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Environmental Monitoring at the Lawrence Livermore National Laboratory

1985 Annual Report

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Foreword

This report is prepared for the U.S. Department of Energy by the Guidance and Support Element of the Environmental Protection Program at Lawrence Livermore National Laboratory. It reports the results of the Environmental Quality Verification Program, which is an expanded continuation of the program of environmental monitoring previously carried out by the Environmental Measurements Group of the Hazards Control Department. Data are obtained through the combined efforts of the Environmental Protection Program, the Nuclear Chemistry Division, and the Hazards Control Department. In addition to the authors listed, the following personnel made significant contributions to this report:

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Introduction

The Laboratory and Adjacent Sites

The Lawrence Livermore National Laboratory (LLNL) is located about 64 km (39 mi) east of San Francisco, California, in the Livermore Valley of eastern Alameda County, approximately 5 km (3 mi) east of the city of Livermore. Sandia National Laboratories, Livermore (SNLL) is located adjacent to LLNL's southern boundary. Nearly 5.1 million people live within 80 km of LLNL (see Fig. 1); of these, approximately 50,000 live in Livermore.

The Lawrence Livermore National Laboratory, operated by the University of California for the United States Department of Energy (DOE), was established in 1952 to conduct nuclear weapons and magnetic fusion energy research. Since then, other major programs have been added, including laser fusion and laser isotope separation, biomedical and environmental sciences, and applied energy technology. These programs, in turn, require research in basic scientific disciplines, including chemistry and materials science, computer science and technology, engineering, and physics. LLNL also carries out a variety of projects for other federal agencies.

Much of LLNL's materials testing and high-explosives diagnostic work is conducted at Site 300, located in the sparsely populated hills of the Diablo Range, 16 km (10 mi) southeast of Livermore. Figure 1 shows the location of LLNL and Site 300 with respect to the city of Livermore and surrounding areas.

In 1985, LLNL employed approximately 8,500 people.

Sandia National Laboratories, Livermore, is operated by AT&T Technologies, Inc., under contract to DOE. SNLL's primary mission is research and development associated with nuclear weapons systems engineering and related national se-

curity tasks. In addition, it has energy programs involving combustion, fusion, and solar research, and conducts research and development projects for other federal agencies.

In 1985, SNLL employed approximately 1,100 people.

LLNL and SNLL are separate facilities, with different DOE operations headquarters and different local management. Some of the SNLL data are included here because the two sites are adjacent and they conduct similar operations.

The complete report of environmental monitoring data for SNLL is published in 1985 *Environmental Monitoring Report, Sandia National Laboratories, Livermore, CA* (SAND86-8012).

The Livermore Site

LLNL and SNLL are located in the southeastern portion of the Livermore Valley, which is an east-west oriented topographic and structural depression within the Diablo Range of the California Coast Range Province. The Livermore Valley forms an irregularly shaped lowland area approximately 25 km (16 mi) long, east to west, and averages 11 km (7 mi) wide, north to south. The floor of the valley slopes to the west from an elevation of approximately 200 m (660 ft) at the eastern end to approximately 90 m (295 ft) at its drainage outlet, located near the southwestern corner.

The climate of the Livermore Valley is characterized by mild, rainy winters and warm, dry summers. The mean annual temperature is 12.5°C (59°F); the normal seasonal temperature range is defined by nighttime winter lows in the vicinity of 0°C (32°F), and summer daytime highs around 38°C (100°F). Annual wind data are given in Fig. 2. Prevailing winds are from the west and

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

southwest during April through September; during the remainder of the year, wind directions are variable. Rainfall, as well as wind pattern, exhibits a strong seasonal pattern. Most of the precipitation occurs between October and April, with very little rainfall during the warmer months of the year. The highest and lowest annual rainfalls on record are 782 mm (30.8 in.) and 138 mm (5.4 in.), with a 115-year average of 369 mm (14.5 in.). Rainfall at LLNL for the 1984-1985 water year (October 1, 1984 through September 30, 1985) was 313 mm (12.3 in.).

Surface drainage is by westward-flowing intermittent streams (arroyos) that merge in the west end of the valley to form the southward flowing Arroyo de la Laguna, a tributary to the Alameda Creek drainage system. Winter flows that are not captured as groundwater recharge flow out of the southwestern corner of the valley and eventually enter San Francisco Bay by way of

Alameda Creek. Surface water bodies near the laboratories include: the South Bay Aqueduct, which runs from northeast to southwest, 0.2 km (0.1 mi) to the southeast of LLNL; the treatment tanks and reservoir of the Patterson Pass water treatment facility, about 1.2 km (0.7 mi) east of LLNL; Frick Lake, an area of enclosed drainage 4 km (2.4 mi) north of LLNL, where winter stormflows accumulate in an intermittent pond; and the Springtown pond, an artificial decorative pond maintained in a community recreation area 2.6 km (1.6 mi) northwest of LLNL. Lake Del Valle, a water storage reservoir 8 km (4.9 mi) south of LLNL, provides aquatic recreation (swimming, boating, and fishing), as does the Shadow Cliffs Regional Park Recreation Area, 11 km (6.7 mi) to the west. Lake Isabel, 9 km (4.9 mi) to the southwest, is a fee-for-fishing area. Both Lake Isabel and the Shadow Cliffs facility are excavations produced by gravel quarry operations,

Average annual percent frequency of wind direction vs. wind speed (m/s)										Average speed (m/s)
Direction	0-2	2-3	3-5	5-7	7-9	9-11	11-16	16-20	>20	
N	1.6	0.5	0.8	0.7	0.4	0.2	0	0	0	3.9
NNE	1.4	0.7	1.4	0.7	0.3	0	0	0	0	3.4
NE	1.6	1.0	1.5	0.5	0	0	0	0	0	2.9
ENE	1.5	0.7	1.0	0.5	0.1	0	0	0	0	3.0
E	1.8	0.6	0.5	0.1	0	0	0	0	0	2.1
ESE	1.6	0.4	0.3	0.1	0	0	0	0	0	1.8
SE	1.4	0.3	0.3	0.1	0	0	0	0	0	1.9
SSE	1.1	0.2	0.1	0	0	0	0	0	0	1.7
S	1.7	0.4	0.4	0.1	0	0	0	0	0	2.5
SSW	2.4	1.0	1.3	0.2	0.1	0	0	0	0	2.6
SW	3.4	3.2	5.5	3.7	1.1	0.1	0	0	0	3.9
WSW	3.2	3.6	5.8	2.8	0.7	0.1	0	0	0	3.6
W	2.4	2.0	5.6	3.8	1.0	0	0	0	0	4.1
WNW	1.3	0.7	0.9	0.7	0.5	0.1	0	0	0	3.7
NW	1.3	0.3	0.1	0.1	0	0	0	0	0	2.0
NNW	1.3	0.3	0.3	0.1	0.1	0.1	0	0	0	2.5
Calm										10.4
Total	29.0	15.7	25.8	14.1	4.2	0.7	0.1	0	0	3.1

Winds are based on 15 minute averages.
No instantaneous winds are available.

Figure 2. Wind rose showing the average annual wind direction and speed during 1985.

which continue to develop additional pits in the same general area. Both LLNL and SNLL normally receive their treated water supply from the Hetch Hetchy Aqueduct (which supplies San Francisco), located 11 km (6.7 mi) southwest of Livermore.

The hydrogeology and groundwater occurrence and movement in the vicinity of the laboratories have been the subjects of several recent and continuing investigations (see the Groundwater Monitoring and Special Assessments sections of this report). The following description has been summarized from the reports of these investigations¹⁻³ and from data supplied by Zone 7, Alameda County Flood Control and Water Conservation District.

The Livermore Valley is bound in the east by the Altamont Hills, where the Miocene-age Neroly, Cierbo Formations, and rocks of the late Cretaceous Great Valley sequence are exposed. Within the valley, lacustrine and fluvial valley fill deposits occur to depths in excess of 1 km. The oldest of these is the Lower Livermore Formation of late Tertiary-age, a hard, locally lithified, predominately fine-grained sedimentary sequence that is exposed in the hills south of the valley, and is encountered beneath the LLNL and SNLL sites at depths ranging from 7 m (23 ft) in the east to 119 m (389 ft) in the west. Above the Lower Livermore Formation are the heterogeneous unconsolidated alluvial sediments of the Pleistocene-age Upper Livermore Formation, which consist of complexly interbedded layers of poorly sorted clay, silt, sand, and gravel. The late Pleistocene and Holocene-age alluvial deposits that form the uppermost sequence of valley sediments are virtually identical to the Upper Livermore Formation.

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley groundwater basin, and is an important water-bearing formation. Annually, approximately 13 million cubic meters (10,500 acre-feet) of groundwater are extracted for domestic and agricultural use in the Livermore Valley. Most of this volume is pumped from municipal supply wells in Pleasanton and Livermore. In 1985, groundwater usage represented approximately 35% of total water consumption in the Livermore Valley.

Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Zone 7, the agency responsible for groundwater management in the Livermore Valley basin, conducts artificial recharge as needed to maintain groundwater levels. This is done by releasing water from Lake Del

Valle or the South Bay Aqueduct into arroyo channels in the eastern portion of the valley. Groundwater flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Groundwater flow in the basin is generally assumed to be primarily horizontal, although a significant vertical component probably exists in fringe areas and under localized sources of recharge.

Beneath the LLNL site, the depth to water table varies from about 43 m (140 ft) to 14 m (45 ft) according to observations during 1985. Figure 3 shows a contour map of water table elevations (feet above mean sea level) for April 1985. Although water table elevations vary with seasonal and year-to-year variations in both natural and artificial recharge, the qualitative patterns shown in Fig. 3 are generally maintained. At the eastern edge of the LLNL site, groundwater gradients (change in elevation per unit of horizontal distance) are quite steep, but under most of the site and farther to the west, the contours flatten out to a gradient of approximately 0.003. Groundwater flow is perpendicular to the elevation contours, and under the northern and western portions of the site is generally westward. Under the southeast corner of the site, there is apparently a groundwater divide and a sink to the southeast. The geologic causes of this are not understood, and it is the subject of continuing investigation. Aquifer tests on monitoring wells in the vicinity of LLNL indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 m/day.⁴ This, in combination with the observed water table gradients, yields groundwater velocity estimates of 5–90 m/yr. The range in these values reflects the heterogeneity typical of the alluvial sediments that underlie the area.

On the LLNL site, storm water is channeled through storm sewers designed to accommodate a 10-year flow. Open ditches are used in undeveloped areas of the site. The Arroyo Las Positas originally crossed the northeast section of the site. In 1965, as part of an erosion control project, the Arroyo Las Positas flow 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 LLNL's surface drainage (storm and irrigation runoff), runs north to the Western Pacific tracks, then west where it joins the Arroyo Seco. The main channel of the Arroyo Seco crosses the center of the SNLL site from the southeast and then the southwest corner of the LLNL site. The LLNL Master Site Plan calls for a

Figure 3. Approximate groundwater surface elevations (feet above mean sea level) in the vicinity of LLNL.

small impoundment to be established in the center of the project. Provisions have been made for re-routing on-site water drainage to fill this lake during the rainy season.

The combined sewage from LLNL and SNLL 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 through a pipeline and discharged into San Francisco Bay. The LWRP was connected to this pipeline on February 8, 1980. While treated effluent from the LWRP 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.

The developed portion of the LLNL site occupies an area of 2.54 km² (1.0 mi²); additional land has recently been acquired for buffer zones on the west and north sides of the existing site, increasing the total area to 3.28 km² (1.3 mi²). The SNLL site occupies an area of 0.75 km² (0.2 mi²). With the exception of SNLL to the south and a business park to the southwest, most of the land adjacent to LLNL is presently in agricultural use (grazing and forage crops). Much of the land to the west,

north, and northeast has been re-zoned for industrial use, however, and future development is anticipated in these areas. The nearest residential area is 0.8 km (0.5 mi) from the west perimeter of the developed portion of the LLNL site.

Site 300

Site 300, LLNL's high explosive testing site, is located 16 km (10 mi) east of LLNL in the Altamont Hills of the Diablo Range. The topography of the site is irregular, with a series of steep hills and ridges oriented along a generally northwest/southeast trend and divided by intervening ravines. The elevation ranges from approximately 150 m (500 ft) at the southeast corner of the site to approximately 25 m (720 ft) in the northwestern portion. The climate is generally similar to that at LLNL, but is modified by the higher elevation and greater relief; the temperature range is somewhat more extreme, and surface wind patterns are influenced by local topography. Rainfall for the 1985 water year was 223 mm (8.8 in.); for the 20-year period from 1966 through 1985, the average rainfall was 273 mm (10.7 in.), with a maximum of 506 mm (19.9 in.) and a minimum of 121 mm (4.8 in.).

Knowledge of the geology and hydrogeology of Site 300 is based upon regional geologic mapping by T. W. Dibblee⁵ and L. A. Raymond⁶ and has been supplemented by detailed hydrogeologic studies⁷⁻¹⁰ of portions of Site 300 in recent years.

The bedrock underlying most of Site 300 consists chiefly of sedimentary rock of the late Tertiary Neroly formation, which is composed of interbedded sandstones, siltstones, claystones, and conglomerates. This formation is underlain by sandstones and claystones of the older Cierbo formation that outcrops in some places. The bedrock is overlain locally by older alluvial and terrace deposits, and more generally by Quaternary colluvial and valley fill deposits.

Groundwater within Site 300 largely occurs within sandstone and conglomerate beds of the late Tertiary Neroly Formation and probably moves through both pores and fractures. Fractures in claystone beds locally convey water.^{7,10} Preliminary aquifer tests on interbedded sand-, silt-, and claystones in the northwest portion of the site yielded hydraulic conductivity values ranging from 4.9×10^{-4} to 1.1×10^{-1} m/day.¹⁰ Folds and faults within the bedrock sequence appear to locally influence groundwater gradients and movement.⁷ In the southern part of Site 300, groundwa-

ter is present in alluvial deposits beneath Corral Hollow.⁸ In the northwestern part of Site 300, there is evidence of temporary groundwater flow in alluvial deposits in directions different from the water table flow. These temporary groundwater bodies appeared to have formed during the above normal rainfall years of 1981-1983,¹⁰ and had largely drained by late 1985 as a result of drier conditions from early 1984 through 1985. The water supply for Site 300 is drawn from production wells located in the southeastern corner of the site adjacent to Corral Hollow.

Figure 4 presents a generalized groundwater map based upon data from water-bearing zones of any significance present beneath those portions of Site 300 for which data are available. The map also includes the locations of fault systems that appear to have hydrologic significance. An area underlain by a very localized, perched groundwater body detected during site-specific studies in the southeastern part of Site 300⁸ is also shown, as is the site of an anomalous, perched spring located in the southern part of Site 300. Other perched springs and isolated groundwater bodies may exist.

The water level map shown in Fig. 4 is based upon elevations measured in several geohydrologic units that do not strictly correlate with one another, although they appear to be in communication at some locations. In the northwestern portion of Site 300, water surface elevations shown are for a shallow perched water table aquifer.^{7,10} In portions of this area, boreholes drilled to a depth of nearly 300 feet beneath the perched aquifer have failed to encounter any deeper water-yielding zones.⁷ Northeast of the Elk Ravine Fault, data depicted is for a semi-confined aquifer that is the uppermost of a sequence of aquifers with differing heads and geochemical properties.⁷ Beneath the southeastern portion of Site 300, both a water table aquifer and a confined aquifer are present. Contours shown are based upon scattered data points obtained from the water-table aquifer.

Sewage from the Site 300 administrative area in the southeast corner of the site is discharged to a lined pond for digestion and percolation. Other facilities at Site 300 are served by septic tanks.

Site 300 occupies an area of 28.3 km² (10.9 mi²). The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300. Adjacent to Site 300 on the east is a high-explosives test facility operated by Physics International; a similar facility operated by SRI International is located approximately 1 km (0.6 mi) south of Site 300.

Figure 4. Topography and groundwater surface elevations, Site 300.

The remainder of the land around Site 300 is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is the city of Tracy (population 25,000), located 10 km (6 mi) to the northeast.

Environmental Monitoring

The Environmental Quality Verification Program (EQVP) at LLNL conducts an environmental

surveillance program to verify the effectiveness of control measures and to determine whether there are any environmental effects of laboratory operations at LLNL and SNLL. Potential emissions include tritium, uranium, plutonium, metals, solvents, and common laboratory chemicals. Because of its proximity to LLNL and the extensive environmental monitoring program at LLNL, SNLL does not duplicate the LLNL program. This report, therefore, assesses the combined environmental impact of both laboratories.

Strict effluent-control programs that emphasize controlling effluents at the source have been in effect at LLNL and SNLL since operations began. The Environmental Quality Verification Program evaluates the effectiveness of these measures, documents whether effluents from LLNL, Site 300, and SNLL operations are within applicable standards, and estimates 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 LLNL using gamma and neutron dosimeters.

Each spring, LLNL 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*.

Summary

Air Samples

In 1985, the annual average airborne gross beta activity in Livermore Valley air samples was 1.7×10^{-14} $\mu\text{Ci}/\text{ml}$, essentially unchanged from 1984. The average gross alpha activity, 0.5×10^{-15} $\mu\text{Ci}/\text{ml}$, shows no significant change from 1984 data. Although isotope ratio measurements indicate the presence of depleted uranium (used in high explosive tests) in air filters at Site 300, the average airborne ^{238}U concentration at the Site was lower than that attributable to natural uranium at the LLNL perimeter. The ^{238}U concentrations observed were well below the standards set by DOE. The annual average beryllium concentrations were less than 1% of the local air pollution standard at both the LLNL perimeter and Site 300. The beryllium concentrations are of the same magnitude as the natural beryllium in typical airborne dust. The total tritium released to the atmosphere by LLNL in 1985 was 2204 Ci, of which about 1000 Ci was accidentally released January 24, 1985. Approximately 624 Ci was in the form of HTO. An additional 450 Ci were released by SNLL. The total quantity of ^{13}N - ^{15}O released in 1985 was 520 Ci. The maximum offsite dose attributable to these airborne radioactive emis-

Appendix A is a tabulation of 1985 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 people from the observed environmental levels of artificially produced radionuclides. This assessment is made by calculating the radiation doses delivered to people and comparing these with the much larger radiation dose received locally from natural sources. This assessment is made for the LLNL effluents only. The dose assessment and other detailed environmental information for SNLL is contained in 1985 *Environmental Monitoring Report*, Sandia National Laboratories, Livermore, CA (SAND-6-8012).

sions was 0.06 mrem, which is far less than the EPA-recommended limit of 25 mrem/yr.

Soil Samples

The concentrations of ^{239}Pu in the soil of the Livermore Valley are similar to those observed in previous years. The highest value of 22.6×10^{-9} $\mu\text{Ci}/\text{g}$ (0.19% of the standard), was found east of the LLNL perimeter. Elevated soil radionuclide concentrations in this area are attributed to pre-existing wind-deposited contamination from solar evaporation pits formerly located near LLNL's southeast boundary. The use of these pits was discontinued many years ago. The proposed EPA soil standard for unrestricted use is 12×10^{-6} $\mu\text{Ci}/\text{g}$. The remaining areas reflect world-wide fallout and naturally occurring concentrations of nuclides.

The soil samples collected at Site 300 show that greater than background concentrations of ^{238}U are limited to isolated regions near the firing tables. The highest value of 350 $\mu\text{g}/\text{g}$ is typical of previous years' data.

During 1985, a number of special assessments were in progress that involved the analyses of soil samples. These assessments are being done to investigate the contamination, if any, at Site 300

(landfills and a chemical handling facility) and at LLNL (a gasoline tank leak, a landfill, and potential groundwater contamination sources). The water samples were analyzed for various contaminants (metals, gasoline, chlorinated hydrocarbons, radioactivity, etc.) as appropriate for the specific assessment. A summary of each of these investigations is presented in the Special Monitoring Assessments section of this report.

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. One water sample from Site 300 showed an above-average level of gross alpha activity (37 pCi/liter). This activity has been found to be naturally occurring uranium at concentrations well within those specified in *DOE Manual 5480.1* and below the health advisory level recommended by the State Department of Health Services. Some groundwater monitoring wells near a landfill at Site 300 show sharply elevated concentrations of tritiated water. The highest value measured was $10.2 \times 10^{-5} \mu\text{Ci/ml}$; this value is above the drinking water standard, but was found in an aquifer that is not used for potable water supplies. Traces of halogenated hydrocarbons were detected in wells down-gradient of this area and in the groundwater down-gradient from another landfill at Site 300. These sites have been under active investigation.

During 1985, a number of special assessments were in progress that involved the analyses of groundwater samples for various contaminants as appropriate for the specific assessment (see the Special Monitoring Assessment section of this report).

The amount of tritiated water (HTO) discharged into the sanitary sewer system in 1985 was 3.6 Ci. This increase over the 1.7 Ci released during 1984 was the result of a 2 Ci release in March, 1985, by SNLL. The discharge of ^{239}Pu was $4.8 \mu\text{Ci}$, which was about 50% more than the amount released during the previous year but well within the allowable range. Tritium analyses were also made on well-water samples collected near the 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 ($9.6 \times 10^{-7} \mu\text{Ci/ml}$) were detected in test wells down-gradient from the LWRP 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 1985 were generally the same as previous years' measurements.

Vegetation and Foodstuff Samples

Tritium levels found in the Livermore Valley and Site 300 vegetation were generally comparable to those observed in 1984, although samples collected during February at two locations in the Livermore Valley showed higher than average concentrations (326×10^{-7} and $440 \times 10^{-7} \mu\text{Ci/ml}$). Vegetation collected from a landfill area at Site 300 contained substantially higher levels of tritium (6.33×10^{-4} and $13.6 \times 10^{-4} \mu\text{Ci/ml}$) than previously observed. This area is under investigation for soil and groundwater tritium contamination and is described in the Special Monitoring Assessment section.

As a means of evaluating the possible impact of LLNL 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 are 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. Milk samples from goats pastured within 5 km of LLNL showed no impact attributable to LLNL activities.

Doses

The 1985 average annual gamma-radiation doses at the LLNL perimeter and off-site locations were 59 ± 6 mrem and 60 ± 11 mrem respectively. Because the method of calculation has been changed to report data on the basis of dose equivalents to tissue, these values appear to be approximately 20% higher than those reported for 1984. When calculated by the same method, however, the results are essentially identical to last year's. The 7-mrem annual neutron dose from a 14-MeV neutron generator in Bldg. 212, near the south perimeter, was sharply reduced from last year's value of 45 mrem. This reduction in neutron dose

was the result of the reinstallation of some shielding that had been removed temporarily for an experiment. The annual radiation dose at LLNL's south perimeter now shows only marginal elevations above the average for all stations, and is well within allowable standards in *DOE Manual 5480.1*. Because there was no significant difference between the average dose at the LLNL perimeter and the average off-site dose (which is considered to represent background), and because doses measured by dosimeters located in close proximity to

the nearest residences were all within one standard deviation of the mean off-site dose, no statistically significant external dose can be identified for the nearest neighbor. Maximum radiation doses from airborne effluents were 0.22 mrem at the site boundary, 0.06 mrem to the nearest neighbor, and 0.30 person-rem within an 80-km radius. The dose to the maximum-exposed individual resulting from LLNL operations thus corresponds to the 0.06 mrem nearest-neighbor dose caused by airborne effluents.

Monitoring Data—Collection, Analysis, and Evaluation

Radioactive Monitoring

Airborne Radioactivity

Concentrations of various airborne radionuclides are measured at the LLNL perimeter, off-site locations near LLNL, and at Site 300. Sampling locations are shown in Figs. 5 through 7. The six samplers on the LLNL perimeter (Fig. 5), seven of the off-site samplers (Fig. 7), and the nine samplers at Site 300 (Fig. 6) use $5.2 \times 10^{-2} \text{ m}^2$ 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.¹¹ The remaining samplers in the Livermore Valley (Fig. 7) use $8.11 \times 10^{-3} \text{ m}^2$ glass-fiber filters (Flanders F-700) and are operated at a flow rate of 85 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 LLNL-perimeter and Site-300 filters are also counted for gamma-emitting radionuclides using low-background Ge(Li) detectors. Following gamma counting, the LLNL perimeter filters from individual locations and the Site 300 composites are analyzed for the presence of ^{239}Pu , ^{238}Pu , ^{235}U , and ^{238}U . Selected off-site samples from the Livermore Valley and the city of Tracy are analyzed for ^{239}Pu .

Tables A-1 and A-2 in Appendix A show airborne gross alpha and gross beta activities for the LLNL perimeter and Livermore Valley samples, and Tables A-3 and A-4 show corresponding ac-

tivities for Site 300. In order to provide more detailed information on analytical sensitivity and the variation in the results, data are presented for the weekly individual filter analyses. These are grouped by months for ease of comparison with the monthly composite data presented in Tables A-5 through A-9. The values reported are similar to those observed in 1984. Gross alpha and gross beta values show no statistically significant differences between Site 300, LLNL perimeter, and Livermore Valley samples. Most of the gross alpha determinations were below the detection limit of the method. Most of the observed alpha and beta activity results from the naturally occurring radioisotopes of U and Th and their decay products.

Tables A-5 and A-6 list the activities of selected gamma-emitting radionuclides that may contribute to the gross beta activity in Livermore and Site 300 samples. Other gamma-emitting nuclides would have been reported if they had been found at levels in excess of the detection limit. Of the nuclides tabulated, ^7Be and ^{40}K are naturally occurring and ^{106}Ru , ^{125}Sb , ^{137}Cs , and ^{144}Ce are fission products. The primary source of the ^{137}Cs is long-term global fallout and fallout resuspension; its measurement provides an index of fallout deposition that can be used to evaluate the sources of nuclides such as ^{239}Pu , which could originate either from fallout or from LLNL operations. The other fission products (not detected in 1985) are normally detectable only after atmospheric nuclear tests by other nations. In addition to providing baseline data on global fallout, analysis of these fission products also serves to monitor the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL.

Table A-7 shows the concentration of plutonium on air filter samples collected in Tracy and

Figure 5. LLNL perimeter air-sampling locations.

the Livermore Valley. Tables A-8 and A-9 show the concentrations of airborne ^{239}Pu , ^{235}U , and ^{238}U in the LLNL perimeter and Site 300 air samples. Location 1 at the southeast corner of the site showed slightly higher concentrations of plutonium in air than the other sample locations. The highest monthly samples were collected during June and October. Their concentrations, $1.3 \times 10^{-17} \mu\text{Ci/ml}$, represent 0.06% of the concentration guide value. No other significant differences between locations or samples were noted and the overall levels determined were essentially the same as those reported in 1984. Substantial quantities of depleted uranium (^{238}U) are used at Site 300; in previous years higher concentrations of this nuclide have been observed at the Site than at the LLNL perimeter. Although the Site 300 $^{235}\text{U}/^{238}\text{U}$ ratios for 1985 indicate the presence of some depleted uranium in the samples, the total concentrations measured were not significantly different from those observed at the Livermore site perimeter. The uranium concentrations observed are similar to 1984 values and are well be-

low the concentration guides (CG) in DOE Manual 5480.1 (see Appendix B).

Concentrations of airborne tritiated water (HTO) were determined for each of the LLNL perimeter air-sampling locations (Fig. 5), off-site locations S1 and S2, and four additional Livermore Valley locations added to the monitoring program during 1985 (Fig. 7). Water vapor was collected on silica-gel samplers 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 $100\text{--}125^\circ\text{C}$, and the HTO was measured by liquid-scintillation counting. Table A-10 shows average biweekly HTO concentrations observed at each sampling location; the overall annual average concentration is $2.0 \times 10^{-11} \mu\text{Ci/ml}$. The highest biweekly concentration occurred in May and was observed at location 1. This concentration, $14.7 \times 10^{-11} \mu\text{Ci/ml}$, is 0.07% of the DOE standard. Location 1 also showed the highest annual average concentration, $4.2 \times 10^{-11} \mu\text{Ci/ml}$. The values observed were generally similar to those reported in 1984. As expected, the samples

Figure 6. Site 300 on-site air-sampling locations.

Figure 7. Livermore Valley air-sampling locations.

from the newly added more remote locations showed slightly lower concentrations than were observed at the locations close to LLNL and SNLL.

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 LLNL 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 LLNL operations. As in previous years, a group of soil samples was collected at sites selected at random from the list of locations sampled in the 1971-1972 study. Figure 8 shows the 1985 soil-sampling locations in the Livermore Valley and Fig. 9 indicates the locations at Site 300. Eleven of the Site 300 soil samples were collected from locations that have been sampled annually since 1973. For 1985, two additional sample locations were added (1031 and 1040); these are in drainage channels where surface runoff might be expected to concentrate suspendable particulate material.

All samples were collected to a depth of 5 cm. After collection, the samples were dried, ground,

Figure 8. Livermore Valley soil-sampling locations.

Figure 9. Site 300 soil-sampling locations.

and blended. Plutonium-239 content was determined in each sample following an acid-leaching 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.

Table A-11 presents data on the concentrations of ²³⁹Pu, ⁴⁰K, ²³²Th, and ²³⁸U in soil at the Livermore Valley sampling locations. The rationale for including the naturally occurring nuclides (⁴⁰K, ²³²Th, and ²³⁸U) and the long-lived fission product (¹³⁷Cs) has been presented in the previous section in the discussion of airborne radioactivity. The concentrations and distributions observed are within the ranges reported in previous years.

Table A-12 shows the ²³⁹Pu, ¹³⁷Cs, and ²³⁸U activities in the Site 300 samples. Since high-explosive tests at Site 300 often involve the use of depleted uranium, one of the purposes of the annual soil samples is 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.^{12,13} With the exception of variations in the elevated ²³⁸U concentrations near the bunkers, there were negligible changes from ac-

tivities observed in previous samples collected in the same locations.¹⁴

Radioactivity in Sewage

Radioactive wastewater is treated to reduce activity to the lowest levels practicable and well below standards in *DOE Manual 5480.1*. After treatment and analysis, the liquid effluents are released into the city of Livermore's sanitary sewer system at the outfall located at the northwest corner of LLNL. The effluent is continuously monitored at the outfall for pH, selected metals, and radioactivity.

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. In February, 1980, the Livermore sewage treatment plant was connected to a pipeline constructed as part of the Livermore-Amador Valley Wastewater Management program to transport wastewater out of the valley for discharge into the San Francisco Bay. Although some treated LWRP effluent is still used for irrigation of municipal property during summer months, sewage is no longer discharged into Arroyo Seco. This has eliminated 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.¹⁵

Samples of the LLNL and LWRP liquid effluents are collected daily. Table A-13 compares the monthly composite activity levels of tritium (HTO), ¹³⁷Cs, and ²³⁹Pu in the LLNL effluent with those in the effluent from the LWRP. The LWRP effluent activity levels are not significantly different from those observed in 1984. LLNL effluent showed measureable increases over 1984 levels for all three nuclides. The increased HTO level in March was traced to a release of approximately 2 curies by SNLL. The sources of the elevated ¹³⁷Cs and ²³⁹Pu values are unknown. Even though moderate increases in effluent levels were observed, all concentrations remain well below stan-

dards in *DOE Manual 5480.1* for discharge into the sanitary sewer system.

Radioactivity in Water

This section describes the ongoing monitoring program for surface and domestic water in the vicinity of LLNL and at Site 300. Expanded water quality monitoring efforts are described in the Groundwater Monitoring section, and special investigations relating to groundwater quality are presented in the Special Monitoring Assessments section.

Water samples are collected from the various Livermore Valley and Site 300 locations shown in Figs. 10 and 11. 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.

Figure 10. Livermore Valley water-sampling locations.

Figure 11. Site 300 water-sampling locations.

Livermore sampling locations 11, 16, 23, 24, 26, and 29 (Fig. 10) are surface water sources (ponds, creeks, aqueducts, or reservoirs), and location 20 is the collection site of LLNL rainfall. The other locations are domestic water sources. Gross alpha and beta activities in these surface and domestic water samples collected in 1985 were below EPA and State of California standards for drinking water.¹⁶

Storm-water samples were collected at four locations shown in Fig. 10 (influent, two effluents to the Arroyo Las Positas and the Arroyo Seco, and the LLNL impoundment) during the first major rain following the dry season and analyzed for gross alpha, gross beta, and tritiated water. The influent samples (water upstream from LLNL as it flowed onto the site) contained the highest concentrations; these were 87% of the concentration guide (CG) for alpha, 37% of the CG for beta, and 0.04% of the CG for tritium. Effluents and the lake sample were below the limit of sensitivity for alpha and beta (32% and 28% of the CG, respectively) and contained approximately 0.04% of the CG for tritium.

Site 300 water samples (Fig. 11) 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. Location 4, a well near the Site 300 entrance, showed an elevated gross alpha concentration of 37 pCi/l during one quarter, with an annual average of 19.9 pCi/l. Similar observations in the past have been traced to the natural uranium content of the groundwater. The State of California Department of Health Services recommends an action level of 10 pCi/l and a health advisory level of 40 pCi/l for natural uranium in drinking water. In the State of California limit for gross alpha activity, uranium is specifically excluded from the total. The uranium concentrations were well within those specified in *DOE Manual 5480.1* (2×10^{-5} μ Ci/ml) and below the health advisory level recommended by DOHS.

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, $34.5 \times$

10^{-7} $\mu\text{Ci/ml}$, occurred in the Livermore Valley rain (location 20) which was collected during June. This represents 0.2% of the DOE concentration guide and 17% of the permissible concentration specified by the State of California for drinking water. Water samples from monitoring wells near a landfill at Site 300 (Table A-34) show much higher concentrations of tritiated water (10.2×10^{-5} $\mu\text{Ci/ml}$). These samples are discussed in the Special Monitoring Assessments section of this report. 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 0.05 mrem, are based on a water consumption of 2 liters/day and the dose-conversion factors contained in ICRP 30¹⁷ (see Appendix 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, tritium measurements are now made annually on well-water samples collected from neighboring wells to determine the extent of tritium migration into the 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 1985 are indicated in Fig. 12, 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 sam-

ples were well below the limits for water adopted by the State of California (Title 22, Chapter 15). The tritium levels in these wells are similar to those observed in the 1984 samples.

Radioactivity in Vegetation and Foodstuffs

Native vegetation samples are collected quarterly at locations in the Livermore Valley (Fig. 13) and at Site 300 (Fig. 14). 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 ICRP 30¹⁷ and the dose-pathway model from NRC Reg. Guide 1.109.¹⁸ Conservatively assuming that an adult's diet includes vegetables with the highest observed average tritium concentration and meat and milk derived from livestock fed on grasses with the same concentration, the maximum potential dose is approximately 0.26 mrem/y.

Table A-22 shows the 1985 tritium data for Site 300 vegetation. Locations 6 and 13 are adjacent to areas that contain 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. Although observed in prior years, the elevated concentrations at location 6 increased to a maximum value of 13.6×10^{-4} $\mu\text{Ci/ml}$ in 1985. The calculated annual average dose from vegetation at this location is

Figure 12. Livermore Valley groundwater-sampling locations (numbers identify specific wells sampled).

Figure 13. Livermore Valley vegetation-sampling locations.

Figure 14. Site 300 vegetation-sampling locations.

9 mrem, using the conservative pathway modeling assumptions. This contamination is further described in the Special Monitoring Assessments section of this report.

Beginning in 1977, as a means of evaluating the possible impact of LLNL 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.¹⁹ Wine samples obtained in 1985 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 analyses of samples purchased in 1985. A comparison of the wines purchased this year showed that the tritium levels of Valley wines were somewhat greater than those of California wines produced from grapes grown outside the Valley, but less than those of the European wines sampled.

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 not significantly different from that of honey from neighboring areas.

Radioactivity in Milk

During 1985, goat-milk samples were obtained from three farms within about 5 km of LLNL. Cow's milk was also sampled when available from one of the farms. A portion of each sample was freeze-dried and the recovered water was analyzed for tritium activity by liquid-scintillation counting. Another portion was preserved with formalin, and a one-liter aliquot was gamma counted in a calibrated Marinelli beaker on a Ge(Li) system. The activities of the ¹³⁷Cs, ⁴⁰K, and ³H in the samples are shown in Table A-25; no other nuclides were present at detectable levels. The annual average concentration of tritium in milk was 1.5×10^{-7} μ Ci/ml. Also shown are the calculated annual 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 ⁴⁰K. The doses of ³H, ⁴⁰K, and ¹³⁷Cs were calculated using dose factors from ICRP 30.¹⁷

Environmental Radiation Measurements

Quarterly, environmental radiation is measured at 30 LLNL perimeter locations (Fig. 15) and at 55 off-site locations (Fig. 16). These measurements are obtained with thermoluminescence dosimeters (TLD) using a previously published procedure.²⁰ Based on past measurements,²¹ environmental terrestrial exposure rates in the Livermore Valley vary from 30 to 60 mR/y. Cosmic radiation, calculated from the local elevation and geomagnetic latitude according to the data of Lowder and Beck,²² is approximately 35 mR/y.

Table A-26 shows the quarterly and annual radiation dose-equivalents for the perimeter locations and Table A-27 presents the data for the off-site locations. These are obtained by applying a correction factor to the measured TLD dose (rads) to yield dose-equivalents in tissue (mrem). When a TLD packet (changed quarterly) is missing, the annual dose is calculated as four times the average quarterly dose determined from the available data. The average annual dose-equivalent of 59 ± 6 mrem at the perimeter does not differ significantly from the 60 ± 11 mrem off-site average. The off-site value is considered the best available estimate of local background radiation. The average values appear to be approximately 20% higher than the previous year's values of 48 and 50 mrem. This apparent difference is a result of a change in calculation procedures rather than an actual increase in environmental radiation levels. Prior to 1985, the measured TLD doses had been reported directly without conversion to dose-equivalents in tissue. When calculated by the same method, the 1985 dose data do not differ significantly from the previous year's data. Since the more accurate method of calculating dose-equivalents now in use results in slightly higher values, the environmental radiation dose data from previous annual reports were recalculated to determine if any change in previously reported interpretations or conclusions would be required. We found that the recalculated data were all well below the applicable standards (*DOE Manual 5480.1*), and that, apart from minor corrections to the numerical values, the substantive conclusions of the previously published reports remain valid.

Figure 17 presents the 1985 annual frequency distribution of environmental dose rates observed at the 55 off-site locations (8 of these locations were newly added for 1985). Figure 18 is a dose-distribution plot combining LLNL perimeter and off-site measurements. The dosimeter that recorded the highest dose (116 mrem) was near an

Figure 15. LLNL perimeter locations for gamma dosimeters.

off-site industrial plant where radiography is performed. With the exception of this location, the data points conform to a straight line on the dose-distribution plot, indicating that the environmental radiation dose data are normally distributed. If the off-site average is recalculated without the 116 mrem value, an average dose of 59 ± 7 mrem is obtained.

Environmental neutron dose rate measurements using ^{235}U track-etch detectors are also made at eight locations on the LLNL site perimeter. A detailed description of the detector and the spark-counting procedure has been published.²³ Neutron-monitoring locations are shown in Fig. 15 and 1985 quarterly measurements are shown in Table A-28. The annual dose-equivalents range from 4 to 7 mrem. In previous years, location 3, near Bldg. 212 (the 14-MeV neutron generator), registered higher neutron doses than the other locations because some shielding had been removed

from the neutron generator for an experiment initiated in 1982. Replacement of the shielding was completed in 1984, and the 1985 neutron dose at location 3 was similar to the doses observed at other locations.

Nonradioactive Monitoring

Beryllium in Air

The concentration of beryllium in the air, both at the source and near LLNL property boundaries, has always been monitored as a part of LLNL's safety program. Monthly, halves of the filters from sampling locations at the LLNL perimeter, Site 300, and in the city of Tracy are composited by sample location. Following sample preparation, the beryllium content of the solutions is determined by atomic absorption analysis.

Figure 16. LLNL off-site locations for gamma dosimeters.

Figure 17. Annual off-site gamma radiation background for 1985.

Figure 18. Thermal Luminescence Dosimeter (TLD) dose-distribution plot for the LLNL perimeter and Livermore Valley during 1985.

Tables A-29 and A-30 show average monthly concentrations of airborne beryllium for LLNL perimeter and Site 300 (including the city of Tracy) sampling locations, respectively. The concentrations, which average less than 1% of the ambient concentration limit established by the Bay Area Air Quality Management District (BAAQMD), 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 air-borne beryllium concentration of 5.0×10^{-5} $\mu\text{g}/\text{m}^3$ can be calculated. In view of the range of natural variation to be expected in these background values, this value is in excellent agreement with the data in Tables A-29 and A-30. The monthly airborne beryllium concentrations for LLNL and Site 300 are plotted in Figs. 19 and 20.

Nonradioactive Pollutants in Sewage

As noted previously, sanitary sewage from LLNL is treated at the LWRP. This effluent is continuously monitored for pH, radioactivity, and selected metal ions before it enters the Livermore sewer system.²⁴ Sewage samples representative of daily flow are collected and composited monthly. These composites are analyzed for the metals shown in Table A-31.

In addition, samples of LLNL sewage effluent are collected quarterly. These samples are analyzed for the parameters specified on LWRP's permit (National Permit Discharge Elimination System). Table A-32 shows the data for 1985. All data demonstrate compliance with the city of Livermore's discharge limits listed in Appendix D.

Noise Pollution

As noted elsewhere, LLNL's high-explosive diagnostic work is conducted at Site 300. Because

Figure 19. Concentration of beryllium on air filters at the LLNL perimeter for 1985.

Figure 20. Concentration of beryllium on air filters at Site 300 and Tracy for 1985.

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 because the Tracy area is in the direction of the prevailing winds. Seven complaints of noise, but no reports of damage, were received from the Tracy area in response to detonations on February 14, 1985. Upon review, it was determined that contributing factors were the lack of adequate upper-air temperature data on the day in question and faulty calibration of the microbarograph network. New meteorological and monitoring equipment has been installed, existing equipment has been recalibrated, and procedures have been reviewed and refined in order to prevent a recurrence of overpressure incidents.

Pollutants in Storm Runoff

Beginning in 1975, LLNL's environmental surveillance program was expanded to include surface runoff monitoring. The program was originally designed to detect the pesticides used at LLNL, which include herbicides, fungicides, and insecticides. A sample was collected from the drainage ditch at the northwest corner of the Laboratory following the first major storm. Most recently, additional sampling points have been

added, and samples are now analyzed for metals, general water quality parameters, and other priority pollutants, in addition to pesticides. In 1985, four locations were sampled after one of the first major runoff-producing storms of the fall season. The sampling sites have been described above in the Radioactivity in Water section.

Most potential pollutants were not present at detectable levels. Of those species with measurable concentrations, only the mercury concentration at the southwest effluent sampling location exceeded the permissible concentrations (0.002 mg/l) set in State of California Title 22, Chapter 15, regulations for public water supplies. Since the runoff is not used for (and does not directly enter any water used for) public supplies, these standards are cited for comparison only. The presence of mercury, TCE, and other materials in the effluent from the southwest portion of the laboratory is believed to be related to the presence of soil contamination in the southern section of the LLNL site. This is under investigation and is discussed in the Special Monitoring Assessments section. The data are shown in Table A-33.

In accordance with the California Regional Water Quality Control Board (CRWQCB), Central Valley Order 80-184, surface water has to be collected at active landfills (Pits 1 and 7) during the rainy season, and analyzed for gross alpha, gross beta, tritium, and beryllium. No samples were collected this year since no runoff was generated from the landfill sites.

Groundwater Monitoring

Groundwater monitoring is conducted under two programs at LLNL. One program is designed to meet regulatory commitments established for specific site investigations, such as the Livermore Site Ground Water Investigation and the Site 300 TCE Investigation. These efforts and others are described in the Special Monitoring Assessments section of this report. The other program includes routine compliance monitoring around landfill and surface waste impoundment units as required by the California Regional Water Quality Control Board, Central Valley (CRWQCB,CV), the U.S. Environmental Protection Agency (EPA), and groundwater quality monitoring for drinking water parameters. This latter program is described below.

The groundwater in the vicinity of Site 300 landfill units is monitored to meet requirements specified by the CRWQCB and EPA. The locations

of monitoring wells are shown in Fig. 21. RCRA groundwater monitoring is conducted in the vicinity of two active landfills, Pit 1 and Pit 7. Well water samples are being analyzed for drinking water parameters, groundwater quality parameters, and indicators of groundwater pollution, as specified in 40 CFR 265.92. Figure 22 shows the installation of a monitoring well near Pit 1.

Five wells were included in the Pit 7 RCRA monitoring network in 1985. Three additional wells and three lysimeters were added to the system in late 1985 (see Fig. 21); data for these will be reported starting in 1986. Background monitoring data for the five Pit 7 wells showed differences in specific conductance, total organic carbon (TOC), and total organic halide (TOX) between the Pit 7 upgradient and downgradient wells. Groundwater monitoring in the Pit 7 area has also shown that tritium and chlorinated solvents (TCE, PCE, and

Figure 21. Landfills and monitoring wells at Site 300.

Figure 22. Installation of monitoring wells near Pit 1, Site 300.

DCE) are present in wells located downgradient from the pit. The solvent concentrations are in the low part per billion range (maximum 15 ppb reported) and appear to be decreasing with time. It is suspected that new pumps installed in the wells may be the source of this contamination. Tritium concentrations in some downgradient wells were substantially in excess of 20,000 pCi/l. A close-in tritium investigation was conducted in 1985 to better understand the tritium migration potential. The investigation findings are currently being reviewed by the CRWQCB (CV) and are described in the Special Monitoring Assessments section of this report. An anomalous measurement of 21 pCi/l of alpha radioactivity was also noted in the second quarter of 1985; water samples analyzed since that time show concentrations below the allowable 15 pCi/l. Although the Pit 7 monitoring wells are showing elevated concentrations of tritium and chlorinated organics, potable supply wells, which are located approximately 2 miles away from the landfill monitoring wells and tap different aquifers, show concentrations below the ac-

ceptable drinking water limits and action levels for organic contaminants. The drinking water suitability data for Pit 7 appears in Table A-34 of this report.

In 1985, five wells were included in the Pit 1 RCRA monitoring network. Because of uncertainty about the direction of groundwater flow, additional wells were added to the system. Late in 1985, data for these additional wells will be reported starting in 1986. Results from the four wells showed concentrations below drinking water maximum contaminant levels and state action levels. However, traces of organics such as phenol (41 ppb), benzoanthracene (2 ppb), di-ethyl phthalate (2 ppb), chloroform (3 ppb), and methyl pyrrolidinone (200 ppb) have been detected in the fourth quarter monitoring samples. These organics will be closely monitored to determine whether they are indicators of contamination or originate from local geological sources, laboratory analysis, or well installation materials.

The two active landfills and six inactive landfills also have groundwater monitoring programs

specified by Waste Discharge Order 80-184, issued by the CRWQCB, Central Valley. The order requires annual groundwater monitoring for gross alpha, gross beta, tritium, and beryllium at Site 300 landfill locations. Beryllium was not detected in any of the samples from the landfill monitoring wells. Gross alpha, gross beta, and tritium results for the Pit 1 and Pit 7 wells were discussed above. Wells in the Pit 6 and Pit 8 inactive landfill area did not show radioactivity levels above drinking water standards. One well water sample taken in the Pit 2 area (well K2-1) showed an alpha concentration of 31 pCi/l in the first quarter of 1985; subsequent samplings have not shown any alpha activity. K2-1 samples have also shown tritium concentrations in excess of drinking water limits. This finding is discussed in more detail in the Special Monitoring Assessment section.

In addition to these regulatory monitoring requirements, the six wells around inactive Pit 6 are being monitored to allow early detection of any contaminants leaving the landfill. Records show that capacitors suspected to be contaminated with PCB, beryllium- and mercury-contaminated materials, miscellaneous chemicals, and other potentially hazardous waste were buried in this pit between 1964 and 1973. In 1985, monitoring results indicate that water samples did not exceed drinking water limits or state action levels. Traces of organics were noted in the first two quarters in the following maximum concentrations: trichloroethane (3 ppb), methyl pyrrolidinone (40 ppb), acetone (20 ppb), and unspecified ketones and esters (20 ppb). These were not detected in the wells in the third and fourth quarter. Methylene chloride was detected once (4 ppb) in the fourth quarter in one of the upgradient wells.

To comply with CRWQCB Waste Discharge Order 80-183, samples were collected monthly from wells located downgradient from wastewater discharge sites (locations 4, 5, 14, and 22 are shown in Fig. 11) and analyzed for total organic carbon, specific conductance, chlorides, and total hardness. The annual average concentrations showed increases over concentrations noted in previous years. In 1985, all wastewater discharges to the ground were discontinued; therefore, the CRWQCB (CV) rescinded Waste Discharge Order 80-183 in June 1985, and the sampling program was discontinued. Data collected through June are presented in Table A-35.

In 1985, the CRWQCB (CV) issued new groundwater monitoring requirements as part of Waste Discharge Order 85-188 for LLNL's new Class II surface impoundment. The impoundment

contains non-hazardous high-explosives process wastewater. Samples from four wells and one lysimeter are analyzed quarterly for pH, TOX, TOC, specific conductance, several explosives compounds (HMX, RDX, nitrate, nitrite), and metallic elements. The 1985 data indicate RDX concentrations of 45 ppb, which is near the detection limit of 20 ppb, in the upgradient well. All other data for the impoundment monitoring installations show both upgradient and downgradient concentrations that are within allowable limits.

As described in the Special Assessments sections, numerous wells were installed as part of the Livermore Groundwater Investigation. As new wells were installed, water samples were collected and analyzed for the primary drinking water standards listed in the California Title 22, Chapter 15 regulations and for organic contaminants identified by the EPA 624/625 method. The analytical results for groundwater collected downgradient from the Livermore Site indicate that primary drinking water standards were not exceeded. State action levels for chlorinated hydrocarbons were exceeded in some well water samples. Analytical results from the sampling effort are shown in Table A-36 of this report. Well locations are shown in Fig. 23.

Environmental Impact of LLNL Operations

Radioactive Airborne Effluents

In 1985, a total of 2204 Ci of tritium was released to the atmosphere (see Table A-37) from Bldg. 212 (14-MeV neutron generator), Bldg. 331 (Tritium Facility), and Bldg. 292 (Rotating Target Neutron Source). Of this quantity, an estimated 1000 Ci of HT was inadvertently released January 24, 1985. Approximately 624 of the remaining 1204 Ci was released as HTO, and is the quantity used to calculate doses since the contribution from HT to the dose is insignificant. Approximately 450 Ci of HTO was released by SNLL; this quantity is not included in dose calculations for LLNL operations. One hundred twenty curies of the short-lived radionuclides, ^{13}N - ^{15}O , were released from Bldg. 194 (electron-positron linear accelerator). An additional 400 Ci of ^{13}N - ^{15}O were released from the Advanced Test Accelerator (ATA) at Site 300.

Comparative releases of radioactive effluents at Livermore during the 5-year period from 1981 through 1985 are shown in Table A-37.

Table A-38 also contains estimated radiation doses to the public from radioactive airborne

Figure 23. Off-site monitoring wells analyzed for water quality parameters in 1985.

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 person-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.²⁵ 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. Meteorological data were obtained from 40-m sensors on the LLNL meteorological tower during 10 months of 1985. The 40-m sensors were inoperative during the months of

February and March and data from the 10-m sensors were used for those two months. From records of these data, wind speed, wind direction, and atmospheric stability estimates were tabulated at 1/4-h intervals over the calendar year.

Digitized meteorological data were not available for Site 360 for 1985, so historical data from a previous year were used to estimate the doses attributable to ATA emission. Computerized equipment has been purchased and will be installed at Site 300 in early 1986.

Variance in the horizontal wind direction was used to estimate Pasquill-Gifford stability categories based on the method described by D. H. Slade.²⁶ 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 χ/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 factors in ICRP 30.⁹ The results (shown in Table A-38) indicate that the maximum estimated dose to the nearest resident from airborne radioactive effluents was 0.06 mrem.

Table A-38 shows a combined population dose of 0.30 person-rem from ^3H and neutron activation products in LLNL airborne effluents. This dose is based on a population of 5.1×10^6 within 80 km of LLNL. Using 100 mrem/y as a typical average radiation dose from natural sources, the comparable natural radiation dose the same group receives is 5.1×10^5 person-rem. By comparison, the population dose from LLNL 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 1985, 4.8×10^{-6} Ci ^{239}Pu and 3.6 Ci HTO were released into the sewer; 2.0 Ci of HTO was the result of a release by SNLL in March, 1985. Table A-37 summarizes the past 5 years of airborne and liquid effluent releases. The 1985 data are within the range of previously reported releases. Table A-13 shows that the 1985 average annual concentration of these radionuclides in LLNL sewage represents 3×10^{-3} % and 0.4% of the DOE standards for ^{239}Pu and HTO, respectively.

Nonradioactive Liquid Effluents

The metals in sewage are listed in Table A-31. Other physical and chemical characteristics of the sewage effluent are presented in Table A-32. The quantities of regulated materials discharged were well within the limits set by the city of Livermore (Appendix D) and the LWRP's discharge limits set by the CRWQCB, San Francisco Bay.

The first storm water runoff of the season, showed no detectable level of specified identifiable chlorinated hydrocarbons and only a few other pollutants at detectable levels. The influent enters LLNL at the east perimeter, flows into the lake, and the effluent exits LLNL primarily at the NW corner with a lesser outflow at the SW corner. The analytical data

are displayed in Table A-33. The only constituent to exceed drinking-water standards was mercury. The only way in which the effluent can influence drinking water is by recharge to the groundwater, and the data presented in Table A-36 show that the groundwater downgradient from LLNL is well below the acceptable limits for mercury concentration.

Quality Assurance

During 1985, LLNL participated in the EPA's Environmental Radioactivity Laboratory Intercomparison Studies Program. Table A-39 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 .

Table A-40 shows the comparison of analyses by LLNL with the known and experimentally determined values for intercomparison of samples provided by the DOE Environmental Measurements Laboratory. All intercomparison results are considered satisfactory except for ^{238}Pu and U. The ^{238}Pu analysis is not a routine part of the monitoring program because the LLNL inventory of this nuclide is too small to create a potential environmental contamination problem. The reason for the variations in the U analytical results is under investigation. It should be noted that the maximum uranium concentration discrepancy is a factor of approximately two, and all uranium concentrations determined in environmental samples were less than the applicable concentration guide by factors much greater than two.

A part of the LLNL Quality Assurance program is accomplished through replicate sampling (Table A-41). Duplicate air samples for particulates are collected weekly on a schedule of alternate months at one of the six perimeter locations taken in sequence. Duplicate air samples that collect tritiated water on silica gel are taken biweekly at one of the perimeter locations during the intervening months. Duplicate samples of sewer effluent from LLNL and the LWRP are collected each week and analyzed for gross alpha, beta, and HTO.

To test the reproducibility of the sampling and analytical procedures, the ratios of the duplicates are presented in Table A-41. These ratios are considered completely acceptable in view of the fact that they include analytical, sampling, and natural environmental variations.

The sampling and analytical procedures are described in Appendix E. Blank samples are routinely analyzed.

Special Monitoring Assessments

The following is a brief description of the special assessments that were initiated or were in progress in 1985 and are being discussed with state, federal, or local environmental agencies. Included is a summary of each project, the status of the assessment, and any remedial action as of December 31, 1985. References are listed that give the detailed status of special assessments for which additional reports have been published.

Solvent Contamination of Groundwater Investigation

A study in 1983 evaluated the potential for contamination of ground water beneath LLNL and revealed the presence of low levels of organic solvents.² Part-per-billion concentrations of 1,1 dichloroethylene (DCE), tetrachloroethylene (PCE), dichloroethane (DCA), trichloroethane (TCA), and chloroform were found in the groundwater beneath LLNL and private wells immediately west of the site. An investigation to define the origin and extent of contamination was conducted between December 1983 and May 1984, and included the analyses of 537 soil samples and 72 water samples. Trace quantities of solvents were detected in the soil at several locations. The highest concentration, 5.7 ppm TCE, was located on site near the southern boundary.

PCE was the principal contaminant in the wells west of LLNL. A private well located near the southwest boundary contained the highest PCE levels, 310 and 490 ppb.

A second phase of investigation has been under way since September 1984 to define the vertical and lateral extent of volatile organic compounds (VOC) in the groundwater on-site and west of the Livermore facility, and to monitor groundwater quality. Investigation plans and activities are reviewed by the State Regional Water Quality Control Board, State Department of Health Services, State Water Resources Control Board, and the United States Environmental Protection Agency. As part of this investigation, a records search to survey past and present use, storage, and disposal of hazardous waste was carried out. A recent report has presented details of the investigation and findings.⁴

In 1985, thirty-two additional monitoring wells were installed at or near the Livermore site in order to: provide baseline hydrogeologic data; define the VOC contamination; and evaluate po-

tential sources of VOCs. PCE, DCE, TCE, DCA, and carbon tetrachloride (CCl_4) were detected in groundwater in the Livermore vicinity in concentrations exceeding action levels recommended by the California Department of Health Services. West of LLNL, maximum concentrations of PCE, DCE, TCE, and DCA detected in groundwater in 1985 were 350, 48, 110, and 2.4 ppb, respectively. CCl_4 was not detected. Wells and borings drilled west of LLNL indicate that VOCs dominated by PCE have been detected in groundwater as far as 3,000 ft west of LLNL. At LLNL, maximum concentrations of PCE, DCE, TCE, CCl_4 , and DCA detected in groundwater in 1985 were 860, 110, 1400, 50, and 120 ppb, respectively.

Analyses of saturated soil and groundwater from borings and monitoring wells indicate sources of VOCs in groundwater exist in the vicinity of:

- MW-116 (Bldg. 111) and TB-11 (Bldg. 212) in the southwest area of LLNL;
- MW-112 (Bldg. 518) in the southeast area of LLNL; and
- MW-18 (former taxi strip area) and MW-142 in the south- and east-central area of LLNL.

However, significant sources of VOCs apparently do not exist at several formerly suspected locations, including:

- the former Righetti property west of LLNL;
- the "dry well" west of Bldg. 331 in the southwest area of LLNL;
- the Bldg. 222 and Bldg. 231 sumps and suspected spill sites in the southwest area of LLNL;
- the former drainage retention tanks at the decommissioned reactor near Bldg. 281; and
- the former fire training area near Bldg. 377.

East Traffic Circle Landfill Investigation Report

An abandoned on-site landfill, near the east LLNL boundary, was discovered on July 19, 1984, during construction activities.^{27,28} Soil samples were collected and analyzed for priority pollutants including Title-22 hazardous constituents and PCBs, and radioactivity. The soil was found to be contaminated with lead, zinc, copper, cadmium,

and PCBs. Approximately 160 PCB-containing capacitors were unearthed.

Small quantities of low-level radioactive material were found in isolated pockets during the excavation. The radioactive material was identified as ^{137}Cs , ^{226}Ra , depleted uranium, ^{232}Th , and ^{241}Am . A total of approximately 6 m³ of this soil was put into drums and sent to the LLNL Hazardous Waste Management Facility for disposal.

The East Traffic Circle Landfill area was generally excavated to a depth of 5–7 ft below grade and to 10 or more ft in the vicinity of the PCB capacitors. Following the post excavation sampling of the site and approval by the California Department of Health Services, the excavated area was backfilled and compacted to grade with a mixture of local and imported fill. The excavated materials were hauled off the LLNL site by registered haulers and disposed of at state-certified hazardous waste disposal sites.²⁸

Construction activities have been completed in the area after the landfill was backfilled and the area has been restored to grade. Much of the area formerly occupied by the landfill will be covered with office buildings, road ways, parking lots, and landscaping. No impact on current or future land use is anticipated. Minimal impact on groundwater quality from the remaining metals is expected since they are relatively insoluble.

Gasoline Contamination of Soil and Groundwater

An estimated 65,000 liters of gasoline leaked from four underground storage tanks, located near LLNL's southern boundary, between October 1978 and March 1979. These tanks, no longer in use, were installed during the Navy's occupation of the property in the 1940s and have been used for storage of gasoline for the LLNL automotive fleet. Forty-three soil samples were analyzed from 20 boreholes drilled around the tank site. The data showed soil contamination to groundwater depth, with liquid gasoline floating on the water. The highest concentration reported was 110 ppm in the two groundwater monitoring wells showing contamination.

LLNL contracted with independent consultants to further assess the area and to take remedial action. Investigation plans and activities are reviewed by the regulatory agencies identified in the Solvent Contamination of Groundwater section.

The composite conclusion of the various investigations can be summarized as follows:

1. Based on soil sample analyses and resulting contour plots, gasoline contamination is present in a soil column roughly cylindrical in shape and centered under the west end of the southern-most of the original four gasoline storage tanks. This column is about 35 ft in diameter and extends from a depth of 20 ft below grade to a depth of 95 ft which is the elevation of the water table. This distribution tends to confirm that the gasoline leak occurred as a result of a failure in the lower section near the end of the tank.
2. The result of water sampling in a limited number of wells shows a contaminated groundwater plume centered about the contaminated soil column. The shape of the plume is estimated to be roughly circular with a diameter of about 300 ft delineating the one (1) ppm concentration contour. The horizontal and vertical extent of this contamination is currently being established.

A reclamation effort has been proposed to consist of two areas of activity. The first will begin with a design for the removal of residual gasoline in the vadose zone. The second effort will deal with clean-up of the contaminated groundwater. The broad target objectives of these designs will be to reduce contaminant levels in the vadose zone and the groundwater to acceptable water quality levels.

High-Explosives (HE)—Wastewater Lagoon—Site 300

For many years, high-explosive-processing rinsewater at Site 300's machining and formulations facilities has been directed through clarifiers and weirs to remove particulate HE. The wastewater was discharged into unlined lagoons.

In 1985, the unlined lagoons were removed from service and replaced with a Class II double-lined surface impoundment (evaporation pond). The new impoundment has a synthetic liner, underlain by a leachate collection system, and a clay secondary liner.

The industrial wastewater discharged to the lagoons has been tested in past years. The results have indicated that effluents are not hazardous, based upon DOHS Title 22 WET extractions tests and EPA toxicity tests. Fish toxicity tests were also run. While wastewater was found to be non-hazardous, the sludge results were inconclusive.

In 1985, duplicate fish toxicity tests were run on effluents from three points in the system: the effluent as it exited the facility, the concrete box where sludge collects, and the influent to the pond. Survival rates of 90% to 100% of the *Pimephales promelas* (fathead minnow) were noted, indicating that the wastestream is non-hazardous.

TCE Spill at Site 300

TCE (trichloroethylene) is used as a heat-exchange fluid in the testing facilities and is also provided for shop use. At Site 300, pump and valve leaks, system overflows, and past house-keeping practices have resulted in TCE spills. This material has been found in soil, rock, and/or water at five locations at Site 300. In 1983, 23 exploratory and soil-sampling holes were drilled and 5 groundwater wells were completed to define the boundaries of contamination. The two feet of significantly contaminated soil nearest the surface was removed, aerated, and replaced. The spill areas were covered with PVC sheeting to prevent infiltration and retard further percolation to groundwater.²⁹

In 1985, following consultation with State of California regulatory agencies, a second phase of studies was initiated. This work included drilling 5 additional soil sampling holes at 2 locations within Site 300 and the installation of 11 monitoring wells and piezometers at 3 locations. Soil and water samples were analyzed for TCE and other volatile organics. This work led to the identification of soil contamination at one additional location.

Quarterly monitoring of 2 observation wells installed at the 834 Complex during 1983 continued. Equipment at the 834 and 854 Complexes has been improved to prevent future spills at these facilities.

Underground Tank Testing

LLNL initiated an underground tank testing program in 1985 to allow for early identification of potential sources of groundwater contamination and to meet the requirements of Title 23, Chapter 3, Subchapter 16. In 1985, 60 petroleum tank systems were tested. No leaks were found in tanks; however, the piping in 9 of the 60 systems showed

leaks. Three of these have been repaired. The other 6 are undergoing either further evaluation, closure, or retesting.

Tritium in Groundwater at Site 300

During 1983 and 1984, increases in tritium concentrations were observed in monitoring wells downgradient from experimental and waste disposal areas in the West Firing Area of Site 300. In 1984, concentrations in excess of the state limit for drinking water (20,000 pCi/l) were observed in wells K7-1, K7-3, and K2-1 (see Fig. 21). The CRWQCB (CV) was notified and an investigation of the contamination was initiated. An extensive report on the results of this work has been published³⁰; the information that follows is summarized from that report.

Two source areas for the contamination have been identified; one consists of Pits 3 and 5 (inactive landfills in the Pit 7 Complex) and the other is a region near Bldg. 850 (a high-explosives firing area south of the Pit 7 Complex). An extensive drilling program has established bounds on the maximum extent of the contaminant plumes and installed monitoring wells downgradient of the contaminated areas.

The contaminated groundwater occurs primarily within a shallow perched aquifer. Groundwater flow is to the east and northeast, with maximum velocities of a few tens of meters per year. The highest concentration of tritium observed is approximately one $\mu\text{Ci/l}$. Table A-34 presents tritium concentration data for some of the monitoring wells in the area of the Pit 7 Complex. Neither the contaminated aquifer nor any hydrologically-connected downgradient aquifers are used for potable water supplies.

The only Site 300 monitoring wells outside of the vicinity of the Pit 7 Complex and Bldg. 850 that have shown elevated tritium levels are K2-1 and K2-4 (near Pit 2, an inactive landfill). The investigation has shown that tritium in these wells originated in the Bldg. 850 area and was transported to the Pit 2 area by a combination of subsurface and stream flow. There is no evidence of local contamination in Pit 2.

The report of the investigation has been submitted to the CRWQCB (CV) and DOHS. Further actions will be determined after review and consultation with these agencies.

Permits and Environmental Assessments

In 1985, LLNL held several environmental permits, orders, and notices that were issued for operations at Site 300 and LLNL. A short description of these follows.

Air Permits

During 1985, LLNL was issued 48 permits to operate equipment at LLNL and Site 300. An additional 125 items are exempt from permitting procedures; the equipment is recorded but operating conditions do not require a permit. The permits allowed the operation of 29 boilers for space heat, 3 degreasers, 2 gasoline pump islands, 5 paint spray booths, 1 gasoline storage facility (2 tanks), and 8 miscellaneous items. LLNL permits expire July 1, 1986; Site 300 permits expire on January 31, 1986. At the appropriate time, LLNL will renew permits for regulated sources. LLNL air-pollution sources are regulated by the Bay Area Air Quality Management District (BAAQMD) and the San Joaquin Air Pollution Control District regulates Site 300 sources.

Groundwater Investigation

As described in the Special Assessments section of this report, LLNL is currently involved in a comprehensive groundwater investigation in the vicinity of the Livermore Site. Waste Discharge Requirements for this investigation were adopted by the State Water Quality Control Board, Bay Section on November 20, 1985.

Liquid Waste Discharge

A Waste Discharge Order (Number 80-183) was issued to LLNL by the CRWQCB (CV) in 1980 for liquid waste discharges at Site 300. This order covered craft-shop rinsewater discharges to drywells, photolab rinsewater discharges to the ground, and high-explosives process wastewater lagoons. All of the units covered by this order have been removed from service; therefore, in 1985, Order 80-183 was rescinded. A new Waste Discharge Order (Number 85-188) has been issued to regulate LLNL's new surface impoundment,

which was built to contain non-hazardous process wastewater, as well as the sewage evaporation pond and septic tank systems.

Site 300 also has an existing Waste Discharge Order (Number 82-105) to cover cooling tower discharges. Flow meters are to be purchased and installed to meet the requirements of that order.

Solid Waste Landfills

Eight landfills were addressed in a Waste Discharge Order (Number 80-184) issued by the CRWQCB (CV). Diversion ditches, groundwater monitoring wells, and lysimeters have been installed to meet the specified requirements, and funds have been requested for upgraded covers. As described in the Groundwater Monitoring section, the landfills are circled by wells to detect changes in groundwater quality. Some contamination has been detected in the Pit 7 area; a discussion of contamination investigation results can be found in the Special Monitoring Assessments section.

Other Hazardous Waste Operations

Both Site 300 and the Livermore Site have Interim Status Documents (ISDs) issued by the State Department of Health Services (DOHS) for generation, treatment, and disposal of hazardous waste. Facilities are being upgraded, and funding for new storage and treatment facilities has been received.

A "Part B" application was filed with EPA for the Livermore Site incinerator, and a trial burn is planned pending EPA approval. In addition, an Operations Plan submittal was prepared and sent to the State DOHS for Livermore Site waste treatment and storage facilities. The Part B Application and Operations Plan are being reviewed by the EPA and State DOHS for final permit issuance.

A "Part B" application was also filed with the EPA for the Site 300 active landfills, Pits 1 and 7. This submittal, which included certification of the groundwater monitoring networks surrounding the landfills, was prepared and sent to the EPA prior to the November 8, 1985, deadline for land disposal facilities.

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Appendix A. Tables

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

Month	Perimeter Locations ^a					
	1	2	12 [10 ⁻¹⁵ μ Ci/ml $\pm 2\sigma$ (%)]	13	14	15
Jan.	≤ 0.4 ≤ 0.7 ≤ 0.5	≤ 0.3 ≤ 0.4 ≤ 0.4 0.4 ± 75	0.4 ± 71 0.8 ± 43 0.6 ± 49 0.6 ± 47 0.4 ± 68	≤ 0.6 ≤ 0.6 ≤ 0.6 — ≤ 0.5	≤ 0.7 ≤ 0.9 ≤ 0.7 1.0 ± 57 0.6 ± 60	≤ 0.3 0.5 ± 48 ≤ 0.3 ≤ 0.3 ≤ 0.2
Feb.	≤ 0.5 ≤ 0.4 ≤ 0.4 ≤ 0.5	≤ 0.3 ≤ 0.3 0.4 ± 72 ≤ 0.4	≤ 0.3 — 0.4 ± 59 0.3 ± 69	— ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.6 ≤ 0.6 ≤ 0.5 ≤ 0.5	≤ 0.3 ≤ 0.3 ≤ 0.3 ≤ 0.3
Mar.	0.5 ± 66 ≤ 0.4 ≤ 0.4 0.6 ± 56	0.4 ± 66 ≤ 0.3 ≤ 0.3 0.4 ± 56	≤ 0.3 — ≤ 0.3 0.4 ± 59	≤ 0.4 ≤ 0.4 ≤ 0.4 0.5 ± 61	≤ 0.5 — ≤ 0.2 0.4 ± 51	≤ 0.3 ≤ 0.2 ≤ 0.2 0.3 ± 56
Apr.	— 0.5 ± 69 0.6 ± 57 ≤ 0.4 0.4 ± 75	≤ 0.3 0.4 ± 56 0.3 ± 72 ≤ 0.3 ≤ 0.4	≤ 0.3 0.4 ± 61 0.5 ± 51 ≤ 0.3 0.5 ± 52	≤ 0.4 0.5 ± 66 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.2 — ≤ 0.5 ≤ 0.4 ≤ 0.5	— ≤ 0.3 0.3 ± 75 — 0.3 ± 75
May	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	0.4 ± 59 ≤ 0.3 ≤ 0.3 ≤ 0.3	≤ 0.3 0.4 ± 66 0.4 ± 66 ≤ 0.3	≤ 0.4 — 0.6 ± 75 ≤ 0.6	≤ 0.5 ≤ 0.5 0.6 ± 66 ≤ 0.4	0.3 ± 65 ≤ 0.3 ≤ 0.3 ≤ 0.3
Jun.	≤ 0.4 ≤ 0.5 ≤ 0.4 0.7 ± 48	0.3 ± 68 ≤ 0.3 0.3 ± 74 ≤ 0.3	0.4 ± 54 0.5 ± 58 ≤ 0.3 0.3 ± 67	≤ 0.6 ≤ 0.5 ≤ 0.6 ≤ 0.6	≤ 0.4 ≤ 0.4 ≤ 0.5 ≤ 0.4	≤ 0.3 0.6 ± 55 ≤ 0.3 ≤ 0.2
Jul.	0.8 ± 42 ≤ 0.5 ≤ 0.4 ≤ 0.4 ≤ 0.4	0.4 ± 54 ≤ 0.3 0.3 ± 74 0.3 ± 74 ≤ 0.3	0.5 ± 54 0.5 ± 58 ≤ 0.3 ≤ 0.3 0.4 ± 67	0.7 ± 59 ≤ 0.5 ≤ 0.6 ≤ 0.7 ≤ 0.4	≤ 0.5 ≤ 0.4 ≤ 0.5 0.4 ± 74 ≤ 0.4	0.5 ± 50 0.6 ± 55 ≤ 0.3 0.3 ± 68 0.3 ± 70
Aug.	≤ 0.4 ≤ 0.4 ≤ 0.4 0.5 ± 67	≤ 0.3 ≤ 0.3 ≤ 0.3 0.3 ± 74	≤ 0.3 0.4 ± 66 0.3 ± 65 ≤ 0.3	≤ 0.4 ≤ 0.4 ≤ 0.5 ≤ 0.6	≤ 0.4 ≤ 0.4 0.5 ± 60 ≤ 0.4	≤ 0.3 ≤ 0.3 0.3 ± 62 ≤ 0.3
Sept.	0.4 ± 70 ≤ 0.4 0.6 ± 60 0.8 ± 47	≤ 0.3 ≤ 0.3 0.6 ± 41 ≤ 0.3	≤ 0.3 ≤ 0.3 0.5 ± 50 0.7 ± 42	≤ 0.6 ≤ 0.6 ≤ 0.6 1.1 ± 41	≤ 0.4 ≤ 0.4 0.6 ± 51 0.6 ± 58	≤ 0.3 ≤ 0.3 0.3 ± 73 0.4 ± 53
Oct.	0.4 ± 73 — 0.8 ± 55 ≤ 0.5 ≤ 0.5	0.4 ± 67 0.6 ± 44 1.0 ± 33 0.5 ± 48 ≤ 0.3	0.4 ± 70 0.8 ± 35 0.7 ± 40 0.3 ± 70 ≤ 0.3	≤ 0.6 1.3 ± 38 ≤ 0.5 — ≤ 0.6	0.6 ± 51 1.0 ± 41 ≤ 0.5 ≤ 0.4 ≤ 0.4	0.5 ± 46 0.8 ± 33 0.4 ± 50 0.5 ± 49 ≤ 0.3
Nov.	0.6 ± 64 ≤ 0.5 1.0 ± 37 ≤ 0.5	0.6 ± 46 0.4 ± 51 0.6 ± 44 0.5 ± 60	0.6 ± 44 0.3 ± 63 0.4 ± 65 ≤ 0.3	1.1 ± 41 ≤ 0.4 ≤ 0.4 ≤ 0.4	0.5 ± 61 0.7 ± 55 ≤ 0.4 ≤ 0.5	1.0 ± 32 0.5 ± 47 0.3 ± 62 ≤ 0.3
Dec.	≤ 0.5 0.7 ± 53 — ≤ 0.5 ≤ 0.4	≤ 0.3 0.4 ± 60 0.8 ± 41 0.4 ± 75 0.3 ± 75	≤ 0.3 0.5 ± 48 0.7 ± 41 0.4 ± 69 ≤ 0.3	≤ 0.4 — 0.9 ± 54 ≤ 0.3 —	≤ 0.6 — 0.9 ± 45 0.6 ± 63 ≤ 0.4	≤ 0.3 ≤ 0.3 0.7 ± 40 0.4 ± 61 0.3 ± 66
Annual average ^b	≤ 0.5	≤ 0.4	≤ 0.4	≤ 0.5	≤ 0.5	≤ 0.4
% SDM	28	36	33	36	33	42
% CG ^c	≤ 3	≤ 2	≤ 2	≤ 3	≤ 3	≤ 2

^a See Fig. 5.

^b LLNL perimeter overall annual average $\leq 0.5 \times 10^{-15} \mu\text{Ci/ml} \pm 16\%$.

^c CG = $2 \times 10^{-14} \mu\text{Ci/ml}$.

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

Month	Valley Locations ^a										
	3	4	5	6	7	8	9	10	11	16	17
	[10 ⁻¹⁵ μ Ci/ml $\pm$ 2 σ (%)]										
Jan.	≤ 0.5 ≤ 0.6 ≤ 0.5 0.9 ± 57 0.6 ± 57	≤ 0.3 ≤ 0.6 ≤ 0.5 0.6 ± 63 ≤ 0.5	— 0.8 ± 52 1.1 ± 39 0.5 ± 66 ≤ 0.4	0.5 ± 68 0.8 ± 54 ≤ 0.4 ≤ 0.4 ≤ 0.4	0.6 ± 59 ≤ 0.5 0.4 ± 75 ≤ 0.4 0.5 ± 70	≤ 0.5 0.6 ± 63 ≤ 0.5 0.8 ± 56 ≤ 0.5	0.6 ± 63 0.5 ± 71 0.5 ± 66 0.6 ± 59 ≤ 0.4	≤ 0.4 ≤ 0.4 ≤ 0.4 0.7 ± 50 0.5 ± 57	— 0.7 ± 59 0.6 ± 56 0.6 ± 57 0.6 ± 60	≤ 0.5 ≤ 0.7 — ≤ 0.5 ≤ 0.4	≤ 0.5 ≤ 0.6 0.7 ± 57 ≤ 0.6 ≤ 0.5
Feb.	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.5 ≤ 0.5 ≤ 0.4 0.6 ± 59	≤ 0.4 ≤ 0.4 0.5 ± 64 0.4 ± 75	≤ 0.4 ≤ 0.4 0.4 ± 75 —	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.5 ≤ 0.5 0.7 ± 51 0.5 ± 72	0.7 ± 52 ≤ 0.4 0.6 ± 61 ≤ 0.4	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.4 ≤ 0.4 0.6 ± 61 ≤ 0.4	≤ 0.4 ≤ 0.4 ≤ 0.4 —	≤ 0.5 ≤ 0.5 ≤ 0.5 ≤ 0.5
Mar.	≤ 0.4 ≤ 0.4 ≤ 0.4 0.6 ± 59	0.8 ± 51 ≤ 0.4 ≤ 0.4 0.5 ± 69	0.5 ± 69 ≤ 0.4 ≤ 0.4 ≤ 0.5	≤ 0.4 ≤ 0.4 ≤ 0.4 0.5 ± 72	≤ 0.4 ≤ 0.4 0.4 ± 75 0.4 ± 72	≤ 0.5 ≤ 0.6 0.7 ± 53 0.7 ± 52	0.5 ± 64 ≤ 0.4 ≤ 0.4 0.5 ± 68	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.3	0.5 ± 69 ≤ 0.4 ≤ 0.4 —	≤ 0.4 ≤ 0.4 ≤ 0.4 —	≤ 0.5 ≤ 0.5 ≤ 0.5 ≤ 0.5
Apr.	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.5	≤ 0.5 — ≤ 0.5 0.5 ± 66	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.4 ≤ 0.4 0.4 ± 75 ≤ 0.4	≤ 0.4 0.5 ± 66 ≤ 0.4 ≤ 0.4	≤ 0.5 ≤ 0.5 ≤ 0.5 ≤ 0.5	≤ 0.4 0.6 ± 59 0.5 ± 72 0.5 ± 68	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.3	≤ 0.6 — — —	≤ 0.5 ≤ 0.4 0.5 ± 61 ≤ 0.4	≤ 0.5 ≤ 0.5 ≤ 0.5 ≤ 0.5
May	≤ 0.5 ≤ 0.4 ≤ 0.5 ≤ 0.5	≤ 0.5 ≤ 0.4 1.1 ± 37 ≤ 0.5	0.6 ± 59 ≤ 0.4 0.7 ± 55 ≤ 0.5	0.8 ± 48 ≤ 0.4 0.5 ± 68 ≤ 0.4	— — — ≤ 0.4	≤ 0.5 ≤ 0.5 0.8 ± 52 ≤ 0.5	0.5 ± 63 ≤ 0.4 0.7 ± 51 ≤ 0.4	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.4 0.4 ± 74 ≤ 0.4 0.5 ± 68	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.5	≤ 0.5 ≤ 0.5 0.6 ± 75 ≤ 0.5
Jun.	≤ 0.5 ≤ 0.5 0.4 ± 74 0.4 ± 74	≤ 0.5 ≤ 0.4 0.5 ± 74 ≤ 0.4	≤ 0.4 ≤ 0.4 0.4 ± 74 ≤ 0.4	≤ 0.4 ≤ 0.5 0.4 ± 74 ≤ 0.4	— ≤ 0.4 0.6 ± 58 ≤ 0.4	≤ 0.5 ≤ 0.5 0.8 ± 57 0.5 ± 58	≤ 0.4 ≤ 0.4 0.6 ± 60 0.5 ± 67	≤ 0.3 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.4 ≤ 0.4 0.6 ± 62 0.6 ± 58	≤ 0.4 9.5 ± 62 0.5 ± 60 ≤ 0.4	≤ 0.5 ≤ 0.5 ≤ 0.5 ≤ 0.7
Jul.	0.4 ± 72 0.4 ± 61 0.3 ± 71 ≤ 0.3 ≤ 0.3	≤ 0.5 ≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	0.4 ± 75 0.7 ± 52 0.5 ± 71 0.6 ± 58 0.6 ± 54	0.5 ± 72 0.6 ± 57 0.5 ± 58 0.5 ± 68 0.5 ± 64	≤ 0.4 0.5 ± 61 ≤ 0.4 0.6 ± 58 ≤ 0.4	≤ 0.5 ≤ 0.5 0.6 ± 65 ≤ 0.4 0.5 ± 67	≤ 0.4 0.8 ± 46 ≤ 0.3 ≤ 0.3 ≤ 0.4	≤ 0.4 ≤ 0.4 ≤ 0.3 ≤ 0.3 ≤ 0.4	0.5 ± 69 — 0.6 ± 59 ≤ 0.4 ≤ 0.4	— ≤ 0.4 0.4 ± 74 ≤ 0.4 ≤ 0.4	≤ 0.5 ≤ 0.6 ≤ 0.6 0.6 ± 71 ≤ 0.6
Aug.	≤ 0.3 0.4 ± 56 ≤ 0.3 0.3 ± 70	≤ 0.4 0.5 ± 62 0.4 ± 70 0.6 ± 53	0.7 ± 50 ≤ 0.4 0.8 ± 46 0.6 ± 58	≤ 0.4 ≤ 0.4 0.4 ± 70 0.7 ± 53	≤ 0.4 0.4 ± 72 0.5 ± 67 0.7 ± 50	≤ 0.4 ≤ 0.5 ≤ 0.6 ≤ 0.5	≤ 0.4 0.6 ± 57 0.4 ± 74 ≤ 0.4	≤ 0.3 ≤ 0.4 ≤ 0.3 ≤ 0.4	≤ 0.4 0.6 ± 57 0.4 ± 74 ≤ 0.4	≤ 0.4 ≤ 0.4 ≤ 0.4 ≤ 0.4	≤ 0.5 ≤ 0.5 0.5 ± 74 ≤ 0.5
Sept.	0.5 ± 50 ≤ 0.3 0.4 ± 64 ≤ 0.4	≤ 0.5 ≤ 0.4 0.6 ± 56 0.6 ± 58	0.9 ± 42 ≤ 0.4 0.4 ± 70 ≤ 0.4	0.7 ± 50 — ≤ 0.5 0.5 ± 70	≤ 0.4 0.6 ± 60 ≤ 0.4 0.5 ± 62	≤ 0.5 ≤ 0.6 0.6 ± 73 0.5 ± 62	0.6 ± 60 0.4 ± 73 0.7 ± 51 0.6 ± 54	≤ 0.3 ≤ 0.4 0.5 ± 56 ≤ 0.3	0.6 ± 58 0.4 ± 73 0.5 ± 67 ≤ 0.4	≤ 0.4 ≤ 0.4 0.6 ± 60 0.6 ± 58	≤ 0.5 ≤ 0.5 1.0 ± 47 0.6 ± 70
Oct.	≤ 0.4 0.8 ± 33 0.3 ± 68 0.4 ± 67 ≤ 0.3	≤ 0.4 1.5 ± 31 1.3 ± 32 — ≤ 0.5	0.6 ± 54 1.3 ± 33 ≤ 0.4 0.6 ± 53 0.5 ± 67	0.6 ± 54 1.0 ± 40 0.5 ± 63 ≤ 0.4 ≤ 0.4	0.8 ± 47 1.1 ± 38 ≤ 0.5 0.8 ± 49 ≤ 0.4	≤ 0.6 — — 0.5 ± 74 ≤ 0.8	≤ 0.4 1.0 ± 39 0.5 ± 68 — —	0.3 ± 73 5.7 ± 15 ≤ 0.3 ≤ 0.2 ≤ 0.3	— 1.6 ± 33 0.6 ± 60 0.4 ± 70 ≤ 0.4	≤ 0.4 1.3 ± 35 ≤ 0.4 ≤ 0.6 ≤ 0.5	≤ 0.5 0.9 ± 48 ≤ 0.5 ≤ 0.5 ≤ 0.4
Nov.	0.6 ± 41 ≤ 0.3 ≤ 0.4 ≤ 0.3	0.8 ± 44 ≤ 0.6 0.5 ± 65 ≤ 0.4	1.0 ± 38 0.5 ± 66 — 0.5 ± 74	0.9 ± 42 0.5 ± 66 1.0 ± 40 0.9 ± 44	1.0 ± 41 — 0.7 ± 58 0.4 ± 44	1.4 ± 40 ≤ 0.5 0.5 ± 56 ≤ 0.4	— — 0.9 ± 45 —	0.5 ± 46 ≤ 0.3 0.5 ± 44 ≤ 0.3	— — 0.7 ± 58 ≤ 0.4	0.5 ± 69 — 1.0 ± 52 ≤ 0.5	0.8 ± 52 ≤ 0.2 ≤ 0.5 0.5 ± 65
Dec.	0.4 ± 70 ≤ 0.3 0.5 ± 45 — —	— ≤ 0.4 — — —	0.5 ± 67 1.2 ± 35 1.1 ± 37 1.2 ± 38 0.5 ± 66	0.8 ± 48 0.6 ± 60 1.6 ± 29 1.6 ± 32 1.7 ± 28	0.7 ± 53 0.7 ± 50 1.1 ± 36 0.7 ± 66 0.9 ± 47	≤ 0.5 — — ≤ 0.9 ≤ 0.9	— — 1.8 ± 29 1.1 ± 42 —	≤ 0.3 ≤ 0.2 0.5 ± 44 ≤ 0.3 0.4 ± 69	≤ 0.4 ≤ 0.4 1.2 ± 35 0.9 ± 50 0.6 ± 57	≤ 0.4 ≤ 0.4 0.8 ± 47 0.7 ± 63 ≤ 0.6	≤ 0.5 0.8 ± 53 ≤ 0.7 ≤ 0.7 ≤ 0.4
Annual average ^b	≤ 0.4	≤ 0.5	≤ 0.6	≤ 0.6	≤ 0.5	≤ 0.6	≤ 0.6	≤ 0.5	≤ 0.5	≤ 0.5	≤ 0.6
% SDM	28	40	43	56	36	30	44	153	43	35	22
% CG ^c	≤ 2	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3	≤ 3

^a See Fig. 6.^b Livermore Valley overall annual average $\leq 0.5 \times 10^{-15}$ μ Ci/ml $\pm$ 13%.^c CG = 2×10^{-14} μ Ci/ml

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

Month	Perimeter Locations ^a					
	1	2	12 [10 ⁻¹⁴ μ Ci/ml $\pm$ 2 σ (%)]	13	14	15
Jan.	2.0 $\pm$ 9 3.6 $\pm$ 8 2.2 $\pm$ 9 — 3.1 $\pm$ 7	1.7 $\pm$ 8 3.0 $\pm$ 7 1.7 $\pm$ 9 2.8 $\pm$ 6 2.6 $\pm$ 7	1.7 $\pm$ 8 3.7 $\pm$ 6 1.8 $\pm$ 8 2.9 $\pm$ 6 3.1 $\pm$ 6	1.8 $\pm$ 12 2.7 $\pm$ 9 1.9 $\pm$ 12 — 3.4 $\pm$ 7	1.8 $\pm$ 14 3.3 $\pm$ 10 2.7 $\pm$ 10 4.5 $\pm$ 7 5.3 $\pm$ 5	1.7 $\pm$ 7 3.4 $\pm$ 5 1.8 $\pm$ 7 3.6 $\pm$ 5 2.9 $\pm$ 5
Feb.	1.2 $\pm$ 13 0.9 $\pm$ 16 2.0 $\pm$ 8 1.2 $\pm$ 12	0.8 $\pm$ 13 0.8 $\pm$ 15 2.0 $\pm$ 8 1.2 $\pm$ 12	1.2 $\pm$ 11 — 2.0 $\pm$ 8 1.0 $\pm$ 11	— 1.0 $\pm$ 14 2.2 $\pm$ 8 1.2 $\pm$ 11	1.9 $\pm$ 11 1.2 $\pm$ 16 2.9 $\pm$ 8 1.5 $\pm$ 13	0.9 $\pm$ 11 0.7 $\pm$ 14 1.9 $\pm$ 7 1.0 $\pm$ 10
Mar.	1.2 $\pm$ 12 0.5 $\pm$ 10 1.5 $\pm$ 10 1.0 $\pm$ 15	1.1 $\pm$ 11 0.6 $\pm$ 16 1.4 $\pm$ 9 1.0 $\pm$ 11	1.0 $\pm$ 11 — 1.5 $\pm$ 8 0.9 $\pm$ 12	1.1 $\pm$ 12 0.5 $\pm$ 21 1.6 $\pm$ 9 1.1 $\pm$ 13	1.4 $\pm$ 12 — 1.4 $\pm$ 7 1.2 $\pm$ 8	0.9 $\pm$ 11 0.5 $\pm$ 15 1.4 $\pm$ 8 1.0 $\pm$ 10
Apr.	— 1.6 $\pm$ 10 1.3 $\pm$ 11 0.8 $\pm$ 16 1.3 $\pm$ 11	0.7 $\pm$ 15 1.5 $\pm$ 8 1.1 $\pm$ 10 0.9 $\pm$ 12 1.0 $\pm$ 11	0.7 $\pm$ 14 1.4 $\pm$ 8 1.2 $\pm$ 10 0.9 $\pm$ 12 1.1 $\pm$ 11	0.7 $\pm$ 17 1.7 $\pm$ 9 1.4 $\pm$ 11 0.9 $\pm$ 15 1.2 $\pm$ 11	0.5 $\pm$ 13 — 1.0 $\pm$ 17 0.8 $\pm$ 16 1.2 $\pm$ 15	— 1.5 $\pm$ 8 1.2 $\pm$ 9 — 1.1 $\pm$ 10
May	1.1 $\pm$ 14 0.9 $\pm$ 15 1.8 $\pm$ 10 0.6 $\pm$ 22	1.1 $\pm$ 10 0.9 $\pm$ 12 1.7 $\pm$ 8 0.5 $\pm$ 18	1.1 $\pm$ 10 1.0 $\pm$ 11 1.6 $\pm$ 8 0.8 $\pm$ 14	1.1 $\pm$ 12 — 2.1 $\pm$ 11 0.8 $\pm$ 23	1.3 $\pm$ 13 1.0 $\pm$ 16 1.7 $\pm$ 11 0.6 $\pm$ 22	1.1 $\pm$ 10 0.9 $\pm$ 11 1.7 $\pm$ 8 0.6 $\pm$ 15
Jun.	0.6 $\pm$ 22 1.0 $\pm$ 15 1.0 $\pm$ 13 0.9 $\pm$ 15	0.5 $\pm$ 19 0.8 $\pm$ 14 1.1 $\pm$ 11 0.9 $\pm$ 12	0.6 $\pm$ 16 0.6 $\pm$ 18 1.2 $\pm$ 10 0.8 $\pm$ 13	1.0 $\pm$ 18 1.0 $\pm$ 18 1.4 $\pm$ 15 1.1 $\pm$ 18	0.5 $\pm$ 25 0.8 $\pm$ 18 1.1 $\pm$ 14 0.8 $\pm$ 16	0.5 $\pm$ 17 1.3 $\pm$ 13 1.1 $\pm$ 9 0.8 $\pm$ 11
Jul.	1.3 $\pm$ 11 1.0 $\pm$ 15 0.9 $\pm$ 14 1.0 $\pm$ 13 0.8 $\pm$ 17	1.2 $\pm$ 11 1.1 $\pm$ 11 1.0 $\pm$ 12 0.8 $\pm$ 15 0.9 $\pm$ 13	1.3 $\pm$ 10 ⁴ 0.9 $\pm$ 12 1.1 $\pm$ 10 0.8 $\pm$ 12 1.2 $\pm$ 12	1.7 $\pm$ 12 0.7 $\pm$ 28 0.9 $\pm$ 23 0.7 $\pm$ 30 1.0 $\pm$ 14	1.1 $\pm$ 16 1.1 $\pm$ 18 1.0 $\pm$ 15 1.1 $\pm$ 12 1.2	1.2 $\pm$ 10 0.8 $\pm$ 13 1.0 $\pm$ 10 0.9 $\pm$ 11 0.9 $\pm$ 11
Aug.	0.7 $\pm$ 17 0.9 $\pm$ 15 0.8 $\pm$ 18 1.4 $\pm$ 11	0.6 $\pm$ 16 0.8 $\pm$ 14 0.8 $\pm$ 13 1.3 $\pm$ 10	0.6 $\pm$ 15 0.8 $\pm$ 14 0.8 $\pm$ 13 1.2 $\pm$ 11	0.9 $\pm$ 15 0.9 $\pm$ 18 0.9 $\pm$ 20 1.2 $\pm$ 17	0.6 $\pm$ 19 0.9 $\pm$ 15 1.1 $\pm$ 13 1.2 $\pm$ 13	0.6 $\pm$ 14 0.7 $\pm$ 13 0.8 $\pm$ 12 1.2 $\pm$ 9
Sept.	1.1 $\pm$ 13 0.7 $\pm$ 21 1.1 $\pm$ 14 1.8 $\pm$ 10	0.9 $\pm$ 12 0.5 $\pm$ 18 0.9 $\pm$ 12 1.5 $\pm$ 9	1.1 $\pm$ 10 0.7 $\pm$ 15 1.0 $\pm$ 12 1.8 $\pm$ 8	0.6 $\pm$ 33 0.7 $\pm$ 25 0.8 $\pm$ 26 1.9 $\pm$ 10	1.1 $\pm$ 14 0.5 $\pm$ 25 0.7 $\pm$ 17 1.5 $\pm$ 11	1.1 $\pm$ 11 0.7 $\pm$ 14 1.0 $\pm$ 10 1.6 $\pm$ 8
Oct.	2.0 $\pm$ 9 — 1.9 $\pm$ 11 1.6 $\pm$ 12 0.9 $\pm$ 16	1.8 $\pm$ 8 2.1 $\pm$ 7 1.9 $\pm$ 8 1.1 $\pm$ 10 0.8 $\pm$ 14	2.0 $\pm$ 8 2.4 $\pm$ 6 1.6 $\pm$ 8 1.2 $\pm$ 9 0.6 $\pm$ 16	1.7 $\pm$ 14 3.5 $\pm$ 7 1.2 $\pm$ 16 — 1.2 $\pm$ 18	2.0 $\pm$ 9 3.5 $\pm$ 7 1.8 $\pm$ 11 1.5 $\pm$ 12 0.9 $\pm$ 16	2.0 $\pm$ 7 2.5 $\pm$ 6 1.5 $\pm$ 8 1.2 $\pm$ 9 0.8 $\pm$ 13
Nov.	2.5 $\pm$ 9 1.3 $\pm$ 13 2.4 $\pm$ 8 1.9 $\pm$ 11	1.9 $\pm$ 8 1.0 $\pm$ 11 2.1 $\pm$ 7 1.5 $\pm$ 10	1.6 $\pm$ 8 0.9 $\pm$ 11 2.0 $\pm$ 7 1.6 $\pm$ 9	3.0 $\pm$ 7 1.3 $\pm$ 12 2.8 $\pm$ 7 2.1 $\pm$ 10	2.3 $\pm$ 8 1.2 $\pm$ 14 2.2 $\pm$ 8 1.8 $\pm$ 12	2.0 $\pm$ 7 1.0 $\pm$ 11 2.3 $\pm$ 6 1.7 $\pm$ 9
Dec.	1.2 $\pm$ 15 0.8 $\pm$ 17 — 3.1 $\pm$ 8 3.1 $\pm$ 7	0.9 $\pm$ 14 0.6 $\pm$ 17 3.0 $\pm$ 6 2.4 $\pm$ 7 2.3 $\pm$ 7	1.1 $\pm$ 12 0.6 $\pm$ 16 2.8 $\pm$ 6 2.9 $\pm$ 7 3.0 $\pm$ 6	1.2 $\pm$ 14 — 4.5 $\pm$ 6 2.5 $\pm$ 6 —	0.8 $\pm$ 25 — 3.2 $\pm$ 7 3.2 $\pm$ 7 3.1 $\pm$ 6	1.0 $\pm$ 11 0.7 $\pm$ 14 3.0 $\pm$ 6 3.0 $\pm$ 6 3.2 $\pm$ 5
Annual average ^b	1.4	1.3	1.4	1.5	1.6	1.4
% SDM	51	51	54	57	65	58
% CG ^c	1	1	1	2	2	1

^a See Fig. 5.^b LLNL perimeter overall annual average $\leq 1.7 \times 10^{-14}$ μ Ci/ml $\pm$ 7%.^c CG = 1×10^{-12} μ Ci/ml.

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

Month	Valley Locations ^a										
	3	4	5	6	7	8	9	10	11	16	17
	[10 ⁻¹⁴ μ Ci/ml $\pm$ 2 σ (%)]										
Jan.	1.8 $\pm$ 10 2.8 $\pm$ 8 1.7 $\pm$ 11 4.2 $\pm$ 7 3.7 $\pm$ 6	2.0 $\pm$ 10 3.1 $\pm$ 8 2.0 $\pm$ 10 3.8 $\pm$ 6 3.4 $\pm$ 7	— 3.5 $\pm$ 7 2.4 $\pm$ 8 3.0 $\pm$ 7 2.6 $\pm$ 7	3.1 $\pm$ 7 4.3 $\pm$ 6 2.4 $\pm$ 8 3.0 $\pm$ 7 2.8 $\pm$ 7	2.0 $\pm$ 9 3.1 $\pm$ 7 2.0 $\pm$ 9 2.2 $\pm$ 8 2.5 $\pm$ 8	2.7 $\pm$ 8 3.2 $\pm$ 7 2.6 $\pm$ 8 4.6 $\pm$ 6 4.2 $\pm$ 6	3.1 $\pm$ 7 4.4 $\pm$ 6 3.1 $\pm$ 7 4.3 $\pm$ 6 3.9 $\pm$ 6	1.4 $\pm$ 12 1.6 $\pm$ 9 1.2 $\pm$ 11 2.6 $\pm$ 7 2.3 $\pm$ 7	— 3.1 $\pm$ 7 2.6 $\pm$ 7 3.0 $\pm$ 7 2.9 $\pm$ 7	2.6 $\pm$ 8 4.1 $\pm$ 8 — 2.5 $\pm$ 8 5.1 $\pm$ 5	1.9 $\pm$ 11 4.0 $\pm$ 7 2.3 $\pm$ 9 4.4 $\pm$ 7 3.8 $\pm$ 6
Feb.	0.9 $\pm$ 15 0.7 $\pm$ 19 2.2 $\pm$ 8 1.2 $\pm$ 13	1.1 $\pm$ 15 0.6 $\pm$ 23 2.0 $\pm$ 8 1.3 $\pm$ 12	2.0 $\pm$ 9 1.9 $\pm$ 9 2.3 $\pm$ 8 1.9 $\pm$ 9	2.0 $\pm$ 9 1.7 $\pm$ 10 — —	1.8 $\pm$ 10 1.7 $\pm$ 10 — 1.4 $\pm$ 11	1.4 $\pm$ 12 1.2 $\pm$ 15 2.4 $\pm$ 8 1.6 $\pm$ 11	2.3 $\pm$ 8 2.0 $\pm$ 9 2.8 $\pm$ 7 2.3 $\pm$ 8	0.7 $\pm$ 19 0.6 $\pm$ 19 1.4 $\pm$ 10 0.6 $\pm$ 20	2.0 $\pm$ 9 1.9 $\pm$ 9 2.6 $\pm$ 7 1.9 $\pm$ 9	1.0 $\pm$ 13 0.9 $\pm$ 14 2.1 $\pm$ 8 —	1.4 $\pm$ 13 1.0 $\pm$ 17 2.5 $\pm$ 8 1.1 $\pm$ 15
Mar.	0.8 $\pm$ 16 0.6 $\pm$ 21 1.5 $\pm$ 10 1.1 $\pm$ 13	1.2 $\pm$ 14 0.7 $\pm$ 19 1.8 $\pm$ 10 0.9 $\pm$ 16	1.9 $\pm$ 9 1.5 $\pm$ 11 2.1 $\pm$ 9 1.9 $\pm$ 10	2.0 $\pm$ 0 1.7 $\pm$ 10 2.2 $\pm$ 8 2.0 $\pm$ 9	2.1 $\pm$ 9 1.7 $\pm$ 10 2.2 $\pm$ 8 1.8 $\pm$ 10	1.6 $\pm$ 12 0.5 $\pm$ 26 1.6 $\pm$ 11 1.0 $\pm$ 15	2.4 $\pm$ 8 2.6 $\pm$ 9 2.7 $\pm$ 7 2.2 $\pm$ 8	0.8 $\pm$ 15 2.6 $\pm$ 9 1.0 $\pm$ 13 0.7 $\pm$ 17	1.8 $\pm$ 9 1.6 $\pm$ 10 2.3 $\pm$ 8 —	1.1 $\pm$ 13 0.5 $\pm$ 25 1.5 $\pm$ 10 —	1.4 $\pm$ 13 0.7 $\pm$ 22 1.8 $\pm$ 10 1.2 $\pm$ 14
Apr.	0.7 $\pm$ 18 1.8 $\pm$ 9 1.4 $\pm$ 10 — 1.1 $\pm$ 14	0.7 $\pm$ 22 — 1.5 $\pm$ 11 0.5 $\pm$ 26 1.1 $\pm$ 13	0.7 $\pm$ 10 2.3 $\pm$ 8 2.0 $\pm$ 9 1.9 $\pm$ 9 2.2 $\pm$ 9	1.9 $\pm$ 9 2.1 $\pm$ 9 2.2 $\pm$ 8 2.1 $\pm$ 9 2.2 $\pm$ 8	1.7 $\pm$ 10 2.2 $\pm$ 8 1.9 $\pm$ 9 2.0 $\pm$ 9 1.8 $\pm$ 9	0.9 $\pm$ 17 1.9 $\pm$ 10 1.4 $\pm$ 13 0.8 $\pm$ 19 1.5 $\pm$ 12	2.1 $\pm$ 9 2.6 $\pm$ 7 2.1 $\pm$ 9 2.1 $\pm$ 9 2.4 $\pm$ 8	$\leq$ 0.1 1.0 $\pm$ 12 0.8 $\pm$ 15 0.5 $\pm$ 23 0.7 $\pm$ 16	1.8 $\pm$ 12 — — — —	1.0 $\pm$ 15 1.7 $\pm$ 9 1.2 $\pm$ 12 0.9 $\pm$ 15 1.3 $\pm$ 12	0.8 $\pm$ 19 1.6 $\pm$ 11 1.3 $\pm$ 13 0.9 $\pm$ 18 1.4 $\pm$ 13
May	1.2 $\pm$ 14 1.0 $\pm$ 15 1.3 $\pm$ 10 0.6 $\pm$ 24	1.3 $\pm$ 13 0.8 $\pm$ 17 2.0 $\pm$ 9 0.7 $\pm$ 21	2.2 $\pm$ 8 2.2 $\pm$ 9 2.6 $\pm$ 8 1.9 $\pm$ 10	2.5 $\pm$ 8 2.3 $\pm$ 8 2.6 $\pm$ 7 1.8 $\pm$ 10	— — — 1.9 $\pm$ 9	1.3 $\pm$ 13 1.3 $\pm$ 13 2.0 $\pm$ 10 0.7 $\pm$ 22	2.4 $\pm$ 8 0.2 $\pm$ 66 3.1 $\pm$ 7 2.1 $\pm$ 9	0.7 $\pm$ 17 0.8 $\pm$ 16 1.1 $\pm$ 12 0.5 $\pm$ 22	2.4 $\pm$ 8 1.6 $\pm$ 10 2.2 $\pm$ 8 2.2 $\pm$ 9	1.0 $\pm$ 14 1.1 $\pm$ 14 1.7 $\pm$ 10 0.7 $\pm$ 20	1.4 $\pm$ 13 1.5 $\pm$ 13 2.0 $\pm$ 11 0.7 $\pm$ 22
Jun.	0.6 $\pm$ 23 0.8 $\pm$ 19 1.4 $\pm$ 12 1.4 $\pm$ 11	0.9 $\pm$ 18 0.9 $\pm$ 16 1.2 $\pm$ 14 1.2 $\pm$ 13	1.7 $\pm$ 10 1.9 $\pm$ 9 2.2 $\pm$ 9 1.4 $\pm$ 10	1.7 $\pm$ 10 2.2 $\pm$ 9 2.4 $\pm$ 8 2.2 $\pm$ 8	— 1.8 $\pm$ 10 2.3 $\pm$ 8 2.0 $\pm$ 9	0.7 $\pm$ 20 1.0 $\pm$ 16 1.9 $\pm$ 10 1.2 $\pm$ 14	1.9 $\pm$ 9 2.1 $\pm$ 9 2.4 $\pm$ 8 2.4 $\pm$ 8	0.4 $\pm$ 25 0.5 $\pm$ 25 0.8 $\pm$ 17 0.8 $\pm$ 17	1.9 $\pm$ 9 2.0 $\pm$ 9 2.2 $\pm$ 9 2.1 $\pm$ 9	0.9 $\pm$ 16 0.9 $\pm$ 14 1.4 $\pm$ 11 1.1 $\pm$ 13	0.9 $\pm$ 18 0.8 $\pm$ 20 0.6 $\pm$ 30 0.6 $\pm$ 32
Jul.	1.7 $\pm$ 9 1.2 $\pm$ 10 0.9 $\pm$ 11 0.9 $\pm$ 12 0.8 $\pm$ 12	1.3 $\pm$ 14 1.1 $\pm$ 15 1.1 $\pm$ 13 1.0 $\pm$ 14 0.9 $\pm$ 16	2.2 $\pm$ 8 2.3 $\pm$ 8 2.1 $\pm$ 9 1.9 $\pm$ 9 2.0 $\pm$ 9	2.2 $\pm$ 8 1.9 $\pm$ 9 2.0 $\pm$ 9 2.4 $\pm$ 8 2.1 $\pm$ 9	2.3 $\pm$ 8 2.3 $\pm$ 8 2.2 $\pm$ 8 2.1 $\pm$ 9 2.1 $\pm$ 9	1.6 $\pm$ 12 1.2 $\pm$ 14 1.9 $\pm$ 10 1.7 $\pm$ 10 1.6 $\pm$ 10	2.8 $\pm$ 7 2.2 $\pm$ 9 2.1 $\pm$ 9 2.1 $\pm$ 9 2.2 $\pm$ 8	0.7 $\pm$ 17 0.7 $\pm$ 17 0.4 $\pm$ 24 $\leq$ 0.1 0.6 $\pm$ 21	— — 2.1 $\pm$ 9 2.0 $\pm$ 9 2.1 $\pm$ 9	1.1 $\pm$ 14 1.1 $\pm$ 14 0.9 $\pm$ 16 1.0 $\pm$ 15 0.9 $\pm$ 17	0.8 $\pm$ 22 0.8 $\pm$ 22 0.7 $\pm$ 25 0.7 $\pm$ 23 0.7 $\pm$ 23
Aug.	0.8 $\pm$ 13 1.0 $\pm$ 11 0.8 $\pm$ 14 1.2 $\pm$ 10	0.7 $\pm$ 20 0.7 $\pm$ 17 0.6 $\pm$ 20 1.2 $\pm$ 12	2.0 $\pm$ 9 2.0 $\pm$ 9 2.1 $\pm$ 9 2.3 $\pm$ 8	2.0 $\pm$ 9 2.0 $\pm$ 9 2.1 $\pm$ 9 2.2 $\pm$ 8	1.9 $\pm$ 9 1.9 $\pm$ 9 0.2 $\pm$ 9 2.2 $\pm$ 8	1.2 $\pm$ 12 0.8 $\pm$ 21 0.8 $\pm$ 22 1.3 $\pm$ 15	2.0 $\pm$ 9 2.1 $\pm$ 9 1.9 $\pm$ 9 2.3 $\pm$ 9	$\leq$ 0.1 0.7 $\pm$ 20 0.5 $\pm$ 21 0.9 $\pm$ 15	2.2 $\pm$ 8 2.4 $\pm$ 8 2.0 $\pm$ 9 2.4 $\pm$ 8	0.7 $\pm$ 20 1.0 $\pm$ 15 0.6 $\pm$ 23 1.1 $\pm$ 13	0.5 $\pm$ 28 0.6 $\pm$ 23 0.7 $\pm$ 23 0.9 $\pm$ 17
Sept.	1.2 $\pm$ 10 0.6 $\pm$ 18 0.8 $\pm$ 15 1.3 $\pm$ 11	1.1 $\pm$ 15 0.6 $\pm$ 24 0.9 $\pm$ 16 1.9 $\pm$ 10	2.2 $\pm$ 8 1.6 $\pm$ 11 1.9 $\pm$ 9 2.6 $\pm$ 8	2.1 $\pm$ 9 — 2.1 $\pm$ 10 2.2 $\pm$ 9	2.0 $\pm$ 9 2.0 $\pm$ 9 2.1 $\pm$ 9 2.3 $\pm$ 8	1.1 $\pm$ 16 0.7 $\pm$ 25 1.0 $\pm$ 18 2.1 $\pm$ 11	2.1 $\pm$ 9 1.9 $\pm$ 10 2.2 $\pm$ 8 2.9 $\pm$ 7	0.7 $\pm$ 16 0.5 $\pm$ 24 0.7 $\pm$ 18 1.1 $\pm$ 13	2.3 $\pm$ 8 1.9 $\pm$ 10 2.1 $\pm$ 9 1.6 $\pm$ 11	1.0 $\pm$ 15 0.6 $\pm$ 22 0.9 $\pm$ 17 1.8 $\pm$ 9	0.8 $\pm$ 20 0.5 $\pm$ 30 0.9 $\pm$ 20 1.3 $\pm$ 14
Oct.	1.5 $\pm$ 10 2.7 $\pm$ 6 1.4 $\pm$ 8 1.1 $\pm$ 11 0.7 $\pm$ 15	1.8 $\pm$ 10 3.6 $\pm$ 6 1.7 $\pm$ 9 — 0.9 $\pm$ 19	2.6 $\pm$ 8 3.3 $\pm$ 7 2.2 $\pm$ 8 2.1 $\pm$ 9 2.0 $\pm$ 10	2.8 $\pm$ 7 3.4 $\pm$ 7 2.8 $\pm$ 7 2.3 $\pm$ 8 2.1 $\pm$ 9	2.9 $\pm$ 7 — 2.7 $\pm$ 8 2.4 $\pm$ 8 1.8 $\pm$ 10	2.0 $\pm$ 11 4.5 $\pm$ 6 — — 1.0 $\pm$ 26	$\leq$ 0.2 4.2 $\pm$ 6 2.9 $\pm$ 7 — —	2.4 $\pm$ 9 3.8 $\pm$ 7 1.5 $\pm$ 9 1.1 $\pm$ 10 0.8 $\pm$ 13	— 3.4 $\pm$ 7 2.9 $\pm$ 8 2.4 $\pm$ 8 2.1 $\pm$ 9	2.3 $\pm$ 8 1.8 $\pm$ 11 1.5 $\pm$ 12 0.9 $\pm$ 8 1.1 $\pm$ 15	1.9 $\pm$ 11 — 1.2 $\pm$ 15 0.9 $\pm$ 18 0.7 $\pm$ 21
Nov.	2.2 $\pm$ 6 0.6 $\pm$ 18 1.6 $\pm$ 9 2.1 $\pm$ 8	2.4 $\pm$ 7 0.5 $\pm$ 35 1.5 $\pm$ 11 2.5 $\pm$ 8	3.1 $\pm$ 7 2.9 $\pm$ 7 — 2.3 $\pm$ 9	3.2 $\pm$ 7 2.6 $\pm$ 8 4.5 $\pm$ 5 3.7 $\pm$ 7	3.0 $\pm$ 7 — 3.0 $\pm$ 8 2.2 $\pm$ 9	4.0 $\pm$ 7 0.9 $\pm$ 19 2.5 $\pm$ 7 2.0 $\pm$ 10	— — 4.0 $\pm$ 6 2.6 $\pm$ 8	2.1 $\pm$ 7 1.0 $\pm$ 11 2.3 $\pm$ 6 2.1 $\pm$ 7	— — 3.3 $\pm$ 7 2.0 $\pm$ 9	3.3 $\pm$ 7 — 2.3 $\pm$ 11 2.0 $\pm$ 10	1.6 $\pm$ 12 0.3 $\pm$ 22 2.3 $\pm$ 10 2.2 $\pm$ 9
Dec.	0.9 $\pm$ 14 0.5 $\pm$ 18 3.5 $\pm$ 4 — —	— 0.6 $\pm$ 22 — — —	2.0 $\pm$ 10 2.0 $\pm$ 8 4.4 $\pm$ 5 7.9 $\pm$ 4 4.9 $\pm$ 5	2.2 $\pm$ 9 2.3 $\pm$ 8 6.7 $\pm$ 4 7.4 $\pm$ 4 6.0 $\pm$ 4	2.3 $\pm$ 9 2.0 $\pm$ 9 3.5 $\pm$ 6 3.7 $\pm$ 8 3.1 $\pm$ 7	0.9 $\pm$ 20 — 6.2 $\pm$ 5 2.6 $\pm$ 13 3.6 $\pm$ 10	— 2.5 $\pm$ 8 — 5.7 $\pm$ 5 —	0.9 $\pm$ 12 0.7 $\pm$ 13 3.2 $\pm$ 5 3.0 $\pm$ 6 3.3 $\pm$ 6	1.8 $\pm$ 10 2.1 $\pm$ 8 3.5 $\pm$ 6 3.7 $\pm$ 7 3.3 $\pm$ 7	1.0 $\pm$ 15 0.8 $\pm$ 18 2.4 $\pm$ 8 3.2 $\pm$ 8 2.5 $\pm$ 9	0.6 $\pm$ 26 0.6 $\pm$ 28 4.1 $\pm$ 7 2.2 $\pm$ 12 2.0 $\pm$ 9
Annual average ^b	1.4	1.4	2.4	2.6	2.2	1.7	2.6	1.1	2.3	1.6	1.4
% SDM	59	59	42	45	22	56	39	78	24	63	68
% CG ^c	1	1	2	3	2	2	3	1	2	2	1

^a See Fig. 6^b Livermore Valley overall annual average $\leq 1.9 \times 10^{-14}$ μ Ci/ml $\pm$ 29%.^c CG = 1×10^{-12} μ Ci/ml.

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

Month	Location ^a									
	1	2	3	4	5	6	8	9	10	
	[10 ⁻¹⁵ μCi/ml ± 2σ (%)]									
Jan.	—	—	—	—	—	≤0.5	—	—	—	
	0.2 ± 41	0.8 ± 43	0.3 ± 66	—	0.4 ± 40	≤0.6	0.5 ± 38	0.2 ± 43	0.2 ± 39	
	0.5 ± 54	≤1.0	≤0.6	—	≤0.5	≤0.5	≤0.6	0.4 ± 63	≤0.5	
	0.2 ± 71	0.2 ± 66	≤0.3	—	≤0.4	≤0.6	≤0.2	0.2 ± 66	0.2 ± 69	
	0.2 ± 63	0.3 ± 48	≤0.3	0.3 ± 49	0.4 ± 55	≤0.5	0.2 ± 65	≤0.2	0.4 ± 42	
Feb.	≤0.3	≤0.3	≤0.4	≤0.6	≤0.4	≤0.5	≤0.3	≤0.4	≤0.3	
	≤0.2	≤0.2	≤0.3	≤0.4	≤0.3	≤0.5	≤0.2	≤0.3	≤0.2	
	≤0.2	0.4 ± 56	≤0.3	≤0.4	—	≤0.5	2.6 ± 59	≤0.3	≤0.3	
	≤0.3	≤0.3	≤0.3	≤0.5	0.4 ± 72	≤0.5	≤0.3	≤0.4	—	
Mar.	0.4 ± 53	≤0.3	≤0.3	≤0.4	≤0.3	0.5 ± 72	≤0.3	0.5 ± 42	—	
	≤0.2	≤0.2	≤0.3	—	≤0.3	≤0.5	≤0.3	≤0.2	—	
	≤0.2	—	≤0.3	—	≤0.2	≤0.5	≤0.3	0.3 ± 69	—	
	0.4 ± 48	—	≤0.3	0.3 ± 43	0.4 ± 50	≤0.5	≤0.3	≤0.2	—	
Apr.	≤0.2	—	≤0.3	≤0.4	≤0.3	≤0.5	≤0.3	≤0.3	—	
	—	—	—	—	—	≤0.5	—	—	—	
	0.5 ± 28	—	0.5 ± 30	0.3 ± 56	0.4 ± 32	≤0.5	0.4 ± 36	0.3 ± 36	—	
	≤0.2	—	≤0.3	≤0.4	≤0.3	≤0.5	≤0.4	≤0.3	≤0.2	
	≤0.3	—	≤0.4	≤0.5	≤0.4	≤0.5	≤0.4	≤0.4	≤0.2	
May	≤0.2	—	0.3 ± 57	≤0.4	≤0.3	≤0.5	≤0.3	≤0.3	≤0.3	
	0.3 ± 59	—	≤0.3	≤0.4	≤0.3	≤0.5	≤0.3	≤0.3	0.3 ± 71	
	0.6 ± 66	0.9 ± 66	0.3 ± 63	0.7 ± 59	≤0.3	0.7 ± 61	0.5 ± 51	0.6 ± 51	≤0.3	
	0.3 ± 57	0.4 ± 55	0.2 ± 74	≤0.4	≤0.2	≤0.6	0.3 ± 71	≤0.2	≤0.2	
June	≤0.2	0.3 ± 65	≤0.2	≤0.4	≤0.3	≤0.5	≤0.3	≤0.2	≤0.3	
	0.3 ± 70	0.3 ± 70	≤0.3	—	≤0.3	≤0.5	≤0.5	≤0.3	≤0.3	
	0.6 ± 40	0.4 ± 60	0.4 ± 58	—	≤0.3	≤0.5	0.4 ± 56	0.5 ± 56	0.5 ± 50	
	0.4 ± 62	0.3 ± 65	0.4 ± 55	—	≤0.3	≤0.5	≤0.3	0.4 ± 67	≤0.3	
July	0.5 ± 46	0.4 ± 51	0.4 ± 54	≤0.3	≤0.7	0.5 ± 69	0.3 ± 75	0.4 ± 72	≤0.3	
	0.4 ± 51	0.3 ± 61	—	≤0.4	≤0.5	—	≤0.3	≤0.3	≤0.4	
	0.6 ± 39	0.4 ± 57	≤0.8	≤0.3	≤0.5	≤0.6	0.3 ± 65	0.5 ± 53	≤0.4	
	0.5 ± 44	0.4 ± 52	≤0.2	≤0.3	≤0.6	≤0.4	0.4 ± 55	0.4 ± 62	≤0.4	
	≤0.3	0.4 ± 64	≤0.3	0.3 ± 73	≤0.5	0.5 ± 60	≤0.3	≤0.3	≤0.4	
Aug.	≤0.2	≤0.2	≤0.3	≤0.3	≤0.5	≤0.4	≤0.3	0.3 ± 62	≤0.3	
	0.2 ± 60	≤0.2	≤0.2	≤0.2	≤0.4	0.6 ± 50	0.2 ± 71	—	0.3 ± 74	
	0.4 ± 54	≤0.2	≤0.3	≤0.3	≤0.5	≤0.4	≤0.3	≤0.3	≤0.3	
	0.3 ± 54	0.4 ± 50	—	≤0.3	0.7 ± 58	≤0.4	≤0.3	0.3 ± 67	≤0.3	
Sep.	0.2 ± 70	≤0.2	—	≤0.2	≤0.3	≤0.4	≤0.3	≤0.3	≤0.2	
	≤0.2	0.2 ± 70	≤0.3	0.2 ± 67	≤0.4	≤0.4	≤0.3	≤0.2	≤0.3	
	≤0.2	≤0.2	≤0.3	≤0.2	≤0.4	≤0.4	—	≤0.2	0.3 ± 67	
	0.4 ± 51	0.3 ± 62	≤0.3	≤0.3	≤0.7	0.5 ± 62	—	0.4 ± 67	≤0.4	
Oct.	0.5 ± 39	≤0.2	≤0.3	0.3 ± 64	0.6 ± 62	0.7 ± 67	—	0.4 ± 54	0.3 ± 73	
	0.6 ± 31	0.3 ± 53	0.3 ± 58	0.3 ± 55	0.6 ± 55	1.2 ± 35	—	0.4 ± 40	0.8 ± 33	
	0.3 ± 65	≤0.3	≤0.4	≤0.3	≤0.7	0.4 ± 74	—	≤0.4	0.6 ± 58	
	0.3 ± 62	0.3 ± 60	≤0.3	≤0.3	0.5 ± 46	0.5 ± 62	—	0.2 ± 65	0.3 ± 74	
	≤0.2	≤0.2	≤0.3	≤0.3	≤0.3	≤0.4	—	≤0.2	≤0.3	

^a See Fig. 6; location 6 is in the city of Tracy.

Table A-3. (Continued).

Month	Location ^a								
	1	2	3	4	5	6	8	9	10
	[10 ⁻¹⁵ μ Ci/ml $\pm$ 2 σ (%)]								
Nov.	0.5 $\pm$ 41	0.5 $\pm$ 48 $\leq$ 0.3		0.5 $\pm$ 56	0.5 $\pm$ 47	0.9 $\pm$ 43	—	0.5 $\pm$ 47	0.3 $\pm$ 66
	0.4 $\pm$ 66	0.2 $\pm$ 75 $\leq$ 0.3		$\leq$ 0.3	$\leq$ 0.3	0.8 $\pm$ 55	—	$\leq$ 0.2	$\leq$ 0.3
	0.2 $\pm$ 68	0.3 $\pm$ 62 $\leq$ 0.3		$\leq$ 0.3	$\leq$ 0.3	—	—	$\leq$ 0.2	0.4 $\pm$ 55
	$\leq$ 0.2	$\leq$ 0.3	$\leq$ 0.3	$\leq$ 0.4	$\leq$ 0.5	0.5 $\pm$ 74	—	$\leq$ 0.2	$\leq$ 0.4
Dec.	0.2 $\pm$ 67	0.4 $\pm$ 51 $\leq$ 0.3		—	$\leq$ 0.5	—	$\leq$ 0.4	—	0.2 $\pm$ 74
	$\leq$ 0.2	$\leq$ 0.2	$\leq$ 0.3	—	$\leq$ 0.3	—	$\leq$ 0.3	$\leq$ 0.2	—
	0.5 $\pm$ 39	0.5 $\pm$ 39	0.5 $\pm$ 40	0.1 $\pm$ 54	0.4 $\pm$ 68	—	$\leq$ 0.3	0.5 $\pm$ 35	0.3 $\pm$ 31
	0.3 $\pm$ 45	0.4 $\pm$ 40 $\leq$ 0.3		—	$\leq$ 0.4	—	$\leq$ 0.3	0.3 $\pm$ 63	0.5 $\pm$ 63
	0.2 $\pm$ 69	2.2 $\pm$ 75 $\leq$ 0.3		—	$\leq$ 0.4	0.6 $\pm$ 62 $\leq$ 0.4	$\leq$ 0.4	0.2 $\pm$ 72	—
Annual average ^b	$\leq$ 0.3	$\leq$ 0.4	$\leq$ 0.3	$\leq$ 0.4	$\leq$ 0.4	$\leq$ 0.5	$\leq$ 0.4	$\leq$ 0.3	$\leq$ 0.3
%SDM	40	13	30	32	32	26	95	35	36
%CG ^c	2	2	2	2	2	2	2	2	2

^a See Fig. 6; location 6 is in city of Tracy.^b Site 300 overall annual average $\leq 0.4 \times 10^{-15}$ μ Ci/ml $\pm$ 19%.^c CG = 2×10^{-14} μ Ci/ml.

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

Month	Location ^a								
	1	2	3	4	5	6	8	9	10
	[10 ⁻¹⁴ μ Ci/ml $\pm$ 2 σ (%)]								
Jan.	—	—	—	—	—	0.3 $\pm$ 7	—	—	—
	2.9 $\pm$ 3	9.0 $\pm$ 3	2.3 $\pm$ 5	—	3.8 $\pm$ 4	0.4 $\pm$ 7	4.7 $\pm$ 3	2.2 $\pm$ 4	1.4 $\pm$ 3
	2.4 $\pm$ 6	7.5 $\pm$ 6	2.5 $\pm$ 9	—	2.4 $\pm$ 9	2.5 $\pm$ 9	4.2 $\pm$ 7	2.1 $\pm$ 7	2.3 $\pm$ 9
	3.8 $\pm$ 4	3.9 $\pm$ 4	2.9 $\pm$ 5	—	5.3 $\pm$ 5	4.6 $\pm$ 6	3.9 $\pm$ 4	3.6 $\pm$ 4	1.4 $\pm$ 7
	3.2 $\pm$ 4	3.3 $\pm$ 4	3.0 $\pm$ 5	3.4 $\pm$ 4	3.2 $\pm$ 5	4.0 $\pm$ 6	3.1 $\pm$ 4	2.6 $\pm$ 4	2.4 $\pm$ 5
Feb.	1.0 $\pm$ 11	0.9 $\pm$ 13	0.9 $\pm$ 15	0.9 $\pm$ 20	1.3 $\pm$ 12	1.4 $\pm$ 13	1.1 $\pm$ 12	1.0 $\pm$ 13	0.9 $\pm$ 14
	0.9 $\pm$ 8	1.0 $\pm$ 10	0.9 $\pm$ 13	1.0 $\pm$ 14	0.6 $\pm$ 16	1.9 $\pm$ 11	0.9 $\pm$ 9	1.1 $\pm$ 10	0.7 $\pm$ 13
	2.4 $\pm$ 5	2.7 $\pm$ 5	2.0 $\pm$ 7	2.2 $\pm$ 9	—	2.3 $\pm$ 9	2.0 $\pm$ 5	2.8 $\pm$ 6	1.7 $\pm$ 7
	1.4 $\pm$ 9	1.3 $\pm$ 10	1.1 $\pm$ 10	1.2 $\pm$ 14	1.7 $\pm$ 9	1.2 $\pm$ 14	1.2 $\pm$ 10	1.4 $\pm$ 10	—
Mar.	1.2 $\pm$ 8	1.3 $\pm$ 9	1.1 $\pm$ 10	1.0 $\pm$ 14	1.0 $\pm$ 10	1.2 $\pm$ 15	1.1 $\pm$ 11	1.2 $\pm$ 9	—
	0.7 $\pm$ 11	0.7 $\pm$ 13	0.5 $\pm$ 17	—	0.6 $\pm$ 15	0.7 $\pm$ 24	0.8 $\pm$ 14	0.6 $\pm$ 14	—
	1.6 $\pm$ 6	—	1.5 $\pm$ 8	—	1.4 $\pm$ 8	1.6 $\pm$ 11	1.6 $\pm$ 9	1.8 $\pm$ 7	—
	1.4 $\pm$ 7	—	1.3 $\pm$ 10	1.2 $\pm$ 6	1.1 $\pm$ 9	1.2 $\pm$ 15	1.2 $\pm$ 10	1.9 $\pm$ 8	—
Apr.	0.6 $\pm$ 12	—	0.6 $\pm$ 17	0.5 $\pm$ 23	0.5 $\pm$ 16	1.0 $\pm$ 17	0.3 $\pm$ 17	0.6 $\pm$ 14	—
	—	—	—	—	—	1.8 $\pm$ 11	—	—	—
	1.8 $\pm$ 4	—	1.7 $\pm$ 5	1.6 $\pm$ 7	1.7 $\pm$ 5	1.4 $\pm$ 12	1.7 $\pm$ 5	1.4 $\pm$ 5	—
	1.0 $\pm$ 10	—	0.9 $\pm$ 13	0.8 $\pm$ 16	0.9 $\pm$ 12	0.8 $\pm$ 19	1.0 $\pm$ 13	0.9 $\pm$ 11	0.7 $\pm$ 11
May	1.1 $\pm$ 10	—	1.6 $\pm$ 9	1.5 $\pm$ 13	1.6 $\pm$ 10	1.6 $\pm$ 12	1.4 $\pm$ 11	1.9 $\pm$ 9	0.8 $\pm$ 11
	1.5 $\pm$ 7	—	1.4 $\pm$ 8	1.4 $\pm$ 12	0.7 $\pm$ 14	1.4 $\pm$ 13	1.4 $\pm$ 8	1.6 $\pm$ 8	1.1 $\pm$ 10
	1.4 $\pm$ 8	—	1.1 $\pm$ 10	1.2 $\pm$ 13	0.6 $\pm$ 16	1.3 $\pm$ 14	1.3 $\pm$ 10	1.3 $\pm$ 9	0.9 $\pm$ 11
	4.3 $\pm$ 6	5.5 $\pm$ 6	2.0 $\pm$ 6	2.0 $\pm$ 10	1.0 $\pm$ 10	2.1 $\pm$ 10	1.9 $\pm$ 7	2.8 $\pm$ 6	1.4 $\pm$ 8
June	1.1 $\pm$ 8	1.1 $\pm$ 9	0.9 $\pm$ 10	0.9 $\pm$ 14	0.5 $\pm$ 15	0.9 $\pm$ 20	0.9 $\pm$ 11	1.0 $\pm$ 10	1.1 $\pm$ 9
	0.8 $\pm$ 11	0.8 $\pm$ 12	0.7 $\pm$ 13	0.8 $\pm$ 17	0.4 $\pm$ 20	0.6 $\pm$ 27	0.9 $\pm$ 12	0.7 $\pm$ 13	0.6 $\pm$ 15
	1.1 $\pm$ 10	1.1 $\pm$ 10	1.1 $\pm$ 11	—	0.5 $\pm$ 21	1.1 $\pm$ 16	1.1 $\pm$ 15	1.1 $\pm$ 12	0.7 $\pm$ 16
	2.1 $\pm$ 6	1.9 $\pm$ 7	1.9 $\pm$ 7	—	0.9 $\pm$ 12	1.3 $\pm$ 13	1.9 $\pm$ 7	2.4 $\pm$ 7	1.2 $\pm$ 9
July	2.1 $\pm$ 7	1.8 $\pm$ 7	1.4 $\pm$ 8	—	0.8 $\pm$ 13	1.2 $\pm$ 14	1.6 $\pm$ 8	2.0 $\pm$ 7	1.2 $\pm$ 10
	1.6 $\pm$ 8	1.4 $\pm$ 8	1.5 $\pm$ 8	0.9 $\pm$ 12	1.4 $\pm$ 17	1.6 $\pm$ 11	1.4 $\pm$ 9	1.7 $\pm$ 9	0.9 $\pm$ 12
	1.4 $\pm$ 8	1.1 $\pm$ 9	—	1.2 $\pm$ 12	1.3 $\pm$ 14	—	1.0 $\pm$ 11	1.5 $\pm$ 9	1.2 $\pm$ 12
	1.8 $\pm$ 7	1.4 $\pm$ 8	1.6 $\pm$ 17	1.2 $\pm$ 10	1.3 $\pm$ 15	1.2 $\pm$ 18	1.7 $\pm$ 8	2.0 $\pm$ 8	1.3 $\pm$ 11
	1.8 $\pm$ 7	1.4 $\pm$ 8	0.8 $\pm$ 11	1.5 $\pm$ 9	2.0 $\pm$ 11	1.3 $\pm$ 11	1.8 $\pm$ 7	2.0 $\pm$ 7	1.6 $\pm$ 10
	2.0 $\pm$ 6	2.4 $\pm$ 7	1.6 $\pm$ 8	1.6 $\pm$ 8	0.9 $\pm$ 18	1.3 $\pm$ 11	1.8 $\pm$ 7	1.4 $\pm$ 10	2.3 $\pm$ 7

^a See Fig. 6; location 6 is in the city of Tracy.

Table A-4. (Continued).

Month	Location ^a									
	1	2	3	4	5	6	8	9	10	
	[10 ⁻¹⁴ μCi/ml ± 2σ (%)]									
Aug.	1.1 ± 9	0.9 ± 11	1.0 ± 13	1.0 ± 11	0.9 ± 18	1.0 ± 14	0.8 ± 12	1.2 ± 9	0.8 ± 15	
	—	—	—	—	—	1.0 ± 14	—	—	—	
	1.6 ± 8	1.1 ± 9	0.8 ± 15	1.0 ± 10	0.9 ± 17	1.1 ± 13	0.9 ± 14	1.1 ± 11	1.1 ± 12	
	1.3 ± 8	1.4 ± 8	—	1.6 ± 9	1.4 ± 13	1.4 ± 11	0.8 ± 16	1.6 ± 8	1.2 ± 10	
Sep.	1.0 ± 9	1.0 ± 9	—	0.7 ± 11	0.8 ± 15	1.3 ± 11	0.7 ± 14	1.2 ± 9	0.7 ± 13	
	0.8 ± 11	0.7 ± 12	0.5 ± 17	0.6 ± 12	0.6 ± 22	0.7 ± 18	0.4 ± 24	0.9 ± 12	0.6 ± 16	
	≤0.1	1.0 ± 10	0.7 ± 14	1.0 ± 10	0.7 ± 19	1.0 ± 13	—	0.9 ± 10	0.5 ± 16	
	1.8 ± 7	1.9 ± 7	0.9 ± 12	1.6 ± 9	2.0 ± 12	2.1 ± 8	—	2.3 ± 7	1.9 ± 10	
Oct.	2.4 ± 5	1.9 ± 6	1.9 ± 8	1.8 ± 7	2.0 ± 9	2.4 ± 8	—	2.3 ± 6	1.8 ± 7	
	2.8 ± 5	2.7 ± 5	1.8 ± 7	1.9 ± 6	2.4 ± 7	3.8 ± 6	—	2.4 ± 5	2.3 ± 6	
	1.8 ± 7	1.8 ± 8	1.4 ± 11	1.4 ± 9	2.0 ± 13	1.7 ± 10	—	2.7 ± 7	2.0 ± 9	
	1.7 ± 6	1.4 ± 7	1.2 ± 10	1.3 ± 10	1.7 ± 8	1.8 ± 9	—	1.4 ± 7	1.5 ± 8	
Nov.	0.8 ± 9	0.6 ± 13	0.5 ± 18	0.7 ± 15	0.7 ± 13	1.2 ± 14	—	0.9 ± 10	0.6 ± 16	
	2.4 ± 5	2.3 ± 6	2.1 ± 7	2.1 ± 7	2.0 ± 7	2.8 ± 7	—	2.1 ± 7	2.0 ± 7	
	1.2 ± 11	0.9 ± 10	1.0 ± 11	0.7 ± 14	0.6 ± 17	1.0 ± 18	—	0.8 ± 10	0.8 ± 18	
	2.8 ± 5	2.8 ± 5	1.8 ± 8	2.0 ± 7	1.2 ± 11	—	—	2.5 ± 5	2.1 ± 6	
Dec.	2.1 ± 7	1.8 ± 7	1.4 ± 10	0.4 ± 29	0.9 ± 19	2.7 ± 8	—	1.7 ± 8	1.3 ± 11	
	1.3 ± 8	1.1 ± 9	0.9 ± 14	—	0.8 ± 20	—	1.4 ± 12	—	1.1 ± 10	
	0.5 ± 13	0.4 ± 17	0.3 ± 28	—	0.5 ± 21	—	0.4 ± 29	0.4 ± 18	—	
	3.4 ± 4	3.6 ± 4	1.9 ± 6	0.1 ± 29	1.1 ± 12	—	3.0 ± 6	3.8 ± 4	1.4 ± 4	
	3.5 ± 4	3.5 ± 4	1.9 ± 7	—	1.3 ± 11	—	0.7 ± 17	0.4 ± 4	1.7 ± 10	
	3.5 ± 4	3.4 ± 4	2.1 ± 7	—	1.6 ± 11	3.9 ± 6	0.9 ± 16	3.4 ± 4	—	
Annual average ^a	1.5	2.1	1.4	1.3	1.3	1.6	1.5	1.7	1.3	
%SDM ^b	65	85	46	48	69	58	67	49	42	
%CG ^c	2	2	1	1	1	2	2	2	1	

^a See Fig. 6; location 6 is in city of Tracy.^b Site 300 overall annual average = $1.5 \times 10^{-14} \mu\text{Ci}/\text{ml} \pm 17$.^c CG = $1 \times 10^{-12} \mu\text{Ci}/\text{ml}$.

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

Month	⁷ Be	⁴⁰ K	¹⁰⁶ Ru	¹²⁵ Sb	¹³⁷ Cs	¹⁴⁴ Ce
	[10 ⁻¹³ $\mu\text{Ci}/\text{ml} \pm 2\sigma$ (%)]	[10 ⁻¹⁶ $\mu\text{Ci}/\text{ml} \pm 2\sigma$ (%)]				
Jan.	1.0 $\pm$ 2	4.9 $\pm$ 60	0.4 $\pm$ 100	0.2 $\pm$ 100	0.1 $\pm$ 100	0.4 $\pm$ 100
Feb.	1.3 $\pm$ 2	1.3 $\pm$ 100	0.4 $\pm$ 100	0.2 $\pm$ 100	0.2 $\pm$ 100	0.4 $\pm$ 100
Mar.	1.3 $\pm$ 2	4.4 $\pm$ 42	0.3 $\pm$ 100	0.1 $\pm$ 100	0.2 $\pm$ 100	0.3 $\pm$ 100
Apr.	1.0 $\pm$ 2	5.1 $\pm$ 56	0.3 $\pm$ 100	0.1 $\pm$ 100	0.2 $\pm$ 36	0.3 $\pm$ 100
May	1.2 $\pm$ 2	4.4 $\pm$ 72	0.4 $\pm$ 100	0.1 $\pm$ 100	0.3 $\pm$ 32	0.3 $\pm$ 100
June	1.2 $\pm$ 2	7.6 $\pm$ 40	0.4 $\pm$ 100	0.2 $\pm$ 100	0.2 $\pm$ 50	0.4 $\pm$ 100
July	1.0 $\pm$ 2	6.9 $\pm$ 46	0.4 $\pm$ 100	0.1 $\pm$ 100	0.3 $\pm$ 48	0.3 $\pm$ 100
Aug.	0.9 $\pm$ 2	1.1 $\pm$ 100	0.3 $\pm$ 100	0.1 $\pm$ 100	0.1 $\pm$ 100	0.2 $\pm$ 100
Sept.	0.5 $\pm$ 2	0.8 $\pm$ 100	0.2 $\pm$ 100	0.1 $\pm$ 100	0.1 $\pm$ 76	0.2 $\pm$ 100
Oct.	1.3 $\pm$ 2	8.7 $\pm$ 20	0.3 $\pm$ 100	0.1 $\pm$ 100	0.3 $\pm$ 32	0.2 $\pm$ 100
Nov.	1.0 $\pm$ 2	4.6 $\pm$ 42	0.3 $\pm$ 100	0.1 $\pm$ 100	0.1 $\pm$ 100	0.2 $\pm$ 100
Dec.	0.9 $\pm$ 2	1.2 $\pm$ 100	0.4 $\pm$ 100	0.1 $\pm$ 100	0.0 $\pm$ 100	0.3 $\pm$ 100
Annual average	1.0	4.2	0.3	0.1	0.2	0.3
%SDM	21	63	19	33	50	24
CG ($\mu\text{Ci}/\text{ml}$)	5×10^{-6}	9×10^{-10}	3×10^{-11}	1×10^{-9}	4×10^{-10}	3×10^{-11}
%CG	2×10^{-4}	5×10^{-5}	1×10^{-4}	1×10^{-6}	5×10^{-6}	1×10^{-4}

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.	1.5 ± 2	0.5 ± 100	0.2 ± 100	0.1 ± 100	0.2 ± 24	0.2 ± 100
Feb.	1.5 ± 2	0.5 ± 100	0.3 ± 100	0.1 ± 100	0.3 ± 32	0.3 ± 100
Mar.	1.8 ± 2	1.0 ± 100	0.3 ± 100	0.1 ± 100	0.4 ± 26	0.3 ± 100
Apr.	1.4 ± 2	3.1 ± 68	0.2 ± 100	0.1 ± 100	0.4 ± 18	0.2 ± 100
May	1.8 ± 2	3.7 ± 60	0.2 ± 100	0.1 ± 100	0.4 ± 11	0.3 ± 100
June	2.0 ± 2	4.9 ± 54	0.2 ± 100	0.1 ± 100	0.3 ± 17	0.3 ± 100
July	1.8 ± 2	4.1 ± 74	0.2 ± 100	0.1 ± 100	0.2 ± 24	0.3 ± 100
Aug.	1.5 ± 2	3.9 ± 30	0.2 ± 100	0.1 ± 100	0.2 ± 26	0.3 ± 100
Sept.	1.2 ± 2	2.2 ± 56	0.2 ± 100	0.1 ± 100	0.1 ± 54	0.2 ± 100
Oct.	1.6 ± 2	4.9 ± 18	0.1 ± 100	0.1 ± 100	0.2 ± 22	0.2 ± 100
Nov.	1.2 ± 2	2.3 ± 56	0.2 ± 100	0.1 ± 100	0.2 ± 44	0.2 ± 100
Dec.	1.0 ± 2	0.5 ± 100	0.2 ± 100	0.1 ± 100	0.1 ± 54	0.2 ± 100
Annual average	1.5	2.6	0.2	0.1	0.2	0.2
% SDM	20	65	22	6	45	22
CG (μCi/ml)	5 × 10 ⁻⁸	9 × 10 ⁻⁹	3 × 10 ⁻¹¹	1 × 10 ⁻⁹	4 × 10 ⁻¹⁰	3 × 10 ⁻¹¹
% CG	3 × 10 ⁻⁴	3 × 10 ⁻⁵	7 × 10 ⁻⁵	1 × 10 ⁻⁶	5 × 10 ⁻⁶	7 × 10 ⁻⁵

Table A-7. ²³⁹Pu 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.	0.1 ± 100	0.1 ± 100	0.1 ± 88	0.1 ± 100	0.1 ± 83	0.1 ± 100
Feb.	0.1 ± 92	0.1 ± 100	0.1 ± 100	0.1 ± 100	0.1 ± 100	0.1 ± 100
Mar.	0.1 ± 100	0.1 ± 79	0.2 ± 100	0.1 ± 80	0.1 ± 71	0.1 ± 67
Apr.	0.1 ± 85	0.1 ± 99	0.1 ± 90	0.1 ± 81	0.1 ± 100	0.1 ± 78
May	0.1 ± 58	0.1 ± 76	0.1 ± 100	0.1 ± 65	0.1 ± 58	0.1 ± 56
June	0.1 ± 69	0.1 ± 85	0.1 ± 100	0.1 ± 63	0.1 ± 89	0.1 ± 94
July	0.1 ± 65	0.1 ± 89	0.1 ± 70	0.1 ± 65	0.1 ± 100	0.1 ± 100
Aug.	0.1 ± 100	0.1 ± 100	0.1 ± 57	0.1 ± 100	0.1 ± 100	0.1 ± 100
Sept.	0.1 ± 100	0.1 ± 100	0.1 ± 100	0.1 ± 63	0.1 ± 86	0.1 ± 69
Oct.	0.1 ± 70	0.1 ± 100	0.1 ± 100	0.1 ± 60	0.1 ± 55	0.1 ± 68
Nov.	0.1 ± 100	0.1 ± 100	0.1 ± 100	0.1 ± 88	0.1 ± 72	0.1 ± 100
Dec.	0.1 ± 100	0.1 ± 100	0.1 ± 85	0.1 ± 100	0.1 ± 100	0.1 ± 100
Annual average	0.1	0.1	0.1	0.1	0.1	0.1
% SDM ^b	0	0	27	0	0	0
% CG ^c	5 × 10 ⁻³	5 × 10 ⁻³	5 × 10 ⁻³	5 × 10 ⁻³	5 × 10 ⁻³	5 × 10 ⁻³

^a See Fig. 7. Location 040-06 is in city of Tracy.^b Values are at or near the detection limit, so %SDM reflects precision of the analytical method rather than environmental ²³⁹Pu distributions.^c CG = 2 × 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.	1	0.1 ± 75	2.2 ± 3	3.0 ± 3	7.3
	2	0.1 ± 100	2.5 ± 3	3.6 ± 3	6.9
	12	0.3 ± 36	3.7 ± 3	5.4 ± 3	6.9
	13	0.1 ± 100	2.2 ± 3	3.1 ± 3	7.1
	14	0.1 ± 63	2.5 ± 3	3.6 ± 3	6.9
	15	0.1 ± 100	1.5 ± 3	2.1 ± 3	7.1
Feb.	1	0.5 ± 20	3.7 ± 3	5.4 ± 3	6.9
	2	0.1 ± 82	3.1 ± 3	4.4 ± 3	7.0
	12	0.2 ± 43	4.9 ± 3	7.2 ± 3	6.8
	13	0.1 ± 75	3.6 ± 3	5.0 ± 3	7.2
	14	0.1 ± 67	3.8 ± 3	5.3 ± 3	7.2
	15	0.1 ± 79	2.5 ± 3	3.5 ± 3	7.1
Mar.	1	0.2 ± 52	3.2 ± 3	4.4 ± 3	7.3
	2	0.1 ± 93	2.5 ± 3	3.5 ± 3	7.1
	12	0.1 ± 65	4.8 ± 3	6.6 ± 3	7.3
	13	0.1 ± 75	3.2 ± 3	4.3 ± 3	7.4
	14	0.2 ± 42	3.1 ± 3	4.3 ± 3	7.2
	15	0.1 ± 81	1.5 ± 3	2.1 ± 3	7.1
Apr.	1	0.5 ± 32	6.0 ± 3	8.6 ± 3	7.0
	2	0.1 ± 81	3.5 ± 3	4.9 ± 3	7.1
	12	0.2 ± 42	5.1 ± 3	8.0 ± 3	6.4
	13	0.1 ± 81	5.6 ± 3	7.9 ± 3	7.1
	14	0.1 ± 90	2.9 ± 3	4.1 ± 3	7.1
	15	0.1 ± 58	6.1 ± 3	8.6 ± 3	7.1
May	1	0.4 ± 18	4.9 ± 3	7.0 ± 3	7.0
	2	0.1 ± 42	2.4 ± 3	3.3 ± 3	7.3
	12	0.1 ± 25	8.2 ± 3	11.8 ± 3	6.9
	13	0.1 ± 48	5.6 ± 3	8.0 ± 3	7.0
	14	0.1 ± 50	4.3 ± 3	6.0 ± 3	7.2
	15	0.1 ± 78	5.7 ± 3	8.1 ± 3	7.0
June	1	1.3 ± 18	8.3 ± 3	11.9 ± 3	7.0
	2	0.1 ± 77	3.6 ± 3	5.1 ± 3	7.1
	12	0.2 ± 46	9.6 ± 3	13.7 ± 3	7.0
	13	0.1 ± 64	4.5 ± 3	6.4 ± 3	7.0
	14	0.1 ± 55	2.9 ± 3	4.1 ± 3	7.1
	15	0.1 ± 100	6.8 ± 3	9.6 ± 3	7.1
July	1	0.5 ± 22	8.5 ± 3	12.1 ± 3	7.0
	2	0.1 ± 85	4.4 ± 3	6.1 ± 3	7.2
	12	0.2 ± 35	9.5 ± 3	13.4 ± 3	7.1
	13	0.1 ± 82	7.1 ± 3	10.0 ± 3	7.1
	14	0.5 ± 21	5.3 ± 3	7.6 ± 3	7.1
	15	0.1 ± 60	9.1 ± 3	12.8 ± 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.	1	0.9 $\pm$ 20	7.3 $\pm$ 3	10.5 $\pm$ 3	7.0
	2	0.1 $\pm$ 79	3.0 $\pm$ 3	4.2 $\pm$ 3	7.1
	12	0.2 $\pm$ 27	6.7 $\pm$ 3	9.7 $\pm$ 3	6.9
	13	0.1 $\pm$ 71	6.7 $\pm$ 3	9.3 $\pm$ 3	7.2
	14	0.2 $\pm$ 29	5.2 $\pm$ 3	7.5 $\pm$ 3	6.9
	15	0.1 $\pm$ 58	7.1 $\pm$ 3	10.2 $\pm$ 3	7.0
Sept.	1	0.9 $\pm$ 17	7.6 $\pm$ 3	11.4 $\pm$ 3	6.7
	2	0.1 $\pm$ 86	3.3 $\pm$ 3	4.7 $\pm$ 3	7.0
	12	0.2 $\pm$ 38	6.3 $\pm$ 3	9.2 $\pm$ 3	6.8
	13	0.1 $\pm$ 100	5.9 $\pm$ 3	8.6 $\pm$ 3	6.9
	14	0.1 $\pm$ 70	6.0 $\pm$ 3	8.2 $\pm$ 3	7.3
	15	0.1 $\pm$ 100	7.4 $\pm$ 3	10.8 $\pm$ 3	6.9
Oct.	1	1.3 $\pm$ 18	8.7 $\pm$ 3	12.4 $\pm$ 3	7.0
	2	0.1 $\pm$ 84	10.5 $\pm$ 3	14.9 $\pm$ 3	7.0
	12	0.1 $\pm$ 42	6.7 $\pm$ 3	9.4 $\pm$ 3	7.1
	13	0.1 $\pm$ 69	10.6 $\pm$ 3	14.9 $\pm$ 3	7.1
	14	0.2 $\pm$ 39	8.3 $\pm$ 3	11.8 $\pm$ 3	7.0
	15	0.1 $\pm$ 53	9.0 $\pm$ 3	12.7 $\pm$ 3	7.0
Nov.	1	0.4 $\pm$ 27	4.7 $\pm$ 3	6.7 $\pm$ 3	7.0
	2	0.1 $\pm$ 84	9.2 $\pm$ 3	13.0 $\pm$ 3	7.1
	12	0.1 $\pm$ 55	4.1 $\pm$ 3	5.8 $\pm$ 3	7.1
	13	0.1 $\pm$ 96	4.6 $\pm$ 3	6.4 $\pm$ 3	7.2
	14	0.1 $\pm$ 65	3.4 $\pm$ 3	4.8 $\pm$ 3	7.1
	15	0.1 $\pm$ 65	4.8 $\pm$ 3	6.7 $\pm$ 3	7.1
Dec.	1	0.2 $\pm$ 38	2.9 $\pm$ 3	4.2 $\pm$ 3	6.9
	2	0.1 $\pm$ 92	4.8 $\pm$ 3	6.8 $\pm$ 3	7.1
	12	0.1 $\pm$ 48	4.2 $\pm$ 3	6.0 $\pm$ 3	7.0
	13	0.1 $\pm$ 100	3.2 $\pm$ 3	4.4 $\pm$ 3	7.2
	14	0.1 $\pm$ 59	2.5 $\pm$ 3	3.7 $\pm$ 3	6.7
	15	0.1 $\pm$ 58	2.6 $\pm$ 3	3.8 $\pm$ 3	7.0

Annual averages

Location	²³⁹ Pu			²³⁵ U			²³⁸ U		
	10 ⁻¹⁷ μ Ci/ml	% SDM	% CG ^c	10 ⁻⁷ μ g/m ³	% SDM	% CG ^d	10 ⁻⁵ μ g/m ³	% SDM	% CG ^e
1	0.6	68	3 $\times$ 10 ⁻²	5.7	42	1 $\times$ 10 ⁻³	8.1	42	3 $\times$ 10 ⁻²
2	0.1	0	5 $\times$ 10 ⁻³	4.4	60	9 $\times$ 10 ⁻⁴	6.2	61	2 $\times$ 10 ⁻²
12	0.2	38	1 $\times$ 10 ⁻²	6.1	33	1 $\times$ 10 ⁻³	8.9	33	3 $\times$ 10 ⁻²
13	0.1	3	5 $\times$ 10 ⁻³	5.2	43	1 $\times$ 10 ⁻³	7.4	44	2 $\times$ 10 ⁻²
14	0.2	73	1 $\times$ 10 ⁻²	4.2	42	9 $\times$ 10 ⁻⁴	5.9	42	2 $\times$ 10 ⁻²
15	0.1	6	5 $\times$ 10 ⁻³	5.3	51	1 $\times$ 10 ⁻³	7.6	52	3 $\times$ 10 ⁻²

^c See Fig. 5.^b In all tables, activity listed as ²³⁹Pu includes activity due to ²⁴⁰Pu isotope.^c CG = 2 $\times$ 10⁻¹⁴ μ Ci/ml for ²³⁹Pu activity in air.^d CG = 1 $\times$ 10⁻¹³ μ Ci/ml (= 0.047 μ g/m³) for ²³⁵U activity in air.^e CG = 1 $\times$ 10⁻¹³ μ Ci/ml (= 0.3 μ g/m³) for ²³⁸U activity in air.

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

Month	²³⁹ Pu [10 ⁻¹⁷ μCi/ml ± 2σ (%)]	¹³⁷ Cs [10 ⁻¹⁶ μCi/ml ± 2σ (%)]	²³⁹ Pu/ ¹³⁷ Cs (10 ⁻²)	²³⁵ U [10 ⁻⁷ μg/m ³ ± 2σ (%)]	²³⁸ U [10 ⁻⁵ μg/m ³ ± 2σ (%)]	²³⁵ U/ ²³⁸ U (10 ⁻³)
Jan.	0.1 ± 14	0.2 ± 24	5.0	1.2 ± 3	2.1 ± 3	5.7
Feb.	0.1 ± 15	0.3 ± 32	3.3	2.4 ± 3	6.6 ± 3	3.6
Mar.	0.5 ± 23	0.4 ± 26	12.5	2.0 ± 3	3.1 ± 3	6.5
Apr.	0.1 ± 12	0.4 ± 18	2.5	3.6 ± 3	7.1 ± 3	5.1
May	0.1 ± 19	0.4 ± 11	2.5	3.8 ± 3	8.7 ± 3	4.4
June	0.1 ± 15	0.3 ± 17	3.3	4.7 ± 3	7.1 ± 3	6.6
July	0.1 ± 16	0.2 ± 24	5.0	4.3 ± 3	6.5 ± 3	6.6
Aug.	0.8 ± 6	0.2 ± 26	39.0	3.6 ± 3	5.6 ± 3	6.4
Sept.	0.1 ± 100	0.1 ± 54	10.0	3.0 ± 3	4.5 ± 3	6.7
Oct.	0.1 ± 19	0.2 ± 22	5.0	4.0 ± 3	6.0 ± 3	6.7
Nov.	0.1 ± 37	0.2 ± 44	5.6	1.7 ± 3	3.1 ± 3	5.5
Dec.	N/A					
Annual average	0.2	0.3		3.1	5.5	
% SDM	111	39		37	37	
CG	2 × 10 ⁻¹⁴ μCi/ml	4 × 10 ⁻¹⁰ μCi/ml		4.7 × 10 ⁻² μg/m ³	0.3 μg/m ³	
% CG	1 × 10 ⁻²	8 × 10 ⁻⁶		7 × 10 ⁻⁴	2 × 10 ⁻²	

Table A-10a. Tritium in air.

Month	Perimeter Locations ^a					
	1	2	12 [10 ⁻¹¹ μ Ci/ml $\pm$ 2 σ (%)]	13	14	15
Jan.	2.3 $\pm$ 4 2.7 $\pm$ 4 4.9 $\pm$ 3	3.8 $\pm$ 3 7.0 $\pm$ 2 7.5 $\pm$ 2	13.6 $\pm$ 1 4.0 $\pm$ 3 3.4 $\pm$ 3	3.4 $\pm$ 4 3.2 $\pm$ 4 3.0 $\pm$ 4	2.9 $\pm$ 4 2.6 $\pm$ 4 —	2.3 $\pm$ 5 — 3.2 $\pm$ 3
Feb.	3.4 $\pm$ 3 —	2.1 $\pm$ 4 2.1 $\pm$ 4	— 2.6 $\pm$ 3	— 1.3 $\pm$ 6	2.7 $\pm$ 4 0.7 $\pm$ 9	2.2 $\pm$ 4 0.6 $\pm$ 11
Mar.	1.2 $\pm$ 7 3.0 $\pm$ 4	0.9 $\pm$ 8 0.7 $\pm$ 12	1.8 $\pm$ 4 1.4 $\pm$ 7	0.5 $\pm$ 15 0.5 $\pm$ 17	1.3 $\pm$ 6 1.8 $\pm$ 6	1.3 $\pm$ 7 1.6 $\pm$ 6
Apr.	4.6 $\pm$ 3 7.5 $\pm$ 2	2.2 $\pm$ 5 1.6 $\pm$ 7	2.2 $\pm$ 4 3.4 $\pm$ 4	1.5 $\pm$ 7 1.5 $\pm$ 7	1.8 $\pm$ 6 3.4 $\pm$ 5	0.7 $\pm$ 11 0.6 $\pm$ 10
May	14.7 $\pm$ 2 4.9 $\pm$ 2	1.1 $\pm$ 8 1.1 $\pm$ 8	3.5 $\pm$ 3 1.8 $\pm$ 5	1.1 $\pm$ 7 0.7 $\pm$ 12	2.0 $\pm$ 5 2.5 $\pm$ 4	1.8 $\pm$ 5 1.9 $\pm$ 5
June	7.0 $\pm$ 2 4.9 $\pm$ 3	0.9 $\pm$ 12 1.7 $\pm$ 6	1.8 $\pm$ 7 2.8 $\pm$ 4	0.7 $\pm$ 13 1.5 $\pm$ 8	2.4 $\pm$ 5 3.3 $\pm$ 3	1.8 $\pm$ 6 2.5 $\pm$ 4
July	2.6 $\pm$ 3 3.7 $\pm$ 3	3.1 $\pm$ 4 0.6 $\pm$ 12	4.4 $\pm$ 3 1.5 $\pm$ 7	— 0.7 $\pm$ 13	— 2.7 $\pm$ 4	5.2 $\pm$ 3 3.4 $\pm$ 3
Aug.	— 2.5 $\pm$ 5 3.1 $\pm$ 4	1.3 $\pm$ 10 1.4 $\pm$ 8 1.2 $\pm$ 9	1.5 $\pm$ 9 2.6 $\pm$ 6 1.7 $\pm$ 6	— 1.4 $\pm$ 8 0.9 $\pm$ 11	4.7 $\pm$ 4 2.3 $\pm$ 5 3.5 $\pm$ 4	— 3.3 $\pm$ 4 2.8 $\pm$ 4
Sept.	3.6 $\pm$ 4 6.7 $\pm$ 2	2.2 $\pm$ 6 5.8 $\pm$ 3	4.0 $\pm$ 4 3.9 $\pm$ 3	1.4 $\pm$ 9 4.1 $\pm$ 3	2.4 $\pm$ 5 4.5 $\pm$ 3	4.0 $\pm$ 4 3.6 $\pm$ 3
Oct.	1.6 $\pm$ 6 —	2.9 $\pm$ 4 1.9 $\pm$ 5	3.2 $\pm$ 4 3.1 $\pm$ 4	2.3 $\pm$ 6 3.2 $\pm$ 4	2.4 $\pm$ 5 2.4 $\pm$ 4	2.5 $\pm$ 4 —
Nov.	2.3 $\pm$ 5 2.8 $\pm$ 4	3.7 $\pm$ 4 2.3 $\pm$ 4	— 1.6 $\pm$ 4	3.4 $\pm$ 4 2.5 $\pm$ 4	2.5 $\pm$ 4 2.4 $\pm$ 4	— —
Dec.	— 2.1 $\pm$ 4	3.9 $\pm$ 3 3.4 $\pm$ 3	5.8 $\pm$ 3 3.0 $\pm$ 3	9.3 $\pm$ 3 2.9 $\pm$ 3	3.4 $\pm$ 4 2.0 $\pm$ 4	— —
Annual average ^b	4.2	2.6	3.3	2.2	2.6	2.4
% SDM	70	72	75	86	34	50
% CG ^c	2 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²	2 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²
Calculated adult whole-body dose (mrem)	3 $\times$ 10 ⁻²	2 $\times$ 10 ⁻²	2 $\times$ 10 ⁻²	2 $\times$ 10 ⁻²	2 $\times$ 10 ⁻²	2 $\times$ 10 ⁻²

^a See Fig. 5.^b LLNL perimeter overall annual average = 2.8 $\pm$ 28%.^c CG = 2 $\times$ 10⁻⁷ μ Ci/ml.

Table A-10b. Tritium in air.

Month	Valley Locations ^a					
	S-1	S-2	V04	V07	V09	V17
	[10 ⁻¹¹ μ Ci/ml $\pm$ 2 σ (%)]					
Jan.	3.2 $\pm$ 4 2.2 $\pm$ 5 3.4 $\pm$ 3	5.7 $\pm$ 2 3.1 $\pm$ 4 1.9 $\pm$ 4	— — 1.9 $\pm$ 4	— — —	— — —	— — —
Feb.	— 0.5 $\pm$ 13	1.0 $\pm$ 6 1.0 $\pm$ 7	3.3 $\pm$ 3 0.3 $\pm$ 23	— —	— —	— —
Mar.	0.7 $\pm$ 12 2.3 $\pm$ 11	0.4 $\pm$ 19 0.3 $\pm$ 23	0.6 $\pm$ 15 1.7 $\pm$ 9	— —	— —	— 0.5 $\pm$ 20
Apr.	1.5 $\pm$ 8 1.4 $\pm$ 8	0.7 $\pm$ 18 0.8 $\pm$ 11	1.1 $\pm$ 9 5.0 $\pm$ 5	— —	— 0.4 $\pm$ 24	0.5 $\pm$ 19 0.5 $\pm$ 18
May	— 1.1 $\pm$ 9	0.7 $\pm$ 10 0.2 $\pm$ 26	1.4 $\pm$ 6 2.3 $\pm$ 6	— —	0.7 $\pm$ 11 0.1 $\pm$ 72	0.7 $\pm$ 11 0.7 $\pm$ 12
June	1.8 $\pm$ 8 4.0 $\pm$ 3	0.7 $\pm$ 12 1.1 $\pm$ 7	2.4 $\pm$ 5 2.6 $\pm$ 4	— 0.6 $\pm$ 14	0.6 $\pm$ 16 0.9 $\pm$ 11	0.6 $\pm$ 17 1.4 $\pm$ 7
July	3.0 $\pm$ 3 2.1 $\pm$ 5	— 0.8 $\pm$ 12	1.3 $\pm$ 6 2.3 $\pm$ 4	0.9 $\pm$ 9 0.6 $\pm$ 14	— 0.2 $\pm$ 26	0.5 $\pm$ 14 0.3 $\pm$ 25
Aug.	1.3 $\pm$ 10 1.4 $\pm$ 7 1.6 $\pm$ 6	1.2 $\pm$ 10 0.6 $\pm$ 18 0.3 $\pm$ 20	2.6 $\pm$ 6 1.8 $\pm$ 6 2.4 $\pm$ 5	0.6 $\pm$ 18 — 0.6 $\pm$ 16	0.1 $\pm$ 100 0.2 $\pm$ 41 —	1.1 $\pm$ 11 0.4 $\pm$ 18 0.4 $\pm$ 19
Sept.	1.7 $\pm$ 7 —	0.6 $\pm$ 18 1.7 $\pm$ 5	1.5 $\pm$ 8 2.1 $\pm$ 5	1.0 $\pm$ 11 1.1 $\pm$ 8	0.6 $\pm$ 21 0.9 $\pm$ 11	0.6 $\pm$ 16 0.9 $\pm$ 8
Oct.	1.2 $\pm$ 8 1.5 $\pm$ 6	1.3 $\pm$ 8 —	— —	— —	0.8 $\pm$ 11 —	0.5 $\pm$ 12 1.2 $\pm$ 8
Nov.	2.7 $\pm$ 6 0.7 $\pm$ 8	— 2.5 $\pm$ 19	— 1.1 $\pm$ 6	0.7 $\pm$ 11 0.3 $\pm$ 16	0.9 $\pm$ 10 —	0.8 $\pm$ 9 0.5 $\pm$ 12
Dec.	— 1.5 $\pm$ 5	— 1.3 $\pm$ 5	— 0.9 $\pm$ 6	1.2 $\pm$ 8 0.8 $\pm$ 8	— 1.2 $\pm$ 6	1.5 $\pm$ 7 1.3 $\pm$ 6
Annual average ^b	1.8	1.3	1.9	0.8	0.6	0.8
% SDM	50	96	54	35	62	48
% CG ^c	1 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²	4 $\times$ 10 ⁻³	3 $\times$ 10 ⁻³	4 $\times$ 10 ⁻³
Calculated adult whole-body dose (mrem)	1 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²	1 $\times$ 10 ⁻²	5 $\times$ 10 ⁻³	4 $\times$ 10 ⁻³	5 $\times$ 10 ⁻³

^a See Fig. 7.^b Livermore Valley overall annual average = 1.2 $\pm$ 51%.^c CG = 2 $\times$ 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 (%)]	
1004	9.4 ± 6	1.1 ± 4	1.6 ± 7	5.1 ± 8	5.8 ± 5
1005	3.6 ± 9	1.2 ± 3	1.8 ± 7	6.6 ± 5	4.0 ± 26
1006	2.2 ± 11	2.6 ± 4	2.3 ± 7	14.7 ± 4	6.8 ± 34
1008	5.7 ± 8	1.2 ± 6	2.9 ± 4	5.3 ± 7	2.9 ± 38
1009	2.6 ± 10	1.3 ± 7	1.2 ± 16	6.4 ± 13	4.9 ± 62
1010	2.5 ± 9	1.4 ± 3	1.4 ± 9	6.8 ± 5	5.3 ± 24
1012	6.4 ± 6	1.4 ± 3	2.9 ± 5	6.9 ± 4	4.1 ± 26
1013 ^b	7.0 ± 8	1.4 ± 3	2.4 ± 16	7.7 ± 6	3.7 ± 26
1014	7.0 ± 7	1.3 ± 3	2.4 ± 6	7.8 ± 4	4.6 ± 40
1015	4.9 ± 8	1.4 ± 3	1.5 ± 8	7.0 ± 5	4.5 ± 28
1016	2.9 ± 11	0.9 ± 3	1.1 ± 9	5.2 ± 5	3.6 ± 34
1017	0.3 ± 30	1.2 ± 3	0.1 ± 60	3.9 ± 5	2.7 ± 30
1018	1.0 ± 12	1.2 ± 3	0.7 ± 17	6.6 ± 5	4.4 ± 13
1019	0.9 ± 12	1.0 ± 6	0.4 ± 14	3.5 ± 11	2.0 ± 32
1020	2.1 ± 9	1.3 ± 3	1.0 ± 9	7.1 ± 5	5.5 ± 12
1021 ^c	1.8 ± 10	1.3 ± 4	0.9 ± 14	7.1 ± 6	5.4 ± 11
1022	1.4 ± 17	1.3 ± 4	0.8 ± 11	6.8 ± 6	5.1 ± 11
1023	0.9 ± 16	1.4 ± 3	0.5 ± 18	7.1 ± 4	4.4 ± 14
1024	3.0 ± 10	0.7 ± 7	1.5 ± 19	1.7 ± 44	2.1 ± 40
1025	3.6 ± 10	1.1 ± 4	1.8 ± 4	4.7 ± 6	2.5 ± 66
1026	10.0 ± 7	1.0 ± 4	3.6 ± 4	5.2 ± 6	3.1 ± 28
1027	22.6 ± 6	1.2 ± 4	2.0 ± 6	7.1 ± 4	5.0 ± 30

^a See Fig. 8 for sample locations.

^b Samples 1013 and 1014 are duplicates.

^c Samples 1021 and 1022 are duplicates.

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 (%)]
1028	0.7 ± 19	0.4 ± 22	6.2 ± 10
1029	0.9 ± 15	0.5 ± 17	5.8 ± 20
1030	1.2 ± 13	0.7 ± 14	2.7 ± 30
1031	0.5 ± 25	0.3 ± 30	8.5 ± 9
1032	1.4 ± 13	0.9 ± 12	350.0 ± 5
1033	6.6 ± 7	3.1 ± 5	4.8 ± 28
1034	1.4 ± 13	0.7 ± 12	5.7 ± 12
1035 ^b	0.5 ± 21	0.3 ± 30	4.5 ± 16
1036	2.6 ± 11	1.2 ± 8	5.4 ± 30
1037	0.6 ± 15	3.5 ± 24	2.7 ± 24
1038	4.0 ± 10	1.8 ± 7	5.4 ± 26
1039	1.9 ± 8	1.2 ± 7	85.7 ± 4
1040	2.8 ± 10	1.8 ± 7	16.0 ± 19
1041	0.7 ± 12	0.5 ± 18	6.3 ± 11

^a See Fig. 9 for location of samples.

^b Samples 1035 and 1036 are duplicates.

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

Month	HTO		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.	1.8 ± 41	1.4 ± 83	5.3 ± 100	1.9 ± 100	8.8 ± 12	0.5 ± 89
Feb.	3.9 ± 52	0.6 ± 80	4.9 ± 28	2.9 ± 100	6.1 ± 24	0.2 ± 100
Mar.	45.7 ± 34	5.1 ± 58	12.5 ± 11	1.8 ± 100	2.2 ± 25	0.1 ± 100
Apr.	2.0 ± 40	0.7 ± 72	10.0 ± 27	3.6 ± 100	5.1 ± 21	0.5 ± 91
May	4.9 ± 55	0.8 ± 80	6.0 ± 7	2.3 ± 100	62.9 ± 7	0.5 ± 51
June	2.4 ± 36	0.8 ± 71	58.3 ± 4	3.6 ± 100	9.8 ± 15	0.2 ± 75
July	3.4 ± 34	0.6 ± 78	7.7 ± 15	3.7 ± 100	3.6 ± 16	0.1 ± 39
Aug.	2.4 ± 31	0.5 ± 84	5.6 ± 30	1.9 ± 100	3.2 ± 29	0.2 ± 76
Sept.	9.0 ± 30	1.1 ± 65	2.9 ± 60	0.8 ± 100	3.5 ± 15	0.3 ± 50
Oct.	2.4 ± 35	0.6 ± 82	9.4 ± 30	0.6 ± 100	4.5 ± 13	0.3 ± 57
Nov.	3.7 ± 43	1.0 ± 81	13.9 ± 16	0.6 ± 100	3.9 ± 21	0.2 ± 82
Dec.	4.7 ± 45	1.1 ± 70	5.6 ± 28	0.6 ± 100	3.1 ± 12	0.1 ± 100
Annual average	7.2	1.2	11.8	2.0	9.7	0.3
% SDM	171	105	127	60	174	56
CG (μCi/ml)	2 × 10 ⁻³	2 × 10 ⁻³	3 × 10 ⁻⁶	3 × 10 ⁻⁶	3 × 10 ⁻⁷	3 × 10 ⁻⁷
% CG	4 × 10 ⁻¹	6 × 10 ⁻²	4 × 10 ⁻³	7 × 10 ⁻⁴	3 × 10 ⁻³	1 × 10 ⁻⁴

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

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CC ^b
		[10 ⁻⁹ μCi/ml ± 2σ (%)]				
11	4	≤4.5	≤2.8	≤3.6	22	12
15	4	≤4.5	≤2.8	≤3.6	22	12
16	4	≤8.1	≤2.8	≤5.4	42	18
19	4	≤4.5	≤2.8	≤3.6	22	12
20	4	≤4.3	≤0.3	≤3.0	61	10
23	4	≤4.5	≤2.8	≤3.6	22	12
24	4	≤4.5	≤2.8	≤3.6	22	12
26	4	≤4.5	≤2.8	≤3.6	22	12
29	4	≤4.5	≤2.8	≤3.6	22	12
31	4	≤4.5	≤2.1	≤3.4	31	12
33	4	≤4.5	≤2.8	≤3.6	22	12
37	4	≤4.5	≤0.4	≤2.1	98	7

^a See Fig. 10 for sample locations.

^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 μ Ci/ml $\pm$ 2 σ (%)]				
3	4	≤ 3.8	≤ 2.9	≤ 3.4	12	11
4	8	37.0 $\pm$ 34	≤ 2.9	19.9	51	66
5	8	13.0 $\pm$ 66	≤ 2.9	≤ 4.9	68	16
6	1	≤ 3.3	≤ 3.3	≤ 3.3	0	11
7	4	≤ 6.5	≤ 2.9	≤ 4.2	38	14
14	8	≤ 6.5	≤ 2.9	≤ 4.2	26	14
20	2	≤ 3.7	≤ 3.0	≤ 3.3	15	12
21	4	≤ 4.5	≤ 2.9	≤ 3.6	19	12
22	8	13.0 $\pm$ 66	≤ 2.9	≤ 4.9	68	16
23	4	≤ 4.5	≤ 2.9	≤ 3.6	19	12

^a See Fig. 11 for sample locations.^b CG = 3×10^{-8} μ Ci/ml.

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

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ μ Ci/ml $\pm$ 2 σ (%)]				
11	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
15	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
16	4	≤ 20.0	≤ 8.6	≤ 14.6	42	15
19	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
20	4	≤ 10.0	4.5 $\pm$ 37	≤ 8.6	32	9
23	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
24	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
26	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
29	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
31	4	≤ 10.0	1.6 $\pm$ 38	≤ 7.9	53	8
33	4	≤ 10.0	≤ 8.6	≤ 9.6	7	10
37	4	≤ 10.0	≤ 1.6	≤ 7.0	57	7

^a See Fig. 10 for sample locations.^b CG = 1×10^{-7} μ Ci/ml.

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

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ μ Ci/ml $\pm$ 2 σ (%)]				
3	4	12.0 $\pm$ 64	≤ 8.6	≤ 10.3	15	10
4	8	31.0 $\pm$ 33	≤ 8.6	16.8	45	17
5	8	12.0 $\pm$ 70	≤ 8.6	≤ 10.0	11	10
6	1	≤ 11.0	≤ 11.0	≤ 11.0	0	11
7	4	≤ 21.0	≤ 8.6	≤ 11.9	51	12
14	8	≤ 21.0	≤ 8.6	≤ 11.0	37	11
20	2	≤ 16.0	≤ 9.9	≤ 12.9	33	13
21	4	≤ 11.0	≤ 8.6	≤ 9.8	10	10
22	8	≤ 11.0	≤ 8.6	≤ 9.7	8	10
23	4	≤ 11.0	≤ 8.6	≤ 9.8	10	10

^a See Fig. 13 for sample locations.^b CG = 1×10^{-7} μ Ci/ml.

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

Location ^a	Number of samples	Maximum [10 ⁻⁷ μ Ci/ml $\pm$ 2 σ (%)]	Minimum	Average	% SDM	% CG ^b	Calculated adult whole-body dose (mrem)
11	4	0.8	0.4	0.6	23	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
15	4	0.8	0.5	0.7	16	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
16	4	2.3	1.3	1.8	27	9 $\times$ 10 ⁻¹	8 $\times$ 10 ⁻³
19	4	0.7	0.5	0.6	18	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
20	10	34.5	0.7	9.9	107	5	5 $\times$ 10 ⁻²
23	4	0.7	0.4	0.5	27	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
24	4	1.5	0.5	0.9	51	4 $\times$ 10 ⁻¹	4 $\times$ 10 ⁻³
26	4	1.7	1.4	1.5	9	8 $\times$ 10 ⁻¹	7 $\times$ 10 ⁻³
29	4	0.7	0.3	0.4	37	2 $\times$ 10 ⁻¹	2 $\times$ 10 ⁻³
30	4	1.0	0.4	0.6	44	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
31	4	0.9	0.3	0.6	44	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
33	4	0.8	0.1	0.5	52	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
37	4	1.2	0.4	0.8	47	4 $\times$ 10 ⁻¹	4 $\times$ 10 ⁻³

^a See Fig. 10 for sample locations.^b CG = 2 $\times$ 10⁻⁵ μ Ci/ml.

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

Location ^a	Number of samples	Maximum [10 ⁻⁷ μ Ci/ml $\pm$ 2 σ (%)]	Minimum	Average	% SDM	% CG ^b	Calculated adult whole-body dose (mrem)
3	4	0.3 $\pm$ 21	0.0	0.1	83	7 $\times$ 10 ⁻²	7 $\times$ 10 ⁻⁴
4	8	0.3 $\pm$ 24	0.0	0.1	65	5 $\times$ 10 ⁻²	5 $\times$ 10 ⁻⁴
5	8	0.6 $\pm$ 10	0.0	0.2	88	9 $\times$ 10 ⁻²	9 $\times$ 10 ⁻⁴
6	1	0.2 $\pm$ 23	0.2 $\pm$ 23	0.2	—	1 $\times$ 10 ⁻¹	1 $\times$ 10 ⁻³
7	4	0.5 $\pm$ 13	0.1 $\pm$ 73	0.2	108	1 $\times$ 10 ⁻¹	1 $\times$ 10 ⁻³
14	8	0.9 $\pm$ 8	0.5 $\pm$ 12	0.6	22	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
20	7	0.8 $\pm$ 9	0.4 $\pm$ 15	0.6	27	3 $\times$ 10 ⁻¹	3 $\times$ 10 ⁻³
21	4	0.5 $\pm$ 12	0.2 $\pm$ 27	0.3	48	1 $\times$ 10 ⁻¹	1 $\times$ 10 ⁻³
22	8	0.8 $\pm$ 8	0.0	0.2	135	1 $\times$ 10 ⁻¹	9 $\times$ 10 ⁻⁴
23	4	0.4 $\pm$ 15	0.1 $\pm$ 44	0.2	58	1 $\times$ 10 ⁻¹	1 $\times$ 10 ⁻³

^a See Fig. 11.^b CG = 2 $\times$ 10⁻⁵ μ Ci/ml.

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

Well identification ^a	Well depth (m)	Activity [10^{-7} μ Ci/ml $\pm 2\sigma$ (%)]	% CG ^b
3S1E-1P2	15	6.88 $\pm$ 2.8	3
3S1E-1R2	17	0.97 $\pm$ 7.1	5 $\times 10^{-1}$
3S1E-1H3	24	0.22 $\pm$ 25.3	1 $\times 10^{-1}$
3S1E-2R1	10	2.72 $\pm$ 4.0	1
3S1E-4G1	16	0.57 $\pm$ 10.7	3 $\times 10^{-1}$
3S1E-8K1	32	0.74 $\pm$ 8.8	4 $\times 10^{-1}$
3S1E-9G1	49	2.31 $\pm$ 4.2	1
3S1E-10A2	27	5.54 $\pm$ 3.0	3
3S1E-11B1	13	9.58 $\pm$ 2.6	5
3S1E-12A2	23	1.36 $\pm$ 6.1	7 $\times 10^{-1}$
3S1E-12D2	14	6.89 $\pm$ 2.8	3
3S1E-12E1	84	0.94 $\pm$ 8.0	5 $\times 10^{-1}$
3S1E-12G1	27	2.84 $\pm$ 4.1	1
3S1E-12H1	104	0.78 $\pm$ 8.7	4 $\times 10^{-1}$
3S1E-16H2	29	0.68 $\pm$ 9.5	3 $\times 10^{-1}$
3S2E-7C2	15	1.44 $\pm$ 5.5	7 $\times 10^{-1}$
3S2E-7N1	41	0.75 $\pm$ 8.4	4 $\times 10^{-1}$
3S2E-10Q1	13	1.53 $\pm$ 5.3	8 $\times 10^{-1}$

^a See Fig. 12 for sample locations.

^b CG = 2×10^{-3} μ Ci/ml.

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

Location ^a	Number of samples	Maximum [10^{-7} μ Ci/ml $\pm 2\sigma$ (%) in water recovered]	Minimum	Average	% SDM	Calculated adult whole-body dose (mrem)
4	4	4.2 $\pm$ 24	2.8 $\pm$ 40	3.6	17	6 $\times 10^{-3}$
15	4	326.0 $\pm$ 1	8.8 $\pm$ 14	91.4	171	2 $\times 10^{-1}$
20	4	17.2 $\pm$ 8	4.5 $\pm$ 24	9.9	55	2 $\times 10^{-2}$
23	4	440.0 $\pm$ 1	26.4 $\pm$ 5	144.3	137	3 $\times 10^{-1}$
29	4	20.7 $\pm$ 6	4.9 $\pm$ 23	11.6	58	2 $\times 10^{-2}$
31	4	17.5 $\pm$ 7	5.2 $\pm$ 22	9.7	57	2 $\times 10^{-2}$
32	4	14.4 $\pm$ 8	2.5 $\pm$ 44	8.8	64	2 $\times 10^{-2}$
33	4	4.4 $\pm$ 23	1.0 $\pm$ 100	1.9	88	3 $\times 10^{-3}$

^a See Fig. 13 for sample locations.

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

Location ^a	Number of samples	Maximum [10^{-7} μ Ci/ml $\pm 2\sigma$ (%) in water recovered]	Minimum	Average	% SDM	Calculated adult whole-body dose (mrem)
1	4	1.6 $\pm$ 68	1.1 $\pm$ 100	1.2	21	2 $\times 10^{-3}$
2	4	1.1 $\pm$ 97	1.0 $\pm$ 100	1.1	1	2 $\times 10^{-3}$
3	4	1.3 $\pm$ 85	1.1 $\pm$ 100	1.1	11	2 $\times 10^{-3}$
6	4	13600.0 $\pm$ 0.4	1.6 $\pm$ 68	4983.6	130	9
12	4	2.2 $\pm$ 45	1.1 $\pm$ 100	1.5	36	3 $\times 10^{-3}$
13	4	151.0 $\pm$ 2	2.4 $\pm$ 46	71.3	171	1 $\times 10^{-1}$

^a See Fig. 14 for sample locations.

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

Location	Number of samples	Maximum	Minimum	Average	% SDM
		[10^{-7} $\mu\text{Ci/ml} \pm 2\sigma$ (%) in water recovered]			
California	2	1.8 ± 12	1.2 ± 14	1.5	27
Europe	4	13.9 ± 3	2.3 ± 10	5.5	102
Livermore	3	3.9 ± 6	3.0 ± 8	3.4	15

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

Location	Number of samples	Maximum	Minimum	Average	% SDM
		[10^{-7} $\mu\text{Ci/ml} \pm 2\sigma$ (%) in water recovered]			
California	2	7.3 $\pm$ 4	2.6 $\pm$ 7	5.0	67
Livermore	2	4.6 $\pm$ 6	3.9 $\pm$ 6	4.2	11

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

	HTO	^{40}K	^{137}Cs
	[10^{-7} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]	[10^{-6} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]	[10^{-9} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]
Number of samples	29	29	29
Maximum	5.2 ± 20	2.1 ± 4	2.2 ± 34
Minimum	1.0 ± 100	1.3 ± 3	0.4 ± 100
Average	1.5	1.7	0.9
% SDM	55.9	13.2	49.3
Calculated adult whole-body dose (mrem)	3×10^{-3}	9.3	1×10^{-2}

Table A-26. Environmental radiation measurements (TLD)—LLNL perimeter.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual ^b
	(mrem)				
1	12.0	14.0	19.0	16.0	61.0
2	14.0	14.0	17.0	14.0	59.0
3	13.0	16.0	19.0	17.0	65.0
4	14.0	15.0	19.0	17.0	65.0
5	13.0	16.0	19.0	17.0	65.0
6	13.0	16.0	19.0	16.0	64.0
7	13.0	15.0	18.0	16.0	62.0
8	13.0	15.0	18.0	15.0	61.0
9	13.0	15.0	18.0	14.0	60.0
10	12.0	13.0	16.0	15.0	56.0
11	13.0	18.0	33.0	16.0	80.0
12	10.0	13.0	16.0	12.0	51.0
13	12.0	14.0	17.0	15.0	58.0
42	12.0	13.0	16.0	15.0	56.0
47	13.0	13.0	16.0	— ^c	56.0
48	12.0	12.0	16.0	—	53.0
49	12.0	12.0	16.0	—	53.0
50	12.0	12.0	17.0	—	55.0
52	12.0	13.0	17.0	—	56.0
53	12.0	13.0	17.0	—	56.0
54	12.0	14.0	17.0	—	57.0
56	12.0	13.0	16.0	—	55.0
Average	12 ± 1	14 ± 2	18 ± 4	15 ± 1	59 ± 6

^a See Fig. 15.

^b The annual dose is calculated by using a fourth quarter total determined by averaging the doses recorded for the first three quarters.

^c No fourth quarter data are available because dosimeters were missing at collection time.

Table A-27. Environmental radiation measurements (TLD)—Livermore Valley.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual ^b
	(mrem)				
14	13.0	14.0	17.0	20.0	64.0
15	14.0	14.0	18.0	17.0	63.0
16	14.0	17.0	20.0	17.0	68.0
17	33.0	29.0	23.0	31.0	116.0
18	15.0	16.0	19.0	17.0	67.0
19	12.0	12.0	14.0	12.0	50.0
20	16.0	12.0	15.0	14.0	57.0
21	10.0	11.0	15.0	14.0	50.0
22	14.0	14.0	— ^c	17.0	60.0 ^b
23	13.0	11.0	18.0	15.0	57.0
24	14.0	15.0	—	16.0	60.0 ^b
25	13.0	15.0	—	17.0	60.0 ^b
26	14.0	15.0	—	17.0	61.0 ^b
27	11.0	11.0	17.0	16.0	55.0
28	15.0	18.0	21.0	18.0	72.0
29	14.0	15.0	19.0	17.0	65.0
30	13.0	14.0	17.0	16.0	60.0
31	14.0	15.0	19.0	17.0	65.0
32	13.0	13.0	17.0	16.0	59.0
33	14.0	15.0	18.0	15.0	62.0
34	12.0	15.0	20.0	16.0	63.0
35	13.0	14.0	17.0	16.0	60.0
36	14.0	14.0	19.0	16.0	63.0
37	12.0	13.0	17.0	17.0	59.0
38	14.0	14.0	16.0	16.0	60.0
39	13.0	15.0	—	17.0	60.0 ^b
40	13.0	16.0	—	17.0	61.0 ^b
41	14.0	14.0	18.0	15.0	61.0
43	16.0	14.0	18.0	20.0	68.0
44	14.0	16.0	—	20.0	67.0 ^b
45	11.0	11.0	16.0	14.0	52.0
46	12.0	13.0	16.0	13.0	54.0
51	13.0	13.0	16.0	20.0	62.0
55	13.0	14.0	17.0	18.0	62.0
57	13.0	14.0	9.0	16.0	52.0
58	12.0	13.0	17.0	15.0	57.0
59	13.0	11.0	16.0	15.0	55.0
60	11.0	14.0	32.0	16.0	73.0
61	10.0	11.0	14.0	12.0	47.0
62	12.0	11.0	14.0	13.0	50.0
63	11.0	13.0	16.0	15.0	55.0
64	12.0	13.0	16.0	15.0	56.0
65	11.0	13.0	16.0	14.0	54.0
66	13.0	15.0	18.0	16.0	62.0
67	15.0	15.0	19.0	16.0	64.0
68	13.0	14.0	17.0	16.0	60.0
69	10.0	13.0	15.0	14.0	52.0
70	11.0	14.0	17.0	15.0	57.0
71	14.0	18.0	20.0	20.0	72.0
72	14.0	16.0	21.0	19.0	70.0
73	14.0	15.0	18.0	20.0	67.0
74	9.0	12.0	15.0	13.0	49.0
75	11.0	11.0	13.0	12.0	47.0
76	8.0	7.0	10.0	10.0	35.0
77	14.0	12.0	14.0	13.0	53.0
Average	13 ± 3	14 ± 3	17 ± 3	16 ± 3	60 ± 11

^a See Fig. 16.^b The annual dose is calculated by using a fourth quarter total determined by averaging the doses recorded for the available quarters.^c No data available; dosimeters missing.

Table A-28. Environmental neutron monitoring—LLNL perimeter.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual ^b
	(mrem)				
1	1.5	1.1	1.5	1.8	5.9
2	1.2	0.8	1.1	1.4	4.5
3	1.2	2.4	2.5	1.1	7.2
4	0.9	0.9	1.1	1.1	4.0
5	1.1	1.6	0.9	1.3	4.9
6	1.4	0.9	0.9	1.1	4.3
7	1.2	0.9	1.0	1.2	4.3
8	1.7	1.7	1.1	1.6	6.1
Annual	1.3 ± 0.2	1.3 ± 0.6	1.3 ± 0.5	1.3 ± 0.3	5.2 ± 1.1

^a See Fig. 15.**Table A-29. Beryllium on air filters—LLNL perimeter.**

Month	Location ^a					
	1	2	12 (10 ⁻⁵ µg/m ³)	13	14	15
Jan.	1.6	3.3	5.0	1.0	1.7	1.5
Feb.	4.7	2.2	2.9	4.3	2.8	1.8
Mar.	1.1	2.3	4.6	1.0	1.6	0.9
Apr.	12.0	7.5	4.6	11.0	4.6	9.1
May	3.6	3.0	12.0	4.8	3.4	5.2
June	20.0	6.5	21.0	7.3	9.1	11.0
July	12.0	7.2	8.1	5.6	4.7	11.0
Aug.	8.7	5.0	8.1	9.3	3.0	11.0
Sept.	1.0	5.8	9.6	8.4	6.4	8.4
Oct.	11.1	15.7	9.8	6.5	11.5	8.2
Nov.	6.6	25.0	9.1	4.1	6.1	12.0
Dec.	0.9	9.6	8.5	4.5	2.6	4.0
Annual average ^b	6.9	7.8	8.6	5.6	4.8	7.0
% SDM	86	85	55	54	63	59
%CG ^c	0.7	0.8	0.9	0.6	0.5	0.7

^a See Fig. 5.^b LLNL perimeter overall annual average = 6.8 ± 20%.^c Ambient concentration guide set by the Bay Area Air Quality Management District is 0.01 µg/m³.

Table A-30. Beryllium on air filters—Site 300.

Month	Location ^a									
	1	2	3	4	5	6 ^b	8	9	10	
	(10 ⁻⁵ µg/m ³)									
Jan.	0.4	0.8	0.4	0.5	1.0	2.6	0.5	0.3	0.5	
Feb.	1.3	3.8	1.1	0.8	0.8	5.6	1.2	0.7	0.9	
Mar.	0.5	1.1	0.4	1.0	1.5	4.8	0.3	0.8	— ^c	
Apr.	8.8	— ^c	2.5	5.2	8.3	10.0	10.0	3.1	3.7	
May	2.2	16.0	1.4	2.9	1.2	14.0	2.0	2.1	2.2	
June	10.0	8.8	5.6	9.0	8.2	8.4	6.0	7.2	7.1	
July	3.6	6.2	2.0	1.7	3.7	22.0	2.4	2.8	2.5	
Aug.	5.3	4.4	2.0	0.6	4.5	9.4	1.5	1.0	7.0	
Sept.	6.8	3.4	2.3	4.0	8.7	9.1	2.8	3.4	5.4	
Oct.	4.9	2.4	4.6	5.4	7.1	3.3	— ^c	4.0	6.6	
Nov.	4.6	3.8	4.4	4.9	5.3	13.0	— ^c	3.7	18.0	
Dec.	1.5	1.0	1.6	0.6	1.3	< 1.3	1.1	0.7	2.0	
Average ^d	4.2	4.3	2.4	3.0	4.3	8.6	2.3	2.5	4.7	
% SDM	77	103	71	88	73	67	127	80	106	
% CC ^e	0.4	0.4	0.2	0.3	0.4	0.9	0.2	0.3	0.5	

^a See Fig. 6.^b Location 6 is in city of Tracy.^c No data available.^d Site 300 overall annual average = 4.0 ± 48%.^e Ambient concentration guide set by the Bay Area Air Quality Management District is 0.01 µg/m³.

Table A-31. Various elements in LLNL liquid effluent.

Month	Cd	Cr	Cu	Fe	Pb	Ni	Ag	Zn	Al	Be
	(mg/liter)									
Jan.	0.001	0.060	0.120	0.480	0.006	0.005	0.002	0.240	0.170	0.000
Feb.	0.002	0.070	0.110	0.530	0.008	0.012	0.003	0.240	0.290	0.000
Mar.	0.001	0.080	0.100	0.730	0.008	0.005	0.010	0.170	0.270	0.000
Apr.	0.001	0.070	0.100	0.600	0.110	0.006	0.020	0.540	0.250	0.000
May	0.002	0.120	0.350	0.970	0.020	0.010	0.007	0.500	0.470	0.000
June	0.050	0.060	0.340	0.520	0.030	0.130	0.002	0.270	0.250	0.000
July	0.002	0.050	0.250	0.550	0.030	0.008	0.004	0.270	0.200	0.000
Aug.	0.017	0.049	0.90	0.800	0.019	0.009	0.006	0.260	0.920	0.000
Sept.	0.002	0.050	0.150	0.820	0.020	0.009	0.002	0.220	0.310	0.000
Oct.	0.002	0.061	0.110	0.840	0.016	0.016	0.008	0.160	0.220	0.000
Nov.	0.001	0.048	0.110	0.960	0.012	0.013	0.004	0.150	0.720	0.000
Dec.	0.002	0.047	0.120	1.100	0.012	0.012	0.004	0.200	0.740	0.001
Average	0.007	0.064	0.162	0.767	0.024	0.020	0.006	0.268	0.401	0.000
% SDM	202	33	58	25	115	179	83	47	63	0

Table A-32. Physical and chemical examinations of LLNL liquid effluents.

	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Average	% SDM
	(mg/liter)					
BOD	19	85	61	10	43.7	81
COD	181	132	140	195	162	19
Oil and grease	<5	42	8.5	38	23.3	82
Phenol	<0.005	0.13	<0.008	0.069	0.053	111
Settleable solids (ml/liter/h)	1.00	2.50	<0.05	1.30	1.21	83
TICH ^a	ND ^b	ND	ND	ND		
Total dissolved solids	341	204	194	131	217	41
Total organic carbon	46	49	66	40	50	22
Total solids	342	224	194	300	265	26
Total suspended solids	54	32	17	50	38	44
Volatile solids (% total solids)	46	50	9	<0.1	26	97
Ammonia nitrogen (as N)	19	31	21	16	22	30
Chloride	8	5	3	18	8	78
Cyanide	<0.02	<0.02	0.02	<0.02	0.02	0
Nitrate nitrogen (as N)		<0.1	<0.1	<0.1	0.1	0
Nitrite nitrogen (as N)	<0.03	<0.03	<0.03	0.15	0.06	100
Sulfate	52	92	46	33	56	46
Total alkalinity (as CaCO ₃)	104		130	88	107	21
Total Kjeldahl nitrogen (as N)	37	31	28	22	29	21
Total phosphorous (as P)	4.5	3.7	4.1	3.3	3.9	13
Arsenic	0.031	0.006	0.002	<0.001	0.010	103
Boron	0.47	0.06	0.37	0.22	0.28	64
Calcium	9.5	8.7	18.0	13.0	12.3	34
Chromium	0.30	0.03	0.06	0.22	0.15	85
Copper	0.27	0.05	0.70	0.09	0.27	108
Magnesium	3.2	1.0	1.2	1.3	1.6	61
Mercury	0.0002	0.0008	0.0009	0.0009	0.0007	43
Nickel	0.06	<0.02	0.04	0.02	0.035	55
Potassium	27	16	18	19	20	24
Selenium	<0.002		<0.001	<0.001	<0.001	
Sodium	29	21	24	13	21.7	31
Sodium (as % cations)	47	50	26	31	38.5	31
Zinc	1.2	0.06	0.43	0.18	0.46	110

^a Total identifiable chlorinated hydrocarbons.^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	$\mu\text{g/liter}$		
Aldrin	0.05	DDD (mixed isomers)	0.05
Chlordane	0.3	Heptachlor	0.05
Endrin	0.1	Heptachlor Epoxide	0.05
Dieldrin	0.05	Methoxychlor	0.2
BHC (mixed isomers)	0.05		
DDT (mixed isomers)	0.1	Polychlorinated biphenyls	
DDE (mixed isomers)	0.05	Aroclors 1016-1262	0.3

Table A-33. LLNL nonradioactive liquid effluent—storm water runoff.

Analyses (mg/l)	Influent	Effluent		Lake
		SW	NW	
Arsenic	0.008	0.000	0.002	0.003
Barium	<0.001	<0.001	<0.001	<0.001
Beryllium	<0.1	<0.1	<0.1	<0.1
Cadmium	<0.01	<0.01	<0.01	<0.01
Chromium	<0.02	<0.02	<0.02	<0.02
Lead	<0.1	<0.1	<0.1	<0.1
Mercury	<0.0002	0.0057	<0.0002	0.0008
Selenium	<0.001	<0.001	<0.001	<0.001
Silver	<0.01	<0.01	<0.01	<0.01
Nitrate (as N)	1.6	1.4	2.5	1.5
Fluoride	<0.1	0.10	0.17	0.15
Chemical Oxygen Demand	265	171	235	100
Total Organic Carbon (TOC)	82	52	48	30
Oil and Grease	80	38	12	80
Title 22 Organics	ND ^a	ND	ND	ND
(μg/l)				
Polychlorinated Biphenyls				
Aroclors 1016-1262	ND	ND	ND	
Purgeable Priority Pollutants				
1,1,1-Trichloroethane	3	4	<1	<1
B/N,A Ext. Priority Pollutants				
Isophorone	<2	3	<1	<1
Phenanthrene	<2	<1	1	<1
Phenol	<2	2	<1	<1
Butoxy Ethoxy Cellosolve	-	-	20	-
C ₁₀ H ₁₈ O	-	-	30	-
C2-Benzene Butanoic acid	-	-	-	10
A Complex Matrix ^b	4000	3000	3000	-
Ethoxy Ethoxy Cellosolve	-	-	20	-
Hydroxy Methoxy Benzoic Acid	-	-	-	10
Hydroxy Methoxy Benzaldehyde	-	-	-	10

^a None detected.^b Unresolved non-polar organic compounds with molecular weights of 200-400.

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

Title 22 Organics (μg/l)		Purgeable Priority Pollutants (μg/l)	
2,4,5-TP (SILVEX)	<0.1	Acrolein	<10
2,4-D	<0.5	Acrylonitrile	<10
Endrin	<0.1	Other Purgeable Priority Pollutants	<1
Lindane	<0.05		
Methoxychlor	<0.3		
Toxaphene	<1		
Polychlorinated Biphenyls (μg/l)		B/N,A Ext. Priority Pollutants (μg/l)	
Aroclor 1016	<0.3	2,4-Dinitrophenol	<50
Aroclor 1221	<0.3	2-Methyl-4,6-dinitrophenol	<100
Aroclor 1232	<0.3	3,3'-Dichlorobenzidine	<80
Aroclor 1242	<0.3	4-Nitrophenol	<50
Aroclor 1248	<0.3	Bis(2-ethylhexyl)phthalate	<200
Aroclor 1254	<0.3	Benzidine	<80
Aroclor 1260	<0.3	Dibutylphthalate	<100
Aroclor 1267	<0.3	Dimethylphthalate	<50
Total PCB's	<2.4	N-Nitrosodi-n-propylamine	<80
		N-Nitrosodimethylamine	<160
		Other B/N,A Ext. Priority Pollutants,	<2

Table A-34. Drinking water suitability parameters for Site 300 monitoring wells.

Parameter: Standard:	Arsenic (mg/l) 0.05	Flouride (mg/l) 1.4	Nitrate as N (mg/l) 10	Selenium (mg/l) 0.01	Radium (pCi/l) 5	Gross Alpha (pCi/l) 15	Gross Beta (pCi/l) 50	HTO (pCi/l) 20,000	Coliform bacteria (/100 ml) 4
Well									
K7-1									
Quarter 1:	<0.001	0.52	9.9	<0.001	1.0 ± 0.1	6 ± 4	12 ± 5	27,000 ± 1000	<2
2:	0.005	0.39	9.5	<0.001	0.9 ± 0.1	21 ± 6	8 ± 3	17,000 ± 1000	a
3:	<0.001	0.46	9.5	<0.001	1.1 ± 0.1	0 ± 4	10 ± 4	27,000 ± 1000	a
4:	a	a	a	a	b	0 ± 4	11 ± 4	22,000 ± 1000	a
K7-3									
Quarter 1:	<0.001	0.39	7.3	<0.001	0 ± 0.1	0 ± 3	6 ± 4	102,000 ± 5000	<2
2:	<0.001	0.29	7.1	<0.001	0 ± 0.1	0 ± 3	0 ± 2	63,000 ± 3000	a
3:	0.004	0.36	7.3	<0.001	0 ± 0.1	0 ± 3	3 ± 3	96,000 ± 5000	a
4:	b	b	b	b	b	0 ± 5	6 ± 4	71,000 ± 4000	a
K7-5									
1:	<0.001	0.25	1.0	<0.001	0.3 ± 0.1	0 ± 3	9 ± 4	0 ± 1000	<2
2:	<0.001	0.21	0.20	<0.001	0.4 ± 0.1	0 ± 4	6 ± 2	0 ± 1000	a
3:	<0.001	0.21	0.16	<0.001	0.3 ± 0.1	0 ± 3	3 ± 3	0 ± 1000	a
4:	a	a	a	a	b	0 ± 5	7 ± 4	0 ± 1000	a
K7-6									
1:	<0.001	0.49	3.5	<0.001	0.2 ± 0.1	0 ± 3	6 ± 4	0 ± 1000	2
2:	0.014	0.34	3.6	<0.001	0.2 ± 0.1	0 ± 2	15 ± 3	0 ± 1000	a
3:	0.010	0.42	3.4	<0.001	0 ± 0.1	0 ± 2	0 ± 3	0 ± 1000	a
4:	a	a	a	a	b	0 ± 4	5 ± 3	0 ± 1000	a
K7-7									
1:	0.005	0.40	5.9	<0.001	0 ± 0.1	3 ± 3	6 ± 4	32,000 ± 1000	<2
2:	0.008	0.35	5.9	<0.001	0 ± 0.1	6 ± 2	6 ± 2	28,000 ± 1000	a
3:	0.030	0.42	6.0	<0.001	0 ± 0.1	0 ± 3	10 ± 4	46,000 ± 2000	a
4:	a	a	a	a	b	0 ± 2	7 ± 4	35,000 ± 2000	a
K1-1									
1:	c	c	c	c	c	c	c	c	c
2:	0.012	0.34	7.9	0.002	a	a	a	0 ± 1000	a
3:	c	c	c	c	c	c	c	c	c
4:	0.008	0.39	9.5	<0.001	0 ± 1	0 ± 3	0 ± 4	0 ± 1000	a

Table A-34. (Continued).

Parameter: Standard:	Arsenic (mg/l) 0.05	Fluoride (mg/l) 1.4	Nitrate as N (mg/l) 10	Selenium (mg/l) 0.01	Radium (pCi/l) 5	Gross Alpha (pCi/l) 15	Gross Beta (pCi/l) 50	HTO (pCi/l) 20,000	Coliform bacteria (/100 ml) 4
Well									
K1-2									
1:	<0.001	0.36	5.9	<0.001	0 ± 0.1	3 ± 3	6 ± 4	0 ± 1000	<2
2:	0.017	0.31	6.4	<0.001	0 ± 0.1	12 ± 5	5 ± 1	0 ± 1000	^a
3:	0.012	0.31	6.1	<0.001	0 ± 0.1	0 ± 4	5 ± 4	0 ± 1000	^a
4:	0.016	0.32	5.7	0.004	0 ± 0.1	0 ± 2	4 ± 3	0 ± 1000	^a
K1-3									
1:	<0.001	0.33	6.2	<0.001	0 ± 0.1	0 ± 4	5 ± 4	0 ± 1000	<2
2:	0.016	0.31	6.7	<0.001	0 ± 0.1	0 ± 2	5 ± 1	0 ± 1000	^a
3:	0.007	0.29	6.4	<0.001	0 ± 0.1	0 ± 2	3 ± 2	0 ± 1000	^a
4:	0.016	0.31	6.1	0.004	0 ± 0.1	0 ± 6	0 ± 4	0 ± 1000	^a
K1-4									
1:	<0.001	0.39	3.5	<0.001	0 ± 0.1	0 ± 2	9 ± 4	0 ± 1000	<2
2:	0.012	0.36	3.9	<0.001	0 ± 0.1	0 ± 1	21 ± 1	0 ± 1000	^a
3:	0.004	0.36	3.7	<0.001	0 ± 0.1	0 ± 2	3 ± 3	0 ± 1000	^a
4:	0.012	0.36	3.5	0.002	0 ± 0.1	0 ± 2	0 ± 4	0 ± 1000	^a
K1-5									
1:	<0.011	0.53	8.5	<0.001	0 ± 0.1	0 ± 2	4 ± 4	0 ± 1000	<2
2:	0.006	0.45	7.7	<0.001	0.2 ± 0.1	0 ± 2	3 ± 1	0 ± 1000	^a
3:	0.011	0.45	8.3	<0.001	0 ± 0.1	0 ± 2	0 ± 3	0 ± 1000	^a
4:	0.011	0.48	8.6	0.008	0 ± 0.1	0 ± 3	0 ± 3	0 ± 1000	^a

Notes: Standards are based on State of California Title 22, Chapter 15 regulations for public water supplies. None of the monitoring wells reported on here sample aquifers used for domestic water supply production. The following parameters were analyzed and would have been reported if any values exceeded the indicated detection limits, all of which are below applicable standards:

Barium	<0.1 mg/l	Endrin	<0.1 µg/l
Cadmium	<0.01 mg/l	Lindane	<0.05 µg/l
Chromium	<0.02 mg/l	Methoxychlor	<0.2 µg/l
Lead	<0.1 mg/l	Toxaphene	<1 µg/l
Mercury	<0.001 mg/l	2,4-D	<0.5 µg/l
Silver	<0.01 mg/l	2,4,5-TP (Silvex)	<0.1 µg/l

^a Not analyzed.

^b Analysis in progress at time of report.

^c Not sampled, pump inoperative.

Table A-35. Site-300 water samples down-gradient from liquid-discharge locations.

Location ^a	Specific conductance (μ mhos/cm at 25°C)				Total hardness as CaCO ₃ (mg/l)				Chloride (mg/l)				Total organic carbon (mg/l)			
	4	5	14	22	4	5	14	22	4	5	14	22	4	5	14	22
Month^b																
Jan.	942	828	1140	824	22	44	513	148	144	77	168	82	5	5	6	5
Feb.	1210	1160	1780	998	22	41	458	75	148	95	165	82	7	7	13	6
Mar.	1070	950	1700	910	23	40	549	70	154	84	170	81	5	5	10	5
Apr.	1160	1260	1880	940	29	51	410	58	154	95	165	68	8	6	11	5
May	1270	1160	2220	920	22	46	600	59	156	79	187	71	7	8	30	8
June	1210	1100	2420	950	26	55	640	63	155	81	196	65	13	13	32	13
Average	1143	1076	1856	923	24	46	528	78	151	85	175	74	7	7	17	7
% SDM	10	15	24	6	12	12	16	43	3	9	7	9	29	43	65	43

^a See Fig. 11.

^b No longer required to sample these locations after June 1985.

Table A-36. Drinking water suitability parameters for off-site monitoring wells downgradient from LLNL's Livermore site.

		Well (date sampled)									
		MW102 (2/22/85)	MW103 (2/22/85)	MW104 (2/22/85)	MW108 (5/2/85)	MW109 (5/2/85)	MW110 (6/10/85)	MW115 (6/10/85)	MW118 (10/11/85)	MW120 (9/13/85)	MW121 (10/16/85)
Analysis	Standard										
Arsenic (mg/l)	0.05	0.016	0.020	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.05	0.021	0.011	<0.0025	<0.0067	<0.038	<0.014	<0.016	<0.011	<0.042	<0.012
Lead (mg/l)	0.05	<0.001	<0.001	<0.001	<0.001	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (mg/l)	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nitrate as NO ₃ (mg/l)	45	22	20	42	15	17	32	42	19	23	
Selenium (mg/l)	0.01	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Gross α (pCi/l)	15	3.6 $\pm$ 1.4	2.9 $\pm$ 1.3	3.2 $\pm$ 2.0	7.1 $\pm$ 2.5	1.9 $\pm$ 1.5	1.9 $\pm$ 1.2	2.9 $\pm$ 1.4	1 $\pm$ 1.6	1.1 $\pm$ 1.0	1.0 $\pm$ 1.3
Gross β (pCi/l)	50	7.1 $\pm$ 11	1.7 $\pm$ 7.8	9.6 $\pm$ 1.2	0.8 $\pm$ 9.8	5.5 $\pm$ 9.8	1.5 $\pm$ 8.2	2.5 $\pm$ 9.7	12 $\pm$ 10	4.5 $\pm$ 8.9	5.0 $\pm$ 9.4
1,1,1-trichloroethane (ppb)	200.00	<1	3	<1	<1	6	<1	<1	<1	<1	<1
1,1,1-dichloroethylene (ppb)	0.4	2	2	<1	<1	48	<1	<1	5	<1	<1
Tetrachloroethylene (ppb)	4.00	<1	4	<1	<1	200	<1	<1	100	<1	<1
Trichloroethylene (ppb)	5.00	<1	2	<1	<1	7	<1	<1	3	<1	<1

		Well (date sampled)								
		MW122 (10/16/85)	MW123 (10/28/85)	MW143 (5/23/85)	MW149 (10/11/85)	MW150 (10/11/85)	MW151 (10/25/85)	MW201 (11/26/85)	MW203 (12/6/85)	MW251 (10/25/85)
Analysis	Standard									
Arsenic (mg/l)	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (mg/l)	0.05	0.013	0.013	0.048	0.023	0.018	0.015	0.017	<0.0001	0.014
Lead (mg/l)	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (mg/l)	0.002	0.0003	0.0001	0.0001	0.0002	0.0002	<0.0001	<0.0001	<0.0001	<0.0001
Nitrate as NO ₃ (mg/l)	45	43	62	17	18	18	36	19	44	40
Selenium (mg/l)	0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Gross α (pCi/l)	15	1.0 $\pm$ 1.6	1.0 $\pm$ 3.0	4.2	1.0 $\pm$ 1.4	<1.0 $\pm$ 1.8	<1.0 $\pm$ 2.0	<1.0 $\pm$ 1.8	<1.0 $\pm$ 1.5	4.0 $\pm$ 3.2
Gross β (pCi/l)	50	1.4 $\pm$ 12.3	<1.0 $\pm$ 1.8	-6.7 $\pm$ 8.8	18.0 $\pm$ 10.0	11.0 $\pm$ 9.0	12.0 $\pm$ 13.0	4.0 $\pm$ 10.0	<1.0 $\pm$ 14.0	20.0 $\pm$ 18.0
1,1,1-trichloroethane (ppb)	200.00	1	1	3	<1	<1	<1	<1	1	1
1,1,1-dichloroethylene (ppb)	0.4	<1	<1	25	5	<1	<1	20		16
Tetrachloroethylene (ppb)	4.00	<1	<1	260	8	<1	<1	31		<1
Trichloroethylene (ppb)	5.00	<1	<1	15	<1	<1	<1	3		<1

See Fig. 23 for well locations. Well depths and completion details are presented in references cited in text. Standards are based on State of California Title 22, Chapter 15 regulations for metals, nitrate, pesticides, and radioactivity in public water supplies and on State of California Department of Health Services recommended action levels for other compounds.

The following parameters were also analyzed for and would have been reported if any values had exceeded the indicated detection levels, all of which are below the applicable standards:

Cadmium	<0.001 mg/l	Lindane	<0.05 μ g/l	2,4,5-TP (SILVEX)	<0.1 μ g/l
Silver	<0.001 mg/l	Methoxychlor	<0.2 μ g/l	Other compounds detectable by EPA 624/725 method	
Tritium	<1000 pCi/l	Toxaphene	<1 μ g/l		
Endrin	<0.1 μ g/l	2,4-D	<0.5 μ g/l		

Table A-37. Radioactive effluent releases from LLNL from 1981 through 1985.

Year	Airborne effluents (Ci)		Liquid effluents (Ci)	
	^3H	^{13}N - ^{15}O	HTO	^{239}Pu
1981	2620	344	6	9.2×10^{-5}
1982	2014	584	1.6	4.3×10^{-6}
1983	3245	855	1.7	6.7×10^{-6}
1984	7354	81	1.7	3.2×10^{-6}
1985	2204	520	3.6	4.8×10^{-6}

Table A-38. Estimated radiation dose to the public from LLNL airborne effluents during 1985.

Nuclide	Facility	Curies	Dose at site boundary (mrem)	Dose to nearest resident (mrem)	Dose within 80-km radius of LLNL (person-rem)
^3H	Tritium facility	1989	0.05 ^a	0.03 ^a	0.22 ^a
	Insulating core accelerator	5	0.00	0.00	0.00
	Rotating target neutron source	210	0.11	0.02	0.08
^{13}N - ^{15}O	Linear accelerator	120	0.06	0.01	0.00
	ATA ^b (Site 300)	400	0.00	0.00	0.00
Total			0.22	0.06	0.30

^a Doses are based on the 624 Ci of HTO released by LLNL. The dose due to the 1365 Ci of HT released by LLNL does not add significantly to the total. SNLL emitted about 450 Ci of HTO which are not included in these calculations.

^b Advanced test accelerator.

Table A-39. Quality-assurance analyses for the participation in the U.S. EPA Environmental Radioactivity Laboratory Intercomparison studies.

Analyses	Media	Value reported (pCi/l $\pm$ 1 σ)		
		LLNL	Known	Grand average of all Laboratories
Gross alpha	Water	6 $\pm$ 0	5 $\pm$ 5.0	5 $\pm$ 2
		11.0 $\pm$ 2.0	12 $\pm$ 5.0	10.5 $\pm$ 3.2
		6.7 $\pm$ 0.6	8.0 $\pm$ 5.0	7.6 $\pm$ 2
Gross beta	Water	21 $\pm$ 2	15 $\pm$ 5.0	17 $\pm$ 3
		14.0 $\pm$ 1.0	11.0 $\pm$ 5.0	12.5 $\pm$ 3.1
		11.3 $\pm$ 1.2	8.0 $\pm$ 5.0	8.4 $\pm$ 2.1
Gross alpha	Air	11.7 $\pm$ 0.6	10.0 $\pm$ 5.0	10.6 $\pm$ 2.4
		34.7 $\pm$ 1.5	32.0 $\pm$ 5.0	30.6 $\pm$ 10.0
Gross beta	Air	84.3 $\pm$ 2.5	72.0 $\pm$ 5.0	70.0 $\pm$ 9.6
		45.0 $\pm$ 1.0	36.0 $\pm$ 5.0	38.3 $\pm$ 5.6
Tritium	Water	4673 $\pm$ 690 (4097 $\pm$ 327) ^a	3796 $\pm$ 366	3916 $\pm$ 372
		3440 $\pm$ 17 (3670 $\pm$ 44)	3559 $\pm$ 364	3534 $\pm$ 268
		4993 $\pm$ 227 (4633 $\pm$ 184)	4480 $\pm$ 448	4422 $\pm$ 341
		1907 $\pm$ 59 (1903 $\pm$ 47)	1974 $\pm$ 345	1984 $\pm$ 200

^a Data in parentheses is provided by the Nuclear Chemistry Division. All other LLNL data is provided by the Hazards Control Department.

Table A-40. Quality-assurance analyses for LLNL's participation in the DOE Environmental Measurements Laboratory (EML) Quality Assessment Program.^{a,b}

Analyses	Media	LLNL	EML value	LLNL/EML ratio	LLNL/mean reported
Be ⁷	Air	0.679	0.572	1.19	1.15
Cs ¹³⁷		0.615	0.527	1.17	1.16
Pu ²³⁹		0.497	0.481	1.03	1.02
U (μ g)		0.148	0.256	0.58	0.57
Mn ⁵⁴		0.502	0.450	1.12	1.13
Co ⁶⁰		0.565	0.500	1.13	1.11
Sb ¹²⁵		0.508	0.394	1.29	1.26
K ⁴⁰		0.195	0.203	0.96	0.99
Cs ¹³⁷		0.774	0.760	1.02	1.05
Ra ²²⁶	Soil	0.551	0.640	0.86	0.93
Pu ²³⁸		0.043	0.400	0.11	0.11
Pu ²³⁹		0.313	0.350	0.89	0.79
U (μ g)		2.10	0.980	2.14	2.23
³ H		0.204	0.185	1.10	1.07
Cs ¹³⁷	Water	0.582	0.536	1.09	1.03
Pu ²³⁹		0.349	0.428	0.82	0.98

^a The following values are relative; the exponents are not included, and therefore do not indicate actual concentrations.

^b All data provided by LLNL's Nuclear Chemistry Division.

Table A-41. Summary of Quality Assurance Program—analyses of replicate sampling.^a

Analyses	Media	Location	Number of duplicates	Number below LOS (Average LOS - μ Ci/ml)	Ratio of duplicates $\pm 1\sigma$ (%)
Gross alpha	Air	Perimeter	7	7 (2.5×10^{-16})	—
Gross beta		Perimeter	7	0	0.83 $\pm$ 21
HTO		Perimeter	5	0	1.1 $\pm$ 20
Gross alpha	Sewage	LLNL	48	29 (3.4×10^{-10})	1.1 $\pm$ 34
Gross beta		LLNL	48	1 (6.1×10^{-10})	1.1 $\pm$ 32
HTO		LLNL	43	3 (3.0×10^{-7})	1.1 $\pm$ 57
Gross alpha	Sewage	LWRP	52	51 (9.6×10^{-9})	1.2
Gross beta		LWRP	52	38 (13.4×10^{-9})	1.0 $\pm$ 19
HTO		LWRP	49	28 (3.7×10^{-7})	1.0 $\pm$ 23
HTO	Vegetation	Livermore Valley	6	0	0.92 $\pm$ 13
		Site 300	4	4 (1×10^{-7})	—
HTO	Water	Livermore Valley	4	0	0.99 $\pm$ 18
		Site 300	3	1 (5×10^{-9})	0.68 $\pm$ 1

^a Sample results less than the limit of detection were not used to calculate the ratios.

Appendix B. Environmental Activity Concentration—Guide Levels

LLNL is subject to a variety of radionuclide concentration guides and standards from state and federal agencies. In cases where these standards differ, the more restrictive (lower) value is the one cited in the text and tables of this report.

The State of California (Title 22, Chapter 15) specifies Maximum Contaminant Levels (MCL) for public water supplies as follows:

Cross alpha particle activity (including ^{226}Ra but excluding Ru and U)	— 15 pCi/l
Cross beta particle activity	— 50 pCi/l
Tritium	— 20,000 pCi/l

Chemical concentration levels for various species are also specified in this regulation and by the California Department of Health Services (recommended action levels); these are cited in the text and tables of this report where they are relevant.

DOE Manual 5484 specifies derived concentration guides for individual radionuclides in drinking water and inhaled air. The values relevant to this report are presented in Table B-1.

DOE Manual 5480.1, Chg 2, issued April 29, 1981, states 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 LLNL. 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 100 mrem/y for prolonged exposures.

Table B-1. DOE concentration guides for individual radionuclides in inhaled air and drinking water.

Nuclide	Concentration in air ($\mu\text{Ci/ml}$)	Concentration in water ($\mu\text{Ci/ml}$)
^3H	1×10^{-7}	2×10^{-3}
^7Be	5×10^{-8}	
^{40}K	9×10^{-10}	
^{106}Ru	3×10^{-11}	
^{125}Sb	1×10^{-9}	
^{137}Cs	4×10^{-10}	3×10^{-6}
^{144}Ce	3×10^{-11}	
$^{235}\text{U}^a$	1×10^{-13}	6×10^{-7}
$^{238}\text{U}^a$	1×10^{-13}	6×10^{-7}
^{239}Pu	2×10^{-14}	3×10^{-7}

^a The mass concentration units for uranium in air derived from these activity limits correspond to $0.3 \mu\text{g/m}^3$.

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*. The dose and dose-rate conversion factor specified by Publication 30 of the International Commission on Radiological Protection, *Limits of Intakes of Radionuclides by Workers*, were used in the calculations. 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

$$\begin{aligned} C_w &= \text{concentration in pCi/liter,} \\ U_w &= \text{intake rate, liters/y,} \\ &= 730 \text{ liters/y for maximum exposed individual,} \\ D_w &= \text{dose factor, mrem/pCi,} \\ &= 6.23 \times 10^{-8} \text{ mrem/pCi for the whole-body ingestion pathway for an adult, and} \\ R_{\text{total body}} &= \text{annual dose in mrem to the total body from ingestion of 730 liters of potable water with} \\ &\quad \text{concentration } C_w. \end{aligned}$$

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

$$\begin{aligned} U_{\text{veg}} &= \text{intake rate, kg/y, } 64 \text{ kg/y for maximum exposed individual,} \\ C_{\text{veg}} &= \text{concentration in pCi/kg} = 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}} \times C_{\text{veg}} \mu\text{Ci/ml (measured),} \\ D_{\text{HTO}} &= \text{dose factor, mrem/pCi} = 6.23 \times 10^{-8} \text{ mrem/pCi for } ^3\text{H for the adult whole-body ingestion pathway,} \\ D_{\text{veg}} (\text{mrem/y}) &= 0.40 \times 10^4 C_{\text{veg}} \mu\text{Ci/ml (measured).} \\ D_{\text{meat}} &= U_{\text{meat}} \times C_{\text{meat}} \times D_{\text{HTO}}, \quad (2b) \end{aligned}$$

where

$$\begin{aligned} U_{\text{meat}} &= 110 \text{ kg/y,} \\ D_{\text{HTO}} &= 6.23 \times 10^{-8} \text{ mrem/pCi,} \end{aligned}$$

$$C_{\text{meat}} = (F_f) (Q_f) (C_{\text{veg}}) \exp (-\lambda_i t_s).$$

F_f = fraction of daily intake of nuclide per kg of animal/fish (pCi/kg in meat per pCi/day ingested by the animal), 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.

$$C_{\text{meat}} = \left(1.2 \times 10^{-2} \frac{\text{day}}{\text{kg}}\right) \left(50 \frac{\text{kg}}{\text{day}}\right) \left(C_{\text{veg}} \frac{\mu\text{Ci}}{\text{ml}}\right) \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}}\right) \\ \times \exp[-1.5 \times 10^{-4}(20)] = 0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}} \times C_{\text{veg}} \frac{\mu\text{Ci}}{\text{ml}} (\text{measured}) ,$$

$$D_{\text{meat}} (\text{mrem/y}) = 0.41 \times 10^4 \times C_{\text{veg}} \mu\text{Ci/ml} (\text{measured}) .$$

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

where

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

$$D_{\text{HTO}} = 6.23 \times 10^{-8} \text{ mrem/pCi},$$

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

F_m = fraction of daily intake of nuclide per liter of milk (pCi/liter in milk per pCi/day ingested by the animal) 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,

$$C_{\text{milk}} = \left(1.0 \times 10^{-2} \frac{\text{day}}{\text{liter}}\right) \left(50 \frac{\text{kg}}{\text{d}}\right) \left(C_{\text{veg}} \frac{\mu\text{Ci}}{\text{ml}}\right) \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}}\right) \\ \times \exp[-1.5 \times 10^{-4}(2)] = 0.5 \times 10^9 \frac{\text{pCi/liter}}{\mu\text{Ci/ml}} \times C_{\text{veg}} \frac{\mu\text{Ci}}{\text{ml}} (\text{measured}) .$$

$$D_{\text{milk}} (\text{mrem/y}) = 0.97 \times 10^4 \times C_{\text{veg}} \mu\text{Ci/ml} (\text{measured}) .$$

$$D_{\text{total}} (\text{mrem/y}) = 0.40 \times 10^4 C_{\text{veg}} \mu\text{Ci/ml} (\text{measured}) + 0.41 \times 10^4 C_{\text{veg}} \mu\text{Ci/ml} (\text{measured}) \\ + 0.97 \times 10^4 C_{\text{veg}} \mu\text{Ci/ml} (\text{measured}) = 1.78 \times 10^4 C_{\text{veg}} \mu\text{Ci/ml} (\text{measured}) .$$

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 ,

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

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,

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

D = dose factor, mrem/pCi ,

for ^3H , $D = 6.23 \times 10^{-8} \text{ mrem}/\text{pCi} \times 1.5$ to include immersion dose = $9.35 \times 10^{-8} \text{ mrem}/\text{pCi}$,

$$\text{for } ^{13}\text{N}, D \times U = 5.22 \times 10^{-3} \frac{\text{mrem} \cdot \text{m}^3}{\text{pCi} \cdot \text{y}},$$

$$\text{for } ^{15}\text{O}, D \times U = 5.25 \times 10^{-3} \frac{\text{mrem} \cdot \text{m}^3}{\text{pCi} \cdot \text{y}},$$

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

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

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

where

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

Q = release rate, Ci/y ,

U = inhalation rate, average individual (adult),

D = dose factor, mrem/pCi .

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 publicly-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 the 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/liter of freon extractable 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-enumerated 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 for such user(s) 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% 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/liter arsenic
0.2	mg/liter cadmium
2.0	mg/liter copper
1.0	mg/liter cyanide
1.0	mg/liter lead
0.01	mg/liter mercury
1.0	mg/liter nickel
0.2	mg/liter silver
1.0	mg/liter total chromium
3.0	mg/liter zinc
0.02	mg/liter total identifiable chlorinated hydrocarbons
1.0	mg/liter phenolic compounds
0.01	mg/liter polychlorinated biphenyls

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 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 employed by the Environmental Quality Verification Program, and the 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 1984 Annual Environmental Monitoring Report and published as a separate manual (LLNL M-122 Rev. 1, *Radiochemical Methods of the Site Environmental Monitoring Program*, 1984). This manual is revised and re-issued biennially; interim changes in procedures are noted in the annual environmental monitoring report.

Some analyses are performed by independent contractors. LLNL contracts with laboratories certified by the State of California whenever possible, and requires its contractors to maintain adequate quality assurance programs and documentation of methods.

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- 1 Lawrence Livermore National Laboratory
- 2 Sandia National Laboratory
- 3 South Bay Aqueduct
- 4 Arroyo Seco
- 5 Arroyo Las Positas
- 6 Nearest residential area

- 7 Vasco Road
- 8 East Avenue
- 9 Greenville Road
- 10 Lupin Way
- 11 Interstate 580

Frontispiece. Lawrence Livermore National Laboratory (looking west).

Sampling and Analytical Procedures

Introduction

Written procedures have been prepared for each environmental monitoring activity at LLNL as part of its quality assurance program. 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 describe the procedures used for each sample medium monitored. A general description of each medium is usually provided. This is followed by the collection procedure used, the provisions for sample identification, and the schedule for sample replication.

The "Analysis" sections cover the analyses of the samples collected. 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 locations around the LLNL perimeter and at nine locations at Site 300 measure particulate radioactivity and beryllium. Particulate radioactivity is also measured at 11 off-site locations near LLNL. Tritiated-water samplers are operated at the six LLNL perimeter locations and at six off-site locations. In all cases, the samplers are so placed to reasonably ensure that any significant concentration of effluents from LLNL operations would be detected regardless of local meteorology.

Collection

Particulates

Samples taken at the LLNL perimeter, selected off-site locations in the Livermore Valley, and at Site 300 are collected on $5.2 \times 10^{-2} \text{ m}^2$ Whatman filters using Hi-Vol samplers with average flow rates of 700 liters/min. These flow rates are verified at monthly intervals with a portable field-calibration unit. If a Hi-Vol air sampler fails, it is repaired and then calibrated with a spirometer that was itself calibrated by using an immersion unit certified by the National Bureau of Standards (NBS).

The remaining off-site samples in the Livermore Valley are collected on $7.5 \times 10^{-3} \text{ m}^2$ Flanders F-700 glass-fiber filters at a flow rate of 80 liters/min. The flow-rate indicators are generally calibrated annually.

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. The average flow rate is calculated from the initial and final flow rates, which are measured with a rotometer that is calibrated annually. Columns are exchanged biweekly.

Identification

Particulates

Particulate samplers run continuously, and the filters are exchanged weekly. Each filter is identified by its location, the date on, date off, the elapsed sampling time, and the flow rate. Filters are placed in glassine envelopes and are transported to the laboratory, where this information is transferred to log

sheets and each filter sample is given a serial number that accompanies it throughout the 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 run continuously, and the silica-gel holders are exchanged biweekly. Each sample is identified by the location, the date on, the date off, the elapsed sampling time, and the flow rate. This information is transferred to log sheets in the laboratory, and each sample is given a serial number that accompanies it throughout the 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, the filters are exchanged weekly, and both filters are submitted for analysis in the usual manner. Bimonthly rotation of the extra sampler among the six locations ensures the 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 the LLNL perimeter locations during alternate months from those in which particulate replicates are being collected.

Soil Sampling

Soil samples are collected annually within the Livermore Valley and at Site 300. Radiochemical analyses of these samples serve to document any changes that may have occurred during the year. Approximately 20 sampling sites within the Livermore Valley are chosen at random from a list of 125 locations which provided the data base of various nuclides in the soil near LLNL. The same sampling sites are used each year at Site 300 to provide an ongoing comparison, with additional sampling sites added from time to time to expand coverage or test specific hypotheses.

Collection

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

Five samples of soil collected from each 2-m square are composited in a plastic bag and 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 analyses and in the annual report.

Replication

During each annual collection of soil samples, approximately 10% of the sites are sampled in duplicate. In such collections, two, adjacent cores, 5-cm-deep, 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 surface and groundwater 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 surface sources such as ponds, creeks, and reservoirs are obtained with a tethered plastic pail. A 500-ml sample is collected for tritium analysis in an argon-flushed glass container fitted with a ground glass stopper. Samples for other analyses are collected in 500-ml polyethylene bottles.

Identification

As samples are collected in the field, they are labeled with the 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 LLNL 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, the treated effluent, and from the digester sludge at the Livermore Water Reclamation Plant (LWRP).

Collection

LLNL Effluent

A 24-hr composite of LLNL sewage effluent is collected daily by a peristaltic pump that functions 9 seconds every 5 minutes to collect 13 liters daily. Aliquots of this composite are transferred to plastic bottles and are submitted for analysis.

LWRP Effluent

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

LWRP Digester Sludge

Composites from both digesters at the LWRP are collected monthly. The composites consist of aliquots taken from the circulating sewage 3 times a week.

Identification

As each sewage sample is collected in the field, it is labeled 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 analysis.

LWRP Effluent

One replicate sample of LWRP effluent is taken every Wednesday and is analyzed for gross alpha, beta, and tritium.

Vegetation Sampling

At quarterly intervals, samples of vegetation (usually native grasses) are collected throughout the Livermore Valley, at Site 300, and at off-site locations near Site 300. After these samples are freeze-dried, the tritium content of the recovered water is determined by 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's surface. Duplicate samples are collected at each location and are later transferred to a freezer in the laboratory.

Identification

Samples of vegetation collected in the field are labeled according to sample type and location. In the laboratory, each sample is assigned a number that accompanies it until the measurement is reported.

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 data.

Milk Sampling

Milk samples are obtained at monthly intervals or when available from three goat farms located about 5 km south and 5 km southeast of LLNL. One of these farms also provides cow's milk on occasion. A portion of each milk sample is freeze-dried, and the tritium content of the recovered water is determined by liquid scintillation. A 1-liter sample is preserved with formaldehyde and gamma-counted in a Marinelli beaker.

Air Analysis

Environmental air samples are analyzed for gross alpha and beta activity and beryllium.

Gross Alpha and Beta Counting

After a 4-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 20-minute counting periods. Normally, this counter is used only for environmental samples to avoid possible contamination.

Standards and Calibration

Separate ^{239}Pu and ^{90}Sr standards on 5-cm-diam stainless-steel planchets are used for determining alpha and beta counting efficiencies, respectively. These standards are traceable to NBS or to equivalent certification 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 milliliters, taking care to prevent the samples from baking dry. After the samples are diluted with water, they are filtered, any residues are discarded, and the filtrates are diluted to 100 ml with deionized water.

Quantification is done by atomic absorption spectrophotometry with electrothermal atomization. Quality control includes a reagent blank with blank filters, a blank spiked with 200-ng Be, and several samples spiked with essentially carrier-free ^7Be .

Standards of 1, 2, and 5 $\mu\text{g/liter}$ are prepared by diluting an intermediate 1-ppm stock solution obtained from an NBS-traceable 1000-ppm stock dilution. The diluent in all cases is 1% HNO_3 in water.

Water Analysis

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

Gross Alpha and Beta Activity

A 100-ml sample or less, depending on the solid content, is digested with a mixture of 80% HNO_3 and 20% HClO_4 and dried. 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 30 min in a Sharp 3-1/4-in proportional counter.

A blank is processed together with each set of samples.

Standards and Calibration

The ^{239}Pu and ^{90}Sr standards are used with every sample set (see similar entry under Soil Analysis). Background measurements are made between every 10 sample-counting measurements.

Beryllium

A 100-ml sample is digested with HNO_3 . The residue is diluted to 100 ml with deionized water, and the analysis is completed using atomic absorption spectrophotometry, as described for air analysis.

Sewage Analysis

Sewage samples are analyzed for gross alpha and beta activities, tritium, and selected metal ions. 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 quenching 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, transferred to 5-cm-diam planchets, and counted.

Tritium

A 5-ml aliquot of sewage sample is added to 15 ml of Packard Instagel in a 25-ml screw-cap polyethylene bottle. Then, 15 ml of Instagel 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 1-h temperature equilibration 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, silver, aluminum, beryllium, and zinc.

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 is 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 metal content is determined with a Perkin-Elmer Model 5000 atomic-absorption spectrophotometer. The required standards are prepared by dilution of 1000-ppm, NBS-traceable stock solution.

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