.2E-06	1498	NNE	3.3E-05	E	Y
801		Area Source	Evaporation from Soil	H-3	3.3E-04	1.0E+00	NA	NA	NA	None	1	3.3E-04	3578	E	2.1E-08	1356	WNW	6.4E-08	E	Y
Well 6 Spring		Area Source	Evaporation from Spring Water	H-3	2.3E-03	1.0E+00	NA	NA	NA	None	1	2.3E-03	4004	E	1.4E-07	132	N	1.5E-06	E	Y
Site 300	All	Area Source	Soil Resuspension	U-238	NA	NA	NA	NA	NA	None	1	NA	0	NA	2.5E-01	NA	NA	NA	E	Y
				U-235	NA	NA						NA								Y
				U-234	NA	NA						NA								Y

Attachment 2. Surrogate Radionuclides List

Although CAP88-PC supports calculations for many radionuclides, there are some in use at LLNL that are not included in CAP88-PC. Consequently, this list of surrogate radionuclides has been developed to account for the contribution of those radionuclides.

Table 2-1. List of surrogate radionuclides.

Radio-nuclide	Half-life	Lung Class[a]	ALI (inh), µCi	DAC, µCi/cm³	Surrogate	Correction Factor[b]
^{108m}Ag	127 y	Y	20	1×10^{-8}	^{60}Co	
^{207}Bi	38 y	W	400	1×10^{-7}	^{214}Bi	
^{45}Ca	163 d	W	800	4×10^{-7}	^{90}Sr	
^{109}Cd	464 d	D	40	1×10^{-8}	^{60}Co	
^{249}Cf	351 y	Y	0.01	4×10^{-12}	^{241}Am	
^{250}Cf	13.1 y	W	0.009	4×10^{-12}	^{241}Am	
^{36}Cl	3.01×10^{5} y	W	200	1×10^{-7}	^{137}Cs	
^{254}Es	276 d	W	0.07	3×10^{-11}	^{239}Pu	
^{149}Eu	93.1 d	W	3000	1×10^{-6}	^{156}Eu	
^{148}Gd	93 y	D	0.008	3×10^{-12}	^{140}La	1×10^{5}
^{185}Os	94 d	D	500	2×10^{-7}	^{99}Mo	
^{33}P	25.4 d	D	8000	4×10^{-6}	^{32}P	
^{184}Re	38.0 d	W	1000	6×10^{-7}	^{99}Mo	
^{75}Se	120 d	W	600	3×10^{-7}	^{32}P	
^{85}Sr	64.8 d	Y	2000	6×10^{-7}	^{90}Sr	
^{182}Ta	115 d	Y	100	6×10^{-8}	^{99}Mo	
^{157}Tb	150 y	W	300	1×10^{-7}	^{140}La	
^{158}Tb	150 y	W	20	8×10^{-9}	^{140}La	50
^{204}Tl	3.78 y	D	2000	9×10^{-7}	^{214}Pb	
^{168}Tm[c]	85 d	W	2000	8×10^{-7}	^{140}La	
^{171}Tm	1.92 y	W	300	1×10^{-7}	^{140}La	5

a D = days, W = weeks, Y = years.

b The annual inventory is multiplied by the correction factor, and a resulting surrogate equivalency is used for the modeling calculation.

Source: Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion, Federal Guidance Report No. 11, EPA-520/1-88-020, U.S. Environmental Protection Agency, 1988.

$$Dose_{inh} = Annual\ Inhalation\ Rate\left(\frac{m^3}{y}\right) \times Air\ Concentration\left(\frac{pCi}{m^3}\right) \times Dose\ Conversion\ Factor\left(\frac{mrem}{pCi}\right)$$

$$Dose_{inh} = 0.917\frac{m^3}{h} \times 24\frac{h}{d} \times 365\frac{d}{y} \times 3.1\frac{pCi}{m^3} \times 1.263 \times 10^{-7}\frac{mrem}{pCi}$$

$$Dose_{inh} = 3.14 \times 10^{-3}\frac{mrem}{y}.$$

The dose conversion factor of 1.263×10^{-7} mrem/pCi is nearly double the inhalation conversion factor of 6.4×10^{-8} mrem/pCi stated in Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake And Air Concentration and Dose Conversion Factors For Inhalation, Submersion, And Ingestion," (EPA 520/1-88-020, 1988), and is based on the ICRP 2 (Report of Committee II on Permissible Dose for Internal Radiation, International Commission on Radiological Protection, 1959) recommendation that skin intake equal the lung intake. ICRP 30 (Limits for Intakes of Radionuclides by Workers, International Commission on Radiological Protection, 1980) contains the recommendation that skin intake should be 50% of the lung intake. (If more current ICRP recommendations were used, the inhalation dose would be 2.39×10^{-3} mrem/y.)

For ingestion doses, CAP88-PC follows the logic that tritium, because it exchanges hydrogen readily with water molecules in air, "may be assumed to follow water almost precisely through the environment." Consequently, the doses from ingestion of food and drinking water at a location are assumed to be in proportion to the concentration of tritium in air.

The total ingestion dose is equal to the sum of the dose for ingestion of vegetables, meat, milk, and water.

$$Dose_{ing} = Dose_{veg} + Dose_{meat} + Dose_{milk} + Dose_{water}.$$

These doses, in turn, are defined as follows:

$$Dose_{veg} = 0.505 \times C_f\left(f_{v1}\chi + f_{v2}\chi_v\right),$$

$$Dose_{meat} = 0.185 \times C_f(f_{m1}\chi + f_{m2}\chi_m),$$

$$Dose_{milk} = 0.310 \times C_f(f_{k1}\chi + f_{k2}\chi_k), \text{ and}$$

$$Dose_{water} = C_w \times \chi \times 0.01, \text{ where}$$

C_f is the dose conversion factor for food (rem-cm^3/pCi-year). It is derived based on the specific activity of tritium in atmospheric moisture with an average specific humidity of 8 grams of water per cubic meter of air. Using a total-body dose conversion factor of 8.993×10^{-5} rem/µCi (not 8.3×10^{-5} rem/µCi as stated in the AIRDOS manual [Steve Maheras, SAIC at INEL, personal communication, 1996]), assuming tritium in food is in equilibrium with atmospheric tritium, and that an adult consumes 1638 g/d of water in food, C_f is 6.4 rem-cm^3/pCi-year. The contribution to the food ingestion dose is 50.5% from vegetables, 18.5% from meat, and 31.0% from milk. "These percentages are based on approximate water contents of foods of 82.4% for vegetables, 62.3% for meat, and 87.5% for milk and for daily intakes of 0.532 kg of vegetables, 0.258 kg for meat, and 0.307 kg of milk." (AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides, R.E. Moore, et al., EPA 520/1-79-009, 1979.)

C_w is the dose conversion factor for water. It is also derived based on the specific activity of tritium in atmospheric moisture with an average specific humidity of 8 grams of water per cubic meter of air. Using a total-body dose conversion factor of 8.3×10^{-5} rem/µCi, assuming tritium in water is in equilibrium with atmospheric tritium, and that an adult consumes 1512 g/d of water, C_f is 5.7 rem-cm^3/pCi-year. To account for dilution by distant sources of drinking water, a factor of 0.01 is applied.

χ is the ground-level concentration of tritium in air at the location (pCi/cm3). χ_v, χ_m, and χ_k are the average ground-level concentration of tritium in air over the assessment area weighted by the quantity of vegetables, meat, and milk, respectively, produced as a function of location.

f_{v1}, f_{m1}, and f_{k1}, are the fractions of vegetable, meat, and milk intake that are produced at the individuals environmental location, and f_{v2},