Environmental Protection Department

Operations and Regulatory Affairs Division

LLNL NESHAPs

1997 Annual Report

Lawrence Livermore National Laboratory
University of California Livermore, California 94550

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

LLNL NESHAPs 1997 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 1997**

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June 1998

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Lawrence Livermore National Laboratory NESHAPs 1997 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 1997 operations were

- Livermore site, 0.097 mrem (0.97 μ Sv) (80% from point-source emissions, 20% from diffuse-source emissions),
- Site 300, 0.014 mrem (0.14 μ Sv) (38% from point-source emissions, 62% 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 inventory data or continuous-monitoring systems data were the specific input to CAP88-PC for each modeled source.

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 mission is to serve as a national resource in science and engineering, with a special responsibility for nuclear weapons. Laboratory activities focus on global security, energy, global ecology, biomedicine, economic competitiveness, and science and mathematics education. The Laboratory's mission is dynamic and has been broadened over the years 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.

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 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. Temperatures typically range from -5°C during some pre-dawn hours in the winter, to 40°C on a few summer afternoons. The 1997 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 1997, the Livermore site received 282 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

Figure 1. Locations of LLNL Livermore site and Site 300

area of 30.3 km². It is close to two other explosives-testing facilities, one operated by Primex 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 approximately 45,000), located 10 km to the northeast.

Table 1. Wind rose for LLNL's Livermore site at the 10-m level for 1997
Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding.

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 05	2 65	1 73	0 58	0 55	5 56
NE	0 05	3 17	2 72	0 29	0 15	6 38
ENE	0 05	3 80	0 29	0 00	0 00	4 14
E	0 05	3 63	0 02	0 00	0 00	3 70
ESE	0 05	4 31	0 00	0 00	0 00	4 37
SE	0 05	2 92	0 00	0 00	0 00	2 98
SSE	0 05	2 62	0 08	0 00	0 00	2 74
S	0 05	5 49	0 74	0 44	0 41	7 12
SSW	0 05	6 27	2 02	0 72	0 23	9 28
SW	0 05	7 35	7 41	2 56	0 84	18 20
WSW	0 05	7 49	5 87	1 35	0 11	14 86
W	0 05	4 52	6 80	2 29	0 05	13 70
WNW	0 05	1 71	0 69	0 22	0 00	2 67
NW	0 05	1 18	0 09	0 00	0 00	1 31
NNW	0 05	1 20	0 31	0 09	0 00	1 65
N	0 05	0 50	0 26	0 25	0 26	1 32
Total	0 72	58 81	29 05	8 79	2 61	100 00

Table 2. Wind rose for LLNL's Site 300 at the 10-m level for 1997. Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals due to rounding

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 12	1 31	0 00	0 00	0 00	1 44
NE	0 12	2 06	0 00	0 00	0 00	2 19
ENE	0 12	1 61	0 00	0 00	0 00	1 74
E	0 12	1 83	0 02	0 02	0 00	1 99
ESE	0 12	1 69	0 09	0 02	0 00	1 92
SE	0 12	1 79	0 30	0 27	0 00	2 48
SSE	0 12	2 02	0 06	0 15	0 09	2 44
S	0 12	3 16	0 31	0 19	0 18	3 96
SSW	0 12	1 76	0 02	0 03	0 00	1 93
SW	0 12	1 44	0 47	0 85	0 86	3 74
WSW	0 12	2 87	6 62	20 29	4 11	34 01
W	0 12	3 84	4 51	2 11	0 02	10 60
WNW	0 12	3 32	1 57	0 54	0 00	5 56
NW	0 12	4 91	2 21	2 45	0 47	10 16
NNW	0 12	4 50	3 09	3 19	1 68	12 58
N	0 12	1 43	0 82	0 63	0 30	3 30
Total	1 86	39 54	20 11	30 74	7 73	100 00

Figure 2. Wind rose showing the average annual wind speed, frequency of occurrence, and direction at the Livermore site, 1997

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 patterns, making the temperature range somewhat more extreme than at the Livermore site. The 1997 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. The average

Figure 3. Wind rose showing the average annual wind speed, frequency of occurrence, and direction at Site 300, 1997

annual rainfall over the past 20 years was 257 mm, Site 300 received 193 mm of precipitation during 1997

Source Description

Many different radioisotopes are used at LLNL for research purposes, including transuranics, 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 stacks, 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 1997

³ H	⁶³ Ni	¹⁰⁹ Cd	¹⁵⁴ Eu	²²⁸ Ac	²³⁹ Pu
⁷ Be	⁷⁵ Se	^{110m} Ag	¹⁵⁵ Eu	²²⁸ Ra	²³⁹ U
¹³ N	⁸⁵ Kr	¹¹⁵ Cd	¹⁶⁰ Tb	²²⁸ Th	²⁴⁰ Pu
¹⁴ C	⁸⁵ Sr	¹²⁴ Sb	¹⁸² Ta	²²⁹ Th	²⁴¹ Am
¹⁵ O	⁸⁸ Y	¹²⁵ I	¹⁹² Ir	²³⁰ Th	²⁴¹ Pu
²² Na	⁸⁹ Sr	¹²⁵ Sb	¹⁹⁵ Au	²³¹ Pa	²⁴² Am
³² P	⁹⁰ Sr	¹³¹ I	²⁰³ Hg	²³² Th	^{242m} Am
³³ P	⁹⁰ Y	¹³³ Ba	²⁰⁷ Bi	²³² U	²⁴² Cm
³⁵ S	⁹⁰ Zr	¹³⁴ Cs	²⁰⁸ Tl	²³³ U	²⁴² Pu
⁴⁰ K	⁹¹ Y	¹³⁷ Cs	²⁰⁹ Po	²³⁴ Th	²⁴³ Am
⁴⁶ Sc	⁹⁴ Nb	¹³⁸ Cs	²¹⁰ Pb	²³⁴ U	²⁴⁴ Am
⁵¹ Cr	⁹⁵ Nb	¹⁴⁰ Ba	²¹⁰ Po	²³⁵ U	²⁴⁴ Cm
⁵⁴ Mn	⁹⁵ Zr	¹⁴¹ Ce	²¹² Bi	²³⁶ Pu	²⁴⁵ Cf
⁵⁵ Fe	⁹⁹ Mo	¹⁴⁴ Ce	²¹² Pb	²³⁶ U	²⁴⁹ Cf
⁵⁶ Co	⁹⁹ Tc	¹⁴⁶ Gd	²¹⁴ Bi	²³⁷ Np	²⁵² Cf
⁵⁷ Co	¹⁰² Rh	¹⁴⁷ Pm	²¹⁴ Pb	²³⁷ U	
⁵⁸ Co	¹⁰³ Rh	¹⁴⁹ Eu	²²³ Ra	²³⁸ Pu	
⁵⁹ Ni	¹⁰⁶ Rh	¹⁵¹ Sm	²²⁶ Ra	²³⁸ U	
⁶⁰ Co	¹⁰⁶ Ru	¹⁵² Eu	²²⁷ Th	²³⁹ Np	

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 1997. Building 514 and five 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 two Site 300 explosives-testing facilities (Buildings 850 and 851 and their associated firing tables). Site 300 is also treated as a diffuse-area source of residual tritium and depleted uranium contamination.

1997 Inventory Update and Effective Dose Equivalent (EDE) Calculations

For this year's report, covering activities in 1997, we updated the radionuclide inventories in all facilities. Radionuclide inventory forms, with guidance for completing them, were sent to the unmonitored facilities. 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 radionuclide inventory data. The model used was CAP88-PC (see Section III), we incorporated 1997 on-site meteorological data (wind, precipitation, and temperature) along with the 1997 radionuclide inventory or monitoring data. Annual dose is reported as whole-body EDE expressed in units of mrem (followed by 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 1995 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 1997
- 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 the introductory material to the attachment

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 inventories, and emissions are not listed.

Actual measurements of air radioactivity and effluent flow are the basis for reported emissions from continuously monitored sources. LLNL facilities that had continuously monitored discharge points are Buildings 166, 175, 231, 251, 331, 332, 419, 490, and 491. Continuous monitoring was terminated at some sample locations due to programmatic changes, and resulting changes in emissions (see Section VI on Continuous Monitoring). For most of the discharge points, sample 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 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, an extremely conservative approach, the total dose attributable to LLNL activities is not significantly affected.

In 1997, samples from four emission points at Building 251 (the unhardened area) yielded gross alpha results greater than the MDC on a significant number of the samples collected throughout the year. We use gross alpha as the primary indicator of potential emissions for operations such as those at Building 251 that involve the use of uranium and transuranic materials. 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 $-3.1 \times 10^{-4} \text{ Bq/m}^3$ ($-8.4 \times 10^{-15} \text{ Ci/m}^3$) to $3.7 \times 10^{-5} \text{ Bq/m}^3$ ($1.0 \times 10^{-15} \text{ Ci/m}^3$). Activity concentrations as measured by low-volume air surveillance samplers whose locations are off-site and not downwind of facility operations show similar concentrations. Thus, the gross alpha and beta emissions measured from Building 251 are not above ambient air concentrations measured and analyzed by similar instrumentation. 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 $6.0 \times 10^3 \text{ Bq/y}$ ($1.6 \times 10^{-7} \text{ Ci/y}$) and $3.9 \times 10^4 \text{ Bq/y}$ ($1.1 \times 10^{-6} \text{ Ci/y}$). Even if the results are considered facility emissions, the resulting radiological dose due to the reported values is far less than the dose due to other facility emissions at the Livermore site.

Operations in Tritium Facility (Building 331) released a total of $1.1 \times 10^{13} \text{ Bq}$ (300 Ci) of tritium. Of this, approximately $9.9 \times 10^{12} \text{ Bq}$ (270 Ci) were released as tritiated water (HTO). The remaining 11% of the tritium released, $1.2 \times 10^{12} \text{ Bq}$ (30 Ci), was elemental tritium gas (HT). The highest single weekly stack emission from the facility was $7.6 \times 10^{11} \text{ Bq}$ (21 Ci), of which $5.0 \times 10^{11} \text{ Bq}$ (13.5 Ci) was HTO. The HTO emissions are modeled using CAP88-PC. The dose from HTO is approximately 25,000 times higher than that of HT, and HT is not readily oxidized to HTO in the atmosphere, so the contribution from HT is negligible and is not modeled.

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, ingestion of foodstuffs 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 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 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 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 1997 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: 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. 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. In some cases, experimenters did not have isotopic analyses of mixtures of radionuclides and could only identify their radionuclide 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 1997 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 1997. 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. A detailed discussion of how the dose from tritium is calculated 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 inventories, together with the EPA-specified fractions for potential release to air of materials in different physical states (solid, liquid, powder, or gas), in accordance with 40 CFR Part 61, Appendix D were used. The state-dependent release fraction was used to adjust (by multiplication) the total annual

inventory to yield the potential annual release to air. If the material was an unconfined gas, then the fraction 1.0 was used; for liquids and powders, 1.0×10^{-3} was used; and for solids, 1.0×10^{-6} was used. In 1996, U.S. EPA granted approved alternative emissions factors for elemental uranium as follows: an emission factor of 1×10^{-6} can be used for elemental uranium heated at temperatures below 1100°C , an emission factor of 1×10^{-3} can be used for elemental uranium heated at temperatures below 3000°C , and an emission factor of 1 shall be used for temperatures greater than 3000°C . These factors are allowed provided that the uranium is not intentionally dispersed to the environment and that the processes do not alter the chemical form of the uranium. In addition, emission-control abatement factors (40 CFR 61, Appendix D), when applicable, were applied. Each HEPA filter stage was given a 0.01 factor, electrostatic precipitators, as well as venturi scrubbers, were each given a 0.05 factor, and each activated-charcoal filter was given a 0.1 factor. (However, abatement factors were not used to evaluate compliance with the 0.1 mrem standard that determines the need for continuous monitoring at a facility.) The use of actual monitoring data is much more direct, and presumably more accurate, than using assumptions based on inventory, release fractions, and emission-control factors.

Site-Wide Maximally Exposed Individual: For LLNL to comply with the NESHAPs regulations, the LLNL site-wide maximally exposed individual cannot receive an EDE greater than 10 mrem/y ($100 \mu\text{Sv/y}$). The site-wide maximally exposed individual (SW-MEI) is 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.

To determine the location of the 1997 SW-MEI, CAP88-PC results from multiple sources were combined. Sources were selected to include those expected to give significant contributions to the EDE. These included Building 331 point and area sources, Building 514 Tank Farm, and Building 612 area source. Because EDE results from CAP88-PC are relative to the location of the specified source, direct summing of results from multiple sources can only be accomplished using an interpolation method. To do this, the location of each selected source relative to a common location (the Livermore-site center) and 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 and

southern Livermore-site boundaries. 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 1997 was located at the UNCLE Credit Union, about 10 m outside the controlled eastern perimeter of the site, as shown in Figure 4.

Figure 4. Location of Site-Wide Maximally Exposed Individual (SW-MEI) at the Livermore site, 1997

Figure 5. Location of Site-Wide Maximally Exposed Individual (SW-MEI) at Site 300, 1997

At Site 300, the 1997 SW-MEI was located in an experimental area 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 5. This bunker is approximately 4 km east of the firing tables at Buildings 850 and 851.

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 ($1.0 \text{ } \mu\text{Sv/y}$)), 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: During Site 300 explosives experiments, the device containing depleted uranium is 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 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 $1 \text{ } \mu\text{m}$. 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 modeling based on radionuclide-inventory data, or can be determined from environmental-surveillance monitoring data.

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 1997 calculated EDE to the SW-MEI from Livermore-site point sources was 0.077 mrem (0.82 μ Sv). Emissions from the two 30-meter stacks at the LLNL Tritium Facility (Building 331) accounted for 0.075 mrem (0.75 μ Sv). In 1996, emissions from the Tritium Facility resulted in a modeled dose of 0.045 mrem (0.45 μ Sv). The relative increase in 1997 in emissions and dose occurred as the result of continued contract decontamination and decommissioning of equipment from other DOE facilities added to the routine outgassing of historically contaminated facility surfaces. These sources made roughly equal contributions.

The calculated EDE to the SW-MEI at Site 300 was calculated to be 0.0054 mrem (0.054 μ Sv) from point-source emissions. All of this EDE resulted from Building 850 and Building 851 firing-table emissions in the course of explosives experiments—52% from the former and 48% from the latter. The 1997 EDE is a decrease from the 0.033 mrem (0.33 μ Sv) dose modeled for 1996. Building 801, which accounted for more than one-half of the dose in 1996, was not in use in 1997 due to construction activities at the Contained Firing Facility being built at that location (discussed below). The decrease in dose is primarily the result of a decrease in the number of experiments that contained depleted uranium and, to a lesser extent, the result of the fact that Buildings 850 and 851 are farther from the fenceline than Building 801.

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

During 1997, no construction projects or modifications were completed for which approval to construct or modify was required or waived under 40 CFR 61.96. Only maintenance, repair, and replacement activities, as well as those considered normal or routine, were conducted. 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, and effluent sampling systems are planned for all three. These facilities are the Contained Firing Facility (CFF) at Site 300, and the National Ignition Facility (NIF) and the Decontamination Waste Treatment Facility (DWTF) 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. Phase I construction (primarily earthwork and site preparation) has been completed. Phase II construction is slated to begin in April 1999. The DWTF is a facility that will allow waste handling to occur in a facility that has improved air emissions control 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 is underway, with completion scheduled for early summer 1998. Construction of the liquid waste processing building has not started due to permitting delays. The National Ignition Facility (NIF) will contain the world's largest laser, a research tool allowing scientists to recreate on earth conditions equivalent to the center of the sun. The NIF will focus 192 extremely

powerful laser beams onto a BB-sized capsule of deuterium and tritium, forcing the two heavy isotopes of hydrogen to combine through compression and heating, producing ignition and self-sustained fusion burn. The NIF construction project began in 1996 and will end in 2003 with initial operations beginning in 2001. It is being designed, built and operated by a team from Lawrence Livermore, Los Alamos and Sandia National Laboratories and the University of Rochester. Site preparation for NIF has been completed, and construction of the steel frame of the building has begun.

Unplanned Releases

There was one unplanned atmospheric radionuclide release from the Livermore site in 1997. Waste shredding operations were resumed in Building 513 in 1997. During those operations, on July 2, 1997, an incorrectly labelled HEPA filter containing curium (^{244}Cm) in excess of the administrative limit for the process was shredded. This activity resulted in the contamination of four workers and the release of small amounts of the material to the environment. The U.S. EPA was briefed on the incident in September 1997. The range of doses calculated to the SW-MEI was 2.3×10^{-5} to 2.1×10^{-4} mrem (2.3×10^{-4} to 2.1×10^{-3} μSv), and the range of doses to the MEI was 5.5×10^{-4} to 5.4×10^{-3} mrem (5.5×10^{-3} to 5.4×10^{-2} μSv). This is not a significant contribution to dose at the SW-MEI and does not trigger the requirement for continuous monitoring.

Modelers took three approaches to evaluating the ^{244}Cm emissions and subsequent doses from the incident. As is shown below, the three approaches resulted in a reasonably narrow range of estimated emissions and subsequent doses from the incident. This modeling information was previously provided to the U.S. EPA in response to its specific questions about the Building 513 shredder unit operations. (See EPA Compliance Investigation, below.)

Evaluation of the off-site doses generated by the curium incident presented a significant modeling challenge. Difficulties in the assessment included (1) the amount of curium in the HEPA filter suspected of causing the incident was not accurately known, (2) the time-line of the incident was imprecisely known and difficult to match up with dynamic meteorological data; (3) the shredder room was not completely closed off from the rest of the building or from the outside environment, and the passive building ventilation dynamics could not be measured because access to the building was restricted due to contamination, (4) immediate swipe sampling indicated no significant contamination outside the building which called into question the need for further environmental

evaluations, and (5) the low-level nature of the curium release, while desirable from an impact point of view, made environmental evaluations difficult

The paucity of data and the difficulties mentioned above required some modeling assumptions. One assumption common to the three approaches was that the ^{244}Cm release occurred over a relatively short time period, all the approaches assumed the ^{244}Cm was released mostly during the first day and that nearly all of it was released during the first week following the incident. Such an assumption is supported by environmental monitoring data collected in the area following the incident. Another common assumption was that ^{244}Cm was the only radionuclide released in the incident. This assumption was supported by analytical data provided by the LLNL Hazards Control Department following analysis of respirator cartridges worn by the workers who were inside Building 513 during the incident. A third assumption common to all modeling was that any release of ^{244}Cm was unabated because the operational status of the HEPA-filtered ventilation system during the incident was unknown, it was conservatively assumed that any releases to the environment during the incident escaped out of the passive vents in Building 513. Estimates of the amount of ^{244}Cm released during the incident were assumed to be actual, and doses to any hypothetical individuals (MEI or SW-MEI) calculated from air dispersion and dose assessment models did not allow credit to be taken for abatement devices, as is the case when using radiological inventories to estimate emissions.

Two of the modeling approaches used surveillance air monitoring data from continuously operating high-volume ambient air samplers that were operating at LLNL the day of the incident. The routine air surveillance filters for the period July 1–7, which included the day of the incident, from three locations in general proximity to Building 513, designated SALV (237 m SE of Building 513), CRED (579 m NE), and B531 (389 m NNW), were analyzed. An additional filter, from a background location designated FCC (about 6 kilometers NW of Building 513) also was submitted for analysis. All filters were submitted to the LLNL Chemistry and Materials Sciences Environmental Services analytical laboratory for low-level ^{244}Cm analysis by alpha spectroscopy.

Original analyses did not detect any ^{244}Cm on the filters above normal detection limits, but the analytical laboratory went to extraordinary lengths, including multiple long counts of the activity, in an attempt to measure any ^{244}Cm on these filters. In the end, very small positive detections, barely above detection limits, were reported. In general, the levels detected were consistent with what is known about the incident and the prevailing meteorological

conditions. That is, locations closer to Building 513 showed higher ^{244}Cm concentrations than locations farther away. However, positive detection was also observed from the background location (FCC) at levels rivaling the highest value detected on site. It is extremely unlikely that ^{244}Cm from the incident would be found so far away. This illustrates the very difficult nature of extremely low level alpha detection, these types of data must be used with caution. It is possible that no curium originating from the incident was present on any of the filters. Nevertheless, dose evaluations of the incident based on the reported data from the on-site locations were used in an attempt to model the event. To be conservative, all dose calculations were performed using the reported ^{244}Cm air concentration data plus the 2σ error. These concentrations are shown in Table 4, below. (Negative values result when the activity counted is less than that counted during evaluations of background radiation.)

The third modeling approach for the incident used data from respirator cartridges and air samplers used inside Building 513 the day of the incident, together with estimates of building ventilation dynamics to estimate the original source term, followed by air dispersion/dose assessment modeling.

Approach 1: A direct, source-term independent, dispersion-model independent, and meteorological-data independent estimate of dose to the SW-MEI, caused by the release of ^{244}Cm , was conducted. This was possible because the estimated SW-MEI dose is precisely the dose received at the CRED routine surveillance air sampler (i.e., this sampler is positioned at the location of the LLNL Livermore site SW-MEI, at the UNCLE Credit Union, 579 m NE of Building 513).

The surveillance air monitoring data for the July 1 through July 7, 1997, period specified the one-week-average concentration of ^{244}Cm plus 2σ at the CRED sampler to be 4.68×10^{-6} pCi/m³. The ^{244}Cm undoubtedly was deposited onto the filter of this sampler in a non-uniform manner throughout this week, with the greatest amount deposited during the first few hours after the release, however, the data only provide a one-week-average concentration. There is no reason to believe the release from Building 513 deposited a significant amount of ^{244}Cm at CRED after the July 1–7 period. The reported concentration was multiplied by the dose-rate-conversion factor for inhalation for ^{244}Cm (0.287 mrem/pCi, EPA 520/1-89-005). This gave an intermediate dose conversion factor of 1.34×10^{-6} mrem for every cubic meter of air inhaled. Because the data were based on a one-week accumulation, the intermediate dose was multiplied by the standard human inhalation rate of 0.917 m³/hour, times 168 hours/week, to derive the calculated dose. Assuming no other significant dose

Table 4. Curium-244 air concentration data.

Location	^{244}Cm Concentration (10^{-6} pCi/m ³ $\pm 2\sigma$)	Minimum Detectable ^{244}Cm Concentration (10^{-6} pCi/m ³)
<i>Sampling period July 1-7</i>		
SALV	11.2 ± 6.86	5.96
CRED	1.34 ± 3.34	3.79
B531	2.73 ± 2.50	2.48
FCC (background)	7.65 ± 5.44	5.24
<i>Sampling period July 30-August 5</i>		
SALV	-2.07 ± 5.86	10.5
CRED	1.19 ± 4.13	7.14
B531	-14.5 ± 3.49	57.9
FCC (background)	1.27 ± 1.80	1.72

accumulation during any of the other 51 weeks in 1997, the source-term/dispersion-modeling/meteorological-data independent estimate for annual dose to the SW-MEI from the release of ^{244}Cm from Building 513 was calculated to be 2.1×10^{-4} mrem/y

This procedure could not be used to estimate the dose to the MEI, because routine air-surveillance samplers are not arrayed in all directions on the LLNL perimeter around Building 513. The dose to the MEI was estimated by using monitoring data from the SALV sampler, located on the LLNL boundary 237 m southeast of Building 513, and scaling the result to apply to the point on the LLNL boundary nearest to Building 513. The air surveillance data for the SALV sampler indicated a one-week-average ^{244}Cm concentration (plus 2σ) of 18.1×10^{-6} pCi/m³. Multiplying by the dose rate conversion factor and inhalation rates over a one-week time period (as above), gave a dose of 8.0×10^{-4} mrem at SALV. This dose was scaled to apply to other distances and directions from Building 513, in particular to apply to the shortest distance-to-the-boundary (91 m to the south). Dispersion theory gives a scaling factor of approximately $(L/\sigma_z)^{-1}$, where L is the distance to the point of interest from the source and σ_z is the distance-dependent mean vertical plume-size parameter. Application of the scaling factor indicated the dose at 91 m to be 6.8-times higher than at SALV, so our estimate of the dose to the MEI was calculated to be 5.4×10^{-3} mrem/y.

Approach 2: In this approach, the source term was estimated using CAP88-PC model runs to produce output results consistent with the concentrations of

^{244}Cm measured at the three on site surveillance air sampler locations (SALV, CRED, and B531). The total estimated release (Ci) of ^{244}Cm from the incident was determined to be the largest value for which the calculated concentrations using the air dispersion modeling equations agreed with the mean concentrations (plus the 2σ measurement uncertainty) exhibited by the air samplers

Among the set of representative scenarios considered, the one deemed to be most plausible featured a stack-type release from the passive vent above the shredder room into an atmosphere characterized by stability class C, with low speed winds (1.3 m/s), and no pronounced directionality for the wind. For this basic scenario, the air-dispersion modeling calculation yielded a release of about 400 nanocuries (nCi, $1 \text{ nCi} = 1 \times 10^{-9} \text{ Ci}$), which produced ^{244}Cm concentrations at the locations of the air surveillance samplers that were consistent with their measured one-week-average values (plus 2σ) for July 1-7, 1997. Using the 400 nCi source term CAP88-PC yielded calculated doses of $2.9 \times 10^{-3} \text{ mrem}$ to the MEI, and $1.2 \times 10^{-4} \text{ mrem}$ to the SW-MEI at the UNCLE Credit Union.

While a single modeling run leading to definite numerical answers is emphasized here, note that modeling gives a *range* of credible values caused by making different, but still plausible assumptions concerning the conditions of the release. Parameter studies carried out in our modeling runs indicate that the total amount of ^{244}Cm that escaped from Building 513 most likely ranged from a few hundred to a thousand nCi, the 400 nCi result above is not a precisely known value. Nevertheless, the small nature of the release can be appreciated by considering the mass of material. The specific activity of ^{244}Cm is 80.9 Ci per gram, so a release of 400 nCi amounts to only about 5 nanograms ($5 \times 10^{-9} \text{ g}$) of this substance.

Approach 3: Model development was based on air concentration measurements made at different times and locations within Building 513 on the day of the incident. These measurements include initial ^{244}Cm air concentrations estimated from respirator cartridge activity and worker breathing rates, continuous air monitor data from inside the shredder room, and high volume air sampler data collected inside Building 513 following the incident. This model used the fluid dynamics principle for steady state flow conditions to estimate the ventilation dynamics responsible for contamination transfer and release. Monte Carlo simulation techniques were used to explore the range of model input parameters that would satisfy the monitoring data. This was accomplished by varying the building intake velocity plus the fractional deposition in the shredder room and the remainder of the building.

over a range of plausible values while constraining the model output by the air concentration measurements $\pm 2\sigma$ within the building. A distribution of possible release levels resulted; a minimum of 77 nCi and a maximum of 575 nCi was calculated for the release based on this model. Of all modeled results, 50% of the output range was between 175 nCi and 327 nCi with only 10% of the cases above 398 nCi. A most likely release value was determined to be 190 nCi. Once the source term was bounded, standard dispersion modeling calculations (as discussed above) were used to determine doses. Calculated doses to the SW-MEI ranged from 2.3×10^{-5} to 1.7×10^{-4} mrem with a dose of 5.7×10^{-5} mrem being most likely. Calculated doses to the MEI ranged from 5.5×10^{-4} to 4.1×10^{-3} mrem with a dose of 1.4×10^{-3} mrem being most likely.

The maximum result of the three approaches are reported in Attachment 1 for the Building 513 incident dose for the SW-MEI and MEI.

There were no unplanned atmospheric releases at Site 300 in 1997.

Diffuse Source Dose Assessments

Diffuse, or non-point, sources are difficult to quantify. There are no EPA-mandated methods for estimation or measurement, although LLNL did review a second draft of EPA guidance on this topic during 1994. At this time, however, dose calculations associated with this type of source remain left to the discretion of the DOE facility. Livermore-site and Site 300 diffuse sources are described separately.

Livermore-Site Diffuse Sources

The dose calculations from 1997 diffuse sources at the Livermore site required three different modeling approaches. Building 331 and Building 612 Yard needed facility personnel knowledge and environmental-surveillance data to estimate emissions, Building 292 required vegetation monitoring and CAP88-PC modeling techniques, Building 514 required radiological-inventory data and CAP88-PC modeling techniques, and data from ambient-air monitoring were used to calculate the dose for the Southeast Quadrant.

Building 292: Elevated tritium concentrations in soil moisture near Building 292 resulted from a historic leak in an underground retention tank. This contamination has resulted in diffuse tritium emissions from transpiration from vegetation. In 1997, monthly samples of the pine tree, which had previously been identified as the primary source of transpired

tritium, were used to estimate the emission of tritium from this source. The maximum concentration of tritium in the tissue water of the pine tree was 8820 pCi/L (300 Bq/L) in 1997. Assuming the tree has an area of 79 m² and a transpiration rate of 190 L/d, the resulting emission rate from this source is 6.1×10^{-4} Ci/y (2.3×10^7 Bq/y). This estimated emission compares well with previous estimates, which ranged from 4.8×10^{-4} Ci/y (1.8×10^7 Bq/y) to 1.4×10^{-3} Ci/y (5.1×10^7 Bq/y) in 1994 through 1996. The current source term produced a calculated 1997 dose to the SW-MEI from the Building 292 area of 6.1×10^{-8} mrem (6.1×10^{-7} μ Sv).

Building 331: As the Tritium Facility (Building 331) conducts operations, tritium-contaminated equipment and material slated for disposal is removed from the building, packaged in a waste-accumulation area, and sent to Hazardous Waste Management Division (HWM) facilities. During 1997, outgassing from such waste processing released approximately 2.5 Ci (9.25×10^{10} Bq) of tritium to the atmosphere outside Building 331. The estimated releases were derived from measurements of surface contamination on the material, process and facility knowledge, and environmental-surveillance measurements. The estimated 2.5 Ci (9.25×10^{10} Bq) release was modeled in CAP88-PC as a 1 m² area source, leading to a calculated 1997 dose to the SW-MEI of 1.7×10^{-3} mrem (1.7×10^{-2} μ Sv).

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 1997 radionuclide inventory was conducted for the facility to determine the diffuse source term (Attachment 1). CAP88-PC modeling gave a 1997 EDE for the Tank Farm to the SW-MEI of 9.5×10^{-4} mrem (9.5×10^{-3} μ Sv).

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 1997 in this area was 110 pCi/m³ (4.1 Bq/m³). 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 4.2 Ci/y ($1.5 \times 10^{11} \text{ Bq/y}$) was required to produce the concentrations measured at the air sampler. This source term produced a calculated 1997 dose to the SW-MEI from the Building 612 Yard of $1.6 \times 10^{-2} \text{ mrem}$ ($1.6 \times 10^{-1} \mu\text{Sv}$).

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, the waste drums are sampled by Hazardous Waste Management. 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. This source term produced a calculated 1997 dose to the SW-MEI from the Waste Accumulation Areas (listed under Diffuse Sources, B612 in Attachment 1) of $1.6 \times 10^{-6} \text{ mrem}$ ($1.6 \times 10^{-5} \mu\text{Sv}$).

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 median annual concentration of ^{239}Pu in air of $1.2 \times 10^{-19} \mu\text{Ci/mL}$ ($4.4 \times 10^{-15} \text{ Bq/mL}$), 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 the standard-man breathing rates of $8.4 \times 10^9 \text{ mL/y}$ were used to calculate the estimated EDE of $3.1 \times 10^{-4} \text{ mrem}$ ($3.1 \times 10^{-3} \mu\text{Sv}$) for 1997.

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 Migration and Evaporation at Site 300: Tritium gas and solid 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 a tritium sampler at a location (designated PRIM) that represents the SW-MEI, and doses from diffuse tritium sources for 1997 are estimated based on the monitoring data for that sampling location. The median annual concentration of tritium in air of 0.21 pCi/m^3 ($7.8 \times 10^{-3} \text{ Bq/m}^3$), the dose-conversion factor of $6.4 \times 10^{-8} \text{ mrem/pCi}$ ($1.73 \times 10^{-11} \text{ Sv/Bq}$) 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 $8.4 \times 10^3 \text{ m}^3/\text{y}$ were used to calculate the estimated EDE of $1.1 \times 10^{-4} \text{ mrem}$ ($1.1 \times 10^{-3} \mu\text{Sv}$) for 1997.

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:

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

where μ is the fraction (by weight) of uranium contributed by operations, CU is composite uranium (both DU and NU), $M(\text{CU}-235)$ the mass of U-235 in the composite (measured) uranium, and $M(\text{CU}-238)$ the mass of U-238 in the composite (measured) uranium (For derivation of the equation see the 1995 NESHAPs annual report, referenced above) This equation is used for those months in which explosives shots were not conducted

Using these calculations to apportion the $M(\text{CU})$ for 1997, and excluding the appropriate months, we obtain an annual average concentration of DU in air from resuspension of 2.36×10^{-11} g/m³. Using the fractions 0.998, 0.002, and 0.000005 to represent the amounts of ²³⁸U, ²³⁵U, and ²³⁴U; specific activities of 3.32×10^{-7} , 2.13×10^{-6} , and 6.16×10^{-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 1.18×10^{11} , 1.23×10^{11} , and 1.32×10^{11} mrem/Ci, we obtain a total dose for resuspended DU of 8.7×10^{-3} mrem for 1997. This increase is due to high measured uranium concentration in February 1997, 18.1×10^{-11} g/m³, which raised the average for the year. Although this measurement is not consistent with experimental or construction activity, it is used in this calculation provide a conservative estimate of dose.

Total Dose Estimate and Comparison with Previous Years' Data

For the Livermore site, the dose calculated for the SW-MEI from diffuse emissions in 1997 was 0.019 mrem (0.19 μ Sv). When point and diffuse sources were combined, the total annual dose was 0.097 mrem (0.97 μ Sv). Therefore, the relative contributions to the total were 20% from diffuse sources and 80% from point source emissions. The total dose to the Site 300 SW-MEI from Site 300 operations in 1997 was 0.014 mrem (0.14 μ Sv). Point-source emissions from firing-table explosives experiments accounted for 0.0054 mrem (0.054 μ Sv), or 38%, of this total, while 0.0088 mrem (0.088 μ Sv), or 62%, was contributed by diffuse sources. Table 5 presents the facilities or sources that account for 90% or more of the doses for the Livermore site or Site 300 SW-MEI.

Comparison of the 1997 total dose estimate with that of previous years can be made by reviewing the information presented in Table 6. No diffuse

emissions were reported at Site 300 for years before 1993, so comparison for total dose can only be made with the values for 1993, 1994, 1995, and 1996; in addition, diffuse source doses were not reported separately from the total dose for the Livermore site for 1990 and 1991

Table 5. 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
Livermore site		
Building 331 (point source)	0.075	78%
Building 612 Area Source (diffuse source)	0.016	17%
Site 300		
Uranium resuspension (diffuse source)	0.0087	61%
850 Firing Table (point source)	0.0028	20%
851 Firing Table (point source)	0.0026	18%

Table 6. Doses (in mrem) calculated for the Site-Wide Maximally Exposed Individual for the Livermore site and Site 300, 1990 to 1997

Year	Total Dose	Point Source Dose	Diffuse Source Dose
Livermore site			
1997	0.097	0.078	0.019
1996	0.093	0.048	0.045
1995	0.041	0.019	0.022
1994	0.065	0.042	0.023
1993	0.066	0.040	0.026
1992	0.079	0.069	0.010
1991	0.234	— ^a	— ^a
1990	0.240	— ^a	— ^a
Site 300			
1997	0.014	0.0054	0.0088
1996	0.033	0.033	0.00045
1995	0.023	0.020	0.003
1994	0.081	0.049	0.032
1993	0.037	0.011	0.026
1992	0.021	0.021	— ^b
1991	0.044	0.044	— ^b
1990	0.057	0.057	— ^b

^aDiffuse source doses were not reported separately from the total dose for the Livermore site for 1990 and 1991

^bNo diffuse emissions were reported at Site 300 for years before 1993

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: Ray Corey
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Signature: **Date:** 6/24/98
Ray Corey

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.

In 1996, we reconstructed the population distributions centered on the two LLNL sites. These population distributions, as were the previous distributions, are based on 1990 census data. However, the 1996 distributions were developed using commercially available, computer-map-based population data and the geographic information system software, ArcView®. The population for each sector segment was determined by selecting census block level data for that segment. In 1997, we further improved the estimates of the population distribution by refining the location of the centers of the grids and by using curved arcs rather than straight lines to define the sector segments. 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 7 and 8 for the Livermore site and Site 300, respectively.

For the evaluation of the population dose, as distinct from the individual dose, all food (and in particular milk) was assumed to be produced locally. This decision was made because, although there are no commercial dairy animals within the distances used to evaluate individual doses, many dairy animals live within 80 km of the Livermore site and Site 300.

The collective EDE, which is the sum of the individual doses to all 6.3 million people within 80 km of the Livermore site, due to 1997 Livermore-site operations was 1.5 person-rem (0.015 person-Sv). This number can be compared to the collective EDE from natural background radioactivity for 6.3 million people of 1.88×10^6 person-rem (1.88×10^4 person-Sv). The 1997 collective EDE value is similar to the 1996 value of 1.1 person-rem.

Table 7. 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 8. 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

(0.011 person-Sv) The values are similar because the stack releases from Building 331 (the Tritium Facility) were similar both years.

The corresponding collective EDE from Site 300 operations in 1997, 3.6 person-rem (0.036 person-Sv), was due to point-source emissions. The total collective EDE value for Site 300 is also similar to the 1996 value of 10.0 person-rem (0.10 person-Sv). The difference in EDE value is the result of differences in the amounts of high explosives and depleted uranium used each year in explosives experiments.

The larger value 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 1997 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.

Based on potential emissions without control devices and EPA agreement, 17 emission points in three facilities at the Livermore site will maintain continuous monitoring systems in compliance with NESHAPs requirements. Continuous monitoring will be maintained in Building 332 and the seismically hardened area of Building 251 instead of a modeling or measurement effort to demonstrate the actual need for monitoring. Continuous monitoring is being continued at Building 331 even though the EDEs that result from measured emissions do not require monitoring under 40 CFR 61.93(b).

Several other Livermore-site facilities (Buildings 175, 251 unhardened, 490, and 491) also will maintain continuous-monitoring systems, however, calculations using unabated potential emissions resulted in EDEs of less than 0.1 mrem/y (1 μ Sv/y) for the emissions from each of these facilities. While this monitoring also will be continued, it is not required under NESHAPs.

For facilities having discharge points without continuous monitoring, the requirement for continuous monitoring was individually evaluated. The evaluation was based on unabated emissions, even if emission-control systems existed. No additional facilities at either LLNL site were found to require continuous monitoring.

Status of compliance with 40 CFR 61 Subpart Q - National Emission Standards for Radon Emissions from Department of Energy Facilities

LLNL does not have storage and disposal facilities for radium-containing materials that would be a significant source of radon.

Status of compliance with 40 CFR 61 Subpart T - National Emission Standards for Radon Emissions from the Disposal of Uranium Mill Tailings

LLNL does not have or store any uranium mill tailings.

Information on Radon-220 and Radon-222 Emissions

Radon emissions occur naturally by emanation from the earth. Radon-222 emissions that were reported in past NESHAPs annual reports from research experiments at the Livermore site did not occur in 1997.

Continuous Monitoring: In the beginning of 1997, there were nine buildings (Buildings 166, 175, 231, 251, 331, 332, 419, 490, and 491) at the LLNL site that had radionuclide air-monitoring systems. These buildings are listed in Table 9, along with the number of samplers, the types of samplers, the analytes of interest, and the number of monitored discharge points at the building. Many would operate from emergency power systems if normal power were lost.

During 1997, sampling at locations in Buildings 166, 231 and 419 was discontinued. For Buildings 166 and 419, sampling was discontinued because the operations originally requiring sampling ceased. The sampler at the

Table 9. Air-effluent sampling locations and systems.

Building	Facility	Analytes	Sample type	Number of samplers	Number of discharge points
166	Pyrochemical Demonstration Facility	Gross α , β on particles	Filters	1 ^a	1
175	MARS	Gross α , β on particles	Filters	6	6
231	Vault	Gross α , β on particles	Filter	1 ^a	1
251	Heavy Elements				
	Unhardened area	Gross α , β on particles	Filters	44	55 ^b
	Hardened area	Gross α , β on particles	Filters	4	4
	Hardened area	Gross α , β on particles	CAM ^c	4	
331	Tritium	Tritium	Ionization Chamber ^c	4	2
		Gaseous tritium/ tritiated water vapor	Molecular sieves	4	
332	Plutonium	Gross α , β on particles	CAM ^c	12	11
		Gross α , β on particles	Filters	16	
419	Decontamination	Gross α , β on particles	Filters	2 ^a	2
490	USEC Laser Isotope Separation	Gross α , β on particles	Filters	4	4
491	USEC Laser Isotope Separation	Gross α , β on particles	Filters	1	1

Note "CAM" denotes Eberline continuous air monitors

^a Sampling at these locations was discontinued during 1997 because it was no longer required by the NESHAPs requirement for continuous monitoring

^b Alternate blower system measured by the same sampler

^c Alarmed systems

Building 231 vault was removed because operations consist of receipt, repackaging and shipping, and involve only sealed or encapsulated sources. Thus, normal operations are not a potential source of emissions nor is the potential exposure to an MEI above 0.1 mrem from these operations, therefore, continuous sampling is not required according to the NESHAPs regulations.

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 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.

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.

Periodic Confirmatory Sampling: NESHAPs periodic confirmatory sampling was conducted at two facilities in 1997. These were a cleaning operation in Building 322 and a drum crushing operation in Building 612.

Neither operation contributes significantly to the dose for the Livermore site SW-MEI Neither operation requires continuous sampling

Building 322: At Building 322, the plating shop, we performed air sampling of a stack exhaust that vents a uranium parts cleaning process. A sample was taken over a 2-day period while cleaning operations were being performed. Samples of particulate emissions were taken by single-probe, isokinetic sampling of the exhaust using 47-mm-diameter, cellulose membrane filters. The filter was analyzed for gross alpha and gross beta activity. The average measured concentration of gross alpha and gross beta in the exhaust air as determined by radiation counting methods was 3.0×10^{-21} Ci/mL and 1.1×10^{-20} Ci/mL, respectively. Modeling of this source was performed with CAP88-PC using a physical state factor of 0.001 and assuming the operation continued 1 week. The resulting dose to the MEI and SW-MEI is 2.1×10^{-8} and 3.6×10^{-8} mrem, respectively. Thus, even if operations took place the entire year this source is not a significant contributor to the Livermore site dose nor is continuous monitoring of the stack emissions required by regulation.

The estimated emission based on the above sampling results was compared to the inventory approach for NESHAPs source evaluation. This was done using the sampling results and knowledge of the amount of uranium processed during the sampling period. A release fraction of 9×10^{-7} was estimated. This fraction is approximately the release for a solid (1×10^{-6} as given in Appendix D of 40 CFR 61 Subpart H), and therefore, using the release fraction for a liquid indicates that the inventory-based approach is conservative for the operation.

Building 612: At Building 612, managed by the Hazardous Waste Management Division, we performed area air sampling of a drum crushing operation. There is a potential for contamination from a variety of radionuclides. A high volume air sample for particles was taken over a 1-day period. The filter was analyzed for gross alpha and gross beta activity. Estimates of potential emissions, based on facility knowledge of the number of such operations occurring during the year, were 8.8×10^{-12} and 5.9×10^{-11} Ci/y for the gross alpha and gross beta activity, respectively. Using a physical state factor of 0.001, modeling with CAP88-PC resulted in a dose of 1.5×10^{-9} mrem to the MEI and 8.5×10^{-10} to the SW-MEI. Since the source term for this operation could not be estimated quantitatively, a release fraction was not calculated.

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 airborne-tritium 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 tritium effluents resulting from LLNL operations will be detected. The data from this 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. This network allows for direct measurements of the overall impact of LLNL operations. Data from this network are presented in the LLNL Environmental Report, which is prepared annually and available to the public (Harrach et al., Environmental Report for 1997, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-97, to be published in October 1998.)

Site-Specific Surveillance Monitoring: Surveillance air monitors are placed near diffuse emission sources, such as those associated with Buildings 292, 331, 514, and 612, as well as in and around the Southeast Quadrant of the Livermore site. The data from these monitoring networks provide continuous measurements of the concentrations of specific radionuclides present in the air near these sources and allow a direct and accurate determination of their environmental impact. This practice will continue at these locations. It has been determined that the use of location-specific surveillance monitoring for Site 300 diffuse sources of tritium is unnecessary because of the low emissions and resultant dose values displayed in Attachment 1.

Comparison of 1997 Modeling Results with Surveillance Monitoring

Data: A comparison was made between CAP88-PC modeling results and surveillance air monitoring data for all eleven tritium air monitors on the Livermore site (designated VIS, SALV, POOL, CAFE, MESQ, MET, COW, B331, B514, B624, and B292) and one off-site tritium air monitor (ZON7). Monitor locations are shown in Figure 6.

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 267 Ci (9.88 TBq) of HTO was emitted from these stacks in 1997. The other two principal

Figure 6. Tritium air-surveillance sampling locations

sources are diffuse areas associated with the Building 612 yard and the Waste Accumulation Area (WAA) outside the Tritium Facility, designated the B331 WAA. Emissions from these sources were estimated to be 4.2 Ci (0.16 Tbq) and 2.5 Ci (0.093 Tbq) in 1997. All other potential sources of tritium release, such as the hazardous waste management operations in Buildings 514 and 513 were too minor to influence the model-data comparison.

Annual-average concentrations (number of pCi/m³ of air) at the locations of the twelve monitors were calculated 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 7.

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

Figure 7. Comparison of measured and modeled tritium concentrations, 1997
 Note that the measured median values for MESQ (0.93 pCi/g) and MET (0.67 pCi/g) are below the scale of this figure.

concentrations at the desired locations. However, both the B331 WAA and the Building 612 Yard emission rates were not independently measured, but rather were determined from the surveillance tritium air monitor data for the particular monitor in the closest proximity, by requiring that the modelled 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 WAA was chosen to give

diffuse source was the dominant source for the monitor in question, accounting for more than 95% of the measured concentration in the nearby monitor. 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 7 is that by taking into account the three leading sources of tritium releases to air—the Building 331 stacks, Building 612 Yard, and the B331 WAA—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 three (at ten out of twelve locations). However, in the case of the off-site monitor location (ZON7) and one on-site monitor (B514), the difference is nearly a factor of four, with the model result higher at ZON7, where public exposures possibly could occur, and lower at B514, well inside the Livermore site perimeter.

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). Memoranda of understanding (MOUs) are in place between EPD and the facilities and/or programs and HCD which formalize responsibilities and obligations of the organizations regarding tasks of 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

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, CAP88-PC 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.

LLNL has drafted a quality assurance project plan (QAPP) which assembles the quality assurance methods including the above information into one complete document. The document is structured similar to that specified for a quality assurance program contained in Appendix B, Method 114 of 40 CFR 61. It describes the organization structure and functional responsibilities, objectives of the quality assurance program, administrative controls in place for handling unplanned emissions, sample collection, analysis and tracking procedures, sample collection systems, sample collection and effluent flow rate measurement systems, corrective actions, and reporting. The draft QAPP is currently under review by EPD.

Quality Control (QC) for 1997 Radiological Inventory Update and Modeling

Radiological Inventory Update QC: Approximately 15% of the 317 facilities that completed radiological-inventory updates in 1997 were randomly selected for validation. For this QC check, radiological inventories from forty-eight potential emission points were selected for validation: six from Building 361; five from Building 151, four from Building 222, three from Buildings 131, 231, 253, and 321, two from Buildings 194, 241, 419, and 612, and one each from Buildings 166, 174, 177, 233, 292, 298, 362, 363, 381, 412,

625, 804, and 810A 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 were compared to the original data The accuracy of the inventory data was confirmed

Modeling QC: Fifteen percent of the CAP88-PC modeling runs were selected for validation by a second analyst using a different computer and copy of CAP88-PC The analyst performing this QC effort ran the model following independent gathering of radionuclide inventories and stack data from the NESHAPs Inventory Forms and pertinent distances from site maps The QC modeling verified the values from the original CAP88-PC modeling runs The data that are presented in the attached spreadsheet are as accurate as possible, demonstrating that quality objectives are being met

EPA Compliance Evaluation Investigation

On September 3, 1997, the U S EPA, Region IX conducted a Compliance Evaluation Investigation at Site 300 LLNL personnel made a number of presentations during the course of the inspection including summaries of explosives tests air dispersion modeling assumptions and calculations, diffuse source modeling calculations for Site 300, the planned operations of the Contained Firing Facility, and the Building 513 shredder incident. U S EPA personnel visited several locations at Site 300, including Bunker 801, Bunker 851, and onsite tritium and air particulate monitors By letter report dated September 29, 1997, the U S EPA indicated that the Site 300 facility met the requirements 40 CFR 61 Subpart H, and no additional compliance activities were required.

By a letter dated January 27, 1998, the U S EPA Air Division raised a number of questions regarding the Building 513 shredder unit these questions addressed routine operations as well as the incident in which workers were contaminated with ^{244}Cm On March 4, 1998, LLNL provided a lengthy reply stating that the routine operations of the unit were conducted in accordance with all NESHAPs requirements, and providing the estimates of dose from the incident LLNL has not yet received a response to this letter from the U S EPA

Attachment 1. 1997 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 1997
- 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.

Radionuclide Inventories with Potential for Release: The annual radionuclide inventories for point-source locations are based on data from facility experimenters and managers. For Buildings 251 (hardened area) and 332, classification issues regarding transuranic-radionuclide inventories make use of the inventory/modeling approach impractical. However, all such affected emission points in these buildings are continuously monitored, and emissions are therefore directly determined. LLNL conducted a complete radionuclide-inventory update in 1997.

Physical-State Factors: The physical-state factors listed are EPA potential-release fractions from 40 CFR 61, Appendix D, whereby emissions are estimated from radionuclide inventories depending on their physical states for use in dispersion/dose assessment modeling. A physical-state factor of 1.0×10^{-6} is used for solids, 1.0×10^{-3} is used for liquids and powders, and 1.0 is used for unconfined gases. In 1996, U.S. EPA granted approved alternative emissions factors for elemental uranium as follows: an emission factor of 1×10^{-6} can be used for elemental uranium heated at temperatures below 1100°C , an emission factor of 1×10^{-3} can be used for elemental uranium heated at temperatures below 3000°C , and an emission factor of 1 shall be used for temperatures greater than 3000°C . These factors are allowed provided that the uranium is not intentionally dispersed to the environment and that the processes do not alter the chemical form of the uranium.

Stack Parameters: Engineering surveys conducted from 1990 through 1992 form the basis for the stack physical parameters shown, which were checked and validated by facility experimenters and managers for 1994 and 1995. Stack physical parameters for sources evaluated in 1997 were updated, as necessary, by experimenters and managers for those facilities.

Emission-Control Devices: High-Efficiency-Particulate-Air (HEPA) filters are used in many LLNL facilities to control particulate emissions. For some discharge points, scrubbers and electrostatic precipitators aid the control of emissions. The operational performance of all HEPA filtration systems is routinely tested. The required efficiency of a single-stage HEPA filter is 99.97%. Double-staged filter systems are in place on some discharge points. Triple-stage HEPA filters are used on glove-box ventilation systems in the Building 332 Plutonium Facility and in the hardened portion of Building 251.

Control-Device Abatement Factors: Similar to physical-state factors, control-device abatement factors, from Table 1 in 40 CFR 61, Appendix D, are those associated with the listed emission-control devices, and are used to better estimate actual emissions for use in dispersion and dose models. By regulation, each HEPA filter stage is given a 0.01 factor (even though the required test efficiency that all LLNL HEPA filters must maintain would yield a factor of 0.0003), venturi scrubbers and electrostatic precipitators are each given a 0.05 factor, and each activated-charcoal filter is given a 0.1 factor.

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, 251, 331, 332, 419, 490, and 491. See the subsection titled "1997 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 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 1997, (2) Unmonitored or non-continuously monitored Livermore site facilities with a previous radionuclide-inventory update (this category is not used in years with complete 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, 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.

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
NOTE: CAP88-PC requires activity rates of curies/year and gives doses in mrem/year. To convert curies to becquerels use 1 Ci=3.7E+10 Bq and to convert millirem to sieverts use 1 Sv=1.0E+05 mrem.																				
LIVERMORE SITE POINT SOURCES																				
Building 151 houses the Isotope Sciences Division which applies nuclear and isotope sciences to a wide range of problems, including stockpile stewardship, nonproliferation, safeguard technologies, forensic science, and waste characterization and analysis.																				
Building 151 also contains the Chemistry and Materials Sciences Environmental Services laboratory where samples of waste streams and environmental media (air, water, soil etc.) are analyzed for their radionuclide content																				
151	1033	FHE-2	Drying of core drilling samples from NTS	Pu-239	4.3E-06	1.0E-03	7.6	0.61	3.1	None	1	4.3E-09	1308	E	1.0E-06	584	WNW	5.5E-06	1	Y
				Cs-137	2.1E-06	1.0E-03						2.1E-09								Y
				Sr-90	9.0E-07	1.0E-03						9.0E-10								Y
				Am-241	1.5E-06	1.0E-03						1.5E-09								Y
				H-3	1.2E-04	1.0E+00						1.2E-04								Y
151	1034B	Room Air	Decontamination operations	Gross alpha	2.0E-08	1.0E-06	NA	NA	NA	None	1	2.0E-14	1308	E	3.0E-12	584	WNW	2.6E-11	1	NA
				Gross beta	2.0E-08	1.0E-06						2.0E-14								NA
151	1043	FHE-5	Drying of core samples	Sr-90	1.7E-06	1.0E-03	7.6	0.46	2.9	None	1	1.7E-09	1308	E	2.0E-06	584	WNW	1.2E-05	1	Y
				Cs-137	4.2E-06	1.0E-03						4.2E-09								Y
				Pu-239	8.5E-06	1.0E-03						8.5E-09								Y
				Am-241	2.9E-06	1.0E-03						2.9E-09								Y
				H-3	2.3E-04	1.0E+00						2.3E-04								Y
151	1143	FHE-64	Sample preparation	Pu-239	2.3E-08	1.0E-03	19.2	0.61	2.8	None	1	2.3E-11	1308	E	1.5E-05	584	WNW	5.3E-05	1	Y
				U-234	1.2E-06	1.0E-03						1.2E-09								Y
				U-235	3.8E-08	1.0E-03						3.8E-11								Y
				U-238	6.0E-10	1.0E-03						6.0E-13								Y
				U-234	3.4E-07	1.0E-06						3.4E-13								Y
				U-235	1.1E-08	1.0E-06						1.1E-14								Y
				U-238	1.7E-10	1.0E-06						1.7E-16								Y
				Cm-244	2.0E-06	1.0E-03						2.0E-09								Y
				Cm-244	1.3E-10	1.0E+00						1.3E-10								Y
151	1241	FHE-68	Sample preparation	U-234	1.6E-10	1.0E-03	11.9	0.61	1.4	None	1	1.6E-13	1308	E	1.5E-09	584	WNW	6.5E-09	1	Y
				U-235	2.2E-11	1.0E-03						2.2E-14								Y
				U-238	1.7E-09	1.0E-03						1.7E-12								Y
				U-234	1.1E-05	1.0E-06						1.1E-11								Y
				U-235	5.1E-07	1.0E-06						5.1E-13								Y
				U-238	1.7E-05	1.0E-06						1.7E-11								Y
151	1318	FHE-26	Sample preparation	Pu-239	1.0E-09	1.0E-03	11.9	0.46	2.9	None	1	1.0E-12	1308	E	2.0E-10	584	WNW	7.7E-10	1	Y
				Am-241	2.0E-10	1.0E-03						2.0E-13								Y
				Cm-244	1.0E-10	1.0E-03						1.0E-13								Y
151	1322	FHE-35	Sample preparation	MFP	2.1E-09	1.0E-03	11.9	0.61	3.5	None	1	2.1E-12	1308	E	2.8E-12	584	WNW	9.4E-12	1	NA
151	1326	FHE-43	Sample preparation	MFP	3.0E-06	1.0E-03	11.9	0.61	3.3	None	1	3.0E-09	1308	E	4.0E-09	584	WNW	1.4E-08	1	NA
				U-233	2.0E-11	1.0E-03						2.0E-14								Y
				U-233	2.0E-11	1.0E-06						2.0E-17								Y
				Am-241	2.0E-11	1.0E-03						2.0E-14								Y
				Am-241	2.0E-11	1.0E-06						2.0E-17								Y
151	1330	FHE-54	Sample screening/disposal	Gross alpha	2.5E-05	1.0E-03	11.9	0.61	1.9	None	1	2.5E-08	1308	E	3.6E-06	584	WNW	1.4E-05	1	NA
				Gross beta	2.5E-05	1.0E-03						2.5E-08								NA
151	2117	FHE-23	Preparation of waste samples for analysis	Gross alpha	2.0E-09	1.0E+00	11.9	0.61	2.5	None	1	2.0E-09	1308	E	2.8E-07	584	WNW	1.1E-06	1	NA
				Gross beta	2.0E-09	1.0E+00						2.0E-09								NA
151	2121	FHE-36	Sample preparation	Gross alpha	2.0E-09	1.0E+00	11.9	0.61	2.8	None	1	2.0E-09	1308	E	2.8E-07	584	WNW	1.0E-06	1	NA
				Gross beta	2.0E-09	1.0E+00						2.0E-09								NA
151	2125	FHE-37	Chemical analysis	Gross Alpha	2.5E-09	1.0E-03	11.9	0.61	2.8	None	1	2.5E-12	1308	E	3.5E-10	584	WNW	1.3E-09	1	NA
				Gross Beta	2.5E-09	1.0E-03						2.5E-12								NA
151	2131	FHE-56	Chemical analysis	Gross Alpha	2.5E-09	1.0E-03	11.9	0.61	2.8	None	1	2.5E-12	1308	E	3.5E-10	584	WNW	1.3E-09	1	NA
				Gross Beta	2.5E-09	1.0E-03						2.5E-12								NA
151	2133	FHE-57	Analysis of waste samples	H-3	1.3E-08	1.0E-03	11.9	0.61	2.9	None	1	1.3E-11	1308	E	3.4E-15	584	WNW	1.2E-14	1	Y
151	2135	FHE-62	Standards preparation	Pu-239	1.0E-08	1.0E-03	11.9	0.61	3.5	None	1	1.0E-11	1308	E	3.3E-09	584	WNW	1.1E-08	1	Y
				H-3	1.0E-05	1.0E-03						1.0E-08								Y
				Cs-137	1.0E-08	1.0E-03						1.0E-11								Y
				Sr-90	1.0E-08	1.0E-03						1.0E-11								Y

Attachment 1 - 1997 LLNL NESHAPs Annual Report Spreadsheet

Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory	Physical	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated	10 mrem/y Site-Wide Dose Requirement			0.1 mrem/y Monitoring Requirement			Source Category	Below App. E Quantity
					with Potential for Release (Ci)	State Factor						Annual Emissions (Ci)	Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		
151	2135 (continued)			Eu-152	1.0E-08	1.0E-03						1.0E-11								Y
				Eu-154	1.0E-08	1.0E-03						1.0E-11								Y
				Co 60	1.0E-08	1.0E-03						1.0E-11								Y
				Th-232	1.0E-08	1.0E-03						1.0E-11								Y
				Ba-133	1.0E 08	1.0E-03						1.0E-11								Y
				U-238	4.7E-09	1.0E 03						4.7E-12								Y
				U-235	2.2E-10	1.0E-03						2.2E-13								Y
				U-234	5.1E-09	1.0E-03						5.1E-12								Y
151	2149	FHE-78	Tracer preparation	Pu-238	2.0E-14	1.0E-03	11.9	0.61	3.3	None	1	2.0E-17	1308	E	6.5E-13	584	WNW	2.3E-12	1	Y
				Pu-239	4.0E-14	1.0E 03							4.0E-17							Y
				Pu-240	4.0E-14	1.0E-03							4.0E-17							Y
				Pu-242	3.0E-12	1.0E-03							3.0E-15							Y
				U-232	1.0E-12	1.0E-03							1.0E 15							Y
				U-233	9.0E-13	1.0E-03							9.0E-16							Y
				U-238	1.9E-15	1.0E-03							1.9E-18							Y
				U-235	8.8E-17	1.0E-03							8.8E-20							Y
				U-234	2.0E-15	1.0E 03					2.0E-18							Y		
151	2308	FHE-16	Actinide research	Th-232	3.0E-10	1.0E-03	11.9	0.61	2.9	Double HEPA	0.0001	3.0E-17	1308	E	1.4E-09	584	WNW	5.2E 05	1	Y
				Pu-239	1.0E-04	1.0E-03							1.0E-11							Y
				Pu-242	5.0E-07	1.0E-03							5.0E-14							Y
151	2312	FHE-21	Actinide research	Pu-242	2.0E 07	1.0E-03	11.9	0.61	2.8	Double HEPA	0.0001	2.0E 14	1308	E	2.8E 09	584	WNW	1.0E 04	1	Y
				U-233	1.6E-08	1.0E 03							1.6E-15							Y
				Np-237	1.4E 04	1.0E-03							1.4E-11							Y
151	2318	FHE-30	Sample preparation	Pu-242	6.0E-07	1.0E-03	11.9	0.61	2.8	Double HEPA	0.0001	6.0E-14	1308	E	8.0E 12	584	WNW	2.9E-07	1	Y
151	2322	FHE-31	Chemical leaching experimentation	Gross alpha	1.2E-06	1.0E-03	11.9	0.61	3.4	None	1	1.2E 09	1308	E	1.7E-07	584	WNW	5.8E 07	1	NA
				Gross beta	1.2E-06	1.0E-03							1.2E-09							NA
151	2326	FHE-39	Chemical analysis of waste	Gross alpha	2.5E-06	1.0E 03	11.9	0.61	2.8	None	1	2.5E-09	1308	E	3.5E-07	584	WNW	1.3E-06	1	NA
				Gross beta	2.5E-06	1.0E-03							2.5E-09							NA
151	2344	FHE-65	Chemical analysis of waste	Gross alpha	2.0E-06	1.0E-03	11.9	0.61	2.8	None	1	2.0E-09	1308	E	2.8E-07	584	WNW	1.0E-06	1	NA
				Gross beta	2.0E-06	1.0E-03							2.0E 09							NA
Building 166 is part of LLNL's Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) program, now affiliated with The United States Enrichment Corporation (USEC).																				
*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 unabated EDE cannot be determined (see discussion on page 46.)																				
166	HiBay	Stack	Conversion of uranium to halides and oxides of uranium	Gross alpha	*	NA	7.9	0.25	3.9	HEPA	0.01	0.0E+00	1291	E	0.0E+00	**	**	**	3	NA
				Gross beta	*	NA							0.0E+00							NA
Building 174 is part of LLNL's Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) program, now affiliated with The United States Enrichment Corporation (USEC).																				
174	Annex-1401	Room air	Pulse laser experimentation	U-238	9.0E-08	1.0E-06	NA	NA	NA	None	1	9.0E-14	1446	ESE	1.5E-12	480	W	5.4E-11	1	Y
				U-235	1.2E-09	1.0E-06							1.2E-15							Y
				U-234	8.4E-09	1.0E 06							8.4E-15							Y
Building 175 is part of LLNL's Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) program, now affiliated with The United States Enrichment Corporation (USEC).																				
*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 unabated EDE cannot be determined (see discussion on page 46.)																				
175		6 Stacks	Cleaning and refurbishment of parts	Gross alpha	*	NA				HEPA	1.0E-02	0.0E+00	**	**	0.0E+00	**	**	**	3	NA
				Gross beta	*	NA							0.0E+00							NA
Building 177 is part of LLNL's Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) program, now affiliated with The United States Enrichment Corporation (USEC).																				
177	1008	Room Air	Corrosion studies of liquid uranium	U-238	5.0E-03	1.0E-03	N/A	N/A	N/A	None	1	5.0E-06	1350	ESE	9.4E-05	615	WNW	2.2E-03	1	Y
				U-235	8.1E-05	1.0E-03							8.1E-08			568	W			Y
				U-234	4.7E-04	1.0E-03							4.7E-07							Y
177	1014	FHE-10	Examination/cleaning of apparatus contaminated by uranium	U-238	3.3E-05	1.0E-03	5.8	0.41	2.4	HEPA	0.01	3.3E-10	1350	ESE	1.2E-08	615	WNW	2.5E-05	1	Y
				U-235	1.5E-06	1.0E-03							1.5E-11							Y
				U-234	3.5E-05	1.0E-03							3.5E-10							Y
177	1015	FHE-27	Preparation and examination of metallographic samples	U-238	8.6E-05	1.0E-06	7.9	0.56	12.9	HEPA	0.01	8.6E-13	1350	ESE	2.9E-11	764	NNE	2.9E-08	1	Y
				U-235	4.5E-06	1.0E-06							4.5E-14							Y
				U-234	1.1E-04	1.0E-06							1.1E-12							Y

Attachment 1 - 1997 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/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
177	1021	FHE-24, 25	Sample preparation	U-238	1.7E-04	1.0E-03	11.0	0.41	7.8	HEPA	0.01	1.7E-09	1350	ESE	6.0E-08	764	NNE	6.0E-05	1	Y
				U-235	9.0E-06	1.0E-03						9.0E-11								Y
				U-234	2.1E-04	1.0E-03						2.1E-09								Y
Building 194 is operated by N-Division for the Physics and Space Technology Directorate. The facility houses a high-energy linear accelerator (LINAC) and research laboratories. The accelerator beam can produce small quantities of short-lived air activation products.																				
194	B122	TE-FE4	Linac accelerator vault	O-15	6.0E-02	1.0E+00	30.5	1.37	4.5	None	1	6.0E-02	1525	SSE	9.4E-06	538	NE	5.3E-04	1	NA
		(Target Exhaust)		N-13	1.1E-01	1.0E+00						1.1E-01								NA
194	B124	TE-FE4	Storage	Na-22	5.0E-05	1.0E-03						5.0E-08								Y
				U-233	1.2E-05	1.0E-06						1.2E-11								Y
				U-234	6.0E-09	1.0E-06						6.0E-15								Y
				U-235	3.9E-06	1.0E-06						3.9E-12								Y
				U-236	3.5E-08	1.0E-06						3.5E-14								Y
				U-238	1.0E-04	1.0E-06						1.0E-10								Y
	B130	TE-FE4	Positron beam generation	O-15	5.5E-01	1.0E+00				None	1	5.5E-01								NA
				N-13	1.1E+00	1.0E+00						1.1E+00								NA
194	1131	Room Air	Positron materials science experiments	Na-22	3.6E-06	1.0E-03	NA	NA	NA	None	1	3.6E-09	1525	ESE	1.3E-09	412	NNE	4.0E-08	1	Y
Building 212 is administered by the Physics and Space Technology Directorate (formerly the Physical Sciences Directorate) for miscellaneous physics experiments. The current radionuclide emissions are due to contamination from past operations of the rotating target neutron source, which is no longer in operation.																				
212	174	FHE-7	Contamination	H-3	1.7E-02	1.0E-06	4.3	0.5	0.5	None	1	1.7E-08	1278	ENE	6.8E-12	38	SW	2.4E-10	1	Y
212	184	Room Air	Contamination	H-3	1.0E-03	1.0E-06	NA	NA	NA	None	1	1.0E-09	1278	ENE	4.0E-13	38	SW	1.4E-11	1	Y
Building 222 is part of the Chemistry and Material Sciences Directorate. Many of the laboratories either store or used depleted uranium. The depleted uranium usually exists as a solid, either as metal pieces or in chemical reagents such as oxide powders. The other source of radionuclides in Building 222 is from analysis of hazardous-waste samples.																				
222	1106	Room Air	Analysis of waste samples	Gross alpha	3.0E-14	1.0E-03	NA	NA	NA	None	1	3.0E-17	1239	ENE	7.3E-15	191	SSW	1.0E-13	1	NA
				Gross beta	3.0E-13	1.0E-03						3.0E-16								NA
				Gross gamma	3.0E-13	1.0E-03						3.0E-16								NA
				H-3	7.5E-13	1.0E-03						7.5E-16								Y
222	1405	Room Air	Chemical analysis	U-238	4.9E-13	1.0E-03	NA	NA	NA	None	1	4.9E-16	1239	ENE	3.9E-14	191	SSW	5.5E-13	1	Y
				U-235	6.3E-15	1.0E-03						6.3E-18								Y
				U-234	4.6E-14	1.0E-03						4.6E-17								Y
				H-3	1.1E-12	1.0E-03						1.1E-15								Y
222	1511B	FHE-113	Chemical analysis	U-234	1.0E-16	1.0E+00	5.5	0.15	5.8	HEPA	0.01	1.0E-18	1239	ENE	1.5E-16	191	SSW	1.2E-13	1	Y
				U-235	4.4E-18	1.0E+00						4.4E-20				253	SW			Y
				U-238	9.5E-17	1.0E+00						9.5E-19								Y
222	1511B	Room Air	Chemical analysis	U-234	5.1E-14	1.0E-03	NA	NA	NA	None	1	5.1E-17	1239	ENE	7.7E-15	191	SSW	1.1E-13	1	Y
				U-235	2.2E-15	1.0E-03						2.2E-18								Y
				U-238	4.7E-14	1.0E-03						4.7E-17								Y
222	1514	Room Air	X-ray fluorescence analysis	U-238	9.9E-11	1.0E-06	NA	NA	NA	None	1	9.9E-17	1239	ENE	8.0E-15	191	SSW	1.1E-13	1	Y
				U-235	1.3E-12	1.0E-06						1.3E-18								Y
				U-234	9.3E-12	1.0E-06						9.3E-18								Y
222	1524C	FHE 87	Sample digestion	Gross alpha	6.0E-10	1.0E+00	6.1	0.26	6.7	None	1	6.0E-10	1239	ENE	1.3E-07	191	SSW	8.2E-07	1	NA
				Gross beta	6.0E-10	1.0E+00						6.0E-10								NA
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 unabated EDE cannot be determined (see discussion on page 46.)																				
231	1128	FHE-31-1,2	Storage of radionuclides	Gross Alpha	*	NA	12.2	0.41	12.0	HEPA	0.01	0.0E+00	1167	E	0.0E+00	**	**	**	3	NA
231	1427	Room Air		U-238	4.1E-03	1.0E-06	NA	NA	NA	None	1	4.1E-09	1167	E	2.8E-07	439	SSW	1.4E-06	1	Y
				U-235	5.2E-05	1.0E-06						5.2E-11								Y
				U-234	3.8E-04	1.0E-06						3.8E-10								Y
231	1737	FGBE-5	Storage area	U-238	1.9E-07	1.0E-06	10.1	0.46	1.5	HEPA	0.01	1.9E-15	1167	E	1.2E-13	725	WNW	4.4E-11	1	Y
				U-235	2.5E-09	1.0E-06						2.5E-17								Y
				U-234	1.8E-08	1.0E-06						1.8E-16								Y
231	1737A	FHE-54	Electron beam welding	U-238	3.6E-05	1.0E-06	10.1	0.46	1.5	HEPA	0.01	3.6E-13	1167	E	2.3E-11	725	WNW	8.1E-09	1	Y
				U-235	4.5E-07	1.0E-06						4.5E-15								Y
				U-234	3.3E-06	1.0E-06						3.3E-14								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 Requirement			0.1 mrem/y Monitoring Requirement			Source Category	Below App. E Quantity
													Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		
231	1737A (continued)			U-238	9.4E-11	1.0E-03						9.4E-16								Y
				U-235	1.2E-12	1.0E-03						1.2E-17								Y
				U-234	8.8E-12	1.0E-03						8.8E-17								Y
231	1900HB	FGBE-7/8	Storage	U-234	4.9E-06	1.0E-06	2.4	0.20	14.4	None	1	4.9E-12	1167	E	3.3E-10	725	WNW	1.4E-09	1	Y
				U-235	6.3E-06	1.0E-06					6.3E-14				671	W				Y
				U-238	3.0E-07	1.0E-06					3.0E-13				439	SSW				Y
231	1944	FHE-42	Metal processing	U-234	1.9E-10	1.0E-06	2.4	0.36	40.4	HEPA	0.01	1.9E-18	1167	E	1.2E-15	439	SSW	2.4E-13	1	Y
				U-235	2.6E-11	1.0E-06					2.6E-19									Y
				U-238	2.0E-09	1.0E-06					2.0E-17									Y
231	1945	FHE-40	Metal characterization	U-234	1.9E-10	1.0E-06	10.7	0.36	3.8	None	1	1.9E-16	1167	E	1.3E-13	725	WNW	4.1E-13	1	Y
				U-235	2.6E-11	1.0E-06					2.6E-17									Y
				U-238	2.0E-09	1.0E-06					2.0E-15									Y
231	1945A	Room Air	Metal characterization	U-234	1.9E-13	1.0E-06	NA	NA	NA	None	1	1.9E-19	1167	E	1.4E-16	439	SSW	6.6E-16	1	Y
				U-235	2.6E-14	1.0E-06					2.6E-20									Y
				U-238	2.0E-12	1.0E-06					2.0E-18									Y
231	1945B	FHE-40	Metal characterization	U-234	1.3E-10	1.0E-03	10.0	0.41	4.6	None	1	1.3E-13	1167	E	9.0E-11	725	WNW	2.8E-10	1	Y
				U-235	1.7E-11	1.0E-03					1.7E-14									Y
				U-238	1.4E-09	1.0E-03					1.4E-12									Y
				U-234	3.7E-09	1.0E-06					3.7E-15									Y
				U-235	5.1E-10	1.0E-06					5.1E-16									Y
				U-238	4.0E-08	1.0E-06					4.0E-14									Y
231	1945C	Room Air	Metal characterization	U-234	1.9E-13	1.0E-06	NA	NA	NA	None	1	1.9E-19	1167	E	1.4E-16	439	SSW	6.6E-16	1	Y
				U-235	2.6E-14	1.0E-06					2.6E-20									Y
				U-238	2.0E-12	1.0E-06					2.0E-18									Y
231	1945D	Room Air	Metal polishing	U-234	1.9E-10	1.0E-06	NA	NA	NA	None	1	1.9E-16	1167	E	1.4E-13	439	SSW	6.6E-13	1	Y
				U-235	2.6E-11	1.0E-06					2.6E-17									Y
				U-238	2.0E-09	1.0E-06					2.0E-15									Y
231	1945E	Room Air	Wet grinding/polishing	U-234	1.9E-07	1.0E-03	NA	NA	NA	None	1	1.9E-10	1167	E	1.4E-07	439	SSW	6.6E-07	1	Y
				U-235	2.6E-08	1.0E-03					2.6E-11									Y
				U-238	2.0E-06	1.0E-03					2.0E-09									Y
231	1956A	FHE-43	Metal casting	U-234	9.3E-06	1.0E-06	9.5	0.40	12.6	HEPA	0.01	9.3E-14	1167	E	6.2E-11	725	WNW	1.3E-08	1	Y
				U-235	1.3E-06	1.0E-06					1.3E-14									Y
				U-238	1.0E-04	1.0E-06					1.0E-12									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 cutting, 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.																				
235	1131	FHE-1A,1B (HDCM-6,7)	Metallographic sample preparation	U-234	1.0E-08	1.0E-06	10.7	2.75	14.3	HEPA	0.01	1.0E-16	1065	ENE	6.7E-14	1541	NE	5.9E-12	1	Y
				U-235	1.5E-09	1.0E-06					1.5E-17				1184	ENE				Y
				U-238	1.2E-07	1.0E-06					1.2E-15								Y	
235	1133	Room Air	Microstructure examination	U-234	2.8E-09	1.0E-06	NA	NA	NA	None	1	2.8E-15	1065	ENE	3.1E-12	473	SSW	9.0E-12	1	Y
				U-235	3.8E-10	1.0E-06					3.8E-16									Y
				U-238	3.0E-08	1.0E-06					3.0E-14									Y
235	1138	FHE-2A,2B/HD-13	Sample preparation	U-234	6.8E-09	1.0E-06	10.7	2.75	14.3	HEPA	0.01	6.8E-17	1065	ENE	4.2E-14	1541	NE	3.7E-12	1	Y
				U-235	9.4E-10	1.0E-06					9.4E-18									Y
				U-238	7.3E-08	1.0E-06					7.3E-16									Y
Building 241 is administered by the Chemistry and Material Sciences Directorate for material properties research and testing.																				
241	1826	Room Air	X-ray Analysis	U-234	9.0E-10	1.0E-06	NA	NA	NA	None	1	9.0E-16	1140	E	1.2E-13	697	W	5.3E-13	1	Y
				U-235	4.0E-11	1.0E-06					4.0E-17									Y
				U-238	8.5E-10	1.0E-06					8.5E-16									Y
241	1838	FGBE-9 &10	Ceramic waste form research	U-234	7.1E-09	1	12.2	0.46	1.6	HEPA	0.01	7.1E-11	1140	E	8.9E-09	754	WNW	2.7E-06	1	Y
				U-235	3.1E-10	1					3.1E-12									Y
				U-238	6.6E-09	1					6.6E-11									Y
241	1838	FHE-6	Ceramic waste form research	U-234	1.4E-06	1.0E-03	6.4	0.54	5.8	None	1	1.4E-09	1140	E	1.8E-07	754	WNW	5.7E-07	1	Y
				U-235	6.2E-08	1.0E-03					6.2E-11									Y
				U-238	1.3E-06	1.0E-03					1.3E-09									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 Requirement			0.1 mrem/y Monitoring Requirement			Source Category	Below App. E Quantity
													Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		
Building 251, the Heavy Element Facility, is managed by the Physics and Space Technology Directorate for the Institutions as a non operational facility in which transuranic isotopes are stored until they can be disposed. 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 unabated EDE cannot be determined (see discussion on page 46.) ***Stack emissions have been combined as permitted by the EPA/DOE Memorandum of Understanding.																				
Unhardened Area***																				
251	1219	FGBE-27,28	Out of service	Gross Alpha	*	NA	10.5	0.15	3.3	HEPA	0.01	1.6E-07	1185	E	3.0E-05	**	**	**	3	NA
	1301	FHE-16	Welding	Gross Beta			6.8	0.15	0.8	HEPA	0.01	1.0E-06								NA
	1310	FHE-15	Hoods removed				6.8	0.35	5.9	HEPA	0.01									
		CD-01					6.4	0.31	9.2	HEPA	0.01									
Unhardened Area***																				
251	1003	FHE-5	General chemistry	Gross Alpha	*	NA	4.3	0.26	8.6	HEPA	0.01	0.0E+00	1188	E	0.0E+00	**	**	**	3	NA
	1003	FHE-4		Gross Beta			4.3	0.27	4.2			0.0E+00								NA
	1108	FFE-7					5.5	0.33	1.1											
	1117	FFE-6					4.3	0.31	7.6											
	1117	FGBE-21,22,23,24					5.5	0.11	7.6											
	1117	FGBE-25,26					8.5	0.10	12.8											
	1142	FHE-8					4.3	0.32	4.1											
	1142	FHE-9					4.3	0.26	5.1											
	1142	FHE-10					4.3	0.28	13.7											
	1150	FGBE-33,34					8.0	0.15	12.8											
	1150	FFE-15					4.3	0.31	7.6											
	1165	FFE-14					4.3	0.34	1.0											
	1165	FGBE-31,32					5.5	0.87	0.1											
	1211	FHE-6					6.4	0.25	8.0											
	1211	FHE-7					6.4	0.25	4.3											
	1212	FGBE-15,16					5.5	0.10	8.0											
	1232	FHE-38,39					7.2	0.15	5.1											
	1234	FFE-9					4.3	0.19	14.7											
	1235	FFE-12					4.3	0.25	7.6											
	1235	FGBE-29,30					5.5	0.13	7.1											
	1310	FHE-14					4.3	0.31	9.1											
	1331	FFE-21					4.3	0.24	6.1											
	1363	FGBE-35,36					4.3	0.13	11.2											
	1363	FHE-12					4.3	0.32	9.1											
	1363	FHE-13					4.3	0.40	6.2											
	1364	FFE-23					4.3	0.34	9.1											
	2126	FFE-22					4.3	1.40	1.0											
	1314, 1354	FGBE-44,45					10.2	0.15	10.2											
	Hot cells	FGBE-40,41					5.5	0.23	5.6											
	Hot cells	FGBE-42,43					5.5	0.36	12.7											
	Mezzanine	FFE-24					4.3	0.45	2.7											
	None	FFE-19					4.3	0.29	8.6											
251	Hardened Area	FGBE-1000	Previous transuranic research	Gross alpha	*	NA	7.8	0.30	4.8	Triple HEPA	0.000001	0.0E+00	1188	E	0.0E+00	**	**	**	3	NA
	Room Exhaust & Glove Boxes***	FGBE-2000		Gross beta			7.8	0.30	4.8			0.0E+00								NA
		FFE-1000					7.8	0.50	11.7	Double HEPA	0.0001									
		FFE-2000					7.8	0.50	11.7											
Building 253 houses the Hazards Control Department, and the facility includes laboratories for the chemical analysis and counting of radioactive samples.																				
253	1734	Room Air	Distillation of environmental samples	H-3	9.9E-10	1.0E+00	NA	NA	NA	None	1	9.9E-10	1122	ESE	2.0E-10	736	W	2.1E-09	1	Y
				Pu-239	2.8E-12	1.0E+00						2.8E-12				798	WNW			Y
				Sr-90	1.2E-11	1.0E+00						1.2E-11								Y
253	1734	FGBE-1,2	Sieve soil samples	Pu-239	2.7E-10	1.0E-06	6.1	0.10	23.6	HEPA	0.01	2.7E-18	1122	ESE	1.8E-16	736	W	1.6E-13	1	Y
				Sr-90	4.6E-10	1.0E-06						4.6E-18				798	WNW			Y
253	1734	FHE-2	Samples and standards plating	Ca-137	1.7E-11	1.0E+00	6.4	0.30	8.7	None	1	1.7E-11	1122	ESE	9.3E-10	798	WNW	8.2E-09	1	Y
				Th-230	2.2E-12	1.0E+00						2.2E-12								Y
				Pu-239	1.2E-11	1.0E+00						1.2E-11								Y
				Sr-90	1.7E-12	1.0E+00						1.7E-12								Y
				Y-90	7.8E-13	1.0E+00						7.8E-13								Y
				Np-237	6.4E-13	1.0E+00						6.4E-13								Y
				H-3	4.3E-12	1.0E+00						4.3E-12								Y
253	1734	FHE-4	Quality control sample aliquoting	H-3	2.2E-14	1.0E+00	6.4	0.30	9.4	None	1	2.2E-14	1122	ESE	7.9E-10	798	WNW	6.8E-09	1	Y
		FHE-20		Np-237	3.0E-12	1.0E+00	6.4	0.30	13.2	None	1	3.0E-12								Y
				Sr-90	2.5E-12	1.0E+00						2.5E-12								Y

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory	Physical	Stack	Stack	Stack	Control	Control Device	Estimated	10 mrem/y Site-Wide Dose Requirement		0.1 mrem/y Monitoring Requirement		Source	Below		
					with Potential for Release (Ci)	State Factor	Height (m)	Diameter (m)	Velocity (m/s)	Device(s)	Abatement Factor	Annual Emissions (Ci)	Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)	Category	App. E Quantity
253	1734 (continued)			Y-90	2.5E-12	1.0E+00						2.5E-12						Y		
				Cs-137	3.8E-12	1.0E+00						3.8E-12						Y		
				Th-230	6.3E-13	1.0E+00						6.3E-13						Y		
				Pu-239	7.5E-12	1.0E+00						7.5E-12						Y		
				Gross alpha	1.4E-13	1.0E+00						1.4E-13						NA		
				Gross beta	2.1E-13	1.0E+00						2.1E-13						NA		
253	1734	FHE-11	Acid digestion for sample analysis	H-3	6.8E-09	1.0E+00	10.4	0.30	12.3	None	1	6.8E-09	1122	ESE	3.3E-09	798	WNW	2.2E-08	1	Y
				Pu-239	5.3E-11	1.0E+00				5.3E-11									Y	
				Sr-90	2.6E-10	1.0E+00				2.6E-10									Y	
				Y-90	2.6E-12	1.0E+00				2.6E-12									Y	
				Np-237	3.1E-12	1.0E+00				3.1E-12									Y	
253	1910	FHE-22	Preparations of calibration standards	H-3	3.0E-11	1.0E-03	7.0	0.20	5.2	None	1	3.0E-14	1122	ESE	1.3E-15	736	W	1.2E-14	1	Y
				C-14	1.5E-11	1.0E-03				1.5E-14	798	WNW						Y		
				P-32	1.5E-10	1.0E-03				1.5E-13								Y		
Building 254 is run by Hazards Control for the purpose of conducting bioassays and providing analytical services.																				
254	110	FHE-1000	Analysis of urine for radionuclides	Am-241	8.6E-14	1.0E-03	8.2	1.07	5.3	None	1	8.6E-17	1038	ESE	1.1E-11	849	WNW	6.1E-11	1	Y
				Am-243	2.7E-12	1.0E-03				2.7E-15									Y	
				C-14	7.0E-11	1.0E-03				7.0E-14									Y	
				Cf-252	8.4E-12	1.0E-03				8.4E-15									Y	
				Cm-242	9.1E-13	1.0E-03				9.1E-16									Y	
				Cm-244	8.6E-18	1.0E-03				8.6E-21									Y	
				Cf-249	6.7E-13	1.0E-03				6.7E-16									Y	
				Gross gamma	1.4E-11	1.0E-03				1.4E-14									NA	
				H-3	1.2E-10	1.0E-03				1.2E-13									Y	
				I-125	3.4E-10	1.0E-03				3.4E-13									Y	
				Np-237	1.1E-10	1.0E-03				1.1E-13									Y	
				Np-239	6.2E-10	1.0E-03				6.2E-13									Y	
				P-32	5.6E-10	1.0E-03				5.6E-13									Y	
				P-33	2.2E-09	1.0E-03				2.2E-12									Y	
				Po-209	7.1E-15	1.0E-03				7.1E-18									NA	
				Pu-239	4.6E-13	1.0E-03				4.6E-16									Y	
				Pu-242	2.8E-12	1.0E-03				2.8E-15									Y	
				S-35	2.3E-10	1.0E-03				2.3E-13									Y	
				Sr-90	2.7E-10	1.0E-03				2.7E-13									Y	
				Th-230	9.4E-12	1.0E-03				9.4E-15									Y	
				U-232	6.4E-13	1.0E-03				6.4E-16									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	2.9E-14	1.0E-03				2.9E-17									Y	
				U-236	8.7E-12	1.0E-03				8.7E-15									Y	
				U-238	2.8E-15	1.0E-03				2.8E-18									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	3.8E-15	1.0E-03	6.9	0.30	5.1	None	1	3.8E-18	1056	E	7.4E-12	790	W	1.3E-11	1	Y
				Am-243	1.9E-14	1.0E-03				1.9E-17									Y	
				Cm-244	3.8E-14	1.0E-03				3.8E-17									Y	
				I-125	2.3E-09	1.0E-03				2.3E-12									Y	
				I-131	7.2E-09	1.0E-03				7.2E-12									Y	
				Np-237	5.7E-14	1.0E-03				5.7E-17									Y	
				Pu-239	1.9E-14	1.0E-03				1.9E-17									Y	
				Pu-242	1.9E-15	1.0E-03				1.9E-18									Y	
				Th-230	5.7E-14	1.0E-03				5.7E-17									Y	
				Th-232	1.0E-16	1.0E-03				1.0E-19									Y	
				U-233	1.0E-11	1.0E-03				1.0E-14									Y	
				U-238	1.3E-16	1.0E-03				1.3E-19									Y	
255	180	FHE-2	Tritium gas monitor calibrations	H-3	2.5E-02	1.0E+00	8.1	0.31	5.2	None	1	2.5E-02	1056	E	9.8E-06	855	WNW	2.5E-05	1	Y
Building 281 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 1323 is used for collection of Nuclear Test Site groundwater samples. These samples contain some tritiated water.																				
281	1174	FHE-13	Tracer work	C-14	3.0E-06	1.0E-03	6.7	0.30	6.1	None	1	3.0E-09	1332	ESE	1.8E-11	579	NNE	2.9E-10	1	Y
281	1307	FHE-6	Tracer work	Ni-63	1.0E-06	1.0E-03	6.4	0.61	2.7	None	1	1.0E-09	1332	ESE	1.7E-12	579	NNE	2.8E-11	1	Y
				Ni-59	3.5E-10	1.0E-03						3.5E-13								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 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
281	1311	FHE-12	Sample preparation	U-233	4.5E-11	1.0E-03	6.1	0.41	4.0	None	1	4.5E-14	1332	ESE	8.6E-13	579	NNE	1.5E-11	1	Y
281	1311A	FHE-3	Sample preparation	Th-232 Pu-242	2.5E-10 1.0E-08	1.0E-03 1.0E-03	4.9	0.25	10.3	None	1	2.5E-13 1.0E-11	1332	ESE	4.9E-10	579	NNE	8.5E-09	1	Y Y
281	1311B	FHE-3	Sample preparation	Pu-242	4.0E-08	1.0E-03	4.9	0.25	10.3	Double HEPA	0.0001	4.0E-15	1332	ESE	1.9E-13	579	NNE	3.3E-08	1	Y
281	1319	FHE-1	Sample preparation	Th-232 Np-237 Pu-242	3.0E-10 7.0E-05 5.0E-07	1.0E-03 1.0E-03 1.0E-03	5.2	0.28	9.2	Double HEPA	0.0001	3.0E-17 7.0E-12 5.0E-14	1332	ESE	4.9E-10	579	NNE	8.5E-05	1	Y Y Y
281	1322	FHE-1	Radioactivity migration studies	U-233 Np-237	2.7E-09 2.2E-08	1.0E-03 1.0E-03	6.7	0.30	6.1	None	1	2.7E-12 2.2E-11	1332	ESE	1.6E-09	579	NNE	2.6E-08	1	Y Y
Building 292 is administered by the Environmental Programs 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	1200,1202	Room Air	Contamination	H-3	1.8E+00	1.0E-03	NA	NA	NA	None	1	1.8E-03	1380	ESE	1.8E-07	456	N	4.6E-06	1	Y
292	1204	Room Air	Contamination	H-3	2.3E+01	1.0E-03	NA	NA	NA	None	1	2.3E-02	1380	ESE	2.3E-06	456	N	5.9E-05	1	Y
292	1402, 1402A 1404, 1406 1407	Room Air	Contamination	H-3	1.8E+00	1.0E-03	NA	NA	NA	None	1	1.8E-03	1380	ESE	1.8E-07	456	N	4.6E-06	1	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	185	FEV-1	Laser cutting	U-238 U-235 U-234	9.0E-05 1.2E-06 8.4E-06	1.0E-06 1.0E-06 1.0E-06	6.5	0.63	15.0	HEPA	0.01	9.0E-13 1.2E-14 8.4E-14	1398	SE	1.1E-11	344	NE	5.8E-08	1	Y Y Y
298	189	FHE-14	Laser fusion target coating	U-238 U-235 U-234	4.5E-04 6.0E-06 4.2E-05	1.0E-06 1.0E-06 1.0E-06	6.4	0.63	15.1	HEPA	0.01	4.5E-12 6.0E-14 4.2E-13	1398	SE	5.3E-11	344	NE	2.9E-07	1	Y Y Y
298	Various	Room Air	Laser fusion target research and development	H-3	4.0E-02	1.0E+00	NA	NA	NA	None	1	4.0E-02	1398	SE	3.5E-06	264	NNE	2.7E-04	1	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 milling, shaping 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. *Stack emissions have been combined as permitted by the EPA/DOE Memorandum of Understanding.																				
321A	1001A	FHE-24	Machining and manufacturing	U-234 U-235 U-238	7.5E-04 1.0E-04 8.1E-03	1.0E-06 1.0E-06 1.0E-06	3.7	0.46	2.9	HEPA	0.01	7.5E-12 1.0E-12 8.1E-11	1032	ESE	8.90E-09	252	SSW	5.2E-06	1	Y Y Y
321C	All**	FHE-9 FHE-11 FHE-15 FEV-1000	Machining and manufacturing	U-234 U-235 U-238	3.2E+00 4.0E-02 3.0E-01	1.0E-06 1.0E-06 1.0E-06	8.5 12.5 11.2 11.3	0.31 0.60 0.23 0.83	16.1 6.0 13.4 6.5	HEPA HEPA HEPA HEPA	0.01 0.01 0.01 0.01	3.2E-08 4.0E-10 3.0E-09	1032	ESE	3.1E-08	252	SSW	6.4E-06	1	Y Y Y Y
Building 322 is operated by the Mechanical Engineering Department.																				
322	109	FHE-1	Cleaning and plating of depleted uranium	U-234 U-235 U-238	3.1E-07 4.3E-08 3.3E-06	1.0E-06 1.0E-06 1.0E-06	7.9	0.35	1.0	None	1	3.1E-13 4.3E-14 3.3E-12	930	ESE	4.3E-10	316	SSW	1.1E-09	1	Y Y Y
Building 327 is operated by the Mechanical Engineering Department.																				
327	1275	Room Air	Non-destructive ultrasonic material evaluation	U-234 U-235 U-238	1.3E-05 1.9E-06 1.4E-04	1.0E-06 1.0E-06 1.0E-06	NA	NA	NA	None	1	1.3E-11 1.9E-12 1.4E-10	1018	ESE	1.6E-08	321	SSW	7.5E-08	1	Y Y Y
Building 331 is operated by the Defense and Nuclear Technologies Directorate. The building houses the tritium research facility and associated laboratories. *Tritium HT and HTO emissions are continuously monitored from the two 30 meter tall stacks in compliance with NESHAPs regulations. Monitoring data, rather than the inventory approach, are used to determine emissions. **Stack emissions have been combined as permitted by the EPA/DOE Memorandum of Understanding.																				
331	All**	Stack 1 Stack 2	Tritium R&D; Decontamination and decommissioning of facility	H-3 H-3	* *	1.0E+00 1.0E+00	30.0 30.0	1.22 1.22	7.6 10.5	None None	1 1	1.0E+01 2.6E+02	957	ESE	7.5E-02	957	ESE	7.5E-02	3	NA

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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 332 is operated by the Defense Sciences Program for plutonium research. Exhausts from glove box operations and the workplace are triply filtered by high efficiency particulate air (HEPA) filters. Exhausts are monitored with both continuous filter sampling (PAMs) and plutonium specific, continuous real time monitors (CAMs).																				
*Because building plutonium inventory and the plutonium associated with specific tasks is classified, the standard NESHAPs approach, based on inventory, cannot be utilized without classifying this report. The air monitoring data for all emission points show no detectable released plutonium activity, i.e. at or below the limit of sensitivity of the analytical analysis.																				
**Because monitoring takes place after HEPA filtration, an unabated EDE cannot be determined (see discussion on page 46.)																				
332	Increment 1 Rooms	FHE-1000/2000	Plutonium research	Transuranics	*	NA	8.8	0.8x1.1	17.3	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	**	**	**	3	NA
332	Increment 1 Glove boxes	FGBE-1000/2000	Plutonium research	Transuranics	*	NA	11	0.3	6.9	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	*	**	**	3	NA
332	Downdraft	FHE 4/5	Plutonium research	Transuranics	*	NA	11	0.2	14.2	Double HEPA	0.0001	0.0E+00	912	ENE	0.0E+00	**	*	*	3	NA
332	Loft	FE-4	Plutonium research	Transuranics	*	NA	11	0.6x0.9	4.6	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	**	**	**	3	NA
FE-5		Plutonium research	Transuranics	*	NA	11	0.6x0.9	4.6	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	**	**	**	3	NA	
332	Increment 1 Glove boxes	FGBE-3000/4000	Plutonium research	Transuranics	*	NA	11	0.3	2	Triple HEPA	0.000001	0.0E+00	912	ENF	0.0E+00	**	**	**	3	NA
332	Increment 3 Room and Glove boxes	FFE-1000/2000 FGBE-7000/8000	Plutonium research	Transuranics	*	NA	10.1	0.9	12.2	Triple HEPA	0.000001	0.0E+00	912	ENE	0.0E+00	**	**	**	3	NA
The research complex for the Biology and Biotechnology Research Directorate includes Buildings 361, 362, 363, 364, 365, 366 and 377. Building 365 contains small amounts of tritium, carbon 14 and sulfur-35 used in animal research, and incorporated in animal carcasses stored frozen pending disposal. The building air is filtered through at least two HEPA filters and one charcoal filter before being exhausted. Most of the organs that contained radionuclides have been removed from the animals for examination.																				
The radionuclide sources in Building 361 include tritium, carbon-14, phosphorous 32, phosphorous-33, and sulfur-35, mostly incorporated as constituent atoms (tracers) in organic compounds																				
361	1020	FHE-5	DNA hybridization	P-32	2.0E-03	1.0E-03	1.7	0.41	0.5	None	1	2.0E-06	919	ESE	2.2E-08	976	W	9.6E-08	1	Y
361	1137	FHE-26	Drying gels from DNA labeling	P-32	1.0E-09	1.0E-03	6.2	0.42	2.5	None	1	1.0E-12	919	ESE	1.1E-14	1047	WNW	4.9E-14	1	Y
361	1242	FHE-24	P-32 Labeling	P-32	2.5E-06	1.0E-03	1.7	0.41	0.5	None	1	2.5E-09	919	ESE	2.8E-11	976	W	1.2E-10	1	Y
361	1245	FHE-20,21	Human Genome	P-32	4.0E-02	1.0E-03	1.7	0.41	0.5	None	1	4.0E-05	919	ESE	4.5E-07	976	W	1.9E-06	1	Y
361	1345	Room Air	Radiolabeling and hybridization	P-32	1.0E-02	1.0E-03	NA	NA	NA	None	1	1.0E-05	919	ESE	1.1E-07	976	W	5.0E-07	1	Y
361	1446	FHE-15	Radiolabeling of DNA substrates	P-32 S-35	2.0E-03 1.0E-03	1.0E-03 1.0E-03	6.2	0.42	1.7	None	1	2.0E-06 1.0E-06	919	ESE	2.7E-08	976 1047	W WNW	1.2E-07	1	Y
361	1542	FHE-12	Hybridization and enzyme assay	P-32	2.5E-06	1.0E-03	7.0	0.41	4.4	None	1	2.5E-09	919	ESE	2.6E-11	1047	WNW	1.2E-10	1	Y
361	1546	FHE-10	DNA protein interaction studies	P-32	4.0E-03	1.0E-03	1.7	0.41	0.5	None	1	4.0E-06	919	ESE	4.5E-08	1047	WNW	1.9E-07	1	Y
361	1642	FHE-11	DNA labeling	P-32	2.5E-06	1.0E-03	7.0	0.41	4.4	None	1	2.5E-09	919	ESE	2.6E-11	1047	WNW	1.2E-10	1	Y
361	1649	FHE-4	DNA hybridization	P-33 P-32	5.0E-04 2.0E-02	1.0E-03 1.0E-03	7.0	0.41	4.4	None	1	5.0E-07 2.0E-05	919	ESE	2.2E-07	1047	WNW	9.4E-07	1	Y
361	1650	Room Air	Gel electrophoresis	P-32	1.0E-03	1.0E-03	NA	NA	NA	None	1	1.0E-06	919	ESE	1.1E-08	976	W	5.0E-08	1	Y
361	1742	FHE-8	DNA hybridization	P-32	2.0E-02	1.0E-03	7.0	0.41	4.4	None	1	2.0E-05	919	ESE	2.1E-07	1047	WNW	9.2E-07	1	Y
361	1846	Room Air	Human genome research	P-32	4.0E-02	1.0E-03	NA	NA	NA	None	1	4.0E-05	919	ESE	4.6E-07	1047	WNW	2.0E-06	1	Y
Building 362																				
362	105	FHE-1000	Compound purification by HPLC	H-3 C-14	1.0E-03 1.0E-03	1.0E-03 1.0E-03	6.8	0.65	2.7	None	1	1.0E-06 1.0E-06	996	ESE	9.5E-09	954	WNW	5.7E-08	1	Y
362	106	FHE-1000	Characterization of metabolic pathways	C-14 H-3	1.0E-07 5.0E-03	1.0E-03 1.0E-03	6.8	0.65	2.7	None	1	1.0E-10 5.0E-06	996	ESE	7.6E-10	954 882	WNW W	4.5E-09	1	Y
Building 363																				
363	1008	FHE-3000	Rotary evaporation	C-14	1.0E-09	1.0E-03	7.6	0.41	6.5	HEPA	0.01	1.0E-14	996	ESE	8.8E-17	954	WNW	5.0E-14	1	Y
363	1009	FHE-2000	Human urine sample project	H-3 C-14	1.0E-09 1.0E-09	1.0E-03 1.0E-03	1.7	0.41	0.4	HEPA	0.01	1.0E-14 1.0E-14	996	ESE	1.0E-16	882	W	7.3E-14	1	Y
363	1010	Room Air	HPLC analysis	H-3 C-14	1.0E-09 1.0E-09	1.0E-03 1.0E-03	NA	NA	NA	None	1	1.0E-12 1.0E-12	996	ESE	1.1E-14	882	W	6.9E-14	1	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 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 364																				
364	1507	Room Air	DNA labeling	P-32	5.0E-03	1.0E-03	NA	NA	NA	None	1	5.0E-06	996	ESE	4.9E-08	893	W	2.9E-07	1	Y
364	1519	Room Air	DNA and protein extraction	C-14 H-3	5.0E-04 5.0E-04	1.0E-03 1.0E-03	NA	NA	NA	None	1	5.0E-07 5.0E-07	996	ESE	5.3E-09	893	W	3.4E-08	1	Y Y
Building 365																				
365	104	FHE-1000	Equipment decontamination	C-14 H-3	1.0E-07 1.0E-07	1.0E-03 1.0E-03	6.1	0.58	7.2	HEPA	0.01	1.0E-12 1.0E-12	996	ESE	8.7E-15	894	NNE	4.7E-12	1	Y Y
365	107	Room Air	Animal research	C-14 H-3	1.3E-04 5.0E-07	1.0E-03 1.0E-03	NA	NA	NA	None	1	1.3E-07 5.0E-10	996	ESE	1.4E-09	902	W	8.5E-09	1	Y Y
365	109	FHE 5	Animal housing	C-14 H-3	1.3E-04 5.0E-07	1.0E-03 1.0E-03	1.7	0.41	0.6	Double HEPA	0.0001	1.3E-11 5.0E-14	996	ESE	1.4E-13	902	W	8.9E-09	1	Y Y
Building 366																				
366	110	Room Air	DNA labeling	P-32	5.0E-04	1.0E-03	NA	NA	NA	None	1	5.0E-07	902	ESE	5.9E-09	901	NNE	2.6E-08	1	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	B150,B154,B156	381-B156-FHE-1	Tritium handling for laser target R&D	H-3	8.0E+00	1.0E-06	11.3	0.36	20.6	None	1	8.0E-06	1092	ESE	7.0E-10	731	NE	7.8E-09	1	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	7.0E-02	1.0E+00	6.1	0.30	9.9	None	1	7.0E-02	1149	SE	7.4E-06	403	NNE	1.7E-04	1	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 46.)																				
419	124 125	FHE-2 FHE-6	Decontamination activities	Gross alpha Gross beta	• •	NA	12.2 11	0.61 0.76	12.6 5.4	Double HEPA HEPA	0.0001 0.01	1.6E-07 2.5E-06	686	NE	1.0E-04	••	••	••	3	NA NA
Building 490 & 491 are part of LLNL's Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) program, now affiliated with The United States Enrichment Corporation (USEC). The Separator Demonstration Facility (SDF), which vaporizes uranium for enrichment, is located in building 490. Stack sampling at both facilities is continuous. Both facilities operate with two in-series high efficiency particulate (HEPA) filter banks to control emissions. *Air emissions are continuously sampled at the post HEPA filter atmospheric discharge points, although emissions are low enough that stack monitoring is not required per the NESHAPs 40 CFR 61 regulations. **Because monitoring takes place after HEPA filtration, an unabated EDE cannot be determined (see discussion on page 46.)																				
490	1061	490 Stack	Isotope separation	Gross alpha Gross beta	• •	NA	9.1	0.90	5.7	Double HEPA	0.0001	0.0E+00 0.0E+00	900	SE	0.0E+00	••	••	••	3	NA NA
Building 491																				
491	All	FFE-1	Isotope separation	Gross alpha Gross beta	• •	NA	9.1	0.9	12.1	Double HEPA	0.0001	0.0E+00 0.0E+00	1000	SSE	0.0E+00	••	••	••	3	NA NA
Building 513 is operated by the Hazardous Waste Management Division. The Stabilization Unit is a mechanized mixing device used to make homogeneous mixtures of waste. Solidification agents are added during mixing to transfer sludges to solids. The Microfiltration Unit filters out waste radioactive particles. In the Laboratory, small quantities of waste materials are sampled, treated, and stored. No releases are assumed to occur from waste storage because the wastes are fully contained. *A potential release from the July incident in the Building 513 Shredder room is included.																				
513	Stabilization	Room Air	Treatment of hazardous, mixed or radioactive waste	Cs-137 U-238 U-235 U-234 H-3 K-40 Th-228 Th-234	2.3E-05 7.5E-05 9.8E-05 7.0E-05 5.8E+00 1.4E-05 6.4E-06 2.5E-05	1.0E-03 1.0E-06 1.0E-06 1.0E-06 1.0E-03 1.0E-03 1.0E-03 1.0E-03	NA	NA	NA	None	1	2.3E-08 7.5E-11 9.8E-11 7.0E-11 5.8E-03 1.4E-08 6.4E-09 2.5E-08	588	NE	1.8E-05	98	SSW	7.0E-05	1	Y Y Y Y Y Y Y Y
513	1000	Hood#21801	Process optimization and treatability studies	Am-241 K-40 Sr-90 H-3 U-233 U-234 U-235 U-238 Pb-212	1.5E-08 4.4E-07 2.3E-03 4.7E-07 9.4E-08 9.4E-08 4.2E-13 1.7E-08 1.0E-08	1.0E-03 1.0E-03 1.0E-03 1.0E-03 1.0E-03 1.0E-03 1.0E-03 1.0E-03 1.0E-03	10.5	0.30	2.5	HEPA	0.01	1.5E-13 4.4E-12 2.3E-08 4.7E-12 9.4E-13 9.4E-13 4.2E-18 1.7E-13 1.0E-13	588	NE	1.9E-07	389	ENE	2.6E-05	1	Y Y Y Y Y Y Y Y Y

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory	Physical	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/s)	Control Device(s)	Control Device	Estimated Annual Emissions (Ci)	10 mrem/y Site-Wide Dose Requirement		0.1 mrem/y Monitoring Requirement			Source	Below App. E Quantity	
					with Potential for Release (Ci)	State Factor					Abatement Factor		Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		Category
513	Shredder	Shredder	Shredding of solid waste (routine operations)	Ac-228	1.0E-06	1.0E-03	8.8	0.59	1.4	HEPA	0.01	1.0E-11	579	NNE	2.2E-04	91	S	3.3E-02	1	Y
				Am-241	1.2E-04	1.0E-03						1.2E-09								Y
				Ba-133	4.0E-06	1.0E-03						4.0E-11								Y
				Bi-212	5.6E-07	1.0E-03						5.6E-12								Y
				Bi-214	3.9E-08	1.0E-03						3.9E-13								Y
				C-14	1.0E-10	1.0E-03						1.0E-15								Y
				Ce-141	4.0E-06	1.0E-03						4.0E-11								Y
				Ce-144	4.0E-06	1.0E-03						4.0E-11								Y
				Cf-249	1.5E-06	1.0E-03						1.5E-11								Y
				Cm-244	2.0E-04	1.0E-03						2.0E-09								Y
				Co-57	4.8E-06	1.0E-03						4.8E-11								Y
				Co-60	5.2E-04	1.0E-03						5.2E-09								Y
				Cs-134	2.6E-08	1.0E-03						2.6E-13								Y
				Cs-137	5.2E-06	1.0E-03						5.2E-11								Y
				Cs-138	1.0E-09	1.0E-03						1.0E-14								Y
				Eu-152	1.1E-03	1.0E-03						1.1E-08								Y
				Eu-154	1.4E-06	1.0E-03						1.4E-11								Y
				Eu-155	2.5E-07	1.0E-03						2.5E-12								Y
				H-3	8.9E-02	1.0E-03						8.9E-07								Y
				K-40	2.3E-06	1.0E-03						2.3E-11								Y
				MFP	1.8E-01	1.0E-03						1.8E-06								NA
				Pa-231	5.6E-06	1.0E-03						5.6E-11								Y
				Pb-210	5.2E-05	1.0E-03						5.2E-10								Y
				Pb-212	9.3E-07	1.0E-03						9.3E-12								Y
				Pb-214	1.4E-07	1.0E-03						1.4E-12								Y
				Pu-239	1.5E-03	1.0E-03						1.5E-08								Y
				Ra-223	3.0E-06	1.0E-03						3.0E-11								Y
				Ra-226	5.7E-07	1.0E-03						5.7E-12								Y
				Ra-228	3.0E-15	1.0E-03						3.0E-20								Y
				Ru-106	4.0E-06	1.0E-03						4.0E-11								Y
				Sr-90	1.8E-03	1.0E-03						1.8E-08								Y
				Th-227	1.1E-05	1.0E-03						1.1E-10								Y
				Th-228	6.4E-08	1.0E-03						6.4E-13								Y
				Th-232	2.3E-05	1.0E-03						2.3E-10								Y
				Th-234	5.0E-05	1.0E-03						5.0E-10								Y
				Ti-208	4.1E-07	1.0E-03						4.1E-12								Y
				U-233	1.0E-04	1.0E-03						1.0E-09								Y
				U-234	5.4E-03	1.0E-03						5.4E-08								Y
				U-235	6.3E-04	1.0E-03						6.3E-09								Y
				U-238	4.9E-02	1.0E-03						4.9E-07								N
				Zr-95	4.0E-06	1.0E-03						4.0E-11								Y
513	Shredder	Shredder	Shredding of solid waste (July Incident) *	Cm-244	Unknown	1.0E-03	NA	NA	NA	None	1	NA	579	NNE	2.1E-04	91	S	5.4E-03	1	NA
Building 514 is operated by the Hazardous Waste Management Division.																				
514	108	Room Air	Vacuum filtration of treated waste water	Am-241	8.0E-07	1.0E-03	NA	NA	NA	None	1	8.0E-10	528	NE	5.1E-04	167 217	SSW SW	1.1E-03	1	Y
				Am-243	3.8E-07	1.0E-03						3.8E-10								Y
				Ba-133	1.6E-05	1.0E-03						1.6E-08								Y
				C-14	3.9E-05	1.0E-03						3.9E-08								Y
				Ce-144	2.9E-06	1.0E-03						2.9E-09								Y
				Co-57	1.6E-05	1.0E-03						1.6E-08								Y
				Co-60	1.6E-05	1.0E-03						1.6E-08								Y
				Cs-137	2.0E-05	1.0E-03						2.0E-08								Y
				Eu-152	9.2E-07	1.0E-03						9.2E-10								Y
				Eu-154	9.2E-07	1.0E-03						9.2E-10								Y
				Eu-155	1.6E-07	1.0E-03						1.6E-10								Y
				H-3	2.3E-01	1.0E-03						2.3E-04								Y
				K-40	1.8E-08	1.0E-03						1.8E-11								Y
				Mn-54	4.4E-08	1.0E-03						4.4E-11								Y
				Nb-95	2.2E-08	1.0E-03						2.2E-11								Y
				Np-239	4.8E-08	1.0E-03						4.8E-11								Y
				P-32	6.8E-07	1.0E-03						6.8E-10								Y
				Pm-147	8.6E-07	1.0E-03						8.6E-10								Y
				Po-209	2.0E-11	1.0E-03						2.0E-14								NA
				Pu-238	2.7E-10	1.0E-03						2.7E-13								Y
Pu-239	2.7E-07	1.0E-03	2.7E-10	Y																
Pu-240	2.7E-07	1.0E-03	2.7E-10	Y																
Pu-241	2.7E-07	1.0E-03	2.7E-10	Y																
Ra-226	2.0E-08	1.0E-03	2.0E-11	Y																
Ru-106	4.0E-07	1.0E-03	4.0E-10	Y																
Sb-125	6.9E-08	1.0E-03	6.9E-11	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 Requirement			0.1 mrem/y Monitoring Requirement			Source Category	Below App. E Quantity
													Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		
514	108 (continued)			Sm-151	6.7E-08	1.0E-03						6.7E-11								Y
				Sr-90	1.8E-06	1.0E-03						1.8E-09								Y
				Th-228	3.1E-06	1.0E-03						3.1E-09								Y
				Th-232	1.4E-05	1.0E-03						1.4E-08								Y
				U-233	2.8E-07	1.0E-03						2.8E-10								Y
				U-236	2.7E-07	1.0E-03						2.7E-10								Y
				Y-88	1.6E-05	1.0E-03						1.6E-08								Y
				U-238	6.0E-04	1.0E-03						6.0E-07								Y
				U-235	1.9E-05	1.0E-03						1.9E-08								Y
				U-234	3.9E-04	1.0E-03						3.9E-07								Y
514	Evaporator	Vent	Waste consolidation	Am-241	5.8E-06	1.0E-03	1.5	0.20	0.0	None	1	5.8E-09	528	NE	1.5E-05	167	SSW	5.9E-05	1	Y
				Co-60	5.0E-09	1.0E-03						5.0E-12								Y
				Cs-137	5.0E-09	1.0E-03						5.0E-12								Y
				H-3	9.6E-05	1.0E+00						9.6E-05								Y
				P-32	8.1E-07	1.0E-03						8.1E-10								Y
				Pu-236	1.0E-10	1.0E-03						1.0E-13								Y
				Pu-242	5.0E-10	1.0E-03						5.0E-13								Y
				S-35	2.5E-03	1.0E-03						2.5E-06								Y
				Sr-89	1.5E-11	1.0E-03						1.5E-14								Y
				Sr-90	1.5E-11	1.0E-03						1.5E-14								Y
				Th-228	1.1E-09	1.0E-03						1.1E-12								Y
				Th-232	1.0E-10	1.0E-03						1.0E-13								Y
				U-232	1.0E-10	1.0E-03						1.0E-13								Y
				U-238	3.8E-06	1.0E-03						3.8E-09								Y
				U-235	5.4E-08	1.0E-03						5.4E-11								Y
				U-234	5.0E-07	1.0E-03						5.0E-10								Y
Building 612 is operated by the Hazardous Waste Management Division. It is a facility in which waste is repackaged for shipment off site.																				
612	100	Room Air	Waste consolidation	Am-241	2.9E-07	1.0E-06	NA	NA	NA	None	1	2.9E-13	444	NE	9.3E-10	295	ENE	1.4E-09	1	Y
				Am-243	3.4E-11	1.0E-06						3.4E-17								Y
				Co-60	1.0E-12	1.0E-06						1.0E-18								Y
				Cs-137	8.8E-09	1.0E-06						8.8E-15								Y
				U-238	1.4E-07	1.0E-06						1.4E-13								Y
				U-235	1.5E-09	1.0E-06						1.5E-15								Y
				U-234	1.1E-08	1.0E-06						1.1E-14								Y
				Eu-152	3.5E-09	1.0E-06						3.5E-15								Y
				H-3	2.0E-06	1.0E-06						2.0E-12								Y
				K-40	1.8E-07	1.0E-06						1.8E-13								Y
				MFP	4.1E-09	1.0E-06						4.1E-15								NA
				Ra-226	1.4E-08	1.0E-06						1.4E-14								Y
				Ra-228	6.4E-09	1.0E-06						6.4E-15								Y
				Th-228	1.2E-08	1.0E-06						1.2E-14								Y
612	100	DOE4820121	Drum crushing	Am-241	2.9E-07	1.0E-06	7.6	0.10	11.2	HEPA	0.01	2.9E-15	444	NE	6.20E-11	295	ENE	8.30E-09	1	Y
				Pu-238	1.1E-07	1.0E-06						1.1E-15								Y
				Pu-239	2.7E-06	1.0E-06						2.7E-14								Y
				Pu-240	5.6E-07	1.0E-06						5.6E-15								Y
				Pu-241	1.6E-05	1.0E-06						1.6E-13								Y
612	101	FHE-4	Laboratory analysis of waste treatment and treatability samples	Ag-110m	2.5E-14	1.0E-06	10.5	0.31	5.4	HEPA	0.01	2.5E-22	444	NE	9.4E-06	295	ENE	1.2E-03	1	Y
				Am-241	2.2E-04	1.0E-03						2.2E-09								Y
				Am-242	7.8E-09	1.0E-03						7.8E-14								Y
				Am-242m	1.8E-09	1.0E-06						1.8E-17								Y
				Am-243	2.2E-07	1.0E-03						2.2E-12								Y
				Am-244	5.1E-06	1.0E-03						5.1E-11								Y
				Au-195	3.1E-15	1.0E-03						3.1E-20								Y
				Ba-133	5.3E-12	1.0E-03						5.3E-17								Y
				Ba-140	3.6E-10	1.0E-03						3.6E-15								Y
				Be-7	1.1E-11	1.0E-03						1.1E-16								Y
				Bi-207	9.3E-12	1.0E-03						9.3E-17								Y
				C-14	2.3E-09	1.0E-03						2.3E-14								Y
				Cd-109	4.6E-05	1.0E-03						4.6E-10								Y
				Cd-115	6.2E-11	1.0E-03						6.2E-16								Y
				Ce-141	1.4E-11	1.0E-03						1.4E-16								Y
				Co-144	4.0E-10	1.0E-03						4.0E-15								Y
				Cl-249	2.6E-10	1.0E-03						2.6E-15								Y
				Cl-252	1.2E-12	1.0E-03						1.2E-17								Y
				Cm-244	1.0E-04	1.0E-03						1.0E-09								Y
				Co-56	1.0E-13	1.0E-03						1.0E-18								Y
				Co-57	3.4E-12	1.0E-03						3.4E-17								Y
				Co-58	1.2E-11	1.0E-03						1.2E-16								Y
				Co-60	1.2E-03	1.0E-03						1.2E-08								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 Requirement			0.1 mrem/y Monitoring Requirement			Source Category	Below App. E Quantity
													Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		
612	101 (continued)			Cr-51	1.0E-11	1.0E-03						1.0E-16								Y
				Cs-134	5.6E-11	1.0E-03						5.6E-16								Y
				Cs-137	8.9E-05	1.0E-03						8.9E-10								Y
				Eu-149	3.2E-12	1.0E-03						3.2E-17								NA
				Eu-152	2.0E-06	1.0E-03						2.0E-11								Y
				Eu-154	3.7E-07	1.0E-03						3.7E-12								Y
				Eu-155	3.3E-08	1.0E-03						3.3E-13								Y
				Fe-55	2.9E-10	1.0E-03						2.9E-15								Y
				Gd-146	1.2E-05	1.0E-03						1.2E-10								NA
				H-3	1.9E-03	1.0E-03						1.9E-08								Y
				Hg-203	1.0E-16	1.0E-03						1.0E-21								Y
				Ir-192	1.0E-13	1.0E-03						1.0E-18								Y
				K-40	6.1E-09	1.0E-03						6.1E-14								Y
				Kr-85	2.6E-10	1.0E+00						2.6E-12								NA
				MFP	5.1E-06	1.0E-03						5.1E-11								NA
				Mn-54	2.3E-10	1.0E-03						2.3E-15								Y
				Mo-99	1.1E-12	1.0E-03						1.1E-17								Y
				Na-22	1.9E-12	1.0E-03						1.9E-17								Y
				Nb-94	3.1E-10	1.0E-03						3.1E-15								Y
				Nb-95	1.2E-10	1.0E-03						1.2E-15								Y
				Np-237	9.6E-09	1.0E-03						9.6E-14								Y
				P-32	2.8E-12	1.0E-03						2.8E-17								Y
				P-33	1.2E-08	1.0E-03						1.2E-13								Y
				Pb-210	2.6E-12	1.0E-03						2.6E-17								Y
				Pm-147	2.7E-12	1.0E-03						2.7E-17								Y
				Po-210	5.1E-17	1.0E-03						5.1E-22								Y
				Pu-238	9.5E-05	1.0E-03						9.5E-10								Y
				Pu-239	1.8E-04	1.0E-03						1.8E-09								Y
				Pu-241	1.5E-05	1.0E-03						1.5E-10								Y
				Pu-242	8.0E-08	1.0E-03						8.0E-13								Y
				Ra-226	1.1E-09	1.0E-03						1.1E-14								Y
				Ra-228	1.7E-10	1.0E-03						1.7E-15								Y
				Rh-102	2.3E-10	1.0E-03						2.3E-15								NA
				Rh-103m	4.7E-12	1.0E-03						4.7E-17								NA
				Rh-106	4.0E-11	1.0E-03						4.0E-16								NA
				S-35	1.9E-07	1.0E-03						1.9E-12								Y
				Sb-124	5.1E-14	1.0E-03						5.1E-19								Y
				Sb-125	6.3E-11	1.0E-03						6.3E-16								Y
				Sc-46	1.0E-11	1.0E-03						1.0E-16								Y
				Se-75	3.3E-11	1.0E-03						3.3E-16								Y
				Sm-151	1.0E-12	1.0E-03						1.0E-17								Y
				Sr-85	1.0E-12	1.0E-03						1.0E-17								Y
				Sr-89	4.5E-12	1.0E-03						4.5E-17								Y
				Sr-90	2.7E-04	1.0E-03						2.7E-09								Y
				Ta-182	1.6E-11	1.0E-03						1.6E-16								Y
				Tb-160	2.0E-13	1.0E-03						2.0E-18								Y
				Tc-99	3.5E-07	1.0E-03						3.5E-12								Y
				Th-228	4.1E-10	1.0E-03						4.1E-15								Y
				Th-229	2.9E-10	1.0E-03						2.9E-15								Y
				Th-232	3.4E-08	1.0E-03						3.4E-13								Y
				Th-234	1.3E-12	1.0E-03						1.3E-17								Y
				U-232	1.0E-09	1.0E-03						1.0E-14								Y
				U-233	2.1E-07	1.0E-03						2.1E-12								Y
				U-234	1.7E-06	1.0E-03						1.7E-11								Y
				U-235	1.7E-04	1.0E-03						1.7E-09								Y
				U-237	7.2E-13	1.0E-03						7.2E-18								Y
				U-238	6.1E-05	1.0E-03						6.1E-10								Y
				U-239	1.1E-11	1.0E-03						1.1E-16								Y
				Y-91	1.2E-11	1.0E-03						1.2E-16								Y
				Zr-90	1.7E-10	1.0E-03						1.7E-15								NA
612	102	Room Air	Laboratory analysis of waste treatment and treatability samples	Ag-110m	2.5E-14	1.0E-06	NA	NA	NA	None	1.0	2.5E-20	444	NE	1.4E-03	295	ENE	2.0E-03	1	Y
				Am-241	2.2E-04	1.0E-03						2.2E-07								Y
				Am-242	7.8E-09	1.0E-03						7.8E-12								Y
				Am-242m	1.8E-09	1.0E-06						1.8E-15								Y
				Am-243	2.2E-07	1.0E-03						2.2E-10								Y
				Am-244	5.1E-06	1.0E-03						5.1E-09								Y
				Au-195	3.1E-15	1.0E-03						3.1E-18								Y
				Ba-133	5.3E-12	1.0E-03						5.3E-15								Y
				Ba-140	3.6E-10	1.0E-03						3.6E-13								Y
				Be-7	1.1E-11	1.0E-03						1.1E-14								Y
				Bi-207	9.3E-12	1.0E-03						9.3E-15								Y
				C-14	2.3E-09	1.0E-03						2.3E-12								Y
				Cd-109	4.6E-05	1.0E-03						4.6E-08								Y

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Building	Room/Area	Stack ID	Operation	Radionuclides	Annual Inventory	Physical	Stack	Stack	Stack	Control Device	Control Device	Estimated	10 mrem/y Site-Wide Dose Requirement		0.1 mrem/y Monitoring Requirement			Source	Below	
					with Potential for	State	Height (m)	Diameter (m)	Velocity (m/s)	Device(s)	Abatement	Annual Emissions	Distance to	Direction	EDE	Distance	Direction	Unabated	Category	App. E
					Release (Ci)	Factor					Factor	(Ci)	SWMEI (m)	to SWMEI	(mrem)	to MEI (m)	to MEI	EDE (mrem)		Quantity
612	102 (continued)			Cd-115	6.2E-11	1.0E-03						6.2E-14								Y
				Ce 141	1.4E 11	1.0E-03						1.4E 14								Y
				Ce-144	4.0E 10	1.0E-03						4.0E-13								Y
				Cf-249	2.6E-10	1.0E 03						2.6E-13								Y
				Cf 252	1.2E-12	1.0E 03						1.2E-15								Y
				Cm 244	1.0E-04	1.0E-03						1.0E-07								Y
				Co 56	1.0E-13	1.0E-03						1.0E-16								Y
				Co-57	3.4E-12	1.0E-03						3.4E-15								Y
				Co-58	1.2E-11	1.0E-03						1.2E-14								Y
				Co-60	1.2E 03	1.0E-03						1.2E-06								Y
				Cr-51	1.0E-11	1.0E-03						1.0E-14								Y
				Cs 134	5.6E-11	1.0E 03						5.6E-14								Y
				Cs 137	8.9E-05	1.0E 03						8.9E 08								Y
				Eu-149	3.2E-12	1.0E-03						3.2E-15								NA
				Eu-152	2.0E-06	1.0E-03						2.0E 09								Y
				Eu-154	3.7E 07	1 0E-03						3.7E 10								Y
				Eu-155	3.3E 08	1.0E-03						3.3E-11								Y
				Fe-55	2.9E-10	1.0E 03						2 9E-13								Y
				Gd 146	1 2E-05	1.0E 03						1.2E-08								NA
				H 3	1.9E-03	1.0E-03						1.9E-06								Y
				Hg-203	1.0E-16	1 0E-03						1.0E-19								Y
				Ir 192	1.0E-13	1.0E-03						1.0E-16								Y
				K 40	6 1E 09	1.0E-03						6.1E-12								Y
				Kr 85	2.6E-10	1.0E+00						2.6E 10								NA
				MFP	5.1E 06	1.0E-03						5.1E-09								NA
				Mn-54	2.3E-10	1.0E-03						2.3E-13								Y
				Mo-99	1.1E-12	1.0E-03						1.1E-15								Y
				Na 22	1 9E-12	1.0E-03						1.9E-15								Y
				Nb 94	3.1E 10	1 0E-03						3 1E-13								Y
				Nb-95	1.2E-10	1.0E 03						1 2E-13								Y
				Np-237	9 6E 09	1.0E 03						9 6E 12								Y
				P-32	1.2E 08	1 0E-03						1 2E 11								Y
				P 33	2.8E-12	1 0E-03						2.8E-15								Y
				Pb-210	2.6E-12	1.0E-03						2 6E-15								Y
				Pm 147	2.7E 12	1 0E-03						2.7E-15								Y
				Po 210	5.1E 17	1.0E 03						5.1E 20								Y
				Pu 238	9 5E 05	1.0E-03						9.5E 08								Y
				Pu 239	1 8E-04	1 0E-03						1.8E-07								Y
				Pu-241	1 5E-05	1.0E-03						1.5E 08								Y
				Pu-242	8.0E 08	1.0E-03						8.0E 11								Y
				Ra-226	1 1E 09	1.0E 03						1.1E-12								Y
				Ra-228	1 7E-10	1 0E 03						1.7E-13								Y
				Rh-102	2 3E-10	1 0E-03						2.3E-13								NA
				Rh-103m	4.7E 12	1.0E-03						4.7E-15								NA
				Rh 106	4 0E-11	1.0E-03						4 0E-14								NA
				S-35	1.9E-07	1.0E 03						1.9E-10								Y
				Sb 124	5.1E-14	1.0E-03						5.1E-17								Y
				Sb 125	6.3E-11	1.0E-03						6 3E-14								Y
				Sc-46	1.0E-11	1.0E-03						1.0E-14								Y
				Se-75	3.3E-11	1.0E 03						3.3E-14								Y
				Sm-151	1.0E-12	1.0E-03						1.0E-15								Y
				Sr 85	1.0E-12	1.0E-03						1.0E-15								Y
				Sr-89	4.5E-12	1.0E-03						4.5E-15								Y
				Sr-90	2.7E 04	1.0E-03						2.7E-07								Y
				Ta-182	1.6E-11	1.0E 03						1.6E 14								Y
				Tb-160	2.0E-13	1.0E-03						2.0E-16								Y
				Tc-99	3.5E-07	1.0E-03						3.5E-10								Y
				Th-228	4.1E-10	1.0E 03						4.1E-13								Y
				Th-229	2.9E-10	1.0E-03						2.9E-13								Y
				Th-232	3.4E-08	1 0E-03						3.4E-11								Y
				Th-234	1.3E-12	1.0E-03						1.3E-15								Y
		U-232	1.0E 09	1.0E-03						1.0E-12								Y		
		U-233	2.1E-07	1.0E-03						2.1E-10								Y		
		U-234	1.7E-06	1.0E-03						1.7E-09								Y		
		U-235	1.7E-07	1.0E-03						1.7E-10								Y		
		U-237	7.2E 13	1.0E 03						7.2E-16								Y		
		U-238	6.1E 05	1.0E-03						6.1E-08								Y		
		U-239	1.1E-11	1.0E-03						1.1E-14								Y		
		Y-91	1.2E-11	1.0E-03						1.2E-14								Y		
		Zr-90	1.7E-10	1.0E 03						1.7E-13								NA		

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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 (in)	Stack Velocity (m/s)	Control Device(s)	Control Device Abatement Factor	Estimated Annual Emissions (Ci)	10 mrem/y Site-Wide Dose Requirement			0.1 mrem/y Monitoring Requirement			Source Category	Below App E Quantity
													Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		
Building 625 is operated by the Hazardous Waste Management Division																				
625	All	Room Air	Repackaging of wastes	Am-241	4.1E-07	1.0E-06	NA	NA	NA	None	1	4.1E-13	378	NE	8.4E-09	289	ENE	9.7E-09	1	Y
				Am-243	2.4E-08	1.0E-06						2.4E-14								Y
				Ba-133	4.4E-11	1.0E-06						4.4E-17								Y
				Bi-214	1.4E-10	1.0E-06						1.4E-16								Y
				C-14	1.6E-09	1.0E-06						1.6E-15								Y
				Cd-109	2.07E-10	1.0E-06						2.1E-16								Y
				Ce-141	2.1E-11	1.0E-06						2.1E-17								Y
				Ce-144	7.4E-09	1.0E-06						7.4E-15								Y
				Co-57	2.7E-10	1.0E-06						2.7E-16								Y
				Co-60	4.6E-08	1.0E-06						4.6E-14								Y
				Cs-134	5.2E-09	1.0E-06						5.2E-15								Y
				Cs-137	3.9E-08	1.0E-06						3.9E-14								Y
				Eu-152	2.1E-08	1.0E-06						2.1E-14								Y
				Eu-154	1.2E-08	1.0E-06						1.2E-14								Y
				Eu-155	1.2E-09	1.0E-06						1.2E-15								Y
				H-3	7.0E-05	1.0E-06						7.0E-11								Y
				K-40	4.1E-07	1.0E-06						4.1E-13								Y
				MFP	4.91E-07	1.0E-06						4.9E-13								NA
				Mn-54	6.4E-09	1.0E-06						6.4E-15								Y
				U-238	7.4E-06	1.0E-06						7.4E-12								Y
				U-235	7.5E-08	1.0E-06						7.5E-14								Y
				U-234	5.2E-07	1.0E-06						5.2E-13								Y
				Nb-95	6.4E-09	1.0E-06						6.4E-15								Y
				Np-237	1.1E-09	1.0E-06						1.1E-15								Y
				P-32	1.7E-12	1.0E-06						1.7E-18								Y
				Y-88	8.0E-13	1.0E-06						8.0E-18								Y
				Pb-212	1.8E-10	1.0E-06						1.8E-16								Y
				Pb-214	2.3E-11	1.0E-06						2.3E-17								Y
				Th-232	1.1E-09	1.0E-06						1.1E-15								Y
				Th-234	2.3E-06	1.0E-06						2.3E-12								Y
				U-239	1.2E-09	1.0E-06						1.2E-15								Y
				Ra-226	7.1E-08	1.0E-06						7.1E-14								Y
				Ra-228	3.1E-06	1.0E-06						3.1E-12								Y
				Ru-106	3.3E-09	1.0E-06						3.3E-15								Y
				Sb-125	4.6E-09	1.0E-06						4.6E-15								Y
				Sr-90	1.1E-08	1.0E-06						1.1E-14								Y
				Th-228	7.3E-09	1.0E-06						7.3E-15								Y
				Zr-95	1.2E-08	1.0E-06						1.2E-14								Y
625	Tent Enclosure	FEV	Repackaging of wastes	Am-241	9.1E-07	1.0E-06	1.5	0.31	12.4	HEPA	0.01	9.1E-15	378	NE	4.6E-10	289	ENE	5.2E-08	1	Y
				Am-243	1.1E-11	1.0E-06						1.1E-19								Y
				Cm-244	1.1E-11	1.0E-06						1.1E-19								Y
				U-238	3.3E-08	1.0E-06						3.3E-16								Y
				U-235	3.8E-11	1.0E-06						3.8E-19								Y
				U-234	2.7E-10	1.0E-06						2.7E-18								Y
				H-3	1.7E-05	1.0E-06						1.7E-13								Y
				Pa-231	2.3E-10	1.0E-06						2.3E-18								Y
				Pu-238	3.6E-07	1.0E-06						3.6E-15								Y
				Pu-239	1.6E-05	1.0E-06						1.6E-13								Y
				Pu-240	1.8E-06	1.0E-06						1.8E-14								Y
				Pu-241	5.1E-05	1.0E-06						5.1E-13								Y
				Pu-242	2.1E-10	1.0E-06						2.1E-18								Y
				Th-232	2.7E-09	1.0E-06						2.7E-17								Y
SITE 300 POINT SOURCES																				
Site 300 - Explosives tests are conducted on open-air firing tables located at Bunkers 801 and 851. These tests have depleted uranium material as part of the material inventory. There are multiple tests per year.																				
A total for 1995 is shown here. The radionuclides in Buildings 804, 810A, 810B, 822B, and 854F are encapsulated or sealed and are not used.																				
810A	133	Room Air	Assembly of explosives	U-238	9.0E-04	1.0E-06	NA	NA	NA	None	1	9.0E-10	2208	NNE	1.2E-08	944	SSE	7.3E-08	1	Y
				U-235	1.2E-05	1.0E-06						1.2E-11								Y
				U-234	8.4E-05	1.0E-06						8.4E-11								Y
850	Firing Table	None	Explosive tests	U-238	1.7E-02	1.0E+00	NA	NA	NA	None	1	1.7E-02	4200	ESE	2.8E-03	1920	SW	9.5E-03	4	Y
				U-235	2.2E-04	1.0E+00						2.2E-04								Y
				U-234	1.6E-03	1.0E+00						1.6E-03								Y
851	Firing Table	None	Explosive tests	U-238	1.0E-02	1.0E+00	NA	NA	NA	None	1	1.0E-02	3870	E	2.6E-03	1828	SW	5.7E-03	4	Y
				U-235	1.4E-04	1.0E+00						1.4E-04								Y
				U-234	9.8E-04	1.0E+00						9.8E-04								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 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
LIVERMORE SITE DIFFUSE SOURCES																				
Building 292 - Diffuse emissions result from tritium contaminated water which leaked from an underground storage tank. Vegetation in the area transpires water with elevated tritium concentrations.																				
292	Spill Area	None	Evaporation and transpiration	H-3	NA	1.0E+00	NA	NA	NA	None	1	6.1E-04	1380	ESE	6.1E-08	456	N	1.7E-06	6	Y
Building 331 - As part of D&D operations contaminated equipment outside the facility is awaiting transport and storage by Hazardous Waste Management.																				
331	Outside	None	Storage of contaminated parts	H 3	NA	1.0E+00	NA	NA	NA	None	1	2.5E+00	957	ENE	1.7E-03	441	SSW	5.0E 03	6	Y
Building 514 is operated by the Hazardous Waste Management Division. The wastewater treatment tank farm and storage tank area processes the liquid waste from facilities on site. The treatment process may involve batch chemical treatment consisting of neutralization, flocculation, oxidation, reduction, precipitation, separation, and filtration. Areas used for storage are not considered to release radionuclides because the wastes are fully contained.																				
514	Tank Farm	Area Source	Processes liquid hazardous mixed and radioactive wastes in open topped tanks.	Am-241	1.5E-06	1.0E-03	NA	NA	NA	None	1	1.5E 09	528	NE	9.5E-04	167	SSW	2.4E-03	5	Y
				Am-243	7.0E-07	1.0E-03						7.0E-10								Y
				Ba-133	3.0E-05	1.0E-03						3.0E-08								Y
				C-14	7.2E 05	1.0E-03						7.2E-08								Y
				Ce-144	5.4E 06	1.0E-03						5.4E-09								Y
				Co-57	3.0E 05	1.0E 03						3.0E 08								Y
				Co-60	3.0E 05	1.0E-03						3.0E-08								Y
				Cs-137	3.7E 05	1.0E 03						3.7E-08								Y
				Eu-152	1.7E-06	1.0E-03						1.7E-09								Y
				Eu-154	1.7E-06	1.0E-03						1.7E-09								Y
				Eu-155	3.0E-07	1.0E-03						3.0E-10								Y
				H-3	4.3E-01	1.0E-03						4.3E-04								Y
				K-40	3.3E-08	1.0E-03						3.3E-11								Y
				Mn-54	8.2E 08	1.0E 03						8.2E-11								Y
				Nb-95	4.1E 08	1.0E 03						4.1E-11								Y
				Np-239	8.9E 08	1.0E 03						8.9E-11								Y
				P-32	1.3E-06	1.0E-03						1.3E-09								Y
				Pm-147	1.6E-06	1.0E-03						1.6E-09								Y
				Po-209	3.8E-11	1.0E-03						3.8E-14								NA
				Pu-238	5.0E-10	1.0E-03						5.0E-13								Y
				Pu-239	5.0E-07	1.0E-03						5.0E-10								Y
				Pu-240	5.0E 07	1.0E-03						5.0E-10								Y
				Pu-241	5.0E 07	1.0E-03						5.0E-10								Y
				Ra-226	3.6E 08	1.0E 03						3.6E-11								Y
				Ru-106	7.4E 07	1.0E 03						7.4E-10								Y
				Sb-125	1.3E 07	1.0E 03						1.3E-10								Y
				Sm-151	1.2E 07	1.0E 03						1.2E-10								Y
				Sr-90	3.3E-06	1.0E 03						3.3E-09								Y
				Th-228	5.8E 06	1.0E-03						5.8E-09								Y
				Ti-232	2.5E-05	1.0E-03						2.5E-08								Y
				U-233	5.2E-07	1.0E-03						5.2E-10								Y
				U-236	5.0E-07	1.0E-03						5.0E-10								Y
				Y-88	3.0E 05	1.0E-03						3.0E 08								Y
				U-238	1.1E-03	1.0E-03						1.1E-06								Y
				U-235	3.6E-05	1.0E-03						3.6E 08								Y
				U-234	7.3E-04	1.0E-03						7.3E 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.																				
*The drum sampling operation takes place at all site Waste Accumulation Areas. Inventories were combined and modeled as if the operation occurred at the center of the site.																				
612	Yard	Area Source	Storage of low level waste	H-3	4.2E+00	1.0E+00	NA	NA	NA	None	1	4.2E+00	420	NNE	1.6E-02	253	ENE	3.3E 02	6	N
612	All WAAs*	Area source	Drum sampling in 612 yard and all LLNL Waste Accumulation Areas (WAAs)	Am-241	2.4E-09	1.0E 03	NA	NA	NA	None	1	2.4E-12	923	ESE	1.6E 06	969	W	7.9E-06	6	Y
				Am-243	1.5E-11	1.0E-03						1.5E-14								Y
				Bi-214	8.5E-13	1.0E 03						8.5E-16								Y
				C-14	5.7E-07	1.0E 03						5.7E-10								Y
				Ce-144	1.2E-10	1.0E 03						1.2E-13								Y
				Cm-244	6.3E-12	1.0E-03						6.3E-15								Y
				Co-57	2.4E-12	1.0E-03						2.4E-15								Y
				Co-60	1.8E-12	1.0E-03						1.8E-15								Y
				Cs-137	7.1E-11	1.0E-03						7.1E 14								Y
				U-238	1.5E-06	1.0E-03						1.5E-09								Y
				U-235	1.9E-08	1.0E-03						1.9E-11								Y
				U-234	1.4E-07	1.0E-03						1.4E-10								Y
				Eu-152	4.9E-11	1.0E-03						4.9E-14								Y
				Eu-154	4.9E-11	1.0E-03						4.9E-14								Y
				Eu-155	3.6E-12	1.0E-03						3.6E-15								Y
				H-3	8.1E+00	1.0E-03						8.1E-03								Y
				K-40	1.1E-10	1.0E-03						1.1E-13								Y
				Mn-54	2.3E-12	1.0E-03						2.3E-15								Y
				Nb-95	1.2E-12	1.0E-03						1.2E-15								Y
				Ni-59	1.9E-11	1.0E-03						1.9E-14								Y
				Ni-63	1.7E-10	1.0E-03						1.7E-13								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 Requirement			0.1 mrem/y Monitoring Requirement			Source Category	Below App. E Quantity
													Distance to SWMEI (m)	Direction to SWMEI	EDE (mrem)	Distance to MEI (m)	Direction to MEI	Unabated EDE (mrem)		
612	All WAAs* (continued)			Np-239	2.5E-12	1.0E-03						2.5E-15								Y
				P 32	8.0E-11	1.0E-03						8.0E-14								Y
				Pu-238	1.0E-14	1.0E-03						1.0E-17								Y
				Pu-239	8.9E-15	1.0E-03						8.9E-18								Y
				Ra-226	1.2E-12	1.0E-03						1.2E-15								Y
				Sb 125	3.6E-12	1.0E-03						3.6E-15								Y
				Tc-99	1.9E-12	1.0E-03						1.9E-15								Y
				Th 228	2.2E-10	1.0E-03						2.2E-13								Y
				Th-234	2.2E-10	1.0E-03						2.2E-13								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	3.1E-04	NA	NA	NA	6	NA
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 purged from wells has been dumped, an open artesian spring, and evaporation of water from soils due to migration from contaminated ground water.																				
Site 300	All	Area Source	Tritium evaporation	H-3	NA	NA	NA	NA	NA	None	1	NA	0	NA	1.1E-04	NA	NA	NA	6	Y
Site 300	All	Area Source	Soil resuspension	U-238	NA	NA	NA	NA	NA	None	1	NA	0	NA	8.7E-03	NA	NA	NA	6	Y
				U-235	NA	NA						NA								Y
				U-234	NA	NA						NA								Y
804	Open Area	Area Source	Low level waste staging area	H-3	NA	NA	NA	NA	NA	None	1	3.9E-04	3108	SE	6.0E-07	828	N	4.5E-06	6	Y
				U-238	NA	NA						5.1E-08								Y
				U-235	NA	NA						6.5E-10								Y
				U-234	NA	NA						3.1E-09								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. This list of surrogate radionuclides has been developed to account for the contribution of those radionuclides. In addition, isotopic analyses of mixtures of radionuclides are not always available, and radionuclide inventories are stated 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.

Table 2-1 List of surrogate radionuclides

Isotope	Half-Life	Lung Class	ALI (inh) μCi	DAC (inh) $\mu\text{Ci}/\text{cm}^3$	Surrogate	Half-Life	Lung Class	ALI (inh) μCi	DAC (inh) $\mu\text{Ci}/\text{cm}^3$
Ag-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	276 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}	Eu-156	15.19 d	W	5.0×10^2	2.0×10^{-7}
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	2.0×10^3	6.0×10^{-7}	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	150 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	151 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	85 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}

(continued)

Table 2-1 List of surrogate radionuclides (concluded)

Isotope	Half-Life	Lung			Surrogate	Half-Life	Lung		
		Class	ALI (inh) μCi	DAC (inh) $\mu\text{Ci}/\text{cm}^3$			Class	ALI (inh) μCi	DAC (inh) $\mu\text{Ci}/\text{cm}^3$
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}
Eu-149	93.1 d	W	3.0×10^3	1.0×10^{-6}	Pm-151	28.4 h	Y	3.0×10^3	1.0×10^{-6}
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}					
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}
Rh-102	2.9 y	Y	6.0×10^1	2.0×10^{-8}	Rh-106	29.9 s	Y	4.0×10^4	1.0×10^{-5}
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}
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}

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

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