NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It has been reproduced from the best available copy to permit the broadest possible availability.

UCRL-50027-83
Distribution Category UC-11

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Environmental Monitoring at the Lawrence Livermore National Laboratory

UCRL--50027-83

DE84 011165

1983 Annual Report

K. S. Griggs

D. S. Myers

R. W. Buddemeier

MASTER

Manuscript Date: February 1984

LAWRENCE LIVERMORE LABORATORY
University of California • Livermore, California • 94550

Available from: National Technical Information Service • U.S. Department of Commerce
5285 Port Royal Road • Springfield, VA 22161 • \$14.50 per copy • (Microfiche \$4.50)

job
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Foreword

This report is prepared for the U.S. Department of Energy by the Environmental Evaluations Group of the Hazards Control Department, Lawrence Livermore National Laboratory. Data are obtained through the combined efforts of the Nuclear Chemistry Division and the Hazards Control Department. In addition to the authors listed, the following personnel made significant contributions to this report.

V. E. Arganbright
J. M. Bazan
R. Bocanegra
H. C. Capwell
A. Conover
R. J. Dupzyk
R. A. Failor
L. A. Fry
J. Garrison
A. R. Grayson
S. L. Kemble
D. L. Kendrick
W. C. King

M. A. Loquist
S. MacLean
W. A. McConachie
M. W. Nathans
K. R. Peterson
D. Prokosch
N. H. Rogers
M. R. Ruggieri
G. L. Seibel
C. W. Sundbeck
R. D. Szidon
C. R. Veith

Contents

Introduction	1
The Laboratory	1
The Site	2
Environmental Monitoring	2
Summary	4
Air Samples	4
Water Samples	4
Vegetation and Foodstuff Samples	4
Doses	5
Monitoring Data—Collection, Analysis, and Evaluation	5
Radioactive Monitoring	5
Airborne Radioactivity	5
Radioactivity in Soil	6
Radioactivity in Sewage	8
Radioactivity in Water	10
Radioactivity in Vegetation and Foodstuffs	12
Radioactivity in Milk	12
Environmental Radiation Measurements	14
Nonradioactive Monitoring	15
Beryllium in Air and Water	15
Nonradioactive Pollutants in Sewage	16
Noise Pollution	17
Pollutants in Storm Runoff and Liquid-Discharge Sites	17
Environmental Impact of LLNL Operations	17
Radioactive Airborne Effluents	17
Radioactive Liquid Effluents	18
Nonradioactive Liquid Effluents	18
Special Monitoring Assessments	18
Quality Assurance	19
References	20
Appendix A. Tables	A-1
Appendix B. Environmental Activity Concentration—Guide Levels	B-1
Appendix C. Method of Dose Calculations	C-1
Appendix D. Discharge Limits to the Sanitary Sewer System of Livermore	D-1
Appendix E. Sampling and Analytical Procedures for Environmental Monitoring at Lawrence Livermore National Laboratory	E-1

① Lawrence Livermore National Laboratory	⑦ Vescio Road
② Sandia National Laboratories, Livermore	⑧ East Avenue
③ South Bay Aqueduct	⑨ Greenville Road
④ Arroyo Seco	⑩ Lupin Way
⑤ Arroyo Las Positas	⑪ Interstate 580
⑥ Nearest residential area	

Frontispiece. Lawrence Livermore National Laboratory (looking west).

Environmental Monitoring at the Lawrence Livermore National Laboratory 1983 Annual Report

Introduction

The Laboratory

The Lawrence Livermore National Laboratory (LLNL) is located about 64 km east of San Francisco, California, in the Livermore Valley of eastern Alameda County, approximately 5 km east of the city of Livermore. The site, which occupies an area of 2.54 km², is surrounded by open

agricultural areas on the north, east, west, and part of the south side. Sandia Laboratories, Livermore, occupies a portion of the adjoining property on the south, and the nearest residential area is 0.8 km from the Laboratory's west perimeter. Of the nearly 4.8 million people who live within 80 km of the Laboratory (Fig. 1), 50,000 live in Livermore.

Figure 1. Estimated population distribution (in thousands) within 80 km of Livermore, by sectors.

The Laboratory, operated by the University of California for the United States Department of Energy, was established in 1952 to conduct nuclear weapons and controlled thermonuclear reaction research. Today, about 60% of its resources are devoted to defense programs, which include weapons and laser fusion research. Other major areas of focus are magnetic fusion energy; laser isotope separation; chemistry, engineering, and physics research; biomedical and environmental sciences; applied energy technology; and work for other federal agencies.

In 1983 the Laboratory employed approximately 7900 people.

Much of the Laboratory's materials testing and high-explosives diagnostic work is conducted at Site 300, 16 km southeast of Livermore. Located in the sparsely populated hills of the Diablo Range, Site 300 covers an area of 27 km². Figure 1 shows the location of LLNL and Site 300 with respect to the city of Livermore and surrounding areas.

The Site

The Livermore Valley has a climate characterized by mild, rainy winters and warm, dry summers. The highest and lowest annual rainfalls on record are 782 mm and 138 mm, with a 113-year average of 369 mm. Rainfall for the 1982-1983 water year (October 1, 1982, through September 30, 1983) was a record 782 mm. Surface water drainage from the Valley is from east to west through various arroyos; the outfall is near Sunol in the southwest corner of the Valley. Prevailing winds are from the west and southwest during April through September. During the remainder of the year, wind directions are variable, as shown by the wind rose in Fig. 2.

The Livermore site is situated on a northwesterly sloping alluvial flood plain bordering the low hills of the Livermore Uplands to the south. Groundwater is found at depths of 15 to 30 m below the LLNL site with a gradient indicating a generally westward flow. The lithology of the area consists of a series of unconsolidated marine and continental sedimentary units such as sandstones, gravels, silts, and clays overlying the interbedded sandstones of the Franciscan Formation. The hilly terrain surrounding the Valley is used for cattle and sheep pasture, and the principal agricultural products in the vicinity of LLNL are grapes and wine, cattle, and poultry.

Water bodies adjacent to the Laboratory include the South Bay Aqueduct, which runs from the northeast to southwest, 1.8 km to the southeast; the Patterson Pass water treatment facility, about 2 km east of LLNL; and Frick Lake, a sag pond that is dry most of the year, 4 km north of LLNL. Aquatic recreation (boating, fishing, and swimming) is available at Lake Del Valle, about 8 km south of LLNL, and at the Shadow Cliffs Recreation Area, 11 km to the west.

The Laboratory normally receives its treated water from the Hetch Hetchy Aqueduct (which supplies San Francisco), located 11 km southwest of Livermore.

Laboratory storm water is channeled through storm sewers designed to accommodate a 10-year flow. Open ditches are used in undeveloped areas of the site. Arroyo Seco crosses LLNL at the southwest corner. Arroyo Las Positas originally crossed the northeast section of the site. However, in 1965, as part of an erosion-control program, Arroyo Las Positas was channeled north to the northeast corner of the site, and then west along the north perimeter to an outlet at the northwest corner. This outlet, which also constitutes the main pathway for the Laboratory's surface drainage (storm and irrigation), runs north to the Western Pacific tracks, then west where it joins Arroyo Seco. The LLNL Master Site Plan calls for a small lake to be established in the center of the project. Provisions have been made for rerouting on-site water drainage and the Arroyo Las Positas to fill this lake during the rainy season.

Laboratory sewage is discharged into the City of Livermore's sanitary sewer system and processed at the Livermore Water Reclamation Plant (LWRP). As part of the Livermore-Amador Valley Wastewater Management program, the treated sanitary wastewater is transported out of the valley via a pipeline and discharged into the San Francisco Bay. The LWRP was connected to this pipeline on February 8, 1980. While the LWRP effluent is still used for summer irrigation of nearby Livermore city property, it is no longer discharged to Arroyo Las Positas, as was done during the wet season before construction of the pipeline.

Environmental Monitoring

A strict effluent-control program that emphasizes controlling effluents at the source has been in effect since the Laboratory began operation.

LIVERMORE

Average annual percent frequency of wind direction vs wind speed
Speed (m/s)

Direction	0-2	2-3	3-5	5-7	7-9	9-11	11-16	16-20	>20	Total Avg.	Speed
N	1.3	0.5	0.6	0.2	0.3	0.2	0	0	0	3.1	3.4
NNE	1.0	0.4	0.2	0	0	0	0	0	0	1.7	2.1
NE	1.2	0.4	0.5	0	0	0	0	0	0	2.1	2.1
ENE	1.7	0.6	1.0	0.3	0	0	0	0	0	3.5	2.5
E	4.3	0.6	0.4	0.2	0	0	0	0	0	5.5	1.7
ESE	3.5	0.5	0.3	0.1	0	0	0	0	0	4.5	1.7
SE	1.8	0.3	0.3	0.1	0	0	0	0	0	2.5	1.8
SSE	1.7	0.4	0.4	0.1	0	0	0	0	0	2.7	2.1
S	3.0	0.4	0.4	0.1	0	0	0	0	0	3.9	1.8
SSW	2.3	1.2	1.4	0.5	0.1	0	0	0	0	5.5	2.8
SW	2.1	2.7	6.2	3.7	1.1	0.2	0	0	0	16.0	4.2
WSW	2.7	2.2	4.3	2.0	0.5	0	0	0	0	11.8	3.6
W	2.1	1.7	3.3	1.4	0	0	0	0	0	8.5	3.4
WNW	1.4	0.7	0.9	0.3	0	0	0	0	0	3.3	2.7
NW	1.5	0.5	0.6	0.5	0.1	0	0	0	0	3.2	2.9
NNW	1.6	0.5	0.6	0.4	0.2	0	0	0	0	3.4	3.0
Calm										18.6	
Total	33.2	13.7	21.6	9.9	2.5	0.5	0	0	0	100.0	2.5

Figure 2. Wind rose showing average annual wind direction and speed during 1983 (measurements are made at 10 m above ground).

The environmental monitoring program is maintained to evaluate the effectiveness of these measures, to document whether effluents from the Laboratory and Site 300 operations are within applicable standards, and to estimate the impact of these operations on the environment. Sensitive monitoring equipment is used that can detect radioactive and nonradioactive pollutants at environmental background levels. The program includes the collection and analysis of air, soil, water, sewer effluent, vegetation, foodstuffs, and milk samples. Also, environmental background radiation is measured at numerous locations in the vicinity of the Laboratory using gamma and neutron dosimeters.

Each spring, the Laboratory reports the results of environmental monitoring for the previous year, noting significant changes in either the scope of the program or the levels of effluents. This report is prepared in compliance with the DOE Manual 5484.1, *Environmental Protection,*

Safety, and Health Protection Information Reporting Requirements.

Appendix A is a tabulation of 1983 environmental monitoring data. Graphics have been used in the body of the report to aid in interpretation. When appropriate, the tabulated data contain maximum, minimum, and average values. Radioactivity values are tabulated with the associated counting uncertainties at the 2σ (95% confidence) level. Unless otherwise stated, the minimum detection limit of these measurements is assumed to have been reached when the 2σ error is $\pm 100\%$. In the case of radioactivity measurements, an attempt has been made to assess the potential impact on man of the observed environmental levels of artificially produced radionuclides. This assessment is made by calculating the whole-body or critical-organ doses delivered to man and comparing these with the much larger radiation dose received locally from natural sources.

Summary

Air Samples

In 1983, the annual average airborne gross beta activity in Livermore Valley air samples was 1.4×10^{-14} $\mu\text{Ci}/\text{ml}$, which was less than the level observed in 1982. Airborne ^{238}U concentrations at Site 300 were higher than those at Livermore because of the "depleted" uranium (a byproduct of ^{235}U enrichment) used in high-explosive tests at the Site. However, these concentrations were well below the standards set by DOE. The average gross alpha activity shows no significant change from 1982 data. The annual average beryllium concentrations were less than 1% of the local air pollution standard at both the Laboratory perimeter and Site 300. The beryllium concentrations can be accounted for by the natural beryllium in typical airborne dust. The total tritium released to the atmosphere in 1983 was 3245 Ci.

Water Samples

Water samples collected in the Livermore Valley and at Site 300 exhibit gross beta and tritium activities within the ranges previously observed in these areas. Two water samples from

Site 300 showed an above-average level of gross alpha activity. This activity has been found to be naturally occurring uranium at concentrations well within those specified in DOE Manual 5480.1.

The discharge of tritiated water (HTO) into the sanitary sewer system in 1983 was 1.7 Ci, essentially unchanged from the previous year. Tritium analyses were also made on well-water samples collected near the Livermore Water Reclamation Plant (LWRP). These analyses, begun in 1977, were made to determine the extent to which low levels of tritium in the LWRP effluent may be migrating into groundwater. As was found during earlier surveys, the highest tritium values were detected in test wells down-gradient of the site near Arroyo Las Positas. Since the LWRP effluent is no longer discharged to the arroyo, the primary means of tritium movement to nearby groundwater has been eliminated. Tritium concentrations observed in local wells in 1983 were generally the same as previous years measurements.

Vegetation and Foodstuff Samples

Tritium levels found in the Livermore Valley and Site 300 vegetation were comparable to those

observed in 1982. As a means of evaluating the possible impact of Laboratory effluents on locally grown foodstuff, the tritium content of Livermore Valley wines was compared with values from other California and European wines. The tritium levels in Valley wines are within the range found to be present in both European wines and surface waters throughout the world, but somewhat higher than those in other California wines. Honey produced in the Livermore Valley contained tritium levels comparable to those found in honey from neighboring areas.

Monitoring Data – Collection, Analysis, and Evaluation

Radioactive Monitoring

Airborne Radioactivity

Concentrations of various airborne radionuclides are measured at the Laboratory perimeter, off-site locations near the Laboratory, and Site 300. Sampling locations are shown in Figs. 3 through 5. The six samplers on the Laboratory perimeter, six of the offsite samplers (Fig. 5), and the nine samplers at Site 300 (Fig. 4) use 5.2×10^{-2} m² Whatman-41 cellulose filters. These samplers are operated at average flow rates of 400 to 700 liters/min. The filters are cut in half; one half of each filter is retained for beryllium analysis. An easily dissolved filter and a low trace-metal background are required for these analyses. Whatman 41 represents a balance between such requirements and particulate-collection efficiency.¹ The remaining samplers in the Livermore Valley (Fig. 5) use 4.56×10^{-3} m² glass-fiber filters (Flanders F-700) and are operated at a flow rate of 80 liters/min. All air filters are changed weekly.

After a four-day delay for decay of the radon-thoron daughters, gross alpha and beta activities on the filters are determined with an automatic gas-flow proportional counter. Monthly composites of Laboratory perimeter and Site 300 filters are also counted for specific gamma-emitting radionuclides using low-background Ge(Li) detectors. Following gamma counting, the Laboratory perimeter filters from individual locations and the Site 300 composites are analyzed for the presence of ²³⁹Pu, ²³⁸Pu, ²³⁵U, and ²³⁸U. Selected off-site samples from the Livermore Valley and the City of Tracy are analyzed for ²³⁹Pu.

Tables A-1 and A-2 in Appendix A show airborne gross alpha and gross beta activities for the

Doses

The 1983 average annual gamma-radiation doses at the Laboratory perimeter and off-site locations were 51 mrem and 50 mrem, essentially unchanged from previous year. A 14-MeV neutron generator (Bldg. 212) near the south perimeter continued to be a source of elevated radiation. However, the annual radiation dose at the Laboratory's south perimeter is within allowable standards in DOE Manual 5480.1.

Livermore Valley samples, and Tables A-3 and A-4 show corresponding activities for Site 300. Both locations showed slightly reduced concentrations from 1982.

Tables A-5 and A-6 list the activities of the principal radionuclides that contribute to the gross beta activity in Livermore and Site 300 samples. Both locations showed prominent increases in the concentration of ⁷Be during January. This isotope is the product of a naturally occurring cosmic reaction and its presence is not attributed to Laboratory activities. These activities are determined by gamma spectra analysis. Table A-7 shows the concentration of plutonium on air filter samples collected in Tracy and the Livermore Valley. Tables A-8 and A-9 show the concentrations of airborne ²³⁹Pu, ²³⁵U, and ²³⁸U in the Livermore perimeter and Site 300 air samples. Location 12 at the south perimeter showed higher concentrations of plutonium-in-air than the other sample sites. The highest monthly sample was collected during April, 1.1×10^{-16} μ Ci/ml, and represented 0.2% of the concentration guide value. Stack sampling data showed that the plutonium facility was not the source of contamination. A likely source was the material resuspended by the soil removal from a waste-storage area that was described in the 1982 annual monitoring report. The higher concentration of ²³⁸U at Site 300 is a result of the "depleted" uranium (a byproduct of ²³⁵U enrichment) used at the Site. The uranium concentrations are well below the concentration guides (CG) in DOE Manual 5480.1 (see App. B).

Concentrations of airborne tritiated water (HTO) were determined for each of the LLNL perimeter air-sampling locations (Fig. 3) and at off-site locations S1 and S2 (Fig. 5). Water vapor

Figure 3. LLNL perimeter locations for air-sampling stations and neutron dosimeters.

was collected on silica-gel sampler that operated at a flow rate of about 0.5 liters/min for a 2-week period. The collected water was recovered by vacuum drying the silica gel at 150°C, and the HTO was measured by liquid-scintillation counting. Table A-10 shows average monthly HTO concentrations observed at each sampling location, the overall annual average concentration is 2.6×10^{-11} $\mu\text{Ci/ml}$. The highest monthly concentration occurred in October and was observed at location 12. This concentration, 10×10^{-11} $\mu\text{Ci/ml}$, is 0.05% of the DOE standard. Location 12 also showed the highest annual average concentration, probably because this location is so close to one of the tritium effluent sources (the 14-MeV neutron generator).

Radioactivity in Soil

An intensive soil-sampling program conducted in 1971 and 1972 provided a data base on

the concentration ranges of various radionuclides in soil near the Laboratory and at Site 300. Since 1972, soil sampling in the vicinity of LLNL and at Site 300 has been part of a continuing LLNL surveillance program to document any changes in environmental levels of radioactivity that have occurred and to evaluate any increase in radioactivity that might have resulted from Laboratory operations. As in previous years, a group of soil samples was collected at random from the list of locations sampled in the 1971-1972 study. Figure 6 shows the 1983 soil-sampling locations in the Livermore Valley; and Fig. 7 indicates the locations at Site 300 where annual samples have been collected since 1973.

All samples were collected to a depth of 5 cm. After collection, the samples were dried, ground, and blended. Plutonium-239 content was determined in each sample following an acid-leaching

Figure 4. Site 300 on-site air-sampling locations.

Figure 5. Livermore Valley air-sampling locations.

Figure 6. Livermore Valley soil-sampling locations.

procedure. For gamma-spectra analysis, approximately 300-g aliquots of soil were sealed in 200-cm³ thin-walled cans of aluminum and counted with a Ge(Li) detector.

The data in Table A-11 are in the range of those reported in the previous year.² Figure 8 is a distribution plot of these activities.

Table A-12 shows the ²³⁹Pu, ¹³⁷Cs, and ²³⁸U activities in the Site 300 samples. There were negligible changes from activities observed in previous samples collected in the same locations.²

High-explosive tests at Site 300 often involve the use of depleted uranium. Accordingly, soil

samples are taken annually to determine how these tests perturb the uranium content of the soil. Uranium measurements were made by gamma spectrometry. As in the past, the analyses indicated that perturbation is essentially limited to areas adjacent to the firing bunkers.^{3,4} The uranium data shown in Table A-12 are comparable to those observed during 1982.

Radioactivity in Sewage

Radioactive wastewater is treated to reduce activity levels to the lowest levels practicable and well below standards in DOE Manual 5480.1.

Figure 7. Site 300 soil-sampling locations.

After treatment and analysis, the liquid effluents are released into the city of Livermore's sanitary sewer system at the outfall located at the north-west corner of the LLNL. The effluent is continuously monitored at the outfall for pH, selected metals, and radioactivity.

Figure 8. Distribution plot of ²³⁹Pu in soil samples collected in the Livermore Valley during 1983.

Liquid wastes from Livermore's sanitary sewer system are treated at the Livermore Water Reclamation Plant (LWRP), a tertiary sewage-treatment plant that serves residential, commercial, and industrial water users in Livermore. The salt content of the LWRP effluent presented a problem for groundwater quality locally and in the Niles Cone aquifers. Accordingly, as part of the Livermore-Amador Valley Wastewater Management program, a pipeline was constructed to transport wastewater out of the valley for discharge into the San Francisco Bay. The Livermore sewage plant was connected to this pipeline on February 8, 1980. Although the effluent will still be used for irrigation of municipal property during summer months, it will no longer be discharged into the arroyo, thus eliminating the primary means of tritium migration to local and downstream groundwater.

Representative San Francisco Bay water samples were collected before and after the LWRP's connection to the pipeline. Results of tritium analysis of these samples indicate no significant difference between the two sample sets.⁵

Samples of the LLNL and LWRP liquid effluents are collected daily. Table A-13 compares the monthly composite activity levels of certain

radionuclides in the LLNL effluent with those in the effluent from the LWRP. All concentrations are well below standards in DOE Manual 5480.1 for discharge into the sanitary sewer system.

Radioactivity in Water

Water samples are collected from the various Livermore Valley and Site 300 locations shown in Figs. 9 and 10. These samples are analyzed for gross alpha and gross beta activity. Tables A-14 and A-15 show the gross alpha activities in Livermore Valley and Site 300 samples. Gross beta activities for Livermore and Site 300 samples are shown in Tables A-16 and A-17.

Livermore sampling locations 11, 16, 24, 26, and 29 (Fig. 9) are surface water sources (ponds, creeks, and reservoirs), and location 20 is the collection site of LLNL rainfall. The other locations are domestic water sources. Gross alpha and beta activities in Livermore water samples collected in

1983 were below EPA and State of California standards for drinking water.⁶

Storm-water samples were collected at three locations (influent, effluent and the LLNL lake) during the first rain following the dry season and analyzed for gross alpha, gross beta, and tritiated water. The alpha and beta in all samples were below the limit of sensitivity, 8% and 3% of the concentration guides respectively. The tritium concentration was less than 0.1% of the concentration guide.

Site 300 water samples (Fig. 10) were collected from on-site wells (locations 1-6 and 22), off-site wells (locations 7 and 23), and an off-site creek (location 14). Location 20 is Site 300 rainwater, and location 21 is a spring-fed pond near Bunker 812. Two locations showed high gross alpha concentrations which specific analyses have identified to be natural uranium: location 4, a well near the Site 300 entrance, which has displayed

Figure 9. Livermore Valley water-sampling locations.

Figure 10. Site 300 water-sampling locations.

these results in previous years; and location 21, the spring-fed pond, which was investigated during 1981. Neither the EPA⁶ nor the State of California⁷ specifies a limit for natural uranium in drinking water. In their limit for gross alpha activity, uranium is specifically excluded from the total. The uranium concentrations were well within that specified in DOE Manual 5480.1 (2×10^{-5} $\mu\text{Ci/ml}$).

The water samples from the Livermore Valley and Site 300 are also analyzed for tritium activity. Because of the low tritium levels typically found it is necessary, to distill and electrolytically enrich the samples before liquid-scintillation counting. Tables A-18 and A-19 show the data for the Livermore and Site 300 samples, respectively. The samples have concentrations that are well below recommended concentration guide values. The highest concentration of tritium in water, 44.6×10^{-7} $\mu\text{Ci/ml}$, occurred in the Livermore Valley rain (location 20) which was collected during February. This represents 0.15% of the concentration guide for drinking water. Tables A-18 and A-19 also include an estimate of the annual dose that may be delivered to an adult who consumes water

containing the listed tritium concentrations. These doses, which are all less than 0.2 mrem, are based on a water consumption of 2 liters/day and the dose-conversion factors contained in NRC Reg. Guide 1.109 (see App. C).

As noted previously, treated effluent from the LWRP is used to irrigate nearby municipal property. This effluent contains low levels of tritium which come from normal LLNL operational releases to the sanitary sewer system. As part of a study begun in 1977,⁸ tritium measurements are now made annually on well-water samples collected from neighboring wells to determine the extent of tritium migration into groundwater. Many of the wells were in the immediate vicinity of the LWRP; however, additional samples were also collected from areas at some distance. Locations sampled during 1983 are indicated in Fig. 11, and the tritium data are shown in Table A-20. The highest tritium values appear in wells down-gradient of the LWRP. Tritium activities in all samples were well below the guidelines for water in uncontrolled areas as stated in DOE Manual 5480.1. The tritium levels in these wells are similar to those observed in the 1982 samples.

Figure 11. Livermore Valley groundwater-sampling locations.

Radioactivity in Vegetation and Foodstuffs

Native vegetation samples are collected quarterly at locations in the Livermore Valley (Fig. 12) and at Site 300 (Fig. 13). These samples are freeze-dried and the tritium activity in the recovered water is determined by liquid-scintillation counting. Table A-21 shows the tritium data for vegetation collected in the Livermore Valley. The whole-body radiation doses shown in Table A-21 were derived using the dose-conversion factors in NRC Reg. Guide 1.109.⁹ Conservatively assuming that an adult's diet comprises vegetables with similar tritium concentrations and meat and milk derived from livestock fed on grasses of these concentrations, these potential doses are all less than 0.1 mrem/y.

Table A-22 shows the 1983 tritium data for Site 300 vegetation. Locations 6 and 13 are adjacent to an area that contains tritium-contaminated debris from a firing table. As a result of the seasonal rains, the tritium apparently entered an aquifer whose outflow is in the area where these samples are routinely collected. This was also observed in prior years.

Beginning in 1977, as a means of evaluating the possible impact of Laboratory effluents on locally grown foodstuff, the tritium content of Livermore Valley wines was measured and compared with that found in other California wines and European wines.⁸ Wine samples collected in 1983 were catalytically oxidized to carbon dioxide and water, and the tritium content of the recovered

water was measured by gas proportional counting. The data in Table A-23 represent the analysis of samples purchased in 1983. As found since 1977, the tritium levels of the Valley wines were somewhat higher than those of California wines produced from grapes grown outside the Valley, but slightly lower than those of the European wines sampled. The same European wines have been sampled in previous years.

Samples of honey produced from a variety of flower sources both in and outside the Livermore Valley were analyzed for tritium content. Following the oxidation of the samples in a Parr oxygen bomb, the tritium content of the water produced was determined by gas proportional counting. The data in Table A-24 show that the tritium content of Livermore Valley honey samples is comparable to that of honey from neighboring areas.

Radioactivity in Milk

During 1983, goat-milk samples were obtained from three farms within about 5 km of the Laboratory. A portion of each sample was vacuum-distilled and the distillate analyzed for tritium activity by liquid-scintillation counting. Another portion was oven-dried, and the residue blended and gamma counted in a Ge(Li) system. The activities of the ¹³⁷Cs, ⁴⁰K, and ³H in the samples are shown in Table A-25. The annual average concentration of tritium in milk was 1.6×10^{-7} μ Ci/ml. Also shown are the calculated annual

Figure 12. Livermore Valley vegetation-sampling locations.

Figure 13. Site 300 vegetation-sampling locations.

whole-body or critical-organ radiation doses that could be received from consuming this milk. These calculations are based on a milk intake of 310 liters/y and on the models previously referenced. The only dose above 1 mrem to an individual is from naturally occurring ^{40}K . The dose due to ^{40}K was calculated using dose factors from ICRP 30.¹⁰

Environmental Radiation Measurements

Quarterly, environmental radiation is measured at the 22 LLNL perimeter locations (Fig. 14) and at the 47 off-site locations (Fig. 15). These measurements are obtained with thermoluminescence dosimeters using a previously published procedure.¹¹ Based on past measurements,¹² environmental terrestrial exposure rates in the Livermore Valley vary from 30 to 60 mR/y. Cosmic ra-

diation, calculated from the local elevation and geomagnetic latitude according to the data of Fowler and Beck,¹³ is approximately 35 mR/y.

Table A-26 shows the quarterly and annual radiation doses for the perimeter locations. The average annual dose of 51 mrem at the perimeter does not differ significantly from the 50 mrem off-site average. Both agree with the previous year's values of 49 and 50 mrem.

Figure 16 presents the 1983 annual frequency distribution of environmental dose rates observed at the 47 off-site locations. The dosimeter that recorded the highest dose (73 mrem) was at the south perimeter. Figure 17 is a dose-distribution plot combining Laboratory perimeter and off-site measurements.

Environmental neutron dose rate measurements using ^{235}U track-etch detectors are also

Figure 14. LLNL perimeter locations for gamma dosimeters.

Figure 15. LLNL off-site locations for gamma dosimeters.

made at eight locations on the LLNL site perimeter. A detailed description of the detector and the spark-counting procedure has been published.¹⁴ Neutron-monitoring locations are shown in Fig. 3 and 1983 quarterly measurements are shown in Table A-27. Location 3 received the highest annual neutron dose, 113 mrem, because of its position near Bldg. 212, the 14-MeV neutron generator.

Figure 16. Annual off-site gamma radiation background for 1983.

tor. This 3-fold increase from the previous year reflects the increased use of the neutron generator.

Nonradioactive Monitoring

Beryllium in Air and Water

Beryllium monitoring of air, both at the source and near LLNL property boundaries, has always been a part of the Laboratory's safety program. Monthly, halves of the filters from the

Figure 17. TLD dose-distribution plot for the LLNL perimeter and Livermore Valley during 1983.

LLNL perimeter and Site 300 are composited by sampling location. Following sample preparation the beryllium content of the solutions is determined by atomic absorption analysis.

Tables A-28 and A-29 show average monthly concentrations of airborne beryllium for LLNL perimeter and Site 300 sampling locations, respectively. The concentrations, which average less than 1% of the ambient concentration limit established by the Bay Area Air Quality Management District, can be accounted for by resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and Livermore's air typically contains 10-100 μg of particulates per cubic meter. By using a value of 50 $\mu\text{g}/\text{m}^3$ for an average dust load and 1 ppm for beryllium content of this dust, an airborne beryllium concentration of $5.0 \times 10^{-5} \mu\text{g}/\text{m}^3$ can be calculated. This value is in good agreement with the data in Tables A-28 and A-29. These concentrations are plotted in Figs. 18 and 19.

Figure 18. Concentration of beryllium on air filters at the LLNL perimeter.

In compliance with the California Regional Water Quality Control Board (WQCB) Order 80-184, we perform monthly sampling for beryllium (in addition to gross alpha, gross beta, and tritium) at Site 300 well-water monitoring locations and in surface water runoff at landfills during the rain season. The highest concentration of beryllium for the monitoring locations was less than 10 parts per billion (ppb). Although rain water accumulated at the landfills, there was no potential for surface-water transport as runoff did not occur.

Nonradioactive Pollutants in Sewage

As noted previously, sanitary sewage from the Laboratory is treated at the LWRP. This effluent is continuously monitored for pH, radioactivity, and selected metal ions, before it enters the Livermore sewer system.¹⁵ Sewage samples representative of daily flow are collected and composited monthly. These composites are analyzed for the metals shown in Table A-30.

Figure 19. Concentration of beryllium on air filters at Site 300.

In addition, samples of Laboratory sewage effluent are collected quarterly. These samples are analyzed for the parameters specified on LWRP's permit (National Permit Discharge Elimination System). Table A-31 shows the data for 1983. All data demonstrate compliance with the City of Livermore's discharge limits listed in App. D.

Noise Pollution

As noted elsewhere, the Laboratory's high-explosive diagnostic work is conducted at Site 300. Because Site 300 is remote, these experiments can be performed with minimal off-site impact from annoying noises or damaging overpressures. On the basis of meteorological measurements made twice each day, a limit is set on the weight of high explosives that can be detonated without impact in populated areas. To monitor these limits, four microbarograph sensors are maintained in or near the City of Tracy. The probability of overpressure is greatest in the Tracy area because of the direction of the prevailing winds. There were no complaints of overpressures attributed to LLNL operations at Site 300 during 1983.

Pollutants in Storm Runoff and Liquid-Discharge Sites

Beginning in 1975, the Laboratory's environmental surveillance program was expanded to include pesticide monitoring. Pesticides used at LLNL include herbicides, fungicides, and insecticides. The most probable way pesticides used at LLNL could be transported to the off-site environment is by entrainment in surface runoff water. Most of this surface drainage leaves the Laboratory via a ditch at the northwest corner of the property. A sample was collected from the ditch following the first major storm.

This sample was extracted with organic solvents, and the extracts were analyzed by gas-liquid chromatography (GLC) using a variety of detectors. Data obtained from these analyses were compared with the pesticides listed in Title 22 of the California Health and Safety Code.⁷ No materials were detected in the samples at concentrations exceeding the state-adopted standards for these organic chemicals.

Order 80-183 from the Water Quality Control Board requires the monthly sampling and analyses of wells which are down-gradient from Site 300 liquid-discharge sites (locations 3, 4, 5, and 14). Any increase in total organic carbon, specific conductance, chlorides, or total hardness could indicate percolation of the liquid waste.

The data shown in Table A-32 do not indicate contamination.

Environmental Impact of LLNL Operations

Radioactive Airborne Effluents

In 1983 (see Table A-33), radioactive airborne effluents consisted of a total of 3245 Ci of tritium from Bldg. 212 (14-MeV neutron generator), Bldg. 331 (tritium facility), and Bldg. 292 (rotating target neutron source), and 855 Ci of the short-lived radionuclides $^{15}\text{O}_2$ - $^{13}\text{N}_2$ from Bldg. 194 (electron-positron linear accelerator). Comparative releases of radioactive effluents at Livermore during the 8-year period 1976 through 1983 are shown in Table A-34. The Livermore reactor was shut down on March 31, 1980, because of a lack of programmatic need. Closure of this facility removed the local source of ^{41}Ar as a contributor to the site radiation dose to the public.

Table A-33 also contains estimated radiation doses to the public from these radioactive airborne effluents. Three dose-reference points were used: (1) the "fence-post" dose at that location on the site boundary where maximum exposure rates exist, (2) the dose to the nearest resident, and (3) the man-rem dose within a radius of 80 km.

Dose calculations were made using a continuous-point-source computer code based on the Gaussian plume model.¹⁶ This code provides ratios of concentration to release rate (χ/Q) through sixteen 22.5° compass sectors, and distances from 0.1 to 100 km from potential release points. The average annual χ/Q values have been calculated using local meteorological data from an instrumented tower. Previously, this tower was located near the Laboratory's east site boundary, and equipped with sensors mounted at 10- and 40-m levels that measure wind direction, wind speed, and temperature. This year the tower was moved 400 m north-west to a temporary location awaiting reinstallation. In this interim only the 10-m sensor is operative. From records of these data, wind speed, wind direction, and atmospheric stability estimates were tabulated at 1/4-h intervals over the calendar year. Variance in the horizontal wind direction was used to estimate Pasquill-Gifford stability categories based on the method described by Slade.¹⁷ Lateral and vertical standard deviations, σ_y and σ_z , are entered in the computer code as functions of these stability categories and the respective distances. From annual

effluent data the release rate Q (in curies per second) was calculated for each of the principal radionuclides released to the atmosphere, and the concentrations at the site boundary and the nearest resident were calculated from appropriate x/Q values. "Nearest resident" means that resident receiving the highest dose from each radioactivity release point, not necessarily the resident nearest to the site boundary. Dose estimates were based on the dose-conversion factor in the NRC Reg. Guide 1.109.⁹ The results indicate that the maximum estimated dose to the nearest resident was less than 1 mrem.

Table A-33 shows a combined population dose of less than 1.0 man-rem from ^3H and neutron activation products in Laboratory airborne effluents. This dose is based on a population of 4.8×10^6 within 80 km of the Laboratory. Using 100 mrem/y as a typical average radiation dose from natural sources, the comparable natural radiation dose the same group receives is 4.8×10^5 man-rem. By comparison, the population dose from Laboratory operations is negligible.

Radioactive Liquid Effluents

Low-level radioactive wastewater is treated to reduce radioactivity to levels as low as reasonably achievable and well within applicable health and safety standards. The treated effluent is then discharged into Livermore's sanitary sewer system. During 1983, 0.67×10^{-5} Ci ^{239}Pu and 1.7 Ci HTO were released into the sewer. Table A-13 shows that the average annual concentration of these radionuclides represents $2 \times 10^{-5}\%$ and $4 \times 10^{-3}\%$ of the DOE standards.

Nonradioactive Liquid Effluents

The metals in sewage are listed in Table A-30. The quantities of metals discharged did not interfere with the LWRP's discharging effluents within limits set by the WQCB.

The first rains of the season, which were collected as storm water runoff, showed no detectable level of specified total identifiable chlorinated hydrocarbons. The influent enters LLNL from the east perimeter, flows into the lake, and the effluent exits the Laboratory at the NW corner. These data are displayed in Table A-35.

Special Monitoring Assessments

Staff personnel at LLNL completed an assessment for potential contamination of groundwater

by eight solid-waste landfills at Site 300.¹⁸ The investigation comprised geological, hydrological, geophysical and geochemical studies to evaluate the hydrogeology and groundwater chemistry of this area. Water samples were collected and analyzed from 26 groundwater sampling points developed from 17 boreholes which were drilled in the vicinity of the landfills. No groundwater contamination was found that would threaten health or the environment.

Information from this study was used to develop the Site 300 Groundwater Assessment Program, a plan to identify contaminant migration from the two active solid-waste landfills. Samples will be taken up-gradient and down-gradient of each site and analyzed for materials discarded to the landfills and those materials which previous monitoring showed to be present above background levels. The results of the analyses will be reported quarterly to the Water Quality Control Board through the Department of Energy. This document was submitted to the U.S. Department of Energy for review, the State Regional Water Quality Control Board for review and approval, and the State Department of Health Services for compliance with the Interim Status Groundwater Monitoring Requirements. Another study evaluated the potential for contamination of the saturated groundwater system at LLNL.¹⁹ This investigation consisted of sampling and analyzing the water from observation wells and the calculation of the shallow areal groundwater flow speed for various parts of the site.

Analyses of water samples from the wells showed: tritium concentrations in all wells are below the drinking water limit;

- one well contained nitrates at two times the drinking water limit;
- two wells contained trichloroethylene (TCE) at concentrations above the suggested drinking water limit;
- two wells contained tetrachloroethylene (PCE) above the suggested drinking water limit;
- water from four wells contained detectable concentrations of chloroform.

Through a series of field and laboratory tests, providing estimates of hydraulic conductivity and effective porosity of the aquifer beneath LLNL, the groundwater flow was calculated to be between 1 and 42 m/yr.

Because this report stated that chlorinated hydrocarbons may have already moved offsite in the southwest part of the Laboratory, private

wells and Alameda County observation wells adjacent to this area were sampled during December 1983. Some of these wells contained higher concentrations of TCE and PCE than were found on the LLNL site. A groundwater and soil investigation plan, comprising the chemical analyses of a series of soil borings and additional monitoring wells, was developed to determine whether LLNL contributed to the groundwater contamination and to determine the extent of contamination. When completed, the results of this investigation will be described in a separate report. The U.S. Department of Energy and the California Regional Water Quality Control Board of the San Francisco Bay Region are apprised of this study.

Quality Assurance:

During 1983, the Laboratory participated in the Environmental Protection Agency's Environmental Radioactivity Laboratory Intercomparison Studies program.

Table A-36 shows the comparison of analyses by LLNL with the known values and the averages of all participants. The plus or minus values are calculated for 1σ . Also shown are comparative analyses by LLNL with the Environmental Measurements Laboratory.

The sampling and analytical procedures were described in Appendix E of the 1982 Annual report.² Blank samples are routinely analyzed.

Air filter blanks consist of collection media which have been handled and processed in the same way as samples. The average values are: for ^{238}U , $0.29 \mu\text{g/blank} \pm 41\% \text{SDM}$; for ^{235}U , $0.0019 \mu\text{g/blank} \pm 42\% \text{SDM}$; for ^{239}Pu , below the detection limit of $4 \times 10^{-9} \mu\text{Ci/sample}$.

Water blanks are tap water which have been analyzed just as the samples. The average values are: for ^{137}Cs , $2.0 \times 10^{-11} \mu\text{Ci/ml} \pm 47\% \text{SDM}$; for ^{239}Pu , $6 \times 10^{-13} \mu\text{Ci/ml} \pm 50\% \text{SDM}$.

Washed and ignited sand is used for the soil blank. The ^{239}Pu content is below the detection limit of $4 \times 10^{-9} \mu\text{Ci/sample}$.

References

1. C. L. Lindeken, R. L. Morgan, and K. F. Petrock, "Collection Efficiency of Whatman 41 Filter Paper for Submicron Aerosols," *Health Phys.* 9, 305 (1963).
2. K. S. Griggs, M. A. Gonzalez, and R. W. Buddemeier, *Environmental Monitoring at the Lawrence Livermore National Laboratory, 1982 Annual Report*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-82 (1983).
3. P. H. Gudiksen, C. L. Lindeken, J. W. Meadows, and K. O. Hamby, *Environmental Levels of Radioactivity in the Vicinity of the LLNL, 1972 Annual Report*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-51333 (1973).
4. W. J. Tipton, *An Aerial Radiological Survey of the Lawrence Livermore Laboratory*, EGG&G, Las Vegas, NV, EGG-1183-1693 (1975).
5. R. W. Buddemeier, *Tritium-Salinity Relationships in San Francisco Bay*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-86669 (1981).
6. *National Interim Primary Drinking Water Regulations*, Environmental Protection Agency, EPA-570/9-76 303 (June 24, 1977).
7. *California Domestic Water Quality and Monitoring Regulations*, California Administrative Title Code 22, State of California (1977).
8. W. J. Silver, C. L. Lindeken, K. M. Wong, E. H. Willes, and J. H. White, *Environmental Monitoring at the Lawrence Livermore Laboratory, 1977 Annual Report*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50027-77 (1978).
9. *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix 1*, U.S. Nuclear Regulatory Commission, Regulatory Guide 1.109 (October 1977).
10. International Commission on Radiological Protection, *Limits for Intakes of Radionuclides by Workers*, *Annals of the ICRP*, vol. 5 (1981), pp. 29 and 30.
11. C. L. Lindeken, J. H. White, A. J. Toy, and C. W. Sundbeck, *Ambient Environmental Radiation Monitoring at the Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-77106 (1975).
12. C. L. Lindeken, P. H. Gudiksen, J. W. Meadows, K. O. Hamby, and L. R. Anspaugh, *Environmental Levels of Radioactivity in Livermore Valley Soils*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-74414 (1973).
13. W. M. Lowder and H. L. Beck, "Cosmic Ray Ionization in the Lower Atmosphere," *J. Geo. Phys. Rev.* 71, 4611 (1966).
14. J. C. Fisher, Jr., "Calibration of Anderson-Braun Remmeters with Track Etch Detectors," in *Hazards Control Progress Report No. 52*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50007-76-1 (1976), p. 37.
15. M. Auyong, J. L. Cate, Jr., and D. W. Rueppel, *On-Line Monitoring of Toxic Materials in Sewage at the Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-83664 (1980).
16. K. R. Peterson, T. W. Crawford, and L. A. Lawson, *CPS: A Continuous-Point-Source Computer Code for Plume Dispersion and Deposition Calculations*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-52049 (1976).
17. D. H. Slade, Ed., *Meteorology and Atomic Energy* (U.S. Atomic Energy Commission, 1968).
18. E. Raber and D. W. Carpenter, *An Evaluation of the Hydrogeology and Groundwater Chemistry Associated with Landfills at LLNL Site 300*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53416 (1983).
19. R. Stone and M. R. Ruggieri, *Groundwater Quality and Movement at Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53474 (1983).

Appendix A. Tables

The statistical values (2σ estimates) that accompany individual measurements of radioactivity in the following tables are the result of counting statistics. The minimum detection limit is assumed reached when the 2σ estimate is $\pm 100\%$. Statistical values for groups of data such as annual averages are calculated standard deviations of the mean (average).

Table A-1. Gross alpha activity on air filters – LLNL perimeter and Livermore Valley.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM ^b	% CG ^c
	(10 ⁻¹⁵ μ Ci/ml)														
Perimeter															
01	0.7	0.6	0.7	N/A ^d	0.7	0.6	0.5	0.7	0.5	0.8	0.4	0.3	0.6	34	3
02	0.6	0.6	0.6	0.8	0.6	0.6	0.5	0.5	0.5	0.7	0.4	0.3	0.6	??	3
12	2.1	0.6	0.6	0.6	0.5	0.6	0.4	0.8	1.0	1.0	0.6	0.6	0.8	57	4
13	0.4	0.3	0.3	0.4	0.5	0.4	0.3	0.5	0.6	0.5	0.3	0.3	0.4	25	2
14	0.8	1.0	0.6	0.5	0.5	0.7	0.6	1.0	1.3	0.9	0.7	0.8	0.8	31	4
15	0.5	0.3	0.3	0.3	0.5	0.4	0.3	0.4	0.6	0.5	0.4	0.3	0.4	25	2
Valley															
03	0.6	0.6	0.6	0.8	0.7	0.7	0.6	0.5	0.6	0.7	0.6	0.6	0.6	13	3
04	0.5	0.5	0.5	0.4	0.5	0.7	0.6	0.6	0.4	0.9	0.6	0.6	0.6	25	3
05	0.8	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.8	0.7	0.7	0.6	0.6	20	3
06	0.9	0.6	0.5	0.6	0.7	0.5	0.7	0.6	0.4	0.8	0.5	0.6	0.6	23	3
07	0.8	0.5	0.5	0.6	0.6	0.6	0.7	0.6	0.8	0.6	0.6	0.6	0.6	16	3
08	0.4	0.3	0.3	0.3	0.4	0.9	0.4	0.6	0.6	0.8	0.6	0.6	0.5	39	3
09	1.0	0.6	0.5	0.6	0.8	0.7	0.6	1.0	1.1	1.2	0.8	0.6	0.8	29	4
10	0.6	0.6	0.6	0.7	0.6	0.7	0.8	0.5	0.6	0.7	0.4	0.3	0.6	24	3
11	0.7	0.6	0.5	0.6	0.6	0.6	0.9	0.7	0.7	0.8	0.6	0.6	0.7	17	4
16	0.9	0.6	0.7	0.6	0.6	0.6	0.5	1.6	3.0	0.8	0.6	0.6	0.9	78	4
17	0.6	0.7	0.8	1.0	0.6	0.7	0.7	0.5	0.6	0.9	0.5	0.5	0.7	24	4
Annual average													0.6	22	3

^a See Figs. 3 and 5.

^b % SDM = % standard deviation of mean at 1σ .

^c Concentration guide (CG) = 2×10^{-14} μ Ci/ml.

^d Not available.

Table A-2. Gross beta activity on air filters—LLNL perimeter and Livermore Valley.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM	% CG ^b
(10 ⁻¹⁴ µCi/ml)															
Perimeter															
01	2.2	0.6	0.3	N/A ^c	0.8	0.7	0.7	1.1	1.4	1.4	1.1	0.8	1.0	52	1
02	1.5	0.6	0.5	0.8	0.9	0.8	0.7	1.2	1.6	1.7	1.1	0.8	1.0	39	1
12	2.5	0.7	0.4	0.9	0.9	0.9	0.6	1.7	1.9	1.6	1.2	0.6	1.2	55	1
13	1.4	0.6	0.5	0.8	0.8	0.7	0.6	1.0	1.3	1.3	0.8	0.8	0.9	34	1
14	3.0	0.7	0.5	0.9	0.8	0.8	0.7	0.7	1.4	1.3	0.9	0.8	1.0	64	1
15	2.0	0.6	0.4	0.9	0.8	0.8	0.6	1.0	1.4	1.4	1.1	0.8	1.0	45	1
Valley															
03	2.3	1.2	1.1	1.6	1.5	1.4	1.2	1.6	1.9	1.9	1.6	1.3	1.6	23	2
04	1.6	0.7	0.4	0.6	0.9	0.7	0.8	1.2	1.6	1.5	1.2	0.8	1.0	41	1
05	3.2	1.6	1.9	1.9	2.1	1.6	1.9	2.4	2.6	2.6	2.4	2.1	2.2	21	2
06	3.3	1.9	1.9	2.2	2.1	2.0	2.0	2.2	2.0	2.2	1.6	1.7	2.1	21	2
07	2.4	1.6	1.6	2.0	2.0	2.0	2.0	2.3	2.6	1.8	2.3	1.6	2.0	16	2
08	2.3	0.8	0.5	1.1	1.4	1.0	0.9	1.2	1.8	2.0	1.6	1.0	1.3	41	1
09	4.0	2.4	2.1	2.2	2.6	2.5	2.4	2.9	3.4	3.5	3.0	1.1	2.7	28	3
10	2.1	0.7	0.5	1.0	1.0	0.7	0.7	1.2	1.6	1.8	1.2	0.9	1.1	44	1
11	2.6	1.9	1.7	2.1	2.3	2.2	2.1	2.4	2.7	2.6	2.5	2.3	2.3	13	2
16	2.7	0.5	0.5	1.1	0.9	0.8	0.5	2.4	2.4	1.7	1.2	0.8	1.3	62	1
17	1.9	0.8	0.4	0.8	1.0	0.7	0.6	1.1	1.4	1.6	1.2	0.7	1.0	43	1
Annual average													1.4	40	1

^a See Figs. 3 and 5.

^b CG = 1×10^{-12} µCi/ml.

^c Not available.

Table A-3. Gross alpha activity on air filters—Site 300.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM	% CG ^b
	(10 ⁻¹⁵ µCi/ml)														
01	0.4	0.3	0.2	0.3	0.3	0.3	0.4	0.3	0.5	0.5	0.3	0.3	0.3	26	2
02	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.6	0.5	0.4	0.4	23	2
03	0.6	0.5	0.3	0.6	0.6	0.8	0.7	0.7	1.9	0.7	0.6	0.5	0.7	52	4
04	0.5	N/A ^c	N/A	0.2	0.4	0.6	0.4	0.4	0.4	0.6	0.5	N/A	0.4	27	2
05	0.4	0.3	0.2	0.3	0.4	0.3	0.4	0.5	0.5	0.7	0.6	0.4	0.4	34	2
06	0.7	0.6	0.6	0.6	0.8	0.6	0.5	0.9	1.1	1.0	0.6	0.6	0.7	27	4
08	0.4	0.3	0.3	0.3	0.4	0.4	0.3	0.4	0.6	0.6	0.4	0.4	0.4	25	2
09	0.8	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.4	41	2
10	0.4	0.2	0.1	0.4	0.3	0.5	0.4	0.4	0.4	0.6	0.4	N/A	0.4	35	2
Annual average													0.5	31	2

^a See Fig. 4. Location 6 is in city of Tracy.

^b CG = 2×10^{-14} µCi/ml.

^c Not available.

Table A-4. Gross beta activity on air filters—Site 300.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM	% CG ^b
	(10 ⁻¹⁴ µCi/ml)														
01	1.8	0.8	0.5	1.1	0.9	1.1	0.9	1.4	1.5	1.6	1.0	0.9	1.1	34	1
02	1.8	0.9	0.5	1.2	1.0	1.1	0.9	1.4	1.6	1.8	1.6	1.3	1.3	32	1
03	2.4	1.2	0.7	1.6	1.5	2.0	1.5	3.1	2.6	1.9	1.5	1.1	1.8	39	2
04	3.0	N/A ^c	N/A	0.9	0.9	1.0	0.7	1.3	1.4	1.4	1.0	N/A	1.3	54	1
05	1.7	1.0	0.6	1.2	0.9	1.1	0.9	1.7	1.8	1.7	1.2	0.9	1.2	33	1
06	2.1	0.9	0.4	1.0	1.3	1.0	0.7	0.9	1.1	1.9	1.2	1.3	1.2	41	1
08	1.8	0.8	0.4	1.0	0.9	0.8	0.6	1.1	1.4	1.3	0.4	0.7	0.9	45	1
09	2.1	0.8	0.5	1.0	0.9	1.1	0.7	1.4	1.5	1.5	1.0	0.8	1.1	40	1
10	2.3	1.1	0.6	1.6	1.0	1.2	0.6	1.2	1.2	1.3	1.0	N/A	1.2	39	1
Annual average													1.2	20	1

^a See Fig. 4. Location 6 is in City of Tracy.

^b CG = 1×10^{-12} µCi/ml.

^c Not available.

Table A-5. Gamma activity on air filters—LLNL perimeter.

Month	⁷ Be [10 ⁻¹³ µCi/ml] ± 2σ (%)	⁴⁰ K	¹⁰⁶ Ru	¹²⁵ Sb	¹³⁷ Cs	¹⁴⁴ Ce
		[10 ⁻¹⁶ µCi/ml] ± 2σ (%)				
Jan.	65.5 ± 2	0.2 ± 50	1.7 ± 100	0.4 ± 100	0.6 ± 40	1.2 ± 100
Feb.	0.6 ± 2	4.6 ± 66	0.5 ± 100	0.2 ± 100	0.7 ± 20	0.9 ± 60
Mar.	0.6 ± 7	1.1 ± 100	0.5 ± 100	0.2 ± 100	0.9 ± 16	0.9 ± 54
Apr.	0.9 ± 2	5.9 ± 100	1.5 ± 100	0.5 ± 100	2.0 ± 26	1.0 ± 100
May	0.8 ± 2	8.5 ± 32	0.5 ± 100	0.2 ± 100	1.1 ± 15	1.5 ± 64
June	0.9 ± 11	12.2 ± 34	0.6 ± 100	0.5 ± 100	1.0 ± 28	0.5 ± 100
July	0.7 ± 2	1.6 ± 100	0.6 ± 100	0.2 ± 100	1.0 ± 20	0.5 ± 100
Aug.	0.8 ± 7	5.8 ± 50	0.5 ± 100	0.2 ± 100	0.6 ± 26	0.4 ± 100
Sept.	1.1 ± 2	5.4 ± 100	n.d. ^a	0.3 ± 100	0.6 ± 50	0.7 ± 100
Oct.	0.8 ± 2	4.3 ± 60	0.04 ± 100	0.2 ± 100	0.4 ± 30	0.3 ± 100
Nov.	0.6 ± 2	2.4 ± 100	0.4 ± 100	0.2 ± 100	0.3 ± 86	0.5 ± 100
Dec.	0.6 ± 2	1.1 ± 100	0.4 ± 100	0.1 ± 100	0.3 ± 42	0.3 ± 100
Annual average	6.2	4.4	0.6	0.3	0.8	0.7
% SDM	303	79	85	49	59	52
CG (µCi/ml)	4 × 10 ⁻⁶	none	2 × 10 ⁻¹⁰	9 × 10 ⁻¹⁰	2 × 10 ⁻⁹	2 × 10 ⁻¹⁰
% CG	2 × 10 ⁻³		3 × 10 ⁻⁵	3 × 10 ⁻⁶	4 × 10 ⁻⁶	4 × 10 ⁻⁵

^a Not detected.

Table A-6. Gamma activity on air filters—Site 300.

Month	⁷ Be	⁴⁰ K	¹⁰⁶ Ru	¹²⁵ Sb	¹³⁷ Cs	¹⁴⁴ Ce
	[10 ⁻¹³ μCi/ml ± 2σ (%)]	[10 ⁻¹⁶ μCi/ml ± 2σ (%)]				
Jan.	102. ± 2	0.4 ± 50	2.9 ± 36	0.2 ± 100	1.0 ± 11	2.6 ± 40
Feb.	9.1 ± 2	8.4 ± 100	11.5 ± 40	4.2 ± 36	11.7 ± 10	17.1 ± 32
Mar.	0.84 ± 2	0.6 ± 100	1.3 ± 42	0.4 ± 38	1.2 ± 8	1.7 ± 32
Apr.	1.5 ± 2	0.6 ± 100	1.8 ± 56	0.8 ± 58	2.1 ± 10	2.4 ± 32
May	1.0 ± 2	0.3 ± 100	0.3 ± 100	0.4 ± 44	1.4 ± 7	1.6 ± 46
June	1.4 ± 2	4.2 ± 36	0.3 ± 100	0.5 ± 38	1.7 ± 7	1.4 ± 39
July	1.0 ± 2	4.6 ± 38	0.3 ± 100	0.1 ± 100	1.3 ± 10	1.2 ± 42
Aug.	1.5 ± 1	0.5 ± 100	0.3 ± 62	0.3 ± 62	1.1 ± 10	0.3 ± 100
Sept.	1.6 ± 8	5.5 ± 38	0.4 ± 100	0.2 ± 100	1.0 ± 13	0.4 ± 100
Oct.	1.1 ± 2	1.0 ± 100	0.3 ± 100	0.1 ± 100	0.4 ± 19	0.3 ± 100
Nov.	0.9 ± 2	3.3 ± 44	0.3 ± 100	0.1 ± 100	0.4 ± 20	0.2 ± 100
Dec.	0.7 ± 2	1.0 ± 100	0.4 ± 160	0.1 ± 100	0.2 ± 50	0.3 ± 100
Annual average	10.2	2.5	1.7	0.6	2.0	2.5
% SDM	284	104	191	186	159	191
CG (μCi/ml)	4 × 10 ⁻⁸	none	2 × 10 ⁻¹⁰	9 × 10 ⁻¹⁰	2 × 10 ⁻⁹	2 × 10 ⁻¹⁰
% CG	3 × 10 ⁻³		8 × 10 ⁻⁵	7 × 10 ⁻⁶	1 × 10 ⁻⁵	1 × 10 ⁻⁴

Table A-7. Plutonium-239 on air filters—selected locations.

Month	Location ^a					
	090-04	090-08	090-10	090-16	090-17	040-06
	[10 ⁻¹⁷ μCi/ml ± 2σ (%)]					
Jan.	0.2 ± 36	0.1 ± 61	0.1 ± 100	0.3 ± 46	0.1 ± 78	0.1 ± 70
Feb.	0.1 ± 56	0.1 ± 35	0.2 ± 46	0.2 ± 41	0.1 ± 77	0.1 ± 58
Mar.	0.1 ± 43	0.1 ± 37	0.1 ± 42	0.1 ± 43	0.2 ± 46	0.1 ± 48
Apr.	0.1 ± 100	0.2 ± 38	0.3 ± 37	0.3 ± 38	0.3 ± 50	0.2 ± 50
May	0.3 ± 25	0.3 ± 43	0.2 ± 41	0.2 ± 32	0.2 ± 40	0.3 ± 35
June	0.4 ± 28	0.1 ± 50	0.1 ± 50	0.4 ± 27	0.2 ± 49	0.2 ± 34
July	0.2 ± 43	0.1 ± 41	0.1 ± 85	0.3 ± 48	0.2 ± 48	0.1 ± 65
Aug.	0.1 ± 39	0.1 ± 64	0.2 ± 32	0.4 ± 52	0.1 ± 70	0.1 ± 98
Sept.	0.1 ± 48	0.1 ± 43	0.1 ± 35	0.6 ± 62	0.1 ± 63	0.2 ± 63
Oct.	N/A ^b	0.1 ± 87	0.1 ± 57	0.1 ± 81	0.1 ± 100	N/A
Nov.	0.1 ± 100	0.1 ± 100	0.1 ± 38	0.1 ± 76	0.1 ± 100	0.1 ± 100
Dec.	0.1 ± 100	0.01 ± 100	0.01 ± 100	0.1 ± 100	0.1 ± 100	0.1 ± 100
Annual average	0.2	0.1	0.2	0.2	0.2	0.1
% SDM	61	50	47	63	45	47
% CG ^c	3 × 10 ⁻³	2 × 10 ⁻³	2 × 10 ⁻³	4 × 10 ⁻³	3 × 10 ⁻³	2 × 10 ⁻³

^a See Fig. 5. Location 040-06 is in City of Tracy.^b Not available.^c CG = 6 × 10⁻¹⁴ μCi/ml.

Table A-8. Plutonium and uranium on air filters – LLNL perimeter.

Month	Location ^a	²³⁹ Pu ^b	²³⁵ U	²³⁸ U	²³⁵ U/ ²³⁸ U
		[10 ⁻¹⁷ μCi/ml ± 2σ (%)]	[10 ⁻⁷ μg/m ³ ± 2σ (%)]	[10 ⁻⁵ μg/m ³ ± 2σ (%)]	(10 ⁻³)
Jan.	01	0.2 ± 34	4.1 ± 3	14.8 ± 3	2.8
	02	0.2 ± 49	2.6 ± 3	4.2 ± 3	6.3
	12	1.0 ± 28	10.7 ± 3	24.5 ± 3	4.4
	13	0.2 ± 29	4.8 ± 3	16.1 ± 3	3.0
	14	0.9 ± 26	5.5 ± 3	21.5 ± 3	2.6
	15	0.2 ± 29	4.8 ± 3	18.7 ± 3	2.6
Feb.	01	0.2 ± 43	2.0 ± 3	2.9 ± 3	6.7
	02	0.2 ± 49	2.6 ± 3	3.9 ± 3	6.8
	12	0.6 ± 25	5.0 ± 3	7.8 ± 3	6.5
	13	0.1 ± 67	3.7 ± 3	5.3 ± 3	6.9
	14	0.2 ± 45	2.6 ± 3	4.2 ± 3	6.2
	15	0.2 ± 44	1.8 ± 3	2.8 ± 3	6.7
Mar.	01	0.3 ± 29	1.5 ± 3	2.3 ± 3	6.4
	02	0.1 ± 39	2.0 ± 3	3.0 ± 3	6.6
	12	2.3 ± 11	4.4 ± 3	7.0 ± 3	6.3
	13	0.1 ± 31	4.7 ± 3	6.8 ± 3	7.0
	14	0.4 ± 21	1.6 ± 3	2.7 ± 3	5.9
	15	0.1 ± 25	1.2 ± 3	1.8 ± 3	6.7
Apr.	01	N/A ^c	N/A	N/A	N/A
	02	0.9 ± 22	3.5 ± 3	5.0 ± 3	7.1
	12	11.1 ± 7	7.4 ± 3	11.3 ± 3	6.6
	13	0.2 ± 30	7.2 ± 3	10.1 ± 3	7.1
	14	1.1 ± 17	3.4 ± 3	4.9 ± 3	6.9
	15	0.2 ± 33	3.8 ± 3	5.3 ± 3	7.1
May	01	N/A	6.0 ± 3	8.4 ± 3	7.1
	02	0.5 ± 19	9.7 ± 3	13.6 ± 3	7.1
	12	4.9 ± 7	7.8 ± 3	11.4 ± 3	6.8
	13	0.2 ± 42	9.3 ± 3	13.1 ± 3	7.1
	14	1.9 ± 17	4.8 ± 3	6.8 ± 3	6.9
	15	0.3 ± 19	5.5 ± 3	7.8 ± 3	7.1
June	01	0.5 ± 29	6.7 ± 3	9.7 ± 3	6.9
	02	0.2 ± 35	5.9 ± 3	8.3 ± 3	7.1
	12	3.6 ± 10	10.9 ± 3	15.8 ± 3	6.9
	13	0.2 ± 26	9.1 ± 3	12.8 ± 3	7.1
	14	3.6 ± 13	13.3 ± 3	19.0 ± 3	7.0
	15	0.4 ± 26	9.2 ± 3	13.0 ± 3	7.1
July	01	0.1 ± 50	7.7 ± 3	11.1 ± 3	6.9
	02	0.1 ± 41	6.2 ± 3	8.7 ± 3	7.1
	12	1.3 ± 23	12.1 ± 3	17.5 ± 3	6.9
	13	0.1 ± 29	6.8 ± 3	9.6 ± 3	7.1
	14	0.6 ± 17	4.9 ± 3	7.0 ± 3	6.9
	15	0.2 ± 29	7.8 ± 3	11.1 ± 3	7.1

Table A-8. (Continued).

Month	Location ^a	²³⁹ Pu ^b	²³⁵ U	²³⁸ U	²³⁵ U/ ²³⁸ U
		[10 ⁻¹⁷ μ Ci/ml] $\pm 2\sigma$ (%)	[10 ⁻⁷ μ g/m ³ $\pm 2\sigma$ (%)	[10 ⁻⁵ μ g/m ³ $\pm 2\sigma$ (%)	(10 ⁻³)
Aug.	01	0.3 $\pm$ 36	5.8 $\pm$ 3	8.4 $\pm$ 3	6.8
	02	0.1 $\pm$ 46	5.0 $\pm$ 3	7.0 $\pm$ 3	7.1
	12	1.5 $\pm$ 22	13.2 $\pm$ 3	16.7 $\pm$ 3	7.0
	13	0.2 $\pm$ 45	6.1 $\pm$ 3	8.6 $\pm$ 3	7.1
	14	0.7 $\pm$ 43	8.2 $\pm$ 3	11.7 $\pm$ 3	7.1
	15	0.2 $\pm$ 37	6.9 $\pm$ 3	9.6 $\pm$ 3	7.1
Sept.	01	0.2 $\pm$ 52	7.2 $\pm$ 3	10.5 $\pm$ 3	6.8
	02	0.2 $\pm$ 41	6.0 $\pm$ 3	8.6 $\pm$ 3	7.0
	12	1.2 $\pm$ 23	16.8 $\pm$ 3	24.2 $\pm$ 3	6.9
	13	0.1 $\pm$ 55	7.7 $\pm$ 3	10.8 $\pm$ 3	7.1
	14	0.5 $\pm$ 41	10.1 $\pm$ 3	14.3 $\pm$ 3	7.1
	15	0.2 $\pm$ 42	6.6 $\pm$ 3	9.3 $\pm$ 3	7.1
Oct.	01	0.1 $\pm$ 100	5.0 $\pm$ 3	7.8 $\pm$ 3	6.8
	02	0.1 $\pm$ 100	4.6 $\pm$ 3	6.3 $\pm$ 3	7.3
	12	0.5 $\pm$ 23	12.4 $\pm$ 3	17.9 $\pm$ 3	6.9
	13	0.1 $\pm$ 45	4.0 $\pm$ 3	5.7 $\pm$ 3	7.0
	14	0.3 $\pm$ 37	6.2 $\pm$ 3	8.8 $\pm$ 3	7.0
	15	0.1 $\pm$ 37	N/A ^c	N/A	N/A
Nov.	01	0.1 $\pm$ 52	3.3 $\pm$ 3	4.8 $\pm$ 3	6.9
	02	0.1 $\pm$ 55	3.9 $\pm$ 3	5.6 $\pm$ 3	7.0
	12	0.7 $\pm$ 21	9.9 $\pm$ 3	14.1 $\pm$ 3	7.0
	13	0.1 $\pm$ 62	3.0 $\pm$ 3	4.4 $\pm$ 3	6.8
	14	0.2 $\pm$ 55	5.6 $\pm$ 3	8.0 $\pm$ 3	7.0
	15	0.1 $\pm$ 77	3.3 $\pm$ 3	4.7 $\pm$ 3	7.0
Dec.	01	0.1 $\pm$ 41	1.5 $\pm$ 3	2.2 $\pm$ 3	6.8
	02	0.1 $\pm$ 66	1.8 $\pm$ 3	2.7 $\pm$ 3	6.7
	12	0.6 $\pm$ 38	5.5 $\pm$ 3	8.1 $\pm$ 3	6.8
	13	0.1 $\pm$ 60	1.3 $\pm$ 3	2.0 $\pm$ 3	6.5
	14	0.1 $\pm$ 100	1.9 $\pm$ 3	2.8 $\pm$ 3	6.8
	15	0.1 $\pm$ 100	1.9 $\pm$ 3	2.8 $\pm$ 3	6.8

Annual averages

Location	²³⁹ Pu			²³⁵ U			²³⁸ U		
	10 ⁻¹⁷ μ Ci/ml	% SDM	% CG ^d	10 ⁻⁷ μ g/m ³	% SDM	% CG ^e	10 ⁻⁵ μ g/m ³	% SDM	% CG ^f
01	0.2	62	3 $\times$ 10 ⁻³	4.6	51	2 $\times$ 10 ⁻⁵	7.5	54	5 $\times$ 10 ⁻⁴
02	0.2	103	3 $\times$ 10 ⁻³	4.5	50	2 $\times$ 10 ⁻⁵	6.4	48	4 $\times$ 10 ⁻⁴
12	2.4	125	4 $\times$ 10 ⁻²	9.7	39	5 $\times$ 10 ⁻⁵	14.9	40	10 $\times$ 10 ⁻⁴
13	0.1	43	2 $\times$ 10 ⁻³	5.6	44	3 $\times$ 10 ⁻⁵	8.8	47	6 $\times$ 10 ⁻⁴
14	0.9	113	2 $\times$ 10 ⁻²	5.7	61	3 $\times$ 10 ⁻⁵	9.3	66	6 $\times$ 10 ⁻⁴
15	0.2	47	3 $\times$ 10 ⁻³	4.8	55	2 $\times$ 10 ⁻⁵	7.9	65	5 $\times$ 10 ⁻⁴

^a See Fig. 3.^b In all tables activity listed as ²³⁹Pu includes activity due to ²⁴⁰Pu isotope.^c Not available.^d CG = 6 $\times$ 10⁻¹⁴ μ Ci/ml for ²³⁹Pu (soluble) activity in air.^e CG = 1.9 μ g/m³ for ²³⁵U (insoluble) activity in air.^f CG = 15 μ g/m³ for ²³⁸U (insoluble) activity in air.

Table A-9. Plutonium, cesium, and uranium on air filters – Site 300.

Month	²³⁹ Pu	¹³⁷ Cs	²³⁹ Pu/ ¹³⁷ Cs (10 ⁻²)	²³⁵ U	²³⁸ U	²³⁵ U/ ²³⁸ U (10 ⁻³)
	[10 ⁻¹⁷ μCi/ml ± 2σ (%)]	[10 ⁻¹⁵ μCi/ml ± 2σ (%)]		[10 ⁻⁷ μg/m ³ ± 2σ (%)]	[10 ⁻⁵ μg/m ³ ± 2σ (%)]	
Jan.	0.1 ± 13	0.1 ± 11	1.0	29.0 ± 3	161. ± 3	1.8
Feb.	0.1 ± 15	1.2 ± 10	0.1	1.31 ± 3	3.23 ± 3	4.0
Mar.	0.1 ± 16	0.1 ± 8	1.0	1.10 ± 3	2.57 ± 3	4.3
Apr.	0.2 ± 12	0.2 ± 10	1.0	3.00 ± 3	5.68 ± 3	5.3
May	0.2 ± 11	0.1 ± 7	2.0	2.76 ± 3	4.60 ± 3	6.0
June	0.3 ± 11	0.2 ± 7	1.5	4.68 ± 3	7.86 ± 3	6.0
July	0.1 ± 12	0.1 ± 10	1.0	4.27 ± 3	7.09 ± 3	6.0
Aug.	0.1 ± 21	0.1 ± 10	1.0	4.43 ± 3	7.49 ± 3	5.9
Sept.	0.04 ± 69	0.1 ± 13	0.4	6.05 ± 3	10.3 ± 3	5.9
Oct.	0.07 ± 17	0.04 ± 19	1.8	3.3 ± 3	5.4 ± 3	6.1
Nov.	0.08 ± 19	0.04 ± 20	2.0	2.3 ± 3	4.2 ± 3	5.4
Dec.	0.02 ± 42	0.02 ± 50	1.0	2.3 ± 3	6.1 ± 3	3.8
Annual average	0.1	0.2		5.4	18.8	
% SDM	68	156		141	239	
CG	6 × 10 ⁻¹⁴ μCi/ml	2 × 10 ⁻⁹ μCi/ml		1.9 μg/m ³	15 μg/m ³	
% CG	2 × 10 ⁻³	1 × 10 ⁻⁵		3 × 10 ⁻⁵	4 × 10 ⁻⁴	

Table A-10. Tritium (HTO) in air—LLNL perimeter and Livermore Valley.

Month	Perimeter location ^a						Valley location ^a		Average	% SDM
	01	02	12	13	14	15	S1	S2		
	(10 ⁻¹¹ μ Ci/ml)									
Jan.	1.6	3.0	3.8	2.9	2.4	2.7	2.8	1.8	2.6	27
Feb.	2.8	3.8	4.3	2.6	3.3	2.8	2.9	2.7	3.2	19
Mar.	3.1	5.1	5.4	4.7	3.7	4.3	1.5	1.4	3.6	42
Apr.	N/A ^b	2.0	2.9	1.5	2.2	2.3	1.2	1.0	1.9	36
May	N/A	0.9	5.6	1.7	1.7	1.7	N/A	0.8	2.1	86
June	0.6	N/A	1.1	0.6	1.8	1.1	N/A	0.3	0.9	58
July	0.8	3.4	1.7	0.6	2.1	2.0	0.5	0.4	1.4	73
Aug.	1.7	1.2	2.5	0.8	4.3	2.8	1.0	0.4	1.8	70
Sept.	1.8	2.1	3.8	1.9	4.9	2.1	0.5	0.8	2.2	65
Oct.	3.2	4.7	9.9	3.4	4.5	4.0	2.8	2.6	4.4	54
Nov.	2.8	4.5	5.2	2.8	5.8	2.7	1.2	1.7	3.3	49
Dec.	3.0	3.8	6.0	2.9	5.6	3.9	2.7	3.2	3.9	32
Annual average									2.6	41
% CG ^c	0.01									
Calculated adult whole-body dose	0.03 mrem									

^a See Figs. 3 and 5.^b Not available.^c CG = 2×10^{-7} μ Ci/ml.

Table A-11. Various radionuclides in soil – Livermore Valley (sampling depth 0-5 cm).

Location ^a	²³⁹ Pu	⁴⁰ K	¹³⁷ Cs	²³² Th	²³⁸ U
	[10 ⁻⁹ μCi/dry g ± 2σ (%)]	[10 ⁻⁵ μCi/dry g ± 2σ (%)]	[10 ⁻⁷ μCi/dry g ± 2σ (%)]	[μg/dry g ± 2σ (%)]	[μg/dry g ± 2σ (%)]
927	6.2 ± 8	0.5 ± 7	0.3 ± 32	4.6 ± 5	2.4 ± 20
928	10.9 ± 6	1.0 ± 4	2.8 ± 7	5.0 ± 9	2.6 ± 38
929	3.3 ± 13	1.1 ± 4	0.7 ± 21	6.5 ± 9	4.1 ± 11
930	4.1 ± 11	1.2 ± 6	0.3 ± 42	6.2 ± 13	3.0 ± 24
931	3.0 ± 11	0.9 ± 5	0.4 ± 24	5.2 ± 6	3.0 ± 13
932	3.0 ± 9	1.4 ± 9	0.3 ± 60	7.2 ± 10	4.6 ± 11
933	6.7 ± 7	1.5 ± 3	1.9 ± 6	6.8 ± 5	4.1 ± 12
934	5.7 ± 7	0.7 ± 5	0.5 ± 18	4.7 ± 8	1.2 ± 60
935	5.7 ± 7	0.7 ± 10	0.6 ± 25	5.0 ± 14	2.5 ± 34
936	9.5 ± 6	0.6 ± 10	3.9 ± 5	4.0 ± 9	1.7 ± 25
937	9.8 ± 7	0.9 ± 8	2.1 ± 11	4.7 ± 12	2.6 ± 48
938	8.3 ± 7	0.8 ± 8	3.1 ± 7	4.9 ± 9	2.7 ± 28
939	7.9 ± 6	1.0 ± 8	3.1 ± 7	5.9 ± 8	2.8 ± 28
940	8.1 ± 7	1.3 ± 6	3.2 ± 5	6.8 ± 8	3.0 ± 42
941	4.8 ± 9	1.3 ± 12	1.5 ± 8	5.8 ± 9	n.d. ^b
942	4.7 ± 8	1.2 ± 9	1.2 ± 12	6.4 ± 10	2.9 ± 38
943	11.9 ± 7	1.0 ± 8	4.0 ± 8	5.4 ± 7	2.8 ± 42
944	23.4 ± 5	1.1 ± 4	2.6 ± 4	6.8 ± 6	2.8 ± 21
945	5.5 ± 8	1.5 ± 5	2.1 ± 10	4.9 ± 14	2.5 ± 36
946	2.8 ± 10	1.3 ± 4	1.1 ± 16	5.3 ± 12	2.8 ± 44
947	1.9 ± 12	1.0 ± 4	0.8 ± 14	6.0 ± 6	3.1 ± 14

^a See Fig. 6.

^b Not detected.

Table A-12. Plutonium, cesium and uranium in soil – Site 300 (sampling depth 0-5 cm).

Location ^a	²³⁹ Pu	¹³⁷ Cs	²³⁸ U
	[10 ⁻⁹ μCi/dry g ± 2σ (%)]	[10 ⁻⁷ μCi/dry g ± 2σ (%)]	[μg/dry g ± 2σ (%)]
948	6.7 ± 7	3.8 ± 5	5.1 ± 20
949	4.6 ± 9	1.6 ± 8	4.0 ± 14
950	2.5 ± 11	2.2 ± 6	62.5 ± 5
951	2.6 ± 10	3.2 ± 5	58.8 ± 5
952	3.1 ± 9	0.2 ± 29	2.3 ± 44
953	7.4 ± 6	2.9 ± 4	1.6 ± 42
954	1.1 ± 14	0.4 ± 21	3.6 ± 30
955	2.4 ± 12	0.4 ± 18	4.8 ± 12
956	0.2 ± 34	2.0 ± 8	5.1 ± 16
957	5.5 ± 8	2.7 ± 6	3.8 ± 23
958	4.5 ± 9	1.7 ± 14	1370. ± 4
959	0.9 ± 17	0.4 ± 23	3.0 ± 14

^a See Fig. 7.

Table A-13. Various radionuclides in effluents—LLNL and Livermore Water Reclamation Plant.

Month	HTQ		¹³⁷ Cs		²³⁹ Pu	
	[10 ⁻⁶ μCi/ml ± 2σ (%)]		[10 ⁻¹¹ μCi/ml ± 2σ (%)]		[10 ⁻¹² μCi/ml ± 2σ (%)]	
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP
Jan.	2.6 ± 50	0.51 ± 91	6.4 ± 15	3.0 ± 43	44.3 ± 9	0.8 ± .
Feb.	3.4 ± 41	0.68 ± 65	22.3 ± 8	1.2 ± 100	13.2 ± 21	0.2 ± 100
Mar.	2.8 ± 36	1.1 ± 62	6.2 ± 17	0.8 ± 100	12.5 ± 15	1.0 ± 45
Apr.	3.6 ± 38	0.4 ± 55	6.8 ± 23	1.1 ± 50	10.5 ± 14	1.4 ± 37
May	1.9 ± 42	0.4 ± 100	5.7 ± 18	1.6 ± 50	9.3 ± 14	1.0 ± 47
June	1.8 ± 52	0.5 ± 50	4.6 ± 14	0.6 ± 100	60.0 ± 8	1.9 ± 35
July	3.4 ± 38	0.4 ± 84	4.5 ± 14	2.5 ± 33	4.4 ± 18	0.5 ± 60
Aug.	5.8 ± 30	0.5 ± 32	2.8 ± 36	1.0 ± 100	6.6 ± 16	0.8 ± 57
Sept.	1.6 ± 62	0.6 ± 76	5.4 ± 23	1.0 ± 100	9.9 ± 16	0.7 ± 54
Oct.	4.2 ± 25	0.7 ± 71	5.2 ± 26	0.8 ± 100	3.5 ± 28	0.2 ± 100
Nov.	16.8 ± 17	2.8 ± 47	7.5 ± 20	0.9 ± 100	29.4 ± 11	0.7 ± 56
Dec.	3.6 ± 40	0.5 ± 85	4.8 ± 30	3.2 ± 40	4.6 ± 20	0.1 ± 100
Annual average	4.3	0.8	6.8	1.5	17.4	0.8
% SDM	96	88	73	62	103	67
CG (μCi/ml)	0.1	3 × 10 ⁻³	4 × 10 ⁻⁴	2 × 10 ⁻⁵	1 × 10 ⁻⁴	5 × 10 ⁻⁶
% CG	4 × 10 ⁻³	2 × 10 ⁻²	2 × 10 ⁻⁵	8 × 10 ⁻⁵	2 × 10 ⁻⁵	2 × 10 ⁻⁵

Table A-14. Gross alpha activity in water—Livermore Valley.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ μCi/ml ± 2σ (%)]				
11	4	≤3.0	≤2.6	≤2.7	7	≤9
15	4	≤3.0	≤2.6	≤2.7	7	≤9
16	4	≤5.2	≤2.6	≤3.4	36	≤11
19	4	≤3.0	≤2.6	≤2.7	7	≤9
20	6	≤2.7	≤0.3	≤2.0	55	≤7
24	4	≤3.0	≤2.6	≤2.7	7	≤9
26	4	≤3.0	≤2.6	≤2.7	7	≤9
29	4	≤3.0	≤2.6	≤2.7	7	≤9
31	4	≤4.2	≤0.4	≤2.5	63	≤8
33	3	≤3.0	≤2.6	≤2.7	8	≤9
34	3	≤3.0	≤2.6	≤2.7	8	≤9
37	4	≤4.2	≤2.7	≤3.1	23	≤10

^a See Fig. 9.

^b CG = 3 × 10⁻⁸ μCi/ml.

Table A-15. Gross alpha activity in water – Site 300.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ µCi/ml ± 2σ (%)]				
01	4	≤4.2	≤2.6	≤3.0	26	≤10
02	4	≤4.2	≤2.6	≤3.0	26	≤10
04	12	22.0 ± 40	≤2.7	≤8.8	68	≤29
05	12	≤4.2	≤2.5	≤2.9	21	≤10
06	4	≤4.2	≤2.6	≤3.0	26	≤10
07	4	≤5.2	≤2.6	≤3.7	34	≤12
14	11	≤4.2	≤2.5	≤2.9	22	≤10
20	7	≤4.2	≤0.3	≤2.6	45	≤9
21	4	30.0 ± 56	≤2.6	≤10.2	131	≤34
22	12	≤4.2	≤2.5	≤2.9	21	≤10
23	4	≤4.2	≤2.6	≤3.0	26	≤10

^a See Fig. 10.^b CG = 3 × 10⁻⁸ µCi/ml.

Table A-16. Gross beta activity in water – Livermore Valley.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ µCi/ml ± 2σ (%)]				
11	4	13.0 ± 54	≤8.1	≤9.5	25	≤3
15	4	≤8.8	≤8.0	≤8.2	4	≤3
16	4	≤16.0	≤8.0	≤10.2	38	≤3
19	4	≤8.8	≤8.0	≤8.2	4	≤3
20	6	≤8.0	≤1.8	≤6.2	46	≤2
24	4	12.0 ± 57	≤8.1	≤9.2	20	≤3
26	4	≤8.8	≤8.0	≤8.2	4	≤3
29	4	≤8.8	≤7.9	≤8.2	5	≤3
31	4	≤12.0	≤1.6	≤7.4	58	≤2
33	3	14.0 ± 51	≤8.8	≤11.3	23	≤4
34	3	27.0 ± 34	13.0 ± 55	≤18.7	39	≤6
37	4	≤12.0	≤7.9	≤9.2	21	≤3

^a See Fig. 9.^b CG = 3 × 10⁻⁷ µCi/ml.

Table A-17. Gross beta activity in water—Site 300.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ µCi/ml ± 2σ (%)]				
01	4	≤12.0	≤8.0	≤9.1	22	≤3
02	4	≤12.0	≤8.0	≤9.1	22	≤3
04	12	32.0 ± 27	≤8.0	≤16.0	38	≤5
05	12	12.0 ± 61	≤8.0	≤9.1	20	≤3
06	4	≤12.0	≤8.0	≤9.1	22	≤3
07	4	≤16.0	≤8.0	≤11.0	34	≤4
14	11	17.0 ± 43	≤8.0	≤10.0	28	≤3
20	7	20.0 ± 36	≤1.8	≤9.6	57	≤3
21	4	79.0 ± 18	10.0 ± 65	37	90	12
22	12	23.0 ± 36	≤8.0	≤10.9	43	≤4
23	4	≤12.0	≤8.0	≤9.1	22	≤3

^a See Fig. 10.^b CG = 3×10^{-7} µCi/ml.

Table A-18. Tritium (HTO) in water—Livermore Valley.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b	Calculated adult whole-body dose (mrem)
		[10 ⁻⁷ µCi/ml ± 2σ (%)]					
11	4	0.55 ± 12	0.45 ± 14	0.48	10	2×10^{-3}	4×10^{-3}
15	4	0.87 ± 9	0.56 ± 11	0.71	18	2×10^{-3}	5×10^{-3}
16	4	2.45 ± 5	1.65 ± 5	1.92	19	6×10^{-3}	15×10^{-3}
19	4	0.62 ± 12	0.57 ± 11	0.60	3	2×10^{-3}	5×10^{-3}
20	10	44.6 ± 2	1.86 ± 8	16.5	76	6×10^{-2}	126×10^{-3}
24	4	1.39 ± 6	0.52 ± 12	1.00	36	3×10^{-3}	8×10^{-3}
26	4	1.75 ± 6	1.61 ± 6	1.68	4	6×10^{-3}	14×10^{-3}
29	4	0.37 ± 17	0.59 ± 13	0.45	20	2×10^{-3}	3×10^{-3}
30	4	0.54 ± 12	0.45 ± 17	0.50	10	2×10^{-3}	4×10^{-3}
31	4	0.92 ± 7	0.37 ± 20	0.61	38	2×10^{-3}	5×10^{-3}
33	3	1.04 ± 8	0.62 ± 10	0.79	28	3×10^{-3}	6×10^{-3}
34	3	0.96 ± 8	0.75 ± 10	0.86	13	3×10^{-3}	7×10^{-3}
37	4	0.70 ± 8	0.46 ± 12	0.59	26	2×10^{-3}	5×10^{-3}

^a See Fig. 9.^b CG = 3×10^{-3} µCi/ml.

Table A-19. Tritium (HTO) in water – Site 300.

Location	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b	Calculated adult whole-body dose
		[10 ⁻⁷ μCi/ml ± 2σ (%)]					(mrem)
01	4	0.75 ± 19	0.58 ± 11	0.69	11	2 × 10 ⁻³	5 × 10 ⁻³
02	4	0.91 ± 8	0.30 ± 18	0.49	58	2 × 10 ⁻³	4 × 10 ⁻³
03	1	0.65 ± 10				2 × 10 ⁻³	5 × 10 ⁻³
04	12	0.66 ± 11	0.05 ± 90	0.21	85	7 × 10 ⁻⁴	2 × 10 ⁻³
05	12	0.45 ± 14	0.06 ± 83	0.22	62	7 × 10 ⁻⁴	2 × 10 ⁻³
06	4	0.12 ± 51	0.05 ± 100	0.08	39	3 × 10 ⁻⁴	1 × 10 ⁻³
07	4	0.38 ± 18	0.10 ± 53	0.23	51	8 × 10 ⁻⁴	2 × 10 ⁻³
14	12	0.80 ± 9	0.41 ± 14	0.58	20	2 × 10 ⁻³	4 × 10 ⁻³
20	9	2.1 ± 5	0.28 ± 22	0.81	78	3 × 10 ⁻³	6 × 10 ⁻³
21	4	1.22 ± 6	0.26 ± 22	0.55	83	2 × 10 ⁻³	4 × 10 ⁻³
22	12	0.50 ± 16	0.05 ± 100	0.18	72	6 × 10 ⁻⁴	1 × 10 ⁻⁴
23	4	0.52 ± 11	0.06 ± 98	0.19	112	6 × 10 ⁻⁴	1 × 10 ⁻⁴

^a See Fig. 10.^b CG = 3 × 10⁻³.

Table A-20. Tritium (HTO) in groundwater – Livermore Valley.

Location ^a	Well identification	Well depth (m)	Activity	% CG
			[10 ⁻⁷ µCi/ml ± 2σ (%)]	
01	3S1E-1P2	15	10.2 ± 2.5	3 × 10 ⁻²
02	3S1E-1R2	17	0.93 ± 7.4	3 × 10 ⁻³
03	3S1E-2R1	10	8.8 ± 2.6	3 × 10 ⁻²
04	3S1E-8H2	62	1.2 ± 6.4	4 × 10 ⁻³
05	3S1E-9G1	49	3.2 ± 3.6	1 × 10 ⁻²
06	3S1E-9P5	32	2.4 ± 4.2	8 × 10 ⁻³
07	3S1E-10A2	26	6.2 ± 29	2 × 10 ⁻²
08	3S1E-11B1	13	11.7 ± 2.5	4 × 10 ⁻²
09	3S1E-12A2	23	2.2 ± 4.4	7 × 10 ⁻³
10	3S1E-12D2	14	6.2 ± 2.8	2 × 10 ⁻²
11	3S1E-12G1	26	5.9 ± 2.9	2 × 10 ⁻²
12	3S1E-12N1	93	1.1 ± 7.0	4 × 10 ⁻³
13	3S1E-16H2	29	0.84 ± 7.6	3 × 10 ⁻³
14	3S2E-1P2	44	0.25 ± 22	1 × 10 ⁻³
15	3S2E-7N1	40	1.3 ± 5.8	4 × 10 ⁻³
16	3S2E-11A1	20	1.3 ± 6.2	4 × 10 ⁻³
17	3S2E-11C1	21	0.79 ± 8.6	3 × 10 ⁻³
18	3S3E-7D2	23	0.26 ± 22	1 × 10 ⁻³

^a See Fig. 11.^b CG = 3 × 10⁻³ µCi/ml.

Table A-21. Tritium (HTO) in vegetation – Livermore Valley.

Location ^a	Number of samples	Maximum [10 ⁻⁷ µCi/ml ± 2σ (%) in water recovered	Minimum	Average	% SDM	Calculated adult whole-body dose (mrem)
04	3	3.0 ± 35	1.0 ± 97	2.1	49	6 × 10 ⁻³
15	3	26.9 ± 5	9.9 ± 11	18.4	46	6 × 10 ⁻²
20	4	9.2 ± 12	4.9 ± 21	6.3	31	2 × 10 ⁻²
23	3	38.6 ± 4	10.9 ± 10	22.4	64	7 × 10 ⁻²
29	5	33.8 ± 4	9.2 ± 12	16.8	59	5 × 10 ⁻²
31	4	16.5 ± 7	3.4 ± 29	8.1	72	2 × 10 ⁻²
32	5	14.4 ± 8	2.7 ± 36	8.3	65	2 × 10 ⁻²
33	3	2.8 ± 35	1.7 ± 62	2.1	29	6 × 10 ⁻³

^a See Fig. 12.

Table A-22. Tritium (HTO) in vegetation – Site 300.

Location ^a	Number of samples	Maximum [10 ⁻⁷ µCi/ml ± 2σ (%) in water recovered	Minimum	Average	% SDM	Calculated adult whole-body dose (mrem)
01	4	1.8 ± 62	1.0 ± 100	1.4	20	4 × 10 ⁻³
02	4	2.5 ± 46	0.9 ± 100	1.4	55	4 × 10 ⁻³
03	4	1.9 ± 50	0.9 ± 100	1.2	37	4 × 10 ⁻³
06	2	10.3 ± 12	1.6 ± 60	6.0	100	2 × 10 ⁻²
12	3	2.1 ± 45	1.1 ± 100	1.6	32	5 × 10 ⁻³
13	4	49.5 ± 4	1.4 ± 67	14.5	161	4 × 10 ⁻²

^a See Fig. 13.

Table A-23. Tritium (HTO) in wine.

Location	Number of samples	Maximum [10 ⁻⁷ µCi/ml ± 2σ (%) in water recovered	Minimum	Average	% SDM
Livermore Valley	5	8.5 ± 4	1.7 ± 17	4.2	68
Other California areas	2	1.8 ± 11	0.7 ± 26	1.2	60
Europe	2	8.8 ± 4	2.6 ± 8	5.7	77

Table A-24. Tritium (HTO) in honey.

Location	Number of samples	Maximum [10^{-7} $\mu\text{Ci/ml} \pm 2\sigma$ (%) in water recovered]	Minimum	Average	% SDM
Livermore Valley	3	9.1 ± 4	6.26 ± 5	7.3	21
Other California areas	1	6.4 ± 5			

Table A-25. Various radionuclides in milk – Livermore Valley.

	HTO [10^{-7} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]	^{40}K [10^{-6} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]	^{137}Cs [10^{-9} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]
Number of samples	9	8	8
Maximum	3.1 ± 36	2.01 ± 1	2.46 ± 22
Minimum	1.0 ± 100	1.29 ± 4	0.43 ± 100
Average	1.6	1.6 ^a	1.07
% SDM	49	16	71
Calculated adult whole-body dose (mrem)	1×10^{-2}	9.1	2×10^{-2}

Table A-26. Environmental radiation measurement (TLD) – LLNL perimeter.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept. (mrem)	Oct.-Dec.	Annual
1	12	14	15	12	53
2	10	12	15	13	50
3	11	14	16	14	55
4	12	14	15	13	54
5	12	14	15	14	55
6	12	14	15	14	55
7	10	12	14	12	48
8	11	13	14	12	50
9	11	13	14	12	50
10	10	12	12	12	46
11	9	11	16	17	53
12	13	16	29	15	73
13	11	12	14	13	50
42	10	12	13	12	47
47	11	12	12	12	47
48	11	12	13	11	47
49	11	12	13	12	48
50	10	12	13	12	47
52	11	12	13	12	48
53	11	13	13	13	50
54	11	12	13	12	48
56	10	13	13	11	47
Average	11 ± 1	13 ± 1	14 ± 3	13 ± 1	51 ± 6

^a See Fig. 14.

Table A-27. Environmental neutron monitoring – LLNL perimeter.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual
	(mrem)				
1	1.2	1.6	0.8	1.1	4.7
2	1.2	1.4	0.9	1.8	5.3
3	21.	31.	34.	27.	113.
4	1.5	1.5	0.8	1.3	5.1
5	3.3	3.3	0.6	2.8	10.
6	1.4	1.2	0.7	1.4	4.7
7	1.9	1.2	1.3	1.5	5.9
8	1.9	1.7	1.3	1.6	6.2
Average	4.2	5.2	5.0	4.8	19.2

^a See Fig. 3.

Table A-28. Beryllium on air filters – LLNL perimeter.

Month	Location ^a						Average	% SDM	% Standard ^b
	01	02	12	13	14	15			
	(10 ⁻⁵ µg/m ³)								
Jan.	2.1	3.0	7.3	2.6	2.0	1.3	3.1	71	0.3
Feb.	0.9	1.1	2.5	1.7	1.3	0.2	1.3	61	0.1
Mar.	0.6	0.9	2.0	2.5	0.6	0.6	1.2	70	0.1
Apr.	N/A ^c	1.5	3.9	2.5	0.1	0.1	1.6	101	0.2
May	2.7	3.0	2.9	4.8	2.1	3.4	3.2	29	0.3
June	3.5	3.2	3.8	4.5	5.1	4.9	4.2	19	0.4
July	2.5	2.8	3.2	1.4	2.6	1.7	2.4	29	0.2
Aug.	1.4	1.0	1.6	1.3	1.2	1.0	1.2	18	0.1
Sept.	2.4	2.0	4.8	2.8	8.4	7.1	4.6	58	0.5
Oct.	2.5	2.6	3.6	2.1	1.0	1.5	2.2	41	0.2
Nov.	1.6	1.4	2.8	1.0	1.0	1.0	1.5	48	0.2
Dec.	2.2	1.8	4.7	1.1	0.9	1.6	2.1	67	0.2
Average	2.0	2.0	3.6	2.4	2.2	2.0	2.4		0.2
% SDM	41	42	42	53	107	103			

^a See Fig. 3.

^b Ambient concentration limit set by the Bay Area Air Quality Management District is 0.01 µg/m³.

^c Not available.

Table A 29. Beryllium on air filters—Site 300.

Month	Location ^a								Average	% SDM	% Standard ^b
	01	02	03	04	05	08	09	10			
	(10 ⁻⁵ µg/m ³)										
Jan.	0.5	0.6	1.5	1.7	1.1	0.7	0.4	0.9	0.9	51	0.1
Feb.	0.2	0.2	1.3	N/A ^c	0.2	0.3	0.2	0.2	0.4	110	0.1
Mar.	0.3	0.5	0.8	N/A	1.4	0.3	0.2	0.1	0.5	88	0.1
Apr.	1.2	1.5	3.4	1.4	2.9	1.5	1.0	1.5	1.8	48	0.2
May	1.0	1.2	2.0	1.7	6.0	1.3	0.9	1.6	2.0	85	0.2
June	1.4	1.7	5.2	3.3	5.5	2.3	1.6	2.9	3.0	54	0.3
July	1.0	1.4	3.8	1.7	3.6	2.4	2.1	2.2	2.3	44	0.2
Aug.	3.5	3.2	5.2	2.6	5.8	2.5	1.2	2.1	3.3	48	0.3
Sept.	0.8	0.7	5.0	0.9	1.4	3.0	1.0	1.2	1.8	87	0.2
Oct.	2.3	1.5	3.8	1.7	4.5	5.5	1.5	1.4	2.8	58	0.3
Nov.	1.6	1.7	2.4	1.6	2.7	1.0	1.0	1.7	1.7	35	0.2
Dec.	0.7	2.3	1.8	N/A	1.0	2.5	1.1	N/A	1.6	47	0.2
Average	1.2	1.4	3.0	1.9	3.0	2.0	1.0	1.4	1.8		0.2
% SDM	77	60	53	40	68	75	56	58			

^a See Fig. 4.^b Ambient concentration limit set by the Bay Area Air Quality Management District is 0.01 µg/m³.^c Not available.

Table A-30. Various elements in LLNL liquid effluent.

	Cd	Cr	Cu	Fe	Pb	Ni	Ag	Zn	Al	Be
	(ppm)									
Jan.	0.002	0.14	0.01	2.06	0.01	0.14	0.015	0.11	2.5	0.00
Feb.	0.003	0.15	0.13	1.6	0.01	0.05	0.029	0.31	1.1	0.00
Mar.	0.002	0.15	0.09	2.2	0.02	0.02	0.089	0.20	3.0	0.00
Apr.	0.002	0.16	0.10	1.1	0.02	0.02	0.017	0.51	0.5	0.00
May	0.002	0.22	0.13	0.90	0.02	0.01	0.031	0.17	0.4	0.00
June	0.003	0.22	0.14	0.87	0.03	0.16	0.003	0.19	0.3	0.00
July	0.002	N/A ^a	N/A	0.49	0.00	N/A	0.02	N/A	0.3	0.00
Aug.	0.002	0.16	0.11	0.45	0.0	0.02	0.003	0.14	0.2	0.00
Sept.	0.002	0.40	0.25	0.91	0.04	0.01	0.012	0.33	0.4	0.00
Oct.	0.002	0.18	0.12	0.64	0.01	0.01	0.010	0.15	0.2	0.00
Nov.	0.002	0.19	0.15	0.66	0.02	0.07	0.020	0.22	0.5	0.00
Dec.	0.001	0.06	0.18	0.44	0.01	0.01	0.012	0.41	0.2	0.00
Average	0.002	0.18	0.13	1.03	0.02	0.05	0.022	0.25	0.8	0.00
% SDM	± 48%	± 53	± 46%	± 59%	± 63%	± 114	± 106%	± 51%	± 119%	

^a Not applicable.

Table A-31. Physical and chemical examinations of LLNL liquid effluent.

	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec. ^a	Average	% SDM
	(mg/liter)					
BOD	47.	64.	78.		63.	25
COD	120.	116.	213.		150.	37
Ammonia nitrogen (as N)	21.	26.	20.		22.	14
Total Kjeldahl nitrogen (as N)	29.	29.	31.		30.	4
Nitrate nitrogen (as N)	0.08	<0.01	<0.1		0.03	120
Nitrite nitrogen (as N)	0.03	<0.001	<0.01		0.01	73
Oil and grease (FEM)	19.	<5.	<5.		10.	84
Sulfate	47.	52.	42.5		48.	9
Arsenic	<0.001	<0.001	<0.001		<0.0001	
Boron	0.57	0.39	0.52		0.49	18
Cyanide	0.09	0.058	<0.02		0.06	71
Mercury	0.009	0.0002	0.0015		0.004	140
Selenium	<0.001	<0.001	<0.001		<0.001	—
Total alkalinity (as CaCO ₃)	104.	102.	88.		98.	9
Total phosphorous (as P)	3.9	4.0	4.5		4.1	8
Chloride	26.	36.	16.		26.	38
Phenols	0.021	0.042	0.016		0.026	53
Calcium	11.	9.0	8.0		9.3	16
Magnesium	2.0	2.2	1.0		1.8	37
Sodium	28.	34.	18.		27.	30
Chromium	0.07	0.12	0.13		0.11	28
Copper	0.034	0.14	0.27		0.15	81
Nickel	0.005	0.17	0.010		0.06	146
Potassium	20.	21.	21.		21.	3
Zinc	0.23	0.14	0.42		0.26	53
Sodium as % of cations	50.	57.	43.5		50.	13
Total solids	185.	283.	192.		220.	25
Total dissolved solids	164.	200.	165.		176.	12
Volatile solids as % of total solids	17.6	20.	86.5		41.	94
Settleable solids (ml/liter/h)	1.3	0.3	0.12		0.57	112
Total suspended solids	—	17.3	23.		20.2	20
Total organic carbon		49.	64.		56.	19
Identifiable chlorinated hydrocarbons including PCB	Lindane: 0.07 µg/liter			n.d. ^b	n.d.	

^a No sample was taken during the fourth quarter.^b None detected.

The following compounds would have been reported had they appeared at or above their respective detection limits as indicated below:

Organochlorine pesticides	µg/liter	Polychlorinated biphenyls	µg/liter
Aldrin	0.05	Aroclors 1016-1262	0.3
Chlordane	0.3		
Endrin	0.1		
Dieldrin	0.05		
BHC (mixed isomers)	0.05		
DDT (mixed isomers)	0.1		
DDE (mixed isomers)	0.05		
DDD (mixed isomers)	0.05		
Heptachlor	0.05		
Heptachlor Epoxide	0.05		
Methoxychlor	0.2		

Table A-32. Site 300 water samples down gradient from liquid-discharge locations.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	%SDM
Specific conductance (μmhos/cm at 25°C)														
Location ^a	4	1350	1300	1300	1200	1570	1180	1210	1340	1280	1260	1240	1294	8
	5	992	1000	1070	949	1050	1220	1080	980	991	1010	960	1027	7
	14	1610	550	698	1040	1300	1260	1400	1580	1580	1510	1600	1090	28
	22	930	930	903	890	1080	1090	1140	1010	973	980	830	978	10
Total hardness as CaCO₃ (mg/l)														
Location	4	22	24	24	22	21	21	22	21	21	22	25	22	6
	5	43	44	42	43	45	55	55	54	46	51	42	47	11
	14	420	350	250	360	416	376	428	403	420	430	540	450	17
	22	42	43	46	47	45	42	59	55	58	47	55	49	13
Chloride (mg/l)														
Location	4	159	160	162	158	165	158	158	156	150	148	160	158	3
	5	86	84	88	78	80	78	65	65	73	66	79	77	11
	14	116	31	36	80	90	112	113	129	130	140	150	94	37
	22	66	66	65	70	72	71	67	69	70	64	71	68	4
Total organic carbon (mg/l)														
Location	4	9	15	34	21	15	2	13	16	12	9	15	15	55
	5	<5	13	35	10	<5	1	12	12	<5	11	12	11	81
	14	21	34	47	17	12	4	24	20	17	<5	26	12	61
	22	8	16	28	7	<5	3	16	7	9	7	14	11	66

^a See Fig. 10.

Table A-33. Estimated radiation dose to the public from LLNL airborne effluents during 1983.

Nuclide	Facility	Curies	Dose at site boundary (mrem)	Dose to nearest resident (mrem)	Dose within 80-km radius of LLNL ^a (man-rem)
³ H	Tritium facility	3024	0.27	0.1	0.8
	Insulating core accelerator	140	0.25	0.1	0.1
	Rotating target neutron source	81	0.1	0.0	0.0
¹³ N- ¹⁵ O	Linear accelerator	855	0.77	0.2	0.0

^aDose rounded to nearest one-tenth mrem.

Table A-34. Radioactive effluent releases from LLNL from 1976 through 1983.

Year	Airborne effluents (Ci)			Liquid effluents (Ci)	
	⁴¹ Ar	³ H	¹³ N- ¹⁵ O	HTO	²³⁹ Pu
1976	470	3991	1035	10	1.5×10^{-4}
1977	380	5210	990	13	3.6×10^{-4}
1978	766	5362	1445	9	8.6×10^{-4}
1979	383	4517	829	7	9.8×10^{-4}
1980	165	2305	1656	5	2.8×10^{-4}
1981	0	2620	344	6	0.92×10^{-4}
1982	0	2014	584	1.6	0.43×10^{-5}
1983	0	3245	855	1.7	0.67×10^{-5}

Table A-35. LLNL nonradioactive liquid effluent – storm drain runoff.

Analyses	Influent	Effluent	Lake
		(mg/liter)	
Nitrate nitrogen (as N)	0.34	<0.01	<0.01
Total phosphorous (as P)	0.61	0.90	0.67
Cyanide	<0.02	<0.02	<0.02
Phenols	<0.040	<0.029	0.026
Oil & grease (freon extractable)	3.4	6.7	9.3
Surfactants (MBAs)	0.41	0.10	0.39
Sulfate	11.3	13.8	14.7
Total identifiable chlorinated hydrocarbons	none ^a	none	none

^a The following compounds would have been reported had they appeared at or above their respective detection limits as indicated below:

<u>Organochlorine pesticides</u>	<u>µg/liter</u>
Aldrin	0.05
Chlordane	0.1
Endrin	0.1
Dieldrin	0.05
BHC (mixed isomers)	0.05
DDT (mixed isomers)	0.1
DDE (mixed isomers)	0.05
DDD (mixed isomers)	0.05
Heptachlor	0.05
 <u>Polychlorinated biphenyls</u>	 <u>µg/liter</u>
Aroclors 1016-1262	0.3

Table A-36. Summary of analyses for the quality assurance program.

		Value reported (pCi/liter)		
Analyses	Media	LLNL	Known	Grand average of all Laboratories
Gross alpha	Water	9 ± 1	14.0 ± 9	N/A ^a
		5 ± 1	7 ± 5	8 ± 2
		6 ± 0	11 ± 5	11 ± 3
		27 ± 2	29 ± 7	26 ± 6
Gross beta	Water	19 ± 1	16 ± 9	N/A
		25 ± 1	22 ± 5	22 ± 4
		63 ± 4	57 ± 5	54 ± 8
		39 ± 2	31 ± 5	32 ± 5
Putorium	Water	8.6 ± 0	8.9 ± 1	8.2 ± 1.5
Gross alpha	Air	16 ± 1	22 ± 10	N/A
		53 ± 2	46 ± 20	N/A
Gross beta	Air	68 ± 2	67 ± 9	N/A
		140 ± 0	143 ± 12	N/A
Tritium	Water	2317 ± 70	2389 ± 608	N/A
		1296 ± 113	1210 ± 324	1226 ± 185
		1843 ± 101	1846 ± 342	1864 ± 207
		1543 ± 110	1529 ± 337	1552 ± 202
		3293 ± 32	3330 ± 362	3298 ± 241
		2673 ± 46	2560 ± 353	2534 ± 273
The following values are relative; the exponents are not included, and therefore do not indicate actual concentrations.				
Be ⁷	Air	0.322	0.300	0.306
		0.336		
Co ⁵⁷		0.386	0.264	0.287
		0.389		
Co ⁶⁰		0.264	0.264	0.265
		0.276		
Sb ¹²⁵		0.278	0.795	0.687
		0.227		
Cs ¹³⁷		0.353	0.341	0.332
		0.745		
Pu ²³⁹		0.294	0.294	0.287
		0.301		
U (μg)		0.508	0.409	0.449
		0.516		
K ⁴⁰ Cs ¹³⁷ Ra ²²⁶ Pu ²³⁸	Soil	0.110	0.164	0.156
		0.170	0.240	0.250
		0.672	1.04	0.914
		0.237	0.270	0.258
Pu ²³⁹ Am ²⁴¹ U (μg)	Soil	0.141	0.156	0.146
		0.284	0.177	0.217
		0.178	0.280	0.239
³ H Mn ⁵⁴ Cs ¹³⁷ Ce ¹⁴⁴	Water	0.106	0.108	0.126
		0.502	1.66	1.64
		0.228	0.239	0.228
		0.430	10.9	10.3
Pu ²³⁹		0.705	0.870	0.688

^a Not available.

Appendix B. Environmental Activity Concentration—Guide Levels

The standards for Radiation Protection (DOE Manual 5480.1 Chg 2, issued April 29, 1981) state that the average activity of a mixture of radionuclides (whose identities and concentrations are unknown) in air and water should not exceed the following values:

1. Air (controlled area) $6 \times 10^{-13} \mu\text{Ci/ml}$
2. Air (uncontrolled area) $2 \times 10^{-14} \mu\text{Ci/ml}$
3. Water (controlled area) $4 \times 10^{-7} \mu\text{Ci/ml}$
4. Water (uncontrolled area) $3 \times 10^{-8} \mu\text{Ci/ml}$

If alpha emitters and ^{227}Ac are definitely not present, the following values may be used to determine permissible average activity:

5. Air (controlled area) $3 \times 10^{-11} \mu\text{Ci/ml}$
6. Air (uncontrolled area) $1 \times 10^{-12} \mu\text{Ci/ml}$

If ^{129}I , ^{226}Ra , and ^{228}Ra are definitely not present, the following values may be used:

7. Water (controlled area) $3 \times 10^{-6} \mu\text{Ci/ml}$
8. Water (uncontrolled area) $1 \times 10^{-7} \mu\text{Ci/ml}$

Both air and water samples are subjected to gross alpha and gross beta measurements. The average annual alpha activities of samples may not exceed the activity values listed as 1-4 above. Since the alpha emitters have been accounted for in the gross alpha measurements and the assumption is made that ^{129}I , ^{227}Ac , ^{226}Ra , and ^{228}Ra are not present in the samples, the average annual gross beta activities of the samples may not exceed the activities listed as 5-8 above. The assumption that ^{129}I , ^{227}Ac , ^{226}Ra , and ^{228}Ra are not present in air and water samples is reasonable in view of the minute quantities of these radionuclides available at the Laboratory. This reference also states that average tritium activities in off-site water samples may not exceed $3 \times 10^{-3} \mu\text{Ci/ml}$.

The external whole-body radiation dose to workers in controlled areas may not exceed 5 rem/y, and the dose to an individual in an uncontrolled area may not exceed 500 mrem/y. Also, a group of individuals in an uncontrolled area may not receive an average annual dose of more than 170 mrem.

Appendix C. Method of Dose Calculations

The doses shown in this report have been calculated using the models and methods in the Nuclear Regulatory Commission Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent*. Examples of these calculations and assumptions are shown in this appendix.

Annual Dose from Potable Water

Assuming that all water sampled is available as drinking water, the annual whole-body dose for tritium has been calculated using the following equation:

$$R_{\text{total body}} = C_w U_w D_w \quad (1)$$

where

C_w = concentration in pCi/liter,

U_w = intake rate, liters/y,

= 730 liters/y for maximum exposed individual,

D_w = dose factor, mrem/pCi,

= 1.05×10^{-7} mrem/pCi for the whole-body ingestion pathway for an adult.

$R_{\text{total body}}$ = annual dose in mrem to the total body from ingestion of 730 liters of potable water with concentration C_w .

Annual Dose from Forage-Cow-Milk Pathway for Tritium in Vegetation

Assuming that all feed for the cattle was pasture grass, the annual whole-body dose per $\mu\text{Ci/ml}$ HTO for the maximum exposed individual has been calculated using the following equation:

$$D_{\text{total body}} = D_{\text{veg}} + D_{\text{meat}} + D_{\text{milk}} \quad (2)$$

$$D_{\text{veg}} (\text{leafy vegetables}) = U_{\text{veg}} \times C_{\text{veg}} \times D_{\text{HTO}} \quad (2a)$$

where

U_{veg} = intake rate, kg/y, 64 kg/y for maximum exposed individual,

C_{veg} = concentration in pCi/kg = $10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}} \times C_{\text{veg}} \mu\text{Ci/ml}$ (measured),

D_{HTO} = dose factor, mrem/pCi = 1.05×10^{-7} mrem/pCi for ^3H for the adult whole-body ingestion pathway.

$$D_{\text{veg}} (\text{mrem/y}) = 0.67 \times 10^4 C_{\text{veg}} \mu\text{Ci/ml (measured)}$$

$$D_{\text{meat}} = U_{\text{meat}} \times C_{\text{meat}} \times D_{\text{HTO}} \quad (2b)$$

where

U_{meat} = 110 kg/y,

D_{HTO} = 1.05×10^{-7} mrem/pCi,

$C_{\text{meat}} = (F_i) (Q_i) (C_{\text{veg}}) \exp(-\lambda_i t_i)$

F_f = fraction of daily intake of nuclide per kg of animal/fish, days/kg,

Q_f = amount of feed consumed, kg/day,

C_{veg} = same as above,

λ_i = radiological decay constant, day⁻¹,

t_s = time between slaughter to consumption, days.

$$C_{meat} = \left(1.2 \times 10^{-2} \frac{\text{day}}{\text{kg}}\right) \left(50 \frac{\text{kg}}{\text{day}}\right) \left(C_{veg} \frac{\mu\text{Ci}}{\text{ml}}\right) \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}}\right) \\ \times \exp[-4.5 \times 10^3(20)] = 0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}} \times C_{veg} \frac{\mu\text{Ci}}{\text{ml}} (\text{measured}) ,$$

$$D_{meat} (\text{mrem/y}) = 0.69 \times 10^4 \times C_{veg} \mu\text{Ci/ml} (\text{measured}) ,$$

$$D_{milk} = U_{milk} \times C_{milk} \times D_{HTO} , \quad (2c)$$

where

$$U_{milk} = 310 \text{ liters/y},$$

$$D_{HTO} = 1.05 \times 10^{-7} \text{ mrem/pCi},$$

$$C_{milk} = F_m Q_f C_{veg} \exp(-\lambda_i t_f),$$

F_m = fraction of daily intake of nuclide per liter of milk, day/liter,

Q_f = amount of feed consumed, kg/day,

C_{veg} = same as above,

λ_i = radiological decay constant, days⁻¹,

t_f = transport time from the feed to milk receptor,

$$C_{milk} = \left(1.0 \times 10^{-2} \frac{\text{day}}{\text{liter}}\right) \left(50 \frac{\text{kg}}{\text{d}}\right) \left(C_{veg} \frac{\mu\text{Ci}}{\text{ml}}\right) \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}}\right) \\ \times \exp[-4.5 \times 10^3(2)] = 0.5 \times 10^9 \frac{\text{pCi/liter}}{\mu\text{Ci/ml}} \times C_{veg} \frac{\mu\text{Ci}}{\text{ml}} (\text{measured}) .$$

$$D_{milk} (\text{mrem/y}) = 1.63 \times 10^4 \times C_{veg} \mu\text{Ci/ml} (\text{measured}) .$$

$$D_{total} (\text{mrem/y}) = 0.67 \times 10^4 C_{veg} \mu\text{Ci/ml} (\text{measured}) + 0.69 \times 10^4 C_{veg} \mu\text{Ci/ml} (\text{measured}) \\ + 1.63 \times 10^4 C_{veg} \mu\text{Ci/ml} (\text{measured}) = 2.99 \times 10^4 C_{veg} \mu\text{Ci/ml} (\text{measured}) .$$

Annual Population Dose

To calculate the "fence-line" site boundary, nearest resident, and population doses, a continuous-point-source computer code based on the Gaussian plume model was used.

$$C_{\text{downwind}} = 3.17 \times 10^4 (\chi/Q)(Q) \quad , \quad (3)$$

where

χ/Q = diffusion parameter, sec/m^3 ,

Q = release rate, Ci/y ,

$$3.17 \times 10^4 = 1 \times 10^{12} \frac{\text{pCi}}{\text{Ci}} / 3.15 \times 10^7 \frac{\text{sec}}{\text{y}} \quad .$$

C_{downwind} = concentration downwind, pCi/m^3 .

$$D_{\text{max individual}} = U \times C_{\text{downwind}} \times D \quad , \quad (4)$$

where

U = intake rate, $\text{m}^3/\text{y} = 8000 \text{ m}^3/\text{y}$, inhalation rate
for adult maximum exposed individual ,

$$C_{\text{downwind}} = 3.17 \times 10^4 (\chi/Q)(Q) \quad ,$$

D = dose factor, mrem/pCi ,

for ^3H , $D = 1.05 \times 10^{-7} \text{ mrem}/\text{pCi} \times 1.5$ to include
immersion dose = $1.58 \times 10^{-7} \text{ mrem}/\text{pCi}$.

$$\text{for } ^{41}\text{Ar}, D = 8.84 \times 10^{-3} \frac{\text{mrem}-\text{m}^3}{\text{pCi}-\text{y}} \quad ,$$

(Inhalation rate is included in the dose factor)

for ^{13}N , $D = D(^{41}\text{Ar})$.

$$\text{for } ^{15}\text{O}, D = D(^{41}\text{Ar}) \times \frac{1.74}{1.2} \quad ,$$

$$D_{\text{max individual}} = \text{mrem}/\text{y} \quad .$$

For population dose, the diffusion factors and population figures for an area within 80 km of the Laboratory were summed over all directions.

$$\text{Dose (man-rem)} = 3.17 \times 10^4 \left[\sum_i^n (\chi/Q)_i P_i \right] Q U D \quad , \quad (5)$$

where

$$\left[\sum_i^n (\chi/Q)_i P_i \right] = \text{Summation of the } (\chi/Q) \text{ for region } i \\ \text{times the population in region } i \text{ for all regions } n, \frac{\text{man-sec}}{\text{m}^3} \quad .$$

Q = release rate, Ci/y ,

U = inhalation rate, average individual (adult),

D = dose factor, rem/pCi ,

Dose = man-rem.

Section 18.62.5 **State Requirements.**

State requirements and limitations on discharges shall apply in any case where they are more stringent than Federal requirements and limitations or those in this article.

Appendix D. Discharge Limits to The Sanitary Sewer System Of the City of Livermore

Sections 18.62, 18.62.2, 18.62.3, 18.62.4, and 18.62.5 of the Code of the City of Livermore (1983) state the discharge limits for Livermore's sanitary sewer system. These limits are as follows:

Section 18.62 General Discharge Prohibitions.

No person shall contribute or cause to be contributed, directly or indirectly, any pollutant or wastewater which will interfere with the operation or performance of the publically-owned treatment works (POTW). These general prohibitions apply to all such users of the POTW whether or not the user is subject to national categorical pretreatment standards or any other national, state, or local pretreatment standards or requirements. A user may not contribute the following substances to the POTW:

(a) Any liquids, solids or gases which by reason of their nature or quantity are, or may be, sufficient either alone or by interaction with other substances to cause fire or explosion or be injurious in any other way to the POTW or to the operation of the POTW. At no time, shall two successive readings on an explosion hazard meter, at the point of discharge into the system (or at any point in the system) be more than five percent (5%) nor any single reading over ten percent (10%) of the lower explosive limit (LEL) of the meter. Prohibited materials include, but are not limited to, gasoline, kerosene, naphtha, benzene, toluene, xylene, ethers, alcohols, ketones, aldehydes, peroxides, chlorates, perchlorates, bromates, carbides, hydrides, and sulfides and any other substances which the city, the state or EPA has notified the user is a fire hazard or a hazard to the system.

(b) Solid or viscous substances which may cause obstruction to the flow in a sewer or other interference with the operation of the wastewater treatment facilities such as, but not limited to: grease, garbage with particles greater than one-half inch (1/2") in any dimension, animal guts or tissues, paunch manure, bones, hair, hides or fleshings, entrails, whole blood, feathers, ashes, cinders, sand, spent lime, stone or marble dust, metal, glass, straw, shavings, grass clippings, rags, spent grains, spent hops, waste paper, wood, plastics, gas, tar, asphalt residues, residues from refining, or processing of fuel or lubricating oil, mud, or glass grinding or polishing wastes.

Specifically excluded from the sewers are waste products resulting from the handling, storage and sale of fruits and vegetables from other than retail produce establishments, or other foods not intended primarily for immediate consumption.

(c) Any wastewater having a pH less than 6.8 or greater than 8.5, unless a city permit is obtained. Wastewater having any other corrosive property capable of causing damage or hazard to structures, equipment, and/or personnel of the POTW is also prohibited.

(d) Any wastewater containing toxic pollutants in sufficient quantity, either singly or by interaction with other pollutants, to injure or interfere with any wastewater treatment process, constitute a hazard to humans or animals, create a toxic effect in the receiving waters of the POTW, or to exceed the limitation set forth in the categorical pretreatment standard. A toxic pollutant shall include, but not be limited to any pollutant identified pursuant to section 307(a) of the Act.

(e) Any noxious or malodorous liquids, gases, or solids which either singly or by interaction with other wastes are sufficient to create a public nuisance or hazard to life or are sufficient to prevent entry into the sewers for maintenance and repair.

(f) Any substance which may cause the POTW's effluent or any other product of the POTW such as residues, sludges, scums, or gases, to be unsuitable for reclamation and reuse or to interfere with the reclamation process. In no case, shall a substance discharged to the POTW cause the POTW to be in noncompliance with sludge use or disposal criteria, guidelines or regulations developed under Section 405 of the Act, any criteria, guidelines, or regulations affecting sludge use or disposal developed pursuant to the Solid Waste Disposal Act, the Clean Air Act, the Toxic Substances Control Act, or state criteria applicable to the sludge management method being used.

(g) Any waters or wastes which contain more than 100 mg/l of freon extractible fat, oil, or grease.

(h) Any substance which will cause the POTW to violate its NPDES Permit or the receiving water quality standards.

(i) Any wastewater with objectionable color not removed in the treatment process, such as, but not limited to, dye wastes and vegetable tanning solutions.

(j) Any wastewater having a temperature which will inhibit biological activity in the POTW treatment plant resulting in interference, but in no case wastewater with a temperature at the introduction into the POTW which exceeds 40°C (104°F).

(k) Any pollutants, including oxygen demanding pollutants (BOD, etc.) released at a flow rate and/or pollutant concentration which a user knows or has reason to know will cause Interference to the POTW.

(l) Any wastewater containing any radioactive wastes or isotopes of such half-life or concentration as may exceed the limits established by the state or federal regulatory agency applicable to the POTW user.

(m) Any wastewater which causes a hazard to human life or creates a public nuisance.

(n) Any waters or wastes containing total dissolved solids increment greater than three hundred and twenty-five mg/l, nor chloride increment greater than seventy-five mg/l, increase during a single cycle use of the water supply, unless a city permit is obtained to exceed this limit.

(o) Any water or wastes having a BOD greater than three hundred (the average BOD for residential users), unless a city permit is obtained.

(p) Any waters or wastes containing more than three hundred mg/l of suspended solids (the average suspended solids for residential users), unless a city permit is obtained.

When the Superintendent determines that a user(s) is contributing to the POTW, any of the above-named substances in such amounts as to interfere with the operation of the POTW, the Superintendent shall (1) advise the user(s) of the impact of the contribution on the POTW, and (2) develop effluent limitations(s) for such user to correct the interference with the POTW.

Section 18.62.2 Federal Categorical Pretreatment Standards.

Upon the promulgation of the Federal Categorical Pretreatment Standards for a particular industrial subcategory, the Federal Standard, if more stringent than limitations imposed under this article for sources in that subcategory, shall immediately supersede the limitations imposed under this article. The Superintendent shall notify all affected users of the applicable reporting requirements under 40 CFR, Section 403.12.

Section 18.62.3 Modification of Federal Categorical Pretreatment Standards.

Where the city's wastewater treatment system achieves consistent removal of pollutants limited by Federal Pretreatment Standards, the city may apply to the state/EPA for modification of specific limits in the Federal Pretreatment Standards. "Consistent Removal" shall mean reduction in the amount of pollutant or alteration of the nature of the pollutant, by the wastewater treatment system, to the less toxic or harmless state, in the effluent which is achieved by the system in 95 percent of the samples taken when measured according to the procedures set forth in section 403.7 (c) (2) of (Title 40 of the Code of Federal Regulations, Part 403)—"General Pretreatment Regulations for Existing and New Sources of Pollution" promulgated pursuant to the Act. The city may then modify pollutant discharge limits in the Federal Pretreatment Standards if the requirements contained in 40 CFR, Part 403, section 403.7, are fulfilled and prior approval from state/EPA is obtained.

Section 18.62.4 Specific Pollutant Limitations.

No person shall discharge wastewater containing in excess of:

0.1	mg/l arsenic
0.2	mg/l cadmium
2.0	mg/l copper
1.0	mg/l cyanide
1.0	mg/l lead
0.01	mg/l mercury
1.0	mg/l nickel
0.2	mg/l silver
1.0	mg/l total chromium
3.0	mg/l zinc
0.02	mg/l total identifiable chlorinated hydrocarbons
1.0	mg/l phenolic compounds
0.01	mg/l polychlorinated biphenyls

Appendix E. Sampling and Analytical Procedures for Environmental Monitoring at Lawrence Livermore National Laboratory

Sample collection and analysis procedures are an integral part of the quality assurance program developed for environmental monitoring at Livermore. These procedures provide a basis for verifying that sampling and analytical activities are being performed as specified.

This appendix describes the sampling procedures, analytical determinations, and preparation for radio-counting by the LLNL Hazards Control Department personnel. The radiochemical methods used by the LLNL Nuclear Chemistry Division, were described in detail in Appendix E in the 1982 Annual Environmental Monitoring Report and remain essentially unchanged.

SAMPLING AND ANALYTICAL PROCEDURES USED BY THE
LLNL HAZARDS CONTROL DEPARTMENT

CONTENTS

Introduction	E-3
Air Sampling	F-3
Collection	E-4
Identification	E-4
Replication	E-5
Soil Sampling	E-5
Collection	E-5
Identification	E-6
Replication	E-6
Water Sampling	E-6
Collection	E-6
Identification	E-7
Replication	E-7
Sewage Sampling	E-7
Collection	E-7
Identification	E-8
Replication	E-8
Vegetation Sampling	E-8
Collection	E-8
Identification	E-9
Replication	E-9
Milk Sampling	E-9
Air Analysis	E-9
Gross Alpha and Beta Counting	E-10
Beryllium	E-10
Water Analysis	E-11
Gross Alpha and Beta Activity	E-11
Sewage Analysis	E-11
Gross Alpha and Beta Radioactivity	E-12
Tritium	E-12
Heavy Metals	E-12

INTRODUCTION

Written procedures have been prepared for each environmental monitoring activity at Livermore as part of the quality assurance program developed for environmental monitoring at LLNL. The sample collection and analysis procedures described herein have been reviewed and approved by those responsible for managing the monitoring program. During a program audit, such written documentation can be used to verify that sampling and analytical procedures meet program specifications.

The "Sampling" sections of this report describe the sampling procedures used for each sample medium monitored. A general description of each medium is usually provided. This is followed by the collection procedure used, provisions for sample identification, and a schedule for sample replication.

The "Analysis" sections of this report cover sample analysis. General comments on each sample medium analyzed are followed by specific descriptions of standards and calibrations, analytical procedures, and/or counting procedures as applicable for each medium.

AIR SAMPLING

Continuously operating air samplers are used at LLNL to measure the concentration of airborne particulate radioactivity, beryllium, and tritiated water. Samplers placed at six perimeter locations at LLNL and at nine locations at Site 300 measure particulate radioactivity and beryllium. Particulate radioactivity is also measured at 10 off-site locations near the Laboratory. Tritiated-water samplers are operated at the six LLNL perimeter locations and at two off-site locations. In all cases, samplers are so placed as to provide reasonable assurance that any significant concentration of effluents from Laboratory operations would be detected regardless of local meteorology.

COLLECTION

Particulates

LLNL perimeter and Site 300 particulate samples are collected on $5.2 \times 10^{-2} \text{ m}^2$ Whatman filters, using average flow rates of 700 liters/min. Off-site samplers in the Livermore Valley use $4.6 \times 10^{-3} \text{ m}^2$ Flanders F-700 glassfiber filters operated at a flow rate of 80 liters/min. Particulate sample flow rates are calibrated with a spirometer that has been calibrated against an immersion unit certified by the National Bureau of Standards. Flow rates of Hi-vol air samplers are verified at monthly intervals with a portable field-calibration unit.

Tritiated Water

Samples of tritiated-water vapor are collected by drawing air through silica-gel-packed columns at flow rates of about 0.5 liters/min. Columns are exchanged weekly.

IDENTIFICATION

Particulates

Particulate samplers are run continuously, and sample filters are exchanged weekly. Each filter is identified by location, date on, date off, elapsed sampling time, and flow rate. Filter samples are placed in glassine envelopes and are transported to the laboratory, where this information is transferred to log sheets and each sample is given a serial number that accompanies it during analysis. Half of each LLNL perimeter and Site 300 filter is used for beryllium analysis; the other half is retained for radioactivity measurements.

Tritiated Water

Tritiated-water vapor samplers are run continuously, and silica-gel holders are exchanged biweekly. Each sample is identified by location, date

on, date off, elapsed sampling time, and flow rate. This information is transferred to log sheets in the laboratory, and each sample is given a serial number that accompanies it during analysis.

REPLICATION

Particulates

At bimonthly intervals, a particulate air sampler is operated in parallel with the permanent sampler at one of the six LLNL perimeter locations. This parallel operation is continued for one month, filters are changed weekly, and both filters are submitted for analysis in the usual manner. Bimonthly rotation of the extra sampler among the six locations ensures samplers are checked annually. The replicate samples are then compared with respect to gross alpha and beta activities and to ^{239}Pu content.

Tritiated Water

Parallel samples of tritiated-water vapor are collected at LLNL perimeter locations during alternate months from those locations in which particulate replicates are being collected.

SOIL SAMPLING

Soil samples are collected annually within the Livermore Valley and at Site 300. Radiochemical analysis of these samples serves to document any changes that may have occurred during the year. Increases in radioactivity that may result from Laboratory operations are brought to the public's attention through annual monitoring reports.

COLLECTION

Sampling sites are selected in reasonably level areas that represent undisturbed soil. A 2-m square is marked off in each such area, and an

8.25-cm-diam coring tool designed at LLNL is used to collect 5-cm-deep samples at the corners and center of the square.

IDENTIFICATION

The five samples of soil collected from each 2-m square are placed in plastic bags and are identified by number. This number is entered in a log book, together with the sampling data and a description of the sample location. The number is used to identify the sample throughout the laboratory analysis and in the annual monitoring report.

REPLICATION

During each annual collection of soil samples, at least 10% of the sites are sampled in duplicate. In such collections, two adjacent 5-cm-deep cores are taken from the corners and center of each 2-m square. Separate composites of the five cores are then made, and the composites are identified by successive numbers.

WATER SAMPLING

At quarterly intervals, water samples from various sources in the Livermore Valley and at Site 300 are analyzed for gross alpha and beta radioactivity and for tritium content. These analyses are performed to determine if detectable changes in radioactivity have occurred.

COLLECTION

Grab samples of such surface sources as ponds, creeks, and reservoirs are obtained with a tethered plastic pail. The samples are transferred to 4-liter plastic containers to which 6.5 ml of concentrated HCl has been added. For tritium analyses, a 1-liter sample is collected in an argon-flushed glass container fitted with a ground-glass stopper.

IDENTIFICATION

As samples are collected in the field, they are tagged with sampling location and date. In the laboratory, each sample is assigned the number that accompanies it during analysis.

REPLICATION

During each sample collection period, at least 10% of the water samples are duplicates.

SEWAGE SAMPLING

Sewage from the Laboratory is discharged into the City of Livermore's sanitary sewer system. Radioactive or otherwise hazardous liquid wastes are first treated to reduce concentration levels to within applicable standards before they are released into the sanitary sewer. Sewage samples are collected from LLNL effluent and from the treated effluent of the Livermore Water Reclamation Plant (LWRP).

COLLECTION

LLNL Effluent

A 24-hr composite of LLNL sewage effluent is collected daily by a motorized proportional sampler. Aliquots of this composite are transported to the laboratory in 500-ml wide-mouthed polyethylene bottles.

LWRP Effluent

Daily composites of treated effluent from the LWRP are also collected by a proportional sampler. Aliquots of these composites are placed in 500-ml polyethylene bottles and are retained for weekly collection by LLNL.

IDENTIFICATION

As each sewage sample is collected in the field, it is tagged with the sampling location and date of sampling. In the laboratory, each sample is assigned a number that accompanies it during analysis.

REPLICATION

LLNL Effluent

Every Wednesday, one replicate sample of LLNL effluent is taken for gross alpha, beta, and tritium. For one month each year, duplicate samples of LLNL effluent are taken each day to permit preparation of duplicate monthly composites.

LWRP Effluent

One replicate sample of LWRP effluent is taken every Wednesday and is analyzed for gross alpha, beta, and tritium. For one month each year, duplicate samples are taken each day to permit preparation of duplicate monthly composites.

VEGETATION SAMPLING

At quarterly intervals, samples of vegetation (usually native grasses) are collected throughout the Livermore Valley, at Site 300, and at the off-site locations near Site 300. After these samples are freeze-dried, the tritium content of the recovered water is determined with liquid-scintillation counting.

COLLECTION

Samples of vegetation are routinely collected from the same locations each sampling period. Grass samples are pulled up or cut close to the ground, and any soil is discarded. The bulk volume of these samples is usually between

0.5 and 1 liter. As each sample is collected, it is placed in a plastic bag and frozen in a dry-ice chest to minimize water loss on the bag surface. The duplicate samples collected at each location are later transferred to a freezer in the laboratory.

IDENTIFICATION

Samples of vegetation collected in the field are tagged according to sample type and location. In the laboratory, each sample is assigned a number that accompanies it until the measurement is reported. Measurement data are permanently retained on computer cards.

REPLICATION

Two samples of vegetation are collected at each location in case the first sample is lost during analysis or the measurement is in question. At least one set of each group of samples collected is analyzed in duplicate to furnish replicate measurement data.

MILK SAMPLING

Milk samples are obtained at monthly intervals from two goat farms located about 5 km south and 5 km southeast of the Laboratory. A 3-liter portion of each milk sample is vacuum-distilled, and the tritium content of the distilled water is determined by liquid scintillation. Each 3-liter sample is then concentrated by evaporation and gamma-counted.

AIR ANALYSIS

Environmental air samples are analyzed for gross alpha and beta activity and for various gamma-emitting radionuclides, plutonium isotopes, uranium isotopes, and beryllium.

GROSS ALPHA AND BETA COUNTING

After a four-day delay to allow for decay of the radon-thoron daughters, all environmental-radioactivity air filters are counted for alpha and beta activity. Counting is done in a Sharp gas-proportional counter using 60-min counting periods. Normally, this counter is used only for environmental samples since a duplicate counting system is provided for routine samples.

Standards and Calibration

Separate ^{239}Pu and ^{90}Sr standards on 5-cm-diam stainless steel convoluted planchets are used for determining alpha and beta counting efficiencies, respectively. These standards are traceable to NBS or to equivalent certified sources. Counting-efficiency measurements are made with each set of filters counted, and a background count is taken at the beginning of each run and between each set of 10 samples. Records are kept of background and counting-efficiency variations in the Sharp counter.

BERYLLIUM

Every month, half of each weekly LLNL perimeter and Site 300 paper air filter is composited by sampling location. Two paper filters at a time are wet-ashed with a mixture of 80% nitric and 20% perchloric acid. The solutions are then evaporated to a few ml, taking care not to allow samples to bake dry. After the samples are diluted with water, they are filtered, any residues are discarded, and the filtrates are diluted to 25 ml with deionized water.

Any fine particulate matter passing through the filter is removed by centrifugation. The analysis is performed in an atomic emission spectrometer with a plasma source. Blanks and known spikes are subjected to the same procedure for quality control.

Standards and Calibration

Beryllium standards are prepared with 0.5 and 1 μg of beryllium per 25 ml of solution. The recorder readout of the Model 306 Perkin Elmer atomic

absorption spectrophotometer is set at 30x absorbance expansion, and the spectrophotometer is zeroed while aspirating deionized water into the flame. Instrument responses from the 0.5- and 1- μ g beryllium standards are then recorded. Following these calculations, the response of each monthly composite is recorded and its beryllium content is calculated from the calibration data.

WATER ANALYSIS

Environmental water samples are analyzed for gross alpha and beta activity and for tritium content.

GROSS ALPHA AND BETA ACTIVITY

A 100-ml sample or less, depending on the solid's content, is digested with a mixture of 80% HNO_3 and 20% HClO_4 , and taken to dryness. The residue is taken up with HNO_3 and a few milliliters of H_2O_2 (5%). The solution is evaporated to about 5 ml and transferred to a 5-cm-diam serrated stainless steel planchet. After drying and flaming the planchet, the sample is counted for 60 min in a Sharp 3-1/4-in proportional counter.

Standards and Calibration

The ^{239}Pu and ^{90}Sr standards are used with every sample set (see the "Soil Analysis" section on standards and calibration). Instrument background measurements are made between every 10 sample-counting measurements.

SEWAGE ANALYSIS

Except for tritium analyses, all sewage samples are wet-digested with a mixture of 20% HClO_4 and 80% HNO_3 . Those sewage samples for tritium analysis are distilled to reduce self-absorption before counting.

GROSS ALPHA AND BETA RADIOACTIVITY

About 25 ml of an 80/20 mixture of HNO_3 and HClO_4 is added to a 500-ml aliquot (100 ml of LWRP effluent), and the mixture is heated to dryness on a hotplate. The residue is taken up in 10 ml HNO_3 and 5 ml H_2O_2 (5%). The volume is reduced to 3-5 ml on a hotplate and transferred to 5-cm-diam planchets and counted.

TRITIUM

A 5-ml aliquot of sewage sample is added to 15 ml of Packard Insta-Gel in a 25-ml screw-cap polyethylene bottle. Then, 15 ml of Insta-Gel is used to prepare a background for the sample, and both are placed in the refrigerated detection chamber of the Packard scintillation counter for a 6-hr temperature-equilibration period prior to counting. The sample and background are each counted for 100 min.

HEAVY METALS

Monthly composites of LLNL sewage effluent are analyzed for cadmium, chromium, copper, iron, lead, nickel, and silver.

A composite is prepared by combining daily samples of 500 ml, as follows: nitric acid (80%) and HClO_4 (20%) are added to the first 500-ml daily sample of the month, and the mixture is reduced in volume to about 100 ml. Each subsequent day the daily sample is added and the total volume reduced to about 100 ml. After the last 500 ml from the last day is added, the combined volume is reduced to about 50 ml. When cool, about 50 ml deionized water is added and the liquid is filtered through No. 40 Whatman paper. The paper is then placed in a platinum crucible and digested with about 5 ml HF, 16 ml HNO_3 , and 4 ml HClO_4 to a residue of about 4-5 ml. Water is added and the liquid is refiltered. The residue is discarded. The filtrates are combined, transferred to a 100-ml volumetric flask, and brought to volume with deionized water. The metals are determined with a Perkin-Elmer Model 306 atomic absorption spectrophotometer. The required standards are prepared by dilution of 1000-ppm NBS-traceable stock solution.

Distribution

External Distribution

T. V. Crawford
W. C. Reinig
E. I. duPont de Nemours and Co.
Savannah River Plant
Aiken, SC 29801

A. P. Hull
Brookhaven National Laboratory
Upton, NY 11973

J. O. Ward
Department of Health Services
Radiologic Health Section
714 P Street
Sacramento, CA 95814

J. T. Davis
U.S. Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, CA 94612

H. F. Anderson
Monsanto Research Corporation
Mound Laboratory
Miamisburg, OH 45342

W. R. Hansen
Los Alamos National Laboratory
Los Alamos, NM 87544

R. E. Yoder
Rockwell International
Rocky Flats Plant
Golden, CO 80401

J. A. Auxier
Oak Ridge National Laboratory
Oak Ridge, TN 37830

P. Lovell
Sandia Laboratories
Livermore, CA 94550

S. F. Crow
Environmental Protection Agency
215 Fremont Street
San Francisco, CA 94105

H. Brinkley
Bay Area Air Quality Management District
939 Ellis Street
San Francisco, CA 94109

H. J. Nafitzger
ABAG
Claremont Hotel
Ashby Ave. and Domingue Ave.
Oakland, CA 94705

P. E. Bramson
Battelle Northwest
P.O. 999
Richland, WA 99352

J. Killingstad
Alameda County Flood Control Dist., Zone 7
1404 Concannon Blvd.
Livermore, CA 94550

L. Horner, City Manager Livermore
2250 First Street
Livermore, CA 94550

R. E. Broz
Vallecitos Nuclear Center
Pleasanton, CA 94566

S. Morse
California Regional Water Quality Control Board
1111 Jackson Street
Oakland, CA 94612

G. Facer
A. Pressesky
J. Miller
C. Sherman
USDOE Headquarters
Washington, DC 20545

E. L. Lenahan
Alameda County Water District
38050 Fremont Blvd.
Fremont, CA 94537

V. V. Williams
San Joaquin Local Health District
P.O. Box 2009
Stockton, CA 95201

W. Adams
Livermore Water Reclamation Plant
1250 Kitty Hawk Road
Livermore, CA 94550

J. Robertson
California Regional Water Quality Control Board
3201 S Street
Sacramento, CA 95816

Tak Shirasawa
Environmental Health Planning
Alameda County Health Care Services Agency
470 27th Street
Oakland, CA 94612

M. Williamson
Director of Radiological
and Environmental
Sciences Laboratory
DOE-IDO
550 2nd Street
Idaho Falls, ID 83401

W. A. Laseter
Mason & Hanger-Silas Mason Co., Inc.
Pantex Plant
P.O. Box 30020
Amarillo, TX 79177

N. W. Golchert
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

D. Harper
British Nuclear Fuels Limited
Health and Safety Directorate
Risley, Warrington, Cheshire,
UNITED KINGDOM

W. A. Scoggins
Reynolds Electrical and Engineering Co., Inc.
2501 Wyandotte
Las Vegas, NV 89114

Distribution Category
UC-11

(239)