

Environmental Protection Department
Operations and Regulatory Affairs Division

LLNL NESHAPs
1999 Annual Report



Lawrence Livermore National Laboratory
University of California Livermore, California 94550

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LLNL NESHAPs 1999 Annual Report

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Radionuclide Air Emission Annual Report
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Lawrence Livermore National Laboratory NESHAPs 1999 Annual 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 μ Sv) to any member of the public. The EDEs for the Lawrence Livermore National Laboratory (LLNL) site-wide maximally exposed members of the public from 1999 operations are summarized here.

- Livermore site: 0.12 mrem (1.2 μ Sv) (77% from point-source emissions, 23% from diffuse-source emissions). The point-source emissions include gaseous tritium modeled as tritiated water vapor as directed by EPA Region IX, and the resulting dose is used for compliance purposes. LLNL believes a more accurate evaluation of dose for compliance evaluation at the Livermore site is 0.10 mrem (1.0 μ Sv) (72% from point-source emissions, 28% from diffuse-source emissions); see discussion beginning on page 11.
- Site 300: 0.035 mrem (0.35 μ Sv) (97% from point-source emissions, 3% from diffuse-source emissions).

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

SECTION I. Facilities Information

Site Description

LLNL was established in 1952 to conduct nuclear weapons research and development, still its primary responsibility. The Laboratory's mission is dynamic and has been broadened over the years to meet new national needs. LLNL serves as a national resource in science and engineering; its activities focus on global security, energy, global ecology, biomedicine, economic competitiveness, and science and mathematics education. 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. The University of California operates LLNL for DOE.

Livermore Site

LLNL's Livermore site occupies an area of 3.3 km² 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 the Livermore site; approximately 73,600 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. Temperatures typically range from -5°C during some pre-dawn hours in the winter, to 40°C on a few summer afternoons. The 1999 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, during the winter, the wind often blows from the northeast. Most precipitation occurs as rain between October and April with very little rainfall during the summer months. In 1999, the Livermore site received 245 mm of precipitation.

Table 1. Wind rose for LLNL's Livermore site at the 10-m level for 1999.

Direction	Wind Speed Range (m/s)					Total
	0.0-0.40	0.50-2.90	3.00-4.90	5.00-6.90	≥7.00	
NNE	0.58	2.11	1.66	0.46	0.05	4.9
NE	0.58	2.84	1.83	0.14	0.00	5.4
ENE	0.58	2.92	0.08	0.00	0.00	3.6
E	0.58	2.41	0.03	0.00	0.00	3.0
ESE	0.58	2.61	0.02	0.00	0.00	3.2
SE	0.58	2.00	0.00	0.00	0.00	2.6
SSE	0.58	1.65	0.00	0.03	0.00	2.3
S	0.58	4.95	0.81	0.29	0.11	6.7
SSW	0.58	5.96	1.89	0.90	0.23	9.6
SW	0.58	7.71	7.72	3.51	0.65	20.2
WSW	0.58	8.44	5.48	0.97	0.16	15.6
W	0.58	5.43	6.52	0.96	0.05	13.5
WNW	0.58	1.86	0.74	0.26	0.00	3.4
NW	0.58	1.31	0.09	0.02	0.00	2.0
NNW	0.58	1.26	0.14	0.03	0.03	2.0
N	0.58	0.76	0.23	0.14	0.27	2.0
Total	9.2	54.2	27.3	7.7	1.6	100.0

Note: Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding.

Table 2. Wind rose for LLNL's Site 300 at the 10-m level for 1999.

Direction	Wind Speed Range (m/s)					Total
	0.0-0.4	0.5-4.9	5.0-6.9	7.0-10.9	≥11.0	
NNE	0.16	1.69	0.05	0.00	0.00	1.9
NE	0.16	1.91	0.03	0.00	0.00	2.1
ENE	0.16	1.91	0.00	0.00	0.00	2.2
E	0.16	1.53	0.05	0.00	0.00	1.7
ESE	0.16	1.62	0.03	0.03	0.00	1.8
SE	0.16	1.50	0.19	0.07	0.00	1.9
SSE	0.16	2.04	0.17	0.10	0.00	2.5
S	0.16	3.77	0.56	0.06	0.00	4.6
SSW	0.16	2.06	0.16	0.03	0.00	2.4
SW	0.16	2.09	0.33	0.38	0.05	3.0
WSW	0.16	3.78	4.56	16.24	5.46	30.2
W	0.16	5.20	5.33	4.09	0.25	15.0
WNW	0.16	4.04	1.21	0.45	0.00	5.9
NW	0.16	6.08	1.20	1.46	0.06	9.0
NNW	0.16	5.65	2.56	2.47	1.12	12.0
N	0.16	1.94	1.29	0.37	0.17	3.9
Total	2.6	46.8	17.7	25.8	7.1	100.0

Note: Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding.

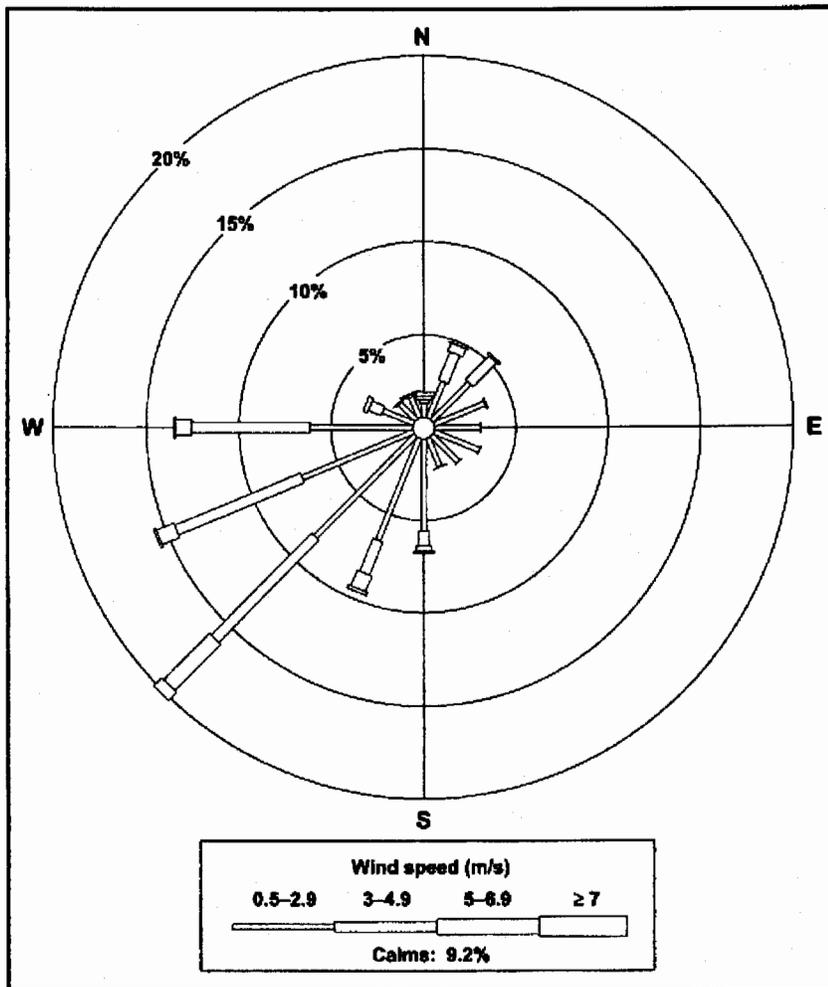


Figure 2. Wind rose showing the average annual wind speed, frequency of occurrence, and direction at the Livermore site, 1999.

primarily pasture land for cattle and sheep. The nearest residential area is the city of Tracy (population approximately 48,000), 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. The climate at Site 300 is similar to

that of the Livermore site, with mild winters and dry summers. The complex topography of the site significantly influences local wind and temperature

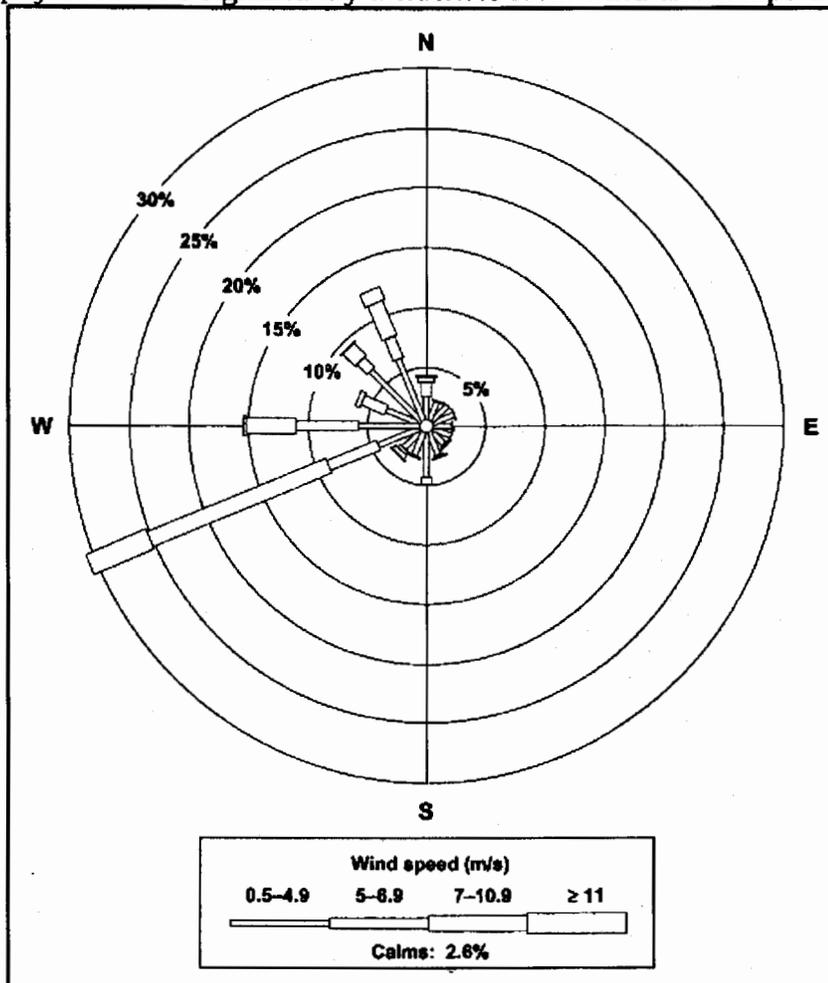


Figure 3. Wind rose showing the average annual wind speed, frequency of occurrence, and direction at Site 300, 1999.

patterns, making the temperature range somewhat more extreme than at the Livermore site. The 1999 annual wind data for Site 300 are shown in Table 2 and displayed as a wind rose in Figure 3. Prevailing winds are from the west-southwest. As is the case at the Livermore site, precipitation is highly seasonal, with most precipitation occurring between October and April. Site 300 received

198 mm of precipitation during 1999. The mean annual temperature is about 16°C.

Source Description

Many different radioisotopes are used at LLNL for research purposes, including transuranic isotopes, biomedical tracers, tritium, mixed fission products, and others (Table 3). Radioisotope-handling procedures and work enclosures are determined for each project, depending on the isotopes, the quantities being used, and the types of operations being performed. Radioisotope handling and working environments include glove boxes, exhaust hoods, and laboratory bench tops. Exhaust paths to the atmosphere range from triple-HEPA (High-Efficiency-Particulate-Air)-filtered ventilation systems, to roof vents and stacks lacking abatement devices, to direct dispersal of depleted uranium during explosives testing at Site 300, to a variety of diffuse-area sources.

Table 3. Radionuclides used at LLNL during 1999.

³ H	⁵⁴ Mn	⁹⁹ Tc	¹⁴⁷ Nd	²²⁸ Th	²³⁸ U
⁷ Be	⁵⁵ Fe	¹⁰³ Ru	¹⁴⁷ Pm	²²⁹ Th	²³⁹ Np
¹³ N	⁵⁷ Co	¹⁰⁶ Ru	¹⁵¹ Pm	²³⁰ Th	²³⁹ Pu
¹⁴ C	⁵⁹ Ni	¹⁰⁹ Cd	¹⁵¹ Sm	²³² Th	²⁴⁰ Pu
¹⁵ O	⁶⁰ Co	¹²⁵ I	¹⁵² Eu	²³² U	²⁴¹ Am
²² Na	⁶³ Ni	¹²⁵ Sb	¹⁵⁴ Eu	²³³ U	²⁴¹ Pu
³² P	⁸⁸ Y	¹³¹ I	¹⁵⁵ Eu	²³⁴ U	²⁴² Pu
³³ P	⁹⁰ Sr	¹³³ Ba	¹⁹⁵ Au	²³⁵ U	²⁴³ Am
³⁵ S	⁹⁰ Y	¹³⁴ Cs	^{195m} Pt	²³⁶ Pu	²⁴⁴ Cm
³⁶ Cl	⁹⁴ Nb	¹³⁷ Cs	²⁰⁷ Bi	²³⁶ U	²⁴⁹ Cf
⁴⁰ K	⁹⁵ Nb	¹⁴⁰ Ba	²⁰⁹ Po	²³⁷ Np	²⁵⁰ Cf
⁴¹ Ar	⁹⁵ Zr	¹⁴¹ Ce	²²³ Ra	²³⁷ U	²⁵² Cf
⁵¹ Cr	⁹⁹ Mo	¹⁴⁴ Ce	²²⁶ Ra	²³⁸ Pu	

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 in the operation
- Annual radionuclide usage 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 for each specific source
- Distance and direction to the maximally exposed individual (MEI) for each specific source
- Calculated EDE to the MEI (source term not adjusted for emission controls)
- Source category

A more complete description of these terms is provided in the introductory material to Attachment 1.

The radionuclides shown in the attachment are those from specific emission points where there was a potential for air emissions. If radionuclides were present, but encapsulated or sealed for the entire year, radionuclides, annual usage inventories, and emissions are not listed.

Actual measurements of radioactivity in air and effluent flow are the basis for reported emissions from continuously monitored sources. LLNL facilities that had continuously monitored discharge points in 1999 are Buildings 175, 177, 251, 292, 331, 332, 490, and 491. Discharge points at Buildings 175, 177, 251, 292, 332, 490, and 491 were monitored for gross alpha and gross beta activity. (During 1999 stack monitoring at some of these locations were removed; see discussion in Section IV, Supplemental Information; in the subpart entitled "Continuous Monitoring"). Building 331 stack discharges were monitored for tritium.

Operations in the Tritium Facility (Building 331) released a total of 280 Ci (1.0×10^{13} Bq) of tritium. Of this, approximately 214 Ci (7.9×10^{12} Bq) were released as tritiated water (HTO). The remaining 24% of the tritium released, 67 Ci (2.5×10^{12} Bq), was elemental tritium gas (HT). The highest single weekly stack emission from the facility was 41 Ci (1.5×10^{12} Bq), of which 15 Ci (5.4×10^{11} Bq) was HTO.

Building 331 tritium emissions, as measured by stack monitoring, while increased compared to 1998, remained considerably lower in 1999 than emissions that occurred during the 1980s. Figure 4 illustrates the combined HTO and HT emissions from the facility since 1981. Increased tritium emissions for 1999 compared to 1998 resulted from a minor equipment failure that occurred in the facility. Small releases from occasional failures of sealing devices are anticipated as part of normal facility operations. The increased 1999 emissions remained below levels that would activate the facility stack exhaust alarms, require notification of facility management, require notification of environmental management, or initiate occurrence reporting. Appropriate, planned responses were taken to repair the equipment and control the environmental consequences. The resulting tritium emissions for 1999 were within

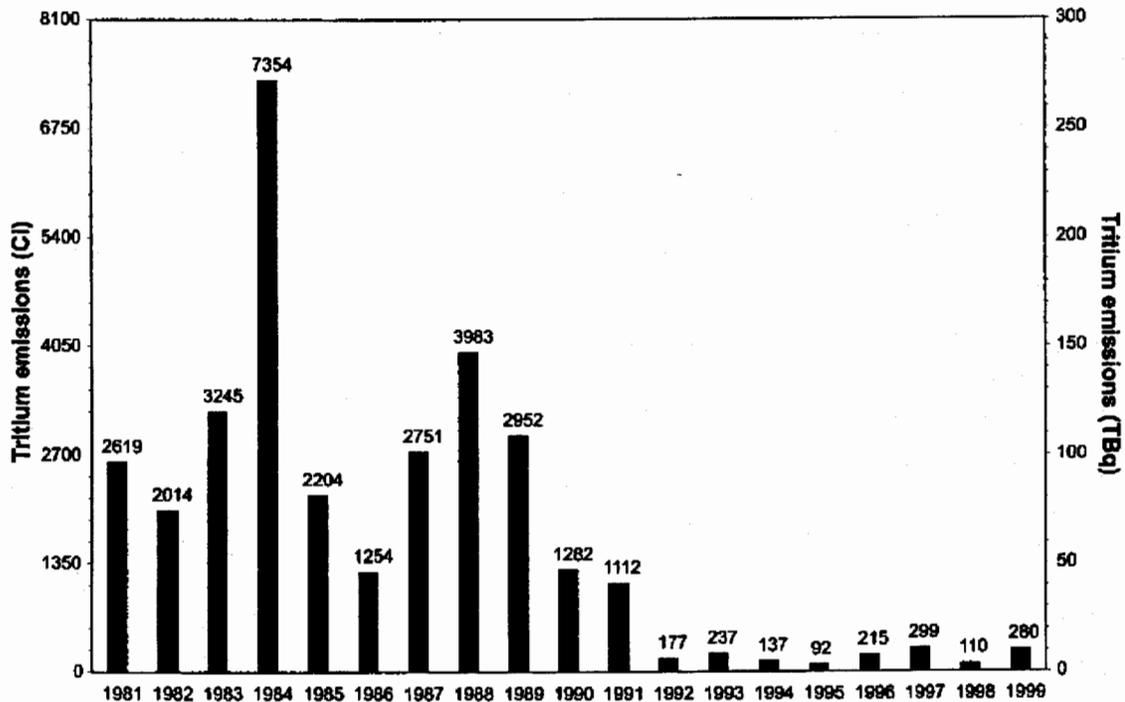


Figure 4. Combined HT and HTO emissions from the Tritium Facility, 1981–1999.

the expected variation in emissions from the facility since 1992, when operations were reduced markedly.

To evaluate the dose from tritium releases, we used the EPA-required CAP88-PC model. The CAP88-PC model ignores the chemical forms of tritiated molecules; all forms are treated as HTO and, therefore, have the same dose consequences. In fact, the doses from exposure to the two major forms of tritiated molecules, HTO and HT, differ greatly. HTO enters the body by ingestion, inhalation, and dermal absorption. Ingested HTO is distributed throughout the entire body and eliminated at the same rate as body water (apart from the small fraction metabolized). Inhaled HTO dissolves in the fluids of the lung and is absorbed. HT enters the body primarily via inhalation, and very little is retained, most being exhaled.

The effective dose equivalent from inhalation of tritium gas is lower by a factor of about 10,000 than that from tritium oxide inhalation, and, when ingestion and dermal absorption are included, HTO is considered to be 25,000 times more toxic (Eckerman et al. 1988). HT requires conversion to HTO (oxidation) to produce a significant dose. This conversion predominately occurs in soil (Brown, Ogram and Spencer, 58 Health Physics, 171-181, 1990) and, to a lesser extent, in vegetation following deposition. HT to HTO conversion is a complicated process to model.

An additional form of tritium for which exposure should be modeled is organically bound tritium (OBT). OBT can be formed by plant or animal metabolism of HTO. The dose rate conversion factor for ingestion of OBT is about 2.3 times larger than that for ingestion of HTO in the free water of plants and animals. However, because the concentration of free water tritium exceeds the concentration of tritium in organic matter for most dietary components in LLNL's ingestion dose assessment, free water tritium makes the dominant contribution to dose, per unit weight consumed. The CAP88-PC model does not address the OBT contribution to dose.

We believe that more work is warranted to develop a more accurate estimate of dose contribution by both HT and OBT. Funding has been provided at LLNL to develop a simple tritium model for incorporation in regulatory compliance codes such as CAP88-PC. The model treats HT releases independently of HTO releases, includes the contribution of organically bound tritium to ingestion dose, and is not overly conservative in predicting doses from HTO.

LLNL discussed the unsuitability of modeling HT as HTO with U.S. EPA Region IX in April 1999. The EPA directed LLNL to evaluate dose from the combined HT and HTO emissions from the Tritium Facility as if they were all HTO. EPA Region IX acknowledged that this dose, based on compliance rules, is a highly conservative overestimate of the actual dose and not indicative of physical reality.

The resulting dose to the SW-MEI from combined emissions of HT and HTO from the Tritium Facility in 1999 is 0.088 mrem (0.88 μ Sv). Modeling only the HTO emissions from the Tritium Facility results in an estimated dose to the SW-MEI of 0.067 mrem (0.67 μ Sv).

For most discharge points at the other facilities where continuous stack sampling is performed, the results are below the minimum detectable concentration (MDC) of the analysis; sometimes as few as 1 to 4 samples (out of 25 to 50 per year) have concentrations greater than the MDC. Generally, these few samples having results above the MDC are only marginally above the MDC. Use of zero values for this type of data can be justified based on knowledge of the facility, the use of tested, multiple-stage, HEPA filters in all significant release pathways, and alpha-spectroscopy-based isotopic analyses of selected air-sampling filters. These isotopic analyses demonstrate that detected activity on air-sampling filters comes from naturally occurring radionuclides, such as radon daughters, e.g., polonium, on the air sampling filters. In addition, because of exhaust configurations at some facilities, the monitoring systems sometimes sample air from the ambient atmosphere along with the HEPA-filtered air from facility operations, giving rise to background atmospheric radioactivity being collected. Because of these considerations, the emissions from such facility operations are reported as zero. Furthermore, even if the MDC values are used in calculations of the emission estimates for these facilities, which would be an extremely conservative approach, the total dose attributable to LLNL activities is not significantly affected.

In 1999, a significant number of samples collected throughout the year from one emission point at Building 251 (the unhardened area) yielded gross alpha results greater than the MDC. We use gross alpha as the primary indicator of potential emissions from Building 251, where operations had involved the use of uranium and transuranic materials (the Building 251 facility is in program standby mode). Gross beta results are used as a further corroboration of those gross alpha results having concentrations above the MDC. The gross alpha monitoring concentrations for Building 251 ranged from -2.1×10^{-15} Ci/m³ (-7.8×10^{-5} Bq/m³) to 1.5×10^{-14} Ci/m³ (5.6×10^{-3} Bq/m³). Because of the number of samples with values above the MDC, we have taken a

conservative approach and are reporting gross alpha and gross beta measurements as actual emissions. The gross alpha and gross beta emissions for Building 251 were determined to be 3.7×10^{-9} Ci/y (1.4×10^2 Bq/y) and 6.8×10^{-8} Ci/y (2.5×10^3 Bq/y). If the results are considered facility emissions, the resulting radiological dose determined with CAP88-PC modeling is 8.8×10^{-7} mrem (8.8×10^{-6} μ Sv), less than the dose due to many other facility emissions at the Livermore site. Because the dose calculated is estimated from a minimum detectable emission rather than an actual measured emission, it represents an upper bound dose estimate, and is consistent with the dose based on the inventory approach and reported in Attachment 1.

SECTION III. Dose Assessment

Description of Dose Model

Estimates of individual and collective radiological doses to the public from all point sources and many diffuse sources at LLNL were obtained using the EPA-developed computer code CAP88-PC. The four principal pathways—internal exposures from inhalation of air, ingestion of foodstuff and drinking water, 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 μ Sv). Separate doses for Livermore site and Site 300 point-source emissions (e.g., stack emissions) and diffuse-source emissions 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 comparison to the 10 mrem/y (100 μ Sv/y) standard; (2) the maximum dose to any member of the public (assumed to be at the LLNL fence line), in any direction, due to each unabated emission point on the site to determine the need for continuous monitoring; and (3) the collective dose to 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 1999 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 sampled 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

CAP88-PC contains a library of 265 radionuclides; however, it does not contain all the radionuclides in use at LLNL. As a consequence, it was necessary in a

few cases to use surrogate radionuclides to estimate EDEs. Attachment 2 shows the surrogate radionuclides used in CAP88-PC. The selection of a suitable surrogate is based upon several criteria, including metabolically similar behavior and similar modes of decay and decay energies of the radiation type of the isotope of interest. Once a surrogate is selected, the equivalent source term is adjusted by the product of the initial inventory of the isotope of interest and the ratio of the effective dose equivalent of the surrogate to that of the isotope of interest. In some cases, experimenters did not have isotopic analyses of mixtures of radionuclides and could only identify their radionuclide usage inventory as "gross alpha," "gross beta," "gross gamma," or "mixed fission products" (MFP). In these cases, ^{239}Pu was used as the surrogate for gross alpha, ^{137}Cs was used as the surrogate for gross gamma, and ^{90}Sr was used as the surrogate for gross beta and mixed fission products 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 1999 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 our investigation in 1995 into the use of the various options, the "user entered" option was again selected for the CAP88-PC modeling effort for 1999. 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 for individual dose assessment. The assumption that all milk comes from local cows is not supported by the agricultural activities conducted in the area. A detailed discussion of tritium dose calculation by CAP88-PC is presented in the LLNL NESHAPs 1995 Annual report (Gallegos et al., 1996, Lawrence Livermore National Laboratory, UCRL-ID-113867-96).

Emission Source Terms

The source term(s) from each emission point in the calculations was determined by one of two methods: For continuously monitored sources, the sampling data (curies released per unit time) for each radionuclide were used directly. For unmonitored facilities, the radionuclide usage inventories, together with time factors and EPA-specified physical state factors, are used to estimate the potential emissions to air from a source. The time factors are used

a set of receptor locations (where the combined EDEs from the selected sources were to be evaluated), also relative to the site center, were specified in the modeling efforts that supported determination of the SW-MEI. The receptor locations included 48 equally spaced directions from the site center and 4 additional receptor locations along the eastern Livermore-site boundary. The interpolation method was used to calculate the EDEs for the desired set of receptor locations for each source. These resulting interpolated EDEs for each source, now for the same set of locations, were then summed, and the SW-MEI determined.

At the Livermore site, the SW-MEI for 1999 was located at the UNCLE Credit Union, about 10 m outside the controlled eastern perimeter of the site, as shown in Figure 5. At Site 300, the 1999 SW-MEI was located in an experimental area

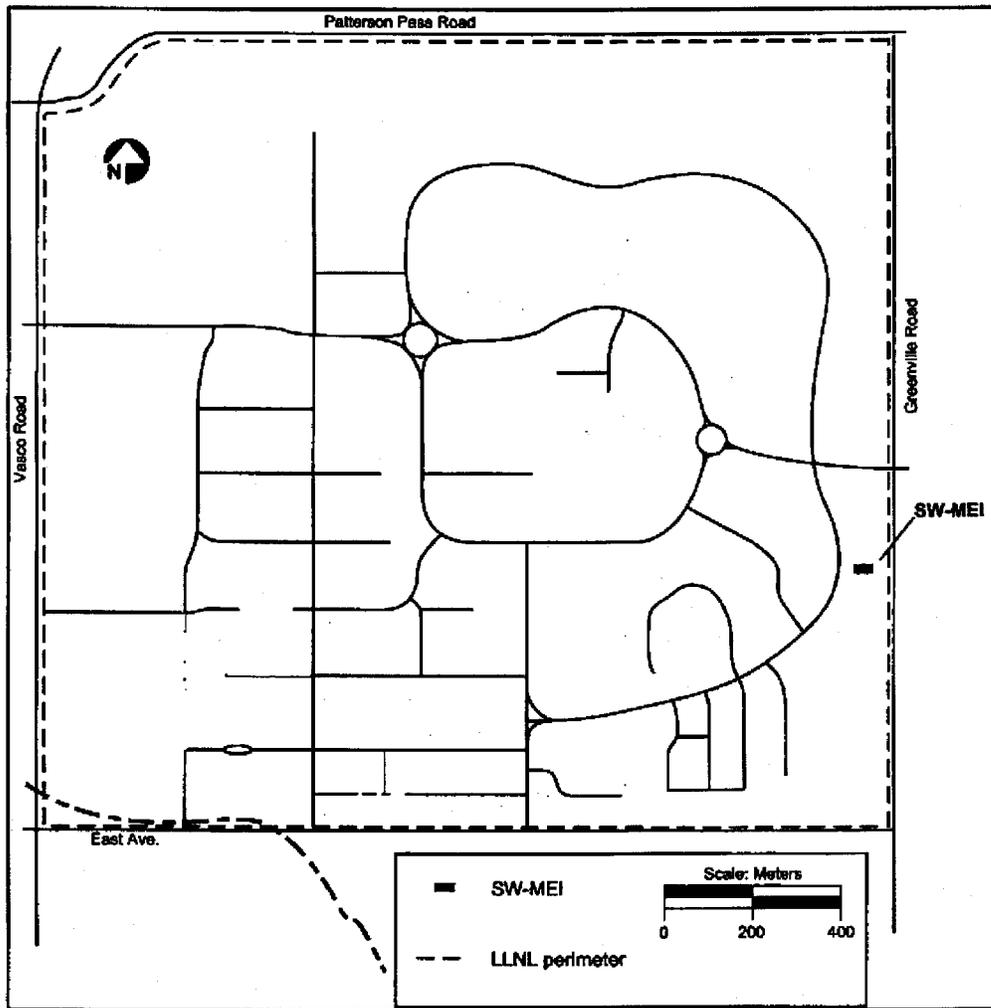


Figure 5. Location of Site-Wide Maximally Exposed Individual (SW-MEI) at the Livermore site, 1999.

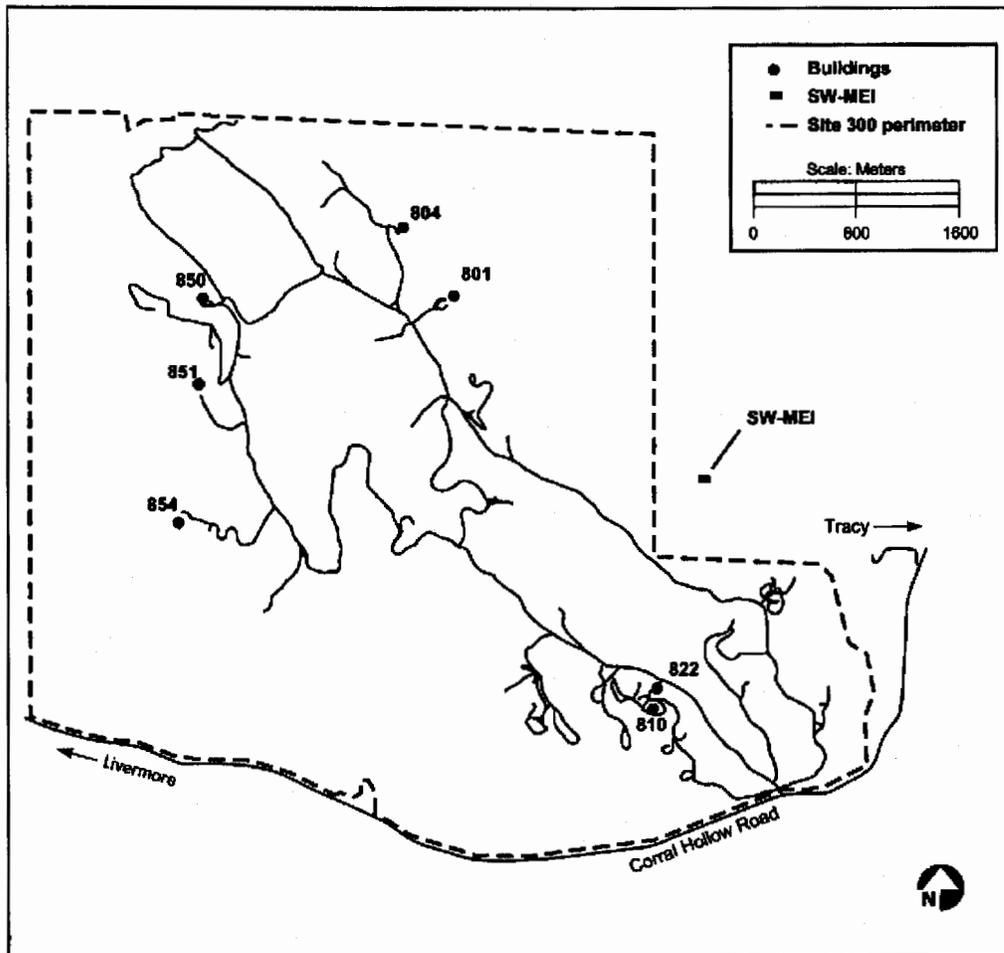


Figure 6. Location of Site-Wide Maximally Exposed Individual (SW-MEI) at Site 300, 1999.

termed "Bunker 2" operated by Primex Physics International. Bunker 2 lies about 300 m outside the east-central boundary of Site 300, as shown in Figure 6. This bunker is approximately 2.4 km east southeast of the firing table at Building 801. (It is unlikely that Bunker 2 will be the SW-MEI for the year 2000 because, as of this writing, operations by Primex Physics International at this site have ended.)

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 "Total Dose Estimate" in Section IV).

Maximally Exposed Public Individual

To assess compliance with the requirement for continuous monitoring (potential dose greater than 0.1 mrem/y [1.0 μ Sv/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 in 40 CFR Section 61.93 (b)(4)(ii), modeling for assessment of continuous monitoring requirements assumed unabated emissions (i.e., no credit was taken for emission abatement devices, such as filters). Attachment 1 provides, for each point source, the dose to the MEI and the distance and direction to the LLNL fence line where the MEI is located.

Special Modeling Challenges

Among the sources at LLNL, explosives tests using depleted uranium at Site 300 and diffuse sources at both sites required special attention.

Site 300 Explosives Experiments: Some of the explosives assemblies for Site 300 explosives experiments contain depleted uranium. The explosives assemblies are placed on an open-air firing table and detonated. Only limited data are available to characterize the initial state of the cloud of explosive decomposition products created by the detonation because properties of the cloud are not routinely measured in the experiments. Empirical scaling laws can be used, however, to define the cloud using the radionuclide usage and explosives inventories. Isotopic ratios for depleted uranium are used; the three uranium isotopes with atomic weights 238, 235, and 234 occur in the weight percentages 99.8, 0.2, and 5×10^{-4} . Their masses are multiplied by their specific activities to determine the total activity for each isotope in the cloud. It is assumed that all the uranium is dispersed into the cloud, and the median particle size is assumed to be the CAP88-PC default value of 1 μ m. The assumption that all uranium is aerosolized and dispersed as a cloud results in a highly conservative off-site dose estimation—we believe a more realistic release-to-air fraction for the uranium is no greater than 0.2, but we lack sufficient data to use a value other than 1.0. CAP88-PC simulates each shot as a low-level, steady state, stack-type emission occurring over one year. An alternative modeling methodology for treating these short-duration explosive

events was submitted for approval in 1992, but LLNL was directed by EPA to use the CAP88-PC code for these calculations.

Diffuse Sources: Diffuse emissions are generally area sources external to buildings, as discussed in Section IV, below. The dose assessments for diffuse sources can be derived from radionuclide-usage-inventory data, from environmental-surveillance monitoring data, or from samples of contaminated materials.

Modeling Documentation

Copies of individual model runs, including input parameters and resultant calculated doses, are on file with the Terrestrial & Atmospheric Monitoring & Modeling Group (TAMM) of the Environmental Protection Department at LLNL.

Point Source Summary

The 1999 calculated EDE to the SW-MEI from Livermore-site point sources was 0.094 mrem (0.94 μ Sv). (The dose from point sources includes HT emissions modeled as HTO as directed by EPA Region IX. EPA Region IX acknowledges that such modeling results in a very conservative overestimation of the dose. This methodology is used for purposes of compliance and, as noted previously, we do not believe it provides a technically accurate dose estimate.) The 1999 dose is higher than the 1998 reported EDE from Livermore-site point sources of 0.031 mrem (0.31 μ Sv). The differences in EDE to the SW-MEI can be attributed to differences in emissions from the Tritium Facility (Building 331) where emissions accounted for 0.088 mrem (0.88 μ Sv) in 1999, compared to 0.029 mrem (0.29 μ Sv) in 1998. One reason for the increase in emissions from 1998 to 1999 from the Tritium Facility was, as stated previously, the release due to an anticipated type of equipment failure within the bounds of routine operations.

The calculated EDE to the SW-MEI at Site 300 was calculated to be 0.034 mrem (0.34 μ Sv) from point-source emissions. Nearly this entire dose resulted from Building 801 and Building 851 firing-table emissions in the course of explosives experiments. The 1999 EDE is an increase from the 0.019 mrem (0.19 μ Sv) dose modeled for 1998. The increase in dose is primarily the result of an increase in the quantity of depleted uranium used in the experiments.

All the dose evaluations from point-source emissions, and those from most diffuse sources discussed below, were made using the EPA-mandated CAP88-PC dispersion model. They result in levels of public exposure well below the EPA standard, which limits the whole-body EDE to members of the public from DOE

activities to 10 mrem/y (100 μ Sv/y). Discussion of the contribution to EDE to members of the public from diffuse sources is presented in Section IV.

SECTION IV. Additional Information

Construction and Modifications

Proposed facilities and significantly modified operations are assessed for NESHAPs requirements during the National Environmental Policy Act (NEPA) process. Under NEPA, all proposed projects or actions that might involve NESHAPs issues or concerns—not just pertaining to radionuclides but to toxic air contaminants as well—are reviewed and evaluated. If the proposal includes operations that require a NESHAPs assessment, necessary modeling is conducted. If insufficient information is available for modeling at the time the NEPA documents are prepared, LLNL includes in the NEPA documents a statement that NESHAPs review, modeling, and monitoring requirements will be met. It is the responsibility of the individual project proponent to supply the specific information required for any NESHAPs modeling, analysis, and review that must be completed before operations described in the document are initiated.

Three new facilities are currently under construction. All of these facilities were assessed prior to construction for compliance with NESHAPs. Effluent sampling systems are planned for all three. These facilities are the Contained Firing Facility (CFF) at Site 300, and the Decontamination Waste Treatment Facility (DWTF) and the National Ignition Facility (NIF) at the Livermore site.

The CFF project will allow containment of some explosives tests currently conducted outdoors at Site 300's Building 801. The CFF project consists of an enclosed firing chamber, a support facility and a diagnostic equipment facility. The final phase of construction began in April 1999 and is still ongoing. CFF plans include stack monitoring for radioactive particulate emissions.

The DWTF is a waste handling facility that will have improved air emissions controls and will enable the handling of additional waste streams. Phase I construction (site preparation and installation of underground utilities) has been completed. Construction of the solid waste processing building, the storage building, and the office building were completed in 1998. Construction of the building housing the stack, air handling systems and liquid waste processing operations began in December 1999, following the issuance of the RCRA Hazardous Waste Facility permit from the State of California. The DWTF stack will be monitored for tritium and radioactive particulate emissions; some of the stack monitoring equipment has been purchased.

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. Several of these containers are not airtight and outgas tritium. A surveillance air monitor has been placed in the Building 612 Yard to provide continuous measurements of tritium in air near this source. The median annual concentration of tritium in air for 1999 in this area was 68 pCi/m^3 (2.5 Bq/m^3). These data were used to calculate the total tritium emissions from the area, using a conservative approach that assumed the source to be 60 m south-southwest of the air sampler. With this assumption, a diffuse source emission of 4.4 Ci/y ($1.63 \times 10^{11} \text{ Bq/y}$) was required to produce the concentrations measured at the air sampler. This source term produced a calculated 1999 dose to the SW-MEI from the Building 612 Yard of $1.8 \times 10^{-2} \text{ mrem}$ ($1.8 \times 10^{-1} \text{ } \mu\text{Sv}$).

Waste Accumulation Area Drum Sampling

Waste Accumulations Areas (WAAs) are maintained by the LLNL programs as storage areas for waste prior to the transfer of the waste to Hazardous Waste Management. Before the wastes are transferred, Hazardous Waste Management samples the waste drums. Because this sampling represents a potential for exposure to the atmosphere, estimates of the potential dose from this activity are provided. The waste areas are maintained at various locations around the LLNL Livermore Site, so the potential emissions were modeled from the center of the site. The emissions estimate for this source was not updated for 1999 because it is a minor contributor to dose. The dose for the Waste Accumulation Area Drum Sampling was incorrectly reported in the 1998 report as $5.1 \times 10^{-4} \text{ mrem}$ ($5.1 \times 10^{-3} \text{ } \mu\text{Sv}$). The source produced a calculated 1998 dose to the SW-MEI of $8.9 \times 10^{-9} \text{ mrem}$ ($8.9 \times 10^{-8} \text{ } \mu\text{Sv}$); this dose serves as the dose estimate for 1999 drum sampling activities.

Southeast Quadrant

The Southeast Quadrant of the Livermore site has elevated levels of $^{239+240}\text{Pu}$ 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 $^{239+240}\text{Pu}$ levels in this area. Monitoring data from this air sampler were used as a direct measurement of potential dose via the air pathway. The median annual concentration of $^{239+240}\text{Pu}$ in air of $1.6 \times 10^{-19} \text{ } \mu\text{Ci/mL}$ ($6.0 \times 10^{-15} \text{ Bq/mL}$), the dose-conversion factor of $3.08 \times 10^5 \text{ mrem/} \mu\text{Ci}$ ($8.33 \times 10^{-5} \text{ Sv/Bq}$) from Federal Guidance Report No. 11, EPA-520/1-88-020, U.S. Environmental Protection Agency (1988) for ^{239}Pu and

^{240}Pu , and the standard-man breathing rates of $8400 \text{ m}^3/\text{y}$ were used to calculate the estimated EDE of $4.2 \times 10^{-4} \text{ mrem}$ ($4.2 \times 10^{-3} \mu\text{Sv}$) for 1999.

Soil Staging Area

The soil staging area is an area near Building 170 where soil and debris are stored and tritium is remediated by evaporation. The emissions were estimated from the measured concentrations of tritium in the debris. The estimated release is $3.1 \times 10^{-2} \text{ Ci}$ ($1.1 \times 10^9 \text{ Bq}$) HTO. The CAP88-PC estimated dose to the SW-MEI is $8.4 \times 10^{-6} \text{ mrem}$ ($8.4 \times 10^{-5} \mu\text{Sv}$).

Building 223 Annex Decontamination

Building 223 annex is a location identified for decontamination. The emissions were estimated from samples of building materials. The estimated release is $6.6 \times 10^{-8} \text{ Ci}$ ($2.4 \times 10^3 \text{ Bq}$) ^{241}Am ; $7.1 \times 10^{-9} \text{ Ci}$ ($2.6 \times 10^2 \text{ Bq}$) ^{238}Pu ; and $5.4 \times 10^{-7} \text{ Ci}$ ($2.0 \times 10^4 \text{ Bq}$) $^{239+240}\text{Pu}$. The CAP88-PC estimated dose to the SW-MEI is $1.7 \times 10^{-4} \text{ mrem}$ ($1.7 \times 10^{-3} \mu\text{Sv}$).

Site 300 Diffuse Sources

Diffuse sources at Site 300 involve tritium and uranium. During remediation efforts at Site 300, LLNL completed a contaminant screening to identify potential routes of migration from soil to air and other environmental media of these radionuclides and other contaminants (Final Site Wide Remedial Investigation Report; Webster-Scholten, Ed., 1994, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-AR-108131). Tritium and ^{238}U were identified as contaminants of potential concern.

Tritium Evaporation and Migration at Site 300

Tritium gas and solids containing tritium (Li^3H) were components of explosives assemblies tested on the firing tables during past experiments. Most of the gaseous tritium escaped to the atmosphere during the tests, but some of the solid Li^3H remained as residue in the firing table gravel. Rainwater and dust-control rinse water percolated through the gravel, causing the tritium to migrate into the subsurface soil and, in some cases, eventually to the ground water. Tritium-contaminated gravel was removed from the firing tables in 1988 and disposed in the Pit 7 landfill. Tritium in landfills, firing-table soils, and ground water are source terms for diffuse emissions of tritium to the atmosphere at Site 300. The tritium contamination at these locations was characterized at Site 300 in 1994. Since that time, natural processes including rainfall and evapotranspiration acted on the locations characterized, but new data have not been collected. Because it is becoming less likely that the 1994 data are representative of current conditions, LLNL personnel installed an air tritium sampler at a location (designated PRIM) that represents the SW-MEI, and doses from diffuse tritium

sources for 1999 are estimated based on the monitoring data for that sampling location. The median annual concentration of tritium in air of 0.11 pCi/m³ (4.1 × 10⁻³ Bq/m³), the dose-conversion factor of 6.4 × 10⁻⁸ mrem/pCi (1.73 × 10⁻¹¹ Sv/Bq) from Federal Guidance Report No. 11, EPA-520/1-88-020, U.S. Environmental Protection Agency (1988) for tritium, and the standard-man breathing rates of 8400 m³/y were used to calculate the estimated EDE of 6.0 × 10⁻⁵ mrem (6.0 × 10⁻⁴ μSv) for 1999.

Resuspension of Depleted Uranium at Site 300

Like tritium, depleted uranium has been used as a component of explosives-test assemblies. It remains as a residue in surface soils, especially near the firing tables. Because surface soil is subject to resuspension by the action of wind, rain, and other environmental disturbances, the collective effects of surface soil uranium residuals on off-site doses were evaluated.

For the 1995 NESHAPs annual report, we developed calculations to separate the contribution to measured uranium activities from naturally occurring uranium (NU) (Gallegos et al., 1996, Lawrence Livermore National Laboratory, UCRL-ID-113867-96). We base our dose estimate for resuspended depleted uranium (DU) on the measured environmental surveillance monitoring total concentration in air of uranium-238, subtracting out the part contributed by NU, from the following equation:

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

where μ is the fraction (by weight) of uranium contributed by operations, CU is composite uranium (both DU and NU), M(CU-235) the mass of U-235 in the composite (measured) uranium, and M(CU-238) the mass of U-238 in the composite (measured) uranium. (For derivation of the equation see the 1995 NESHAPs annual report, referenced above.) In previous years, this equation was used only for those months in which explosives shots were not conducted. For 1999, we used the median concentration of all months to represent the potential annual exposure from resuspension of DU at Site 300.

Using these calculations to apportion the M(CU) for 1999, we obtain an annual average concentration of DU in air from resuspension of 3.2 × 10⁻¹² g/m³. Using the fractions 0.998, 0.002, and 0.000005 to represent the amounts of ²³⁸U, ²³⁵U, and ²³⁴U; specific activities of 3.33 × 10⁻⁷, 2.14 × 10⁻⁶, and 6.20 × 10⁻³ Ci/g for ²³⁸U, ²³⁵U, and ²³⁴U; a yearly inhalation rate of 8400 m³/y, and dose conversion factors from EPA Regulatory Guide 11 of 1.18 × 10¹¹, 1.23 × 10¹¹, and

1.32×10^{11} mrem/Ci; we obtain a total dose for resuspended DU of 1.2×10^{-3} mrem (1.2×10^{-2} μ Sv).

Errata in 1998 Annual Report

For the Livermore site, the inventory and the dose that was reported for the drum sampling operations at all waste accumulation areas was incorrect. The inventory of all nuclides was reported as zero; the correct inventory values are reported in Attachment 1. The dose at the SW-MEI from these operations should have been reported as 8.9×10^{-9} mrem (8.9×10^{-8} μ Sv). The dose to the fenceline MEI should have been reported as 3.6×10^{-8} mrem (3.6×10^{-7} μ Sv). The correction has no effect on the total dose to the SW-MEI. The correct dose estimates are also presented in Attachment 1.

For Site 300, the 1998 report incorrectly stated on page 31 that the population dose for operations conducted in 1997 was 3.6 person-rem (0.0036 person-Sv); the 1998 report should have stated the population dose was 7.2 person-rem (0.0072 person-Sv). The population dose is correctly reported in Attachment 3 of the 1998 report.

Total Dose Estimate and Comparison with Previous Years' Data

For the Livermore site, the dose calculated for the SW-MEI from diffuse emissions in 1999 totaled 0.028 mrem (0.28 μ Sv). The dose due to point sources was 0.094 mrem (0.94 μ Sv). When combined, the total annual dose was 0.12 mrem (1.2 μ Sv). The dose from point sources includes Tritium Facility HT emissions modeled as HTO, as directed by EPA Region IX. EPA Region IX acknowledges that such modeling results in a very conservative overestimation of the dose. A more accurate dose from both point and diffuse source emissions from the Livermore site is 0.10 mrem (0.10 μ Sv).

The total dose to the Site 300 SW-MEI from operations in 1999 was 0.035 mrem (0.35 μ Sv). Point-source emissions from firing-table explosives experiments accounted for 0.034 mrem (0.34 μ Sv), of this total, while 0.0012 mrem (0.012 μ Sv), or about 3%, was contributed by diffuse sources. Table 4 presents the facilities or sources that account for 90% or more of the doses for the Livermore site or Site 300 SW-MEI.

Table 4. List of facilities or sources whose emissions account for 90% or more of the doses for the Livermore site and Site 300 SW-MEI.

Facility or Source	Dose (mrem)	Percent Contribution to Total Dose
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This methodology is used for purposes of compliance and we do not believe that it provides a technically valid dose estimate. For 1999, the total dose not having HT emission modeled as HTO is 0.10 mrem; the point source dose is 0.073 mrem.

- b Diffuse source doses were not reported separately from the total dose for the Livermore site for 1990 and 1991.
- c No diffuse emissions were reported at Site 300 for years before 1993.

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

Direction	Range of distance from site (km)					Total
	0-16	16-32	32-48	48-64	64-80	
N	235	12558	25414	6068	1932	46207
NNW	2135	1785	121044	1396	166741	293101
NW	6975	17085	247376	117130	102863	491429
WNW	1774	71710	224893	482899	152988	934264
W	49338	78214	312603	410117	568185	1418457
WSW	28590	115085	133563	311837	19824	608899
SW	304	85476	251417	129576	5113	471886
SSW	53	20234	600957	335772	59236	1016252
S	89	155	48296	61359	58915	168814
SSE	175	209	3	33	2481	2901
SE	321	55	50	25	9811	10262
ESE	139	166	1918	14064	55714	72001
E	77	7961	7103	153249	138118	306508
ENE	127	32766	60254	10831	3349	107327
NE	75	681	101717	219898	13442	335813
NNE	5	7115	1421	5570	18971	33082
Total	90412	451255	2138029	2259824	1377683	6317203

Table 7. Population distribution for LLNL's Site 300, based on 1990 census information. Values are population in sector segments bounded by the indicated inner and outer radii, for each of sixteen 22.5°-sector directions.

Direction	Range of distance from site (km)					Total
	0-16	16-32	32-48	48-64	64-80	
N	866	3363	2494	3633	6034	16390
NNW	104	4774	72306	4130	33751	115065
NW	88	225	25796	267551	107081	400741
WNW	152	20378	94428	309007	588389	1012354
W	454	72602	168776	285461	492124	1019417
WSW	49	43	188555	283552	123768	595967
SW	54	72	381738	641040	26040	1048944
SSW	4	3	46491	150412	24369	221279
S	19	242	3	26045	41175	67484
SSE	0	2	2	14	88	106
SE	33	15	151	8173	4938	13310
ESE	131	1286	13423	50535	32525	97900
E	270	2137	129980	133301	10026	275714
ENE	1264	21973	30017	22099	2845	78198
NE	32442	15122	87148	7502	4079	146293
NNE	4411	928	186995	69583	21515	283432
Total	40341	143165	1428303	2262038	1518747	5392594

The collective EDE not having HT emission modeled as HTO is 1.7 person-rem (0.017 person-Sv). The collective dose is greater than the 1998 value of 0.84 person-rem (0.0084 person-Sv) because the stack releases from Building 331 (the Tritium Facility) increased in 1999. This collective EDE can also be compared to the collective dose from natural background radioactivity for 6.3 million people of 1.88×10^6 person-rem (1.88×10^4 person-Sv).

The corresponding collective EDE from Site 300 operations in 1999, 11 person-rem (0.11 person-Sv), was due to point-source emissions. The total collective EDE value for Site 300 is the same as the 1998. The similarity of the population dose for the two years is coincidental; the individual dose to the SW-MEI differed by 0.011 mrem (0.11 μ Sv) for the two years.

The larger collective dose for Site 300 compared to the Livermore site is traceable primarily to the highly conservative assumptions about the Site 300 explosives experiments, especially regarding the fraction of radioactive material that is aerosolized and the height and trajectory of the explosive-debris cloud. This conservative modeling methodology over-predicts the quantity of radionuclides released to air by at least a factor of five, we believe, and over-estimates the long-range dispersal of material in these experiments. In 1992, we submitted to EPA a modeling protocol designed to treat the transient explosive experiments more realistically than does CAP88-PC, but this protocol was not accepted.

Compliance with 40 CFR 61 Subpart H (61.93)

Calculations of effective dose equivalents for all Livermore-site and Site 300 facilities having the potential to release radionuclides to the atmosphere have been completed. Annual doses from actual total emissions of all facilities during 1999 were found to be well below the 10 mrem (100 μ Sv) NESHAPs dose standard. Tritium accounted for most of the Livermore-site calculated dose, while at Site 300 practically the entire calculated dose was due to the isotopes ^{238}U , ^{235}U , and ^{234}U , in depleted uranium.

Stack monitoring is based on evaluations of potential emissions without control devices or on EPA concurrence for those facilities for which classification or other issues prevent a usage-inventory-based evaluation. Facilities in the latter category include Building 331, Building 332, and the seismically hardened area of Building 251.

Several other Livermore-site facilities (Buildings 175, 251 unhardened, and 491) also will maintain continuous-monitoring systems; however, calculations using unabated potential emissions resulted in EDEs of less than 0.1 mrem/y

Table 8. Air-effluent sampling locations and systems.

Building	Facility	Analytes	Sample type	Number of samplers
175	MARS	Gross α , β on particles	Filter	6
177	Extractor Test	Gross α , β on particles	Filter	1
251	Heavy Elements			
	Unhardened area	Gross α , β on particles	Filters	44 ^a
	Hardened area	Gross α , β on particles	Filters	4
	Hardened area	Gross α , β on particles	CAM ^b	4 ^c
292	Molten Salt Oxidation	Gross α , β on particles	Filter	1 ^c
331	Tritium	Tritium	Ionization Chamber ^b	4
		Gaseous tritium/ tritiated water vapor	Molecular sieves	4
332	Plutonium	Gross α , β on particles	CAM ^b	12
		Gross α , β on particles	Filters	16
490	USEC Laser Isotope Separation	Gross α , β on particles	Filters	4 ^c
491	USEC Laser Isotope Separation	Gross α , β on particles	Filters	1

Note: "CAM" denotes Eberline continuous air monitors.

^a Sixteen of these systems were deactivated in 1999.

^b Alarmed systems.

^c Sampling at this location was terminated in 1999.

In 1999, sampling at several air effluent locations was terminated. In the past, operations performed in Buildings 175, 177, 490, and 491 have supported research and development for the separation of uranium isotopes under the Advanced Vapor Laser Isotope Separation Program (AVLIS). In 1999, the AVLIS Program was shutdown and samplers on a Building 490 exhaust system were deactivated because the operation of the ventilation system was stopped. Air effluent sampling systems at the Building 175, 177, and 491 continue to operate as part of the maintenance and surveillance shutdown plan for AVLIS facilities. At the Heavy Element Facility, 20 samplers were deactivated. This facility has been in program standby mode for some time and activities involving the use of radiological materials are not expected to resume in the areas previously monitored by the deactivated samplers. Finally, a sampling system located at the Expedited Technology of Molten Salt

Oxidation project in Building 292 was removed because the project was completed. At the end of 1999, LLNL was operating 76 air effluent sampling systems at 6 facilities.

Air samples for particulate emissions are extracted downstream of HEPA filters and prior to the discharge point to the atmosphere. Particles are collected on membrane filters. The sample filters are removed and analyzed for gross alpha and beta activity on a weekly or bi-weekly frequency depending on the facility. In most cases, simple filter-type aerosol collection systems are used. However, in some facilities, alpha continuous-air monitors (CAMs) are used for sampling. In addition to collecting a sample of particles, 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 the end of sample collection 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. Each sieve sampler (not alarmed) is in parallel with an alarmed monitor and consists of two molecular sieves. The first sieve collects tritiated water vapor; the second sieve contains a palladium-coated catalyst that converts molecular tritium to tritiated water, which is then collected. 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.

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

activity concentrations was also compared to the average of activity from low-volume air surveillance samplers during and surrounding the period of sampling. These samplers, located at the FCC and HOSP off-site surveillance locations, are considered to be representative of ambient radioactivity concentrations since the locations are typically not downwind of site operations. (See Larson et al., Environmental Report for 1998, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-98, (October 1999) for a description of the location of these air samplers.) The activity concentrations for the Building 251 measurements were found to differ significantly from those at the FCC location, but not those at the HOSP location. These results, along with the fact that no operations were taking place at the time of sampling, make it likely that the detected concentrations are not indicative of actual emissions. Nevertheless, if projected throughout the entire year, the estimated emissions for gross alpha and gross beta activities are 1.7×10^{-8} Ci (6.1×10^2 Bq) and 9.4×10^{-8} Ci (3.5×10^3 Bq), respectively. The EDE estimated for these potential emissions are 2.8×10^{-6} mrem (2.8×10^{-5} μ Sv) at the SWMEI and 1.6×10^{-5} mrem (1.6×10^{-4} μ Sv) for the MEI. The EDE at the SWMEI is less than 0.003% of the EDE resulting from all 1999 Livermore site potential emissions.

General Surveillance Monitoring

Surveillance air monitoring for tritium and radioactive particles has been in place since the 1970s and will continue. LLNL currently maintains eight continuously operating, high-volume, air-particulate samplers on the Livermore site, nine in the Livermore Valley, eight at Site 300, one offsite near Site 300, and one in Tracy. LLNL also maintains eleven continuously operating tritiated water vapor samplers on the Livermore site, six samplers in the Livermore Valley and one offsite near Site 300. The samplers are positioned to ensure reasonable probability that any significant airborne concentration of particulate and tritiated water vapor effluents resulting from LLNL operations will be detected. Many of the surveillance air monitors are placed near diffuse emission sources, such as those near Buildings 292, 331, 513, 514, and 612, as well as in and around the Southeast Quadrant of the Livermore site. As such, their results can be used to estimate and/or confirm the emissions from the associated diffuse sources. Also included are air-particulate and tritiated water vapor monitors positioned at the locations of the SW-MEI for the Livermore site and Site 300. Results from the latter samplers provide a source term for large area diffuse sources and also serve to confirm the SW-MEI EDEs as determined from facility emissions using air effluent monitoring results and usage inventories.

The data from the air surveillance monitoring network provide continuous measurements of the concentrations of radionuclides present in the air at the Livermore site, Site 300, and in the surrounding areas. Data from the network are presented in the LLNL Environmental Report, which is prepared annually and available to the public. (Larson et al., Environmental Report for 1999, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-99, to be published in October 2000.)

Comparison of 1999 Modeling Results with Surveillance Monitoring Data

A comparison was made between CAP88-PC modeling results and surveillance air monitoring data for the eleven tritiated water vapor monitors on the Livermore site (designated VIS, SALV, POOL, CAFE, MESQ, MET, COW, B331, B514, B624, and B292) and one off-site tritiated water vapor (ZON7). Monitor locations are shown in Figure 7.

Only the three most significant sources of tritium releases to air at the Livermore site were included in the model-data comparison. The largest source is the Tritium Facility (Building 331), where the tritium is emitted from two 30-m-high, continuously monitored stacks; a total of 214 Ci (7.9 TBq) of HTO was

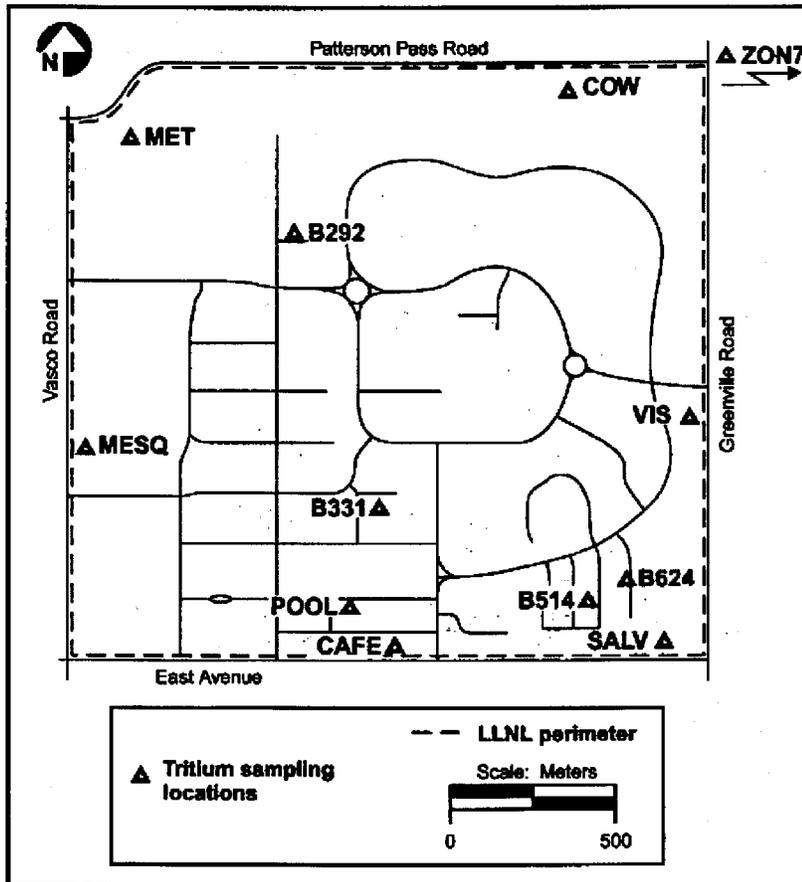


Figure 7. Tritiated water vapor surveillance sampling locations.

emitted from these stacks in 1999. The other two principal sources are diffuse areas associated with the Building 612 yard and Tritium Facility (Building 331) yard. Emissions from these sources were estimated to be 4.4 Ci (0.16 TBq) and 7.3 Ci (0.27 TBq) in 1999. All other potential sources of tritiated water vapor release, such as the hazardous waste management operations in Building 514 and the Building 292 diffuse source were too minor to influence the model-data comparison.

Annual-average concentrations ($\mu\text{Ci}/\text{m}^3$ of air) at the locations of the twelve monitors were modeled for the three sources individually and collectively, and compared to the measured annual median concentrations at the twelve monitoring locations. The results are displayed in Figure 8.

The Building 331 stack emissions were used as input to CAP88-PC with the site-specific meteorological data to calculate the annual-average concentrations at

the desired locations. However, both the B331 Yard and the B612 Yard emission rates

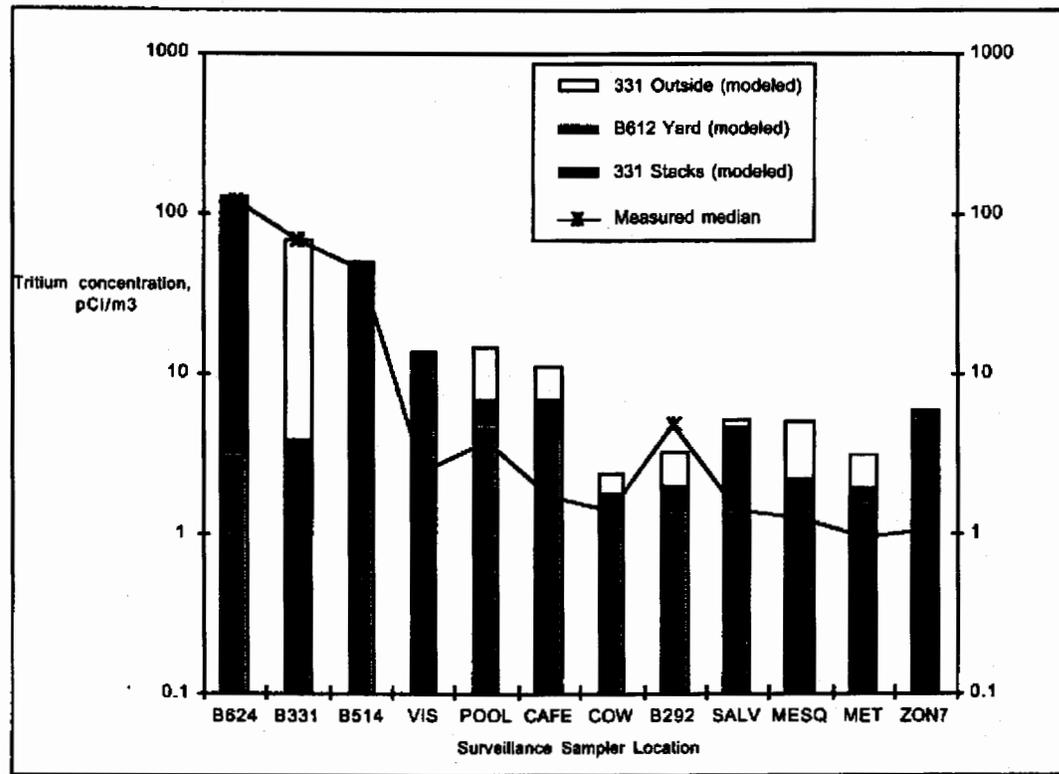


Figure 8. Comparison of measured and modeled tritium concentrations, 1999. Note that the logarithmic scaling used visually distorts the smaller concentration values. were not independently measured, but rather were determined from the surveillance tritiated water vapor monitor data for the particular monitor in the closest proximity, by requiring that the modeled concentration match the data from that particular monitor. The source term for Building 612 Yard was adjusted to give the observed value at the B624 monitor, and the source term for the B331 Yard was chosen to give agreement with the measured value at all other monitors. Using this approach, the modeling results, by design, agree with the monitoring data at the B624 and B331 locations.

The main conclusion shown in Figure 8 is that by taking into account the three leading sources of tritiated water vapor releases to air—the Building 331 stacks, Building 612 Yard, and the Building 331 Yard—fairly good agreement is obtained with data for all of the monitors. Generally, the modeling results agree with the on-site monitoring data within a factor of 4.0 (at 9 out of twelve

locations). However, in the case of three monitors (CAFE, VIS and ZON7), the difference is nearly a factor of seven, with the model resulting in higher concentration predictions where public exposures could occur. The model result is a factor of 1.6 lower than the measured result at B292, a location well inside the site perimeter and near buildings, where CAP88-PC dispersion modeling is less realistic.

Status of the NESHAPs QA Program

The LLNL NESHAPs Quality Assurance (QA) Program is a multi-organizational effort that relies on the Quality Assurance/Quality Control programs that are in place at the LLNL facilities with continuous air-monitoring systems, the Radiological Measurements Laboratory (RML) and the Analytical Laboratory of the Hazards Control Department (HCD), and the Environmental Protection Department (EPD). NESHAPs Agreement Roles and Responsibilities (NARRs) documents are in place between EPD and the facilities and/or programs and HCD; these NARRs formalize responsibilities and obligations of the organizations regarding many tasks for the air effluent sample network. Tasks that are addressed include air sampler design and installation, procedures and their implementation, sampling, sample analysis and tracking, maintenance and repair of sampling systems, guidance on regulatory requirements, documentation of the sampling network, reporting, and the archival of records.

Facility Safety Procedures (FSPs), Safety Analysis Reports (SARs) and QA Manuals for monitored facilities describe their organizational structures, responsibilities for sampling locations used for continuous air monitoring, and the procedures to be followed in the case of unplanned radionuclide 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 real-time and passive (i.e., not alarmed) air-monitoring systems, and procedures to be used for measuring flow rates, sampling, and calibration.

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 air sampler filters for radioactivity.

emissions, resulting in the treatment of HT as HTO for the purposes of NESHAPs compliance (see discussion on page 10), and a discussion of time-weighting factors in the estimation of emissions from inventoried sources (see "Emission Source Terms" in Section III). The meeting ended after a presentation on a non-NESHAPs topic, i.e., a summary of the results from the soil sampling effort at Big Trees Park in Livermore (Larson et al., Environmental Report for 1998, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-98, October 1999).

Estimated Annual Emissions

For unmonitored and non-continuously monitored sources, estimated annual emissions for each radionuclide are based on the product of (1) usage inventory data, (2) time factors (discussed in "Emission Source Terms" of in Section III), (3) EPA potential-release fractions (physical-state factors), and (4) applicable emission-control-device abatement factors.

Actual emission measurements are the basis for reported emissions from continuously monitored facilities. LLNL facilities that had continuous monitoring systems at the beginning of 1999 were Buildings 175, 177, 251, 292, 331, 332, 490, and 491; as noted earlier, systems at Buildings 292 and 490 were removed before the end of the year. See the subsection titled "1999 Usage Inventory Update and Effective Dose Equivalent (EDE) Calculations" 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 μ Sv/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 "Total Dose Estimate" in Section IV).

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 μ Sv/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 and time 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 seven 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-usage-inventory update for 1999; (2) Unmonitored or non-continuously monitored Livermore site facilities with a previous radionuclide-usage-inventory update (this category is not used in years with complete usage inventory updates, like 1997); (3) Continuously monitored Livermore-site facilities; (4) Site 300 explosives experiments; (5) Diffuse sources where emissions and subsequent doses were estimated using inventory processes; (6) Diffuse sources where emission and dose estimates were supported by environmental-surveillance measurements; and (7) Sources whose emissions estimates and subsequent doses were estimated based on periodic confirmatory air sampling rather than continuous sampling.

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Attachment 1 - 1998 LLNL NESHAPs Annual Report Spreadsheet

Building	Room/Area	Task ID	Operation	Multitask	Annual Inventory with Potential for Release (lb)	Physical State	Stack Height (ft)	Stack Diameter (in)	Stack Velocity (ft/s)	Control Device(s)	Control Device Efficiency (%)	Estimated Annual Emissions (lb)	10 Percentile Max. 5-Min. Area (sq ft)	Distance to Downwind (ft)	10 Percentile Max. 5-Min. Area (sq ft)	Distance to Downwind (ft)	10 Percentile Max. 5-Min. Area (sq ft)	Distance to Downwind (ft)	Source Category
Building 381	381-0154-3154	381-0154-3154-1	Titan handling for laser target (RAD)	H-3	0.01-0.0	Solid	11.3	0.38	26.8	None	1	0.02-06	1092	7.0E+10	7.0E+10	7.0E+10	7.0E+10	7.0E+10	2
Building 381	381-0154-3154	381-0154-3154-1	Titan handling for laser target (RAD)	H-3	0.01-0.0	Solid	11.3	0.38	26.8	None	1	0.02-06	1092	7.0E+10	7.0E+10	7.0E+10	7.0E+10	7.0E+10	2
Building 490	490	490-0154-3154	Titan handling for laser target (RAD)	H-3	0.01-0.0	Solid	11.3	0.38	26.8	None	1	0.02-06	1092	7.0E+10	7.0E+10	7.0E+10	7.0E+10	7.0E+10	2
Building 491	491	491-0154-3154	Titan handling for laser target (RAD)	H-3	0.01-0.0	Solid	11.3	0.38	26.8	None	1	0.02-06	1092	7.0E+10	7.0E+10	7.0E+10	7.0E+10	7.0E+10	2
Building 513	513	513-0154-3154	Titan handling for laser target (RAD)	H-3	0.01-0.0	Solid	11.3	0.38	26.8	None	1	0.02-06	1092	7.0E+10	7.0E+10	7.0E+10	7.0E+10	7.0E+10	2
Building 514	514	514-0154-3154	Titan handling for laser target (RAD)	H-3	0.01-0.0	Solid	11.3	0.38	26.8	None	1	0.02-06	1092	7.0E+10	7.0E+10	7.0E+10	7.0E+10	7.0E+10	2

Attachment 1 - 1999 LLNL NESHAPs Annual Report Spreadsheet

Building	Room/Area	Stack ID	Operation	Restructures	Annual Inventory with Potential for Release (Ci)	Physical State Factor	Stack Height (ft)	Stack Diameter (in)	Stack Velocity (m/s)	Control Device (Develop)	Control Device Assignment Factor	Estimated Annual Emissions (Ci)	Distance to Stack (ft)	Distance to Stack (mi)	Source Category									
Building 012 (logwood)				Co-141	7,052.0	1.0E-01	100	100	100			7,052.0												
				Co-142	1,175.0	1.0E-01	100	100	100					1,175.0										
				Co-143	8,175.0	1.0E-01	100	100	100						8,175.0									
				Co-144	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-145	3,345.0	1.0E-01	100	100	100						3,345.0									
				Co-146	6,775.0	1.0E-01	100	100	100						6,775.0									
				Co-147	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-148	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-149	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-150	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-151	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-152	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-153	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-154	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-155	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-156	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-157	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-158	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-159	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-160	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-161	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-162	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-163	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-164	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-165	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-166	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-167	1,135.0	1.0E-01	100	100	100						1,135.0									
				Co-168	1,135.0	1.0E-01	100	100	100						1,135.0									
Co-169	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-170	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-171	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-172	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-173	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-174	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-175	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-176	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-177	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-178	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-179	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-180	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-181	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-182	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-183	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-184	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-185	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-186	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-187	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-188	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-189	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-190	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-191	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-192	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-193	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-194	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-195	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-196	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-197	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-198	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-199	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-200	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-201	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-202	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-203	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-204	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-205	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-206	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-207	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-208	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-209	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-210	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-211	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-212	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-213	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-214	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-215	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-216	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-217	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-218	1,135.0	1.0E-01	100	100	100						1,135.0													
Co-219	1,135.0	1.0E-01	100	100	100																			

Attachment 1 - 1998 LLNL NESHAP's Annual Report Spreadsheet

Source Category	Source ID	Operation	Reference	Annual Inventory with Records for Release (Ci)	Physical State Factor	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s) Name	Control Device Factor	Estimated Annual Emissions (Ci)	13. control Stack/Shaft/Duct Requirements Diameter to MEI (m)	13. control Stack/Shaft/Duct Requirements Direction to SWMS	13. control Stack/Shaft/Duct Requirements ESE (m/min)	13. control Stack/Shaft/Duct Requirements Diameter to MEI (m)	13. control Stack/Shaft/Duct Requirements Direction to MEI	Unassessed ESE (m/min)	Source Category
Gaseous Methane (contaminants 1% or more to the potential reactive dose equivalent at each site)	311	311	H-3			30	1.22	7.5	Name	1	5.7E+00	917	ENE	8.0E-02	917	ENE	8.0E-02	3
	312	312	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3
	313	313	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3
Gaseous Methane (contaminants 1% or more to the potential reactive dose equivalent at each site)	311	311	H-3			30	1.22	7.5	Name	1	5.7E+00	917	ENE	8.0E-02	917	ENE	8.0E-02	3
	312	312	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3
	313	313	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3
Gaseous Methane (contaminants 1% or more to the potential reactive dose equivalent at each site)	311	311	H-3			30	1.22	7.5	Name	1	5.7E+00	917	ENE	8.0E-02	917	ENE	8.0E-02	3
	312	312	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3
	313	313	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3
Gaseous Methane (contaminants 1% or more to the potential reactive dose equivalent at each site)	311	311	H-3			30	1.22	7.5	Name	1	5.7E+00	917	ENE	8.0E-02	917	ENE	8.0E-02	3
	312	312	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3
	313	313	H-3			30	1.22	10.3	Name	1	2.7E+00	917	ENE	8.7E-02	917	ENE	8.7E-02	3

Attachment 2. Surrogate Radionuclides List

The need for selection of a surrogate isotope occurs when an isotope used in operations (isotope of interest) is not contained in the limited nuclide library in the NESHAPs dose compliance model CAP88-PC. The selection of a suitable surrogate is based upon several criteria. If possible, a surrogate isotope is chosen from the CAP88-PC radionuclide library that has a metabolically similar behavior to the isotope of interest. Following an acute inhalation exposure, the metabolically similar surrogate would concentrate in specific organs and tissues as the isotope of interest. In most cases the surrogate selected possesses similar modes of decay and decay energies of the radiation type of the isotope of interest. Thus, the surrogate models the behavior of the isotope with similar relative biological effect due to deposition energy.

According to present knowledge, the daughter nuclides produced following physical decay are assumed to remain organ site specific and follow the translocation pathway of the parent. Therefore, when a surrogate of similar metabolic behavior is not available or has a greatly dissimilar half-life, the surrogate chosen is a daughter nuclide of the isotope of interest that will remain organ site specific and follow the translocation pathway of the parent.

Once a surrogate has been selected, the equivalent source term is adjusted by the product of the initial inventory of the isotope of interest and the ratio of the effective dose equivalent of the surrogate to that of the isotope of interest. For determining the dose ratio, the primary exposure pathway is assumed to be that of inhalation and inhalation dose conversion factors (International Commission on Radiological Protection Publication No. 71, "Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 4 Inhalation Dose Coefficients," Elsevier Science Ltd., 1996) are used for determination of the effective dose equivalents.

In addition, isotopic analysis of mixtures of radionuclides are not always available, and radionuclide usage inventories are stated as "gross alpha," "gross beta," "gross gamma," or "mixed fission products" (MFP). In these cases, ^{239}Pu is used as the surrogate for gross alpha, ^{137}Cs is used as the surrogate for gross gamma, and ^{90}Sr is used as the surrogate for gross beta and mixed fission products to provide conservative dose estimates.

Table 2-1 provides a list a radionuclides not in the CAP88-PC library and their respective surrogates.

Table 2-1. List of surrogate radionuclides.

Isotope	Half-Life	Lung Class ^a	ALI (inh) μCi	DAC (inh) $\mu\text{Ci}/\text{m}^3$	Surrogate	Half-Life	Lung Class ^a	A LI (inh) μCi	DAC (inh) $\mu\text{Ci}/\text{m}^3$
Ca-108m	127 y	Y	2.0×10^1	1.0×10^{-8}	Co-60	5.271 y	Y	3.0×10^1	1.0×10^{-8}
Bi-207	38 d	W	4.0×10^2	1.0×10^{-7}	Bi-214	19.9 min	W	9.0×10^2	4.0×10^{-7}
Ca-45	163 d	W	8.0×10^2	4.0×10^{-7}	Sr-90	29.12 y	D	2.0×10^1	8.0×10^{-9}
Cd-109	464 d	Y	1.0×10^2	5.0×10^{-8}	Co-60	5.271 y	Y	3.0×10^1	1.0×10^{-8}
Cf-249	350.6 y	Y	1.0×10^{-2}	4.0×10^{-12}	Cm-245	8500 y	W	6.0×10^{-3}	3.0×10^{-12}
Cf-250	13.1 y	W	9.0×10^{-3}	4.0×10^{-12}	Am-241	432.2 y	W	6.0×10^{-3}	3.0×10^{-12}
Cl-36	3.01×10^5 y	W	2.0×10^2	1.0×10^{-7}	Cs-137	30 y	D	2.0×10^2	6.0×10^{-8}
Es-254	275.7 d	W	7.0×10^{-2}	3.0×10^{-11}	Pu-239	24065 y	Y	2.0×10^{-2}	7.0×10^{-12}
Eu-149	93.1 d	W	3.0×10^3	1.0×10^{-6}	Pm-151	28.4 hr	Y	3.0×10^3	1.0×10^{-6}
Gd-148	93 y	D	8.0×10^{-3}	3.0×10^{-12}	La-140	40.272 h	W	1.0×10^3	5.0×10^{-7}
Os-185	94 d	D	5.0×10^2	2.0×10^{-7}	Mo-99	66 h	Y	1.0×10^3	6.0×10^{-7}
P-33	25.4 d	W	3.0×10^3	1.0×10^{-6}	P-32	14.29 d	D	9.0×10^2	4.0×10^{-7}
Re-184	38 d	W	1.0×10^3	6.0×10^{-7}	Mo-99	66 h	Y	1.0×10^3	6.0×10^{-7}
Se-75	119.8 d	W	6.0×10^2	3.0×10^{-7}	As-76	26.32 h	W	1.0×10^3	6.0×10^{-7}
Sr-85	64.8 d	D	3.0×10^3	1.0×10^{-6}	Sr-90	29.12 y	D	2.0×10^1	8.0×10^{-9}
Ta-182	115 d	Y	1.0×10^2	6.0×10^{-8}	Hf-181	42.4 d	W	4.0×10^2	2.0×10^{-7}
Tb-157	110 y	W	3.0×10^2	1.0×10^{-7}	La-140	40.272 h	W	1.0×10^3	5.0×10^{-7}
Tb-158	180 y	W	2.0×10^1	8.0×10^{-9}	La-140	40.272 h	W	1.0×10^3	5.0×10^{-7}
Tl-204	3.78 y	D	2.0×10^3	9.0×10^{-7}	Pb-214	26.8 min	D	8.0×10^2	3.0×10^{-7}
Tm-168	93.1 d	W	2.0×10^3	8.0×10^{-7}	La-140	40.272 h	W	1.0×10^3	5.0×10^{-7}
Tm-171	1.92 y	Y	3.0×10^2	1.0×10^{-7}	La-140	40.272 h	W	1.0×10^3	5.0×10^{-7}
Y-88	106.64 d	Y	2.0×10^2	1.0×10^{-7}	Y-90	64 h	Y	6.0×10^2	3.0×10^{-7}
Am-244	10.1 h	W	2.0×10^2	8.0×10^{-8}	Cm-244	18.11 y	W	1.0×10^{-2}	5.0×10^{-12}
Au-195	183 d	Y	4.0×10^2	2.0×10^{-7}	Ba-133	10.74 y	D	7.0×10^2	3.0×10^{-7}
Co-56	78.76 d	Y	2.0×10^2	8.0×10^{-8}	Co-60	5.271 y	Y	3.0×10^1	1.0×10^{-8}
Gd-146	48.3 d	W	3.0×10^2	1.0×10^{-7}	Sm-147	1.06×10^{11} y	W	4.0×10^{-2}	2.0×10^{-11}
Kr-85	10.72 y	Gas	See Note	1.0×10^{-4}					
Rh-102	2.9 y	Y	6.0×10^1	2.0×10^{-8}	Rh-106m	29.9 s	Y	4.0×10^4	1.0×10^{-5}
U-239	23.54 min	Y	2.0×10^5	6.0×10^{-5}	U-240	14.1 h	Y	2.0×10^3	1.0×10^{-6}
Zr-90	809 ms	W	N/A	N/A	Y-90	64 h	Y	6.0×10^2	3.0×10^{-7}
Po-209 ^b	102 y	N/A	N/A	N/A	Pu-239	24065 y	Y	2.0×10^{-2}	7.0×10^{-12}

Note: The DAC for Kr-85 also has been relaxed considerably since its beta emission only irradiates the skin. The DAC is based on limitation of non-stochastic effects in the skin; the MPC was derived assuming that the beta particles of energy greater than 0.1 MeV contributed to the whole body dose.

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

^b No ALI or DAC information available. Pu-239 used to provide a conservative alpha-emitter dose.

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.

