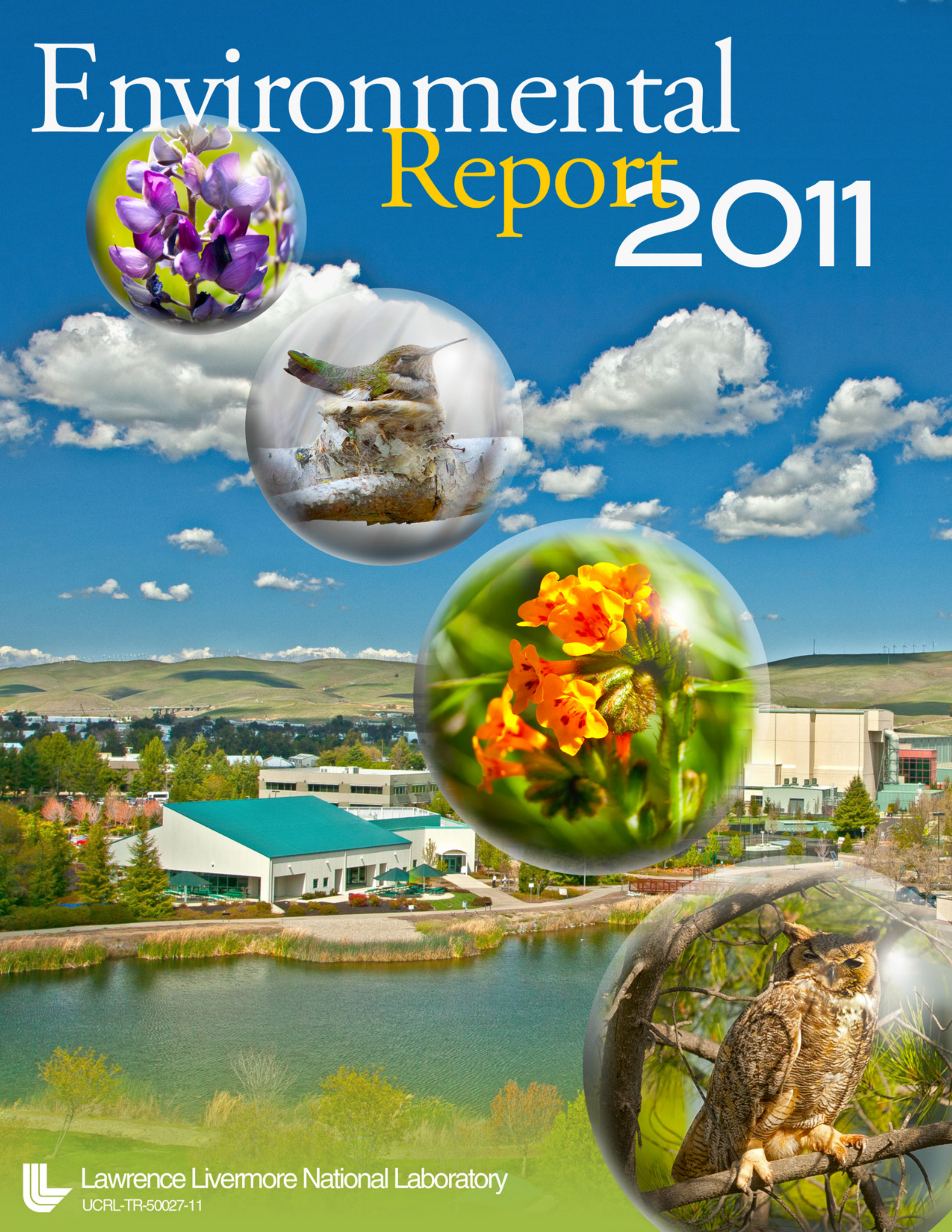
Environmental Report 2011



Lawrence Livermore National Laboratory

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Lawrence Livermore National Laboratory

Environmental Report 2011

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MEMORANDUM FOR DISTRIBUTION

FROM: KIMBERLY A. DAVIS

SUBJECT: 2011 ANNUAL SITE ENVIRONMENTAL REPORT FOR THE LAWRENCE LIVERMORE NATIONAL LABORATORY

The Annual Site Environmental Report (ASER) was prepared by the Lawrence Livermore National Laboratory (LLNL) for the Department of Energy/National Nuclear Security Administration (NNSA)/Livermore Site Office, and provides a comprehensive summary of the environmental program activities at LLNL for calendar year 2011.

The information in this report has been reviewed by NNSA and LLNL personnel for accuracy. The review was based on quality assurance and quality control protocols applied to monitoring and data analyses at LLNL.

The environmental protection and compliance programs at LLNL are implemented to ensure the health and safety of employees, and residents of neighboring communities, in addition to the preservation of the environment. Remediation activities continue to reduce on-site and off-site contaminants.

LLNL is committed to continuous improvement in environmental performance through pollution prevention, waste minimization, energy efficiency, and other measures. LLNL has achieved and is maintaining International Organization for Standardization (ISO) 14001 certification for its Environmental Management System to implement a systematic approach to setting and achieving environmental goals and objectives.

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Preface

The purposes of the *Lawrence Livermore National Laboratory Environmental Report 2011* are to record Lawrence Livermore National Laboratory's (LLNL's) compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring at the two LLNL sites—the Livermore site and Site 300. The report is prepared for the U.S. Department of Energy (DOE) by LLNL's Environmental Functional Area. Submittal of the report satisfies requirements under DOE Order 231.1B, Environmental Safety and Health Reporting, and DOE Order 458.1, Radiation Protection of the Public and Environment.

The report is distributed electronically and is available at https://saer.llnl.gov/, the website for the LLNL annual environmental report. Previous LLNL annual environmental reports beginning in 1994 are also on the website. Some references in the electronic report text are underlined, which indicates that they are clickable links. Clicking on one of these links will open the related document, data workbook, or website that it refers to.

The report begins with an executive summary, which provides the purpose of the report and an overview of LLNL's compliance and monitoring results. The first three chapters provide background information: Chapter 1 is an overview of the location, meteorology, and hydrogeology of the two LLNL sites; Chapter 2 is a summary of LLNL's compliance with environmental regulations; and Chapter 3 is a description of LLNL's environmental programs with an emphasis on the Environmental Management System including pollution prevention.

The majority of the report covers LLNL's environmental monitoring programs and monitoring data for 2010: effluent and ambient air (Chapter 4); waters, including wastewater, storm water runoff, surface water, rain, and groundwater (Chapter 5); and terrestrial, including soil, sediment, vegetation, foodstuff, ambient radiation, and special status wildlife and plants (Chapter 6). Complete monitoring data, which are summarized in the body of the report, are provided in Appendix A.

The remaining three chapters are Chapter 7 which discusses the radiological impact on the public from LLNL operations, Chapter 8 contains LLNL's groundwater remediation program and Chapter 9 the quality assurance for the environmental monitoring programs.

The report uses Système International units, consistent with the federal Metric Conversion Act of 1975 and Executive Order 12770, Metric Usage in Federal Government Programs (1991). For ease of comparison to environmental reports issued prior to 1991, dose values and many radiological measurements are given in both metric and U.S. customary units. A conversion table is provided in the glossary.

The report is the responsibility of LLNL's Environmental Functional Area. Monitoring data were obtained through the combined efforts of the Environmental Functional Area; Environmental

Restoration Department; Physical and Life Sciences Environmental Monitoring Radioanalytical Laboratory; and the Hazards Control Department.

Special recognition is given to the technologists who gathered the data—Gary A. Bear, Karl Brunckhorst, Crystal Rosene, Steven Hall, Terrance W. Poole, and Robert Williams; and to the data management personnel—Kimberley A. Swanson, Cheryl Paguia, Suzanne Chamberlain, Nancy Blankenship, Connie Wells, Lisa Graves, Della Burruss, Beth Schad and Susan Lambaren. Special thanks to Rosanne Depue for proofreading, compositing, and distributing the report.

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Executive Summary

Lawrence Livermore National Laboratory (LLNL) is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducting major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory is managed and operated by Lawrence Livermore National Security, LLC (LLNS), and serves as a scientific resource to the U.S. government and a partner to industry and academia.

LLNL operations have the potential to release a variety of constituents into the environment via atmospheric, surface water, and groundwater pathways. Some of the constituents, such as particles from diesel engines, are common at many types of facilities while others, such as radionuclides, are unique to research facilities like LLNL. All releases are highly regulated and carefully monitored.

LLNL strives to maintain a safe, secure and efficient operational environment for its employees and neighboring communities. Experts in environment, safety and health (ES&H) support all Laboratory activities. LLNL's radiological control program ensures that radiological exposures and releases are reduced to as low as reasonably achievable to protect the health and safety of its employees, contractors, the public, and the environment.

LLNL is committed to enhancing its environmental stewardship and managing the impacts its operations may have on the environment through a formal Environmental Management System. The Laboratory encourages the public to participate in matters related to the Laboratory's environmental impact on the community by soliciting citizens' input on matters of significant public interest and through various communications. The Laboratory also provides public access to information on its ES&H activities.

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore site," which occupies 1.3 square miles; and a rural Experimental Test Site, referred to as "Site 300," near Tracy, California, which occupies 10.9 square miles. In 2011 the Laboratory had a staff of approximately 6800.

Purpose and Scope of the Environmental Report

The purposes of the *Environmental Report 2011* are to record LLNL's compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring. Specifically, the report discusses LLNL's Environmental Management System; describes significant accomplishments in pollution prevention; presents the results of air, water, vegetation, and foodstuff monitoring; reports radiological doses from LLNL operations; summarizes LLNL's activities involving special status wildlife, plants, and habitats; and describes the progress LLNL has made in remediating groundwater contamination.

Environmental monitoring at LLNL, including analysis of samples and data, is conducted according to documented standard operation procedures. Duplicate samples are collected and analytical results are reviewed and compared to internal acceptance standards.

This report is prepared for DOE by LLNL's Environmental Functional Area (EFA). Submittal of the report satisfies requirements under DOE Order 231.1B, Environmental Safety and Health Reporting, and DOE Order 458.1, Radiation Protection of the Public and Environment. The report is distributed in electronic form and is available to the public at https://saer.llnl.gov/, the website for the LLNL annual environmental report. Previous LLNL annual environmental reports beginning in 1994 are also on the website.

Regulatory Permitting and Compliance

LLNL undertakes substantial activities to comply with many federal, state, and local environmental laws. The major permitting and regulatory activities that LLNL conducts are required by the Clean Air Act; the Clean Water Act and related state programs; the Emergency Planning and Community Right-to-Know Act; the Resource Conservation and Recovery Act and state and local hazardous waste regulations; the National Environmental Policy Act; the Endangered Species Act; the National Historic Preservation Act; the Antiquities Act; and the Comprehensive Environmental Response, Compensation and Liability Act.

Integrated Safety Management System and Environmental Management System

LLNL established its Environmental Management System (EMS) to meet the requirements of the International Organization for Standardization (ISO) 14001:1996 in June 2004. In June 2006, LLNL upgraded its EMS to meet the requirements of ISO 14001:2004. During 2006 and 2007, LLNL developed Environmental Management Plans (EMPs) that address lab-wide and programmatic significant aspects. During 2008, more focus was placed on raising lab-wide awareness of EMS and on continued development of EMPs. In October 2009, LLNL became ISO 14001:2004 certified. In 2011, LLNL had 8 active Lab-wide EMPs and initiatives on significant aspects, including eco-friendly purchasing, waste generation and greenhouse gas reductions, energy use, water conservation, fossil fuel consumption, hazardous material use/waste generation and radioactive materials use.

Pollution Prevention

A strong Pollution Prevention/Sustainability Program (P2S) is an essential supporting element of LLNL's EMS. The P2S Program at LLNL strives to systematically reduce all types of waste generated and eliminate or minimize pollutant releases to all environmental media from all aspects of the operations at the Livermore site and Site 300.

Each year, the LLNL submits nominations for the NNSA environmental awards program, which recognizes exemplary performance in integrating environmental stewardship practices to reduce risk, protect natural resources, and enhance site operation.

In 2011, LLNL received three NNSA Environmental Stewardship awards, two DOE EStar awards, a California Department of Resources Recycling and Recovery (CalRecycle) Waste Reduction Award Program (WRAP) award for recycling efforts, and a Federal Electronics Challenge Bronze award for management of electronics.

P2 Program outreach in 2011 included participation in a community Earth Day event, assisting LLNL and Sandia in starting a Farmers Market, publishing articles in the LLNL newspaper, and maintaining of an internal P2S website and a green hotline for all LLNL employees.

Air Monitoring

LLNL operations involving radioactive materials had minimal impact on ambient air during 2011. Estimated nonradioactive emissions are small compared to local air district emission criteria.

Releases of radioactivity to the environment from LLNL operations occur through stacks and from diffuse area sources. In 2011, radioactivity released to the atmosphere was monitored at six facilities on the Livermore site and one at Site 300. In 2011, 6978 GBq (188.6 Ci) of tritium was released from the Tritium Facility, and 0.56 GBq of tritium (0.015 Ci) was released from the Decontamination and Waste Treatment Facility and 45.1 GBq of tritium (1.22 Ci) was released from the National Ignition Facility (NIF). The Contained Firing Facility at Site 300 had 210 Bq (5.6 nCi) of depleted uranium released in particulate form in 2011. The dose to the hypothetical, site-wide maximally exposed individual (SW-MEI) member doses at the Livermore site and Site 300 are less than one percent of the annual NESHAPs standard, which is 100 µSv/y (10 mrem/y) total site effective dose equivalent. None of the other facilities monitored for gross alpha and gross beta radioactivity had emissions in 2011.

The magnitude of nonradiological releases (e.g., reactive organic gases/precursor organic compounds, nitrogen oxides, carbon monoxide, particulate matter, sulfur oxides) is estimated based on specifications of equipment and hours of operation. Estimated releases in 2011 for the Livermore site and Site 300 were similar to 2010 levels. Nonradiological releases from LLNL continue to be a very small fraction of releases from all sources in the Bay Area or San Joaquin County.

In addition to air effluent monitoring, LLNL samples ambient air for tritium, radioactive particles, and beryllium. Some samplers are situated specifically to monitor areas of known contamination; some monitor potential exposure to the public; and others, distant from the two LLNL sites, monitor the natural background. In 2011, ambient air monitoring data confirmed estimated releases from monitored stacks and were used to determine source terms for resuspended plutonium-contaminated soil and tritium diffusing from area sources at the Livermore site and resuspended uranium-contaminated soil at Site 300. In 2011, radionuclide particulate, tritium, and beryllium concentrations in air at the Livermore site and in the Livermore Valley were well below the levels that would cause concern for the environment or public health.

Water Monitoring

Water monitoring is carried out to determine whether any radioactive or nonradioactive constituents released by LLNL might have a negative impact on public health and the environment. Data indicate LLNL has good control of its discharges to the sanitary sewer, and discharges to the surface water and groundwater do not have any apparent environmental impact.

Permits, including one for discharging treated groundwater from the Livermore site Ground Water Project, regulate discharges to the City of Livermore sanitary sewer system. During 2011, monitoring data under the LLNL Wastewater Permit #1250 (2011–2012) demonstrated full compliance with all discharge limits, and most of the measured values were a small fraction of the allowed limits. All discharges to the Site 300 sewage evaporation pond and percolation ponds were within permitted limits, and groundwater monitoring related to this area showed no measurable impacts.

Storm water is sampled for constituents such as radioactivity, metals, oxygen, dioxins, polychlorinated biphenyls (PCBs), and nitrate both upstream and downstream from both the Livermore site and Site 300. In 2011, no issues were identified as a result of acute or chronic toxicity tests in runoff waters, and data showed that the quality of Livermore site storm water effluent was similar to that entering the site (influent). Storm water sampling at Site 300 revealed low concentrations of radioactivity, consistent with the background concentrations of naturally occurring radionuclides and low levels of dioxins continue to be observed. Storm water visual observations and best management practices inspections indicated that LLNL’s storm water program continues to protect water quality.

In addition to the CERCLA-driven monitoring (i.e., for volatile organic compounds [VOCs]) conducted by LLNL’s Environmental Restoration Department (ERD), extensive monitoring of groundwater occurs at and near the Livermore site and Site 300. Groundwater from wells downgradient from the Livermore site is analyzed for anions, hexavalent chromium, and radioactivity. To detect any off-site contamination quickly, the well water is sampled in the uppermost water-bearing layers. Near Site 300, monitored constituents in off-site groundwater include explosives residue, nitrate, perchlorate, metals, volatile and semivolatile organic compounds, tritium, uranium, and other (gross alpha and beta) radioactivity. With the exception of VOCs in wells monitored for CERCLA compliance, the constituents of all off-site samples collected at both the Livermore site and Site 300 were below allowable limits for drinking water.

Surface waters and drinking water are analyzed for tritium and gross alpha and gross beta radioactivity. In the Livermore Valley, the maximum tritium activity was less than 1% of the drinking water standard, and the maximum gross alpha and gross beta measurements were less than 5% of their respective drinking water standards. For Lake Haussmann (formerly called the Drainage Retention Basin) on the Livermore site, levels of gross alpha, gross beta, tritium, metals, and pesticides were below discharge limits, and organics and PCBs were below detection limits. Aquatic bioassays for acute and chronic toxicity showed no effects in water discharged from Lake Haussmann. At Site 300, maintenance and the operation of drinking water and cooling systems resulted in permitted discharges without adverse impact on surrounding waters.

Terrestrial Radiological Monitoring

The impact of LLNL operations on surface soil in 2011 was insignificant. Soil is analyzed for plutonium, gamma-emitting radionuclides, tritium, and PCBs as appropriate. Plutonium concentrations at the Livermore Water Reclamation Plant continued to be high relative to other sampled locations, but even this concentration was only 1.8% of the screening level for cleanup recommended by the National Council on Radiation Protection (NCRP). At Site 300, soils are analyzed for gamma-emitting radionuclides and beryllium. In 2011, uranium-238 concentrations in soils at Site 300 were below NCRP-recommended screening levels. Beryllium concentrations were within the ranges reported since sampling began in 1991.

Vegetation and Livermore Valley wine were sampled for tritium. In 2011, the median of concentrations in all off-site vegetation samples was below the lower limit of detection of the analytical method. The highest concentration of tritium in Livermore Valley wines sampled in 2011 was less than 0.49% of the drinking water standard.

LLNL's extensive network of thermoluminescent dosimeters measures the natural terrestrial and cosmogenic background; in 2011, as in recent years, no impact from LLNL operations was detected.

Biota

Through monitoring and compliance activities in 2011, LLNL avoided most impacts to special status species and enhanced some habitats. LLNL studies, preserves, and tries to improve the habitat of five species at Site 300 that are covered by the federal or California Endangered Species Acts—California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana draytonii*), Alameda whipsnake (*Masticophus lateralis euryxanthus*), valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), and the large-flowered fiddleneck (*Amsinckia grandiflora*)—as well as species that are rare and otherwise of special interest. At Site 300, LLNL monitors populations of birds and rare species of plants and also continues restoration activities for the four rare plant species known to occur at Site 300—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*, also known as *Blepharizonia plumosa* subsp *plumosa*), the diamond-petaled poppy (*Eschscholzia rhombipetala*), and the round-leaved filaree (*Erodium macrophyllum*).

LLNL took several actions to control invasive species in 2011. Measures taken at the Livermore site to control bullfrogs, which are a significant threat to California red-legged frogs, included dispatching adults and allowing part of Arroyo Las Positas to dry out in October 2011. As in previous years, Site 300's invasive species control efforts have been focused largely on dispatching feral pigs and animals that threaten red-legged frog habitat.

The 2011 radiological doses calculated for biota at the Livermore site or Site 300 were far below screening limits set by DOE, even though highly conservative assumptions maximized the potential effect of LLNL operations on biota.

Radiological Dose

Annual radiological doses at the Livermore site and Site 300 in 2011 were found to be well below the applicable standards for radiation protection of the public. Dose calculated to the site-wide maximally exposed individual (SW-MEI) for 2011 was 0.17 µSv (0.017 mrem) for the Livermore site and 9×10^{-7} µSv (9×10^{-8} mrem) at Site 300. These doses are well below the federal National Emissions Standards for Hazardous Air Pollutants of 100 µSv (10 mrem) and are significantly less than the doses from natural background radiation. There were no unplanned releases of radionuclides to the atmosphere at the Livermore site or at Site 300.

Groundwater Remediation

Groundwater at both the Livermore site and Site 300 is contaminated from historical operations; the contamination, for the most part, is confined to each site. Groundwater at both sites is undergoing cleanup under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Remediation activities removed contaminants from groundwater and soil vapor at both sites, and documentation and investigations continue to meet regulatory milestones.

At the Livermore site, contaminants include volatile organic compounds (VOCs), fuel hydrocarbons, metals, and tritium, but only the VOCs in groundwater and saturated and unsaturated soils need remediation. VOCs are the main contaminant found at the nine Site 300 Operable Units (OUs). In addition, nitrate, perchlorate, tritium, high explosives, depleted uranium, organosilicate oil, polychlorinated biphenyls, and dioxins, furans, and metals have been identified for remediation at one or more of the OUs.

In 2011, concentrations continued to decrease in most of the Livermore site VOC plumes due to active remediation and the removal of more than 55 kg of VOCs from both groundwater and soil vapor. Hydraulic containment along most portions of the western and southern boundaries of the site was fully established in 2011 and limited progress was made toward interior plume and source area clean up.

In 2011 at Site 300, perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 11 kg of VOCs. Each Site 300 OU has a different profile of contaminants, but overall, groundwater and soil vapor extraction and natural attenuation continue to reduce the mass of contaminants in the subsurface. Cleanup remedies have been fully implemented and are operational at eight of the nine OUs at Site 300. The CERCLA pathway for the last OU, Building 812, was negotiated with the regulatory agencies in 2011. All milestones were met (see Chapter 2).

Conclusion

LLNL's Environmental Management System provides a framework that integrates environmental protection into all work planning processes. The success of EMS is evidenced by LLNL's certification to the ISO 14001:2004 standard in 2009, coupled with a consistent record of good environmental stewardship and compliance. The combination of surveillance and effluent monitoring, source characterization, and dose assessment showed that the radiological dose to the hypothetical, maximally-exposed individual member of the public caused by LLNL operations in 2011 was substantially less than the dose from natural background. Potential dose to biota was well below DOE screening limits. LLNL demonstrated good compliance with permit conditions for releases to air and to water. Analytical results and evaluations of air and various waters potentially impacted by LLNL operations showed minimal contributions from LLNL operations. Remediation efforts at both the Livermore site and Site 300 further reduced concentrations of contaminants of concern in groundwater and soil vapor.

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1. Introduction

Lawrence Livermore National Laboratory (LLNL) is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). LLNL is managed and operated by Lawrence Livermore National Security, LLC (LLNS); the management team includes Bechtel National, University of California, Babcock and Wilcox, Washington Division of URS Corporation, and Battelle. NNSA awarded Contract Number DE-AC52-07NA27344 to LLNS to manage and operate LLNL.

As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory, with a staff of approximately 6,800, serves as a scientific resource to the U.S. government and a partner to industry and academia.

1.1 Location

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore site"; and a rural experimental test site, referred to as "Site 300," near Tracy, California. See **Figure 1-1**.

Figure 1-1. Location of the two LLNL sites—the Livermore site and Site 300.

The Livermore site is just east of Livermore, a city with a population of about 80,000 in Alameda County. The site occupies 1.3 mi^2, including the land that serves as a buffer zone around most of the site.

Within a 50-mi radius of the Livermore site are communities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 7.7 million people within 50 mi of the Laboratory, only about 10% are within 20 mi.

Site 300, LLNL's Experimental Test Site, is located in the Altamont Hills of the Diablo Range and straddles the San Joaquin and Alameda county line. The site is 12 mi east of the Livermore site and occupies 10.9 mi^2.

The city of Tracy, with a population of over 80,000, is approximately 6 mi to the northeast (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 7.1 million people who live within 50 mi of Site 300, 95% are more than 20 mi away in distant metropolitan areas such as Oakland, San Jose, and Stockton.

1.2 Meteorology

Meteorological towers at both the Livermore site and Site 300 continuously gather data including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature. Mild, rainy winters and warm-to-hot, dry summers characterize the climate at both sites. For a detailed review of the climatology for LLNL, see Gouveia and Chapman (1989). A new 52-m meteorological tower was installed at Site 300 in 2007; this new tower and the old 8-m tower in use since 1979 provided simultaneous measurements during 2007 for continuity and to observe any differences between the two tower locations. The old tower was retired in early 2008.

Both wind and rainfall exhibit strong seasonal patterns. Wind patterns at both sites tend to be dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley during the warm season, increasing in intensity as the valley heats up. During the winter, the wind blows from the northeast more frequently as cold, dense air spills out of the San Joaquin Valley. Approximately 55% of the seasonal rain at both sites falls in January, February, and March and approximately 80% falls in the five months from November through March, with very little rain falling during the warmer months. For a detailed review of rainfall at LLNL, see Bowen (2007). The meteorological conditions at Site 300 are modified by higher elevation and more pronounced topological relief. The complex topography of the site strongly influences local wind and temperature patterns.

Temperature, rainfall, and wind speed data for the Livermore site and Site 300 towers during 2011 are summarized in **Table 1-1**. Annual wind data for the Livermore site and Site 300 are shown in **Figure 1-2**.

Table 1-1. Summary of temperature, rainfall, and wind speed data at the Livermore site and Site 300 during 2011.

	Livermore Site		Site 300	
Temperature	**°C**	**°F**	**°C**	**°F**
Mean daily maximum	20.9	69.6	20.1	68.1
Mean daily minimum	7.8	46.1	11.9	53.4
Average	13.8	56.9	15.6	60.2
High	37.3	99.1	37.0	98.6
Low	–3.8	25.1	-0.9	30.4
Rainfall	**cm**	**in.**	**cm**	**in.**
Total for 2011	25.2	9.9	23.1	9.11
Climatological normal[(a)]	34.8[(b)]	13.7[(b)]	27.3	10.7
Wind	**m/s**	**mph**	**m/s**	**mph**
Average speed	2.3	5.2	5.6	12.5
Peak gust speed	20.0	44.8	31.6	70.6

(a) Climatological normal is calculated for a 30-year period (e.g., 1981–2010).

(b) Based on the mean, 1981–2010 (Mean calculated every 10 years).

1.3 Topography

The Livermore site is located in the southeastern portion of the Livermore Valley, a prominent topographic and structural depression oriented east–west within the Diablo Range. The most prominent valley in the Diablo Range, the Livermore Valley is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 14 mi long and varies in width generally between 2.5 and 7 mi. The valley floor is at its highest elevation of 720 ft above sea level along the eastern margin near the Altamont Hills and dips gradually to 300 ft at the southwestern corner. The valley floor is covered primarily by alluvial and floodplain deposits consisting of gravels, sands, silts, and clays with an average thickness of about 325 ft. Ephemeral waterways flowing through the Livermore site include Arroyo Seco along the southwestern corner and Arroyo Las Positas along the eastern and northern perimeters.

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest–southeast trend and is separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation of Site 300 ranges from about 1740 ft above sea level at the northwestern corner of the site to approximately 490 ft in the southeastern portion. Corral Hollow Creek, an ephemeral stream that drains toward the San Joaquin Basin, runs along the southern and eastern boundaries of Site 300.

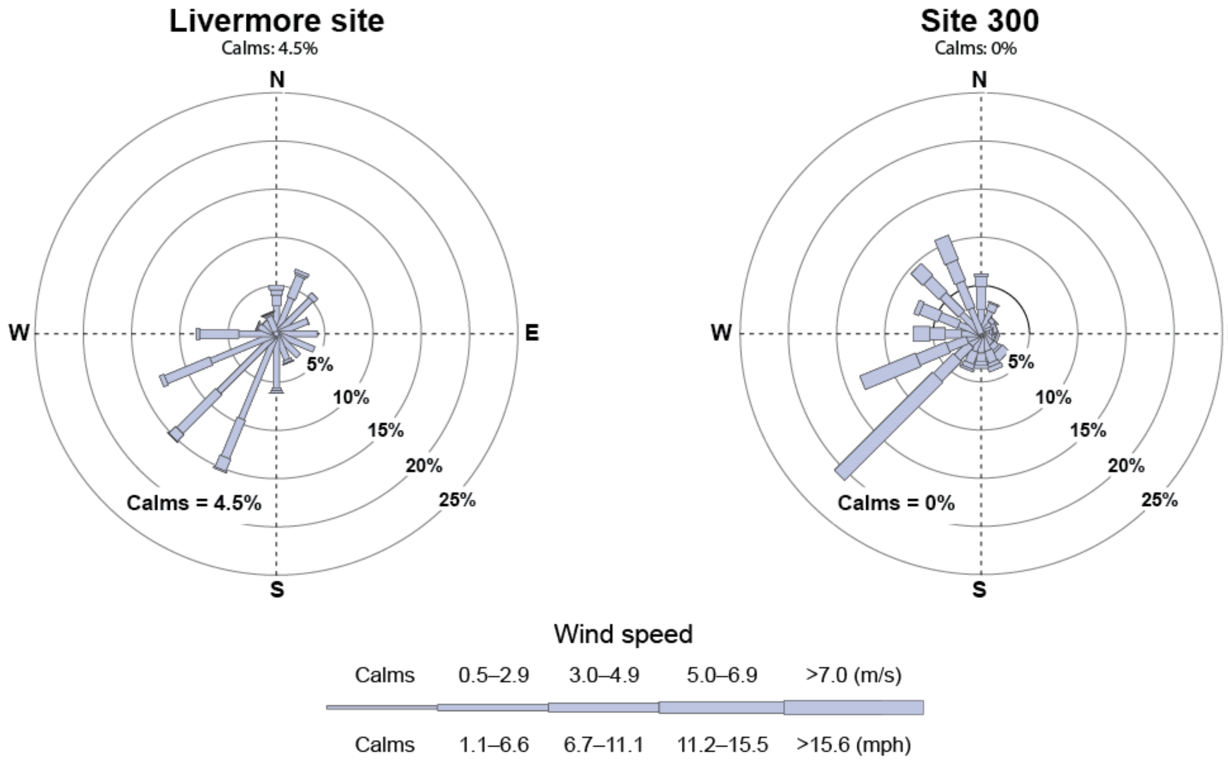

Figure 1-2. Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2011. The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes.

1.4 Hydrogeology

The Livermore Formation and overlying alluvial deposits contain the primary aquifers of the Livermore Valley groundwater basin. Natural recharge occurs primarily along the basin margins and arroyos during wet winters. In general, groundwater flows toward the central east–west axis of the valley and then westward through the central basin. Groundwater flow in the basin is primarily horizontal, although a significant vertical component probably exists along the basin margins under localized sources of recharge and near heavily used extraction or water production wells. Beneath the Livermore site, the depth to the water table varies from about 30 to 130 ft below the ground surface. See Thorpe et al. (1990) for a detailed discussion of Livermore site hydrogeology.

Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock primarily consists of interbedded sandstone, siltstone, and claystone. Groundwater occurs principally in the Neroly Formation upper and lower blue sandstone units and in the underlying Cierbo Formation. Significant groundwater is also locally present in permeable Quaternary alluvium valley fill and underlying decomposed bedrock, especially during wet winters. Minor quantities of groundwater are present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined groundwater separated from an underlying main body of groundwater by impermeable layers; normally these perched zones are laterally discontinuous. Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock or where permeable bedrock strata crop out along the canyon bottom because of structure or topography. The thick Neroly Formation lower blue sandstone unit, stratigraphically near the base of the formation, generally contains confined groundwater. Wells located in the southern part of Site 300 pump water from this aquifer, which is used for drinking and process supply. See Webster-Scholten et al. (1994) and Ferry et al. (2006) for a detailed discussion of Site 300 hydrogeology.

Contributing Authors

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2. Compliance Summary

LLNL activities comply with federal, state, and local environmental regulations, internal requirements, Executive Orders, and DOE Orders as specified in Contract DE-AC52-07NA27344. This chapter provides an overview of LLNL's compliance programs and activities during 2011.

2.1 Environmental Restoration and Waste Management

2.1.1 Comprehensive Environmental Response, Compensation and Liability Act

Ongoing remedial investigations and cleanup activities for legacy contamination of environmental media at LLNL fall under the jurisdiction of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Title I of the Superfund Amendments and Reauthorization Act (SARA). CERCLA is commonly referred to as the Superfund law.

CERCLA compliance activities for the Livermore site and Site 300 are summarized in **Sections 2.1.1.1** and **2.1.1.2**. Community relations activities conducted by DOE/LLNL are also part of these projects. See **Chapter 8** for more information on the activities and findings of the investigations.

2.1.1.1 Livermore Site Ground Water Project

The Livermore site came under CERCLA in 1987 when it was placed on the National Priorities List. The Livermore site Ground Water Project (GWP) complies with provisions specified in a Federal Facility Agreement (FFA) entered into by the U.S. Environmental Protection Agency (EPA), DOE, the California EPA's Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). As required by the FFA, the GWP addresses compliance issues by investigating potential contamination source areas (e.g., suspected old release sites, solvent-handling areas, leaking underground tank systems), monitoring water quality through an extensive network of wells, and remediating contaminated soil and groundwater. The primary soil and groundwater contaminants (constituents of concern) are common volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE). Background information on LLNL Livermore Site environmental characterization and restoration activities are presented in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al, 1990). The *LLNL Ground Water Project 2011 Annual Report* (Buscheck et al. 2012) presents the current status of clean up at the Livermore Site.

Regulatory Milestones. During 2011, the Remedial Project Managers signed a Consensus Statement for Environmental Restoration of the Livermore site that included 24 Federal Facility Agreement (FFA) milestones. The Livermore site environmental restoration project had 9 milestones scheduled for completion in calendar year 2011. The following deliverables were submitted to the regulatory agencies:

- Fourth Quarter 2010 Self Monitoring Report
- 2010 Annual Report
- First, Second, and Third Quarter 2011 Self Monitoring Report
- Draft, Draft Final, and Final Addendum to the Remedial Design Report No. 1 for Treatment Facility A (TFA)

The other regulatory milestones included the following:

- Receive regulatory comments on Draft Addendum to the Remedial Design Report No. 1 for TFA

All calendar year 2011 milestones were met.

Treatment Facilities. During 2011, the Livermore GWP maintained 29 groundwater and 9 soil vapor treatment facilities. The groundwater extraction wells and dual phase extraction wells extracted about 1,124 million L of groundwater during 2011. The dual-phase extraction wells and soil-vapor extraction wells together removed 1.5 million m^3 of soil vapor.

In 2011, the Livermore GWP treatment facilities removed about 94 kg of VOCs. Since remediation efforts began in 1989, more than 15.5 billion L of groundwater and approximately 13.8 million m^3 of soil vapor have been treated, removing about 2,970 kg of VOCs.

Community Relations. Livermore site community relations activities in 2011 included regular communication and meetings with Livermore senior leaders, local, regional, and national elected officials, as well as presentations to interest groups and other community organizations. Environmental-related activities include maintenance of information repositories and an administrative record; periodic meetings with members of Tri-Valley Communities Against a Radioactive Environment (Tri-Valley CAREs) and the organization's scientific advisor as part of the activities funded by an EPA Technical Assistance Grant (TAG); hosted tours of site environmental activities, including a Tri-Valley CAREs main site tour in November; and responses to public and news media inquiries. In addition, DOE/LLNL environmental documents, letters, and public notices are also maintained on a public website: http://www-envirinfo.llnl.gov.

2.1.1.2 Site 300 Environmental Restoration Project

Remedial activities are ongoing at Site 300, which became a CERCLA site in 1990 when it was placed on the National Priorities List. Remedial activities are overseen by the EPA, the Central Valley Regional Water Quality Control Board (CVRWQCB), and DTSC, under the authority of an FFA for the site. Contaminants of concern at Site 300 include VOCs (primarily TCE), high-explosive compounds, tritium, depleted uranium, silicone-based oils, nitrate, perchlorate, polychlorinated biphenyls, dioxins, furans, and metals. The contaminants present in environmental media vary within the different environmental restoration operable units (OUs) at the site. See Webster-Scholten (1994), and Ferry et al. (1999) for background information on LLNL environmental characterization and restoration activities at Site 300. The *LLNL Site 300 2011 Annual Compliance Monitoring Report* (Dibley et al. 2012) presents the current status of clean up at Site 300.

Regulatory Milestones. During 2011, DOE and the regulatory Remedial Project Managers signed a new FFA Schedule of Deliverables for Site 300 that included 87 FFA milestones. The Site 300 environmental restoration project had 25 milestones scheduled for completion in calendar year 2011. The following deliverables were submitted to the regulatory agencies:

- Draft, Draft Final, and Final Building 832 Five-Year Review
- Draft, Responses to regulatory comments, and Final Building 812 Gamma Surface Soil Survey Characterization Work Plan
- Annual 2010 Compliance Monitoring Report
- Draft, Responses to regulatory comments, and Final Building 812 Characterization Work Plan (Part 2)
- Draft, Draft Final, and Final General Services Area (GSA) Five-Year Review
- Draft, Responses to regulatory comments, and Final Building 812 Baseline Risk Assessment Work Plan
- Draft Building 834 Five-Year Review
- First Semester 2011 Compliance Monitoring Report (CMR)

The other regulatory milestones included:

- Initiate Building 812 Gamma Surface Soil Survey
- Regulatory comments due on Draft Building 832, Building 834, and GSA Five-Year Reviews
- Regulatory comments due on Draft Building 812 Baseline Risk Assessment Work Plan
- Regulatory comments due on Draft Building 812 Characterization Work Plan (Part 2)
- Regulatory comments due on Draft Building 812 Gamma Surface Soil Survey Characterization Work Plan

Treatment Facilities. During 2011, the Site 300 ERP operated 15 groundwater and 5 soil vapor treatment facilities at Site 300. The groundwater extraction wells and dual-phase extraction wells extracted about 40.3 million L of groundwater during 2011. The dual-phase extraction wells and soil-vapor extraction wells together removed 1.3 million m^3 of soil vapor.

In 2011, the Site 300 treatment facilities removed nearly 11 kg of VOCs, 0.14 kg of perchlorate, 1,600 kg of nitrate, 0.14 kg of the high explosive compound RDX, 0.00085 kg of silicone oils (TBOS/TKEBS), and 0.0048 kg of uranium. Since ground water remediation began in 1990, approximately 1,500 million L of ground water and 17.6 million m^3 soil vapor has been treated, resulting in removal of more than 560 kg of VOCs, 1.2 kg of perchlorate, 11,000 kg of nitrate, 1.6 kg of RDX, 9.5 kg of silicone oils, and 0.013 kg of uranium.

Remediation efforts in the Eastern GSA have successfully reduced concentrations of TCE and other VOCs in ground water to below their respective cleanup standards set in the GSA Record of Decision (ROD) (United States [U.S.] Department of Energy [DOE], 1997). The Eastern GSA ground water extraction and treatment system was shut off on February 15, 2007 with the U.S. EPA, RWQCB, and California DTSC approval. As required by the GSA ROD, ground water monitoring will be conducted for five years after shutdown to determine if VOC concentrations rise or “rebound” above cleanup standards. TCE concentrations were below the 5 µg/L cleanup standard for all Eastern GSA ground water samples collected during 2011. The status of the Eastern GSA cleanup and disposition of the treatment system and monitoring wells will be discussed with the regulatory agencies in 2012.

Community Relations. Site 300 community relations activities in 2011 included communication and meetings with neighbors and/or local, regional, and national interest groups and other community organizations; public presentations; maintenance of information repositories and an administrative record; tours of site environmental activities; and responses to public and news media inquiries. In addition, DOE/LLNL met with members of Tri-Valley CAREs and the organization’s scientific advisor as part of the activities funded by an EPA TAG. Community questions were also addressed via electronic mail, and project documents, letters, and public notices were posted on a public website: http://www-envirinfo.llnl.gov.

2.1.2 Emergency Planning and Community Right-to-Know Act and Toxics Release Inventory Report

Title III of SARA, known as the Emergency Planning and Community Right-to-Know Act (EPCRA), requires owners and operators of facilities who handle certain hazardous chemicals on site to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management, directs all federal agencies to comply with the requirements of the EPCRA, including SARA, Section 313, the Toxic Release Inventory (TRI) Program. EPCRA requirements and LLNL compliance are summarized in **Table 2-1.**

On June 23, 2011, LLNL submitted to DOE/NNSA the TRI Form R for mercury for the Livermore site detailing environmental release estimates for calendar year (TRI reporting year) 2010. Form R is used for reporting TRI chemical releases and includes information about waste management and waste minimization activities.

LLNL has reported lead release data for Site 300 since 2002. Over 99 percent of lead releases are associated with activities at the Site 300 Small Firearms Training Facility (SFTF). Data for the 2010 TRI Form R for lead at Site 300 was submitted to DOE/NNSA on June 23, 2011. Over the past several years, the lead releases have decreased due to increased use of frangible bullets.

Table 2-1 Compliance with EPCRA.

EPCRA section	Brief description of requirement	LLNL action
302	Notify State Emergency Response Commission (SERC) of presence of extremely hazardous substances.	Originally submitted 5/87.
303	Designate a facility representative to serve as emergency response coordinator.	Update submitted 6/20/11 to San Joaquin County for Site 300 and 6/20/11 to Alameda County for Livermore site.
304	Report releases of certain hazardous substances to SERC and Local Emergency Planning Committee (LEPC).	No EPCRA-listed extremely hazardous substances were released above reportable quantities in 2011.
311	Submit MSDSs or chemical list to SERC, LEPC, and Fire Department.	As per the California Emergency Management Agency, the EPCRA Section 311 requirement is satisfied by the EPCRA Section 312 submittal and the filing of necessary amendments within 30 days of handling a previously un-disclosed hazardous material subject to Section 312 inven-tory requirements.
312	Submit hazardous chemical inventory to local administering agency (county).	Submitted to San Joaquin and Alameda counties on 1/12/11 and 3/1/11, respectively.
313	Submit Form R to U.S. EPA and California EPA for toxic chemicals released above threshold levels.	Form R for lead for Site 300 and mercury for Livermore site submitted to DOE on 6/23/11; DOE forwarded it to U.S. EPA and California EPA 6/27/11.

2.1.3 Resource Conservation and Recovery Act and Related State Laws

The California Accidental Release Prevention (CalARP) Program is the combined federal and state program for the prevention of accidental release of regulated toxic and flammable substances. The goal of the combined program is to eliminate the need for two separate and distinct chemical risk management programs.

In June 2000, LLNL Site 300 submitted a risk-management plan (RMP) to the San Joaquin County, Office of Emergency Services (SJCOES). The RMP described the systems in place to prevent or mitigate the hazards associated with chlorine used in the LLNL Site 300 water treatment system. In accordance with the Final CalARP Program Regulations in the California Code of Regulations (Title 19, Division 2, Chapter 4.5), the LLNL Site 300 RMP was last updated in September 2010. It has been determined that the Site 300 water treatment system falls under CalARP Program Level 2. This plan is updated at least every five years.

LLNL submitted a revised Livermore site CalARP Level 1 RMP in December 2011. The Livermore site RMP includes lithium hydride, nitric acid and hydrofluoric acid.

2.1.4 Resource Conservation and Recovery Act and Related State Laws

The Resource Conservation and Recovery Act (RCRA) provides the framework at the federal level for regulating solid wastes, including wastes designated as hazardous. The California Hazardous Waste Control Law (HWCL) and California Code of Regulations (CCR) Title 22 set requirements for managing hazardous wastes and implementing RCRA in California. LLNL works with DTSC to comply with these regulations and obtain hazardous waste permits.

The hazardous waste management facilities at the Livermore site consist of permitted units in Area 612 and Building 625 plus Buildings 693, 695, and 696, which make up the Decontamination and Waste Treatment Facility (DWTF). Permitted waste-management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction). LLNL submitted the permit renewal application to DTSC in April 2009, followed by submittal of the human health risk assessment (HHRA) in December 2010 as part of the permit renewal process. DTSC approved the Building 419 Closure Plan in October 2009. Closure activities that were completed include sampling of the facility structure, abatement and demolition of the facility, and partial concrete, asphalt, and soil sampling around the facility's footprint. During 2010/2011, LLNL submitted several Class 1 permit modification requests to DTSC, all of which have been approved and implemented.

The hazardous waste management facilities at Site 300 consist of three operational RCRA-permitted facilities. The Explosives Waste Storage Facility (EWSF) and the Explosives Waste Treatment Facility (EWTF) are permitted to store and treat explosives waste, respectively. The Building 883 container storage area (CSA) is permitted to store routine facility-generated waste such as spent acids, bases, contaminated oil, and spent solvents. Site 300 has one post-closure permit for the RCRA-closed Building 829 High Explosives Burn Pits. LLNL is currently in the process of renewing the hazardous waste facility permit for EWSF, EWTF, and Building 883 CSA. The Building 829 permit will not expire until April 2, 2013. Transportation of hazardous or mixed waste over public roads occurs by DTSC-registered transporters, including LLNL.

2.1.5 California Medical Waste Management Act

All LLNL medical waste management operations are conducted in accordance with the California Medical Waste Management Act (CMWMA). The program is administered by the California Department of Public Health (DPH) and is enforced by the Alameda County Department of Environmental Health (ACDEH). LLNL's medical waste permit is renewed on an annual basis and covers medical waste generation and treatment activities for the six Biosafety Level (BSL) 2 facilities, and the BSL 3 facility at Building 368.

2.1.6 Radioactive Waste and Mixed Waste Management

LLNL manages radioactive waste and mixed waste in compliance with applicable sections of DOE Order 435.1, and the LLNL-developed *Radioactive Waste Management Basis for the Lawrence Livermore National Laboratory* (LLNL 2009), which summarizes radioactive waste management controls relating to waste generators and treatment and storage facilities. Additional information on the management of radioactive and mixed wastes, prepared by EFA, is available to LLNL employees in the *Environment, Safety and Health (ES&H) Manual.* LLNL does not release to the public any property with residual radioactivity above the limits specified in DOE Order 458.1. Excess property of this type is either transferred to other DOE facilities for reuse or transferred to LLNL's Radioactive and Hazardous Waste Management Division for disposal.

2.1.7 Federal Facility Compliance Act

LLNL continues to work with DOE to maintain compliance with the Federal Facilities Compliance Act (FFCA) Site Treatment Plan (STP) for LLNL, which was signed in February 1997. LLNL completed 10 milestones during 2011. In addition, four milestones were determined to no longer be applicable and removed from the STP, and four waste streams were treated prior to milestones being established/enforceable.

An additional 141 m^3 of newly generated mixed waste was accepted into the approved storage facilities and added to the STP. LLNL removed approximately 165 m^3 of mixed waste from LLNL in 2011, reflecting an overall reduction of 24 m^3 of mixed waste being stored by LLNL.

Reports and certification letters were submitted to DOE as required. LLNL continued the use of available commercial treatment and disposal facilities that are permitted to accept LLNL mixed waste. These facilities provide LLNL greater flexibility in pursuing the goals and milestones set forth in the STP.

2.1.8 Toxic Substances Control Act

The Federal Toxic Substances Control Act (TSCA) and implementing regulations found in Title 40 of the Code of Federal Regulation, Parts 700–789 (40 CFR 700-789) govern the uses of newly developed chemical substances and TSCA-governed waste.

In 2011, LLNL did not generate, store or dispose of any TSCA-regulated PCB waste.

2.2 Air Quality and Protection

2.2.1 Clean Air Act

All activities at LLNL are evaluated to determine the need for air permits or equipment registrations. Air permits are obtained from the Bay Area Air Quality Management District (BAAQMD) for the Livermore site and from the San Joaquin Valley Air Pollution Control District (SJVAPCD) and/or BAAQMD for Site 300. The BAAQMD also administers a boiler registration program for natural gas fueled boilers with rated heat input capacities greater than 2 million British Thermal Units per hour (Btu/hr) and less than 10 million Btu/hr.

Both the BAAQMD and the SJVAPCD are overseen by the California Air Resources Board (CARB). CARB also oversees the statewide permitting for portable diesel fuel-driven equipment such as portable generators and portable air compressors. In addition, CARB presides over the state-wide registration of in-use off-road diesel vehicles, such as diesel powered forklifts, loaders, backhoes, graders, and cranes.

In 2011, LLNL operated 180 permitted air-pollutant emission sources at the Livermore site and 36 permitted air-pollutant emission sources at Site 300. In addition, the Livermore site continues to maintain a Synthetic Minor Operating Permit (SMOP), which was initially issued by the BAAQMD in 2002 and revised in 2009, to ensure the Livermore site does not emit regulated air pollutants in excess of federal Clean Air Act (CAA) Title V limits. As such, LLNL is able to demonstrate that it does not have any major sources of air pollutant emissions per 40 CFR 70.2. In 2011, LLNL also maintained the registrations for 38 natural gas boilers with the BAAQMD and continued the registrations for 79 in-use off-road diesel vehicles with CARB.

Under the authority of California Assembly Bill 32 (AB32), the State of California has adopted several new regulations regarding emissions of greenhouse gases (GHG). In 2011, California required the mandatory reporting of stationary-source air emissions from combustion of natural gas that exceeded 25,000 metric tons per year of CO_2 equivalent emissions. For the previous three mandatory reporting years (CY2009, CY2010, and CY2011), the Livermore site has been slightly below the reporting threshold. LLNL continues to implement reductions and controls that should reduce CO_2 emissions in future years. LLNL is replacing diesel engines, boilers and hot water heaters on a continuing basis, and the new equipment is more efficient than the replaced equipment, in terms of fuel use and air emissions, such as CO_2. LLNL has been working with Johnson Controls to improve boiler control systems, which is reducing fuel usage and CO_2 emissions. LLNL Site 300 emissions of CO_2 are much lower than Livermore site emissions, and there is no natural gas service at Site 300 that would generate CO_2 emissions.

Also under the authority of AB32, California has adopted special regulations pertaining to sulfur hexafluoride (SF_6), because of its high GHG potential. In CY2011, LLNL was required to submit an annual report to CARB describing the research uses of SF_6 and the measures taken to control the SF_6 emissions from such research activities, and was required to keep records on the amounts of SF_6 contained in and used for electrical switchgear. The reduction of greenhouse gases has been further encouraged by Executive Order 13514, which establishes an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal agencies.

In addition, the federal EPA has a mandatory reporting regulation for stationary-emission sources, similar to California's regulation. LLNL is currently below the reporting threshold for EPA mandatory reporting at both the Livermore site and Site 300.

2.2.2 National Emission Standards for Hazardous Air Pollutants, Radionuclides

To demonstrate compliance with 40 CFR Part 61, Subpart H (National Emission Standards for Hazardous Air Pollutants [NESHAPs] for radiological emissions from DOE facilities), LLNL monitors certain air-release points and evaluates the maximum possible dose to the public. The *LLNL NESHAPs 2011 Annual Report* (Wilson 2012), submitted to EPA, reported that the estimated maximum radiological doses that could have been received by a member of the public in 2011 were 0.17 µSv (0.017 mrem) for the Livermore site and 0.0000009 µSv (0.00000009 mrem) for Site 300. The totals are well below the 100 µSv/y (10 mrem/y) dose limits defined by the NESHAPs regulations.

2.3 Water Quality and Protection

LLNL complies with requirements of the federal Clean Water Act (CWA), Porter-Cologne Water Quality Control Act, and Safe Drinking Water Act (SDWA); the California Aboveground

Petroleum Storage Act, Water Code, and Health and Safety Code; and City of Livermore ordinances, by complying with regulations and obtaining permits issued by several agencies whose mission is to protect water quality.

LLNL complies with the requirements of National Pollutant Discharge Elimination System (NPDES) and Waste Discharge Requirement (WDR) permits, and Water Quality Certifications issued by Regional Water Quality Control Boards (RWQCBs) and the State Water Resources Control Board (SWRCB) for discharges to waters of the U.S. and waters of the State. Discharges to the City of Livermore's sanitary sewer system are governed by permits issued by the Water Resources Division (WRD). The SDWA requires that LLNL register Class V injection wells with EPA, and LLNL obtains permits from the Army Corps of Engineers (ACOE) for work in wetlands and waters of the U.S.

The CWA and California Aboveground Petroleum Storage Act require LLNL to have and implement Spill Prevention Control and Countermeasure (SPCC) plans for aboveground, oil-containing containers. The ACDEH and the San Joaquin County Environmental Health Department (SJCEHD) also issue permits for operating underground storage tanks containing hazardous materials or hazardous waste (see **Table 2-2**). LLNL's permitted underground storage tanks, for which permits are required, contain diesel fuel, gasoline, and used oil; aboveground storage tanks, for which permits are not required, contain fuel, insulating oil, and process wastewater.

2.4 Other Environmental Statutes

2.4.1 National Environmental Policy Act and Floodplains and Wetland Assessments

The National Environmental Policy Act (NEPA) of 1969 is the U.S. government's basic environmental charter. When considering a proposed project or action at LLNL, DOE/NNSA must (1) consider how the action would affect the environment and (2) make certain that environmental information is available to public officials and citizens before decisions are made and actions are taken. The results of the evaluations and notice requirements are met through publication of "NEPA documents," such as environmental impact statements (EISs) and environmental assessments (EAs) under DOE NEPA Implementing Procedures in 10 CFR 1021.

In 2005, DOE/NNSA completed the *Final Site-Wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (2005 SWEIS) (U.S. DOE/NNSA 2005). In 2011, DOE/NNSA prepared a Supplement Analysis (DOE/EIS-0348-SA-03) of the 2005 SWEIS to consider whether the 2005 SWEIS should be supplemented, a new environmental impact statement (EIS) should be prepared, or no further NEPA documentation is required (U.S. DOE/NNSA 2011). The SA examined changes in programs, projects, or operations since the 2005 SWEIS was prepared; new and modified plans, projects, and operations for the period from 2010 to 2015; as well as new information that was not available for consideration when the 2005 SWEIS was prepared. The SA process involved an extensive public outreach campaign, including a 45-day public comment period. The SA concluded that a supplement to the 2005 SWEIS or a new SWEIS is not needed, and therefore, no further NEPA documentation is needed for the new and modified projects and modifications in site operations considered in the SA. The 2011 SA to the SWEIS and the 2005 SWEIS are available on the web at http://www-envirinfo.llnl.gov.

In 2011, no other EISs, or EAs were completed. A Categorical Exclusion under DOE NEPA Regulations (10 CFR 1021) was completed for Building 850 Mitigation Pond (Pool BC) at Site 300 (ESH-EFA-NEPA-11-1178). There were no proposed actions at LLNL that required separate DOE floodplain or wetlands assessments under DOE regulations in 10 CFR Part 1022.

2.4.2 National Historic Preservation Act

The National Historic Preservation Act (NHPA) provides for the protection and preservation of historic properties that are significant in the nation's history. LLNL resources subject to NHPA consideration range from prehistoric archeological sites to remnants of LLNL's own history of scientific and technological endeavors. The responsibility to comply with the provisions of the NHPA rests with DOE/NNSA as the lead federal agency in this undertaking. LLNL supports the agency's NHPA responsibilities with direction from DOE/NNSA.

In 2005, in consultation with DOE/NNSA, the California State Historic Preservation Officer (SHPO) formally determined that five archaeological resources, five individual buildings, two historic districts (encompassing 13 additional individual buildings), and selected objects in another building at LLNL are eligible for listing in the National Register of Historic Places (NRHP). To assist DOE and SHPO in developing an agreement as to how to manage the NRHP-eligible properties, LLNL prepared a draft Programmatic Agreement (PA), which includes a draft Archaeological Resources Treatment Plan and a draft Historic Buildings Treatment Plan as attachments. These plans describe specific resource management and treatment strategies that DOE/NNSA, in cooperation with LLNL, could implement to ensure that NRHP-eligible historic properties under LLNL's jurisdiction are managed and maintained in a way that considers the preservation of historic values in compliance with Sections 106 and 110 of the NHPA. As of the end of 2011, the draft PA and treatment plans were being reviewed by SHPO.

In 2011, LLNL also completed a five-year reevaluation of the historic building assessment originally completed in 2004 (published in 2007). The five-year cycle of reevaluations for NRHP-eligibility are a requirement of the draft Programmatic Agreement. Final recommendations from the re-evaluation include allowing two of the five existing NRHP-eligible buildings to be removed from the inventory of historic properties and allowed to evolve as needed to meet LLNL's scientific mission requirements. These two buildings have been preserved via recordation, a mitigation option identified in the draft Historic Buildings Treatment Plan. One building was recommended for addition to the inventory of NRHP-eligible buildings. The Final report was sent to LSO on November 29, 2011.

2.4.3 Antiquities Act of 1906

Provisions of the Antiquities Act provide for protection of items of antiquities (i.e., archaeological sites and paleontological remains). The five NRHP-eligible archaeological sites noted in Section 2.4.2 are protected under the Antiquities Act. No paleontological remains subject to the provisions of the Antiquities Act were identified in 2011.

2.4.4 Endangered Species Act and Sensitive Natural Resources

LLNL meets the requirements of the federal and state Endangered Species Act (ESA), the Eagle Protection Act, the Migratory Bird Treaty Act, and other applicable regulations as they pertain to endangered species, threatened species, and other special-status species (including their habitats) and designated critical habitats that exist at the LLNL sites. The following list highlights 2011 compliance activities:

- DOE/NNSA requested formal consultation with the U.S. Fish and Wildlife Service (FWS) on July 29, 2011 for two Livermore site projects [the East Campus Site Improvements (ECSI) project and the installation of an access road near Treatment Facility B (TFB)] through the submittal of a Biological Assessment (BA). On October 18, 2011, the FWS issued a Biological Opinion (BO) and Incidental Take Statement for these projects.
- On August 18, 2011, DOE/NNSA requested formal consultation for a soil characterization project in the area surrounding Building 812 at Site 300 that will be completed as part of the CERCLA process. On December 15, 2011, the FWS issued a BO and Incidental Take Statement for this project.

2.4.5 Federal Insecticide, Fungicide, and Rodenticide Act

LLNL complies with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which provides federal control of the distribution, sale, and use of pesticides and requires that commercial users of pesticides are certified pesticide applicators. The California Department of Pesticide Regulation (DPR) has enforcement responsibility for FIFRA in California; DPR has in turn given enforcement responsibility to county departments of agriculture. All pesticides at LLNL are applied, stored, and used in compliance with FIFRA and other California, Alameda County, and San Joaquin County regulations governing the use of pesticides. The staff of the Landscape and Pest Management Shop at the Livermore site and the Laborer/Gardener Shop at Site 300 includes certified pesticide applicators. These shops ensure that all storage and use of pesticides at LLNL is in accordance with applicable regulations. LLNL also reviews pesticide applications to ensure they do not result in impacts to water quality or special status species.

2.5 Environmental Permits, Inspections, and Occurrences

LLNL's various missions require a variety of permits. **Table 2-2** is a summary of active permits in 2011 at the Livermore site and Site 300. The External agencies that issue the permits may also perform inspections required by the permits. **Table 2-3** lists environmental inspections and findings from both LLNL sites in 2011.

Notification of environmental occurrences is required under a number of environmental laws and regulations as well as DOE Order 232.2. **Table 2-4** provides a list of environmental incidents reportable under DOE Order 232.2.

Table 2-2. Active permits in 2011 at the Livermore site and Site 300.

Type of permit	Livermore site[a]	Site 300[a]
Hazardous waste	EPA ID No. CA2890012584. Hazardous Waste Facility Permit Number 99-NC-006 (RCRA Part B permit)—to operate hazardous waste management facilities. Registered Hazardous Waste Hauler authorized to transport wastes from Site 300 to the Livermore site. Permit number 1351. Conditionally Exempt Specified Wastestream Permit to mix resin in Unit CE231-1. Conditional Authorization Permit to operate sludge dewatering unit in Building 322A. PT0305819. RCRA large-quantity hazardous waste generation facility——ACDEH.	EPA ID No. CA2890090002. Hazardous Waste Facility Permit—CSA (Building 883) and EWSF. Hazardous Waste Facility Permit—EWTF. Hazardous Waste Facility Post-Closure Permit—Building 829 High Explosives Open Burn Treatment Facility. PT0010318. Hazardous waste generation facility—SJCEHD.
Medical waste	ACDEH issued a permit that covers medical waste generation and treatment activities for the six BSL 2 facilities, and the BSL 3 facility at Building 368.	NA
Air	BAAQMD issued 165 permits for operation of various types of equipment. BAAQMD issued a revision to the SMOP in 2009, which was initially issued in 2002 to ensure the NOx and HAPs emissions from the site do not exceed federal Clean Air Act Title V emission limits. BAAQMD issued 10 Asbestos Removal and Demolition Permits. CARB issued 5 permits for the operation of portable diesel air compressors and generators.	SJVAPCD issued 34 permits for operation of various types of equipment. SJVAPCD approved a Prescribed Burn Plan for the burning of 2,176.5 acres of grassland. BAAQMD issued 1 permit for the operation of an emergency diesel generator. CARB issued 1 permit for the operation of portable diesel air compressor BAAQMD approved a Prescribed Burn Plan for the burning of 139.1 acres of grassland.
Storage tanks	Seven operating permits covering 10 underground petroleum storage tanks.	One operating permit covering three underground petroleum storage tanks assigned individual permit numbers.
Sanitary sewer	Discharge Permit 1250[b] for discharges of wastewater to the sanitary sewer. Permit 1510G for discharges of groundwater from CERCLA restoration activities.	WDR R5-2008-0148 for operation of sewage evaporation pond.

Table 2-2. (cont.) Active permits in 2011 at the Livermore site and Site 300.

Type of permit	Livermore site[(a)]	Site 300[(a)]
Water	WDR No. 88-075 for discharges of treated groundwater from Treatment Facility A to recharge basin.[(c)] NPDES Permit No. CA0030023 for discharges of storm water associated with industrial activities and low-threat non-storm water discharges to surface waters. NPDES General Permit No. CAS000002,) for discharges of storm water associated with construction activities affecting 0.4 hectares (1 acre) or more. FFA for groundwater investigation/remediation.	WDR No. 93-100 for post-closure monitoring requirements for two Class I landfills. WDR R5-2008-0148 for discharges to percolation pits and septic systems. NPDES General Permit No. CAS000001 for discharge of storm water associated with industrial activities. NPDES Regional General Permit No. CAG995001 for large volume discharges from the drinking water system. FFA for groundwater investigation/remediation. 32 registered Class V injection wells.

Note: See the **Acronyms and Glossary** section for acronym definitions.

a) Numbers of permits are based on actual permitted units or activities maintained and/or renewed by LLNL during 2011.

b) Permit 1250 includes some wastewater generated at Site 300 and discharged at the Livermore site.

c) Recharge basin referenced in WDR Order No. 88-075 is located south of East Avenue within Sandia National Laboratories/California boundaries. The discharge no longer occurs; however, the agency has not rescinded the permit.

Table 2-3. Inspections of Livermore site and Site 300 by external agencies in 2011.

Medium	Description	Agency	Date	Finding
Waste	Hazardous waste facilities Compliance Evaluation Inspection (CEI)	DTSC	04/28/11 & 05/02/11	Two violations related to B419 Closure Project. DTSC issued a final CEI report on 8/12/11, which identified a major violation as failure to collect and contain contaminated rainwater and failure to implement the Contingency Plan. A second violation was classified as “Non-minor” was for failure to include information on the manifest showing hazardous waste from B419 was transported by rail.
			The 2012 CEI was conducted on 11/30/11 & 12/05/11	No violations.
	Medical Waste Inspection	ACDEH	05/12/11	No violations
	Waste Tire Inspection	ACDEH	09/22/11	No violations
		BAAQMD	01/21/11 02/04/11 05/15/11 05/26/11 07/13/11 10/27/11 11/30/11 12/14/11	No violations
Air	Air pollutant emission sources	BAAQMD	01/21/11 02/04/11 05/15/11 05/26/11 07/13/11 10/27/11 11/30/11 12/14/11	No violations
	Synthetic Minor Operating Permit (SMOP)	BAAQMD	01/21/11 05/26/11 07/13/11 08/25/11 10/27/11 11/30/11	No violations

Table 2-3. (cont.) Inspections of Livermore site and Site 300 by external agencies in 2011.

Medium	Description	Agency	Date	Finding
Sanitary sewer	Categorical sampling/inspection Building 153 and Building 321C.	WRD	10/03/11	No violations
	Annual compliance sampling at the Sewer Monitoring Complex	WRD	10/04/11	No violations
	Building 490—Magnetorheological Facility	WRD	10/20/11	No violations
	Building 381—National Ignition Facility (NIF) Target Fabrication Laboratory	WRD	10/20/11	No violations
	Café grease interceptor inspections, Buildings 123 and 471	WRD	10/04/11	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits	ACDEH	08/10–11/11	One violation. 1) Sump for B111 UST failed its hydrostatic leak test. Leak was repaired; sump was retested and passed which resulted to no further action being required.
			09/13/11 & 09/20–21/11	Two violations. 1) Light bulb in alarm panel for B365 UST failed to light when tested. Bulb was immediately replaced which resulted to no further action being required. 2) Two vacuum sensors for the E85 UST failed to detect a vacuum loss when tested. New sensors were installed, tested, and certified which resulted to no further action being required.
Pesticides	Pest control records inspections	ACCDA	01/25/2011	No violations
Waste				
	Hazardous waste generator areas: B80l, rooms 116 photo process and 100 machine shop, B806, room 119, B823 photo process, B899 armory, B883 waste accumulation area, B874 machining, B879 fleet management, B875 heavy equipment, B872 paint shop (activity shut down), B873 pipe, weld, electric shop.	San Joaquin County Environmental Health Department, Certified Unified Program Agency (CUPA)	06/20/11	Violation 1: Failed to check the hazardous waste characteristic “toxic” box on a hazardous waste label. The violation was corrected upon discovery by checking the “toxic” box. Violation 2: Failed to update the name of one of the Emergency Coordinators in the B883 Waste Accumulation Area Contingency Plan. The violation was corrected by replacing Rex Beach with Craig Wuest in the Contingency Plan. The violation response letter and Return to Compliance Certification was submitted to San Joaquin County CUPA on July 19, 2011.
Air	Air pollutant emission sources	SJVAPCD	04/06/11 09/12/11	No violations
Water	Permitted operations	CVRWQCB	04/07/11	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits	SJCEHD	08/02–08/03/11	No violations

Note: See the **Acronyms and Glossary** section for acronym definitions.

Table 2-4. Environmental Occurrences reported under the Occurrence Reporting System in 2011.

Date[(a)]	Occurrence category/ group	Description
6/1/11	Significance Category SC4 Occurrence under Group 9(2) OR 2011-0030	On May 17, 2011, LLNL shipped a load of Low-Level Radioactive Waste to Energy Solutions, LLC, in Clive, Utah. The shipment was received by Energy Solutions on May 19, 2011. The Division of Radiation Control in the Utah Department of Environmental Quality reviewed the manifest and issued a Notice of Deficiency (NOD) on June 1, 2011, for failure to include the number "7" on the waste manifest in field 11 of the document where the hazard class for the waste is identified.
6/20/11	Significance Category SC4 Occurrence under Group 9(2) OR 2011-0032	LLNL Site 300 received a Notice of Violation (NOV) from the San Joaquin County Hazardous Waste Program inspection for two minor violations: Violation 1: Failure to check the hazardous waste characteristic “toxic” box on a hazardous waste label. The violation was corrected upon discovery by checking the “toxic” box. Violation 2: Failure to update the name of one Emergency Coordinator in the B883 Waste Accumulation Area Contingency Plan. The Emergency Coordinator information in the Contingency Plan was updated and the violation response letter and Return to Compliance Certification was submitted to San Joaquin County CUPA on July 19, 2011.
8/15/11	Significance Category SC4 Occurrence under Group 9(2) OR 2011-0043	LLNL received a Notice of Violation (NOV) from the California Department of Toxic Substances Control (DTSC) following a Compliance Evaluation Inspection (CEI) that cited the following two violations related to the Building 419 Decontamination and Demolition Project: Class 1 violation - On June 28, 2011, LLNL did not capture and contain rainwater that fell on the exposed Building 419 slab during an unseasonable rainstorm. The Closure Plan requires that rainwater is captured and sampled prior to release. This was categorized as a Major Violation. Class 1 violation - In reviewing manifests associated with shipping waste from demolition of the Building 419 structure in December 2010, DTSC noted that information regarding a subcontracted hauler was not fully identified on the manifest as required by regulations.
9/21/11	Significance Category SC4 Occurrence under Group 9(2) OR 2011-0049	LLNL received a Notice of Violation (NOV) from the Alameda County Department of Environmental Health (ACDEH) -Certified Unified Program Agency (CUPA) following an annual inspection of Underground Storage Tank (UST) monitoring systems. A minor violation was received during the inspection of the Building 365 UST. During the inspection, the external visual alarm was not functioning. The malfunctioning light bulb was replaced during the inspection and the violation was corrected.
9/22/11	Significance Category SC4 Occurrence under Group 9(2) OR 2011-0051	LLNL received a Notice of Violation (NOV) from the Alameda County Department of Environmental Health (ACDEH) -Certified Unified Program Agency (CUPA) following an annual inspection of Underground Storage Tank (UST) monitoring systems. A minor violation was received during the inspection of the E-85 UST at Building 611. During the inspection, monitoring system sensors (numbers S2 and S3) failed to detect a vacuum loss as required. This was noted as a minor violation. The two sensors were replaced so that the system would function as required.

(a) Date the occurrence was categorized, not discovered.

Contributing Authors

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3. Environmental Program Information

Jennifer Doman, Heather Ottaway, Kelly Heidecker, Alison Terrill

LLNL is committed to enhancing its environmental stewardship and to reducing any impacts its operations may have on the environment. This chapter describes LLNL's Environmental Management System (EMS) and Pollution Prevention/Sustainability Program (P2S).

3.1 Environmental Management System

LLNL continues to mature and enhance its EMS through systematic process improvements and increased focus on establishing specific environmental performance objectives and targets contained in Environmental Management Plans (EMPs). Progress toward goals is regularly measured and reported to senior management and other interested parties through a variety of means including regular senior management reports and the yearly update of the Site-wide Annual Environmental Report (SAER). The Laboratory's EMS has successfully maintained its International Organization for Standardization (ISO) 14001 registration since 2009, and is regularly audited by NSF International Strategic Registrations, an internationally recognized ISO auditor, for continued conformance and certification.

3.1.1 Environmental Management Plans

EMPs are designed and implemented to address the Laboratory's most significant environmental aspects and achieve environmental objectives and targets. EMPs are continually updated to incorporate new initiatives and effectively demonstrate LLNL's commitment to continuous improvement. During FY2010-2011, eight EMPs were implemented. **Table 3-1** lists the eight *EMPs along with their related DOE sustainability goals, progress towards those goals as of* November 2011, and LLNL's noteworthy contributions towards achievement of those goals.

Table 3-1. Environmental Management Plans (EMPs) and Related DOE Sustainability Goals.

Title	Significant Aspect(s) Addressed	EMP Objective(s)	Related DOE Sustainability Goals	Progress Towards DOE Sustainability Goals and Noteworthy EMP Contributions
Improving Environmentally Preferable Purchasing (EPP)	• Nonhazardous Materials Use • Municipal Waste Generation	Improve Environmentally Preferable Purchases at LLNL through benchmarking with other sites and identifying and implementing best purchasing practices	4501A Goal: Maximize the acquisition and use of environmentally preferable products	Progress: Electronic Product Environmental Assessment Tool (EPEAT) compliance increased from 69% to 93.6%; transitioned to use of green cleaning materials site-wide Noteworthy Accomplishments: • Outreach to Lab employees, with targeted training to Technical Release Representatives (TRRs) on Sustainable Acquisition and EPEAT goals and practices • Implemented new green cleaning program utilizing Green Seal garbage bags and non-hazardous cleaners
Municipal Waste Reduction	• Municipal Waste Generation	Optimize use of printer/copier supplies and reduce municipal waste through recycling	450.1A Goal #1: Reduce or eliminate the generation of waste through pollution prevention 450.1A Goal #5: recycling	Progress: Increased municipal landfill diversion rate to 74% Noteworthy Accomplishments: • Implemented alternative reuse/recycle options for several non-standard waste items (concrete rubble, lead shielding blocks, foam insulation panels, etc.) • Eliminated use of Styrofoam to-go containers in cafes
Greenhouse Gas Emissions Reductions	• Greenhouse Gas Emissions	Reduce LLNL greenhouse gas emissions through management of sulfur hexafluoride (SF6) and vehicle fleet	430.2b.1.b(10) Goal: Replacement of conventional vehicles with alternative fuel and hybrid vehicles EO13514 Goal: Support DOE goal to reduce greenhouse gas emissions	Progress: Reduced GHG emissions (Scope 1-2 >12%, Scope 3 ≈10%) Noteworthy Accomplishments: • Implemented boiler temperature set-back project • Developed SF6 Management Plan; funded SF6 reduction initiative in Center for Accelerator Mass Spectrometry (CAMS) (Building 190 [B190]) • Many of the accomplishments achieved in Energy Conservation and Fossil Fuel Consumption also contribute to the reduction of greenhouse gases

Table 3-1 (cont). Environmental Management Plans (EMP) and Related DOE Sustainability Goals

Title	Significant Aspect(s) Addressed	EMP Objective(s)	Related DOE Sustainability Goals	Progress Towards DOE Sustainability Goals
Energy Conservation	• Electrical Energy Use • Greenhouse Gas Emissions • Fossil Fuel Consumption	Meet or exceed DOE O 430.2B and EO 13514 energy conservation goals	430.2b Goal: 30% reduction in energy intensity by FY2015 from FY2003 baseline	Progress: Achieved 14.16% energy intensity reduction Noteworthy Accomplishments: • Continued programmable thermostat installation program (92 facilities by end of FY2011) • Implemented light-emitting diode (LED) street light conversion project (over 200 replaced by end of FY2011) • Installed automatic light shut-off capabilities in several facilities • Achieved Leadership in Energy and Environmental Design (LEED)-Silver certification for B451 • Received award for most (energy) efficient supercomputer from Green500 • Provided targeted training to TRRs on purchasing Energy Star appliances
Water Conservation	• Water Use	Meet or exceed Performance Evaluation Plan (PEP) 7.5.3, DOE O 430.2B and EO 13514 water conservation goals	430.2b Goal: 16% reduction in potable water use by FY2015 from FY2007 baseline	Progress: Achieved 15.52% water intensity reduction Noteworthy Accomplishments: • Installed Smart Irrigation Controllers in landscaped areas • Reused 100% of water associated with disinfecting and rinsing the pipeline used to transfer Hetch Hetchy water to Site 300 as dust control and/or as evaporation makeup water in the Site 300 sewage pond • Initiated project to survey and upgrade autoclaves to water (and energy) efficient models • Developed Newsline articles to inform employees of Lab and DOE water conservation goals
Fossil Fuel Consumption	• Fossil Fuel Consumption	Reduce government vehicle fossil fuel consumption, replacement of light duty fleet with alternative fueled vehicles, and promote alternative fuels usage	Optimization of alternative fuel, hybrid and plug-in electric vehicles when commercially available, and the expansion and maintenance of an alternative fuel infrastructure as it is economically feasible	Progress: Continued transition to hybrid fleet Noteworthy Accomplishments: • Continued Lab-wide initiative to swap out traditional vehicles for hybrids

Table 3-1 (cont). Environmental Management Plans (EMP) and Related DOE Sustainability Goals

Title	Significant Aspect(s) Addressed	EMP Objective(s)	Related DOE Sustainability Goals	Progress Towards DOE Sustainability Goals
Hazardous Materials Use and Hazardous Waste Generation	• Hazardous Materials Use • Hazardous Waste Generation	Achieve targeted and overall reductions in the use of hazardous materials (not to include radioactive or biological materials) at the Laboratory Reduce the generation of hazardous waste	450.1 Goal #2: Reduce or eliminate the acquisition, use and release of toxic and hazardous chemicals and materials EO 13423.2(e) Goal: Reduce the quantity of toxic and hazardous chemicals and materials acquired, used or disposed of	Progress: Reduction of high-risk legacy inventory; custodial chemical usage declined from 6,224 to 1,960 gal Noteworthy Accomplishments: • Reduced legacy inventory of alkali metals, peroxidizable solvents, corrosive gases and toxic gases • Replaced six milling machines thereby reducing oil consumption and extend life of coolants by six months
Radioactive Materials use	• Radioactive Materials Use	Reduce significantly the amount of radioactive materials on-site in accordance with PEP 7.3.1	450.1A Goal: Reduce or eliminate the acquisition, use and release of toxic and hazardous chemicals and materials	Progress: Achieved 90% reduction of nuclear material inventory Noteworthy Accomplishments: • Nuclear Material Inventory reduction was achieved under an accelerated timeframe

3.1.2 EMS Audits and Reviews

The Laboratory successfully completed two external independent audits of its ISO 14001 EMS program (April 11–14 and August 15–18) with recommendations from the auditor to continue LLNL's ISO 14001:2004 registration. These independent audits were conducted by NSF International Strategic Registrations and validated the Laboratory's solid commitment to environmental stewardship.

3.1.2.2 Internal Assessments and Reviews

In May 2011, a Senior Management Review of the EMS was conducted, reaffirming its commitment to the Lab's environmental policy and stewardship through the implementation of EMS.

In accordance with LLNL's EMS, the Laboratory's environmental compliance is regularly evaluated through reviews of internal assessments including Management Self Assessments (MSAs); Management Observations, Verifications and Inspections (MOVIs); regulatory inspections; internal and external monitoring and compliance reports; and facility walk-throughs and work-control assessments. As a result of these reviews, LLNL identifies specific practices and recommendations for corrective and preventive measures, demonstrating the Laboratory's commitment to environmental compliance.

3.2 Pollution Prevention/Sustainability Program

LLNL's P2S Program operates within the framework of the Integrated Safety Management System (ISMS) and EMS and in accordance with applicable laws, regulations, and DOE orders as required by contract. It encompasses stewardship and maintenance, waste stream analysis, reporting of waste generation and P2S accomplishments, and fostering of P2S awareness through presentations, articles, and events. The P2S Program supports institutional and directorate P2S activities via environmental teams and includes implementation and facilitation of source reduction and/or reclamation, recycling, and reuse programs for hazardous and nonhazardous waste; facilitation of sustainable acquisition; and preparation of P2S opportunity assessments.

The P2S Program at LLNL strives to systematically reduce all types of waste generated and eliminate or minimize pollutant releases to all environmental media from all aspects of the operations at the Livermore site and Site 300. These efforts help protect public health and the environment by reducing or eliminating waste, improving resource usage, and reducing inventories and releases of hazardous chemicals. These efforts also benefit LLNL by reducing compliance costs and minimizing the potential for civil and criminal liabilities under environmental laws. In accordance with EPA guidelines and DOE policy, the P2S Program uses a hierarchical approach to waste reduction (i.e., source elimination or reduction, material substitution, reuse and recycling, and lastly treatment and disposal), which is applied, where feasible, to all types of waste. Waste generation is tracked using RHWM's HazTrack database. By reviewing the information in this database, program managers and P2S Program staff can monitor and analyze waste streams to determine cost-effective improvements to LLNL operations.

3.2.1 Routine Hazardous, Transuranic, and Radioactive Waste

Routine waste listed in **Tables 3-2 and 3-3** includes waste from ongoing operations produced by any type of production, analysis, and research and development taking place at LLNL. The increase in routine low-level waste in FY 2011 is attributed to radiological control protocols implemented at the National Ignition Facility following the introduction of tritiated targets. The slight increases in routine mixed waste and routine hazardous waste are attributed to normal variation in waste generation.

Table 3-2. Routine hazardous waste at LLNL, FY 2009–2011.

Waste category	FY 2009	FY 2010	FY 2011
Routine hazardous waste generated (MT)	159	116	143

Table 3-3. Routine transuranic and radioactive waste at LLNL, FY 2009–2011.

Waste category	FY 2009	FY 2010	FY 2011
Routine low-level waste generated (m^3)	203.5	211.2	678.3
Routine mixed waste generated (m^3)	24.6	21.0	27.4
Routine TRU/mixed TRU waste generated (m^3)	9.4	0.6	0.4

3.2.2 Diverted Waste

LLNL maintains an active waste-diversion program, encouraging recycling and reuse of both routine and non-routine waste. In 2010, DOE changed the annual reporting requirements for waste diversion in response to Executive Order 13514, issued October 5, 2009. This change required separate accounting for construction/demolition and municipal solid wastes and is reflected in the tables below.

3.2.2.1 Municipal Solid Waste

Together, the Livermore site and Site 300 generated 3,159 MT of routine nonhazardous solid waste in FY 2011. This volume includes diverted waste (e.g., material diverted through recycling and reuse programs) and landfill waste.

Both sites combined diverted a total 2,261 MT of routine nonhazardous waste in FY 2011, which represents a diversion rate of 72%. The diverted routine nonhazardous waste includes waste recycled by RHWM and materials diverted through the surplus sales program. In 2011, LLNL also diverted recyclable material, food scraps, and other compostable waste through a pilot comingled recycling and composting program implemented in May 2011 at select buildings throughout the Livermore site. The portion of routine nonhazardous waste sent to landfill was 898 MT. See **Table 3-4**.

In 2011, LLNL transferred or donated for reuse 55 laptops computers and recycled 7,509 computers, monitors, and laptops, which were managed as universal waste.

LLNL recycled 40 MT of large and small batteries, which were also managed as universal waste.

Table 3-4. Routine municipal waste in FY 2011, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2011 (MT)
Diverted	Baled paper	67
	Corrugated cardboard	105
	Cooking grease	20
	Mixed metals	999
	Office paper	165
	Tires and scrap	8
	Toner cartridges	9
	Greenwaste (chips, compost, mulch)	555
	Wood	262
	Comingled recycling	32
	Compost (food scraps, paper towels, food containers)	39
	TOTAL diverted	**2,261**
Landfill	Compacted (landfill)	898
	TOTAL landfill	**898**
TOTAL routine nonhazardous waste		**3,159**

3.2.2.2 Construction and Demolition (C&D) Waste

C&D wastes include excavated soils, wastes and metals from construction, decontamination and demolition activities. The Livermore site and Site 300 generated a total of 5821 MT of waste related to construction and demolition activities in FY 2011.

In FY 2011, the two sites combined diverted 5,015 MT of nonroutine nonhazardous solid waste through reuse or recycling, which represents a diversion rate of 86%. Diverted C&D waste includes soil reused either on site for other projects or as cover soil at Class II landfills. See **Table 3-5**.

Table 3-5. Construction and Demolition waste in FY 2011, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2011 (MT)
Diverted	Class II cover soil (reused at landfill)	2,529
	Class II concrete (reused at landfill)	2,318
	Scrap metals (recycled)	168
	TOTAL diverted	**5,015**
Landfill	Construction and demolition (non-compacted landfill)	806
	TOTAL landfill	**806**
	TOTAL non-routine non-hazardous waste	**5,821**

3.2.3 Sustainable Acquisition

LLNL has a comprehensive Sustainable Acquisition (formally Environmentally Preferable Purchasing) program that includes preferential purchasing of recycled content and biobased products. In 2011, the Sustainable Acquisition program continued to include a preference for Electronic Product Environmental Assessment Tool (EPEAT) registered products. 94% of all desktop electronics purchases in FY 2011 were EPEAT Silver or EPEAT Gold, indicating that the products meet or exceed the Institute of Electrical and Electronics Engineers (IEEE) 1680-2006 environmental performance standard for electronic products. Additional sustainable acquisition highlights can be found in the LLNL FY12 Site Sustainability Plan https://facilities.llnl.gov/documents/LLNL_FY12_SSP.pdf.

3.2.4 Pollution Prevention/Sustainability Activities

3.2.4.1 Environmental Stewardship Accomplishments and Awards

Each year, the P2S Program submits nominations for the NNSA environmental awards program, which recognizes exemplary performance in integrating environmental stewardship practices to reduce risk, protect natural resources, and enhance site operations. P2S also submits nominations for various other awards recognizing excellence in P2S projects. In 2011, LLNL received three NNSA Environmental Stewardship awards, two DOE EStar awards, a California Department of Resources Recycling and Recovery (CalRecycle) Waste Reduction Award Program (WRAP) award for recycling efforts, and a Federal Electronics Challenge Bronze award for management of electronics.

The LLNL Global Security Paperless eSystems project won an NNSA 2011 Environmental Stewardship Best-In-Class Award in the Change Agents category for a series of electronic paperless applications that save time, money, and the environment. Paperless systems were developed to perform employee move requests (eMove), travel approvals (eTravel), and checkout (eCheckout) of employees transferring out of the division. Based on eMove alone, approximately

$500,000 and 200 pounds of paper are saved annually. This project also won a DOE 2011 EStar Honorable mention award.

The LLNL Site 300 Sulfur Hexafluoride Reduction project won an NNSA 2011 Environmental Stewardship Award in the Cradle to Cradle category for minimizing Flash X-Ray (FXR) program releases of sulfur hexafluoride (SF6), which had both environmental and economic benefits. The project involved installation of a reclamation system to capture SF6, a recirculation system to purify the SF6 for reuse, and electronic scales to more accurately measure the SF6 used. Before these systems were put into place, operation of the FXR was estimated to release over 5,000 pounds of SF6 annually. The same system now uses less than a single 115 pound cylinder of SF6. This project also won a DOE 2011 EStar award.

The LLNL Beryllium Reduction project won an NNSA 2011 Environmental Stewardship Award in the Health and the Environment category for taking steps to minimize, and in many cases eliminate, the potential for worker exposure to beryllium. LLNL sent 2,086 pounds of beryllium materials for recycling or reuse, saving over $28,000 in avoided disposal costs and earning $186,842 for the sale of recyclable material.

LLNL received the CalRecycle 2011 WRAP award for recycling accomplishments during the 2010 calendar year. The award recognizes California businesses and organizations that have made outstanding efforts to reduce nonhazardous waste by implementing resource-efficient practices, aggressive waste reduction, reuse and recycling activities, and procurement of recycled-content products. This is the fourth consecutive year that LLNL has won the WRAP award.

LLNL won a Federal Electronics Challenge (FEC) Bronze award in 2011 for meeting all the general mandatory activities outlined in the FEC and all mandatory activities in the end-of-life management phase of the electronics life-cycle. The FEC is a partnership program that encourages federal facilities and agencies to purchase greener electronics, reduce impacts of electronics during use, and manage used electronics in an environmentally safe way.

3.2.4.2 SB14 Hazardous Waste Source Reduction and Management Review Act of 1989

Every four years, LLNL is required to conduct source reduction audits, prepare a progress report and source reduction plan. The P2S Program coordinated preparation of these documents in accordance with the California Department of Toxic Substances Control (DTSC) requirements. A combined document set was prepared for DOE California sites, including information from LLNL, Sandia National Laboratory/California and Stanford Linear Accelerator Laboratory.

3.2.4.3 High-Performance Sustainable Buildings and Energy Conservation

The Facilities and Infrastructure Directorate manages the implementation of DOE Order 430.2B objectives related to sustainable building materials and practices. In FY 2008, a Green Cleaning Policy was developed that meets the U.S. Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED) requirements. The goal of the Policy is to reduce the usage of potentially hazardous cleaning chemicals and their adverse impact on indoor air quality, occupant health, and the environment. LLNL continues to expand green cleaning lab-wide, with the goal to implement green cleaning at all applicable locations. Alternative solutions are evaluated as the industry improves and more green products that perform effectively become available. In FY11, the program identified an alternative floor finish and plans to investigate floor wax stripper products during FY 2012.

In FY11, another datacenter/office mixed-use building, Building 451, was awarded USGBC LEED-EB Operations and Maintenance "Silver" certification. Five additional buildings were assessed in FY 11 using the High Performance Sustainable Building (HPSB) Assessment tool. These buildings (T3724, T3725, T3726, T4727, and T4729) were studied and benchmarked using both the EPA's Portfolio Manager Database and the HPSB Assessment Tool in six categories: integrated design, energy performance, water conservation, indoor air quality and reduction of environmental impact.

3.2.5 Pollution Prevention/Sustainability Employee Training and Awareness Programs

In celebration of Earth Day 2011, P2S staff held an awards ceremony and reception in honor of the 2011 NNSA Environmental Stewardship Award winners.

During 2011, LLNL and Sandia/CA worked together to bring a Farmers' Market to the labs. The P2S Program collaborated with the Farmers' Market project team to incorporate sustainability measures into the market events. P2S staff implemented a recycling and composting program for the market and distributed handout materials on the laboratory's sustainability programs.

The P2S Program conducted other awareness activities during the year. Articles on pollution prevention appeared in *NewsOnLine* (LLNL's internal online newsletter). The P2S Program continues to conduct training for purchasing staff on Sustainable Acquisition requirements.

The P2S Program maintains an internal P2S website for LLNL employees. The website is a resource for employees who have questions regarding pollution prevention, energy efficiency, reuse and recycling of materials, green building, and other environmental topics. Employees can also use the site to suggest P2S ideas, and ask questions about P2S planning and implementation.

The EFA Green Hotline provides support for employees with questions, suggestions, or ideas regarding LLNL's pollution prevention and waste diversion endeavors, as well as other environmental issues.

4. Air Monitoring Programs

Kent Wilson • Dave Armstrong • Nicholas A. Bertoldo • Steven Cerruti •

Lawrence Livermore National Laboratory performs continuous air sampling to evaluate its compliance with local, state, and federal laws and regulations and to ensure that human health and the environment are protected. Federal environmental air quality laws and U.S. DOE regulations include 40 CFR 61, Subpart H—the NESHAPs section of the Clean Air Act; applicable portions of DOE Order 458.1; and ANSI standards. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) provides the guidance for implementing DOE Order 458.1.

The EPA Region IX has enforcement authority for LLNL compliance with radiological air emission regulations. Enforcement authority for the Clean Air Act regulations pertaining to nonradiological air emissions belongs to two local air districts: the BAAQMD and the SJVAPCD.

4.1 Air Effluent Monitoring

Air effluent monitoring of atmospheric discharge points is in place for compliance with 40 CFR 61, Subpart H and is used to determine the actual radionuclide releases from individual facilities during routine and nonroutine operations and to confirm the operation of facility emission control systems. Subpart H requires continuous monitoring of facility radiological air effluents if the potential off-site (fence-line) dose equivalent is greater than 1 µSv/y (0.1 mrem/y), as calculated using the U.S. EPA-mandated air dispersion dose model, CAP88-PC, without credit for emission control devices. The results of monitoring air discharge points provide the actual emission source information for modeling, which is used to ensure that the NESHAPs standard of 100 µSv/y (10 mrem/y) total site effective-dose equivalent from the airborne pathway is not exceeded. See **Chapter 7** for further information on radiological dose assessment.

Currently, the air effluent sampling program measures only radiological emissions. For LLNL operations with nonradiological discharges, LLNL obtains permits and registrations from local air districts (i.e., BAAQMD and SJVAPCD) for stationary emission sources and from CARB for portable emission sources such as diesel air compressors and generators and for off-road diesel vehicles. Current permits and registrations do not require monitoring of air effluent but do require monitoring of equipment inventory, equipment usage, material usage, and/or record keeping during operations. Based on air toxics emissions inventory and risk assessment required by the California Air Toxics “Hot Spots” Information and Assessment Act of 1987, BAAQMD and SJVAPCD have ranked LLNL as a low-risk facility for nonradiological air emissions.

4.1.1 Air Effluent Radiological Monitoring Results and Impact on the Environment

In 2011, LLNL measured releases of radioactivity from air exhausts at six facilities at the Livermore site and at one facility at Site 300. Air effluent monitoring locations at the Livermore site and Site 300 are shown in **Figures 4-1** and **4-2**, respectively.

Four facilities had measureable emissions in 2011. A total of 6978 GBq (188.6 Ci) of measured tritium was released from the stack exhausts at the Tritium Facility. Of this, approximately 32% of tritium was released as vapor (HTO). The remaining 68% released was gaseous tritium (HT).

The DWTF released a total of 0.56 GBq (0.015 Ci) of measured tritium from the stack exhaust. The tritium released was approximately 75% vapor (HTO) and 25% gaseous tritium (HT).

The National Ignition Facility (NIF) released a total of 45.1 GBq (1.22 Ci) of measured tritium from the stack exhaust in 2011. A total of 30.9 GBq (0.836 Ci) was released as vapor (HTO), 14.2 GBq (0.385 Ci) as gaseous (HT), and 5.2×10^{-3} GBq (1.4×10^{-4} Ci) of tritiated particulate.

The Contained Firing Facility (CFF) at Site 300 had measured depleted uranium stack emissions in 2011. A total of 2.1×10^{-7} GBq (5.6×10^{-9} Ci) of uranium-234, 1.5×10^{-8} GBq (4.1×10^{-10} Ci) of uranium-235, and 1.2×10^{-6} GBq (3.2×10^{-8} Ci) of uranium-238 was released in particulate form.

The measured emissions from monitored facilities were a result of planned activities with radioactive material.

None of the other facilities monitored for radionuclides had reportable emissions in 2011. The data tables in **Appendix A, Section A.1** provide summary results of all air effluent monitored facilities and include upwind locations (control stations) which are used for gross alpha and gross beta background comparison to stack effluent gross alpha and gross beta results.

The dose to the hypothetical, site-wide maximally exposed individual (SW-MEI) member of the public caused by the measured air emissions from the Tritium Facility (modeling HT emissions as HTO as required by EPA) was 1.5×10^{-1} µSv./y (1.5×10^{-2} mrem/y); the dose from the DWTF (modeling HT emissions as HTO) was 5.8×10^{-6} µSv/y (5.8×10^{-7} mrem/y); the dose from the NIF (modeling HT emissions as HTO) was 2.8×10^{-4} µSv/y (2.8×10^{-5} mrem/y), and the dose from the CFF was 9.0×10^{-7} µSv/y (9.0×10^{-8} mrem/y).

All of the reported SW-MEI doses at the Livermore site and Site 300 are less than one percent of the annual NESHAPs standard, which is 100 µSv/y (10 mrem/y) total site effective dose equivalent. As shown in **Chapter 7**, the estimated radiological dose caused by measured air emissions from LLNL operations was minimal. See also the *LLNL NESHAPs 2011 Annual Report* (Wilson et al. 2012) for a complete description of air effluent monitoring, this report is located in **Appendix D**.

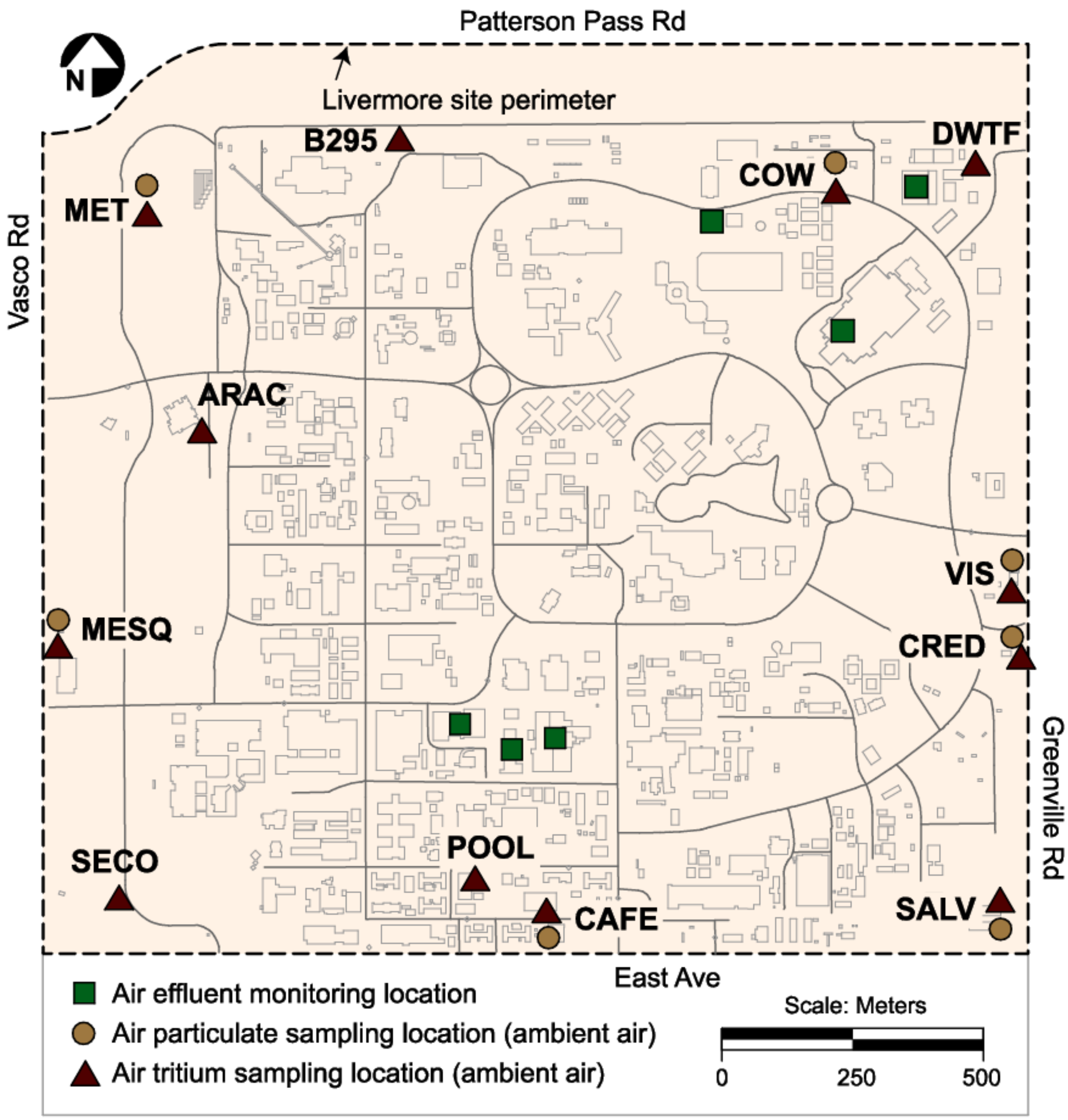

Figure 4-1. Air effluent and ambient air monitoring locations at the Livermore site, 2011.

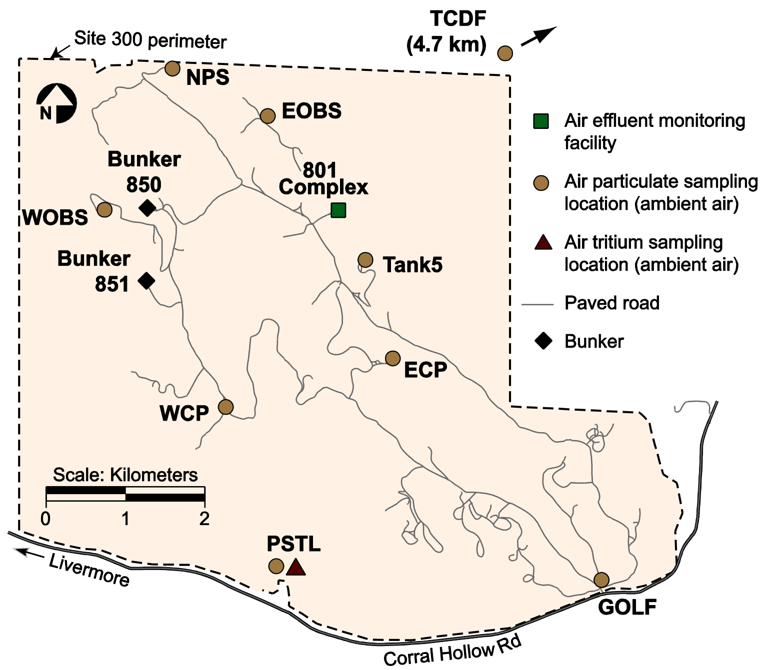

Figure 4-2. Air effluent and ambient air monitoring locations at Site 300, 2011.

4.1.2 Nonradiological Air Releases and Impact on the Environment

In 2011, the Livermore site emitted approximately 109 kg/d of regulated air pollutants as defined by the Clean Air Act, including nitrous oxides (NOx), sulfur oxides (SOx), particulate matter (PM-10), carbon monoxide (CO), and reactive organic gases/precursor organic compounds (ROGs/POCs) (see **Table 4-1**). The stationary emission sources that released the greatest amount of regulated pollutants at the Livermore site were natural gas fired boilers, internal combustion engines (such as diesel generators), solvent cleaning, and surface coating operations (such as painting). Pollutant emission information was primarily derived from monthly material and equipment usage records.

Table 4-1. Nonradioactive air emissions, Livermore site and Site 300, 2011.

	Estimated releases (kg/d)	
Pollutant	**Livermore site**	**Site 300**
ROGs/POCs	10.8	0.33
Nitrogen oxides	48.1	2.70
Carbon monoxide	43.3	0.71
Particulates (PM-10)	4.8	0.56
Sulfur oxides	1.5	0.17
Total	108.5	4.47

Livermore site air pollutant emissions were very low in 2011 compared to the daily releases of air pollutants from all sources in the entire Bay Area. For example, the average daily emission of NOx in the Bay Area was approximately 3.63×10^5 kg/d, compared to the estimated daily release from the Livermore site of 48.1 kg/d, which is 0.013% of total Bay Area source emissions for NOx. The 2011 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was 2.71 × 10^5 kg/d, while the daily emission estimate for 2011 from the Livermore site was 10.8 kg/d, or 0.004% of the total Bay Area source emissions for ROGs/POCs.

Certain operations at Site 300 require permits from the SJVAPCD. The estimated daily air pollutant emissions during 2011 from operations (permitted and exempt stationary sources) at Site 300 are listed in **Table 4-1**. The stationary emission sources that release the greatest amounts of regulated air pollutants at Site 300 include internal combustion engines (such as diesel-powered generators), a gasoline-dispensing facility, and general research operations. Combustion pollutant emissions, such as NOx, CO, PM-10 and SOx, increased in 2011 primarily from the increased usage of two diesel-powered generators in response to two emergency power outages.

4.2 Ambient Air Monitoring

LLNL conducts ambient air monitoring at on- and off-site locations to determine whether airborne radionuclides or beryllium are being released to the environs in measurable quantities by LLNL operations. Ambient air monitoring also serves to verify the air concentrations predicted by air dispersion modeling and to determine compliance with NESHAPs regulations.

The derived concentration technical standard (DCS), which complements DOE Order 458.1, specifies the concentrations of a radionuclide that can be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public, which is 1 mSv/y (100 mrem/y) effective dose equivalent.

Beryllium is the only nonradiological emission from LLNL that is monitored in ambient air. LLNL requested and was granted a waiver by the BAAQMD for source-specific monitoring and record keeping for beryllium operations, provided that LLNL can demonstrate that monthly average beryllium concentrations in air are well below regulatory limits of 10,000 pg/m^3. LLNL meets this requirement by sampling for beryllium at perimeter locations.

Based on air-dispersion modeling using site-specific meteorological data, the ambient air samplers, particularly those on the site perimeters, have been placed to monitor locations where elevated air concentrations due to LLNL operations may occur. Sampling locations for each monitoring network are shown in **Figures 4-1**, **4-2**, and **4-3**.

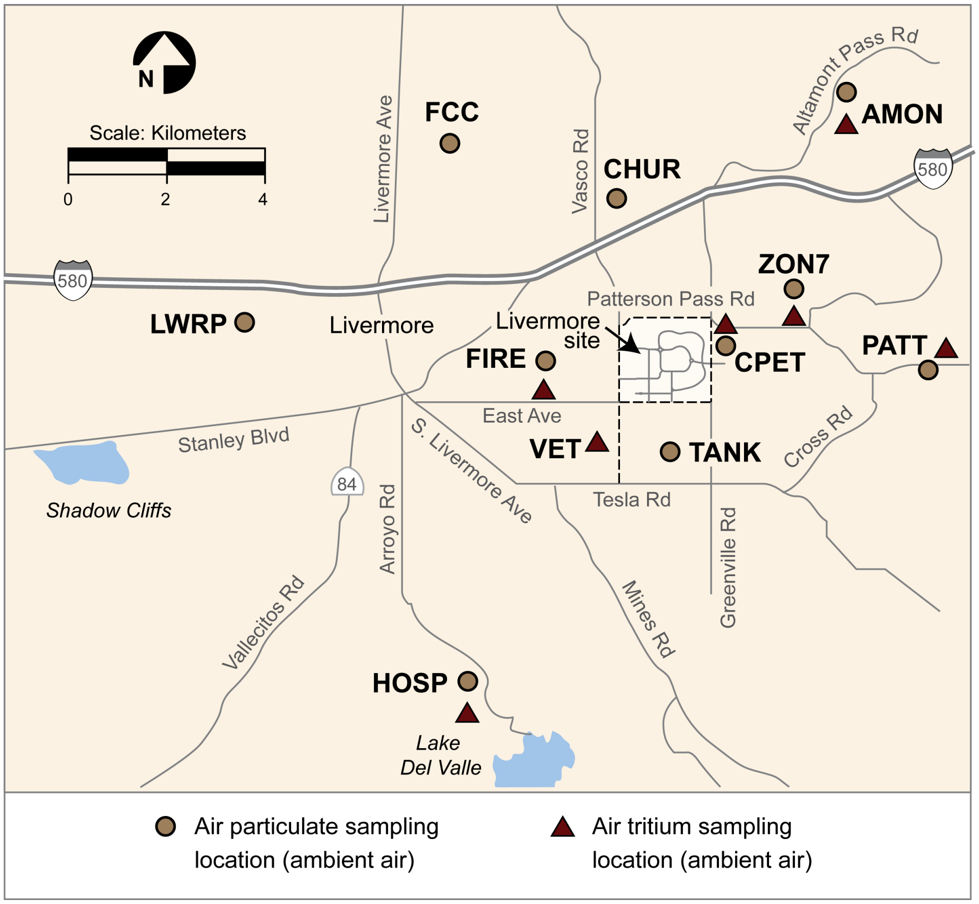

Figure 4-3. Air particulate and tritium monitoring locations in the Livermore Valley, 2011.

4.2.1 Ambient Air Radioactive Particulates

Composite samples for the Livermore site and Site 300 were analyzed by gamma spectroscopy for an environmental suite of gamma-emitting radionuclide concentrations in air that include fission products, activation products, actinides, and naturally occurring products. The isotopes detected at both sites throughout 2011 were beryllium-7 (cosmogenic), lead-210, radium-226, and potassium-40, all of which are naturally occurring in the environment.

On March 11 of 2011, the Japanese Fukushima reactor crisis began. Detections of iodine-131, cesium-134, and cesium-137 in ambient air were seen in March, April, and May of 2011. After that time, sampled air returned to non-detections for these isotopes. The detections are attributed to the Fukushima reactors (see **Appendix A**, **Section A.2** for data tables); the sampled results were consistent with the EPA's RadNet air concentration measurement data from fallout of the Fukushima reactors (U.S. EPA, 2011).

EPA stated that *it is important to note that all of the radiation levels detected by RadNet monitors and sampling have been very low, well below any level of public health concern* (U.S. EPA, 2011).

Composite samples were analyzed by alpha spectroscopy for plutonium-239+240, which was detected in 9 out of 216 samples taken in 2011. Detections at the Livermore site and Livermore off-site locations for plutonium-239+240 are attributed to resuspension of plutonium-contaminated soil (see Chapter 6) to ambient air from historical operations. The highest values and percentage of the DCS for the plutonium-239+240 detections were as follows:

- Livermore site perimeter: 16.5 nBq/m^3 (0.44 aCi/m^3); 0.00018% of the DCS
- Livermore off-site locations: 16.7 nBq/m^3 (0.45 aCi/m^3); 0.00019% of the DCS
- Site 300 composite: There were no detections in 2011.

Uranium-235 and uranium-238 were detected at all sample locations. Uranium ratios are used to determine the type of uranium present in the environment. Natural uranium has a mathematical uranium-235/uranium-238 ratio of 0.00725, and depleted uranium has a uranium-235/uranium-238 ratio of 0.002. Uranium isotopes are naturally occurring. The annual median uranium-235/uranium-238 isotopic ratios for 2011 were as follows:

- Livermore site perimeter composite: 0.0072
- Site 300 sample locations: 0.0071
- Site 300 off-site location: 0.0072

The annual uranium-235/uranium-238 isotopic ratio medians are consistent with naturally occurring uranium. All of the individual uranium-235 and uranium-238 results were less than one percent of the DCS as shown in **Appendix A**, Section A.2.

Gross alpha and gross beta were sampled for at all locations. The primary sources of alpha and beta activities are naturally occurring radioisotopes. Routine isotopic gamma results indicate the activities are the result of naturally occurring isotopes (uranium, thorium, potassium, and lead), which are also routinely found in local soils. See **Appendix A, Section A.2**.

4.2.2 Ambient Air Tritium Concentrations

The biweekly air tritium data that are provided in **Appendix A**, **Section A.2** are summarized in **Table 4.2**. Area (diffuse) sources include stored containers of tritium waste or tritium-contaminated equipment from which HTO diffuses into the atmosphere. Because HTO air concentrations observed at the Livermore site sample locations are low, the concentrations at remote sample locations are readily predicted to be below the minimum detectable concentration (MDC). However, some samples from these remote locations yielded results greater than the MDC. These results are attributed to the inability to discriminate between a true signal and a background signal in the observed data. The Derived Concentration Standards were formerly published in DOE Order 5400.5 in 1993. The current radiation protection standards approach, which has changed from the previously adopted 1993 guidance, uses age and gender specific attributes for the population subgroups of members of the public subject to exposure incorporating more sophisticated biokinetic and dosimetric information from the International Commission on Radiological Protection (ICRP).

Table 4-2. Air tritium sampling summary for 2011.

Sampling locations	Detection frequency	Concentration (mBq/m^3)				Median % DCS[a]	Mean Dose (nSv)
		Mean	Median	IQR	Maximum		
Livermore site perimeter	267 of 311	87.3	53.6	66.8	799	0.00069	21.0
Livermore Valley	114 of 180	29.5	19.6	27.3	336	0.00025	7.08
Site 300	6 of 25	3.39	6.77	13.1	28.3	0.000087	<5

(a) DCS = Derived Concentration Technical Standard = 7.8×10^6 mBq/m^3 for tritium in air.

For a location at which the mean concentration is at or below the MDC, inhalation dose from tritium is assumed to be less than 5 nSv/y (0.5 µrem/y) (i.e., the annual dose from inhaling air with a concentration at the MDC of about 25 mBq/m^3 [0.675 pCi/m^3]).

4.2.3 Ambient Air Beryllium Concentrations

LLNL measures the monthly concentrations of airborne beryllium at the Livermore site, Site 300, and at the off-site sampler northeast of Site 300. The highest value recorded at the Livermore site perimeter in 2011 for airborne beryllium was 12 pg/m^3 This value is only 0.12% of the BAAQMD ambient concentration limit for beryllium (10,000 pg/m^3). There is no regulatory requirement to monitor beryllium in San Joaquin County; however, LLNL analyzes samples from three Site 300 perimeter locations as a best management practice. The highest value recorded at the Site 300 perimeter in 2011 was 16 pg/m^3 and the highest value at the off-site location was 23 pg/m^3. These data are similar to data collected from previous years.

4.2.4 Impact of Ambient Air Releases on the Environment

LLNL operations involving radioactive materials had minimal impact on ambient air during 2011. The measured radionuclide particulate and tritium concentrations in air at the Livermore site and Site 300 were all less than one percent of the DOE primary radiation protection standard for the public (DCS).

Beryllium is naturally occurring and has a soil concentration of approximately 1 part per million. The sampled results are believed to be from naturally occurring beryllium that was resuspended from the soil and collected by the sampler. Even if the concentrations of beryllium detected were from LLNL activities, the amount is still less than one percent of the BAAQMD ambient air concentration limit.

5. Water Monitoring Programs

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Lawrence Livermore National Laboratory monitors a multifaceted system of waters that includes wastewaters, storm water, and groundwater, as well as rainfall and local surface waters. Water systems at the two LLNL sites (the Livermore site and Site 300) operate differently. For example, the Livermore site is serviced by publicly owned treatment works but Site 300 is not, resulting in different methods of treating and disposing of sanitary wastewater at the two sites. Many drivers determine the appropriate methods and locations of the various water monitoring programs, as described below.

In general, water samples are collected according to written, standardized procedures appropriate for the medium (Gallegos 2009). Sampling plans are prepared by the LLNL network analysts who are responsible for developing and implementing monitoring programs or networks. Network analysts decide which analytes are sampled (see **Appendix B**) and at what frequency, incorporating any permit-specified requirements. Except for analyses of certain sanitary sewer and retention tank analytes, analyses are usually performed by off-site, California-certified contract analytical laboratories.

5.1 Sanitary Sewer Effluent Monitoring

In 2011, the Livermore site discharged an average of 0.87 million L/d (230,000 gal/d) of wastewater to the City of Livermore sewer system or 3.3% of the total flow into the City's system. This volume includes wastewater generated by Sandia/California and a very small quantity from Site 300. In 2011, Sandia/California generated approximately 11% of the total effluent discharged from the Livermore outfall. Wastewater from Sandia/California and Site 300 is discharged to the LLNL collection system and combined with LLNL sewage before it is released at a single point to the municipal collection system.

LLNL's wastewater contains both sanitary sewage and process wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below. Most of the process wastewater generated at the Livermore site is collected in various retention tanks and discharged to LLNL's collection system under prior approval from LLNL's Water, Air, Monitoring and Analysis (WAMA) Wastewater Discharge Authorization Requirement (WDAR) approval process.

5.1.1 Livermore Site Sanitary Sewer Monitoring Complex

LLNL's sanitary sewer discharge permit (Permit 1250, 2010/2011 and 2011/2012) requires continuous monitoring of the effluent flow rate and pH. Samplers at the Sewer Monitoring Station (SMS) collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, total toxic organics, and other water-quality parameters.

5.1.1.1 Radiological Monitoring Results

DOE orders and federal regulations establish the standards of operation at LLNL (see **Chapter 2**), including the standards for sanitary sewer discharges. Primarily the standards for radioactive material releases are contained in sections of the DOE Order 458.1 and 10 CFR Part 20.

For sanitary sewer discharges, DOE Order 458.1 provides the criteria DOE has established for the application of best available technology to protect public health and minimize degradation of the environment. These criteria (the DCTSs) limit the concentration of each radionuclide discharged to publicly owned treatment works. If the measured monthly average concentration of a radioisotope exceeds its concentration limit, LLNL is required to improve discharge control measures until concentrations are again below the DOE limits.

The 10 CFR Part 20 sanitary sewer discharge numerical limits include the following annual discharge limits for radioactivity: tritium, 185 GBq (5 Ci); carbon-14, 37 GBq (1 Ci); and all other radionuclides combined, 37 GBq (1 Ci). The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq [5 Ci]) takes precedence over the DOE Order 458.1 concentration-based limit for tritium for facilities that generate wastewater in large volumes, such as LLNL. In addition to complying with the 10 CFR Part 20 annual mass-based discharge limit for tritium and the DOE monthly concentration-based discharge limit for tritium, LLNL also complies with the daily effluent concentration-based discharge limit for tritium established by WRD for LLNL. The WRD limit is smaller by a factor of 30 than the DOE monthly limit, so the limits are therefore essentially equivalent; however, the WRD limit is more stringent in that it prevents large single event discharges.

The radioisotopes with the potential to be found in sanitary sewer effluent at LLNL and their discharge limits are discussed below. All analytical results are provided in **Appendix A**, **Section A.3**.

LLNL determines the total radioactivity contributed by tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. As shown in **Table 5-1**, the 2011 combined release of alpha and beta sources was 0.19 GBq (0.005 Ci), which is 0.5% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The tritium total was 1.37 GBq (0.04 Ci), which is 0.7 % of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

Table 5-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2011.

Radioactivity	Estimate based on effluent activity (GBq)	Limit of sensitivity (GBq)
Tritium	1.37	0.75
Gross alpha	-0.001[a]	0.03
Gross beta	0.19	0.04

(a) The result is negative when the measured activity is less than the measured background activity.

Discharge limits and a summary of the measurements of tritium in the sanitary sewer effluent from LLNL and the Livermore Water Reclamation Plant (LWRP) are reported in LLNL monthly reports. The maximum daily concentration for tritium of 0.04 Bq/mL (1.09 pCi/mL) was far below the permit discharge limit of 12 Bq/mL (333 pCi/mL).

Measured concentrations of cesium-137 and plutonium-239 in the sanitary sewer effluent from LLNL, the LWRP, and in LWRP sludge are reported in the LLNL February 2012 Report (Jones 2012). Cesium and plutonium results are from monthly composite samples of LLNL and LWRP effluent and from quarterly composites of LWRP sludge. For 2011, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCTSs. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The highest plutonium concentration observed in 2011 sludge is 3.7 mBq/g (0.010 pCi/g), which is many times lower than the National Council on Radiation Protection and Measurements (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for commercial or industrial property.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-2** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2011, a total of 1.37 GBq (0.04 Ci) of tritium was discharged to the sanitary sewer, an amount that is well within environmental protection standards and is comparable to the lowest amounts discharged during the past 10 years.

Table 5-2. Historical radioactive liquid effluent releases from the Livermore site, 2001–2011.[(a)]

Year	Tritium (GBq)	Plutonium-239 (GBq)
2001	4.9	1.1×10^{-4}
2002	0.74	0.42×10^{-4}
2003	1.11	0.51×10^{-4}
2004	1.34	1.16×10^{-5}
2005	3.12	9.64×10^{-6}
2006	19.9	7.56×10^{-6}
2007	2.83	6.24×10^{-6}
2008	0.83	5.52×10^{-6}
2009	1.01	5.93×10^{-6}
2010	1.47	5.25×10^{-6}
2011	1.37	2.00×10^{-6}

(a) Starting in 2002, following DOE guidance, actual analytical values instead of limit of sensitivity values were used to calculate total.

5.1.1.2 Nonradiological Monitoring Results

LLNL monitors sanitary sewer effluent for chemical and physical parameters at different frequencies depending on the intended use of the result. For example, LLNL's wastewater discharge permit requires LLNL to collect monthly grab samples and 24-hour composites, weekly composites, and daily composites. Once a month, a 24-hour, flow-proportional composite is collected and analyzed; this is referred to as the monthly 24-hour composite in the discussion below. The weekly composite refers to the flow-proportional samples collected over a 7-day period continuously throughout the year. The daily composite refers to the flow-proportional sample collected over a 24-hour period, also collected continuously throughout the year. LLNL's wastewater discharge permit specifies that the effluent pollutant limit (EPL) is equal to the maximum pollutant concentration allowed per 24-hour composite sample. Only when a weekly composite sample concentration is at or above 50% of its EPL are the daily samples that were collected during the corresponding period analyzed to determine whether any of the concentrations are above the EPL.

A summary of the analytical results from the permit-specified monthly and weekly composite sampling programs is presented in **Table 5-3**. The permit also requires that grab samples of effluent be collected on a monthly and semiannual basis and analyzed for total toxic organic (TTO) compounds and cyanide, respectively. (Complete results from LLNL's 2011 sanitary sewer effluent monitoring program are provided in **Appendix A**, **Section A.3**.)

During 2011, concentrations of the regulated metals show generally good agreement between the monthly composite samples and the corresponding weekly composite samples, and these results closely resemble the 2010 results. In **Table 5-3**, the 2011 maximum concentration for each metal is shown and compared with the EPL. These maximum values did not exceed 10% of their respective EPLs for six of the nine regulated metals. The three metals that did exceed their EPL were Arsenic, with maximum values of 20% of its EPL, copper, with maximum values that were 17% of its EPL, and Mercury, with maximum values that were 32% of its EPL. Weekly composite concentrations were comparable to 2010 results. All of the weekly composite samples were in compliance with LLNL's wastewater discharge permit limits.

Table 5-3. Summary of analytical results for permit-specified composite sampling of the LLNL sanitary sewer effluent, 2011.

Sample	Parameter	Detection frequency(a)	PQL(b)	EPL(c)	Minimum	Maximum	Median	Maximum % of EPL
Monthly 24-hour Composite	**Oxygen demand (mg/L)**							
	Biochemical oxygen demand	12 of 12	2	None Specified	66	380	84	N/A
	Solids (mg/L)							
	Total dissolved solids	12 of 12	1	None Specified	220	600	325	N/A
	Total suspended solids	12 of 12	1	None Specified	18	510	35	N/A
Weekly Composite	**Total metals (mg/L)**							
	Silver	0 of 52	0.010	0.20	<0.01	<0.01	n/a	<5.0
	Arsenic	50 of 52	0.0020	0.06	<0.002	0.012	0.0034	20
	Cadmium	0 of 52	0.0050	0.14	<0.005	<0.005	n/a	<3.6
	Chromium	0 of 52	0.010	0.62	<0.01	<0.05	n/a	<8.1
	Copper	51 of 52	0.010	1.0	<0.01	0.17	0.038	17
	Mercury	3 of 52	0.00020	0.01	<0.0002	0.0032	<0.0002	32
	Nickel	2 of 52	0.0050	0.61	<0.005	0.0064	<0.005	1
	Lead	20 of 52	0.0020	0.20	<0.002	0.023	<0.002	11
	Zinc	42 of 52	0.050	3.00	<0.05	0.24	0.066	8

(a) The number of times an analyte was positively identified, followed by the number of samples that were analyzed.

(b) PQL = Practical quantitation limit (these limits are typical values for sanitary sewer effluent samples).

(c) EPL = Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2009/2010 and 2010/2011).

As previously noted, grab samples of LLNL's sanitary sewer effluent are collected monthly for TTO analysis (permit limit = 1.0 mg/L) and semiannually for cyanide analysis (permit limit = 0.04 mg/L). In 2011, LLNL did not exceed either of these discharge limits. Results from the monthly TTO analyses for 2011 show that no priority pollutants, listed by the EPA as toxic organics, were identified in LLNL effluent above the 10 µg/L permit-specified reporting limit. As shown in **Appendix A**, <u>**Section A.3**</u>, one non-regulated organic compound, acetone, was identified in monthly grab samples at concentrations above the 10 µg/L permit-specified reporting limit. Cyanide was below the analytical detection limit in April (<0.02 mg/L) and October (<0.03 mg/L).

5.1.2 Categorical Processes

The EPA has established pretreatment standards for categories of industrial processes that EPA has determined are major contributors to point-source water pollution. These federal standards include prescribed sampling, self-monitoring, reporting, and numerical limits for the discharge of category-specific pollutants. At LLNL, the categorical pretreatment standards are incorporated into the wastewater discharge permit (Permit 1250 2009/2010 and 2010/2011), which is administered by the WRD.

The processes at LLNL that are defined as categorical change as programmatic requirements dictate. During 2011, the WRD identified 14 wastewater-generating processes at LLNL that are defined under either 40 CFR Part 469 or 40 CFR Part 433.

Only processes that discharge to the sanitary sewer require semiannual sampling, inspection, and reporting. During 2011, only two of the 14 processes discharged wastewater to the sanitary sewer: semiconductor processes located in the Building 153 microfabrication facility, and the abrasive jet machining located in Building 321C. In 2011, LLNL analyzed compliance samples for all regulated parameters from both processes and demonstrated compliance with all federal categorical discharge limits. As a further environmental safeguard, LLNL sampled the wastewater in each categorical wastewater tank prior to each discharge to the sanitary sewer. These monitoring data were reported to the WRD in July 2011 and January 2012 semiannual wastewater reports (Grayson et al. 2010, 2011).

In addition, WRD source control staff performed their required annual inspection and sampling of the two discharging categorical processes in October 2011. The compliance samples were analyzed for all regulated parameters, and the results demonstrated compliance with all federal and local pretreatment limits.

The remaining 12 processes, which do not discharge wastewater to the sanitary sewer, are regulated under 40 CFR Part 433. Wastewater from these processes is either recycled or contained for eventual removal and appropriate disposal by RHWM.

5.1.3 Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2011–2012) allows treated groundwater from the Livermore site GWP to be discharged in the City of Livermore sanitary sewer system (see **Chapter 8** for more information on the GWP). During 2011, a total of 46,434 L (12,267 gal) of treated groundwater were discharged to the sanitary sewer. Of this entire volume, approximately 17% was associated with GWP sampling operations at the off-site location well W-404, and 83% resulted from pumping and monitoring operations at on-site wells or treatment facilities. LLNL did not discharge groundwater from any other location to the sanitary sewer during 2011. All discharges were in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in Revelli (2012a).

5.1.4 Environmental Impact of Sanitary Sewer Effluent

During 2011, no discharges exceeded any discharge limits for either radioactive or nonradioactive materials to the sanitary sewer. The data are comparable to the lowest historical LLNL values. All the values reported for radiological releases are a fraction of their corresponding limits. For nonradiological releases, LLNL achieved excellent compliance with all the provisions of its wastewater discharge permit.

The data demonstrate that LLNL continues to have excellent control of both radiological and nonradiological discharges to the sanitary sewer. Monitoring results for 2011 reflect an effective year for LLNL's wastewater discharge control program and indicate no adverse impact to the LWRP or the environment from LLNL sanitary sewer discharges.

5.2 Site 300 Sewage Ponds and Site 300 Waste Discharge Requirements

Wastewater samples collected at Site 300 from the influent to the sewage evaporation pond, within the sewage evaporation pond, and flow to the sewage percolation pond were obtained in accordance with the written, standardized procedures summarized in Gallegos (2009).

5.2.1 Sewage Evaporation and Percolation Ponds

Sanitary effluent (nonhazardous wastewater) generated at buildings in the General Services Area at Site 300 is disposed of through a lined evaporation pond. However, during winter rains, treated wastewater may discharge into an unlined percolation pond where it enters the ground and the shallow groundwater. Although this potential exists, it did not occur during 2011.

In September 2008, Waste Discharge Requirement (WDR) 96-248 was replaced by WDR R5-2008-0148, a new permit issued by the Central Valley Regional Water Quality Control Board (CVRWQCB) for discharges to ground at Site 300. Monitoring and Reporting Program (MRP) Number R5-2008-0148 was adopted in September 2008 and was revised effective December 1, 2009. The revised MRP terms and conditions have been reflected in this summary. This revised MRP puts in place new monitoring requirements for additional systems at Site 300.

Under the terms of this MRP, LLNL submits semiannual and annual monitoring reports detailing its Site 300 discharges of domestic and wastewater effluent to sewage evaporation and percolation ponds in the General Services Area, and cooling tower blow down to percolation pits and septic systems, and mechanical equipment discharges to percolation pits located throughout the site.

The monitoring data collected for the 2011 semi-annual and annual reports shows compliance with all MRP and permit conditions and limits. All networks were in compliance with the new permit requirements. Compliance certification accompanied this report, as required by federal and state regulations.

5.2.2 Environmental Impact of Sewage Ponds

There were no discharges from the Site 300 sewage evaporation pond to the percolation pond. Groundwater monitoring related to this area indicated there were no measurable impacts to the groundwater from the sewage pond operations (Blake 2012).

5.3 Storm Water Compliance and Surveillance Monitoring

LLNL monitors storm water at the Livermore site in accordance with Permit WDR 95-174 (SFBRWQCB 1995) and at Site 300 in accordance with the California NPDES General Permit for Storm Water Discharges Associated with Industrial Activities (WDR 97-03-DWQ) (SWRCB 1997). Site 300 storm water monitoring also meets the requirements of the *Post-Closure Plan for the Pit 6 Landfill Operable Unit* (Ferry et al. 1998). For construction projects that disturb one acre of land or more, LLNL also meets storm water compliance monitoring requirements of the California NPDES General Permit for Storm Water Discharges Associated with Construction Activity (Order Number 2009-0009-DWQ) (SWRCB, 2009). Storm water monitoring at both sites also follows the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) and meets the applicable requirements of DOE Order 458.1. **Appendix B** includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

At all monitoring locations, grab samples are collected by submerging sample bottles directly into the storm water discharge or by using a sampling pump. If a sample location is not directly accessible, an automatic water sampler is used to pump water into the appropriate containers. LLNL permits require sample collection and analysis at the sample locations specified in the permits two times per rainy season. Influent (upstream) sampling is also required at the Livermore site. In addition, LLNL is required to visually inspect the storm drainage system during one storm event per month in the wet season (defined as October through April for the Livermore site and October through May for Site 300) to observe runoff quality and twice during the dry season to identify any dry weather flows. Annual facility inspections are also required to ensure that the best management practices for controlling storm water pollution are implemented and adequate.

5.3.1 LLNL Site-Specific Storm Water

Various chemical analyses are performed on the storm water samples collected. There are no numeric concentration limits for storm water effluent; moreover, the EPA’s benchmark concentration values for storm water are not intended to be interpreted as limits (U.S. EPA 2000). To evaluate the program, LLNL has established site-specific thresholds for selected parameters (Campbell and Mathews 2006). A value exceeds a parameter’s threshold when it is greater than the 95% confidence limit for the historical mean value for that parameter (see **Table 5-4**). The thresholds are used to identify out-of-the-ordinary data that merit further investigation to determine whether concentrations of that parameter are increasing in the storm water runoff.

Table 5-4. Site-specific thresholds for selected water quality parameters for storm water runoff.[a]

Parameter	Livermore site	Site 300
Total suspended solids (TSS)	750 mg/L[b]	1700 mg/L[b]
Chemical oxygen demand (COD)	200 mg/L[b]	200 mg/L[b]
pH	<6.0, >8.5[b]	<6.0, >9.0[c]
Nitrate (as NO_3)	10 mg/L[b]	Not monitored
Orthophosphate	2.5 mg/L[b]	Not monitored
Beryllium	1.6 µg/L[b]	1.6 µg/L[b]
Chromium(VI)	15 µg/L[b]	Not monitored
Copper	36 µg/L[b]	Not monitored
Lead	15 µg/L[d]	30 µg/L[b]
Zinc	350 µg/L[b]	Not monitored
Mercury	above RL[e]	1 µg/L[b]
Diuron	14 µg/L[b]	Not monitored
Oil and grease	9 mg/L[b]	9 mg/L[b]
Tritium	36 Bq/L[b]	3.17 Bq/L[b]
Gross alpha radioactivity	0.34 Bq/L[b]	0.90 Bq/L[b]
Gross beta radioactivity	0.48 Bq/L[b]	1.73 Bq/L[b]

(a) If data exceed the threshold comparison criteria, the data are reviewed to determine if additional investigation is necessary to assess if those data are indicative of a water quality problem.

(b) Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for COD, TSS, and zinc.

(c) EPA benchmark.

(d) California and EPA drinking water action level.

(e) RL (reporting limit) = 0.0002 mg/L for mercury.

5.3.2 Storm Water Inspections

Each principal directorate at LLNL conducts an annual inspection of its facilities to verify implementation of the Storm Water Pollution Prevention Plans (SWPPPs) and to ensure that measures to reduce pollutant discharges to storm water runoff are adequate. LLNL's principal associate directors certified in 2011 that their facilities complied with the provisions of LLNL's SWPPPs. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Revelli 2011a) and to the CVRWQCB (Revelli 2011b) with the results of sampling, observations, and inspections.

For each construction project permitted by Order Number 2009-0009-DWQ, LLNL conducts visual monitoring of construction sites before, during, and after storms to assess the effectiveness of the best management practices. Annual compliance certifications summarize the inspections.

5.3.3 Livermore Site

The Livermore site storm water permit (WDR 95-174) requires collection of samples twice each wet season at two effluent locations ASW and WPDC, and at four influent locations ALPE, ALPO, ASS2, and GRNE (see Figure 5-1). Sampling locations CDB and CDB2 are internal sites used by LLNL staff, outside the requirements of the storm water permit, to characterize storm water runoff quality entering Lake Haussmann; location CDBX characterizes water leaving Lake Haussmann. Except as noted below, LLNL collected samples at the six permit required locations on three occasions during 2011; February 16 and February 25, 2011, for the two required storms of the 2010–2011 water year, and October 6, 2011, for the first required storm of the 2011–2012 water year. One influent location, ALPO, could not be sampled during the first storm of either water year because there was no flow through that upstream location. Also, in accordance with the permit, fish toxicity tests (both acute and chronic) were performed using effluent runoff (sampling location WPDC) from the first storm of each of the water years and no issues were identified.

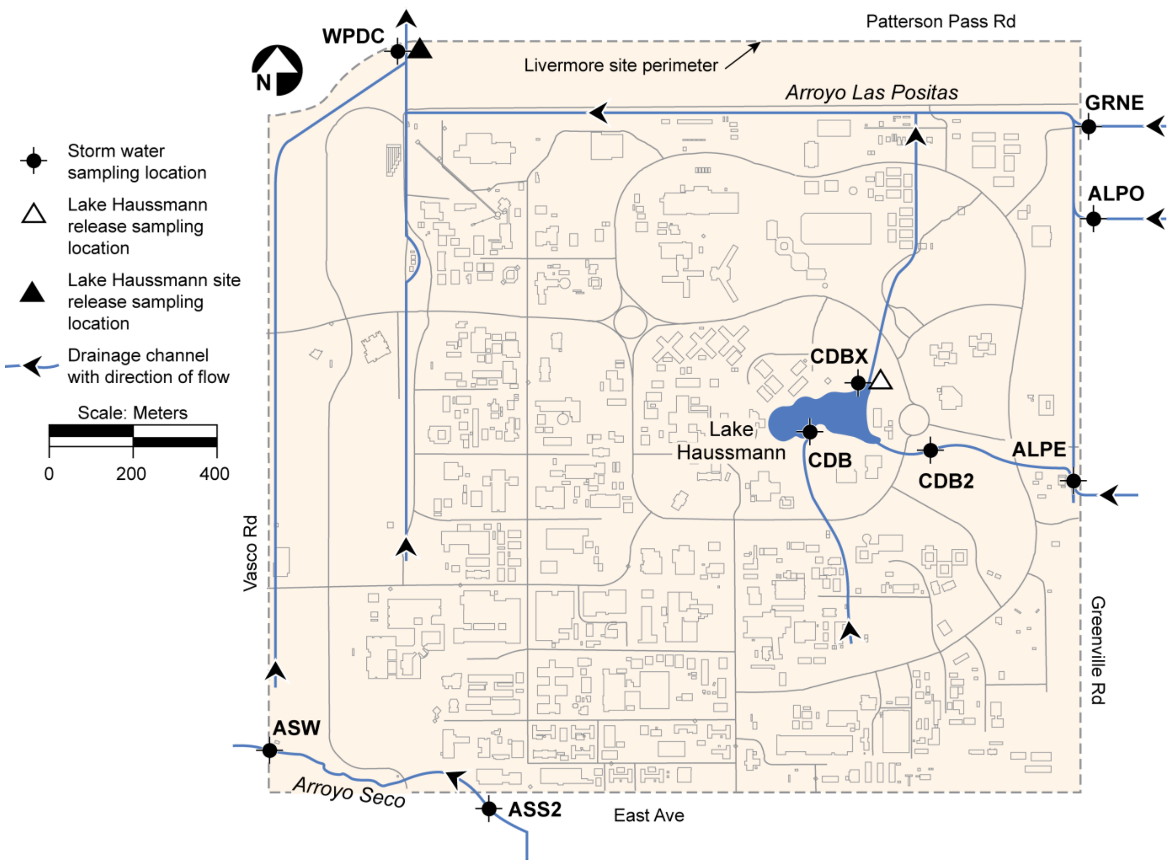

Figure 5-1. Storm water runoff and Lake Haussmann sampling locations, Livermore site, 2011.

5.3.3.1 Radiological Monitoring Results

Storm water tritium, gross alpha, and gross beta results are summarized in **Table 5-5**. (Complete analytical results are provided in **Appendix A**, **Section A.4**.) The median value for tritium activity at the site effluent sampling locations was approximately 1% of the maximum contaminant level (MCL). Median values for gross alpha and gross beta radioactivity in the effluent storm water samples collected during 2011 were also generally low, less than 12% and 9% of their MCLs, respectively. While the median tritium, gross alpha, and gross beta activities were all below their respective LLNL site-specific thresholds listed in **Table 5-4**, the maximum values for gross alpha (0.67 Bq/L) and gross beta (0.94 Bq/L), reported in the effluent sample collected on October 6, 2011 from the WPDC location, were both approximately a factor of two above their respective thresholds. It should be noted, however, that during this same sampling event the influent location GRNE (immediately upstream of WPDC) showed a gross alpha activity of 2.9 Bq/L and a gross beta activity of 3.1 Bq/L (see **Table 5.6)**. Given that both the gross alpha and gross beta activities at the influent location (GRNE) are more than three times the corresponding activities at the downstream effluent location (WPDC), these effluent results appear to be unrelated to LLNL operations.

LLNL began analyzing for plutonium in storm water in 1998. Current storm water sampling locations for plutonium are the Arroyo Seco and the Arroyo Las Positas effluent locations (ASW and WPDC, respectively). In 2011, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.10 pCi/L).

Table 5-5. Radioactivity in storm water from the Livermore site, 2011.[(a)]

Parameter	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Minimum	-1.4	0.011	0.043
Maximum	2.8	2.9	3.1
Median	1.2	0.089	0.29
Effluent			
Minimum	0.9	0.003	0.080
Maximum	29	0.67	0.94
Median	6.5	0.065	0.16

(a) See chapter 9 for an explanation of calculating summary statistics.

5.3.3.2 Nonradiological Monitoring Results

Nonradiological results were compared to the site-specific thresholds listed in **Table 5-4**. Of interest were the constituents that exceeded the thresholds at effluent points and whose concentrations were lower in influent than in effluent water samples. If influent concentrations are higher than effluent concentrations, the source is generally assumed to be unrelated to LLNL operations and LLNL conducts no further investigation. (Complete analytical results are provided in **Appendix A**, **Section A.4**.)

Constituents that exceeded site-specific thresholds for effluent and/or influent storm water sampling locations are listed in **Table 5-6**. In all but two cases during 2011, the detection of nonradiological constituents above site threshold values occurred in samples collected from influent locations. One effluent location, WPDC, showed a TSS value of 960 mg/L (above the site threshold value of 750 mg/L) during the October 6, 2011 storm; however, during this same sampling event, the influent location GRNE (immediately upstream of WPDC) showed a TSS value of 2600 mg/L. A second effluent location, ASW, showed a nitrate value of 12 mg/L (above the site threshold value of 10 mg/L) during the February 16, 2011 storm. While this value was within the range of nitrate results for influent samples from Arroyo Las Positas collected during the same storm, a nitrate concentration of 2.3 mg/L was reported for the influent Arroyo Seco sampling location ASS2 (immediately upstream of ASW). Results from subsequent sampling events (February 25, 2011 and October 6, 2011) showed no nitrate concentrations above the site-specific threshold. LLNL continues to monitor for nitrates and investigate potential sources (Revelli 2011a).

Table 5-6. Water quality parameters in storm water runoff above LLNL site-specific thresholds, Livermore site in 2011.

Radioactive/ Nonradioactive	Parameter	Date	Location	Influent / Effluent	Result	LLNL Threshold
Radioactive	Gross Alpha	2/16/11	ALPE	Influent	0.50 Bq/L	0.34 Bq/L
		10/6/11	GRNE	Influent	2.9 Bq/L	0.34 Bq/L
		10/6/11	WPDC	Effluent	0.67 Bq/L	0.34 Bq/L
	Gross Beta	2/16/11	ALPE	Influent	0.84 Bq/L	0.48 Bq/L
		10/6/11	GRNE	Influent	3.1 Bq/L	0.48 Bq/L
		10/6/11	WPDC	Effluent	0.94 Bq/L	0.48 Bq/L
Nonradioactive	TSS	2/16/11	ALPE	Influent	910 mg/L	750 mg/L
		10/6/11	GRNE	Influent	2600 mg/L	750 mg/L
		10/6/11	WPDC	Effluent	960 mg/L	750 mg/L
	pH	10/6/11	GRNE	Influent	8.58 (pH Units)	<6.0, >8.5 (pH Units)
	Nitrate (as NO3)	2/16/11	GRNE	Influent	23 mg/L	10 mg/L
		2/16/11	ASW	Effluent	12 mg/L	10 mg/L
	Beryllium	10/6/11	GRNE	Influent	3.3 µg/L	1.6 µg/L
	Copper	2/16/11	ALPE	Influent	57 µg/L	36 µg/L
		10/6/11	GRNE	Influent	160 µg/L	36 µg/L
	Lead	2/16/11	ALPE	Influent	35 µg/L	15 µg/L
		10/6/11	GRNE	Influent	91 µg/L	15 µg/L
	Mercury	10/6/11	GRNE	Influent	0.45 µg/L	0.2 µg/L
	Zinc	10/6/11	GRNE	Influent	460 µg/L	350 µg/L

5.3.4 Site 300

On March 24, 2011, LLNL collected and analyzed one complete set of storm water samples from all locations that normally have storm water flow at Site 300. These sampling locations characterize runoff from on-site industrial activities (NLIN, NLIN2, NPT7, and N883), an upstream off-site location (CARW2), and a downstream off-site location (GEOCRK) on the Corral Hollow Creek (**Figure 5-6**). No significant runoff was detected at two similar on-site sampling locations (NPT6 and N829). Only one complete set of storm water samples was collected at Site 300 during calendar year 2011 because the March 24, 2011 storm was the only qualifying event that generated runoff to be sampled during the 2010–2011 water year, and there were no major storms during the last quarter of 2011 that would have been sampled for the 2011–2012 water year.

5.3.4.1 Radiological Monitoring Results

During 2011, none of the radiological analytical results from the stormwater samples exceeded the site-specific thresholds listed in Table 5-4. (Complete analytical results are provided in **Appendix A, Section A.4**.)

Table 5-7. Water quality parameters in storm water runoff above LLNL site-specific thresholds, Site 300 in 2011.

Radioactive/ Nonradioactive	Parameter	Date	Location	Upstream / Downstream / Effluent	Result	LLNL Threshold
Nonradioactive	Beryllium	3/24/11	CARW2	Upstream	1.7 µg/L	1.6 µg/L
		3/24/11	NLIN2	Effluent	2.4 µg/L	1.6 µg/L

5.3.4.2 Nonradiological Monitoring Results

Storm water samples collected at Site 300 in 2011 were analyzed for nonradiological water quality parameters, and sample results were compared with the site-specific thresholds listed in **Table 5-4**. Constituents that exceeded the thresholds for sampled locations are listed in **Table 5-7**. (Complete analytical results are provided in **Appendix A**, **Section A.4.**)

During the March 24, 2011 storm, samples collected from upstream location CARW2 and from effluent location NLIN2 showed beryllium concentrations slightly above the Site 300 threshold comparison value. These detections, however, did not adversely affect downstream runoff; beryllium was not detected in the sample collected at effluent location NLIN (approximately 0.25 km downgradient from NLIN2), nor was beryllium detected in the downstream location GEOCRK (see **Figure 5-6**).

As in the past, low concentrations of dioxins were detected in water samples from storm runoff at Site 300. The federal MCL for dioxin and furans (dioxin-like compounds) is for the most toxic congener 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (2,3,7,8-tetraCDD). The other dioxin and furan congeners have varying degrees of toxicity. EPA has assigned toxicity equivalency factors (TEFs) to specific dioxin and furan congeners. The congeners 2,3,7,8-tetraCDD and 1,2,3,7,8-pentaCDD have an assigned TEF of 1; the other dioxin and furan congeners have TEFs of <1. The toxicity equivalency (TEQ) is determined by multiplying the concentration of a dioxin and furan congener by its TEF. See **Appendix A**, **Section A.4**, for the concentrations of dioxin and furan compounds that have non-zero TEFs. To calculate the total TEQ for a sampling event at a given location, LLNL used the approach of multiplying the dioxin and furan congener concentrations by their respective TEFs, adding them together, and conservatively including those congeners reported to be less than their detection limits as half the reported detection limit. For the runoff event sampled at Site 300 on March 24, 2011, the total TEQs are shown in **Table 5-8**. All dioxins detected were below the equivalent federal MCL of 30 pg/L. LLNL will continue to monitor storm water concentrations to determine whether trends are emerging.

Table 5-8. Dioxin-specific water quality parameters in Site 300 storm water runoff, 2011.

Location [a]	Total TEQ (pg/L)
CARW2	1.6
NLIN	1.5
NLIN2	5.6
GEOCRK	2.1

(a) Sampled March 24.

5.3.5 Environmental Impact of Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impact in 2011. Tritium activities in storm water runoff effluent were approximately 1% of the drinking water MCL. Gross alpha and gross beta activities in effluent samples at the Livermore site were both less than their respective MCLs. Site 300 storm water monitoring continues to show low concentrations of dioxins.

5.4 Groundwater

LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and at Site 300 through networks of wells and springs that include off-site private wells and on-site DOE CERCLA wells. To maintain a comprehensive, cost-effective monitoring program, LLNL determines the number and locations of surveillance wells, the analytes to be monitored, the frequency of sampling, and the analytical methods to be used. A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local groundwater resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in groundwater, contamination can be detected before it significantly impacts groundwater resources. Groundwater monitoring wells at the Livermore site, in the Livermore Valley, and at Site 300 are included in LLNL's *Environmental Monitoring Plan* (Gallegos 2009).

Beginning in January 2003, LLNL implemented a new CERCLA comprehensive compliance monitoring plan at Site 300 (Ferry et al. 2002) that adequately covers the DOE requirements for on-site groundwater surveillance. In addition, LLNL continues two additional surveillance networks to supplement the CERCLA compliance monitoring plan and provide additional data to characterize potential impacts of LLNL operations. LLNL monitoring related to CERCLA activities is described in **Chapter 8**. Additional monitoring programs at Site 300 comply with numerous federal and state controls such as state-issued permits associated with closed landfills containing solid wastes and with continuing discharges of liquid waste to sewage ponds and percolation pits; the latter are discussed in **Section 5.2.1**. Compliance monitoring is specified in WDRs issued by the CVRWQCB and in landfill closure and post-closure monitoring plans. (See **Chapter 2**, **Table 2-1** for a summary of LLNL permits.)

The WDRs and post-closure plans specify wells and discharges to be monitored, constituents of concern (COCs) and parameters, frequency of measurement, inspections, and the frequency and form of required reports. These monitoring programs include quarterly, semiannual, and annual monitoring of groundwater, monitoring of various influent waste streams, and visual inspections. LLNL performs the maintenance necessary to ensure the physical integrity of closed facilities, such as those that have undergone CERCLA or RCRA closure, and their monitoring networks.

During 2011, representative samples of groundwater were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures* (Goodrich and Lorega 2009). The procedures cover sampling techniques and information concerning the parameters monitored in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps or had to be bailed. All of the chemical and radioactivity analyses of groundwater samples were performed by California-certified analytical laboratories. For comparison purposes only, some of the results were compared with drinking water limits (MCLs).

5.4.1 Livermore Site and Environs

5.4.1.1 Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. HTO is potentially the most mobile groundwater contaminant from LLNL operations. Groundwater samples were obtained during 2011 from 16 of 18 water wells in the Livermore Valley (see **Figure 5-2**) and measured for tritium activity. Two wells (8F1 and 1R2) were out of service and could not be sampled during 2011.

Tritium measurements of Livermore Valley groundwaters are provided in **Appendix A**, **Section A.5**. The measurements continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) MCL established for drinking water in California. The maximum tritium activity measured off site was in the groundwater at well 16A2, located about 13 km (8 mi) west of LLNL (see **Figure 5-2**). The measured activity there was 2.3 Bq/L (62.2 pCi/L) in 2011, less than 0.32% of the MCL, and below background activity (2.4 Bq/L, 64.9 pCi/L) associated with this measurement.

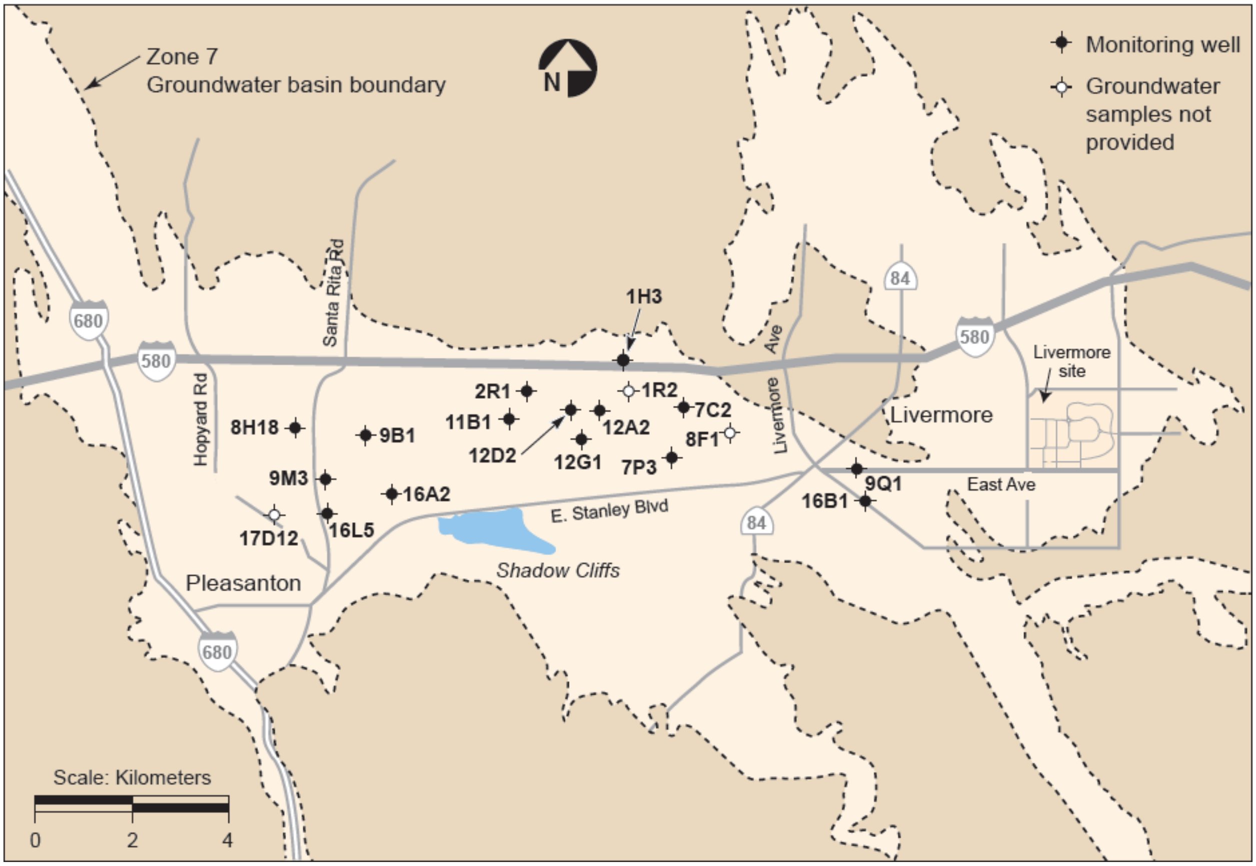

Figure 5-2. Off-site tritium monitoring wells in the Livermore Valley, 2011.

5.4.1.2 Livermore Site Perimeter

LLNL's groundwater surveillance monitoring program was designed to complement the Livermore Site GWP (see **Chapter 8**). The intent of the program is to monitor for potential groundwater contamination from LLNL operations. The perimeter portion of the surveillance groundwater monitoring network uses three upgradient (background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven downgradient monitoring wells located near the western boundary (wells 14B1, W-121, W-151, W-1012, W-571, W-556, and W-373) (see **Figure 5-3**). As discussed in **Chapter 8**, the alluvial sediments have been divided into nine hydrostratigraphic units (HSUs—water bearing zones that exhibit similar hydrolic and geochemical properties) dipping gently westward. Screened intervals (depth range from which groundwater is drawn) for these monitoring wells range from the shallow HSU-1B to the deeper HSU-5. Two of the background wells, W-008 and W-221, are screened partially in HSU-3A; well W-017 is considered a background well for the deeper HSU-5. To detect contaminants as quickly as possible, the seven western downgradient wells (except well 14B1, screened over a depth range that includes HSU-2, HSU-3A, and HSU-3B) were screened in shallower HSU-1B and HSU-2, the uppermost water-bearing HSUs at the western perimeter. These perimeter wells were sampled and analyzed at least once during 2011 for general minerals (including nitrate) and for certain radioactive constituents. Analytical results for the Livermore site perimeter wells are provided in **Appendix A**, Section A.5. Although there have been variations in these concentrations since regular surveillance monitoring began in 1996, the concentrations detected in the 2011 groundwater samples from the upgradient wells represent current background values.

Historically, chromium(VI) had been detected above the MCL (50 µg/L) in groundwater samples from western perimeter well W-373; however, concentrations of this analyte first dropped below the MCL in 2002. The 2011 sample from this location showed a concentration of 29 µg/L; a value consistent with the range of chromium(VI) concentrations (5 µg/L to 52 µg/L) detected at well W-373 since 2002. Groundwater samples collected in 2010 from the nearby wells W-556 and W-1012, also along the western perimeter of the LLNL site, showed chromium(VI) concentrations of 19 µg/L and 14 µg/L, respectively.

From 1996 through 2004, concentrations of nitrate detected in groundwater samples from downgradient well W-1012 were greater than the MCL of 45 mg/L. The nitrate concentration detected in the 2011 sample from this well (28 mg/L) was again, as in the past six years, below the MCL. During 2011, concentrations of nitrate in on-site shallow background wells W-008 and W-221 were reported to be 31 mg/L and 35 mg/L, respectively. Detected concentrations of nitrate in western perimeter wells ranged from 13 mg/L (in well W-373) to 44 mg/L (in well W-151).

During 2011, gross alpha, gross beta, and tritium were detected occasionally in LLNL's site perimeter wells, at levels consistent with the results from recent years; however, the concentrations again remain below drinking water MCLs.

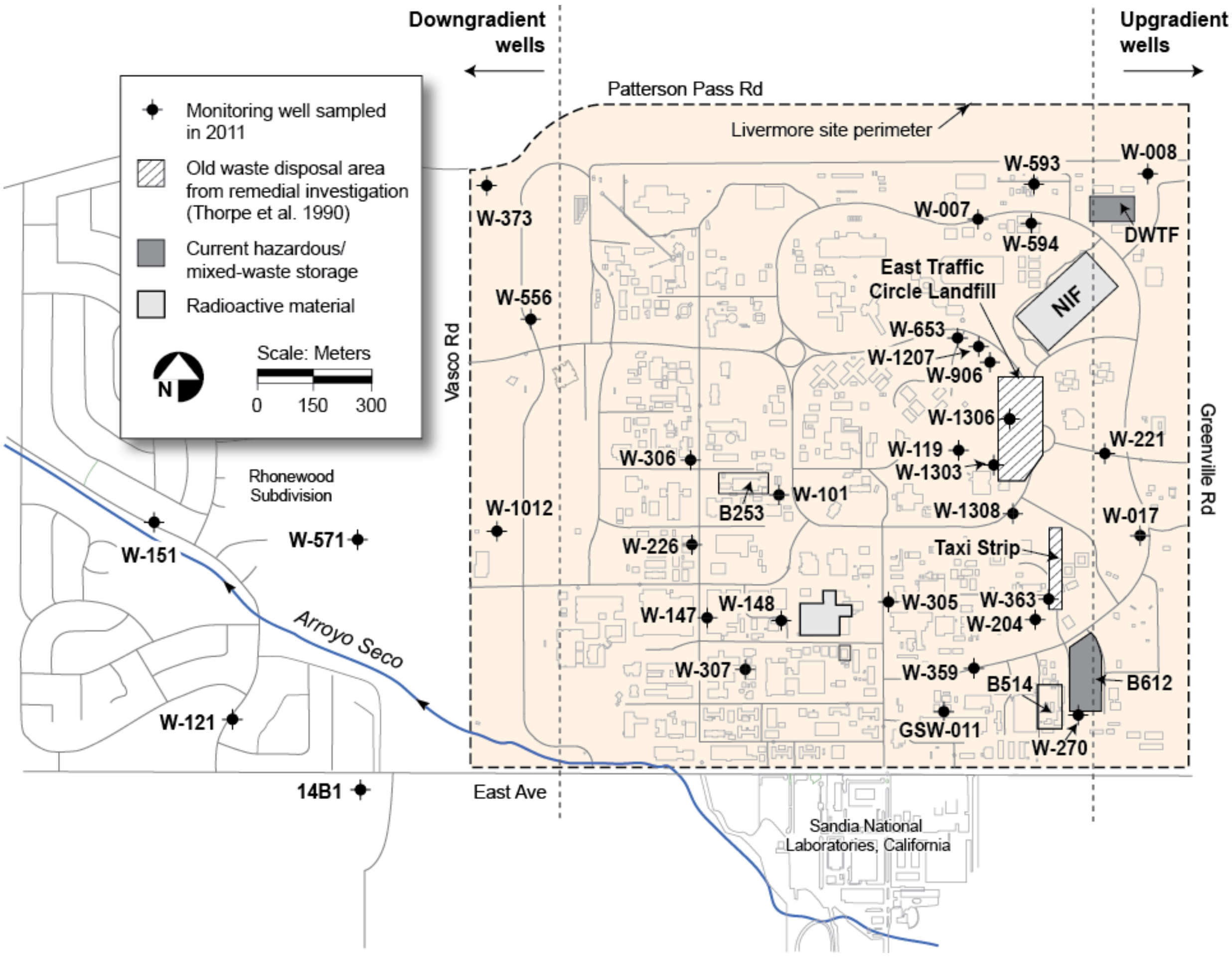

Figure 5-3. Routine surveillance groundwater monitoring wells at the Livermore site, 2011.

5.4.1.3 Livermore Site

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past, where previously detected COCs have low concentrations that do not require CERCLA remedial action, and where baseline information needs to be gathered for the area near a new facility or operation. Wells selected for monitoring are screened in the uppermost aquifers and are downgradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 5-3**. All analytical results are provided in **Appendix A**, **Section A.5**.

The Taxi Strip and East Traffic Circle Landfill areas (see **Figure 5-3**) are two potential sources of historical groundwater contamination. Samples from monitoring wells screened in HSU-2 (W-204) and HSU-3A (W-363) downgradient from the Taxi Strip area were analyzed in 2011 for copper, lead, zinc, and tritium. Samples from monitoring wells screened at least partially in HSU-2 (W-119, W-906, W-1303, W-1306, and W-1308) within and downgradient from the East Traffic Circle Landfill were analyzed for the same elements as the Taxi Strip area. Concentrations of tritium remained well below the drinking water MCLs and none of the trace metals (copper, lead, zinc) were detected in any of these seven monitoring wells during 2011. Although the

National Ignition Facility (NIF) has not yet begun full operations, LLNL measures pH, conductivity, and tritium concentration of nearby groundwater to establish a baseline. During 2011, tritium analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSU-3A and HSU-2, respectively) downgradient of NIF. Samples were also obtained downgradient from the DWTF from wells W-007, W-593, and W-594 (screened in HSU-2/3A, HSU-3A, and HSU-2, respectively) during 2011 and were analyzed for tritium. Monitoring results from the wells near NIF and DWTF showed no detectable concentrations of tritium, above the limit of sensitivity of the analytical method, in the groundwater samples collected during 2011. Monitoring will continue near these facilities to determine baseline conditions.

The former storage area around Building 514 and the hazardous waste/mixed waste storage facilities around Building 612 are also potential sources of contamination. The area and facilities are monitored by wells W-270 and W-359 (both screened in HSU-5), and well GSW-011 (screened in HSU-3A). During 2011, groundwater from these wells was sampled and analyzed for gross alpha, gross beta, and tritium. No significant contamination was detected in the groundwater samples collected downgradient from these areas in 2011.

Groundwater samples were obtained from monitoring well W-307 (screened in HSU-1B), downgradient from Building 322. Soil samples previously obtained from this area showed concentrations elevated above the Livermore site's background levels for total chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals would migrate from the site. In 2011, the monitoring results for well W-307 showed only slight variations from the concentrations reported last year.

Groundwater samples were obtained downgradient from a location where sediments containing metals (including cadmium, chromium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253. In 2011, the samples obtained from monitoring wells W-226 and W-306 (screened in HSU-1B and HSU-2, respectively) again contained dissolved chromium at concentrations above the analytical reporting limit, but these concentrations remained low and essentially unchanged from recent years.

Additional surveillance groundwater sampling locations, established in 1999, are in areas surrounding the Plutonium Facility and Tritium Facility. Potential contaminants include plutonium and tritium from these facilities, respectively. Plutonium is much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, can migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU-2; downgradient wells W-101, W-147, and W-148 are screened in HSU-1B. In August 2000, elevated tritium activity was detected in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L [3100 ± 135 pCi/L]). The activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater in this area had remained at or near the same level through 2005, but samples collected from well W-148 in 2006 through 2011 have shown significantly lower values—a downward trend ranging from approximately one-half to one-third of the August 2000 value due to the natural decay and dispersion of tritium. LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that tritium contents remain below MCLs.

5.4.2 Site 300 and Environs

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses DOE CERCLA wells and springs on site and private wells and springs off site. Representative groundwater samples are obtained at least once per year at every monitoring location; they are routinely measured for various elements (primarily metals), a wide range of organic compounds, general radioactivity (gross alpha and gross beta), uranium activity, and tritium activity. Groundwater from the shallowest water-bearing zone is the target of most of the monitoring because it would be the first to show contamination from LLNL operations at Site 300.

Brief descriptions of the Site 300 groundwater monitoring networks that are reported in this chapter are given below. (All analytical data from 2011 are included in **Appendix A**, **Section A.6**.)

5.4.2.1 Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see **Figure 5-4**). Storm water runoff in the Elk Ravine drainage area collects in arroyos and quickly infiltrates into the ground. Groundwater from wells in the Elk Ravine drainage area is monitored for COCs to determine the impact of current LLNL operations on the system of underground flows that connects the entire Elk Ravine drainage area. The area contains eight closed landfills, known as Pits 1 through 5 and 7 through 9, and firing tables where explosives tests are conducted. None of these closed landfills has a liner, which is consistent with the disposal practices when the landfills were constructed. The following descriptions of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See **Chapter 8** for a review of groundwater monitoring in this drainage area conducted under CERCLA.)

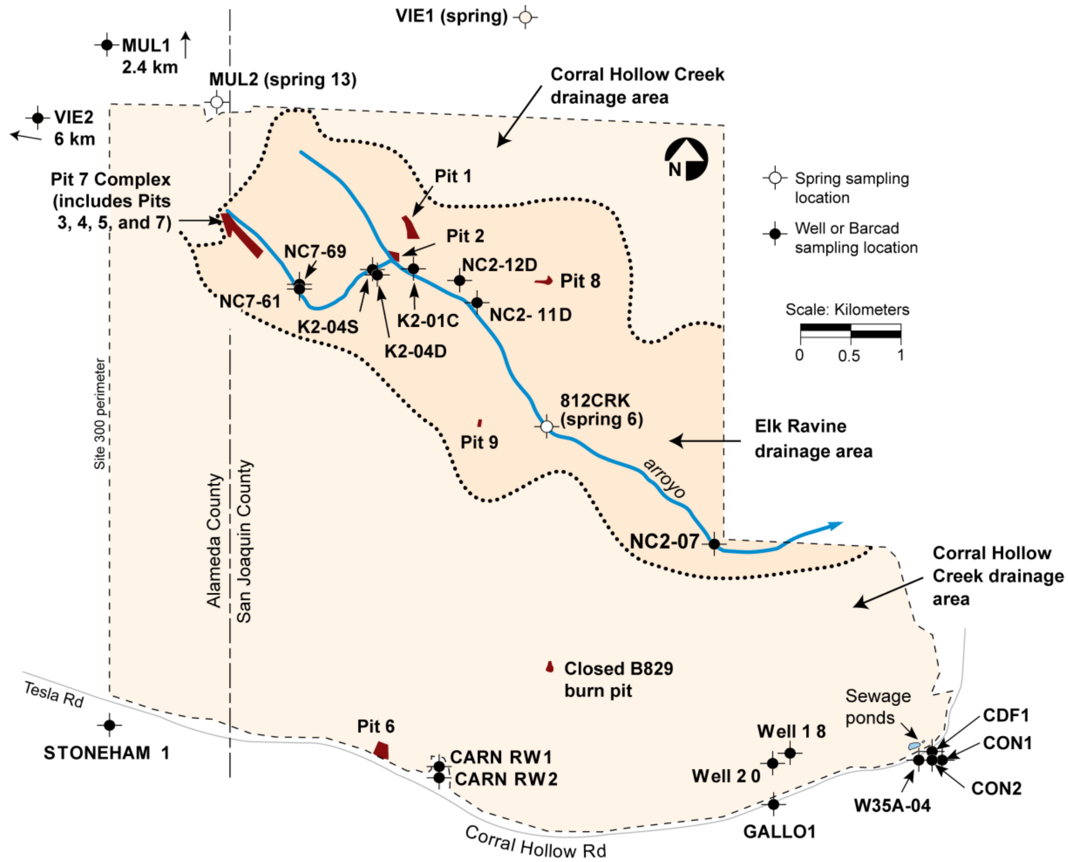

Figure 5-4. Surveillance groundwater wells and springs at Site 300, 2011.

Pit 7 Complex. The Pit 7 landfill was closed in 1992 in accordance with U.S. EPA and California Department of Health Services (now Department of Toxic Substances Control, or DTSC)-approved RCRA Closure and Post-Closure Plans using the LLNL CERCLA Federal Facility Agreement (FFA) process. From 1993 until 2009, monitoring requirements were specified in WDR 93-100, administered by the CVRWQCB (1993, 1998), and in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990). An Amendment to the Interim ROD for the Pit 7 Complex (U.S. DOE, 2007) was signed in 2007 under CERCLA. The remedial actions specified in the Interim ROD, including a hydraulic drainage diversion system, extraction and treatment of groundwater, and Monitored Natural Attenuation for tritium in groundwater) were implemented in 2008. In 2010, detection monitoring and reporting was transferred to CERCLA. Analytes and frequencies of sampling are documented in the CERCLA Compliance Monitoring Plan and Contingency Plan for Site 300 (Dibley et al., 2010). The objective of this monitoring continues to be the early detection of any new release of COCs from Pit 7 to groundwater.

For compliance purposes, during 2010 LLNL obtained annual or more frequent groundwater samples from the Pit 7 detection monitoring well network. Samples were analyzed for tritium, VOCs, fluoride, high explosive compounds (HMX and RDX), nitrate, perchlorate, uranium (isotopes or total), metals, lithium, and PCBs. For a detailed account of Pit 7 compliance monitoring during 2011, including well locations, maps of the distribution of COCs in groundwater, and analytical data tables, see Dibley et al, 2012.

Elk Ravine. Groundwater samples were obtained on various dates in 2011 from the widespread Elk Ravine surveillance monitoring network shown in **Figure 5-4** (NC2-07, NC2-11D, NC2-12D, NC7-61, NC7-69, 812CRK [SPRING6], K2-04D, K2-04S, K2-01C). Samples from NC2-07 were analyzed for inorganic constituents (mostly metallic elements), general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX). Samples from the remaining wells were analyzed only for general radioactivity.

No new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2011. The major source of contaminated groundwater beneath Elk Ravine is from historical operations in the Building 850 firing table area (Webster-Scholten 1994; Taffet et al. 1996). Constituents that are measured as part of the Elk Ravine drainage area surveillance monitoring network are listed in **Appendix B**.

The result of tritium analysis for well NC7-61 was 810 Bq/L in 2011, down from 1100 Bq/L in 2010. This tritium activity remains elevated with respect to the background concentrations. Tritium, as HTO, has been released in the past in the vicinity of Building 850. The majority of the Elk Ravine surveillance-network tritium measurements made during 2011 support earlier CERCLA studies that show that the tritium in the plume is diminishing over time because of natural decay and dispersion (Ziagos and Reber-Cox 1998). CERCLA modeling studies indicate that the tritium will decay to background levels before it can reach a site boundary.

Groundwater surveillance measurements of gross alpha, gross beta, and uranium radioactivity in Elk Ravine are low and are indistinguishable from background levels. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.) Additional detections of nonradioactive elements including arsenic, barium, chromium, selenium, vanadium, and zinc are all within the natural ranges of concentrations typical of groundwater elsewhere in the Altamont Hills.

Pit 1. The Pit 1 landfill was closed in 1993 in accordance with a California Department of Health Services (now Department of Toxic Substances Control, or DTSC) approved RCRA Closure and Post-Closure Plan using the LLNL CERCLA Federal Facility Agreement (FFA) process. Monitoring requirements are specified in WDR 93-100, which is administered by the CVRWQCB (1993, 1998, and 2010), and in Rogers/Pacific Corporation (1990). The main objective of this monitoring is the early detection of any release of COCs from Pit 1 to groundwater. LLNL obtained groundwater samples quarterly during 2011 from the Pit 1 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA Methods 601 and 8260). Additional annual analyses were conducted on groundwater samples for extractable organics (EPA Method 625), as well as pesticides and PCBs (EPA Method 608). Compliance monitoring showed no new releases at Pit 1 in 2011; a detailed account of Pit 1 compliance monitoring during 2011, including well locations and tables and graphs of groundwater COC analytical data, is in Blake (2012).

5.4.2.2 Corral Hollow Creek Drainage Area

Pit 6. Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in Ferry et al. (1998, 2002). Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Plan (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Plan (CAMP), which monitors the movement and fate of historical releases. To comply with monitoring requirements, LLNL collected groundwater samples monthly, quarterly, semiannually, and annually during 2011 from specified Pit 6 monitoring wells. No new releases were detected at Pit 6 in 2011. A detailed account of Pit 6 compliance monitoring during 2011, including well locations, tables of groundwater analytical data, and maps showing the distribution of COC plumes, is in Blake and Valett (2012).

Building 829 Closed High Explosives Burn Facility. Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in Mathews and Taffet (1997), and in LLNL (2001), as modified by DTSC (2003). As planned for compliance purposes, LLNL obtained groundwater samples during 2011 from the three wells in the Building 829 monitoring network. Groundwater samples from these wells, screened in the deep regional aquifer, were analyzed for inorganics (mostly metals), turbidity, explosive compounds (HMX, RDX, and TNT), VOCs (EPA Method 624), extractable organics (EPA Method 625), and general radioactivity (gross alpha and beta).

During 2011, there were no confirmed COC detections above their respective statistical limits in groundwater samples from any of the Building 829 network monitoring wells. Among the inorganic constituents, perchlorate was not detected above its reporting limit in any sample. With the exception of barium in well W-892-15 (which remains below its statistical limit, but at a level approximately twice the originally calculated background concentration) and manganese in well W-829-1938 (which exhibits a low of approximately half the originally calculated background concentration), the metal COCs that were detected showed concentrations that are not significantly different from background concentrations for the deep aquifer beneath the High Explosives Process Area. Two elevated molybdenum concentrations were reported in groundwater samples collected at well W-829-1938; and while the third quarter value did equal the SL, the SL was not exceeded. Typically, molybdenum concentrations are below the reporting limit; and prior to this year, only in the year following well development (2004), had molybdenum been detected above the RL in samples collected from well W-829-1938. Elevated turbidity appears to be correlated with these molybdenum detections and could suggest possible sampling anomalies. LLNL will continue to track these results as additional data become available to determine whether or not this concentration fluctuation is due to natural variation.

There were no organic or explosive COCs detected above reporting limits in any samples. Similarly, all results for the radioactive COCs (gross alpha and gross beta) were below their statistical limit values. For a detailed account of compliance monitoring of the closed burn pit during 2011, including well locations and tables and graphs of groundwater COC analytical data, see Revelli (2012b).

Water Supply Well. Water supply well 20, located in the southeastern part of Site 300 (**Figure 5-4**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer ($Tnbs_1$) and can produce up to 1500 L/min (396 gal/min) of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2011 from well 20. Groundwater samples were analyzed for inorganic COCs (mostly metals), VOCs, general radioactivity (gross alpha and gross beta), and tritium activity. Quarterly measurements of groundwater from well 20 do not differ significantly from previous years. As in past years, the primary potable water supply well at Site 300 showed no evidence of contamination. Gross alpha, gross beta, and tritium activities were very low and are indistinguishable from background level activities.

5.4.2.3 Off-site Surveillance Wells and Springs

As planned for surveillance purposes, during 2011 LLNL obtained groundwater samples from two off-site springs (MUL2 and VIE1) and ten off-site wells (MUL1, VIE2, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04) **(Figure 5-4)**. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at a private residence 6 km west of the site. It represents a typical potable water supply well in the Altamont Hills.

Samples from CARNRW2 and GALLO1 were analyzed at least quarterly for inorganic constituents (mostly metals), general radioactivity (gross alpha and beta), tritium activity, explosive compounds (HMX and RDX), and VOCs (EPA method 502.2). Additional annual analyses were conducted for uranium activity and extractable organic compounds (EPA Method 625) for samples collected from CARNRW2 only. In addition, CARNRW1 and CON2 samples were analyzed for VOCs; samples from well CARNRW1 were also sampled for perchlorate and tritium.

Groundwater samples were obtained once (annually) during 2011 from the remaining off-site surveillance monitoring locations: MUL1, MUL2, and VIE1 (north of Site 300); VIE2 (west of Site 300); and STONEHAM1, CON1, CDF1, and W-35A-04 (south of Site 300). Samples were analyzed for inorganic constituents (metals, nitrate, and perchlorate), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs, and extractable organic compounds (EPA Method 625).

Generally, no constituents attributable to LLNL operations at Site 300 were detected in the off-site groundwater samples. Arsenic and barium were detected at the off-site locations, but their concentrations were below MCLs and are consistent with naturally occurring concentrations. Radioactivity measurements in samples collected from off-site groundwater wells are generally indistinguishable from naturally occurring activities.

5.5 Other Monitoring Programs

5.5.1 Rainwater

Rainwater is sampled and analyzed for tritium activity in support of DOE Order 458.1. Rainwater is collected in rain gauges at fixed locations. The tritium activity of each sample is measured and all analytical results are provided in **Appendix A**, **Section A.7**.

5.5.1.1 Livermore Site and Environs

Rain sampling locations are shown in **Figure 5-1**. During 2011, LLNL collected rainwater samples following two rain events in the Livermore Valley. All of the rainwater sampling dates closely track with two of the storm water runoff sampling dates. During 2011, no on-site measurement of tritium activity was above the MCL of 740 Bq/L (20,000 pCi/L) established by the EPA for drinking water. A 2007 internal analysis of the LLNL rain sampling network demonstrated that current discharges were not likely to produce activities greater than the analytical laboratory detection limit in rainwater beyond the Livermore site perimeter. In 2011, rain sampling continued at the same four locations on the Livermore site perimeter (see **Figure 5-3**) as in 2010. Some rainwater samples collected in calendar year 2011 showed maximum tritium activity greater than the minimum reporting limit of 3.7 Bq/L (100 Ci/L); this is consistent with historical values.

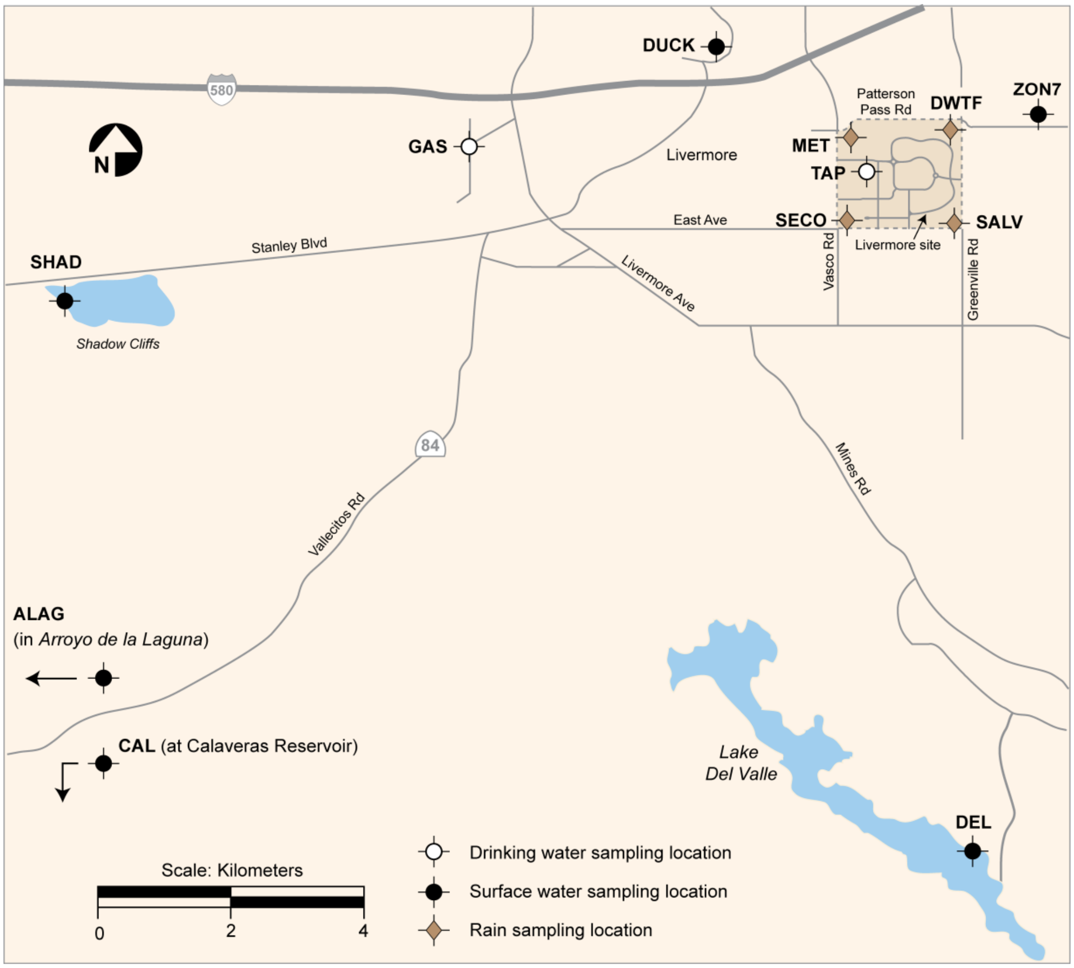

Figure 5-5. Livermore site and Livermore Valley sampling locations for rain, surface water, and drinking water, 2011.

5.5.1.2 Site 300 and Environs

During 2010, LLNL positioned two rain gauges at on-site locations ECP and PSTL (see **Figure 5-6**) to collect rainfall to measure tritium activity at Site 300. However, because of the dry Site 300 climate, only one rain sample was collected in calendar year 2011. Rainfall samples are usually collected at the same time storm water samples are collected. The maximum tritium activity measured in Site 300 rainwater samples during 2011 show values below the minimum reporting limit of 3.7 Bq/L (100 pCi/L) .

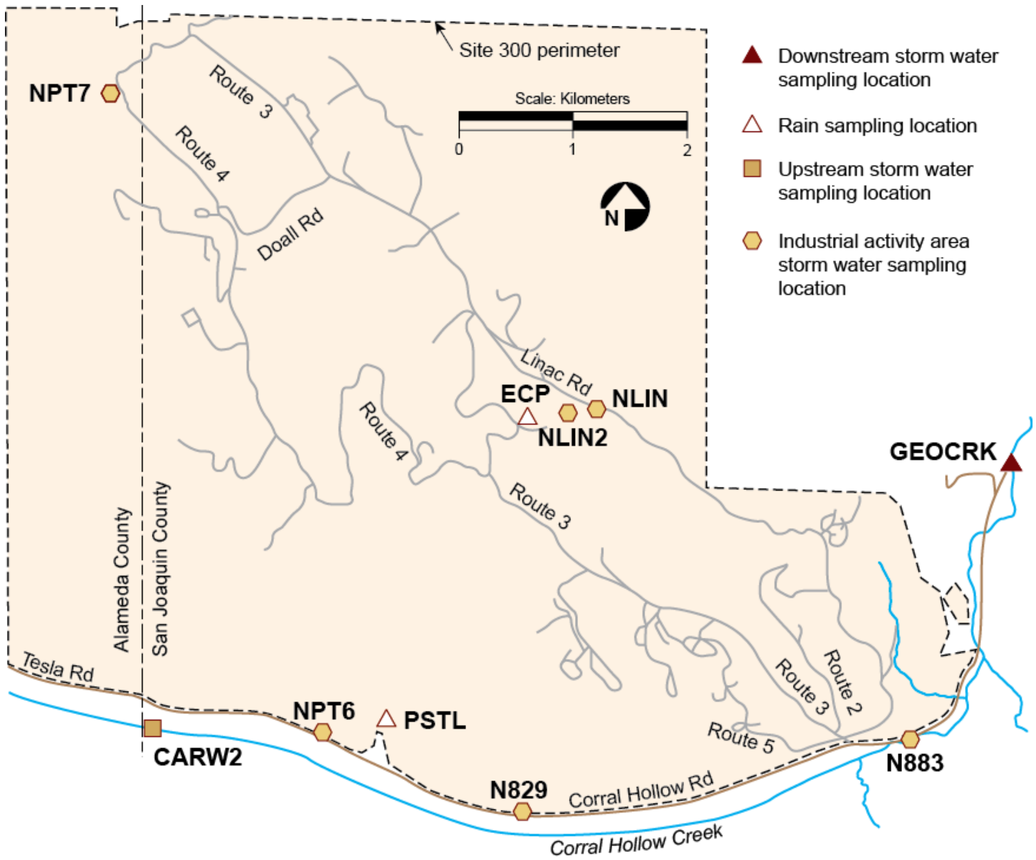

Figure 5-6. Storm water and rainwater sampling locations at Site 300, 2011.

5.5.2 Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 458.1. Surface and drinking water near the Livermore site and in the Livermore Valley were sampled at the locations shown in **Figure 5-5** in 2011. Off-site sampling locations CAL, DEL, DUCK, ALAG, SHAD, and ZON7 are surface water bodies; of these, CAL, DEL, and ZON7 are also drinking water sources. GAS and TAP are drinking water outlets; radioactivity data from these two sources are used to calculate drinking water statistics (see **Table 5-9**).

Samples are analyzed according to written, standardized procedures summarized in Gallegos (2009). LLNL sampled the two drinking water outlets semiannually and the other locations annually in 2011. All locations were sampled for tritium, gross alpha, and gross beta. All analytical results are provided in **Appendix A**, **Section A.7**.

The median activity for tritium in all water location samples was estimated from calculated values to be below the analytical laboratory's minimum detectable activities, or minimum quantifiable activities. The maximum tritium activity detected in any sample collected in 2011 was 0.87 Bq/L 23.5 pCi/L), less than 1% of the drinking water MCL. Median activities for gross alpha and gross beta radiation in all water samples were less than 5% of their respective MCLs. Historically, concentrations of gross alpha and gross beta radiation in drinking water sources have fluctuated around the laboratory's minimum detectable activities. At these very low levels, the counting error associated with the measurements is nearly equal to, or in many cases greater than, the calculated values so that no trends are apparent in the data. The maximum activity detected for gross alpha occurred in a sample collected at ALAG, while the maximum gross beta radioactivity occurred in a sample collected at SHAD. These maximum values (gross alpha at 0.063 Bq/L [1.69 pCi/L] and gross beta at 0.105 Bq/L [2.84 pCi/L]) were still less than 12% and 6% of their respective drinking water MCLs (see **Table 5-9**).

Table 5-9. Radioactivity in surface and drinking waters in the Livermore Valley, 2011.

Location	Metric	Tritium (Bq/L)[a]	Gross alpha (Bq/L)[a]	Gross beta (Bq/L)[a]
All locations	Median	-0.45	0.0186	0.0394
	Minimum	-2.32	-0.0128	-0.0230
	Maximum	0.87	0.0625	0.1050
	Interquartile range	2.18	0.0190	0.0222
Drinking water outlet locations	Median	0.40	0.0197	-0.0193
	Minimum	-1.10	-0.0128	-0.0230
	Maximum	0.87	0.0299	0.0414
	Drinking water MCL	740	0.555	1.85

(a) A negative number means the sample radioactivity was less than the background radioactivity.

(b) The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

5.5.3 Lake Haussmann Monitoring

Lake Haussmann is an artificial water body that has a 45.6 million L (37 acre-feet) capacity. It is located in the central portion of the Livermore site and receives storm-water runoff and treated groundwater discharges. Previous LLNL environmental reports and documents detail the history of the construction and management, the regulatory drivers, sampling requirements, and discharge limits of Lake Haussmann, which was formerly called the Drainage Retention Basin (DRB) (see Harrach et al. 1995, 1996, 1997; Jackson 2002). LLNL collects discharge samples at location CDBX (**Figure 5-2)** and compares them with samples collected at location WPDC to identify any change in water quality. Written, standardized sample collection procedures are summarized in Gallegos (2009). State-certified laboratories analyze the collected samples for chemical, biological, and physical parameters. All analytical results are included in **Appendix A**, **Section A.7**.

The only limit exceeded for samples collected at CDBX and WPDC were two pH discharge limits of 9.1 and 8.6 at CDBX in June and October. Dry season and wet season pH has historically averaged 9.0 and 8.4, respectively. The higher pH readings seen in Lake Haussmann discharge samples during the dry season correspond to the summer algal bloom (i.e., increased photosynthesis) within Lake Haussmann. While some metals were detected, no metals were above discharge limits. All organics and PCBs were below analytical detection limits. Pesticides, gross alpha, gross beta, and tritium levels were well below discharge limits, and acute and chronic toxicity tests were above minimum limits.

5.5.4 Site 300 Drinking Water System Discharges

LLNL currently maintains coverage under General Order R5-2008-0081-025, NPDES Permit No. CAG995001 for occasional large volume discharges from the Site 300 drinking water system that reaches surface water drainage courses. (Prior to 2009, this coverage was provided by the now superseded WDR 5-00-175.) The monitoring and reporting program that LLNL developed for these discharges was approved by the CVRWQCB. Discharges, with the potential to reach surface waters that are subject to these sampling and monitoring requirements are:

- Drinking water storage tank discharges
- System-flush and line-dewatering discharges
- Dead-end flush discharges
- Supply well W-18 intermittent operational discharges

Complete monitoring results from 2011 are detailed in the quarterly self-monitoring reports to the CVRWQCB. During the third quarter of 2011, LLNL conducted routine annual flushing of the drinking water system for water quality purposes. In accordance with the CVRWQCB requirements and the LLNL *Pollution Prevention and Monitoring and Reporting Program* (PPMRP), LLNL monitored one flush per pressure zone of drinking water discharged. All 2011 releases from the Site 300 drinking water system quickly percolated into the drainage ditches or streambed and did not reach Corral Hollow Creek, the potential receiving water.

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6. Terrestrial Monitoring

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Lawrence Livermore National Laboratory monitors several aspects of the terrestrial environment. LLNL measures the radioactivity present in soil, vegetation, and wine, and the absorbed gamma radiation dose at ground-level receptors from terrestrial and atmospheric sources. LLNL also monitors the abundance of distribution of rare plants and wildlife, and tracks the health of special habitats.

The LLNL terrestrial radioactivity monitoring program is designed to measure any changes in environmental levels of radioactivity. All monitoring activities follow U.S. DOE guidance criteria. On-site monitoring activities detect radioactivity released from LLNL that may contribute to radiological dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation.

Terrestrial pathways from LLNL operations leading to potential radiological dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air. Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground-level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota (see **Chapter 7**) is calculated using a screening model that requires knowledge of radionuclide concentrations in soils and surface water.

Sampling for all media is conducted according to written, standardized procedures summarized in Gallegos (2009).

In addition to terrestrial radioactivity monitoring, LLNL monitors the abundance, distribution, and ecological requirements of plant and wildlife species, and conducts research relevant to the protection of rare plants and animals. Monitoring and research of biota on LLNL property is conducted to ensure compliance with requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and other applicable regulations as they pertain to endangered, threatened, and other special status species, their habitats, and designated critical habitats that exist at both LLNL sites.

6.1 Soil Monitoring

The number of soil sampling locations is as follows:

Livermore site—7 (see **Figure 6-1**)

Livermore Valley—10, including 3 at the LWRP (see **Figure 6-2**)

Site 300—12 (see **Figure 6-3**)

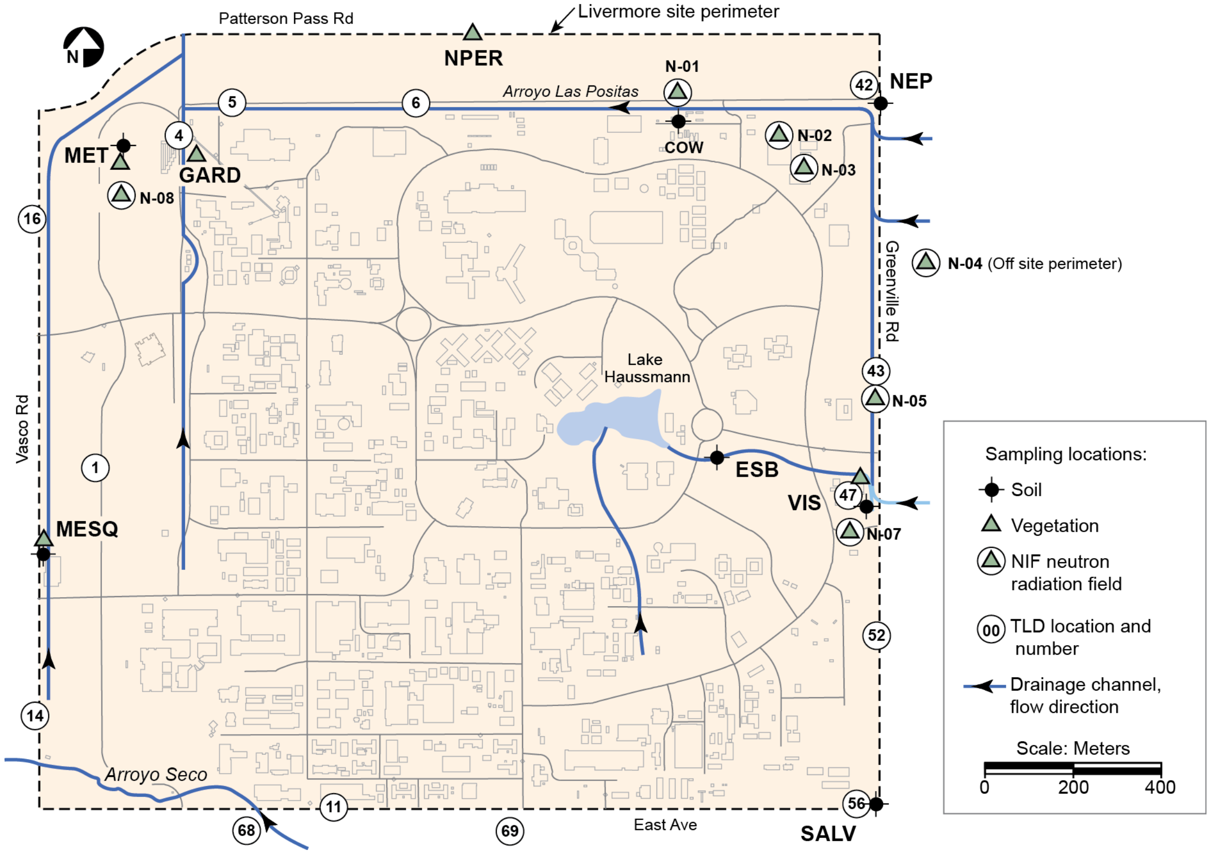

Figure 6-1. Soil and vegetation sampling locations and TLD locations, Livermore site, 2011.

These locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas with the potential to be affected by LLNL operations. Sampling locations also include areas with known contaminants, such as the LWRP and around explosives testing areas at Site 300.

Surface soil samples are collected from the top 5 cm of soil because aerial deposition is the primary pathway for potential contamination, and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations. Two 1-m squares are chosen from which to collect the sample. Each sample is a composite consisting of 10 subsamples that are collected at the corners and center of each square by an 8.25-cm-diameter, stainless-steel core sampler.

Additional samples are collected for tritium, gross alpha, gross beta, and metals analyses. At one of the subsample locations, a 15-cm deep sample is taken for tritium analysis; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis. Vadose zone samples are collected at the same location as the tritium subsample but at increased depths. A 45- to 65-cm deep sample is also collected at location ESB for analysis for PCBs.

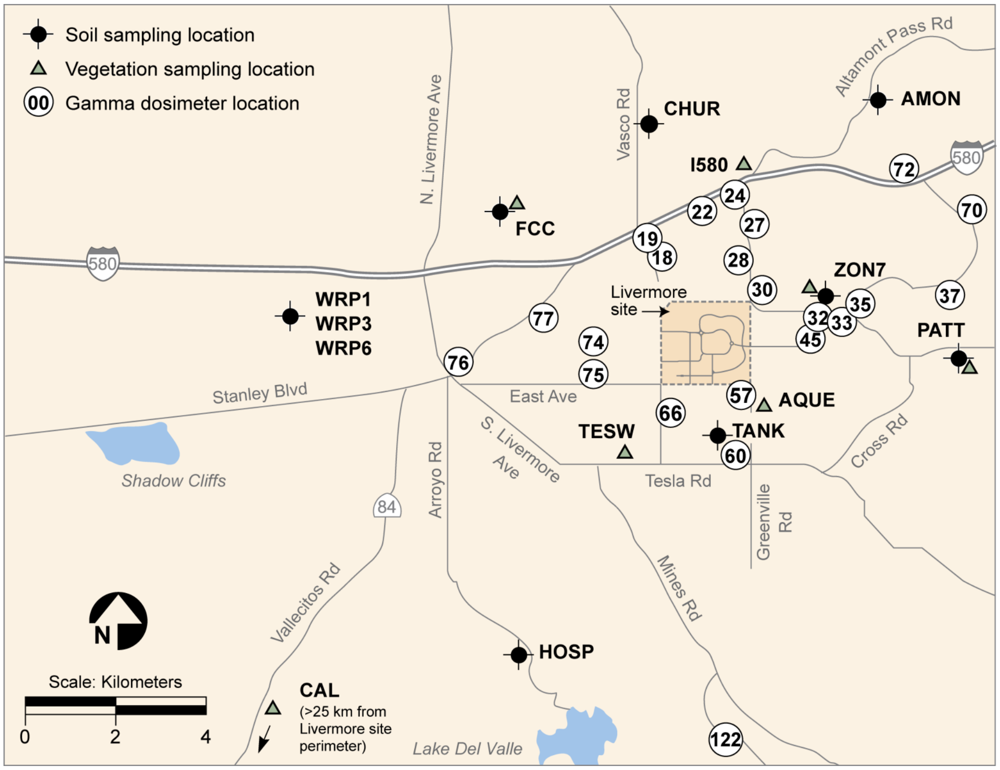

Figure 6-2. Soil and vegetation sampling locations and TLD locations, Livermore Valley, 2011.

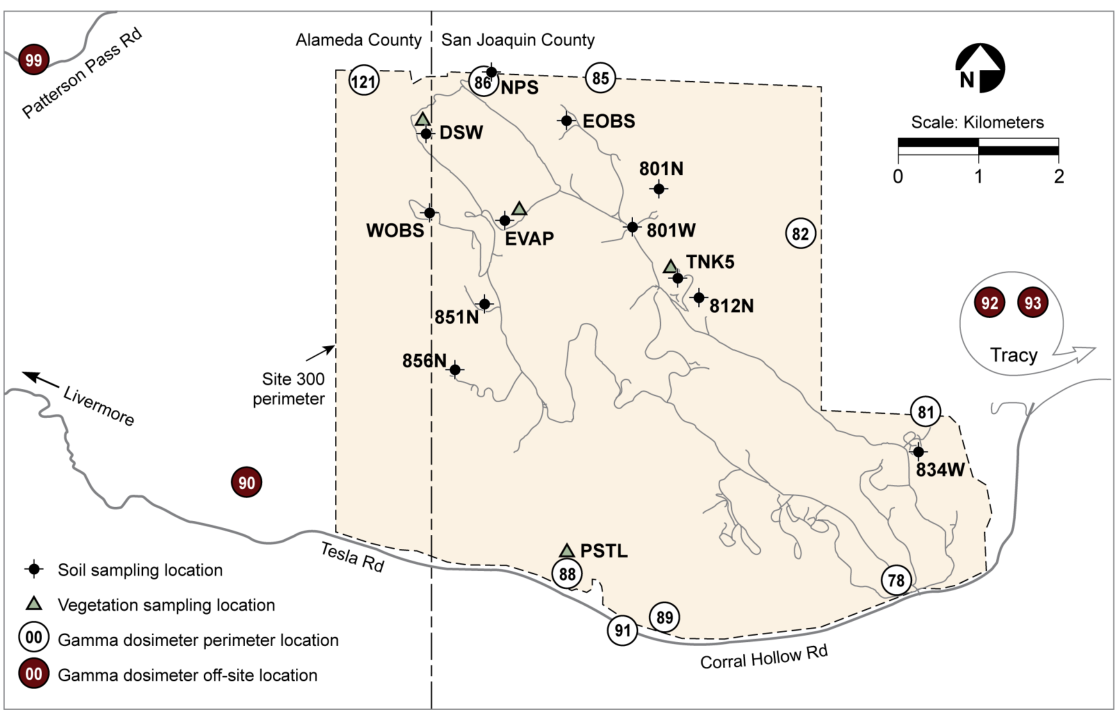

Figure 6-3. Soil and vegetation sampling locations and TLD locations, Site 300 and off-site, 2011.

In 2011, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides; samples at selected locations were analyzed for tritium, gross alpha, and gross beta. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium.

Prior to radiochemical analysis, the surface soil is dried, sieved, ground, and homogenized. The plutonium content of a 100-g sample aliquot is determined by alpha spectrometry. Other sample aliquots (300 g) are analyzed by gamma spectrometry using a high-purity germanium (HPGe) detector for 47 radionuclides, including fission products, activation products from neutron interactions on steel, actinides, and natural products. Tritium is analyzed by liquid scintillation counting. For beryllium, 10-g subsamples are analyzed by atomic emission spectrometry. Standard EPA methods are used to analyze soil samples for PCBs.

6.1.1 Radiological Monitoring Results

The 2011 data on the concentrations of radionuclides in surface soil from the Livermore Valley sampling locations are provided in **Appendix A**, **Section A.8**.

The concentrations and distributions of all observed radionuclides in soil for 2011 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Slightly higher values at and near the Livermore site have been attributed to historical operations (Silver et al. 1974), including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant of the site. LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste. Sampling at location ESB, which is in the drainage area for the southeast quadrant of the Livermore site, shows the effects of the historical operation of solar evaporators. The measured value for plutonium-239+240 at this location in 2011 was 1.50 mBq/dry g (5.6×10^{-2} pCi/dry g). Elevated levels of plutonium-239+240 resulting from an estimated 1.2×10^{9} Bq (32 mCi) plutonium release to the sanitary sewer in 1967 and earlier releases were again detected at LWRP sampling locations in 2011. The highest detected plutonium-239+240 value at the LWRP in 2011 was 8.3 mBq/dry g (2.2×10^{-1} pCi/dry g). In addition, americium-241 was detected in one LWRP sample at a concentration of 2.9 mBq/dry g (7.8×10^{-1} pCi/dry g) and was most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in these historical releases to the sewer.

The highest detected value for tritium in 2011 (10.0 Bq/L [270 pCi/L]) was at location ESB, which is downwind of the Tritium Facility. This value is consistent with measured tritium emissions associated with the Tritium Facility's operations, as described in **Chapter 4**. All tritium concentrations were within the range of previous data.

The soils data for Site 300 for 2011 are provided in **Appendix A**, **Section A.8**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2011 lie within the ranges reported in all years since monitoring began. At the majority of the sampling locations, the ratio of uranium-235 to uranium-238 reflects the natural ratio of 0.00725. There is significant uncertainty in calculating the ratio, however, due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. In 2011, the highest measured values for uranium-235 and uranium-238 in a single sample were 0.25 µg/g (0.020 Bq/g or 0.5 pCi/g) and 120 µg/g (1.5 Bq/g or 40 pCi/g), respectively. The uranium-235 to uranium-238 ratio in this sample is 0.0021, which at the levels of uncertainty associated with the analysis, equals the ratio for depleted uranium of 0.002. Such values at Site 300 result from the use of depleted uranium in explosive experiments.

6.1.2 Nonradiological Monitoring Results

Nonradiological monitoring is limited to constituents of concern such as PCBs and beryllium. Samples taken at the Livermore site location ESB are analyzed for PCBs, and samples from Site 300 locations are analyzed for beryllium.

Aroclor 1260, a PCB, has been detected at location ESB since surveillance for PCBs began at this location in 2000. In 2011, samples analyzed for PCBs were found to be below regulatory reporting limits. The presence of PCBs suggests residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see **Chapter 5**). The previously detected concentrations are below the federal and state hazardous waste limits. LLNL will continue to consistently monitor for one more year, unless the results continue to be below the regulatory reporting limits, at which time the need for PCB monitoring will be reassessed.

Beryllium results for soils at Site 300 were within the ranges reported since sampling began in 1991. The highest value in 2011, 5.9 mg/kg, was found in an area that has historically been used for explosives testing. This value is much lower than the 110 mg/kg detected in 2003. The differing results reflect the particulate nature of the contamination.

6.1.3 Environmental Impact on Soil

6.1.3.1 Livermore Site

Routine surface soil sample analyses indicate that the impact of LLNL operations on this medium in 2011 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations or in trace amounts or could not be measured above detection limits.

The highest value for plutonium-239+240 in 2011 (8.3 mBq/dry g [0.22 pCi/dry g]), measured at LWRP, is 1.8% of the National Council on Radiation Protection (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999).

LLNL has investigated the presence of radionuclides in local soils frequently over the years including possible impacts of the distribution to the public of sludge contaminated by the 1967 plutonium release (see Table 6-5 in the *Environmental Report 2006* [Mathews et al. 2007] for a list of previous studies). The studies have consistently shown that the concentrations of radionuclides in local soils are below levels of health concern. In fact, the concentrations are of such low levels of health concern that the Agency for Toxic Substances and Disease Registry

(ATSDR) (2003) strongly recommended against further study of local soils for the purpose of identifying locations where plutonium-contaminated sludge from the 1967 release may remain.

6.1.3.2 Site 300

The concentrations of radionuclides and beryllium detected in soil samples collected at Site 300 in 2011 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occurred near the firing tables. They result from the fraction of the firing table operations that disperse depleted uranium. The highest measured uranium-238 concentration was 120 µg/g (1.5Bq/g or 40 pCi/g) and was well below the NCRP-recommended screening level for commercial sites (313 µg/g [3.9 Bq/g or 105 pCi/g]). These values occurred near Bunker 812 and are a result of historic operations at that location. In 2008, a Remedial Investigation/Feasibility Study was submitted for the Building 812 operating unit (OU) (Taffet et al. 2008). This Investigation/Feasibility Study specifies the nature and extent of contamination, risk assessment, and remedial alternatives for CERCLA cleanup of the site (see **Chapter 8**). Cleanup remedies to address soil and groundwater contamination in the Building 812 OU are being negotiated with the regulatory agencies.

6.2 Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore site (see **Figure 6-1**) and in the Livermore Valley (see **Figure 6-2**) are divided for comparison into the following three groups:

- Near locations (AQUE, GARD, MESQ, NPER, MET, and VIS) are on-site or less than 1 km from the Livermore site perimeter.
- Intermediate locations (I580, PATT, TESW, and ZON7) are in the Livermore Valley and 1 to 5 km from the Livermore site perimeter.
- Far locations (FCC and CAL) are more than 5 km from the Livermore site perimeter; FCC is about 5 km away and CAL is more than 25 km away. Both locations are generally upwind of the Livermore site.

Tritium in vegetation due to LLNL operations is most likely to be detected at the Near and Intermediate locations and is highly unlikely to be detected at the Far locations.

Site 300 has four monitoring locations for vegetation (PSTL, TNK5, DSW, and EVAP) (see **Figure 6-3**). Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to occasional uptake of contaminated groundwater by the roots. At the other two locations, TNK5 and PSTL, the only likely potential source of tritium uptake is the atmosphere, although groundwater in the vicinity of PSTL is contaminated with low levels of tritium.

Vegetation is sampled and analyzed quarterly. Water is extracted from vegetation by freeze-drying and analyzed for tritiated water (HTO) using liquid scintillation techniques.

Wines for sampling in 2011 were purchased from a supermarket in Livermore. The wines represent the Livermore Valley, two other regions of California, and the Rhone Valley in France. Wines were prepared for sampling using a method that separates the water fraction from the other components of the wine and were analyzed using an ultra-low-level scintillation counter.

6.2.1 Vegetation Monitoring Results

Median and mean concentrations of tritium in vegetation based on samples collected at the Livermore site, in the Livermore Valley, and Site 300 in 2011 are shown in **Table 6-1**. (See **Appendix A**, **Section A.9**, for quarterly tritium concentrations in plant water). The highest mean tritium concentration for 2011 was 9.9 Bq/L at the Near location VIS located on the east-central perimeter of the Livermore site. For Site 300, the highest mean concentration for 2011 was 140 Bq/L at EVAP located in an area where the groundwater is contaminated with tritium.

Median concentrations of tritium in vegetation at sampling locations at the Livermore site and in the Livermore Valley have decreased noticeably since 1989 (see **Figure 6-4**). Median concentrations at the Far locations have been below the detection limit of approximately 2.0 Bq/L since 1993. Median concentrations at the Intermediate locations have been below the detection limit since 1998, except in 2002 when the median concentration was 2.3 Bq/L. Median concentrations at the near locations have been at or slightly above the detection limit since 2003.

At Site 300, the median concentrations of tritium in vegetation at locations PSTL and TNK5 were below the detection limit. The median concentrations of tritium in vegetation at DSW and EVAP were 5.4 Bq/L and 120 Bq/L, respectively.

6.2.2 Wine Monitoring Results

Tritium concentrations in wines purchased in 2011 are shown in **Table 6-2**. The highest concentration in a Livermore Valley wine is 3.6 Bq/L (98 pCi/L) from a wine made from grapes harvested in 2008. The highest concentration in a California (other than the Livermore Valley) wine is 1.2 Bq/L (33 pCi/L) from a wine made from grapes harvested in 2010. The highest concentration in a Rhone Valley (France) wine is 3.3 Bq/L (90 pCi/L) from a wine made from grapes harvested in 2007.

Analysis of the wines purchased annually since 1977 have demonstrated the following relationship between the Livermore Valley, California, and the Rhone Valley wines: Tritium concentrations in the Rhone Valley wines are typically higher than tritium concentrations in the Livermore Valley wines. Tritium concentrations in the California (other than the Livermore Valley) wines are typically lower than tritium concentrations in the Livermore Valley wines.

Table 6-1. Median and mean concentrations of tritium in plant water for the Livermore site, Livermore Valley, and Site 300 sampled in 2011. The table includes mean annual ingestion doses calculated for 2011.

Sampling locations		Concentration of tritium in plant water (Bq/L) Median	Mean	Mean annual ingestion dose[(a)] (nSv/y)
NEAR (on-site or <1 km from Livermore site perimeter)	AQUE	2.8	3.3	16
	GARD	5.2	4.3	21
	MESQ	4.5	6.4	31
	MET	3.5	5.0	25
	NPER	4.2	3.3	16
	VIS	9.7	9.9	49
INTERMEDIATE (1–5 km from Livermore site perimeter)	I580	1.4	2.4	12
	PATT	1.4	1.7	<10[(b)]
	TESW	1.5	1.4	<10[(b)]
	ZON7	2.4	3.6	18
FAR (>5 km from Livermore site perimeter)	CAL	0.050	0	<10[(b)]
	FCC	0.17	0.41	<10[(b)]
Site 300	DSW[(c)]	5.4	5.2	[(d)]
	EVAP[(c)]	120	140	[(d)]
	PSTL	0.59	23	[(d)]
	TNK5	0.78	0.88	[(d)]

(a) Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 6-3**.

(b) When concentrations are less than the detection limit (about 2.0 Bq/L), doses can only be estimated as being less than the dose at that concentration.

(c) Plants at these locations are rooted in areas of known subsurface contamination.

(d) Dose is not calculated because there is no pathway to dose to the public.

The Livermore Valley wines represent vintages from 2004, 2007, 2008, 2009 and 2010; the California wines represent vintages from 2010; and the Rhone Valley wines represent vintage from 2007 and 2009. Tritium concentrations must be decay-corrected to the year of harvest to correlate with tritium concentrations in air and soil to which the grape was exposed. In 2011, decay-corrected concentrations for Livermore Valley wine samples ranged from 0.91 to 4.4 Bq/L; for the two California wine samples, 1.0 and 1.3 Bq/L; and for the two Rhone Valley wine samples, 2.2 and 4.3 Bq/L.

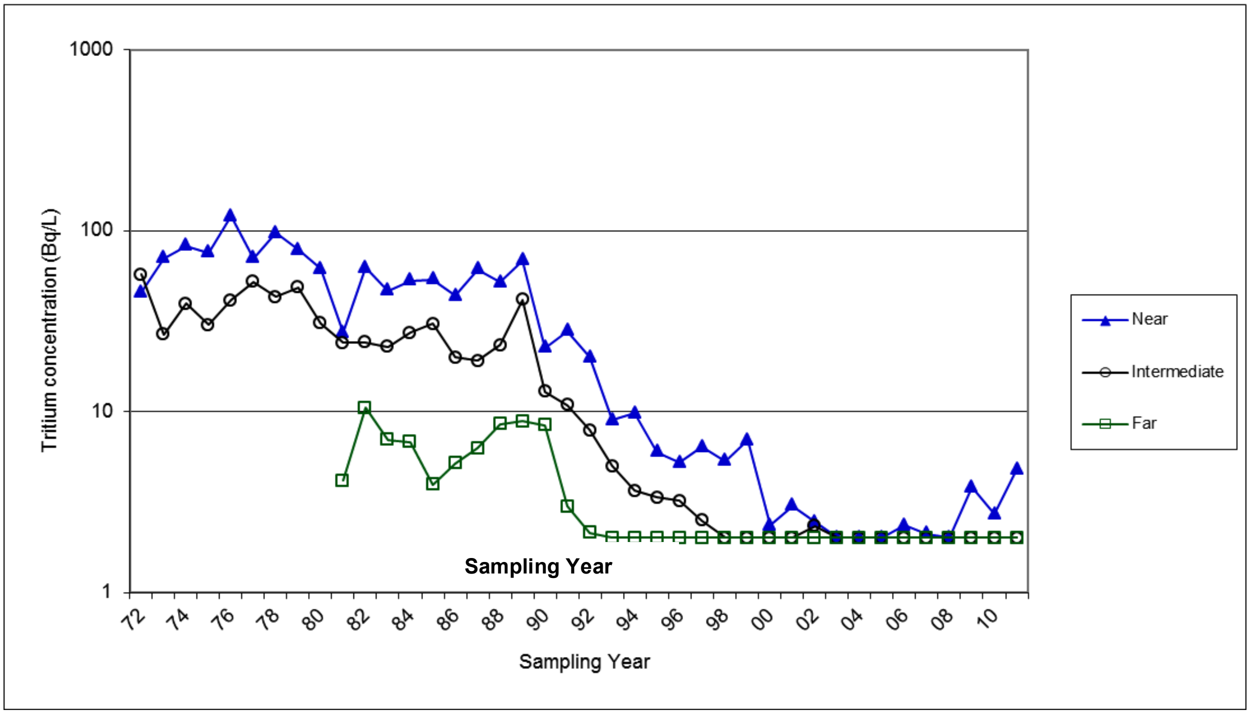

Figure 6-4. Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2011.

Table 6-2. Tritium in retail wine, 2011[a, b].

Sample	Concentration by area of production (Bq/L)		
	Livermore Valley	California	Europe
1	1.3 ± 1.6	0.92 ± 1.6	3.3 ± 1.8
2	2.6 ± 1.7	1.2 ± 1.6	1.9 ± 1.7
3	0.71 ± 1.6		
4	1.2 ± 1.7		
5	3.6 ± 1.8		
6	2.0 ± 1.7		
Dose (nSv/y)[c]	4.4	1.5	4.0

(a) Radioactivity is reported here as the measured concentration and an uncertainty (±2σ counting error).

(b) Wines from a variety of vintages were purchased and analyzed for the 2011 sampling. Concentrations are those measured in April 2012.

(c) Calculated based on consumption of 52 L wine per year at maximum concentration. Doses account for contribution of OBT as well as of HTO.

6.2.3 Environmental Impact on Vegetation and Wine

6.2.3.1 Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 6-1**. These hypothetical doses, from ingestion of HTO in vegetables, milk, and meat, were calculated from annual mean measured concentrations of HTO in vegetation using the transfer factors from **Table 6-3** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). The hypothetical annual ingestion dose, based on the highest observed mean HTO concentration in vegetation for 2011, was 49 nSv (4.9 µrem).

Table 6-3. Bulk transfer factors used to calculate inhalation and ingestion doses (in µSv) from measured concentrations in air, vegetation, and drinking water.

Exposure pathway	Bulk transfer factors[(a)] times observed mean concentrations
Inhalation and skin absorption	0.21 x concentration in air (Bq/m^3)
Drinking water	0.013 x concentration in drinking water (Bq/L)
Food ingestion	0.0049 x concentration in vegetation (Bq/kg); factor obtained by summing contributions of 0.0011 for vegetables, 0.0011 for meat and 0.0027 for milk

(a) See Sanchez et al. (2003), Appendix C, for the derivation of bulk transfer factors.

Doses calculated based on Regulatory Guide 1.109 neglect the contribution from organically bound tritium (OBT). However, according to a panel of tritium experts, "the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this" (ATSDR 2002, p. 27). Thus, the maximum estimated ingestion dose from LLNL operations for 2011, including OBT, is 98 nSv/y (9.8 µrem/y). This maximum dose is about 1/31,000 of the average annual background dose in the United States from all natural sources and about 1/100 the dose from a panoramic dental x-ray.

Ingestion doses of Site 300 vegetation were not calculated because neither people nor livestock ingest vegetation at Site 300.

6.2.3.2 Wine

For Livermore Valley wines purchased in 2011, the highest concentration of tritium (3.6 Bq/L [98 pCi/L]) was just 0.49% of the EPA's standard for maximal permissible level of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Drinking one liter per day of the Livermore Valley wine with the highest concentration purchased in 2011 would have resulted in a dose of 31 nSv/y (3.1 µrem/y). A more realistic dose estimate, based on moderate drinking (one liter per week) [(1)]

(1) Moderate consumption is higher than the average consumption of wine in California (15.7 L/yr) (Avalos 2005).

at the mean of the Livermore Valley wine concentrations (1.9 Bq/L [51 pCi/L]) would have been 2.3 nSv/y (0.23 µrem/y). Both doses explicitly account for the added contribution of OBT. (2)

The potential dose from drinking Livermore Valley wines in 2011, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/330 of a single dose from a panoramic dental x-ray.

6.3 Ambient Radiation Monitoring

LLNL's ambient radiation monitoring program is designed to monitor for any changes in the natural radiation field that may be attributable to LLNL operations. By sampling at enough locations in the surrounding community, the variance in the natural background from season to season and the variance from location to location is measured and compared to a five-year trend. The long-term trend analysis allows any radiation field effects from operations to be readily recognized. Evaluation of long-term averages reduces the effects of uncontrollable variance due to seasonal effects.

Changes to the TLD network for 2011 include the addition of eight background locations for the National Ignition Facility (NIF) neutron radiation field. Locations for these dosimeters are shown in **Figure 6.1**, designated by N-# e.g., N-01. Data from these dosimeters were below detection limits of this dosimeter type of 100 µSv (10 mrem). NIF TLDs are deployed monthly.

6.3.1 Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter that absorbs it. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thulium-activated calcium sulfate ($CaSO_4$: Tm), to measure environmental gamma exposure.

The Panasonic UD-810 contains two-elements of lithium borate ($^{7}Li_2{}^{11}B_4O_7$), one-element of lithium borate ($^{6}Li_2{}^{10}B_4O_7$), and one-element of $CaSO_4$: Tm. This composition with lead filtration is specially designed to absorb the energy of slow-neutrons. With a 10-mR sensitivity, locations sited for this network include both near-field and far-field locations. Packaging of the dosimeters is done as described below for the rest of the TLD network, with the exception that the dosimeter once sealed in the Mylar protective package is submersed in a water bath. This enables Fast-neutrons of energy ranging greater than (>) 0.5 MeV to be absorbed by the hydrogen in water to thermal-neutron energy range of 0.025 eV to 0.1 eV obtaining thermal equilibrium with their surroundings. The ^{10}B composition has a very high neutron capture cross-section of 3837 barn (which thereby increases the geometric target nuclei probability of the (n,α) ^{7}Li reaction), 1 barn = 1×10^{-24} cm^2.

The TLD measurements are corrected in the following way for reporting: the results of the TLD measurement process are normalized to 90-day quarters from their actual exposure period, and

(2) Dose from wine was calculated based on the measured concentration of HTO multiplied by 1.3 to account for the potential contribution of OBT that was removed so that the tritium in wine could be counted using liquid scintillation counting. The dose coefficient for HTO is 1.8 x 10^{-11} Sv/Bg per the International Commission on Radiological Protection (1996).

the measurement units are converted from absorbed exposure units to reported dose units. These corrections allow the TLDs measurements to be representative of external exposure to the public at these sample locations. Comparisons are made for LLNL perimeter locations to those of the Livermore Valley (background locations) for the purposes of determining an elevated radiation field. This is similarly done for Site 300 and its nearby locations.

TLD crystals absorb ionizing energy by trapping this energy. A solid-state physical process controls the energy trapping during crystal ionization. Electron–hole (vacancy) pairs are created in the crystal lattice, trapping this absorbed energy in the crystal's excited state. The absorbed energy released in the form of light emission upon heating in the reading process is proportional to the TLD's absorbed dose. Comparative dose is reported relative to the calibrated standard of cesium-137 gamma energy of 662 keV. The calculated result of the TLD exposure is then reported in the SI unit of sievert (Sv) from the measured dose in milliroentgen (mR).

In order to see any deviation in the dose trend over a five-year period, each site-wide location quarterly average is plotted for each year. These site-wide quarterly averages for each year are shown with their respective five-year average and associated error (the measured location's quarterly average is the average of the four quarterly measurements; and the site-wide quarterly average is the average of all the location quarterly averages).

The results of these comparisons of the Livermore Site to Livermore Valley and Site 300 to the Site 300 Vicinity, (which includes the City of Tracy), are shown in **Figure 6-5.**

A true representation of local site exposure and any dose contribution from LLNL operations is obtained through a quarterly deployment cycle. TLDs are deployed at a height of 1 m, adhering to regulatory guidance.

For the purpose of reporting comparisons, data are reported as a "standard 90-day quarter" with the dose reported in millisievert (mSv; 1 mSv = 100 mrem).

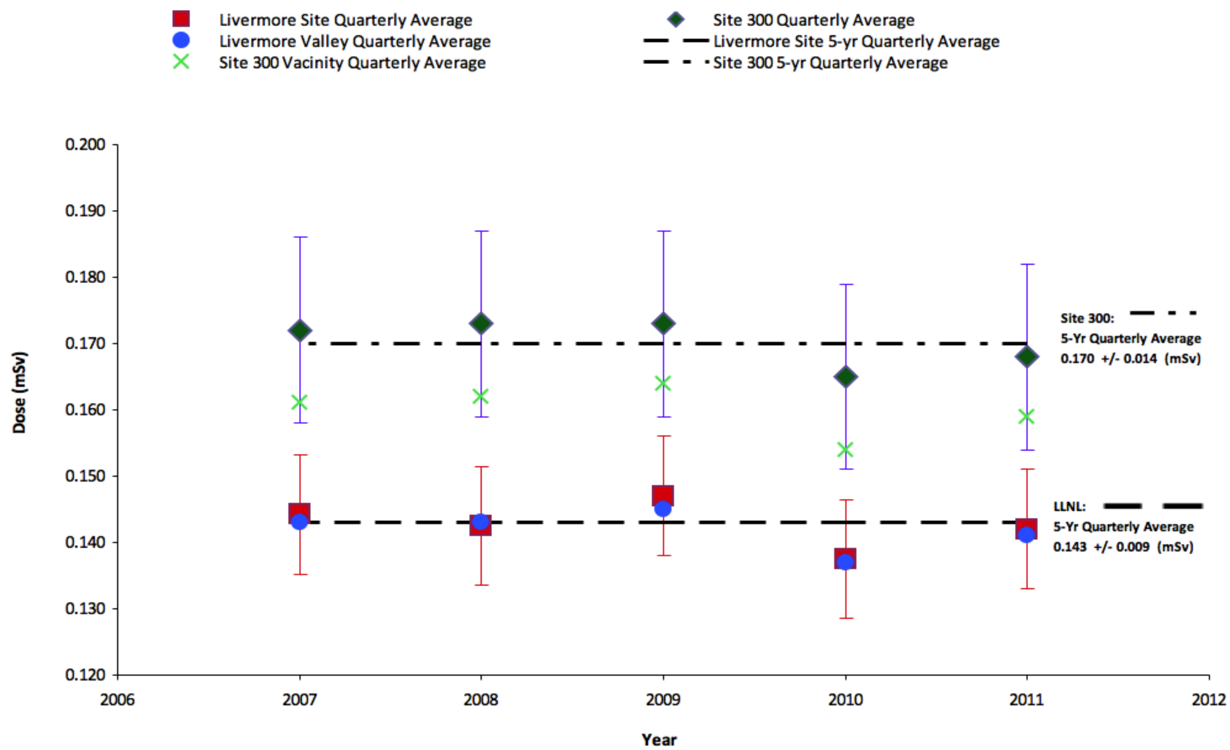

Figure 6-5. Comparison of the five year consecutive quarterly average dose (mSv) is plotted for each year from 2007 through 2011 for the Livermore Site and Livermore Valley and Site 300 and Site 300 vacinity with the average five year quarterly dose and standard deviation of the data set. Error bars represent the five-year standard deviation and are centered on the individual quarterly averages for the given year.

6.3.2 Monitoring Results

Figure 6-5 represents the average quarterly dose (in mSv) for the recent five-year period for the Livermore site perimeter, Livermore Valley, Site 300 and Site 300 environs. Tabular data for each sampling location are provided in **Appendix A**, **Section A.9**.

The difference in the doses at the Livermore site perimeter, Livermore Valley, and Site 300 can be attributed directly to the difference in the geological substrates. The Neroly Formation in the region around Site 300 contains higher levels of naturally occurring thorium that provides the higher external radiation dose.

6.3.3 Environmental Impact from Laboratory Operations

There is no increased ambient radiation field produced as a direct result of LLNL operations for 2011 as measured by this network. Radiation dose trends remain consistent with annual average levels for each sample location and synonymous to natural background levels. As depicted in **Figure 6-5**, the annual average gamma radiation dose for the LLNL site perimeter and the Livermore Valley from 2007 to 2011 are statistically equivalent and show no discernible impact due to operations conducted at LLNL.

6.4 Special Status Wildlife and Plants

Special status wildlife and plant monitoring at LLNL focuses on species considered to be rare, threatened, or endangered (including species listed under the federal or California Endangered Species Acts); species considered of concern by the California Department of Fish and Game [CDFG] and the USFWS; and species that require inclusion in NEPA.

The California red-legged frog (*Rana draytonii*), a threatened species, is known to occur at the Livermore site (see **Figure 6-6**). Because California tiger salamanders (*Ambystoma californiense*) have been observed within 1.1 km of the Livermore site, portions of the Livermore site are considered potential upland habitat for the California tiger salamander. There is no occupied or potential breeding habitat for the California tiger salamander at the Livermore site.

Five species that are listed under the federal ESAs are known to occur at Site 300—the California tiger salamander, California red-legged frog, Alameda whipsnake (*Masticophus lateralis euryxanthus)*, valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and the large-flowered fiddleneck (*Amsinckia grandiflor*a). Although there are no recorded observations of the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*) at Site 300, this species is known to have historically occurred in the adjacent Carnegie and Tracy Hills areas (USFWS 1998). Because of the proximity of known observations of San Joaquin kit fox to Site 300, it is necessary to consider potential impacts to San Joaquin kit fox during activities at Site 300. California threatened Swainson's Hawks (*Buteo swainsoni*) and California-endangered Willow Flycatchers (*Empidonax traillii*) have also been observed at Site 300.

Known observations of the five listed species and two California Species of Special Concern (Western Burrowing Owl [*Athene cunicularia*] and Tricolored Blackbird [*Agelaius tricolor*]) are shown in **Figures 6-7** and **6-8**. Vertebrate species and rare invertebrate species known to occur at Site 300, including state and federally listed species and other species of special concern are listed in **Appendix C**. A similar list has not been prepared for the Livermore site.

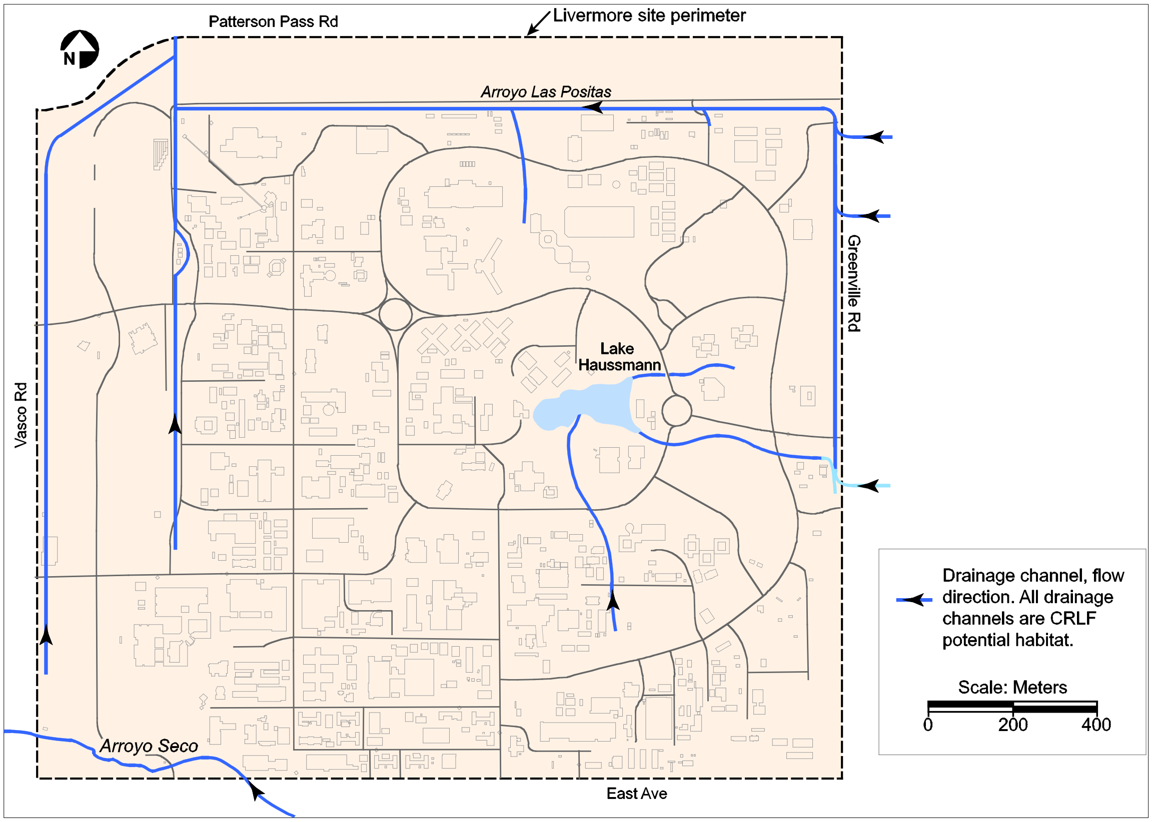

Figure 6-6. Potential California red-legged frog habitat, Livermore site, 2011.

Including the federally endangered large-flowered fiddleneck, four rare plant species and four uncommon plant species are known to occur at Site 300. The four rare species—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*), the round-leaved filaree *(California macrophylla),* and the diamond-petaled California poppy (*Eschscholzia rhombipetala*)—are included in the California Native Plant Society (CNPS) List 1B (CNPS 2009). These species are considered rare and endangered throughout their range. The location of these four rare plant species at Site 300 is shown in **Figure 6-8**.

The four uncommon plant species—the gypsum-loving larkspur (*Delphinium gypsophilum* subsp. *gypsophilum*), California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperevax caulescens*)—are all included on the CNPS List 4 (CNPS 2009). Past surveys have failed to identify any rare plants on the Livermore site (Preston 1997, 2002).

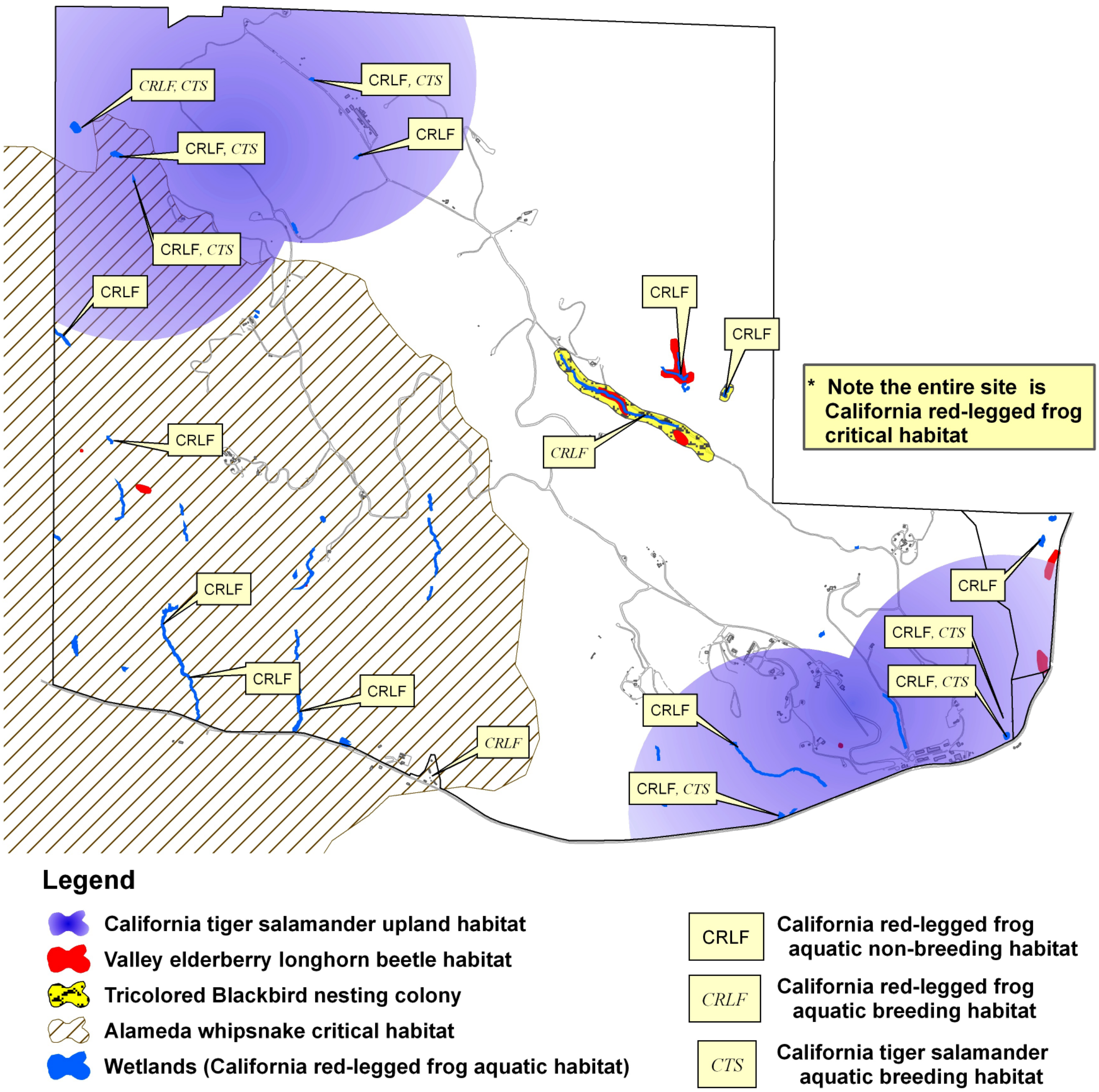

Figure 6-7. Distribution of special status wildlife, Site 300, 2011.

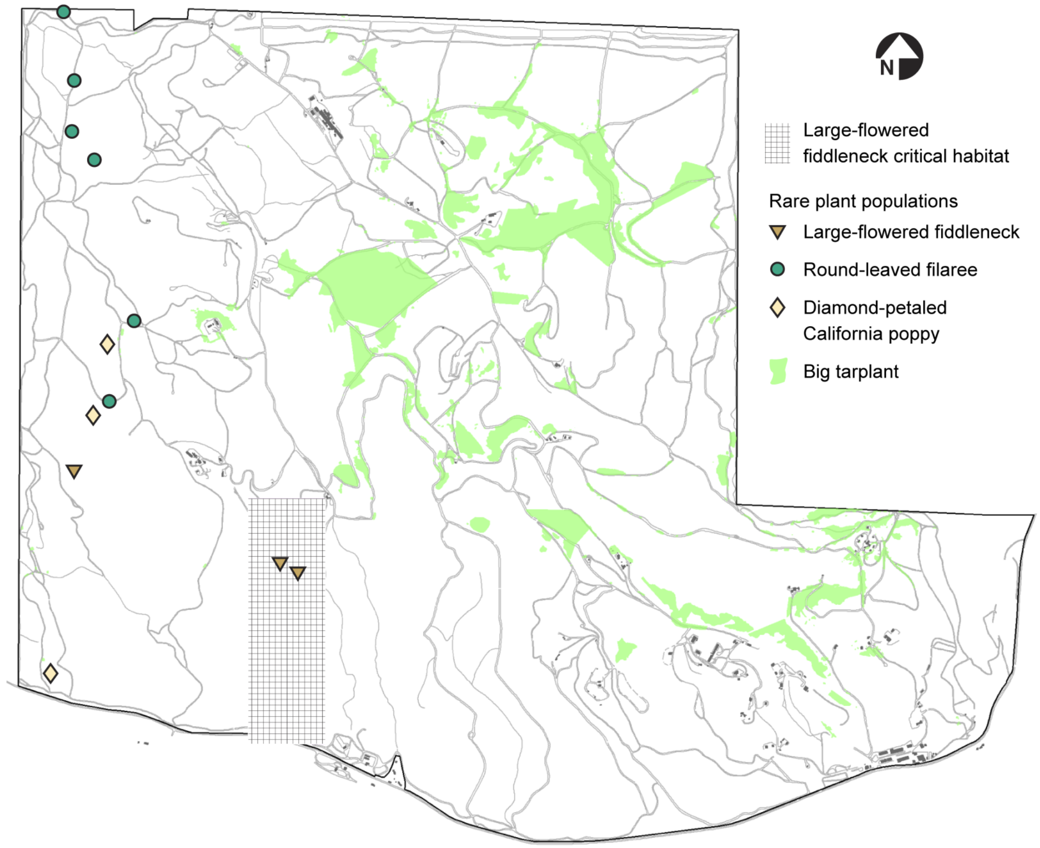

Figure 6-8. Distribution of special status plants, Site 300, 2011.

6.4.1 Compliance Activities

6.4.1.1 Habitat Enhancement Projects

In late August 2005, LLNL implemented a habitat enhancement project for California red-legged frogs at Site 300 in accordance with a 2002 USFWS biological opinion (BO) and ACOE and RWQCB permits. California red-legged frogs were translocated to the new habitat enhancement pools in February and March of 2006. Monitoring demonstrated that California red-legged frogs successfully reproduced in these pools in 2006, 2007, 2008, 2009, and 2011.

In fall 2005, a depression in the northwest corner of Site 300 (Pool M2) was deepened and expanded to serve as mitigation for California tiger salamander habitat lost as a result of closing two man-made, high explosives rinse water ponds in the Process Area. In 2006, California tiger salamanders successfully reproduced in this pool. In 2007, 2008, and 2009 the pool received inadequate inundation and evaporated before the salamander larvae could reach maturity and leave the pool. In 2010 and 2011, Pool M2 did fill and California tiger salamanders were able to successfully reproduce at this location.

In 2006, LLNL completed culvert replacement projects at two Site 300 locations (the Oasis and Round Valley) where unpaved fire trails cross-intermittent drainages. The Round Valley project included the creation of a pool upstream of the project area in part as mitigation for the impacts at the Oasis site and to serve as enhanced habitat for amphibian species. These projects were completed under the USFWS BO for maintenance and operations of Site 300 and ACOE and RWQCB permits. The Round Valley pool did not receive enough water during the 2007 through 2011 winters to pool and afford potential breeding habitat for amphibians.

6.4.1.2 2011 Livermore Site Drainage Channel Maintenance

In July and August of 2011, drainage channel maintenance was completed in four artificial drainages at the Livermore site. This work involved removing vegetation and sediment from the channels using and excavator equipped with a clamshell bucket. Service Approved Biologists conducted pre-activity surveys at all work sites and monitored all in-channel work.

This work was conducted under the requirements of the *Arroyo Maintenance Project on Arroyo las Postias at Lawrence Livermore National Laboratory Biological Opinion* (Service File Number 1-1-97-0173) and the associated Incidental Take Statement.

A total of 40 California red-legged frogs were safely relocated from the project sites to suitable habitat on site in Arroyo las Positas and the habitat enhancement pool portion of Lake Haussmann. Most of these frogs were found while clearing vegetation by hand prior to the use of heavy equipment. No California red-legged frogs were injured or killed during this work.

6.4.2 Invasive Species Control Activities

Invasive species control is an important part of LLNL’s effort to protect special status species at both sites. Prevention of the downstream dissemination of invasive species is also important to protect native species throughout our region. The bullfrog *(Lithobates catesbeiana)* is a significant threat to California red-legged frogs at the Livermore site, and the feral pig (*Sus scrofa*) threatens California red-legged frog habitat at Site 300. The exotic fish, largemouth bass *(Micropterus salmoides),* has also historically occurred in Lake Haussmann at the Livermore site.

At the Livermore site, bullfrog control measures were implemented between May and September of 2011. Bullfrog control measures included dispatching adults and removing egg masses in Lake Haussmann and Arroyo Las Positas. To remove bullfrog tadpoles and invasive fish, the LLNL reach of Arroyo Las Positas was allowed to dry out in October of 2011 by temporarily halting groundwater discharges to the arroyo.

6.4.3 Surveillance Monitoring

6.4.3.1 Wildlife Monitoring and Research

Nesting Bird Surveys. LLNL conducts nesting bird surveys to ensure LLNL activities comply with the Migratory Bird Treaty Act and do not result in impacts to nesting birds. White-tailed Kites frequently nest in the trees along the north, east, and south perimeters of the Livermore site.

California Red-Legged Frog Nocturnal Surveys. LLNL continued nocturnal visual surveys for California red-legged frogs in Lake Haussmann and Arroyo las Postias. No egg masses were observed in Arroyo Las Positas in 2011. Although, no egg masses were observed in the Habitat Enhancement portion of Lake Haussmann in 2011, several newly metamorphosed California red-legged frogs were observed in the Habitat Enhancement Pool and nearby areas indicating that California red-legged frogs did successfully breed in Lake Haussmann or the Habitat Enhancement Pool in 2011.

6.4.3.2 Rare Plant Research and Monitoring

Large-Flowered Fiddleneck. This species is currently known to exist naturally in only two locations—at the Site 300 Drop Tower and on nearby conservation property owned by the Contra Costa Water District. A third population occurs in Draney Canyon at Site 300, but no large-flowered fiddleneck have been observed at this location since a landslide that occurred at the population site in 1997. The Drop Tower native population contained no large-flowered fiddleneck plants in 2011.

LLNL established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. LLNL maintains the experimental population by periodically planting large-flowered fiddleneck seeds in established plots within the population. The size of the experimental population fluctuates as a result of these seed bank enhancement efforts.

In December of 2010, 100 large-flowered fiddleneck seeds were planted in each of the 11 plots in the experimental population, and the experimental population contained 215 large-flowered fiddleneck plants at flowering (April) of 2011. These plants are a result of seeds produced from plants present in the population in 2010 and previous years and the 2010 seed bank enhancement efforts.

Big Tarplant. The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September through November of 2011. It is estimated that between 6,700 and 29,000 individual big tarplants occurred at Site 300 in 2011. While this species is extremely rare throughout its range, it can be abundant at Site 300, especially in or near areas where prescribed burns are routinely conducted and where wildfires have occurred. As is typical with annual plant species, the abundance of big tarplant varies greatly between years depending on environmental conditions. For example in 2009, the Site 300 big tarplant population was estimated to contain no more than 22,000 individual plants while up to 214,000 big tarplants were found at Site 300 in 2010.

Diamond-Petaled California Poppy. Although the species is not listed under the federal or California ESAs, it is extremely rare and is currently known to occur only at Site 300 and in one location in San Luis Obispo County. Currently three populations of this species are known to occur at Site 300; these population locations are referred to as Site 1, Site 2, and Site 3. The most recently discovered population, Site 3, is the largest and typically contains the largest population of this rare species. As with the big tarplant and other annual plants, the number of diamond-petaled California poppy plants present in these populations is expected to vary from year to year.

A spring census of these three populations has been conducted annually between 2000 and 2011. During this time, the largest diamond-petaled California poppy populations were observed in 2008 when over 7,000 plants were observed. A census of the three Site 300 populations was conducted in April 2011. The number of diamond-petaled California poppies observed in 2011 was the lowest seen since surveys began (a total of only 46 plants).

Round-Leaved Filaree. Six populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwest portion of the site. This species thrives in the disturbed soils of the annually graded fire trails at Site 300, but also occurs in grasslands. Of the six known Site 300 populations, four occur on fire trails and two occur in grasslands. During the spring of 2011, the extent of the six populations was mapped using a handheld GPS, and the size of each population was estimated. The six populations combined were estimated to contain 5,000 plants. In 2011, the majority of these plants (approximately 3,400) occurred in the two large grassland populations that are located away from fire trails.

6.4.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2011, LLNL has been able to avoid most impacts to special status wildlife and plants. Although California red-legged frogs were relocated as part of the 2011 drainage channel maintenance project, invasive species control efforts resulted in benefits to this species. In addition, LLNL continues to monitor and maintain several restoration sites and habitat enhancements that are beneficial to native plants and animals at the Livermore site and Site 300 and ensures the protection of listed and special status species through monitoring programs.

7. Radiological Dose Assessment

Nicholas A. Bertoldo • Kent Wilson

Lawrence Livermore National Laboratory assesses potential radiological doses to biota, off-site individuals, and the population residing within 80 km of each of the two LLNL sites, the Livermore site and Site 300. These potential doses are calculated to determine the impact of LLNL operations, if any, on the general public and the environment, and to demonstrate compliance with regulatory standards set by the U.S. DOE and the U.S. EPA. For protection of the public, DOE has set the limit for prolonged exposure of a maximally exposed individual in an uncontrolled area at 1 mSv/y whole-body effective dose equivalent (EDE), which equals 100 mrem/y EDE. For occasional exposure, the limit is 5 mSv/y (500 mrem/y) EDE. EDEs and other technical terms are defined in the glossary and discussed in "Supplementary Topics on Radiological Dose" (see **Appendix D**).

A release of radioactive material to air would be the primary source pathway of public radiological exposure from LLNL operations. Therefore, LLNL expends a significant effort monitoring stack air effluent for radiological releases and ambient air for radiological impact due to LLNL operations and to ensure that the doses to the public are kept as low as reasonably achievable (ALARA).

Measurements of radiological releases to air and modeling the dispersion of the released radionuclides are used to determine LLNL's dose to the public. Because LLNL is a DOE facility, it is subject to the requirements of 40 CFR Part 61, Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAPs). The EPA's radiation dose standard for members of the public limits the EDE to 100 µSv/y (10 mrem/y) for air emissions. LLNL uses the EPA CAP88-PC computer model to demonstrate site compliance with NESHAPs regulations. CAP88-PC is used to evaluate the four principal exposure pathways: ingestion, inhalation, air immersion, and irradiation by contaminated ground surface. The relative significance of inhalation dose depends on radionuclide air emission from operations and dose from resuspended radionuclides in soil, whereas the ingestion dose is predicted on assumptions made about the radionuclide concentration in food from the assessment area contributing to the total dose.

In 2011, the radionuclides measured and modeled that contributed to individual and collective doses were tritium and plutonium- 239+240 at the Livermore site and uranium-234, uranium-235, and uranium-238 at Site 300. All radionuclides measured at the Livermore site and Site 300 were used to assess dose to biota in 2011.

This chapter summarizes detailed radiological dose determinations and identifies trends over time while placing them in perspective with natural background and other sources of radiation exposure.

7.1 Air Dispersion and Dose Models

Computational models are needed to describe the transport and dispersion in air of contaminants and the doses to exposed persons via all pathways. CAP88-PC is the EPA-mandated computer model used by LLNL to compute individual or collective (i.e., population) radiological doses resulting from any radionuclide air emissions. The meteorological input file is prepared from data collected at each LLNL meteorological tower. The mathematical models and equations used in CAP88-PC are described by Parks (1992).

7.2 Identification of Key Receptors

Dose is assessed for two types of receptors. First is the dose to the site-wide maximally exposed individual (SW-MEI) member of the public. Second is the collective or "population" dose received by people who reside within 80 km of either of the two LLNL sites.

The SW-MEI is defined as the hypothetical member of the public at a single, publicly accessible location who receives the greatest LLNL-induced EDE from all sources at a site. In order for LLNL to comply with the NESHAPs regulation, the LLNL SW-MEI must not receive an EDE equal to or greater than 100 µSv/y (10 mrem/y) from any radioactive air emission. This hypothetical person is assumed to remain at the SW-MEI location 24 hours per day, 365 days per year, continuously breathing air having the predicted or observed radionuclide concentration, and consuming a specified fraction of food and drinking water[1] that is affected by the same predicted or observed air concentration caused by releases of radioactivity from the site. Since the SW-MEI dose is not received by any actual individual and is considered a hypothetical dose, this estimate is the highest possible dose that might be received by any member of the public predicated on the exposure conditions specified above.

In 2011, the SW-MEI at the Livermore site was located at the UNCLE Credit Union, about 10 m outside the site's controlled eastern perimeter, and 957 m east-northeast of the Tritium Facility. The SW-MEI at Site 300 was located on the site's south-central perimeter, which borders the Carnegie State Vehicular Recreation Area. The location was 3170 m south–southeast of the firing table at Building 851. The two SW-MEI locations are shown in **Figure 7-1**.

7.3 Results of Radiological Dose Assessment

This section summarizes the doses to the most exposed public individuals from LLNL operations in 2011, shows the temporal trends compared with previous years, presents the potential doses to the populations residing within 80 km of either the Livermore site or Site 300, and places the potential doses from LLNL operations in perspective with doses from other sources.

(1) Calculated for tritium only.

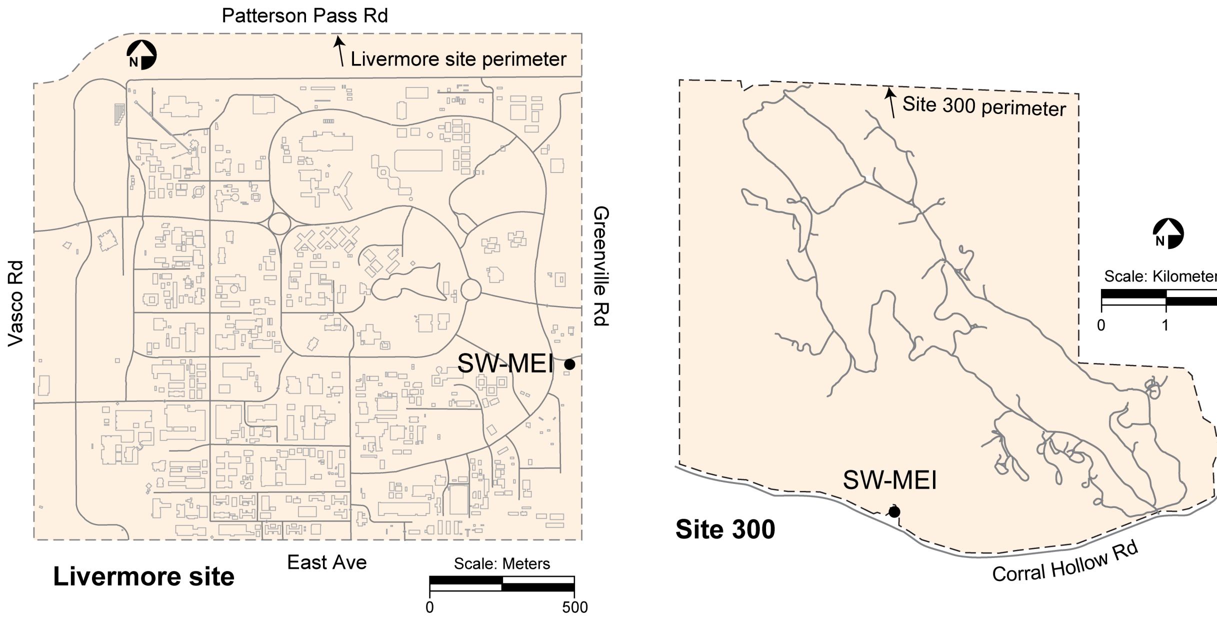

Figure 7-1. Location of the SW-MEI at the Livermore site and Site 300, 2011.

7.3.1 Total Dose to Site-Wide Maximally Exposed Individuals

The total dose to the SW-MEI from Livermore site operations in 2011 was 0.165 μSv/y (0.0165 mrem/y), where point source emissions account for 89% of the total. Of this, the dose attributed to HTO diffuse emissions (area sources) was 0.0152 μSv (0.00152 mrem) or 9% of the total; Pu diffuse emissions (soil resuspension from former evaporation pond area in the south east quadrant) was 0.0033 μSv (0.00033 mrem) or 2% of the total. The point source dose includes Tritium Facility elemental tritium gas (HT) emissions modeled as tritiated water (HTO), as directed by EPA Region IX.

Table 7-1 shows the facilities or sources that accounted for nearly 100% of the dose to the SW-MEI for the Livermore site and Site 300 in 2011. Although LLNL has nearly 150 sources with the potential to release radioactive material to air according to NESHAPs prescriptions, most are very minor. Nearly the entire radiological dose to the public in 2011 from LLNL operations came from no more than six sources. LLNL uses, with permission from EPA, surveillance monitoring in place of inventory-based modeling to account for dose contributions from the numerous minor sources.

In 2011 at Site 300, there were no outdoor firing table explosive experiments using depleted uranium to produce any emissions. No resuspension of depleted uranium was detected at the SW-MEI location from pre-existing concentrations. Radioactive emissions from Site 300 were solely from the Contained Firing Facility. The calculated dose to the SW-MEI (9.0×10^{-7} μSv/y) (9.0×10^{-8} mrem/y) was due to (1.18×10^{-6} GBq) (3.2×10^{-8} Ci) of uranium-238, (1.52×10^{-8} GBq) (4.12×10^{-10} Ci) uranium-235, and (2.07×10^{-7} GBq) (5.6×10^{-9} Ci) of uranium-234.

Table 7-1. List of facilities or sources whose combined emissions accounted for nearly 100% of the SW-MEI doses for the Livermore site and Site 300 in 2011.

Site	Facility (source category)	CAP88-PC dose (μSv/y)[a]	CAP88-PC contribution to total dose[b]
Livermore Site	Tritium Facility stacks (point source)	1.5×10^{-1}	89%
	Building 331 WAA, Building 612 Yard (diffuse sources)	1.52×10^{-2}	9%
	Southeast quadrant soil resuspension (diffuse source)	3.3×10^{-3}	2%
Site 300	Contained Firing Facility	9.0×10^{-7}	100%

(a) 1 μSv = 0.1 mrem.

(b) Contributions from B695 and B581 stacks account for much less than 1% of the total dose from Livermore site operations.

The doses to the SW-MEI from emissions at the Livermore site and Site 300 since NESHAPs reporting began are shown in **Table 7-2**. These SW-MEI dose estimates are conservative, predicting potential doses that are higher than actually would be experienced by any member of the public, and are all less than 1% of the federal standard of 100 μSv/y (10 mrem/y).

7.3.2 Doses from Unplanned Releases

There were no unplanned atmospheric releases of radionuclides at the Livermore site or Site 300 in 2011.

7.3.3 Collective Dose

Collective dose is the sum of the individual doses received in a given period by a specified population from exposure to a specified source of radiation. The origin of the concept was to associate risk with the hereditary effects of an exposed population.

Collective dose for both LLNL sites was calculated using CAP88-PC for a radius of 80 km from the site centers. Population centers affected by LLNL emissions within the 80-km radius include the nearby communities of Livermore and Tracy; the more distant metropolitan areas of Oakland, San Francisco, and San Jose; and the San Joaquin Valley communities of Modesto and Stockton. Within the 80-km radius specified by DOE, there are 7.77 million residents included for the Livermore site collective dose determination and 7.11 million for Site 300. The populations were derived using ORNL LANDSCAN™ 2010 data and ESRI ARCMAP software.

The CAP88-PC result for potential maximum collective dose attributed to 2011 Livermore site operations was 0.0291 person-Sv (2.91 person-rem); the corresponding collective dose from Site 300 operations was 2.34×10^{-7} person-Sv (2.34×10^{-5} person-rem).

Because LLNL is surrounded by a significant population residing within an 80-km radius, even a very small dose when multiplied by a large population number will result in a collective dose that overemphasizes the operational dose to the public at specific distances from the source. For this reason, the National Council on Radiological Protection (NCRP) recommended that regulatory limits not be set in term of a collective dose (NRCP 1995). As in LLNL's case, when individual doses range greatly over large distances, the dose distribution are more appropriately characterized by subdividing the individual dose into several ranges whereby the population size, mean individual dose, collective dose, and associated uncertainties are representative of each range. (For further information, see NCRP [1995] and ICRP [2005]).

Table 7-2. Doses calculated for the SW-MEI for the Livermore site and Site 300, 1990 to 2011.

Site	Year	Annual Dose (μSv)[(a)]	Site	Year	Annual Dose (μSv)[(a)]
Livermore site	2011	0.17	Site 300	2011	9.0×10^{-7}
	2010	0.11		2010	5.7×10^{-6}
	2009	0.042		2009	2.7×10^{-6}
	2008	0.013		2008	4.4×10^{-7}
	2007	0.031		2007	0.035
	2006	0.045		2006	0.16
	2005	0.065		2005	0.18
	2004	0.079		2004	0.26
	2003	0.44		2003	0.17
	2002	0.23		2002	0.21
	2001	0.17		2001	0.54
	2000	0.38		2000	0.19
	1999	1.2		1999	0.35
	1998	0.55		1998	0.24
	1997	0.97		1997	0.20
	1996	0.93		1996	0.33
	1995	0.41		1995	0.23
	1994	0.65		1994	0.81
	1993	0.66		1993	0.37
	1992	0.79		1992	0.21
	1991	2.34		1991	0.44
	1990	2.40		1990	0.57

(a) 1 μSv = 0.1 mrem.

7.3.4 Doses to the Public Placed in Perspective

As a frame of reference to gauge the size of the LLNL doses, **Table 7-3** compares them to average doses received in the United States from exposure to natural background radiation and other sources. The collective dose is high even though the individual dose is very small. This is due to the high population density in the 80-km radius. Moreover, the overall contribution of dose from LLNL operations in 2011 is overshadowed by natural radiation.

Table 7-3. Comparison of radiation doses from LLNL sources to average doses from background (natural and man-made) radiation, 2011.

Location/source	Category	Individual dose[a] (μSv)[c]	Collective dose[b] (person-Sv)[d]
LLNL			
Livermore site sources	Atmospheric emissions	0.165	0.0291
Site 300 sources	Atmospheric emissions	9.0×10^{-7}	2.34×10^{-7}
Other sources[e] (background)	Natural radioactivity[f, g]		
	Cosmic radiation	300	2,330
	Terrestrial radiation	300	2,330
	Internal (food and water consumption)	400	3,110
	Radon	2,000	15,540
	Medical radiation (diagnostic procedures)[f]	530	4,120
	Weapons test fallout[f]	10	78
	Nuclear fuel cycle	4	31

(a) For LLNL sources, this dose represents that experienced by the SW-MEI.

(b) The collective dose is the combined dose for all individuals residing within an 80-km radius of LLNL (approximately 7.22 million people for the Livermore site and 7.11 million for Site 300), calculated with respect to distance and direction from each site. The Livermore site population estimate of 7.77 million people was used to calculate the collective doses for "Other sources."

(c) 1 μSv = 0.1 mrem.

(d) 1 person-Sv = 100 person-rem.

(e) From National Council on Radiation Protection and Measurements (NCRP 1987a,b).

(f) These values vary with location.

(g) This dose is an average over the U.S. population.

7.4 Special Topics on Dose Assessment

LLNL demonstrates NESHAPs compliance for minor sources by comparing measured ambient air concentrations at the location of the SW-MEI to concentration limits set by the EPA in 40 CFR Part 61, Table 2, Appendix E. The radionuclides for which the comparison is made are tritium and plutonium-239+240 for the Livermore site SW-MEI and uranium-238 for the Site 300 SW-MEI. At the Livermore site, the average of the monitoring results for location CRED represents the SW-MEI. At Site 300, the minor source that has the potential to have a measurable effect is the resuspension of depleted uranium contaminated soil and is represented by location PSTL.

The standards contained in 40 CFR Part 61, Table 2, Appendix E, and the measured concentrations at the SW-MEI are presented in SI units in **Table 7-4**. As demonstrated by the calculation of the fraction of the standard, LLNL measured air concentrations for tritium and plutonium-239+240 and uranium-238 are less than one one-hundredth of the health protective standard for these radionuclides.

Table 7-4. Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2011.

Location	Nuclide	EPA concentration standard (Bq/m^3)	Detection limit (approximate) (Bq/m^3)	Mean measured concentration (Bq/m^3)	Measured concentration as a fraction of the standard[(b)]
Livermore SW-MEI	Tritium	56	0.037	9.3×10^{-2}(a)	1.7×10^{-3}
Livermore SW-MEI	Plutonium-239	7.4×10^{-5}	1.9×10^{-8}	4.7×10^{-9}	6.5×10^{-5}
Site 300 SW-MEI	Uranium-238	3.07×10^{-4}	1.1×10^{-9}	4.2×10^{-7}	1.4×10^{-3}(c)

Note: 1 Bq = 2.7×10^{-11} Ci.

(a) The measured tritium value includes contributions from all minor sources (including the Building 331 Stacks and Outside Yard), B612 outside yard, DWTF, and B581 stack at the location of the SW-MEI.

(b) Conversion from the standard units in the NESHAPs report to SI units in the SAER will result in a few percent differences due to rounding to two significant figures (Wilson et. al., 2012).

(c) The ratio for the mean uranium-235 and uranium-238 concentrations for 2011 is 0.0072, which is equal to the ratio of these isotopes for naturally occurring uranium. This value for uranium-238 is from naturally occurring uranium resuspended in the soil.

7.4.1 Estimate of Dose to Biota

Biota (flora and fauna) also need to be protected from potential radiological exposure from LLNL operations since their exposure pathways are unique to their environment (e.g., a ground squirrel may be exposed to dose by burrowing in contaminated soil). Thus, LLNL calculates potential dose to biota from LLNL operations according to *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (U.S. DOE 2002) and by using the RESRAD-BIOTA computer code, a tool for implementing DOE's graded approach to biota dose evaluation.

Limits on absorbed dose to biota are 10 mGy/d (1 rad/d) for aquatic animals and terrestrial plants, and 1 mGy/d (0.1 rad/d) for terrestrial animals. At LLNL in 2011, radionuclides contributing to dose to biota were americium-241, cesium-137, tritium, potassium-40, plutonium-238, plutonium-239, thorium-232, uranium-234, uranium-235, and uranium-238. In the 2011 LLNL assessment, the maximum concentration of each radionuclide measured in soils and surface waters was used in the dose screening calculations. This approach resulted in an assessment that is extremely conservative, given that the maximum concentrations in the media are distributed over a very large area by combining both site media. Specifically, it accounts for the exposure at both the Livermore site and Site 300 and no plant or animal would likely be exposed to both. Furthermore, although biota would most likely live in and near permanent bodies of water (i.e., surface water), measurements of storm water runoff were used for the assessment because higher concentrations of radionuclides are measured in runoff than in surface waters.

In the RESRAD-BIOTA code, each radionuclide in each medium (e.g., soil, sediment, and surface water) is assigned a Biota Concentration Guide (BCG). Measured radionuclide concentrations in the soil and water media are divided by the BCG, and the resulting fractions for each nuclide and medium are summed. For aquatic and riparian animals, the sum of the fractions for water exposure is added to the sum of the fractions for sediment exposure. Similarly, fractions for water and soil exposures are summed for terrestrial animals. If the sums of the fractions for the aquatic and terrestrial systems are both less than 1 (i.e., the dose to the biota does not exceed the screening limit), then the site has passed the screening analysis and the biota are assumed to be protected.

In 2011, the sum of the water fractions for the terrestrial animal was 2.36×10^{-3}, and the sum of the soil fraction for the terrestrial animal was 0.186 with a total ratio of 0.189 for the combined fraction. The predominant contribution is due to gross alpha and gross beta in the terrestrial system.

7.5 Environmental Impact

The annual radiological doses from all emissions at the Livermore site and Site 300 in 2011 were found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs standard. This standard limits the dose to 100 µSv/y (10 mrem/y) Effective Dose Equivalent (EDE) to any member of the public arising as a result of releases of radioactive material to air from DOE facilities. Using an EPA-mandated computer model and actual LLNL meteorology appropriate to the two sites, potential doses to the LLNL SW-MEI members of the public from LLNL operations in 2011 were:

- Livermore site: 0.17 µSv (0.017 mrem)—89% from point-source emissions; 9% from diffuse-source emissions.
- Site 300: 9.0×10^{-7} µSv (9.0×10^{-8} mrem)—100% from the point source emissions.

As noted earlier, the major radionuclides accounting for the doses were tritium and plutonium at the Livermore site and the three isotopes of uranium (uranium-234, uranium-235, and uranium-238) at Site 300. The only significant exposure pathway contributing to dose from LLNL operations was release of radioactive material to air, leading to doses by inhalation and ingestion.

The collective EDE attributable to LLNL operations in 2011 was estimated to be 0.0291 person-Sv (2.91 person-rem) for the Livermore site and 2.34×10^{-7} person-Sv (2.34×10^{-5} person-rem) for Site 300. These doses include potentially exposed populations of 7.77 million people for the Livermore site and 7.11 million people for Site 300 living within 80 km of the site centers.

The doses to the SW-MEI, which represent the maximum doses that could be received by members of the public, resulting from Livermore site and Site 300 operations in 2011 were insignificant compared to both the federal standard and the dose received from natural background sources. The collective doses from LLNL operations in 2011 reflect the large population within the 80-km range of the Livermore site and Site 300.

Potential doses to aquatic and terrestrial biota from LLNL operations were assessed using RESRAD-BIOTA and found to be well below DOE screening dose limits due to the extremely low levels of the radionuclides of concern present in the soil and water samples that represent the source of exposure for the biota.

Potential radiological doses from LLNL operations were well below regulatory standards and were very small compared with doses normally received from natural background radiation sources, even though highly conservative assumptions were used in the determination of LLNL doses. The potential maximum doses to the public indicate that LLNL's use of radionuclides had no credible impact on public health during 2011.

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8. Groundwater Investigation and Remediation

Valerie Dibley

Lawrence Livermore National Laboratory samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology and nature and extent of the contamination and its source. Where necessary, remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants in groundwater and the progress LLNL has made in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300. The sites are similar in that the contamination is, for the most part, confined on site. The sites differ in that Site 300, with an area of 28.3 km^2 (10.9 mi^2), is much larger than the Livermore site and has been divided into nine operable units (OUs) based on the nature and extent of contamination, and topographic and hydrologic considerations. The Livermore site at 3.3 km^2 (1.3 mi^2) is effectively one OU.

8.1 Livermore Site Environmental Restoration Project

Initial releases of hazardous materials occurred at the Livermore site in the mid-to-late 1940s during operations at the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed VOCs, fuel hydrocarbons, metals, and tritium to the unsaturated zone and groundwater in the post-Navy era. The Livermore site was placed on the U.S. Environmental Protection Agency National Priorities List in 1987.

An analysis of all environmental media showed that groundwater and both saturated and unsaturated soils are the only media that require remediation (Thorpe et al. 1990). Compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards (MCLs) are TCE, PCE, 1,1-dichloroethylene, cis-1,2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, and carbon tetrachloride. PCE is also present at low concentrations slightly above the MCL in off-site plumes that extend from the southwestern corner of the Livermore site. LLNL operates groundwater extraction wells in both on-site and off-site areas. In addition, LLNL maintains an extensive network of groundwater monitoring wells in the off-site area west of Vasco Road.

8.1.1 Physiographic Setting

The general topography of the Livermore site is described in **Chapter 1**. The Livermore Valley groundwater system consists of several semiconfined aquifers. Rainfall from the surrounding hills and seasonal surface water in the arroyos recharge the groundwater system, which flows toward the east-west axis of the valley.

The thickest sediments and aquifers are present in the central and western portions of the Livermore Valley, where they form an important resource for the Zone 7 Water Agency. These sediments comprise two aquifers: the Livermore Formation and overlying alluvium. The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium, which is about 100 m thick, is the principal water-producing aquifer within the valley.

8.1.2 Hydrogeology of the Livermore Site

Sediments at the Livermore site are grouped into four grain-size categories: clay, silt, sand, and gravel. Groundwater flow beneath the site occurs primarily in alluvial sand and gravel deposits, which are bounded by lower permeability clay and silt deposits. The alluvial sediments have been subdivided into nine HSUs beneath the Livermore site. HSUs are defined as sedimentary sequences whose permeable layers show evidence of being hydraulically interconnected and geochemically similar. Six of the nine HSUs contain contaminants at concentrations above their MCLs: HSU-1B, -2, -3A, -3B, -4, and -5 (Blake et al. 1995; Hoffman et al. 2003). HSU-1A, -6, and -7 do not contain contaminants of concern above action levels.

8.1.3 Remediation Activities and Monitoring Results

In 2011, LLNL maintained and operated 38 treatment facilities. The groundwater extraction wells and dual (groundwater and soil vapor) extraction wells produced more than 1,124 million L of groundwater and the treatment facilities removed 55 kg of VOCs. Since remediation began in 1989, approximately 17 billion L of groundwater have been treated, resulting in removal of more than 1,495 kg of VOCs. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2012).

LLNL also maintained and operated 9 soil vapor treatment facilities in 2011. The soil vapor extraction wells and dual extraction wells produced more than 1.5 million m^3 of soil vapor and the treatment facilities removed 39 kg of VOCs. Since initial operation, nearly 14 million m^3 of soil vapor has been extracted and treated, removing more than 1,475 kg of VOCs from the subsurface. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2012).

One ground water treatment facility (Treatment Facility A-West) remained offline during 2011 while a remedial design is completed to connect the offsite well, W-404, to Treatment Facility A via a pipeline extension. This work is scheduled for completion by September 2012. A public meeting was held in October 2010 to discuss the project with the community. Preconstruction soil sampling and potholing associated with the planned Treatment Facility A (TFA) Arroyo Seco pipeline extension was conducted in October 2011. The objective of the effort was threefold: 1) to confirm the location, vertical elevation, size, and type of pipe or conduit for certain underground utilities that currently exist along the planned pipeline extension; 2) to screen the soil for hazardous materials that could pose a hazard to pipeline workers or the community during the construction phase of the project; and (3) to assist in determining waste disposal requirements for pipeline trenching soil. A total of four locations along the proposed pipeline route were pot-holed to a maximum depth of 8 ft below ground surface (bgs), and soil samples were obtained from seven locations at depths between two and five feet bgs. The samples were submitted for VOC, metals, pesticide, and gross alpha and gross beta analysis. Results are pending. Dust mitigation and air monitoring to be conducted during pipeline construction is discussed in Bourne et al. 2011.

Restoration activities in 2011 at the Livermore Site were primarily focused on enhancing and optimizing ongoing operations at treatment facilities, while continuing to evaluate technologies that could be used to accelerate clean up of the Livermore Site source areas and to address the mixed-waste management issue discussed in the DRAFT Focused Feasibility Study of Methods to Minimize Mixed Hazardous and Low Level Radioactive Waste from Soil Vapor and Ground Water Treatment Facilities at the Lawrence Livermore National Laboratory Site (Bourne et al. 2010). Three ground water treatment facilities (Treatment Facility 518 North and Treatment Facilities 5475-1 and 5475-3) and one soil vapor treatment facility (Vapor Treatment Facility 5475) remained offline during 2011 while these treatability studies are conducted (see below).

An enhanced source area remediation (ESAR) bioremediation treatability test continued at the TFD Helipad and hydraulic and pneumatic aquifer testing was conducted following the ESAR pneumatic fracturing treatability test at TFE Hotspot. In 2011, the ESAR conductive heating treatability test at TFE Eastern Landing Mat was initiated, and planning and detailed source area delineation was conducted for an ESAR treatability test using pneumatic fracturing and zero valent iron (ZVI) to initiate *in situ* VOC destruction at TFC Hotspot.

Additional LLNL GWP environmental restoration activities performed in 2011 included:

- Continuing hydraulic control and treatment of VOCs in ground water along the western and southern margins of the site where concentrations declined or remained stable during the year.
- Installing one extraction well, sealing and destroying one damaged extraction well, and conducting an extensive direct-push cone penetration testing (CPT) survey to better delineate the TFC Hotspot source area.
- Upgrading treatment facility TFB, including a well field expansion with two new pipelines.
- Improving Livermore Site treatment facility hours of operation by 6% over 2010, excluding treatment facilities in enhanced source area remediation (ESAR) treatability test areas.
- Assisting with a second phase of soil sampling in support of the Resource Conservation and Recovery Act (RCRA) closure of Building 419.
- Confirming tritium activities in ground water from all wells remained below the 20,000 picocuries per liter (pCi/L) U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL), and tritium continued to decline by radioactive decay.
- Submitting the Summary Report for the Delineation of Mercury in Soil at the Former Building 212 Facility (LLNL, 2011).

During 2011, the Remedial Project Managers signed a Consensus Statement for Environmental Restoration of the Livermore Site that included 21 Federal Facility Agreement milestones. The

Livermore Site environmental restoration project had 9 milestones scheduled for completion in 2011. All milestones were met (see Chapter 2).

Groundwater concentration and hydraulic data indicate subtle but consistent declines in the VOC concentrations and areal extent of the contaminant plumes in 2011. Once again, there was little to no evidence of measureable contaminant plume migration resulting from the shutdown of treatment facilities in late 2008 and early 2009. Hydraulic containment along the western and southern boundaries of the site was fully maintained in 2011, and progress was made toward interior plume and source area clean up. See Buscheck et al. (2012) for the current status of cleanup progress.

8.1.4 Environmental Impacts

LLNL strives to reduce risks arising from chemicals released to the environment, to conduct all its restoration activities to protect environmental resources, and to preserve the health and safety of all site workers. LLNL's environmental restoration project is committed to preventing present and future human exposure to contaminated soil and groundwater, preventing further contaminant migration of concentrations above drinking water standards, reducing concentrations of contaminants in groundwater, and minimizing contaminant migration from the unsaturated zone to the underlying groundwater.

Remedial solutions that have been determined to be most appropriate for individual areas of contamination are implemented. The selected remedial solutions, which include groundwater and soil vapor extraction and treatment, have been agreed upon by DOE and the regulatory agencies with public input and are designed to achieve the goals of reducing risks to human health and the environment and satisfying remediation objectives, and of meeting regulatory standards for chemicals in water and soil, and other state and federal requirements.

8.2 Site 300 Environmental Restoration Project

A number of contaminants were released to the environment during past LLNL Site 300 operations including waste fluid disposal to dry wells, surface spills, piping leaks, burial of debris in unlined pits and landfills, detonations at firing tables, and discharge of rinse water to unlined lagoons. Environmental investigations at Site 300 began in 1981. As a result of these investigations, VOCs, high explosive compounds, tritium, depleted uranium, organosilicate oil, nitrate, perchlorate, polychlorinated biphenyls, dioxins, furans, and metals were identified as contaminants of concern in soil, rock, groundwater, or surface water. This contamination is confined within the site boundaries with the exception of VOCs that are present in off-site monitor wells near the southern site boundary. LLNL maintains an extensive network of on-site and off-site wells to monitor this contamination. All characterized contaminant release sites that have a CERCLA pathway have been assigned to one of nine OUs based on the nature, extent, and sources of contamination, and topographic and hydrologic considerations. Site 300 was placed on the U.S. Environmental Protection Agency National Priorities List in 1990. Cleanup activities began at Site 300 in 1982 and are ongoing.

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in Webster-Scholten (1994), *Final Remedial Investigation/Feasibility Study for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300* (Taffet et al., 2005), and the *Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2006).

8.2.1 Physiographic Setting and Geology of Site 300

Site 300 is located in the southeastern Altamont Hills of the Diablo range. The topography of Site 300 consists of a series of steep hills and canyons generally oriented northwest to southeast. The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists of interbedded conglomerates, sandstones, siltstones, and claystones of the late Miocene Neroly Formation (Tn), and a Pliocene nonmarine unit (Tps). The bedrock units are locally overlain by mid- to late-Pleistocene terrace deposits and late-Pleistocene to Holocene floodplain, ravine fill, landslide, and colluvial deposits.

The bedrock within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence groundwater flow within the site.

8.2.2 Contaminant Hydrogeology of Site 300

Site 300 is a large and hydrogeologically diverse site. Due to the steep topography and structural complexity, stratigraphic units and groundwater contained within many of these units are discontinuous across the site. Consequently, site-specific hydrogeologic conditions govern the occurrence and flow of groundwater and the fate and transport of contaminants beneath each OU.

An HSU is a water-bearing zone that exhibits similar hydraulic and geochemical properties. At Site 300, HSUs have been defined consisting of one or more stratigraphic intervals that compose a single hydraulic system within one or more OU. Groundwater movement and contaminant migration in groundwater are discussed in the context of HSUs.

Groundwater contamination at Site 300 occurs in three types of water-bearing zones:

1. Quaternary deposits including the alluvium and weathered bedrock (Qal/WBR HSU), alluvial terrace deposits (Qt), and landslide deposits (Qls HSU).
2. Tertiary perched groundwater in fluvial sands and gravels (Tpsg HSU) and semilithified silts and clay of the Tps HSU.
3. Tertiary Neroly Formation bedrock including the $Tnsc_2$, $Tnbs_2$, $Tnsc_{1b}$ $Tnbs_1$, $Tnbs_0$, and $Tnsc_0$ HSUs.

Groundwater in bedrock is typically present under confined conditions in the southern half of the site but is often unconfined elsewhere. Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out.

8.2.3 Remediation Activities and Monitoring Results

Cleanup activities were initiated at Site 300 in 1982 and are underway or are in the process of being implemented at all nine OUs. These activities include:

- Operating up to 20 groundwater and soil vapor extraction and treatment facilities.
- Capping and closing four landfills, six high explosives rinse water lagoons and one high explosives burn pit.
- Removal and/or closure of numerous dry wells throughout the site.
- Removal of contaminated soil from source areas throughout the site.
- Installation of a drainage diversion system at the Pit 7 Complex to prevent ground water from rising into the landfills and releasing contaminants in the waste.
- Remediation (consolidation and solidification) of 29,000 cubic yards of PCB-, dioxin-, and furan-contaminated soil in a Corrective Action Management Unit (CAMU) at Building 850.
- Treatability studies for the *in situ* bioremediation of VOCs and perchlorate in ground water.
- Installation and sampling of over 680 groundwater monitor wells to track plume migration and remediation progress.

These remediation efforts have resulted in (1) the elimination of risk to on-site workers from contaminant exposure at eight locations throughout Site 300, (2) a reduction in maximum concentrations of the primary contaminant (VOCs) in Site 300 groundwater by 50% to 99%, and (3) the remediation of VOCs in groundwater in the Eastern General Services Area to meet cleanup standards (see Chapter 2).

In 2011, the Site 300 Environmental Restoration Project operated 15 groundwater and 5 soil vapor treatment facilities extracting and treating approximately 40.3 million L of groundwater and 1.3 million m^3 of contaminated soil vapor. The Site 300 treatment facilities removed nearly 11 kg of VOCs, 0.14 kg of perchlorate, 1,600 kg of nitrate, 0.14 kg of the high explosive compound RDX, 0.00085 kg of silicone oils (TBOS/TKEBS), and 0.0048 kg of uranium in 2011. Since groundwater remediation began in 1990, approximately 1,500 million L of groundwater and over 17.6 million m^3 soil vapor have been treated, resulting in removal of more than 560 kg of VOCs, 1.2 kg of perchlorate, 11,000 kg of nitrate, 1.6 kg of RDX, 9.5 kg of silicone oils, and 0.013 kg of uranium. Tritium in ground water continues to decay on site, reducing tritium activities in Site 300 ground water. Detailed flow and mass removal by OU is presented in Dibley et al. (2012).

Cleanup remedies have been fully implemented and are operational in eight of the nine OUs at Site 300 to date (Operable Unit 8 and General Services Area, Building 834, Pit 6 Landfill, High Explosives Process Area, Building 850/Pit 7 Complex, Building 854, and Building 832 Canyon OUs). The CERCLA pathway for the last OU, Building 812, was negotiated with the regulatory agencies in 2011. The Remedial Project Managers signed a new FFA Schedule of Deliverables for Site 300 that included 87 FFA milestones. The majority of these new milestones were for the Building 812 OU. The Site 300 environmental restoration project had 25 milestones scheduled for completion in calendar year 2011. All milestones were met (see Chapter 2). Building 812 characterization activities were initiated in 2011 and will continue into 2012.

Additional Site 300 Environmental Restoration Project activities performed in 2011 included:

- Installing five wells that are being evaluated for use as groundwater extraction wells to increase contaminant capture and mass removal.
- Upgrading the Building 815-Distal Site Boundary treatment facility to replace aging system components and to increase its capacity and efficiency in preventing offsite plume migration.
- Upgrading the Building 829-Source treatment facility to increase its operational efficiency.
- Inspecting and maintaining the Pit 7 drainage diversion system and Building 850 Corrective Action Management Unit.
- Initiating the Building 850 In Situ Perchlorate Bioremediation Treatability Test. This test will continue into 2012.

Groundwater concentration and hydraulic data collected and analyzed for Site 300 during 2011 provided evidence of continued progress in reducing contaminant concentrations in Site 300 soil vapor and groundwater, controlling and cleaning up contaminant sources, and mitigating risk to on-site workers. A more detailed description of remediation progress at the Site 300 OUs in 2011 is available in the *2011 Annual Compliance Monitoring Report for LLNL Site 300* (Dibley et al. 2012).

8.2.4 Environmental Impacts

LLNL strives to reduce elevated risks arising from chemicals released to the environment at Site 300, to conduct its activities to protect ecological resources, and to protect the health and safety of site workers. LLNL's cleanup remedies at Site 300 are designed and implemented to achieve the goals of reducing risks to human health and the environment and satisfying remediation action objectives, meeting cleanup standards for chemicals and radionuclides in water and soil, and preventing contaminant migration in groundwater to the extent technically and economically feasible. These remedies are selected by DOE and the regulatory agencies with public input. These actions include groundwater and soil vapor extraction and treatment; source control through the capping of lagoons and landfills, removal and remediation of contaminated soil, and hydraulic drainage diversion; and monitored natural attenuation, monitoring, and institutional controls.

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9. Quality Assurance

Donald H. MacQueen • Gene Kumamoto

Quality assurance (QA) is a system of activities and processes put in place to ensure that products or services meet or exceed customer specifications. Quality control (QC) consists of activities used to verify that deliverables are of acceptable quality and meet criteria established in the quality planning process.

9.1 Quality Assurance Activities

Nonconformance reporting and tracking is a formal process used to ensure that problems are identified, resolved, and prevented from recurring. The LLNL Environmental Functional Area (EFA) tracks problems using the LLNL Institutional Tracking System (ITS). ITS items are initiated when items or activities are identified that do not comply with procedures or other documents that specify requirements for EFA operations or that cast doubt on the quality of EFA reports, integrity of samples, or data and that are not covered by other reporting or tracking mechanisms. Nonconformances involving the EFA are captured and used to provide trending information for environmental compliance evaluations. There were no laboratory data nonconformances documented. Many minor sampling or data problems are resolved without an ITS item being generated.

LLNL averts sampling problems by requiring formal and informal training on sampling procedures. Errors that occur during sampling generally do not result in lost samples but may require extra work on the part of laboratory or sampling and data management personnel to correct the errors.

LLNL addresses commercial analytical laboratory problems as they arise. Many of the documented problems concern minor documentation errors and are corrected soon after they are identified. Other problems, such as missed holding times, late analytical results, incorrect analysis and typographical errors on data reports, account for the remaining issues and are not tracked as nonconformances. These problems are corrected by the commercial laboratory reissuing reports or correcting paperwork and do not affect associated sample results.

LLNL participates in the Department of Energy Consolidated Auditing Program (DOECAP). Annual, on-site visits to commercial laboratories under contract to LLNL are part of the auditing program to ensure that accurate and defensible data are generated. The audit program is based on National Environmental Laboratory Accreditation Program (NELAP) requirements. All commercial laboratories used by LLNL are DOE-qualified vendors and are NELAP certified (or equivalent). LLNL has qualified auditors under the national DOECAP program in the areas of quality assurance, organic chemistry, inorganic chemistry, laboratory information management, and hazardous material management. Audit reports, checklists, and Corrective Action Plans are maintained under the DOECAP program for qualified commercial labs.

In FY2011, the laboratories certified by the State of California operating at LLNL as government owned and contractor operated were not internally assessed or qualified by LLNL due to budgetary and staff limitations, but were recertified by the State of California under the Environmental Laboratory Accreditation Program (ELAP).

9.2 Analytical Laboratories and Laboratory Intercomparison Studies

In 2011, LLNL had Blanket Service Agreements (BSAs) with six commercial analytical laboratories and maintained an open requisition with one radiometrics laboratory. All analytical laboratory services used by LLNL are provided by facilities certified by the State of California. LLNL works closely with these analytical laboratories to minimize problems and ensure that QA objectives are maintained.

LLNL uses the results of intercomparison performance evaluation program data to identify and monitor trends in performance and to draw attention to the need to improve laboratory performance. If a laboratory performs unacceptably for a particular test in two consecutive performance evaluation studies, LLNL may stop work and select another laboratory to perform the affected analyses until the original laboratory has demonstrated that the problem has been corrected. If an off-site laboratory continues to perform unacceptably or fails to prepare and implement acceptable corrective action responses, the LLNL Procurement Department formally notifies the laboratory of its unsatisfactory performance. If the problem persists, the off-site laboratory's BSA could be terminated for that test. If an on-site laboratory continues to perform unacceptably, use of that laboratory could be suspended until the problem is corrected. In 2011, all contracted commercial labs were successful in participation in performance evaluation studies and where there were individual failures to perform, the commercial labs were verified to have corrective actions in place.

Although laboratories are also required to participate in laboratory intercomparison programs, permission to publish their accreditation results for comparison purposes was not granted for 2011. To obtain DOE Mixed Analyte Performance Evaluation Program (MAPEP) reports that include the results from all participating laboratories, see http://www.inl.gov/resl/mapep/reports.html. MAPEP is a DOE program and the results are publicly available from laboratories that choose to participate.

9.3 Duplicate Analyses

Duplicate (collocated) samples are distinct samples of the same matrix collected as close to the same point in space and time as possible. Collocated samples that are processed and analyzed by the same laboratory provide information about the precision of the entire measurement system, including sample acquisition, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples that are processed and analyzed by different laboratories provide information about the precision of the entire measurement system that also captures interlaboratory variation (U.S. EPA 1987). Collocated samples may also identify errors such as mislabeled samples or data entry errors.

Tables 9-1, **9-2**, and **9-3** present summary statistics for collocated sample pairs, grouped by sample matrix and analyte. Samples from both the Livermore site and Site 300 are included. **Tables 9-1** and **9-2** are based on data pairs in which both values are considered detections (that is, are above the analytical contract reporting limit; see **Section 9.4**). **Table 9-3** is based on data pairs in which either or both values are considered nondetections (that is, are below the analytical contract reporting limit).

Table 9-1. Quality assurance collocated sampling: Summary statistics for analytes with more than eight pairs in which both results were above the reporting limit.

Media	Analyte	N(a)	%RSD(b)	Slope	r^2(c)	Intercept
Air	Gross alpha(d)	10	24.4	0.653	0.59	2.14×10^{-5} (Bq/m3)
	Gross beta(e)	75	21.7	0.921	0.46	7.9×10^{-5} (Bq/m3)
	Beryllium(e)	13	25.4	0.378	0.2	2.05 (pg/m3)
	Uranium-235 by mass measurement	11	9.9	1.14	0.99	-5.83×10^{-9} (μg/m3)
	Uranium-238 by mass	11	10.1	1.13	0.99	-5.95×10^{-7} (μg/m3)
	Tritium	35	18.5	0.912	0.9	0.00788 (Bq/m3)
Dose (TLD)	90-day radiological dose	31	3.03	1.04	0.87	-0.491 (mrem)
Groundwater	Gross alpha	14	31.5	0.87	0.87	0.0185 (Bq/L)
	Gross beta(d)	32	30.5	0.685	0.48	0.104 (Bq/L)
	Arsenic	28	13.9	1.03	0.99	-0.000902 (mg/L)
	Barium	15	2.7	1.04	0.89	-0.000902 (mg/L)
	Chloride	9	0	1	1	-0.512 (mg/L)
	cis-1,2-Dichloroethene	19	11.2	0.832	0.99	121 (μg/L)
	1,2-Dichloroethene (total)	17	10.9	0.831	0.99	137 (μg/L)
	Fluoride	9	4.16	1.04	0.98	-0.0139 (mg/L)
	Nitrate (as NO_3)	53	17	0.969	0.91	2.21 (mg/L)
	Perchlorate	21	6.43	1.01	0.99	0.00105 (μg/L)
	Potassium	9	0	1.01	1	0.0069 (mg/L)
	Sodium	10	1.22	1.01	1	-0.93 (mg/L)
	Sulfate	9	0	1.01	1	-3.01 (mg/L)
	Trichloroethene	77	7.86	1.04	1	-31.7 (μg/L)
	Tritium	30	17.1	1.11	0.98	-0.925 (Bq/L)
	Uranium-234+233(e)	25	15.8	1.03	1	-0.000782 (Bq/L)
	Uranium-235	16	20.3	0.891	0.97	0.00141 (Bq/L)
	Uranium-238	23	8.72	1.04	1	-0.000962 (Bq/L)
Sewer	Gross beta(d)	12	17	0.0771	0.01	0.000465 (Bq/mL)

(a) Number of collocated pairs included in regression analysis.

(b) 75th percentile of percent relative standard deviations (%RSD) where %RSD = $\left(\frac{200}{\sqrt{2}}\right)\frac{|x_1 - x_2|}{x_1 + x_2}$ where x_1 and x_2 are the reported concentrations of each routine–collocated pair.

(c) Coefficient of determination.

(d) Outside acceptable range of slope or r^2 because of variability.

(e) Outside acceptable range of slope or r2 because of outliers.

Table 9-2. Quality assurance collocated sampling: Summary statistics for selected analytes with eight or fewer pairs in which both results were above the reporting limit.

Media	Analyte	N(a)	Mean ratio	Minimum ratio	Maximum ratio
Aqueous	Gross alpha	1	0.61	0.61	0.61
Aqueous	Gross beta	1	1.1	1.1	1.1
Aqueous	Uranium-234+233	1	1	1	1
Aqueous	Uranium-235+236	1	0.87	0.87	0.87
Aqueous	Uranium-238	1	0.94	0.94	0.94
Groundwater	Radium-226	4	1.2	0.56	1.9
Groundwater	Uranium-235 by mass measurement	1	1	1	1
	Uranium-338 by mass measurement	1	1	1	1
Surface water	Gross beta	1	0.73	0.73	0.73
Runoff	Gross alpha	3	0.55	0.32	0.69
(From Rain)	Gross beta	3	0.69	0.38	0.92
	Uranium-234+233	1	1.1	1.1	1.1
	Uranium-235+236	1	2.3	2.3	2.3
	Uranium 238	1	0.86	0.86	0.86
Soil	Americium-241	1	1.5	1.5	1.5
	Cesium-137	3	0.9	0.87	0.94
	Potassium-40	3	0.98	0.93	1.1
	Plutonium-238	1	1	1	1
	Plutonium-239+240	2	0.95	0.85	1.1
	Radium-226	3	1	0.9	1.2
	Radium-228	3	0.98	0.89	1.1
	Thorium-228	3	1	0.88	1.2
	Uranium-235	3	1.1	0.83	1.2
	Uranium-238	2	0.9	0.77	1
Sewer	Gross alpha	1	1.3	1.3	1.3
	Tritium	4	1.1	0.75	1.3
Vegetation	Tritium	7	0.81	0.11	1.3

(a) Number of collocated pairs used in ratio calculations.

Table 9-3. Quality assurance collocated sampling: Summary statistics for analytes with at least four pairs in which one or both results were below the reporting limit.

Media	Analyte	No. inconsistent pairs[(a)]	No. pairs	Percent inconsistent pairs
Air	Tritium	1	16	6.2
Groundwater	Bromomethane	1	227	0.44
	Nitrate (as NO_3)	2	85	2.4
	Perchlorate	1	124	0.81
	RDX	1	59	1.7
	Uranium-235+236	2	26	7.7
Vegetation	Tritium	2	4	50

(a) Inconsistent pairs are those for which one of the results is more than twice the reporting limit of the other.

When there were nine or more data pairs with both results in each pair considered detections, precision and regression analyses were performed; those results are presented in **Table 9-1**. When there were eight or fewer data pairs with both results considered detections, the ratios of the individual data pairs for selected analytes were calculated; the mean, minimum, and maximum ratios are given in **Table 9-2**. The mean ratio should be between 0.7 and 1.3. When either of the results in a pair is considered a nondetection, the other result should be a nondetection or less than two times the reporting limit. **Table 9-3** identifies the sample media and analytes for which at least one pair failed this criterion. Media and analytes with fewer than four pairs are omitted from the table.

Precision is measured by the percent relative standard deviation (%RSD); see the EPA's *Data Quality Objectives for Remedial Response Activities: Development Process*, Section 4.6 (U.S. EPA 1987). Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, lower values represent better precision. The results for %RSD given in **Table 9-1** are the 75th percentile of the individual precision values. Routine and collocated sample results show good %RSD—90% of the pairs have %RSD of 29% or better; 75% have %RSD of 14% or better.

Regression analysis consists of fitting a straight line to the collocated sample pairs. Good agreement is indicated when the data lie close to a line with a slope equal to 1 and an intercept equal to 0, as illustrated in **Figure 9-1**. Allowing for normal analytical and environmental variation, the slope of the fitted line should be between 0.7 and 1.3, and the absolute value of the intercept should be less than the detection limit. The coefficient of determination (r^2) should be greater than 0.8. These criteria apply to pairs in which both results are considered above the detection limit.

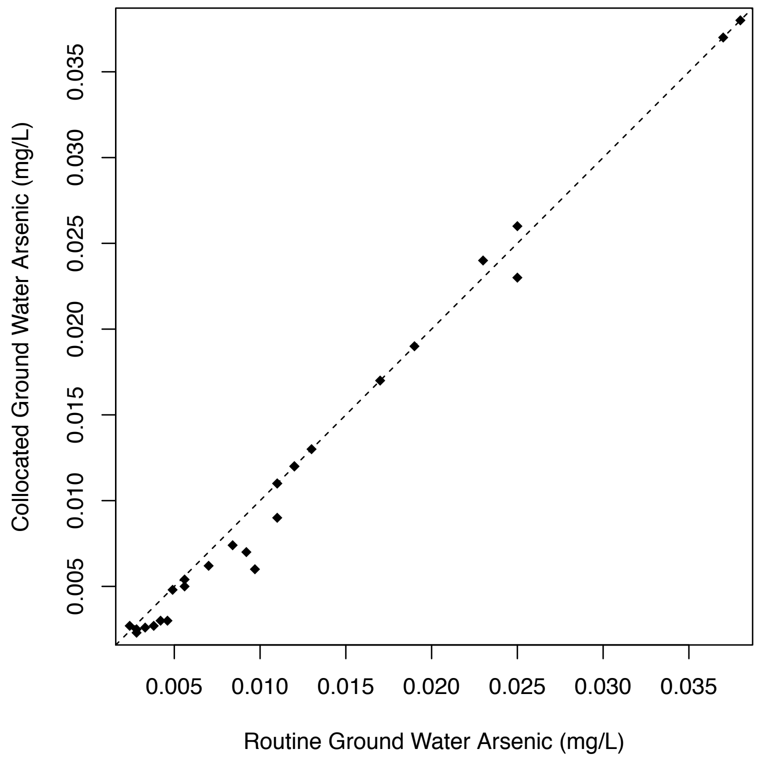

Figure 9-1. Example of data points that demonstrate good agreement between collocated sample results using arsenic concentrations in groundwater.

Collocated sample comparisons are more variable when the members of the pair are analyzed by different methods or with different criteria for analytical precision. For example, radiological analyses using different counting times or different laboratory aliquot sizes will have different amounts of variability. Different criteria are rarely, if ever, used with collocated sample pairs in LLNL environmental monitoring sampling. Different criteria are sometimes used in special studies if more than one agency is involved and each sets its own analytical criteria.

Data sets that do not meet LLNL regression analysis criteria fall into one of two categories: outliers and high variability. Outliers can occur because of data transcription errors, measurement errors, or real but anomalous results. Of the 26 data sets reported in **Table 9-1**, two did not meet the criterion for acceptability because of outliers. **Figure 9-2** illustrates a set of collocated pairs with one outlier.

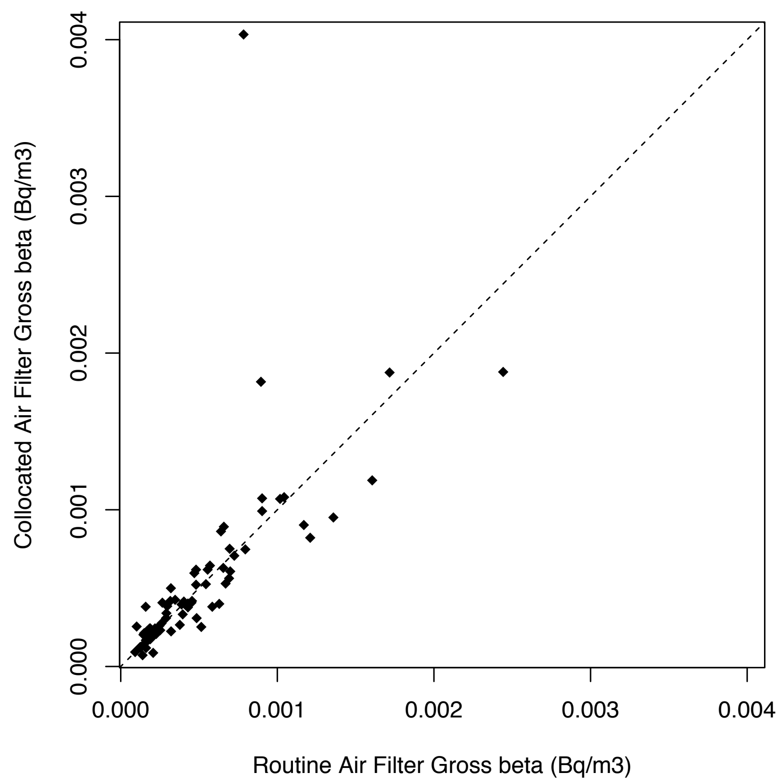

Figure 9-2. Example of data with one outlier using collocated air filter gross beta concentrations.

The second category, high variability, occurs when the measurement process inherently has substantial variability (see **Figure 9-3** for an example). It also tends to occur at extremely low environmental concentrations. Low concentrations of radionuclides on particulates in air highlight this effect because a small change in the number of radionuclide-containing particles on an air filter can significantly affect results. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 26 data sets listed in **Table 9-1**, three show sufficient variability in the results to make them fall outside the acceptable range.

9.4 Data Presentation

The data tables in **Appendix A** were created using computer scripts that retrieve data from a database, convert the data into Système International (SI) units when necessary, calculate summary statistics, format data as appropriate, format the table into rows and columns, and present a draft table. The tables are then reviewed by the responsible analyst. Analytical laboratory data and the values calculated from the data are normally displayed with two, or at most three, significant digits. Significant trailing zeros may be omitted.

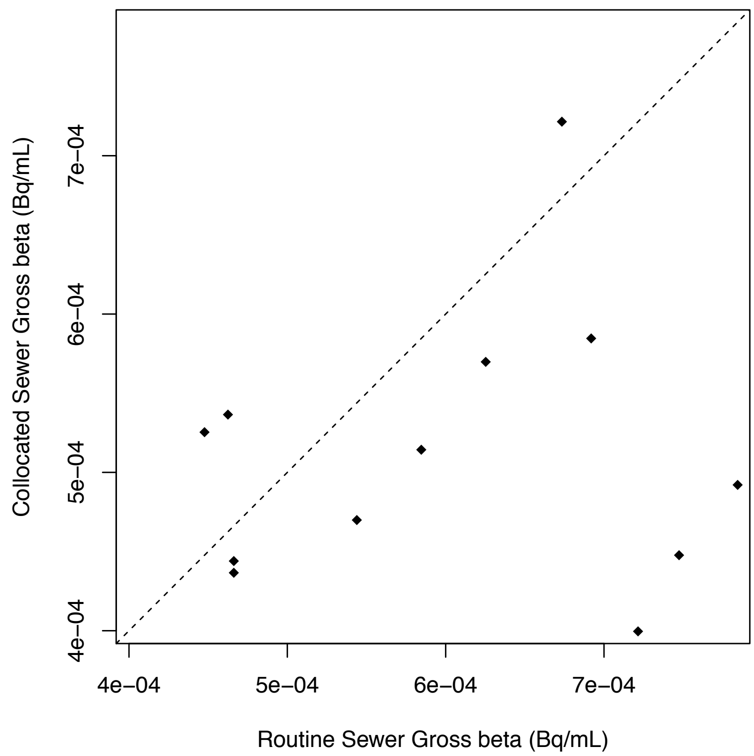

Figure 9-3. Example of variability using collocated sewer gross beta concentrations.

9.4.1 Radiological Data

Most of the data tables in **Appendix A** that have radiological data display the result plus or minus (±) an associated 2σ (sigma) uncertainty. This measure of uncertainty represents intrinsic variation in the measurement process, most of which is due to the random nature of radioactive decay (see **Section 9.6**). The uncertainties are not used in summary statistic calculations. Any radiological result exhibiting a 2σ uncertainty greater than or equal to 100% of the result is considered a nondetection.

Some radiological results are derived from the number of sample counts minus the number of background counts inside the measurement apparatus. Therefore, a sample with a concentration at or near background may have a negative value. Such results are reported in the data tables and used in the calculation of summary statistics and statistical comparisons.

Some data tables provide a limit-of-sensitivity value instead of an uncertainty when the radiological result is below the detection criterion. Such results are displayed with the limit-of-sensitivity value in parentheses.

9.4.2 Nonradiological Data

Nonradiological data reported by the analytical laboratory as being below the reporting limit are displayed in tables with a less-than symbol (<). Reporting limit values are used in the calculation of summary statistics, as explained below.

9.5 Statistical Comparisons and Summary Statistics

Standard comparison techniques such as regression analysis, *t*-tests, and analysis of variance are used where appropriate to determine the statistical significance of trends or differences between means. When a comparison is made, the results are described as either “statistically significant” or “not statistically significant.” Other uses of the word “significant” in this report do not imply that statistical tests have been performed but relate to the concept of practical significance and are based on professional judgment.

Summary statistics are calculated according to Gallegos (2009). The usual summary statistics are the median, which is a measure of central tendency, and interquartile range (IQR), which is a measure of dispersion (variability). However, some data tables may present other measures at the discretion of the analyst.

The median indicates the middle of the data set (i.e., half of the measured results are above the median, and half are below). The IQR is the range that encompasses the middle 50% of the data set. The IQR is calculated by subtracting the 25th percentile of the data set from the 75th percentile of the data set. When necessary, the percentiles are interpolated from the data. Different software vendors may use slightly different formulas for calculating percentiles. Radiological data sets that include values less than zero may have an IQR greater than the median. In this report, at least four values are required to calculate the median and at least six values are required to calculate the IQR.

Summary statistics are calculated from values that, if necessary, have already been rounded, such as when units have been converted from picocuries to becquerels, and are then rounded to an appropriate number of significant digits. The calculation of summary statistics is also affected by the presence of nondetections. A nondetection indicates that no specific measured value is available; instead, the best information available is that the actual value is less than the reporting limit. Adjustments to the calculation of the median and IQR for data sets that include nondetections are described below.

For data sets with all measurements above the reporting limit and radiological data sets that include reported values below the reporting limit, all reported values, including any below the reporting limit, are included in the calculation of summary statistics.

For data sets that include one or more values reported as “less than the reporting limit,” the reporting limit is used as an upper bound value in the calculation of summary statistics.

If the number of values is odd, the middle value (when sorted from smallest to largest) is the median. If the middle value and all larger values are detections, the middle value is reported as the median. Otherwise, the median is assigned a less-than (<) sign.

If the number of values is even, the median is halfway between the middle two values (i.e., the middle two when the values are sorted from smallest to largest). If both of the middle two values and all larger values are detections, the median is reported. Otherwise, the median is assigned a less-than (<) sign.

If any value used to calculate the 25th percentile is a nondetection, or any value larger than the 25th percentile is a nondetection, the IQR cannot be calculated and is not reported.

The median and the IQR are not calculated for data sets with no detections.

9.6 Reporting Uncertainty in Data Tables

The measurement uncertainties associated with results from analytical laboratories are represented in two ways. The first of these, significant digits, relates to the resolution of the measuring device. For example, if an ordinary household ruler with a metric scale is used to measure the length of an object in centimeters, and the ruler has tick marks every one-tenth of a centimeter, the length can reliably and consistently be measured to the nearest tenth of a centimeter (i.e., to the nearest tick mark). An attempt to be more precise is not likely to yield reliable or reproducible results because it would require a visual estimate of a distance between tick marks. The appropriate way to report a measurement using this ruler would be, for example, 2.1 cm, which would indicate that the "true" length of the object is nearer to 2.1 cm than to 2.0 cm or 2.2 cm (i.e., between 2.05 and 2.15 cm). A measurement of 2.1 cm has two significant digits. Although not stated, the uncertainty is considered to be ± 0.05 cm. A more precise measuring device might be able to measure an object to the nearest one-hundredth of a centimeter; in that case a value such as "2.12 cm" might be reported. This value would have three significant digits and the implied uncertainty would be ± 0.005 cm. A result reported as "3.0 cm" has two significant digits. That is, the trailing zero is significant and implies that the true length is between 2.95 and 3.05 cm—closer to 3.0 than to 2.9 or 3.1 cm.

When performing calculations with measured values that have significant digits, all digits are used. The number of significant digits in the calculated result is the same as that of the measured value with the fewest number of significant digits.

Most unit conversion factors do not have significant digits. For example, the conversion from milligrams to micrograms requires multiplying by the fixed (constant) value of 1000. The value 1000 is exact; it has no uncertainty and therefore the concept of significant digits does not apply.

The other method of representing uncertainty is based on random variation. For radiological measurements, there is variation due to the random nature of radioactive decay. As a sample is measured, the number of radioactive decay events is counted and the reported result is calculated from the number of decay events that were observed. If the sample is recounted, the number of decay events will almost always be different because radioactive decay events occur randomly. Uncertainties of this type are reported as 2σ uncertainties. A 2σ uncertainty represents the range of results expected to occur approximately 95% of the time if a sample were to be recounted many times. A radiological result reported as, for example, "2.6 ± 1.2 Bq/g," would indicate that with approximately 95% confidence, the "true" value is in the range of 1.4 to 3.8 Bq/g (i.e., 2.6 – 1.2 = 1.4 and 2.6 + 1.2 = 3.8). When necessary, results are converted from pCi to Bq by multiplying by 0.037; this introduces extraneous digits that are not significant and should not be shown in data tables. For example, 5.3 pCi/g × 0.037 = 0.1961 Bq/g. The initial value, 5.3, has two significant digits, so the value 0.1961 would be rounded to two significant digits, that is, 0.20.

However, the rounding rule changes when there is a radiological uncertainty associated with a radiological result. In this case, data are presented according to the method recommended in Multi-Agency Radiological Laboratory Analytical Protocols (MARLAP) Section 19.3.7 (U.S. NRC/U.S. EPA 2004). First the uncertainty is rounded to the appropriate number of significant digits, after which the result is rounded to the same number of decimal places. For example, suppose a result and uncertainty after unit conversion are 0.1961 ± 0.05436, and the appropriate number of significant digits is two. First, 0.05436 is rounded to 0.054 (two significant digits). 0.054 has three decimal places, so 0.1961 is then rounded to three decimal places, i.e., 0.196. These would be presented in the data tables as 0.196 ± 0.054.

When rounding a value with a final digit of "5," the software that was used to prepare the data tables implements the ISO/IEC/IEEE 60559:2011 rule, which is "go to the even digit." For example, 2.45 would be rounded down to 2.4, and 2.55 would be rounded up to 2.6.

The software that prepares the data tables pays careful attention to the details of rounding for significant digits. It should be noted, however, that these details are of little practical significance. For example, if a result of 5.6 is incorrectly rounded to 5.5 or 5.7, the introduced "error" is less than 2% (0.1/5.6 = 0.018). Such an error will rarely have any impact on the interpretation of the data with respect to human health or environmental impact.

9.7 Quality Assurance Process for the Environmental Report

Unlike the preceding sections, which focused on standards of accuracy and precision in data acquisition and reporting, this section describes the actions that are taken to ensure the accuracy of this data-rich environmental report, the preparation of which involves many operations and many people. The key elements that are used to ensure accuracy are described below.

Analytical laboratories send reports electronically, which are loaded directly into the database. This practice should result in perfect agreement between the database and data in printed reports from the laboratories. In practice, however, laboratory reporting is not perfect, so the EFA and ERD Data Management Teams (DMTs) carefully check incoming data throughout the year to make sure that electronic and printed reports from the laboratories agree. This aspect of QC is essential to the report's accuracy. Because of this ongoing QC of incoming data, data stored in the database and used to prepare the annual environmental report tables are unlikely to contain errors.

As described in **Section 9.4**, scripts are used to pull data from the database directly into the format of the table, including unit conversion and summary statistic calculations. All of the data tables contained in **Appendix A** were prepared for this report in this manner. For these tables, it is the responsibility of the appropriate analyst to check each year that the table is up-to-date (e.g., new locations/analytes added, old ones removed), that the data agree with the data he or she has received from DMT, and that the summary calculations have been done correctly.

For this 2011 environmental report, LLNL staff checked tables and figures in the body of the report. Forms to aid in the QC of tables and figures were distributed along with the appropriate figure, table, and text, and a coordinator kept track of the process. Items that were checked included clarity and accuracy of figure captions and table titles; data accuracy and completeness; figure labels and table headings; units; significant digits; and consistency with text. Completed QC forms and the corrected figures or tables were returned to the report editor, who, in collaboration with the responsible author, ensured that corrections were made.

There are multiple levels of document review performed to ensure the accuracy and clarity of this report. Authors, technical and scientific editors and DOE LSO all participate in multiple review cycles throughout document production.

9.8 Errata

Appendix E contains the protocol for errata in LLNL *Environmental Reports* and the errata for *LLNL Site Annual Environmental Report 2010*.

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Acronyms and Glossary

Symbols and Units of Measure

ºC	degree centigrade
ºF	degree Fahrenheit
σ	sigma
aCi	attocurie (10^{-18} Ci)
µBq	microbecquerel (10^{-6} Bq)
µg/g	microgram per gram (10^{-6} g/g)
µg/L	microgram per liter (10^{-6} g/L)
µg/m^3	microgram per cubic meter (10^{-6} g/m^3)
µrem	microrem (10^{-6} rem)
µSv/y	microsievert per year
Bq	becquerel (*See also* definition in **Key Terms** section.)
Bq/g	becquerel per gram
Bq/kg	becquerel per kilogram
Bq/L	becquerel per liter
Bq/m^3	becquerel per cubic meter
Bq/mL	becquerel per milliliter
Ci	curie (*See also* definition in **Key Terms** section.)
cm	centimeter
ft	foot
g	gram
gal	gallon
gal/d	gallon per day
gal/min	gallon per minute
GBq	gigabecquerel (10^{9} Bq)
in.	inch
keV	kiloelectronvolt (10^{3} eV) (*See also* definition of “electronvolt” in **Key Terms** section.)
kg	kilogram (10^{3} g)
kg/d	kilogram per day (10^{3} g/d)
km	kilometer (10^{3} m)
L	liter
L/d	liter per day
L/y	liter per year
m	meter
mBq	millibecquerel (10^{-3} Bq)
mBq/g	millibecquerel per gram (10^{-3} Bq/g)
mBq/dry g	millibecquerel per dry gram (10^{-3} Bq/dry g)
mBq/m^3	millibecquerel per cubic meter (10^{-3} Bq/m^3)
mCi	millicurie (10^{-3} Ci)
mg/L	milligram/liter (10^{-3} g/L)
mi	mile
mph	mile per hour
mR	milliroentgen (10^{-3} R) (*See also* definition of “roentgen” in **Key Terms** section.)
mrem	millirem (10^{-3} rem) (*See also* definition of “rem” in **Key Terms** section.)
mrem/y	millirem per year (10^{-3} rem/y)
m/s	meter per second
mSv	millisievert (10^{-3} Sv)
mSv/y	millisievert per year (10^{-3} Sv/y)

MT	metric ton
nBq	nanobecquerel (10^{-9} Bq)
nSv	nanosievert (10^{-9} Sv)
nSv/y	nanosievert per year (10^{-9} Sv/y)
pCi	picocurie (10^{-12} Ci)
pCi/g	picocurie per gram (10^{-12} Ci/g)
pCi/dry g	picocurie per dry gram (10^{-12} Ci/dry g)
pCi/L	picocurie per liter (10^{-12} Ci/liter)
person-Sv	person-sievert (*See also* definition in **Key Terms** section.)
person-Sv/y	person-sievert/year
pg/L	picogram per liter (10^{-12} g/L)
pg/m^3	picogram per cubic meter (10^{-12} g/m^3)
Sv	sievert (*See also* definition in **Key Terms** section.)
TBq	terabecquerel (10^{12} Bq)

Acronyms and Abbreviations

%RSD	Percent relative standard deviation
ACCDA	Alameda County Community Development Agency
ACDEH	Alameda County Department of Environmental Health
ACOE	Army Corps of Engineers
AFV	alternative fuel vehicle
ALARA	as low as reasonably achievable
ATSDR	Agency for Toxic Substances and Disease Registry
BAAQMD	Bay Area Air Quality Management District (*See also* definition in **Key Terms** section.)
BCG	Biota Concentration Guide
BGS	Below Ground Surface
BO	biological opinion
BSA	Blanket Service Agreement
BSL	Biosafety Level
CAA	Clean Air Act
CalARP	California Accidental Release Prevention
CAMP	Corrective Action Monitoring Plan
CAMU	Corrective Action Management Unit
CARB	California Air Resources Board
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CEI	Compliance Evaluation Inspection
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980 (*See also* definition in **Key Terms** section.)
CFF	Contained Firing Facility
CFR	Code of Federal Regulations
CMWMA	California Medical Waste Management Act
CNPS	California Native Plant Society
CO	carbon monoxide
COC	constituent of concern
COD	chemical oxygen demand
CSA	container storage area
CUPA	Certified Unified Program Agencies

CVRWQCB	Central Valley Regional Water Quality Control Board (*See also* definition in **Key Terms** section.)
CWA	(Federal) Clean Water Act
DCS	Derived Concentration Technical Standard
DMP	Detection Monitoring Plan
DMT	Data Management Team
DOE	(U.S.) Department of Energy (*See also* definition in **Key Terms** section.)
DOECAP	(U.S.) Department of Energy Consolidated Auditing Program
DOT	(U.S.) Department of Transportation
DPH	Department of Public Health
DPR	(California) Department of Pesticide Regulation
DRB	Drainage Retention Basin
DTSC	(California Environmental Protection Agency) Department of Toxic Substances Control
DWTF	Decontamination and Waste Treatment Facility
E85	Vehicle fuel, 85% ethanol and 15% gasoline
EA	environmental assessment
EDE	effective dose equivalent (*See also* definition in **Key Terms** section.)
EDO	Environmental Duty Officer
EIS	environmental impact statement
ELAP	Environmental Laboratory Accreditation Program
EMP	Environmental Management Plan
EMS	Environmental Management System
EPA	Environmental Protection Agency (*See also* definition in **Key Terms** section.)
EPCRA	Emergency Planning and Community Right-to-Know Act of 1986 (*See also* definition in **Key Terms** section.)
EPD	(LLNL) Environmental Protection Department
EPEAT	Electronic Product Environmental Assessment Tool
EPL	effluent pollutant limit
EPP	Environmentally Preferable Purchasing
ERD	(LLNL) Environmental Restoration Department
ERP	Environmental Restoration Project
ES&H	Environment, Safety, and Health
ESA	Endangered Species Act
ESAR	Enhanced Source Area Remediation
EWSF	Explosives Waste Storage Facility
EWTF	Explosives Waste Treatment Facility
FFA	Federal Facility Agreement (*See also* definition in **Key Terms** section.)
FFCA	Federal Facilities Compliance Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FY	fiscal year (*See also* definition in **Key Terms** section.)
GHG	greenhouse gases
GPS	global positioning system
GSA	(U.S.) General Services Administration
GWP	(Livermore site) Ground Water Project
HAP	hazardous air pollutant
HPGe	high-purity germanium
HSU	hydrostratigraphic unit
HRA	health risk assessment
HT/TT	tritiated hydrogen gas
HTO/TTO	tritiated water or tritiated water vapor
HWCL	Hazardous Waste Control Law (*See also* definition in **Key Terms** section.)

ICRP	International Commission on Radiological Protection
IEEE	Institute of Electrical and Electronics Engineers
IQR	Interquartile range (*See also* definition in **Key Terms** section.)
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
ITS	Institutional Tracking System
LEED	Leadership in Energy and Environmental Design
LEED-EB	Leadership in Energy and Environmental Design for Existing Buildings
LEPC	Local Emergency Planning Committee
LLNL	Lawrence Livermore National Laboratory
LLNS	Lawrence Livermore National Security, LLC
LWRP	Livermore Water Reclamation Plant
MAPEP	Mixed Analyte Performance Evaluation Program
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols
MCL	maximum contaminant level (*See also* definition in **Key Terms** section.)
MDC	minimum detectable concentration
MRP	Monitoring and Reporting Program
MSAs	Management Self Assessments
MSDS	material safety data sheet
NCRP	National Council on Radiation Protection and Measurements
NELAP	National Environmental Laboratory Accreditation Program
NEPA	National Environmental Policy Act (*See also* definition in **Key Terms** section.)
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NOx	nitrous oxides
NPDES	National Pollutant Discharge Elimination System (*See also* definition in **Key Terms** section.)
NRHP	National Register of Historic Places
OBT	organically bound tritium
ODS	ozone depleting substance
ORNL	Oak Ridge National Laboratory
OU	operable unit
P2	pollution prevention
PA	Programmatic Agreement
PEP	Performance Evaluation Plan
PCB	polychlorinated biphenyl
PCE	perchloroethylene (or perchloroethene); also called tetrachloroethylene or tetrachloroethene
PM-10	particulate matter with diameter equal to or less than 10 micrometer
PPMRP	Pollution Prevention and Monitoring and Reporting Program
PQL	practical quantitation limit (*See also* definition in **Key Terms** section.)
PRAD	(LLNL) Permits and Regulatory Affairs Division
QA	quality assurance (*See also* definition in **Key Terms** section.)
QC	quality control (*See also* definition in **Key Terms** section.)
RCRA	Resource Conservation and Recovery Act of 1976 (*See also* definition in **Key Terms** section.)
REC	Renewable Energy Credit
RHWM	(LLNL) Radioactive and Hazardous Waste Management Division
RL	reporting limit
RMP	risk management plan
ROG/POC	reactive organic gases/precursor organic compounds

RPM	Remedial Project Managers
RWQCB	Regional Water Quality Control Board (*See also* definition in **Key Terms** section.)
SARA	Superfund Amendment and Reauthorization Act of 1986 (*See also* definition in **Key Terms** section.)
SDWA	Safe Drinking Water Act
SERC	State Emergency Response Commission
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board (*See also* definition in **Key Terms** section.)
SFTF	Small Firearms Training Facility
SHPO	State Historic Preservation Officer
SI	Système International d'Unités (*See also* definition in **Key Terms** section.)
SJCEHD	San Joaquin County Environmental Health Department (*See also* definition in **Key Terms** section.)
SJCOES	San Joaquin County, Office of Emergency Services
SJVAPCD	San Joaquin Valley Air Pollution Control District (*See also* definition in **Key Terms** section.)
SMOP	Synthetic Minor Operating Permit
SMS	(LLNL) Sewer Monitoring Station
SOx	sulphur oxides
SPCC	Spill Prevention Control and Countermeasure
STP	Site Treatment Plan
SW-MEI	site-wide maximally exposed individual member (of the public) (*See also* definition in **Key Terms** section.)
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TAG	Technical Assistance Grant
TBOS/TKEBS	tetrabutyl orthosilicate/tetrakis 2-ethylbutyl silane
TCE	trichloroethene (or trichloroethylene)
TEF	toxicity equivalency factor
TEQ	toxicity equivalency
TF	treatment facility
TLD	thermoluminescent dosimeter (*See also* definition in **Key Terms** section.)
TRI	Toxics Release Inventory
Tri-Valley CAREs	Tri-Valley Communities Against a Radioactive Environment
TRU	transuranic (waste) (*See also* definition in **Key Terms** section.)
TSCA	Toxic Substances Control Act
TSF	Terascale Simulation Facility
TSS	total suspended solids (*See also* definition in **Key Terms** section.)
TTO	total toxic organic (compounds)
USGBC	U.S. Green Building Council
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound (*See also* definition in **Key Terms** section.)
VTF	vapor treatment facility
WAA	waste accumulation area (*See also* definition in **Key Terms** section.)
WDAR	Waste Discharge Authorization Requirement
WDR	Waste Discharge Requirement
WRD	Water Resources Division (*See also* definition in **Key Terms** section.)

Metric and U.S. Customary Unit Equivalents

Category	From metric unit to U.S. customary equivalent unit		From U.S. customary unit to metric equivalent unit	
	Metric	U.S.	U.S.	Metric
Length	1 centimeter (cm)	0.39 inches (in.)	1 inch (in.)	2.54 centimeters (cm)
	1 millimeter (mm)	0.039 inches (in.)		25.4 millimeters (mm)
	1 meter (m)	3.28 feet (ft)	1 foot (ft)	0.3048 meters (m)
		1.09 yards (yd)	1 yard (yd)	0.9144 meters (m)
	1 kilometer (km)	0.62 miles (mi)	1 mile (mi)	1.6093 kilometers (km)
Volume	1 liter (L)	0.26 gallons (gal)	1 gallon (gal)	3.7853 liters (L)
		8.11×10^{-7} acre-feet	1 acre-foot	1.23×10^{6}liters (L)
	1 cubic meter (m^3)	35.32 cubic feet (ft^3)	1 cubic foot (ft^3)	0.028 cubic meters (m^3)
		1.35 cubic yards (yd^3)	1 cubic yard (yd^3)	0.765 cubic meters (m^3)
Weight	1 gram (g)	0.035 ounces (oz)	1 ounce (oz)	28.6 gram (g)
	1 kilogram (kg)	2.21 pounds (lb)	1 pound (lb)	0.373 kilograms (kg)
	1 metric ton (MT)	1.10 short ton (2000 pounds)	1 short ton (2000 pounds)	0.90718 metric ton (MT)
Area	1 hectare (ha)	2.47 acres	1 acre	0.40 hectares (ha)
Radioactivity	1 becquerel (Bq)	2.7×10^{-11} curie (Ci)	1 curie (Ci)	3.7×10^{10} becquerel (Bq)
Radiation dose	1 gray (Gy)	100 rad	1 rad	0.01 gray (Gy)
Radiation dose equivalent	1 sievert (Sv)	100 rem	1 rem	0.01 sievert (Sv)
Temperature	^{o}Fahrenheit = (^{o}Centigrade x 1.8) + 32		^{o}Centigrade = (^{o}Fahrenheit – 32) / 1.8	

Multipying Prefixes

Symbol	Prefix	Factor	Symbol	Prefix	Factor
v	vendeko	10^{-30}	da	deca	10^{1}
x	xenno	10^{-27}	h	hecto	10^{2}
y	yocto	10^{-24}	k	kilo	10^{3}
z	zepto	10^{-21}	M	mega	10^{6}
a	atto	10^{-18}	G	giga	10^{9}
f	femto	10^{-15}	T	tera	10^{12}
p	pico	10^{-12}	P	peta	10^{15}
n	nano	10^{-9}	E	exa	10^{18}
µ	micro	10^{-6}	Z	zetta	10^{21}
m	milli	10^{-3}	Y	yotta	10^{24}
c	centi	10^{-2}			
d	deci	10^{-1}			

Key Terms

Absorbed dose. Amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material, in which the absorbed dose is expressed in units of rad or gray (1 rad = 0.01 gray).

Accuracy. Closeness of the result of a measurement to the true value of the quantity measured.

Action level. Defined by regulatory agencies, the level of pollutants which, if exceeded, requires regulatory action.

Alluvium. Sediment deposited by flowing water.

Alpha particle. Positively charged particle emitted from the nucleus of an atom, having mass and charge equal to those of a helium nucleus (two protons and two neutrons).

Ambient air. Surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures; for monitoring purposes, it does not include air immediately adjacent to emission sources.

Analyte. Specific component measured in a chemical analysis.

Aquifer. Saturated layer of rock or soil below the ground surface that can supply usable quantities of groundwater to wells and springs, and be a source of water for domestic, agricultural, and industrial uses.

Bay Area Air Quality Management District (BAAQMD). Local agency responsible for regulating stationary air emission sources (including the LLNL Livermore site) in the San Francisco Bay Area.

Becquerel (Bq). SI unit of activity of a radionuclide, equal to the activity of a radionuclide having one spontaneous nuclear transition per second.

Beta particle. Negatively charged particle emitted from the nucleus of an atom, having charge, mass, and other properties of an electron.

Categorical discharge. Discharge from a process regulated by EPA rules for specific industrial categories.

Central Valley Regional Water Quality Control Board (CVRWQCB). Local agency responsible for regulating ground and surface water quality in the Central Valley.

Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Administered by EPA, this federal law, also known as Superfund, requires private parties to notify the EPA of conditions that threaten to release hazardous substances or after the release of hazardous substances, and undertake short-term removal and long-term remediation.

Cosmic radiation. Radiation with very high energies originating outside the earth's atmosphere; it is one source contributing to natural background radiation.

Curie (Ci). Unit of measurement of radioactivity, defined as the amount of radioactive material in which the decay rate is 3.7×10^{10} disintegrations per second or 2.22×10^{12} disintegrations per minute; one Ci is approximately equal to the decay rate of 1 gram of pure radium.

Depleted uranium. Uranium having a lower proportion of the isotope uranium-238 than is found in naturally occurring uranium. The masses of the three uranium isotopes with atomic weights 238, 235, and 234 occur in depleted uranium in the weight-percentages 99.8, 0.2, and 5×10^{-4}, respectively. Depleted uranium is sometimes referred to as D-38 or DU.

Derived concentration technical guide (DCS). Concentrations of radionuclides in water and air that could be continuously consumed or inhaled for one year and not exceed the DOE primary radiation standard to the public (100 mrem/y EDE).

Dose. Energy imparted to matter by ionizing radiation; the unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.

Dose equivalent. Product of absorbed dose in rad (or gray) in tissue and a quality factor representing the relative damage caused to living tissue by different kinds of radiation, and perhaps other modifying factors representing the distribution of radiation, etc. expressed in units of rem or sievert (1 rem = 0.01 sievert).

Dosimeter. Portable detection device for measuring the total accumulated exposure to ionizing radiation.

Downgradient. In the direction of groundwater flow from a designated area; analogous to downstream.

Effective dose equivalent (EDE). Estimate of the total risk of potential effects from radiation exposure, it is the summation of the products of the dose equivalent and weighting factor for each tissue. The weighting factor is the decimal fraction of the risk arising from irradiation of a selected tissue to the total risk when the whole body is irradiated uniformly to the same dose equivalent. These factors permit dose equivalents from nonuniform exposure of the body to be expressed in terms of an effective dose equivalent that is numerically equal to the dose from a uniform exposure of the whole body that entails the same risk as the internal exposure (ICRP 1980). The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent caused by penetrating radiation from sources external to the body, and is expressed in units of rem (or sievert).

Effluent. Liquid or gaseous waste discharged to the environment.

Electronvolt (eV). A unit of energy equal to the amount of kinetic energy gained by an electron when it passes through a potential difference of 1 volt in a vacuum.

Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA). Act that requires facilities that produce, use, or store hazardous substances to report releases of reportable quantities or hazardous substances to the environment.

Environmental impact statement (EIS). Detailed report, required by the National Environmental Policy Act, on the environmental impacts from a federally approved or funded project. An EIS must be prepared by a federal agency when a “major” federal action that will have “significant” environmental impacts is planned.

Federal facility. Facility that is owned or operated by the federal government, subject to the same requirements as other responsible parties when placed on the Superfund National Priorities List.

Federal facility agreement (FFA). Negotiated agreement that specifies required actions at a federal facility as agreed upon by various agencies (e.g., EPA, RWQCB, DOE).

Fiscal year (FY). LLNL’s fiscal year is from October 1 through September 30.

Freon-11. Trichlorofluoromethane.

Freon-113. 1,1,2-trichloro-1,2,2-trifluoroethane; also known as CFC 113.

Gamma ray. High-energy, short-wavelength, electromagnetic radiation emitted from the nucleus of an atom, frequently accompanying the emission of alpha or beta particles.

Groundwater. All subsurface water.

Hazardous waste. Waste that exhibits ignitability, corrosivity, reactivity, and/or EP-toxicity (yielding toxic constituents in a leaching test), and waste that does not exhibit these characteristics but has been determined to be hazardous by EPA. Although the legal definition of hazardous waste is complex, according to EPA the term generally refers to any waste that, if managed improperly, could pose a threat to human health and the environment.

(California) Hazardous Waste Control Law (HWCL). Legislation specifying requirements for hazardous waste management in California.

Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). High-explosive compound.

Inorganic compounds. Compounds that either do not contain carbon or do not contain hydrogen along with carbon, including metals, salts, and various carbon oxides (e.g., carbon monoxide and carbon dioxide).

International Commission on Radiological Protection (ICRP). International organization that studies radiation, including its measurement and effects.

Interquartile range (IQR). Distance between the top of the lower quartile and the bottom of the upper quartile, which provides a measure of the spread of data.

Isotopes. Forms of an element having the same number of protons in their nuclei, but differing numbers of neutrons.

Lake Haussmann. Man-made, lined pond used to capture storm water runoff and treated water at the Livermore site. Formerly called Drainage Retention Basin (DRB).

Less than detection limits. Phrase indicating that a chemical constituent was either not present in a sample, or is present in such a small concentration that it cannot be measured by a laboratory’s analytical procedure, and therefore is not identified or not quantified at the lowest level of sensitivity.

Livermore Water Reclamation Plant (LWRP). City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site.

Low-level waste. Waste defined by DOE Order 5820.2A, which contains transuranic nuclide concentrations less than 100 nCi/g.

Maximum contaminant level (MCL). Highest level of a contaminant in drinking water that is allowed by the U.S. Environmental Protection Agency or California Department of Health Services.

Metric units. Except for temperature for which specific equations apply, U.S. customary units can be determined from metric units by multiplying the metric units by the U.S. customary equivalent. Similarly, metric units can be determined from U.S. customary equivalent units by multiplying the U.S. customary units by the metric equivalent.(*See also* **Metric and U.S. Customary Unit Equivalents** table in this Glossary.)

Mixed waste. Waste that has the properties of both hazardous and radioactive waste.

National Environmental Policy Act (NEPA). Federal legislation enacted in 1969 that requires all federal agencies to document and consider environmental impacts for federally funded or approved projects and the legislation under which DOE is responsible for NEPA compliance at LLNL.

National Pollutant Discharge Elimination System (NPDES). Federal regulation under the Clean Water Act that requires permits for discharges into surface waterways.

Nuclear Regulatory Commission (NRC). Federal agency charged with oversight of nuclear power and nuclear machinery and applications not regulated by DOE or the Department of Defense.

Nuclide. Species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons, number of neutrons, and energy content; or, alternatively, by the atomic number, mass number, and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable length of time.

Part B permit. Second, narrative section submitted by generators in the RCRA permitting process that covers in detail the procedures followed at a facility to protect human health and the environment.

Perched aquifer. Aquifer that is separated from another water-bearing stratum by an impermeable layer.

Person-Sievert (person-Sv). The product of the average dose per person times the number of people exposed. 1 person-Sv = 100 person-rem.

pH. Measure of hydrogen ion concentration in an aqueous solution. The pH scale ranges from 0 to 14. Acidic solutions have a pH less than 7; basic solutions have a pH greater than 7; and neutral solutions have a pH of 7.

Pliocene. Geological epoch of the Tertiary period, starting about 12 million years ago.

PM-10. Fine particulate matter with an aerodynamic diameter equal to or less than 10 micrometer.

Point source. Any confined and discrete conveyance (e.g., pipe, ditch, well, stack).

Practical quantitation limit (PQL). Level at which the laboratory can report a value with reasonably low uncertainty (typically 10–20% uncertainty).

Pretreatment. Any process used to reduce a pollutant load before it enters the sewer system.

Quality assurance (QA). System of activities whose purpose is to provide the assurance that standards of quality are attained with a stated level of confidence.

Quality control (QC). Procedures used to verify that prescribed standards of performance are attained.

Quaternary. Geologic era encompassing the last 2 to 3 million years.

Rad. Unit of absorbed dose and the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue, and equal to 0.01 joule per kilogram, or 0.01 gray.

Radioactive decay. Spontaneous transformation of one radionuclide into a different nuclide (which may or may not be radioactive), or de-excitation to a lower energy state of the nucleus by emission of nuclear radiation, primarily alpha or beta particles, or gamma rays (photons).

Radioactivity. Spontaneous emission of nuclear radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope.

Radionuclide. Unstable nuclide. See also **nuclide** and **radioactivity**.

Regional Water Quality Control Board (RWQCB). California regional agency responsible for water quality standards and the enforcement of state water quality laws within its jurisdiction. California is divided into nine RWQCBs; the Livermore site is in the San Francisco Bay Region, and Site 300 is in the Central Valley Region.

Rem. Unit of radiation dose equivalent and effective dose equivalent describing the effectiveness of a type of radiation to produce biological effects; coined from the phrase "roentgen equivalent man," and the product of the absorbed dose (rad), a quality factor (Q), a distribution factor, and other necessary modifying factors. 1 rem = 0.01 sievert.

Resource Conservation and Recovery Act of 1976 (RCRA). Program of federal laws and regulations that govern the management of hazardous wastes, and applicable to all entities that manage hazardous wastes.

Risk assessment. Qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants.

Roentgen (R). Unit of measurement used to express radiation exposure in terms of the amount of ionization produced in a volume of air.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). Local agency responsible for regulating ground and surface water quality in the San Francisco Bay Area.

San Joaquin County Environmental Health Department (SJCEHD). Local agency that enforces underground-tank regulations in San Joaquin County, including Site 300.

San Joaquin Valley Air Pollution Control District (SJVAPCD). Local agency responsible for regulating stationary air emission sources (including Site 300) in San Joaquin County.

Sanitary waste. Most simply, waste generated by routine operations that is not regulated as hazardous or radioactive by state or federal agencies.

Saturated zone. Subsurface zone below which all rock pore-space is filled with water; also called the phreatic zone.

Sensitivity. Capability of methodology or instrumentation to discriminate between samples having differing concentrations or containing varying amounts of analyte.

Sievert (Sv). SI unit of radiation dose equivalent and effective dose equivalent, that is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. 1 sievert = 100 rem.

Sigma (σ) denotes the standard deviation of a statistical distribution.

Site-wide maximally exposed individual (SW-MEI). Hypothetical person who receives, at the location of a given publicly accessible facility (such as a church, school, business, or residence), the greatest LLNL-induced effective dose equivalent (summed over all pathways) from all sources of radionuclide releases to air at a site. Doses at this receptor location caused by each emission source are summed, and yield a larger value than for the location of any other similar public facility. This individual is assumed to continuously reside at this location 24 hours per day, 365 days per year.

Specific conductance. Measure of the ability of a material to conduct electricity; also called conductivity.

Superfund. Common name used for the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). California has also established a "State Superfund" under provisions of the California Hazardous Waste Control Act.

Superfund Amendments and Reauthorization Act (SARA). Enacted in 1986, these laws amended and reauthorized CERCLA for five years.

Surface impoundment. A facility or part of a facility that is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials, although it may be lined with man-made materials. The impoundment is designed to hold an accumulation of liquid wastes, or wastes containing free liquids, and is not an injection well.

Système International d'Unités (SI). International system of physical units which include meter (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent).

Thermoluminescent dosimeter (TLD). Device used to measure external beta or gamma radiation levels, and which contains a material that, after exposure to beta or gamma radiation, emits light when processed and heated.

Total dissolved solids (TDS). Portion of solid material in a waste stream that is dissolved and passed through a filter.

Total suspended solids (TSS). Total mass of particulate matter per unit volume suspended in water and wastewater discharges that is large enough to be collected by a 0.45 micron filter.

Tritium. Radioactive isotope of hydrogen, containing one proton and two neutrons in its nucleus, which decays at a half-life of 12.3 years by emitting a low-energy beta particle.

Transuranic waste (TRU). Material contaminated with alpha-emitting transuranium nuclides, which have an atomic number greater than 92 (e.g., plutonium-239), half-lives longer than 20 years, and are present in concentrations greater than 100 nCi/g of waste.

Universal waste. Hazardous waste that is widely produced by households and many different types of businesses. Universal waste includes televisions, computers and other electronic devices as well as batteries, fluorescent lamps, mercury thermostats, and other mercury-containing equipment. California's Universal Waste Rule allows individuals and businesses to transport, handle, and recycle universal waste in a manner that differs from the requirements for most hazardous wastes.

Unsaturated zone. Portion of the subsurface in which the pores are only partially filled with water and the direction of water flow is vertical; is also referred to as the vadose zone.

U.S. Department of Energy (DOE). Federal agency responsible for conducting energy research and regulating nuclear materials used for weapons production.

U.S. Environmental Protection Agency (EPA). Federal agency responsible for enforcing federal environmental laws. Although some of this responsibility may be delegated to state and local regulatory agencies, EPA retains oversight authority to ensure protection of human health and the environment.

Vadose zone. Partially saturated or unsaturated region above the water table that does not yield water to wells.

Volatile organic compound (VOC). Liquid or solid organic compounds that have a high vapor pressure at normal pressures and temperatures and thus tend to spontaneously pass into the vapor state.

Waste accumulation area (WAA). Officially designated area that meets current environmental standards and guidelines for temporary (less than 90 days) storage of hazardous waste before pickup by the Radioactive and Hazardous Waste Management Division for off-site disposal.

Wastewater treatment system. Collection of treatment processes and facilities designed and built to reduce the amount of suspended solids, bacteria, oxygen-demanding materials, and chemical constituents in wastewater.

Water Resources Division: The City of Livermore governmental organization dedicated to meeting Livermore's water, wastewater, and storm water utility needs.

Water table. Water-level surface below the ground at which the unsaturated zone ends and the saturated zone begins, and the level to which a well that is screened in the unconfined aquifer would fill with water.

Weighting factor. Tissue-specific value used to calculate dose equivalents which represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue.

Zone 7. Common name for the Alameda County Flood Control and Water Conservation District, Zone 7, which is the water agency for the Livermore–Amador Valley with responsibility for regional flood control and drinking water supply.

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APPENDIX A
Data Tables

The data tables listed in this appendix are accessible on CD or https://saer.llnl.gov/. In the electronic version of this appendix, the data tables listed below are linked to the tables, which are read-only Excel files.

A.1 Air Effluent (Chapter 4)

A.2 Ambient Air (Chapter 4)

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APPENDIX B
EPA Methods of Environmental Water Analysis

Table B-1. Inorganic constituents of concern in water samples, the analytical methods used to determine their concentrations, and their contractual reporting limits.

Constituent of concern		Analytical method	Reporting limit[(a,b)]
Metals and minerals (mg/L)	All alkalinities	SM 2310	1
	Aluminum	EPA 200.7 or 200.8	0.05 or 0.2
	Ammonia nitrogen (as N)	EPA 350.1 or SM 4500-NH3	0.03 or 0.1
	Antimony	EPA 204.2 or 200.8	0.005
	Arsenic	EPA 206.2 or 200.8	0.002
	Barium	EPA 200.7 or 200.8	0.025 or 0.01
	Beryllium	EPA 210.2 or 200.8	0.0005 or 0.0002
	Boron	EPA 200.7	0.05
	Bromide	EPA 300.0	0.5
	Cadmium	EPA 200.8 or SM 3113B	0.0005
	Calcium	EPA 200.7	0.5
	Chloride	EPA 300.0	1 or 0.5
	Chlorine (residual)	SM-4500-CL	0.1
	Chromium	EPA 218.2 or 200.8	0.01 or 0.001
	Chromium(VI)	EPA 218.4 or 7196	0.002
	Cobalt	EPA 200.7 or 200.8	0.025 or 0.05
	Copper	EPA 220.2, 200.7 or 200.8	0.001, 0.01 or 0.05
	Cyanide	EPA 335.2 or 4500-CN	0.02
	Fluoride	EPA 340.2 or 340.1	0.05
	Hardness, total (as $CaCO_3$)	SM 2320B	1
	Iron	EPA 200.7 or 200.8	0.1
	Lead	EPA 200.8 or SM3113B	0.002 or 0.005
	Magnesium	EPA 200.7 or 200.8	0.5
	Manganese	EPA 200.7 or 200.8	0.03
	Mercury	EPA 245.2 or 245.1	0.0002
	Molybdenum	EPA 200.7 or 200.8	0.025
	Nickel	EPA 200.7, 200.8 or SM 3113B	0.002, 0.005 or 0.1
	Nitrate (as NO_3)	EPA 353.2 300.0 or SM 4500-NO3	0.5
	Nitrite (as NO_2)	EPA 353.2or 300.0, SM 4500-NO2	0.5
	Ortho-phosphate	EPA 300.0 or SM4500	0.05
	Perchlorate	EPA 314.0	0.004
	Potassium	EPA 200.7	1
	Selenium	EPA 200.8 or SM 3113B	0.002
	Silver	EPA 200.8 or SM 3113B	0.001 or 0.0005
	Sodium	EPA 200.7	1 or 0.1
	Sulfate	EPA 300.0	1
	Surfactants	SM 5540C or EPA 425.1	0.5
	Thallium	EPA 279.2 or 200.8	0.001

B. EPA Methods of Environmental Water Analysis

Table B-1 (cont.). Inorganic constituents of concern in water samples, the analytical methods used to determine their concentrations, and their contractual reporting limits.

Constituent of concern		Analytical method	Reporting limit[a,b]
Metals and minerals (mg/L) (cont.)	Total dissolved solids	SM 2540C	1
	Total suspended solids	SM 2540D	1
	Total Kjeldahl nitrogen (as N)	EPA 351.2 or SM 4500-Norg	0.2
	Total phosphorus (as P)	EPA 365.4 or SM 4500-P	0.05
	Vanadium	EPA 200.7 or 200.8	0.02 or 0.025
	Zinc	EPA 200.7 or 200.8	0.02 or 0.05
General indicator parameters	pH (pH units)	SM 4500-H+	none
	Biochemical oxygen demand (mg/L)	SM 5210B	2
	Conductivity (µS/cm)	EPA 120.1	none
	Chemical oxygen demand (mg/L)	EPA 410.4	5
	Dissolved oxygen (mg/L)	SM 4500-O G	0.05
	Total organic carbon (mg/L)	EPA 9060 or SM 5310B	1
	Total organic halides (mg/L)	EPA 9020	0.02
	Toxicity, acute (fathead minnow)	EPA 600/4-AB5-013	NA
	Toxicity, chronic (fathead minnow)	EPA 1000	NA
	Toxicity, chronic (daphnid)	EPA 1002	NA
	Toxicity, chronic (green algae)	EPA 1003	NA
Radioactivity (Bq/L)	Gross alpha	EPA 900	0.074
	Gross beta	EPA 900	0.11
Radioisotopes (Bq/L)	Americium-241	U-NAS-NS-3050	0.0037
	Plutonium-238	U-NAS-NS-3050	0.0037
	Plutonium-239+240	U-NAS-NS-3050	0.0037
	Radon-222	EPA 913	3.7
	Radium-226	EPA 903	0.0093
	Radium-228	EPA 904	0.037
	Thorium-228	U-NAS-NS-3050	0.009
	Thorium-230	U-NAS-NS-3050	0.006
	Thorium-232	U-NAS-NS-3050	0.006
	Tritium	EPA 906	3.7
	Uranium-234	EPA 907	0.0037
	Uranium-235	EPA 907	0.0037
	Uranium-238	EPA 907	0.0037

(a) The number of decimal places displayed in this table vary by constituent. These variations reflect regulatory agency permit stipulations, or the applicable analytical laboratory contract under which the work was performed, or both.

(b) These reporting limits are for water samples with low concentrations of dissolved solids. If higher concentrations are present, limits are likely to be higher.

Table B-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[(a,b)]
EPA Method 1664	
Oil & Grease	1000
EPA Method 420.1	
Phenolics	5
EPA Method 502.2	
1,1,1,2-Tetrachloroethane	0.2
1,1,1-Trichloroethane	0.2
1,1,2,2-Tetrachloroethane	0.2
1,1,2-Trichloroethane	0.2
1,1-Dichloroethane	0.2
1,1-Dichloroethene	0.2
1,1-Dichloropropene	0.2
1,2,3-Trichlorobenzene	0.2
1,2,3-Trichloropropane	0.2
1,2,4-Trichlorobenzene	0.2
1,2,4-Trimethylbenzene	0.2
1,2-Dichlorobenzene	0.2
1,2-Dichloroethane	0.2
1,2-Dichloropropane	0.2
1,3,5-Trimethylbenzene	0.2
1,3-Dichlorobenzene	0.2
1,3-Dichloropropane	0.2
1,4-Dichlorobenzene	0.2
2,2-Dichloropropane	0.2
2-Chlorotoluene	0.2
4-Chlorotoluene	0.2
Benzene	0.2
Bromobenzene	0.2
Bromochloromethane	0.2
Bromodichloromethane	0.2
Bromoform	0.2
Bromomethane	0.2
Carbon tetrachloride	0.2
Chlorobenzene	0.2
Chloroethane	0.2
Chloroform	0.2
Chloromethane	0.2
cis-1,2-Dichloroethene	0.2
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.2
Dibromomethane	0.2
Dichlorodifluoromethane	0.2
Ethylbenzene	0.2
Freon 113	0.2
Hexachlorobutadiene	0.2
Isopropylbenzene	0.2
m- and *p*-Xylene isomers	0.2
Methylene chloride	0.2
n-Butylbenzene	0.2
n-Propylbenzene	0.2
Naphthalene	0.2
o-Xylene	0.2
Isopropyl toluene	0.2
sec-Butylbenzene	0.2
Styrene	0.2
tert-Butylbenzene	0.2
Tetrachloroethene	0.2
Toluene	0.2
trans-1,2-Dichloroethene	0.2
trans-1,3-Dichloropropene	0.2
Trichloroethene	0.2
Trichlorofluoromethane	0.2
Vinyl chloride	0.2
EPA Method 507	
Alachlor	0.5
Atraton	0.5
Atrazine	0.5
Bromacil	0.5
Butachlor	0.5
Diazinon	0.5
Dichlorvos	0.5
Ethoprop	0.5
Merphos	0.5
Metolachlor	0.5
Metribuzin	0.5
Mevinphos	0.5
Molinate	0.5
Prometon	0.5

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[(a,b)]
EPA Method 507 (cont.)	
Prometryn	0.5
Simazine	0.5
Terbutryn	0.5
EPA Method 547	
Glyphosate	20
EPA Method 601	
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,2-Dichlorobenzene	0.5
1,2-Dichloroethane	0.5
1,2-Dichloroethene (total)	0.5
1,2-Dichloropropane	0.5
1,3-Dichlorobenzene	0.5
1,4-Dichlorobenzene	0.5
2-Chloroethylvinylether	0.5
Bromodichloromethane	0.5
Bromoform	0.5
Bromomethane	0.5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5
Chloroform	0.5
Chloromethane	0.5
cis-1,2-Dichloroethene	0.5
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.5
Dichlorodifluoromethane	0.5
Freon-113	0.5
Methylene chloride	0.5
Tetrachloroethene *trans*-1,2-	0.5
Dichloroethene *trans*-1,3-	0.5
Dichloropropene	0.5
Trichloroethene	0.5
Trichlorofluoromethane	0.5
Vinyl chloride	0.5

Constituent of concern	Reporting limit (µg/L)[(a,b)]
EPA Method 608	
Aldrin	0.05
BHC, alpha isomer	0.05
BHC, beta isomer	0.05
BHC, delta isomer	0.05
BHC, gamma isomer (Lindane)	0.05
Chlordane	0.2
Dieldrin	0.1
Endosulfan I	0.05
Endosulfan II	0.1
Endosulfan sulfate	0.1
Endrin	0.1
Endrin aldehyde	0.1
Heptachlor	0.05
Heptachlor epoxide	0.05
Methoxychlor	0.5
4,4'-DDD	0.1
4,4'-DDE	0.1
4,4'-DDT	0.1
Toxaphene	1
EPA Method 615	
2,4,5-T	0.5
2,4,5-TP (Silvex)	0.2
2,4-D	1
2,4-Dichlorophenoxy acetic acid	2
Dalapon	10
Dicamba	1
Dichloroprop	2
Dinoseb	1
MCPA	250
MCPP	250
EPA Method 624	
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 624 (cont)	
1,2-Dichloroethene (total)	1
1,2-Dichloropropane	1
1,3-Dichlorobenzene	1
1,4-Dichlorobenzene	1
2-Butanone	20
2-Chloroethylvinylether	20
2-Hexanone	20
4-Methyl-2-pentanone	20
Acetone	10
Benzene	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon disulfide	1
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,2-Dichloroethene	1
cis-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1
Dichlorodifluoromethane	2
Ethylbenzene	1
Freon 113	1
Methylene chloride	1
Styrene	1
Tetrachloroethene	1
Toluene	1
Total xylene isomers	2
trans-1,2-Dichloroethene	1
trans-1,3-Dichloropropene	1
Trichloroethene	0.5
Trichlorofluoromethane	1
Vinyl acetate	1
Vinyl chloride	1

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 625	
1,2,4-Trichlorobenzene	5
1,2-Dichlorobenzene	5
1,3-Dichlorobenzene	5
1,4-Dichlorobenzene	5
2,4,5-Trichlorophenol	5
2,4,6-Trichlorophenol	5
2,4-Dichlorophenol	5
2,4-Dimethylphenol	5
2,4-Dinitrophenol	25
2,4-Dinitrotoluene	5
2,6-Dinitrotoluene	5
2-Chloronaphthalene	5
2-Chlorophenol	5
2-Methylphenol	5
2-Methyl-4,6-dinitrophenol	25
2-Methylnaphthalene	5
2-Nitroaniline	25
3,3’-Dichlorobenzidine	10
3-Nitroaniline	25
4-Bromophenylphenylether	5
4-Chloro-3-methylphenol	10
4-Chloroaniline	10
4-Chlorophenylphenylether	5
4-Nitroaniline	25
4-Nitrophenol	25
Acenaphthene	25
Acenaphthylene	5
Anthracene	5
Benzo[*a*]a nthracene	5
Benzo[*a*]p yrene	5
Benzo[*b*]f luoranthene	5
Benzo[*g,h,i*]p erylene	5
Benzo[*k*]fluoranthene	5
Benzoic acid	25
Benzyl alcohol	10
Bis(2-chloroethoxy)methane	5
Bis(2-chloroisopropyl)ether	5

Table B-2 (cont.). Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[(a,b)]
EPA Method 625 (cont)	
Bis(2-ethylhexyl)phthalate	5
Butylbenzylphthalate	5
Chrysene	5
Di-*n*-butylphthalate	5
Di-*n*-octylphthalate	5
Dibenzo[*a,h*]a nthracene	5
Dibenzofuran	5
Diethylphthalate	5
Dimethylphthalate	5
Fluoranthene	5
Fluorene	5
Hexachlorobenzene	5
Hexachlorobutadiene	5
Hexachlorocyclopentadiene	5
Hexachloroethane	5
Indeno[*1,2,3-c,d*]p yrene	5
Isophorone	5
m- and *p*-Cresol	5
N-Nitroso-di-*n*-propylamine	5
Naphthalene	5
Nitrobenzene	5
Pentachlorophenol	5
Phenanthrene	5
Phenol	5
Pyrene	5
EPA Method 632	
Diuron	0.1
EPA Method 8082	
Polychlorinated biphenyls (PCBs)	0.5
EPA Method 8140	
Bolstar	1
Chlorpyrifos	1
Coumaphos	1
Demeton	1
Diazinon	1
Dichlorvos	1
Disulfoton	1
Ethoprop	1
Fensulfothion	1
Fenthion	1
Merphos	1
Methyl Parathion	1
Mevinphos	1
Naled	1
Phorate	1
Prothiophos	1
Ronnel	1
Stirophos	1
Trichloronate	1
EPA Method 8260	
1,1,1,2-Tetrachloroethane	0.5
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,2,3-Trichloropropane	0.5
1,2-Dibromo-3-chloropropane	0.5
1,2-Dichloroethane	0.5
1,2-Dichloroethene (total)	0.5
1,2-Dichloropropane	0.5
2-Butanone	0.5
2-Chloroethylvinylether	0.5
2-Hexanone	0.5
4-Methyl-2-pentanone	0.5
Acetone	10
Acetonitrile	100
Acrolein	50
Acrylonitrile	50
Benzene	0.5
Bromodichloromethane	0.5
Bromoform	0.5
Bromomethane	0.5
Carbon disulfide	5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5
Chloroform	0.5
Chloromethane	0.5
Chloroprene	5
Dibromochloromethane	0.5
Dichlorodifluoromethane	0.5
Ethanol	1000
Ethylbenzene	0.5
Freon-113	0.5
Methylene chloride	0.5
Styrene	0.5
Tetrachloroethene	0.5
Toluene	0.5

Table B-2 (cont.). Organic constituents of cncern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L)[a,b]
EPA Method 8260 (cont)	
Total xylene isomers	0.5
Trichloroethene	0.5
Trichlorofluoromethane	0.5
Vinyl acetate	20
Vinyl chloride	0.5
cis-1,2-Dichloroethene	0.5
cis-1,3-Dichloropropene	0.5
trans-1,2-Dichloroethene	0.5
trans-1,3-Dichloropropene	0.5
EPA Method 8290	
1,2,3,4,6,7,8-HpCDD	0.00025
1,2,3,4,6,7,8-HpCDF	0.00025
1,2,3,4,7,8,9-HpCDF	0.00025
1,2,3,4,7,8-HxCDF	0.00025
1,2,3,6,7,8-HxCDD	0.00025
1,2,3,6,7,8-HxCDF	0.00025
1,2,3,7,8,9-HxCDD	0.00025
1,2,3,7,8,9-HxCDF	0.00025
1,2,3,7,8-PeCDD	0.0001
1,2,3,7,8-PeCDF	0.0001
2,3,4,6,7,8-HxCDF	0.00025
2,3,4,7,8-PeCDF	0.0001
2,3,7,8-TCDD	0.0001
2,3,7,8-TCDF	0.0001
OCDD	0.0005
OCDF	0.0005
EPA Method 8330B	5 or 1
HMX[c]	5 or 1
RDX[d]	5
TNT[e]	0.0001
EPA Method 9131 or Standard Method 9221	MPN[f]/100mL
Fecal coliform bacteria	1 to 2
Total coliform bacteria	1 to 2

(a) The number of decimal places displayed in this table vary by constituent. These variations reflect regulatory agency permit stipulations, the applicable analytical laboratory contract under which the work was performed, or both.

(b) These reporting limits are for water samples with low concentrations of dissolved solids. If higher concentrations are present, limits are likely to be higher.

(c) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

(d) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

(e) TNT is 2,4,6-trinitrotoluene.

(f) MPN = most probable number (of organisms).

APPENDIX C
Wildlife Survey Results

Table C-1. Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[a]	Source
Mammals	Pallid bat	*Antrozous pallidus*	CASSC	Rainey 2003
	Western red bat	*Lasiurus blossevillii*	CASSC	Rainey 2003
	Hoary bat	*Lasiurus cinereus*		Rainey 2003
	California myotis	*Myotis californicus*		Rainey 2003
	Western pipistrelle	*Pipistrellus hesperus*		Rainey 2003
	Brazilian free-tailed bat	*Tadarida brasiliensis*		Rainey 2003
	Desert cottontail	*Sylvilagus audubonii*		LLNL 2002; Clark et al. 2002
	Black-tailed jackrabbit	*Lepus californicus*		LLNL 2002; Clark et al. 2002
	Heermann’s kangaroo rat	*Dipodomys heermanni*		LLNL 2002; West 2002
	California pocket mouse	*Chaetodipus californicus*		LLNL 2002; West 2002
	San Joaquin pocket mouse	*Perognathus inornatus inornatus*		Clark et al. 2002
	California ground squirrel	*Spermophilus beecheyi*		LLNL 2002
	Botta’s pocket gopher	*Thomomys bottae*		LLNL 2002; West 2002
	California vole	*Microtus californicus*		LLNL 2002; West 2002
	House mouse	*Mus musculus*		LLNL 2002; West 2002
	Dusky-footed woodrat	*Neotoma fuscipes*		LLNL 2002; West 2002
	Brush mouse	*Peromyscus boylii*		LLNL 2002; West 2002
	Deer mouse	*Peromyscus maniculatus*		LLNL 2002; West 2002
	Western harvest mouse	*Reithrodontomys megalotis*		LLNL 2002; West 2002
	Red fox	*Vulpes vulpes*		Woollett 2005
	Gray fox	*Urocyon cinereoargenteus*		Woollett 2005
	Coyote	*Canis latrans*		LLNL 2002; Clark et al. 2002
	Raccoon	*Procyon lotor*		LLNL 2002; Orloff 1986
	Long-tailed weasel	*Mustela frenata*		LLNL 2002 ; Orloff 1986
	Striped skunk	*Mephitis mephitis*		LLNL 2002; Orloff 1986
	Western spotted skunk	*Spilogale gracilis*		LLNL 2002; Orloff 1986
	American badger	*Taxidea taxus*	CASSC	LLNL 2002; Clark et al. 2002
	Bobcat	*Lynx rufus*		LLNL 2002; Clark et al. 2002
	Mountain Lion	*Puma concolor*		LLNL 2002
	Mule deer	*Odocoileus hemionus*		LLNL 2002; Clark et al. 2002
	Wild pig	*Sus scrofa*		LLNL 2002; Clark et al. 2002
Herpetofauna	Arboreal salamander	*Aneides lugubris*		Woollett 2005
	California tiger salamander	*Ambystoma californiense*	FT, ST, CASSC	LLNL 2002
	California slender salamander	*Batrachoseps attenuatus*		Burkholder 2008
	Coast Range newt	*Taricha torosa torosa*	CASSC	Woollett 2005

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[a]	Source
Herpetofauna (cont.)	California red-legged frog	*Rana draytonii*	FT, CASSC	LLNL 2002
	Pacific treefrog	*Pseudacris regilla*		LLNL 2002
	Western spadefoot toad	*Spea hammondii*	CASSC	LLNL 2002
	Western pond turtle	*Actinemys marmorata*	CASSC	Woollett 2005
	Western toad	*Anaxyrus boreas halophilus*		LLNL 2002
	Alameda whipsnake	*Masticophis lateralis euryxanthus*	FT, ST	Swaim 2002
	San Joaquin coachwhip	*Masticophis flagellum ruddocki*	CASSC	LLNL 2002
	Coast horned lizard	*Phrynosoma coronatum*	CASSC	LLNL 2002
	California legless lizard	*Anniella pulchra*	CASSC	Swaim 2002
	Side-blotched lizard	*Uta stansburiana*		LLNL 2002; Swaim 2002
	Western whiptail	*Aspidoscelis tigris*		LLNL 2002; Swaim 2002
	Northwestern fence lizard	*Sceloporus occidentalis occidentalis*		LLNL 2002; Swaim 2002
	Western skink	*Eumeces skiltonianus*		LLNL 2002; Swaim 2002
	Gilbert skink	*Eumeces gilberti*		LLNL 2002; Swaim 2002
	California alligator lizard	*Elgaria multicarinata multicarinata*		LLNL 2002; Swaim 2002
	Racer	*Coluber constrictor*		LLNL 2002; Swaim 2002
	Gopher snake	*Pituophis catenifer*		LLNL 2002; Swaim 2002
	California kingsnake	*Lampropeltis getula californiae*		LLNL 2002; Swaim 2002
	Northern Pacific rattlesnake	*Crotalus oreganus oreganus*		LLNL 2002; Swaim 2002
	Night snake	*Hypsiglena torquata*		LLNL 2002; Swaim 2002
	Glossy snake	*Arizona elegans*		LLNL 2002; Swaim 2002
	Long-nosed snake	*Rhinocheilus lecontei*		LLNL 2002; Swaim 2002
	California black-headed snake	*Tantilla planiceps*		Swaim 2002
	Pacific ring-necked snake	*Diadophis punctatus amabilis*		Woollett 2005
Birds	Pied-billed Grebe	*Podilymbus podiceps*	MBTA	LLNL 2003
	Double-crested Cormorant	*Phalacrocorax auritus*	MBTA	LLNL 2003
	Great Egret	*Ardea alba*	MBTA	LLNL 2003
	Turkey Vulture	*Cathartes aura*	MBTA	LLNL 2003
	Bufflehead	*Bucephala albeola*	MBTA	LLNL 2003
	Common Goldeneye	*Bucephala clangula*	MBTA	LLNL 2003
	Mallard	*Anas platyryynchos*	MBTA	LLNL 2003
	Northern Shoveler	*Anas clypeata*	MBTA	LLNL 2003
	Cinnamon Teal	*Anas cyanoptera*	MBTA	LLNL 2003

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[a]	Source
Birds (cont.)	Red-shouldered Hawk	*Buteo lineatus*	MBTA	LLNL 2003
	Osprey	*Pandion haliaetus*	MBTA	LLNL 2003
	Golden Eagle	*Aquila chrysaetos*	CAFPS, MBTA, EPA	LLNL 2003
	Rough-legged Hawk	*Buteo lagopus*	MBTA	LLNL 2003
	Ferruginous Hawk	*Buteo regalis*	MBTA	LLNL 2003
	Red-tailed Hawk	*Buteo jamaicensis*	MBTA	LLNL 2003
	Swainson's Hawk	*Buteo swainsoni*	ST, MBTA	LLNL 2003
	White-tailed Kite	*Elanus leucurus*	CAFPS, MBTA	LLNL 2003
	Cooper's Hawk	*Accipiter cooperii*	MBTA	LLNL 2003
	Sharp-shinned Hawk	*Accipiter striatus*	MBTA	LLNL 2003
	Northern Harrier	*Circus cyaneus*	CASSC, MBTA	LLNL 2003
	Prairie Falcon	*Falco mexicanus*	MBTA	LLNL 2003
	American Kestrel	*Falco sparverius*	MBTA	LLNL 2003
	Wild Turkey	*Meleagris gallopavo*		LLNL 2003
	California Quail	*Callipepla californica*		LLNL 2003
	Virginia Rail	*Rallus limicola*	MBTA	U.S. DOE and UC 1992
	Killdeer	*Charadrius vociferus*	MBTA	LLNL 2003
	Greater Yellowlegs	*Tringa melanoleuca*	MBTA	LLNL 2003
	Wilson’s Snipe	*Gallinago delicata*	MBTA	LLNL 2003
	Mourning Dove	*Zenaida macroura*	MBTA	LLNL 2003
	Rock Dove	*Columba livia*		U.S. DOE and UC 1992
	Greater Roadrunner	*Geococcyx californianus*	MBTA	LLNL 2003
	Barn Owl	*Tyto alba*	MBTA	LLNL 2003
	Short-eared Owl	*Asio flammeus*	CASSC, MBTA	LLNL 2003
	Great Horned Owl	*Bubo virginianus*	MBTA	LLNL 2003
	Burrowing Owl	*Athene cunicularia*	CASSC, BCC, MBTA	LLNL 2003
	Western Screech Owl	*Megascops kennicottii*	MBTA	LLNL 2003
	Common Poorwill	*Phalaenoptilus nuttalii*	MBTA	LLNL 2003
	White-throated Swift	*Aeronautes saxatalis*	MBTA	LLNL 2003
	Allen’s Hummingbird	*Selasphorus sasin*	BCC, MBTA	U.S. DOE and UC 1992
	Rufous Hummingbird	*Selasphorus rufus*	MBTA	LLNL 2003
	Costa's Hummingbird	*Calypte costae*	BCC, MBTA	LLNL 2003
	Anna's Hummingbird	*Calypte anna*	MBTA	LLNL 2003
	Northern Flicker	*Colaptes auratus*	MBTA	LLNL 2003
	Nuttal's Woodpecker	*Picoides nuttallii*	BCC, MBTA	LLNL 2003
	Acorn Woodpecker	*Melanerpes formicivorus*	MBTA	U.S. DOE and UC 1992
	Ash-throated Flycatcher	*Myiarchus cinerascens*	MBTA	LLNL 2003

C. Wildlife Survey Results

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Birds (cont.)	Cassin's Kingbird	*Tyrannus vociferans*	MBTA	LLNL 2003
	Western Kingbird	*Tyrannus verticalis*	MBTA	LLNL 2003
	Western Wood-pewee	*Contopus sordidulus*	MBTA	U.S. DOE and UC 1992
	Willow Flycatcher	*Empidonax traillii*	SE, MBTA	van Hattem 2005
	Pacific-slope Flycatcher	*Empidonax difficillis*	MBTA	LLNL 2003
	Black Phoebe	*Sayornis nigricans*	MBTA	LLNL 2003
	Say's Phoebe	*Sayornis saya*	MBTA	LLNL 2003
	Loggerhead Shrike	*Lanius ludovicianus*	CASSC, BCC, MBTA	LLNL 2003
	Western Scrub Jay	*Aphelocoma californica*	MBTA	LLNL 2003
	American Crow	*Corvus brachyrhynchos*	MBTA	LLNL 2003
	Common Raven	*Corvus corax*	MBTA	LLNL 2003
	Horned Lark	*Eremophila alpestris*	MBTA	LLNL 2003
	Tree Swallow	*Tachycineta bicolor*	MBTA	LLNL 2003
	Cliff Swallow	*Petrochelidon pyrrhonota*	MBTA	LLNL 2003
	Northern Rough Winged Swallow	*Stelgidopteryx serripennis*	MBTA	LLNL 2003
	Oak Titmouse	*Baeolphus inornatus*	BCC, MBTA	LLNL 2003
	Bushtit	*Psaltriparus minimus*	MBTA	LLNL 2003
	House Wren	*Troglodytes aedon*	MBTA	LLNL 2003
	Rock Wren	*Salpinctes obsoletus*	MBTA	LLNL 2003
	Bewick's Wren	*Thryomanes bewickii*	MBTA	LLNL 2003
	Ruby-crowned Kinglet	*Regulus calendula*	MBTA	LLNL 2003
	Hermit Thrush	*Catharus guttatus*	MBTA	LLNL 2003
	Swainson's Thrush	*Catharus ustulatus*	MBTA	LLNL 2003
	Western Buebird	*Sialia mexicana*	MBTA	LLNL 2003
	Mountain Bluebird	*Sialia currucoides*	MBTA	LLNL 2003
	American Robin	*Turdus migratorius*	MBTA	LLNL 2003
	Varied Thrush	*Ixoreus naevius*	MBTA	LLNL 2003
	California Thrasher	*Toxostoma redivivum*	MBTA	LLNL 2003
	Northern Mockingbird	*Mimus polyglottos*	MBTA	LLNL 2003
	European Starling	*Sturnus vulgaris*		LLNL 2003
	Cedar Waxwing	*Bombycilla garrulus*	MBTA	LLNL 2003
	Phainopepela	*Phainopepla nitens*	MBTA	LLNL 2003
	MacGillivary's Warbler	*Oporornis tolmiei*	MBTA	LLNL 2003
	Common Yellowthroat	*Geothlypis trichas*	MBTA	LLNL 2003
	Wilson's Warbler	*Wilsonia pusilla*	MBTA	LLNL 2003
	Orange-crowned Warbler	*Vermivora celata*	MBTA	LLNL 2003
	Yellow Warbler	*Dendroica petechia*	CASSC, MBTA	LLNL 2003

Table C-1 (cont.). Site 300 wildlife species list. Includes species for which there are verified observations; it is not intended to be a complete list of Site 300 species.

Taxa	Common Name	Scientific Name	Regulatory Status[a]	Source
Birds (cont.)	Yellow-rumped Warbler	*Dendroica coronata*	MBTA	LLNL 2003
	Black-throated Gray Warbler	*Dendroica nigrescens*	MBTA	LLNL 2003
	Western Tanager	*Piranga ludoviciana*	MBTA	LLNL 2003
	Song Sparrow	*Melospiza melodia*	MBTA	LLNL 2003
	Lincoln's Sparrow	*Melospiza lincolnii*	MBTA	LLNL 2003
	Fox Sparrow	*Passerella iliaca*	MBTA	LLNL 2003
	White-crowned Sparrow	*Zonotrichia leucophrys*	MBTA	LLNL 2003
	Golden-crowned Sparrow	*Zonotrichia atricapilla*	MBTA	LLNL 2003
	Dark-eyed Junco	*Junco hyemalis*	MBTA	LLNL 2003
	Black-throated Sparrow	*Amphispiza bilineata*	MBTA	LLNL 2003
	California Towhee	*Pipilo crissalis*	MBTA	LLNL 2003
	Vesper Sparrow	*Pooecetes gramineus*	MBTA	U.S. DOE and UC 1992
	Lark Sparrow	*Chondestes grammacus*	MBTA	LLNL 2003
	Bell's Sage Sparrow	*Amphispiza belli*	MBTA	LLNL 2003
	Savannah Sparrow	*Passerculus sandwichensis*	MBTA	LLNL 2003
	Grasshopper Sparrow	*Ammodramus savannarum*	CASSC, MBTA	LLNL 2003
	Rufous Crowned Sparrow	*Aimophila ruficeps*	MBTA	LLNL 2003
	Lazuli Bunting	*Passerina amoena*	MBTA	LLNL 2003
	Blue-grosbeak	*Passerina caerulea*	MBTA	LLNL 2003
	Black-headed Grosbeak	*Pheucticus melanocephalus*	MBTA	U.S. DOE and UC 1992
	Bullock's Oriole	*Icterus bullockii*	MBTA	LLNL 2003
	Brown-headed Cowbird	*Molothrus ater*	MBTA	LLNL 2003
	Red-winged Blackbird	*Agelaius phoeniceus*	MBTA	LLNL 2003
	Tricolored Blackbird	*Agelaius tricolor*	CASSC, BCC, MBTA	LLNL 2003
	Western Meadowlark	*Sturnella neglecta*	MBTA	LLNL 2003
	Brewer's Blackbird	*Euphagus cyanocephalus*	MBTA	LLNL 2003
	Lesser Goldfinch	*Carduelis psaltria*	MBTA	LLNL 2003
	House Finch	*Carpodacus mexicanus*	MBTA	LLNL 2003
Invertebrates	Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	FT	Arnold 2002
	California fairy shrimp	*Linderiella occidentalis*		Weber 2002
	California clam shrimp	*Cyzicus californicus*		Weber 2002

(a) BCC = U.S. Fish and Wildlife Service Birds of Conservation Concern (US Fish and Wildlife Service 2008)
CAFPS = California Department of Fish and Game Fully Protected Species (CA Fish and Game Code Section 3511)
CASSC = California Species of Special Concern (CA Dept. of Fish and Game, Special Animals List, March 2006)
EPA = Eagle Protection Act
FT = Threatened under the Federal Endangered Species Act
MBTA = Migratory Bird Treaty Act
SE = Endangered under the State Endangered Species Act
ST = Threatened under the State Endangered Species Act

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APPENDIX D
Extra Resources

The documents listed below are accessible as PDFs on CD or at https://saer.llnl.gov, the website for the LLNL annual environmental report. In the electronic version of this appendix, the resources are linked to the PDFs.

Livermore Site Storm Water Monitoring for Waste Discharge Requirements 95-174, 2010–2011

Revelli, M.A. (2011). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174, Annual Report 2010–2011*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-126783-11.

LLNL Ground Water Project Annual Report, 2011

Buscheck, M., P. McKereghan and M. Dresen, (2012). *LLNL Ground Water Project 2011 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126020-11.

LLNL NESHAPs Annual Report, 2011

Wilson, K., G. Gallegos, D. MacQueen, A. Wegrecki, and N. Bertoldo. (2012). *LLNL NESHAPs 2011 Annual Report*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-TR-113867-11.

Site 300 Building 829 Compliance Monitoring Annual Report, 2011

Revelli, M.A. (2012). *Lawrence Livermore National Laboratory Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2011*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-143121-11.

Site 300 Compliance Monitoring Annual Report, 2011

Dibley, V. (2012). *2011 Annual Monitoring Compliance Report for Lawrence Livermore National Laboratory Site 300*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-206319-11.

Site 300 Storm Water Monitoring for Waste Discharge Requirements 97-03-DWQ Annual Report, 2011

Revelli, M. (2011). *Lawrence Livermore National Laboratory Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-144362-11.

Site 300 Compliance Monitoring for Water Discharge Requirement Order No. R5-2008-0148 Annual Report, 2011

Blake, R. (2012). *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements Order No. R5-2008-0148, Annual/Second Semester Report 2011*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-411431-12-3.

Site 300 Pit 6 Compliance Monitoring Annual Report, 2011

Blake, R, and J. Vallet. (2012). *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report 2011*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-132057-11-4.

Site 300 Pit 1 Compliance Monitoring Annual Report, 2011

Blake, R. (2012). *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pit 1, Annual Report for 2011*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-10191-11-4.

Supplementary Topics on Radiological Dose

Sanchez, L., P.E. Althouse, N.A. Bertoldo, R.G. Blake, S.L. Brigdon, R.A, Brown, C.G. Campbell, T. Carlson, E. Christofferson, L.M. Clark, G.M. Gallegos, A.R. Grayson, R.J. Harrach, W.G. Hoppes, H.E. Jones, J. Larson, D. Laycak, D.H. MacQueen, S. Mathews, M. Nelson, L. Paterson, S.R. Peterson, M.A. Revelli, M.J. Taffet, P.J. Tate, R. Ward, R.A. Williams, and K. Wilson. (2003). *Environmental Report 2002*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-50027-02, Appendix D.

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APPENDIX E
Errata

Protocol for Errata in LLNL Environmental Reports

The primary form of publication for the LLNL Environmental Report is electronic: the report is posted on the Internet. A limited number of copies are also printed and distributed, including to local libraries. If errors are found after publication, the Internet version is corrected. Because the printed versions cannot be corrected, errata for these versions are published in a subsequent report. In this way, the equivalency of all published versions of the report is maintained.

In 1998, LLNL established the following protocol for post-publication revisions to the environmental report: (1) the environmental report website must clearly convey what corrections, if any, have been made and provide a link to a list of the errata, (2) the Internet version must be the most current version, incorporating all corrections, and (3) the electronic and printed versions must be the same in that the printed version plus errata, if any, must provide the same information as the Internet version.

LLNL environmental reports from 1994 through 2011 can be accessed at https://saer.llnl.gov/.

Record of Changes to Environmental Report 2010

The following changes have been made to the Internet version of *Environmental Report 2010*.

- **Appendix D, Table A.7.3:** The date in the second column was changed to February 10th and in the third column February 24th.

Data Workbooks

A.1.1 Summary of gross alpha and gross beta (µBq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 235, 2011

Analyte Emission Point	No. > MDC [(a)]	Minimum	Median	Maximum
Gross alpha				
PAM_1	0 of 51	-11.2	-4.59	66.6
Gross beta				
PAM_1	0 of 51	-134	-7.03	99.5

(a) MDC = minimum detectable concentration

A.1.2 Summary of gross alpha and gross beta (µBq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 491, 2011

Analyte Emission Point	No. > MDC[a]	Minimum	Median	Maximum
Gross alpha				
PAM_1	0 of 11	-3.29	5.48	20.5
Gross beta				
PAM_1	3 of 11	1.98	13.1	99.5

(a) MDC = minimum detectable concentration

A.1.3 Summary of gross alpha and gross beta (µBq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2011

Analyte Emission Point	No. > MDC [(a)]	Minimum	Median	Maximum
Gross alpha				
PAM_1	0 of 51	-4.18	-1.61	28.7
Gross beta				
PAM_1	0 of 51	-54.0	-10.8	42.6

(a) MDC = minimum detectable concentration

A.1.4 Summary of tritium (Bq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2011

Analyte	No. > MDC [(a)]	Minimum	Median	Maximum
HT [(b)]	1 of 46	-27.1	0.304	6.53
HTO [(c)]	2 of 46	-29.5	0.634	11.3

(a) MDC = minimum detectable concentration
(b) HT = tritiated hydrogen gas
(c) HTO = tritiated water and water vapor

A.1.5 Summary of gross alpha and gross beta (µBq/m3) in air effluent samples from the monitored emission points at Livermore site, Building 332, 2011

Analyte Emission Point	No. > MDC [a]	Minimum	Median	Maximum
Gross alpha				
SP-1B	0 of 52	-16.6	-3.22	54.0
SP-1A	0 of 52	-6.77	-3.20	53.3
SP-2A	0 of 52	-6.77	-3.22	45.9
SP-2B	0 of 52	-6.77	-3.22	73.3
SP-3	0 of 36	-6.73	-3.23	34.7
SP-4	0 of 35	-6.77	-3.22	35.0
SP-6A	0 of 52	-6.77	-3.23	76.6
SP-6B	0 of 52	-6.77	-3.22	100
SP-7B	1 of 52 [b]	-6.77	-3.23	577
SP-7A	0 of 52	-6.77	-3.22	100
SP-8	0 of 52	-16.7	-3.23	28.7
SP-9	0 of 52	-6.77	-3.23	40.7
SP-10	0 of 52	-6.77	-3.22	34.7
SP-11	0 of 52	-6.77	-3.22	35.0
SP-12	0 of 52	-6.77	-3.22	54.4
Gross beta				
SP-1B	0 of 52	-72.9	7.62	157
SP-1A	0 of 52	-103	-10.6	158
SP-2A	0 of 52	-93.6	-21.6	95.5
SP-2B	0 of 52	-117	-16.6	96.9
SP-3	0 of 36	-72.2	-22.1	110
SP-4	1 of 35	-87.7	-25.8	518
SP-6A	2 of 52	-103	-25.7	1590
SP-6B	2 of 52	-102	-25.7	1680
SP-7B	2 of 52	-87.3	-6.60	1720
SP-7A	2 of 52	-71.0	-10.6	1620
SP-8	0 of 52	-87.3	-18.5	130
SP-9	0 of 52	-88.4	-8.25	85.1
SP-10	0 of 52	-103	-11.0	111
SP-11	0 of 52	-101	-11.4	112
SP-12	0 of 52	-87.3	-24.2	83.3

(a) MDC = minimum detectable concentration
(b) The gross alpha detect was associated with thorium weld rods due to facility maintenance activites.

A.1.6 Summary of tritium in air effluent samples (Bq/m3) from the monitored emission points at Livermore site, Building 331, 2011

Analyte Emission Point	No. > MDC [a]	Minimum	Median	Maximum
HT [b]				
Stack1	53 of 53	10.9	83.1	405000
Stack2	46 of 52	3.61	680	34700
HTO [c]				
Stack1	53 of 53	170	1440	20700
Stack2	52 of 52	14.5	3730	19100

(a) MDC = minimum detectable concentration
(b) HT = tritiated hydrogen gas
(c) HTO = tritiated water and water vapor

A.1.7 Summary of gross alpha and gross beta (μBq/m3) in air effluent samples from the monitored emission point at Site 300, Building 801, 2011

Analyte Emission Point	No. > MDC [a]	Minimum	Median	Maximum
Gross alpha				
PAM_1	8 of 31	-3.92	10.6	84.7
Gross beta				
PAM_1	24 of 31	-7.66	130	407

(a) MDC = minimum detectable concentration

A.1.8 Summary of gross alpha and gross beta (uBq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 581, 2011

Analyte	Emission Point	No. > MDC [a]	Minimum	Median	Maximum
Gross alpha	B581	0 of 49	1.8981	23.9	17427000
Gross beta	B581	3 of 49	6.475	70.7	30377000

(a) MDC = minimum detectable concentration

A.1.9 Summary of representative gamma suite for radioactive particulate (uBq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 581, 2011

Analyte	Emission Point	No. > MDC [a]	Minimum	Median	Maximum
Barium 140	B581	0 of 48	<28.416	(b)	<5809
Cerium 141	B581	0 of 48	<4.847	(b)	<4662
Iodine 131	B581	0 of 48	<9.176	(b)	<1576.2
Neptunium 239	B581	0 of 47	<84.73	(b)	<32856
Tellurium 132	B581	0 of 48	<59.2	(b)	<223110

(a) MDC = minimum detectable concentration
(b) Medians were not calculated as all results were nondetections

A.1.10 Summary of tritium in air effluent samples (Bq/m3) from the moniotred emission point at Livermore, Building 581, 2011

Analyte	Emission Point	No. > MDC [a]	Minimum	Median	Maximum
HT [b]	B581	27 of 52	-3.34	4.96	1460
HTO [c]	B581	46 of 52	0.399	18.5	1070

(a) MDC = minimum detectable concentration
(b) HT = tritiated hydrogen gas
(c) HTO = tritiated water and water vapor

A.1.11 Summary of tritiated particulate (Bq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 581, 2011

Analyte	Emission Point	No. > MDC [(a)]	Minimum	Median	Maximum
Tritium	B581	42 of 49	0.00023902	0.0034	0.17612

(a) MDC = minimum detectable concentration

A.1.12 Summary of Iodine-131 (uBq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 581, 2011

Analyte	Emission Point	No. > MDC [(a)] [(b)]	Minimum	Median	Maximum
Iodine 131	B581	7 of 49	<1.3727	<128	<29304

(a) MDC = minimum detectable concentration
(b) Iodine-131 detections were attributable to the Fukushima reactors (see chpater 4)

A.2.1 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore perimeter locations, 2011[(a)]

Date	Gross alpha CAFE	Gross alpha COW	Gross alpha CRED	Gross alpha MESQ	Gross alpha MET	Gross alpha SALV	Gross alpha VIS
Jan 4	9.2 ± 23.8	3.5 ± 21.0	15.1 ± 26.5	20.8 ± 28.6	20.9 ± 28.8	9.3 ± 23.9	44.0 ± 36.7
Jan 11	17.3 ± 30.3	23.8 ± 32.7	23.8 ± 32.7	4.0 ± 24.0	37.0 ± 37.4	10.7 ± 27.3	23.8 ± 32.7
Jan 18	10.5 ± 27.1	23.9 ± 33.0	3.9 ± 23.1	23.8 ± 32.7	30.6 ± 35.4	17.2 ± 30.1	17.2 ± 30.2
Jan 25	30.5 ± 35.4	37.0 ± 37.7	17.9 ± 31.4	4.0 ± 23.8	44.0 ± 40.0	43.7 ± 40.0	30.6 ± 35.4
Feb 1	10.6 ± 27.2	4.0 ± 24.0	30.3 ± 35.2	17.2 ± 30.1	69.9 ± 47.4	37.0 ± 37.7	4.0 ± 23.8
Feb 8	10.6 ± 27.3	4.0 ± 24.0	-2.7 ± 20.2	17.2 ± 30.2	-9.3 ± 15.4	-9.2 ± 15.3	10.7 ± 27.3
Feb 15	28.2 ± 36.4	1.5 ± 25.3	8.1 ± 28.5	21.5 ± 34.0	-5.2 ± 21.7	1.5 ± 25.5	1.5 ± 25.3
Feb 22	8.1 ± 28.3	-11.8 ± 17.3	-5.1 ± 21.6	8.1 ± 28.4	8.1 ± 28.3	-5.1 ± 21.6	34.6 ± 38.5
Mar 1	8.1 ± 28.4	1.5 ± 25.3	1.5 ± 25.3	-5.2 ± 21.8	8.1 ± 28.4	-5.1 ± 21.6	-11.8 ± 17.3
Mar 8	8.1 ± 28.3	21.3 ± 33.8	8.1 ± 28.4	27.9 ± 36.2	21.3 ± 33.8	-5.1 ± 21.6	1.5 ± 25.2
Mar 15	14.8 ± 31.5	-5.2 ± 21.8	-11.9 ± 17.5	1.5 ± 25.4	-11.9 ± 17.4	-11.9 ± 17.5	-5.2 ± 21.8
Mar 22	1.5 ± 25.2	-5.1 ± 21.6	1.5 ± 25.1	1.5 ± 25.0	1.5 ± 25.2	-11.8 ± 17.3	1.5 ± 25.1
Mar 29	-5.2 ± 21.7	-5.2 ± 21.7	(b)	1.5 ± 25.3	8.1 ± 28.5	-12.0 ± 17.6	1.5 ± 25.3
Mar 30	(b)	(b)	1.2 ± 21.3	(b)	(b)	(b)	(b)
Apr 5	14.5 ± 30.8	-5.1 ± 21.3	1.5 ± 26.0	8.0 ± 28.0	-5.1 ± 21.3	-5.1 ± 21.4	-5.1 ± 21.3
Apr 12	41.8 ± 41.1	14.9 ± 31.7	24.3 ± 38.5	21.8 ± 34.5	14.9 ± 31.7	-5.2 ± 22.0	-12.0 ± 17.6
Apr 19	21.5 ± 34.0	1.5 ± 25.2	21.3 ± 33.8	1.5 ± 25.2	1.5 ± 25.2	-6.3 ± 26.6	(b)
Apr 26	14.7 ± 31.1	47.7 ± 42.6	-5.2 ± 21.8	-5.1 ± 21.5	21.3 ± 33.8	21.4 ± 33.9	-5.1 ± 21.7
May 3	14.8 ± 31.4	14.7 ± 31.2	1.5 ± 25.5	1.5 ± 25.3	1.5 ± 25.3	14.8 ± 31.4	8.1 ± 28.5
May 10	28.3 ± 36.6	28.0 ± 36.3	8.0 ± 28.0	34.4 ± 38.1	14.8 ± 31.3	-11.7 ± 17.2	27.8 ± 36.0
May 17	-5.2 ± 21.8	-5.1 ± 21.6	1.5 ± 25.0	34.8 ± 38.8	8.1 ± 28.4	8.1 ± 28.4	8.1 ± 28.5
May 24	8.1 ± 28.3	21.4 ± 33.9	8.1 ± 28.5	-5.2 ± 21.7	1.5 ± 25.3	8.1 ± 28.5	8.1 ± 28.5
May 31	8.1 ± 28.3	-11.7 ± 17.2	(b)	1.5 ± 25.2	-11.7 ± 17.2	1.5 ± 25.2	1.5 ± 25.1
Jun 1	(b)	(b)	7.3 ± 25.7	(b)	(b)	(b)	(b)
Jun 7	-11.9 ± 17.5	8.1 ± 28.5	-13.2 ± 19.4	-5.2 ± 21.7	14.8 ± 31.3	34.7 ± 38.5	1.5 ± 25.3
Jun 14	14.7 ± 31.0	-5.2 ± 21.7	21.3 ± 33.7	21.2 ± 33.6	21.4 ± 33.9	-5.1 ± 21.7	1.5 ± 25.3
Jun 21	21.3 ± 33.8	1.5 ± 25.2	1.3 ± 22.0	8.1 ± 28.4	-5.1 ± 21.6	8.1 ± 28.4	1.5 ± 25.2
Jun 28	1.5 ± 25.1	-11.7 ± 17.2	(b)	8.1 ± 28.3	1.5 ± 25.2	(b)	1.5 ± 25.2
Jun 29	(b)	(b)	14.8 ± 31.3	(b)	(b)	(b)	(b)
Jun 30	(b)	(b)	(b)	(b)	(b)	-11.8 ± 17.3	(b)
Jul 5	1.5 ± 25.3	-5.2 ± 21.7	50.7 ± 49.9	1.5 ± 25.5	14.7 ± 31.2	11.3 ± 39.6	8.1 ± 28.5
Jul 12	1.5 ± 25.5	1.5 ± 25.4	14.7 ± 31.1	14.8 ± 31.4	8.2 ± 28.6	1.8 ± 30.9	41.1 ± 40.3
Jul 19	-11.7 ± 17.1	-11.7 ± 17.2	1.5 ± 25.3	1.5 ± 25.1	1.5 ± 25.0	-11.7 ± 17.2	-5.2 ± 21.7
Jul 26	8.1 ± 28.4	1.5 ± 25.2	14.7 ± 31.2	14.7 ± 31.0	1.5 ± 25.2	1.5 ± 25.3	-11.8 ± 17.3
Aug 2	14.8 ± 31.4	1.5 ± 25.4	21.5 ± 34.0	21.6 ± 34.2	1.5 ± 25.4	14.8 ± 31.4	1.5 ± 25.4
Aug 9	1.5 ± 25.3	1.5 ± 25.3	41.4 ± 40.7	1.5 ± 25.3	1.5 ± 25.3	21.4 ± 33.9	14.8 ± 31.3
Aug 16	34.4 ± 38.1	14.7 ± 31.0	14.3 ± 30.3	14.7 ± 31.0	27.8 ± 36.0	41.1 ± 40.3	41.1 ± 40.3

A.2.1 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore perimeter locations, 2011[(a)]

Date	Gross alpha CAFE	Gross alpha COW	Gross alpha CRED	Gross alpha MESQ	Gross alpha MET	Gross alpha SALV	Gross alpha VIS
Aug 23	8.1 ± 28.4	8.1 ± 28.5	8.3 ± 29.2	27.8 ± 36.0	8.1 ± 28.5	-5.2 ± 21.7	8.1 ± 28.5
Aug 30	21.3 ± 33.7	41.1 ± 40.3	1.5 ± 25.2	1.5 ± 25.4	34.7 ± 38.5	14.7 ± 31.1	8.1 ± 28.3
Sep 6	21.5 ± 34.0	14.8 ± 31.3	41.4 ± 40.7	28.0 ± 36.3	21.4 ± 33.9	-5.2 ± 21.8	28.0 ± 36.3
Sep 13	28.1 ± 36.4	1.5 ± 25.3	54.8 ± 44.8	48.1 ± 42.9	1.5 ± 25.3	61.4 ± 46.6	8.1 ± 28.5
Sep 20	41.1 ± 40.3	14.7 ± 31.1	-11.8 ± 17.3	27.9 ± 36.1	14.7 ± 31.1	21.3 ± 33.7	1.5 ± 25.2
Sep 27	8.2 ± 28.7	34.6 ± 38.5	21.3 ± 33.8	34.6 ± 38.5	14.7 ± 31.2	8.1 ± 28.5	34.6 ± 38.5
Oct 4	34.6 ± 38.5	8.1 ± 28.3	21.3 ± 33.7	14.7 ± 31.2	27.9 ± 36.2	41.1 ± 40.7	27.9 ± 36.1
Oct 11	(b)	7.8 ± 27.3	(b)	-11.3 ± 16.6	14.1 ± 30.0	(b)	(b)
Oct 12	1.3 ± 22.1	(b)	59.6 ± 42.2	(b)	(b)	1.3 ± 22.2	-10.3 ± 15.2
Oct 18	48.1 ± 47.4	29.3 ± 37.7	53.6 ± 40.7	36.2 ± 40.3	57.0 ± 46.6	55.9 ± 49.6	55.9 ± 49.6
Oct 25	27.8 ± 36.0	28.0 ± 36.2	14.2 ± 30.2	34.6 ± 38.5	61.0 ± 46.2	41.1 ± 40.7	81.0 ± 51.8
Nov 1	61.8 ± 47.0	14.8 ± 31.4	91.4 ± 55.5	48.1 ± 42.9	48.1 ± 42.9	61.4 ± 46.6	74.7 ± 50.3
Nov 8	21.1 ± 33.4	21.1 ± 33.4	34.2 ± 38.1	1.4 ± 24.9	21.1 ± 33.4	1.4 ± 24.9	27.6 ± 35.8
Nov 15	47.4 ± 42.2	47.4 ± 42.2	8.0 ± 28.2	47.4 ± 42.2	40.7 ± 40.3	34.4 ± 38.1	60.7 ± 46.2
Nov 22	-5.2 ± 21.9	8.2 ± 28.7	21.6 ± 34.2	8.2 ± 28.7	28.2 ± 36.6	28.3 ± 36.6	55.1 ± 45.1
Nov 29	40.7 ± 40.3	21.2 ± 33.5	34.3 ± 38.1	8.0 ± 28.1	54.0 ± 44.0	21.2 ± 33.5	27.7 ± 35.9
Dec 6	55.1 ± 45.1	14.9 ± 31.6	41.8 ± 41.1	48.5 ± 43.3	28.3 ± 36.7	35.1 ± 38.8	28.3 ± 36.7
Dec 12	250.0 ± 76.6	124.0 ± 56.6	134.0 ± 58.1	140.0 ± 59.6	157.0 ± 62.2	189.0 ± 67.7	134.0 ± 58.1
Dec 20	36.1 ± 30.1	50.7 ± 33.7	68.1 ± 37.7	79.6 ± 40.0	39.2 ± 30.9	44.8 ± 32.3	59.6 ± 35.8
Dec 28	88.8 ± 49.6	59.6 ± 42.6	77.0 ± 47.0	118.0 ± 55.5	59.6 ± 42.6	(b)	88.8 ± 49.6
Detection frequency	10 of 52	6 of 52	11 of 52	7 of 52	10 of 52	9 of 51	11 of 51
Median	14.8	8.10	14.7	14.7	14.8	8.10	8.14
IQR [(c)]	20.8	20.5	29.8	26.4	27.4	36.5	31.1
Maximum	250	124	134	140	157	189	134

A.2.1 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore perimeter locations, 2011[(a)]

Date	Gross beta CAFE	Gross beta COW	Gross beta CRED	Gross beta MESQ	Gross beta MET	Gross beta SALV	Gross beta VIS
Jan 4	256.0 ± 81.8	199.0 ± 76.2	287.0 ± 85.5	227.0 ± 78.8	199.0 ± 76.2	198.0 ± 76.2	249.0 ± 81.8
Jan 11	585 ± 120	577 ± 118	555 ± 117	470 ± 110	696 ± 127	503 ± 113	570 ± 118
Jan 18	485 ± 111	411 ± 105	503 ± 110	481 ± 110	533 ± 115	592 ± 120	536 ± 115
Jan 25	588 ± 120	429 ± 107	551 ± 120	570 ± 118	636 ± 124	636 ± 123	507 ± 113
Feb 1	599 ± 120	777 ± 133	729 ± 130	725 ± 130	659 ± 125	636 ± 123	551 ± 116
Feb 8	396 ± 104	333.0 ± 98.0	310.0 ± 95.8	396 ± 104	314.0 ± 95.8	440 ± 107	290.0 ± 94.0
Feb 15	503 ± 113	374 ± 101	377 ± 102	455 ± 109	462 ± 110	455 ± 110	392 ± 103
Feb 22	135.0 ± 76.6	38.8 ± 64.0	154.0 ± 78.8	135.0 ± 76.6	87.0 ± 70.7	106.0 ± 72.9	130.0 ± 75.8
Mar 1	155.0 ± 79.2	184.0 ± 82.5	222.0 ± 86.6	219.0 ± 86.6	246.0 ± 89.2	159.0 ± 79.6	169.0 ± 80.7
Mar 8	121.0 ± 74.7	154.0 ± 78.8	154.0 ± 78.8	111.0 ± 73.6	207.0 ± 84.7	111.0 ± 73.6	82.1 ± 69.9
Mar 15	151.0 ± 79.2	151.0 ± 78.8	170.0 ± 81.4	199.0 ± 84.4	180.0 ± 82.5	161.0 ± 80.3	161.0 ± 80.3
Mar 22	1670 ± 185	833 ± 137	1050 ± 150	1450 ± 173	903 ± 142	977 ± 147	1390 ± 170
Mar 29	1240 ± 162	1090 ± 154	(b)	2130 ± 207	1040 ± 151	1600 ± 183	1040 ± 151
Mar 30	(b)	(b)	1210 ± 146	(b)	(b)	(b)	(b)
Apr 5	477 ± 110	422 ± 105	448 ± 110	644 ± 123	451 ± 107	862 ± 138	514 ± 112
Apr 12	485 ± 112	323.0 ± 97.7	440 ± 117	522 ± 116	485 ± 112	426 ± 107	503 ± 114
Apr 19	218.0 ± 86.2	149.0 ± 78.4	212.0 ± 85.5	222.0 ± 86.2	202.0 ± 84.4	213.0 ± 99.5	(b)
Apr 26	178.0 ± 81.4	222.0 ± 86.6	219.0 ± 86.6	245.0 ± 88.8	222.0 ± 86.6	212.0 ± 85.5	212.0 ± 85.5
May 3	247.0 ± 89.5	164.0 ± 79.9	190.0 ± 83.6	291.0 ± 94.0	188.0 ± 82.9	204.0 ± 84.7	175.0 ± 81.4
May 10	214.0 ± 86.2	184.0 ± 82.5	209.0 ± 84.4	317.0 ± 95.8	222.0 ± 86.6	269.0 ± 91.4	268.0 ± 91.0
May 17	223.0 ± 87.0	145.0 ± 77.7	148.0 ± 77.7	165.0 ± 80.7	178.0 ± 81.8	159.0 ± 79.6	116.0 ± 74.4
May 24	216.0 ± 85.8	169.0 ± 80.7	242.0 ± 88.8	227.0 ± 87.3	179.0 ± 81.8	242.0 ± 88.8	107.0 ± 73.3
May 31	154.0 ± 78.8	139.0 ± 77.0	(b)	173.0 ± 81.0	159.0 ± 79.2	168.0 ± 80.3	159.0 ± 79.2
Jun 1	(b)	(b)	171.0 ± 75.1	(b)	(b)	(b)	(b)
Jun 7	151.0 ± 79.2	92.1 ± 71.4	167.0 ± 87.7	107.0 ± 73.3	111.0 ± 74.0	116.0 ± 74.4	135.0 ± 77.0
Jun 14	231.0 ± 87.0	188.0 ± 82.9	255.0 ± 89.9	225.0 ± 86.6	285.0 ± 92.9	179.0 ± 81.8	150.0 ± 78.4
Jun 21	256.0 ± 90.3	149.0 ± 78.4	357.0 ± 91.4	227.0 ± 87.0	222.0 ± 86.6	275.0 ± 92.1	256.0 ± 89.9
Jun 28	187.0 ± 82.5	125.0 ± 75.1	(b)	192.0 ± 82.9	231.0 ± 87.3	(b)	135.0 ± 76.2
Jun 29	(b)	(b)	131.0 ± 76.2	(b)	(b)	(b)	(b)
Jun 30	(b)	(b)	(b)	(b)	(b)	154.0 ± 78.8	(b)
Jul 5	194.0 ± 83.6	179.0 ± 81.8	296 ± 109	199.0 ± 84.7	295.0 ± 94.0	275 ± 117	295.0 ± 94.4
Jul 12	268.0 ± 92.1	306.0 ± 95.5	289.0 ± 93.2	243.0 ± 89.2	429 ± 107	260 ± 105	226.0 ± 87.0
Jul 19	62.2 ± 66.6	67.3 ± 67.7	14.8 ± 60.7	19.4 ± 60.7	52.9 ± 65.5	124.0 ± 74.7	67.7 ± 68.1
Jul 26	227.0 ± 87.3	145.0 ± 77.7	285.0 ± 92.9	130.0 ± 75.5	159.0 ± 79.6	208.0 ± 85.1	155.0 ± 79.2
Aug 2	349.0 ± 99.5	252.0 ± 90.3	296.0 ± 94.4	307.0 ± 95.8	243.0 ± 89.2	320.0 ± 96.9	354.0 ± 99.9
Aug 9	194.0 ± 83.6	198.0 ± 84.0	169.0 ± 80.7	126.0 ± 75.5	227.0 ± 87.3	159.0 ± 79.6	227.0 ± 87.3
Aug 16	336.0 ± 97.7	264.0 ± 90.6	337.0 ± 96.2	254.0 ± 89.5	226.0 ± 86.6	317.0 ± 95.8	283.0 ± 92.5

A.2.1 Weekly gross alpha and gross beta concentrations (μBq/m3) from air particulate samples from the Livermore perimeter locations, 2011[(a)]

Date	Gross beta CAFE	Gross beta COW	Gross beta CRED	Gross beta MESQ	Gross beta MET	Gross beta SALV	Gross beta VIS
Aug 23	208.0 ± 85.1	194.0 ± 83.6	347 ± 101	231.0 ± 87.0	213.0 ± 85.8	266.0 ± 91.4	213.0 ± 85.8
Aug 30	433 ± 107	385 ± 102	503 ± 112	496 ± 112	518 ± 114	481 ± 110	451 ± 108
Sep 6	648 ± 124	492 ± 112	629 ± 122	518 ± 114	540 ± 116	462 ± 110	574 ± 119
Sep 13	766 ± 133	500 ± 112	662 ± 125	536 ± 115	696 ± 128	677 ± 126	640 ± 124
Sep 20	736 ± 130	514 ± 113	773 ± 133	574 ± 118	607 ± 121	651 ± 124	670 ± 125
Sep 27	751 ± 132	474 ± 110	818 ± 136	648 ± 124	536 ± 115	692 ± 127	699 ± 128
Oct 4	555 ± 117	411 ± 104	500 ± 112	356.0 ± 99.9	385 ± 102	544 ± 116	388 ± 103
Oct 11	(b)	162.0 ± 77.3	(b)	121.0 ± 72.5	111.0 ± 71.4	(b)	(b)
Oct 12	156.0 ± 71.4	(b)	229.0 ± 79.6	(b)	(b)	165.0 ± 72.9	102.0 ± 65.1
Oct 18	1190 ± 174	736 ± 134	969 ± 135	1030 ± 154	903 ± 145	995 ± 161	1020 ± 163
Oct 25	851 ± 138	681 ± 126	1120 ± 152	733 ± 130	866 ± 139	814 ± 135	796 ± 135
Nov 1	1220 ± 162	981 ± 147	1400 ± 175	858 ± 139	1110 ± 155	1150 ± 157	1170 ± 159
Nov 8	448 ± 107	305.0 ± 94.0	514 ± 112	400 ± 103	357.0 ± 99.2	411 ± 104	352.0 ± 98.8
Nov 15	1030 ± 149	818 ± 135	1210 ± 160	777 ± 132	947 ± 144	981 ± 146	1030 ± 149
Nov 22	341.0 ± 99.2	258.0 ± 91.0	322.0 ± 97.3	341.0 ± 99.2	297.0 ± 94.7	287.0 ± 94.0	346.0 ± 99.5
Nov 29	562 ± 117	429 ± 106	629 ± 122	462 ± 109	488 ± 111	555 ± 116	448 ± 107
Dec 6	629 ± 124	422 ± 107	585 ± 120	500 ± 113	474 ± 111	474 ± 111	429 ± 107
Dec 12	2490 ± 204	1790 ± 175	2440 ± 201	1760 ± 174	2090 ± 188	2050 ± 186	1840 ± 177
Dec 20	1250 ± 128	1140 ± 123	1360 ± 133	1140 ± 123	1190 ± 125	1100 ± 121	1060 ± 119
Dec 28	1580 ± 168	1240 ± 151	1610 ± 170	1300 ± 154	1350 ± 157	(b)	1040 ± 139
Detection frequency	51 of 52	50 of 52	51 of 52	51 of 52	51 of 52	51 of 51	50 of 51
Median	372	306	352	348	336	320	352
IQR [(c)]	421	326	416	350	403	435	400
Maximum	2490	1790	2440	2130	2090	2050	1840

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.

(b) Different sample dates occur when samples could not be collected on scheduled sampling date due to access or weather, or sampler malfunction, or power (GFI) is out

(c) IQR = Interquartile range

A.2.2 Tritium concentrations (mBq/m^3) in air on the Livermore site, 2011 [(a)]

Week	Month	ARAC	CAFE	COW	CRED	DWTF	MESQ	MET	B295	POOL	SALV	SECO	VIS
1	Jan	47.7 ± 13.9	83.6 ± 15.2	83.6 ± 17.1	45.9 ± 13.9	60.3 ± 13.7	68.8 ± 15.2	50.3 ± 13.5	87.7 ± 15.5	125.0 ± 16.8	41.1 ± 14.8	68.4 ± 15.7	53.6 ± 13.9
3	Jan	62.2 ± 16.2	50.0 ± 15.6	45.1 ± 18.9	267.0 ± 23.0	45.1 ± 14.7	69.6 ± 17.1	69.2 ± 16.0	96.2 ± 18.8	275.0 ± 23.3	46.2 ± 17.2	239.0 ± 22.5	52.9 ± 15.9
5	Feb	74.7 ± 16.4	74.7 ± 16.2	86.6 ± 22.1	37.7 ± 15.5	62.2 ± 15.3	74.4 ± 17.2	48.5 ± 15.1	138.0 ± 20.8	262.0 ± 22.2	25.6 ± 16.7	215.0 ± 24.4	52.5 ± 15.9
7	Feb	57.7 ± 13.4	131.0 ± 15.4	71.8 ± 14.9	32.3 ± 13.2	37.4 ± 11.9	55.1 ± 14.3	56.2 ± 13.1	131.0 ± 18.6	187.0 ± 16.8	61.8 ± 16.0	61.0 ± 11.0	41.1 ± 13.6
9	Mar	18.0 ± 13.0	33.4 ± 13.0	71.4 ± 16.3	44.0 ± 14.9	57.4 ± 13.4	41.4 ± 15.3	21.2 ± 12.8	47.0 ± 12.2	49.6 ± 13.2	24.2 ± 11.0	33.6 ± 11.5	55.5 ± 16.1
11	Mar	16.7 ± 17.5	22.8 ± 17.6	57.0 ± 16.4	57.0 ± 16.7	78.1 ± 18.2	37.4 ± 19.5	30.1 ± 17.7	42.6 ± 15.4	50.0 ± 17.8	8.3 ± 14.4	51.4 ± 16.1	59.2 ± 16.7
13	Mar	22.1 ± 13.8	29.2 ± 13.0	92.1 ± 14.3	23.5 ± 11.9	13.5 ± 12.1	25.5 ± 15.2	28.7 ± 13.8	82.5 ± 13.5	48.8 ± 13.7	47.0 ± 12.4	6.1 ± 10.5	35.4 ± 12.4
15	Apr	33.0 ± 13.2	48.5 ± 13.2	54.4 ± 12.7	44.8 ± 12.7	73.3 ± 14.1	37.0 ± 14.8	22.6 ± 13.4	54.8 ± 12.4	198.0 ± 18.2	11.5 ± 10.7	31.3 ± 11.4	67.7 ± 20.5
17	Apr	9.3 ± 16.1	3.6 ± 14.7	54.8 ± 15.8	52.5 ± 15.5	91.4 ± 17.8	6.9 ± 12.6	5.0 ± 16.1	5.0 ± 12.9	23.2 ± 16.0	6.5 ± 12.1	9.8 ± 13.8	80.7 ± 15.6
19	May	45.9 ± 14.4	223.0 ± 19.4	77.7 ± 14.2	55.9 ± 13.1	223.0 ± 19.1	24.9 ± 10.7	26.0 ± 14.0	26.6 ± 11.5	229.0 ± 20.1	46.2 ± 12.1	12.6 ± 10.4	49.2 ± 12.5
21	May	24.3 ± 13.7	21.8 ± 15.4	106.0 ± 17.6	126.0 ± 18.2	459.0 ± 27.6	13.1 ± 12.5	31.2 ± 17.4	82.9 ± 16.2	5.4 ± 15.2	16.7 ± 12.9	20.5 ± 13.1	106.0 ± 16.6
23	Jun	0.4 ± 12.9	-6.0 ± 15.2	46.2 ± 16.7	192.0 ± 21.6	366.0 ± 27.0	1.6 ± 13.7	-4.1 ± 11.1	12.1 ± 14.2	35.4 ± 17.4	23.0 ± 14.0	1.1 ± 13.2	114.0 ± 17.5
25	Jun	1.7 ± 15.2	33.9 ± 16.7	121.0 ± 21.3	76.2 ± 19.0	500.0 ± 32.7	6.7 ± 16.2	6.6 ± 13.5	42.6 ± 18.4	87.7 ± 20.5	20.4 ± 15.5	13.4 ± 14.9	88.4 ± 17.4
27	Jul	34.7 ± 17.9	81.8 ± 19.2	152.0 ± 23.5	155.0 ± 23.8	566.0 ± 35.5	12.7 ± 16.7	18.2 ± 14.3	25.9 ± 16.5	123.0 ± 22.3	49.6 ± 17.1	17.9 ± 15.8	145.0 ± 20.0
29	Jul	-2.4 ± 18.3	6.1 ± 17.9	62.9 ± 23.4	189.0 ± 29.2	481.0 ± 36.6	-2.7 ± 18.8	-3.1 ± 15.1	7.1 ± 17.7	24.4 ± 20.9	60.7 ± 20.0	4.2 ± 17.6	200.0 ± 25.7
31	Aug	1.7 ± 17.7	0.0019 ± 0.0179	71.4 ± 24.0	150.0 ± 27.9	684.0 ± 42.6	-4.3 ± 18.5	-11.0 ± 17.5	23.1 ± 18.4	16.4 ± 20.7	82.5 ± 20.5	2.4 ± 17.8	122.0 ± 21.9
33	Aug	1.1 ± 16.8	12.6 ± 17.2	145.0 ± 25.9	115.0 ± 25.9	799.0 ± 44.4	11.1 ± 17.8	8.0 ± 17.2	20.0 ± 17.1	12.5 ± 19.7	10.6 ± 16.5	-9.3 ± 17.2	87.3 ± 19.7
35	Sep	5.4 ± 16.7	50.3 ± 19.3	166.0 ± 26.7	92.9 ± 17.1	784.0 ± 42.6	7.5 ± 17.9	20.9 ± 18.0	25.5 ± 17.4	54.0 ± 22.5	32.1 ± 17.9	19.9 ± 19.3	117.0 ± 20.5
37	Sep	53.6 ± 18.1	146.0 ± 21.3	265.0 ± 24.8	215.0 ± 19.7	773.0 ± 35.5	18.9 ± 16.8	47.0 ± 17.5	113.0 ± 20.5	555.0 ± 36.6	114.0 ± 19.6	42.2 ± 16.9	385.0 ± 26.8
39	Sep	116.0 ± 20.2	151.0 ± 19.9	96.9 ± 19.0	95.5 ± 18.5	82.5 ± 19.5	98.0 ± 19.1	86.6 ± 18.9	152.0 ± 22.8	429.0 ± 32.6	162.0 ± 21.4	117.0 ± 20.2	103.0 ± 18.0
41	Oct	21.9 ± 20.8	(b)	98.4 ± 22.2	129.0 ± 23.6	98.4 ± 20.7	48.1 ± 21.0	3.3 ± 18.3	73.6 ± 23.6	173.0 ± 25.8	259.0 ± 28.3	111.0 ± 27.3	174.0 ± 28.1
43	Oct	77.0 ± 18.6	75.8 ± 15.4	113.0 ± 19.9	79.2 ± 19.0	96.6 ± 18.5	68.1 ± 18.9	69.6 ± 18.0	138.0 ± 22.9	182.0 ± 23.5	69.9 ± 18.8	133.0 ± 20.7	82.5 ± 21.3
45	Nov	62.9 ± 13.6	79.2 ± 11.8	59.2 ± 13.4	19.2 ± 13.1	32.9 ± 12.2	59.2 ± 14.7	69.9 ± 13.6	108.0 ± 16.7	514.0 ± 26.7	16.1 ± 13.2	63.3 ± 13.9	38.8 ± 14.9
47	Nov	38.8 ± 16.0	35.5 ± 12.7	47.0 ± 15.6	39.6 ± 18.6	43.3 ± 16.6	29.9 ± 16.5	38.1 ± 15.1	65.1 ± 16.8	86.2 ± 19.7	33.1 ± 17.6	32.7 ± 15.7	40.0 ± 17.5
49	Dec	76.2 ± 12.8	56.2 ± 11.1	22.9 ± 10.2	62.9 ± 12.8	27.1 ± 12.1	67.3 ± 12.9	47.7 ± 10.9	91.0 ± 13.4	204.0 ± 18.9	50.7 ± 14.0	58.8 ± 12.1	45.1 ± 12.7
51	Dec	56.2 ± 12.5	131.0 ± 13.9	34.9 ± 11.1	26.90 ± 7.40	27.7 ± 10.6	66.6 ± 14.3	59.2 ± 11.6	124.0 ± 17.9	540.0 ± 23.5	31.9 ± 10.8	89.2 ± 13.8	39.6 ± 12.8
	Median	33.8	50.0	74.8	69.6	87.0	33.4	29.4	69.4	124	37.1	33.2	74.2
	IQR [(c)]	46.2	59.0	48.8	84.0	427	53.2	39.3	79.0	174	37.2	54.3	62.0
	Median Percent of DCS[(d)]	0.00043	0.00064	0.00096	0.00089	0.0011	0.00043	0.00038	0.00089	0.0016	0.00048	0.00043	0.00095
	Mean Dose (nSv)[(e),(f)]	8.83	15.1	21.3	22.4	60	8.71	7.80	16.8	41.5	12.5	13.3	22.5

(a) See *Environmental Report 2011,* Figure 4-2 for map of sampling locations.

(b) Data missing, lost sample or below detection limit.

(c) IQR = Interquartile range

(d) DCS = Deririved Concentration Standard of 7.8E+06 mBq/m3 for tritium in air. Percent of DCS is calculated from the median concentraton.

(e) The annual dose is calculated from the mean concentration and represents the effective dose equivalent from inhalation and skin absorption.

(f) When the mean dose is based on a concentration less than the lower limit of detection (about 25 mBq/m3), the dose is assumed to be less than that calculated from the lower limit of detection (5 nSv/yr).

A.2.3 Beryllium concentration (pg/m3) in air particulate samples at the Livermore site and Site 300 locations, 2011(a)

Month	Livermore Site Perimeter	Livermore Site Perimeter	Livermore Site Perimeter	Livermore Site Perimeter	Livermore Site Perimeter	Livermore Site Perimeter	Site 300 Perimeter	Site 300 Perimeter	Site 300 Perimeter	Site 300 Off site
	CAFE	COW	MESQ	MET	SALV	VIS	TNK5	EOBS	GOLF	TCDF
Jan	2.60	2.50	2.60	3.10	2.00	2.40	1.40	1.100	1.30	3.10
Feb	2.40	2.50	2.70	2.50	2.80	2.20	1.70	1.50	1.80	3.10
Mar	1.900	1.50	2.00	1.40	1.200	1.400	1.300	1.70	1.200	2.20
Apr	4.30	3.80	3.00	4.00	3.50	3.30	2.40	2.20	3.400	3.70
May	4.20	4.00	4.70	4.50	3.20	4.20	7.20	6.30	7.00	7.60
Jun	4.00	3.20	2.80	4.20	3.50	3.80	4.00	3.90	3.30	2.30
Jul	4.00	4.00	2.20	3.30	3.70	3.60	8.50	7.70	6.80	6.10
Aug	6.90	7.00	5.50	5.30	5.60	5.40	11.00	9.90	9.50	14.00
Sep	11.00	11.00	9.50	11.00	10.00	12.00	16.00	14.00	14.0	23.0
Oct	3.60	3.30	2.90	3.20	3.00	3.50	6.20	3.00	7.90	4.40
Nov	5.30	6.90	4.70	6.20	5.20	6.50	9.30	8.90	7.60	11.00
Dec	5.40	7.00	5.30	5.40	4.40	5.20	4.50	4.30	4.60	6.80
Detection frequency	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12
Median	4.1	3.9	3.0	4.1	3.5	3.7	5.4	4.1	5.7	5.2
IQR	2.0	3.9	2.2	2.1	1.7	2.2	6.5	5.9	4.7	5.4
Maximum	11	11	9.5	11	10	12	16	14	14	23
Median Percent of ACL	0.041	0.039	0.030	0.041	0.035	0.037	0.054	0.041	0.057	0.052
ACL	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.

A.2.4 Beryllium-7 concentrations (mBq/m3) composites for the Livermore site and Site 300 air particulate samples, 2011[(a)]

Month	LLNL Composite	Site 300 Composite
Jan	2.600 ± 0.118	2.620 ± 0.143
Feb	2.830 ± 0.178	2.630 ± 0.164
Mar	1.5600 ± 0.0903	1.5300 ± 0.0862
Apr	2.690 ± 0.169	2.610 ± 0.182
May	1.920 ± 0.135	3.330 ± 0.205
Jun	1.980 ± 0.125	2.630 ± 0.148
Jul	2.160 ± 0.103	3.040 ± 0.170
Aug	2.480 ± 0.127	4.330 ± 0.206
Sep	3.400 ± 0.153	4.960 ± 0.248
Oct	3.540 ± 0.151	3.470 ± 0.171
Nov	3.240 ± 0.139	2.070 ± 0.104
Dec	3.770 ± 0.160	3.920 ± 0.184
Detection frequency	12 of 12	12 of 12
Median	2.64	2.84
IQR (b)	1.16	0.965
Maximum	3.77	4.96

(a) See *Environmental Report 2011,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) IQR = Interquartile range

A.2.5 Plutonium-239+240 concentrations (nBq/m3) in air particulate samples from the Livermore site and Site 300 composite, 2011[(a)]

Month	Livermore Site Perimeter CAFE	Livermore Site Perimeter COW	Livermore Site Perimeter CRED	Livermore Site Perimeter MESQ	Livermore Site Perimeter MET	Livermore Site Perimeter SALV	Livermore Site Perimeter VIS	Site 300 Perimeter Perimeter Composite
Jan	0.26 ± 4.22	-5.18 ± 6.59	-4.92 ± 9.10	-3.17 ± 8.29	1.55 ± 4.18	3.22 ± 8.47	-1.50 ± 7.55	-2.59 ± 2.68
Feb	2.8 ± 12.1	0.46 ± 7.51	0.00 ± 7.92	1.65 ± 9.99	-2.32 ± 6.07	-20.7 ± 20.3	5.48 ± 9.44	0.92 ± 2.48
Mar	0.4 ± 10.8	-9.06 ± 8.58	5.11 ± 8.66	3.0 ± 14.1	-3.00 ± 4.26	10.8 ± 12.4	2.7 ± 15.7	-0.99 ± 2.40
Apr	-2.47 ± 6.44	-0.93 ± 9.18	-5.40 ± 5.22	-1.6 ± 11.2	1.66 ± 4.48	-9.18 ± 6.29	3.69 ± 9.95	3.06 ± 9.88
May	-11.70 ± 8.62	-5.8 ± 10.4	11.6 ± 11.4	-6.2 ± 10.3	-12.30 ± 7.07	-17.6 ± 19.1	-5.7 ± 12.3	0.48 ± 1.19
Jun	-4.85 ± 2.45	9.10 ± 5.66	0 ± 0	-3.26 ± 1.90	-7.07 ± 3.12	-10.10 ± 5.48	0.41 ± 4.33	-10.00 ± 7.77
Jul	7.3 ± 10.9	3.4 ± 11.4	1.17 ± 4.85	16.5 ± 16.2	-0.36 ± 4.77	2.61 ± 9.99	7.07 ± 7.66	5.11 ± 6.29
Aug	-1.68 ± 6.07	16.0 ± 32.8	4.07 ± 5.70	-15.3 ± 17.7	-15.1 ± 11.2	8.2 ± 12.6	8 ± 781	1.93 ± 6.25
Sep	4.9 ± 28.5	4.6 ± 10.2	24.0 ± 49.2	9 ± 788	1.11 ± 6.51	8.9 ± 11.2	7.8 ± 12.1	0.94 ± 2.08
Oct	6.29 ± 7.73	5.70 ± 7.03	-1.6 ± 14.6	7.62 ± 8.07	5.51 ± 6.99	2.01 ± 4.40	12.9 ± 15.7	1.74 ± 3.81
Nov	1.22 ± 5.03	1.89 ± 6.36	2.82 ± 8.25	-1.27 ± 4.59	6.7 ± 10.5	-4.22 ± 4.26	4.4 ± 10.5	-4.62 ± 5.44
Dec	7.55 ± 7.36	-1.82 ± 6.59	7.62 ± 9.32	4.48 ± 5.66	3.81 ± 4.70	2.66 ± 6.96	5.81 ± 7.33	2.93 ± 3.68
Detection frequency	1 of 12	1 of 12	1 of 12	1 of 12	0 of 12	0 of 12	0 of 12	0 of 12
Median	0.804	1.17	2.00	0.190	0.373	2.31	4.94	0.932
IQR	7.11	7.55	6.13	8.46	6.22	13.9	5.10	3.57
Maximum	7.55	16.0	24.0	16.5	6.73	10.8	12.9	5.11
Median Percent of DCS	0.0000089	0.000013	0.000022	0.0000021	0.0000041	0.000026	0.000055	0.000010
DCS	9000000	9000000	9000000	9000000	9000000	9000000	9000000	9000000

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.

A.2.6 Uranium mass concentrations (pg/m3) in air particulate samples from the Livermore site (composite) and Site 300 onsite and offsite locations, 2011(a)

Month	TNK5 Uranium-235	TNK5 Uranium-238	TNK5 U235/U238 ratio	ECP Uranium-235	ECP Uranium-238	ECP U235/U238 ratio	EOBS Uranium-235	EOBS Uranium-238	EOBS U235/U238 ratio	GOLF Uranium-235	GOLF Uranium-238	GOLF U235/U238 ratio	NPS Uranium-235	NPS Uranium-238	NPS U235/U238 ratio
Jan	0.03960 ± 0.00909	5.65 ± 1.29	0.006930	0.0651 ± 0.0243	8.89 ± 3.31	0.007230	0.03670 ± 0.00657	5.070 ± 0.896	0.007140	0.0387 ± 0.0220	5.37 ± 3.05	0.007110	0.0548 ± 0.0164	7.44 ± 2.22	0.007280
Feb	0.0486 ± 0.0123	6.93 ± 1.75	0.0069300	0.0527 ± 0.0113	7.18 ± 1.53	0.007240	0.0666 ± 0.0102	9.22 ± 1.41	0.0071400	0.0542 ± 0.0150	7.48 ± 2.06	0.007150	0.0587 ± 0.0144	8.05 ± 1.96	0.007200
Mar	0.0381 ± 0.0104	5.59 ± 1.51	0.006740	0.04540 ± 0.00560	6.510 ± 0.781	0.006880	0.04480 ± 0.00877	6.25 ± 1.22	0.007080	0.0399 ± 0.0126	5.53 ± 1.74	0.007130	0.03880 ± 0.00651	5.290 ± 0.863	0.007240
Apr	0.0661 ± 0.0279	9.56 ± 4.02	0.006830	0.0753 ± 0.0142	10.50 ± 1.96	0.007080	0.0712 ± 0.0258	10.30 ± 3.73	0.006830	0.0734 ± 0.0183	10.10 ± 2.51	0.007170	0.0650 ± 0.0215	9.00 ± 2.94	0.007130
May	0.1350 ± 0.0423	20.80 ± 6.51	0.006400	0.2080 ± 0.0726	29.0 ± 10.1	0.007080	0.1360 ± 0.0384	20.00 ± 5.64	0.006720	0.1350 ± 0.0421	18.60 ± 5.78	0.007140	0.1520 ± 0.0660	20.90 ± 9.06	0.007200
Jun	0.1050 ± 0.0321	17.20 ± 5.25	0.006000	(b)	(b)	(b)	0.1060 ± 0.0356	16.10 ± 5.40	0.006510	0.1010 ± 0.0340	14.30 ± 4.79	0.006950	0.0965 ± 0.0300	13.60 ± 4.21	0.007000
Jul	0.1910 ± 0.0252	34.00 ± 4.47	0.0055400	(b)	(b)	(b)	0.2140 ± 0.0446	35.70 ± 7.42	0.005920	0.2030 ± 0.0558	28.50 ± 7.83	0.0070400	0.1790 ± 0.0341	25.20 ± 4.79	0.0070000
Aug	0.2330 ± 0.0665	42.8 ± 12.2	0.0053700	0.1730 ± 0.0518	25.60 ± 7.66	0.006650	0.2410 ± 0.0764	40.4 ± 12.8	0.0058800	0.2290 ± 0.0871	32.6 ± 12.4	0.0069200	0.2090 ± 0.0627	32.10 ± 9.63	0.0064300
Sep	0.4120 ± 0.0676	64.8 ± 10.6	0.0062800	0.3960 ± 0.0661	56.50 ± 9.40	0.0069200	0.445 ± 0.165	68.2 ± 25.3	0.0064400	0.4090 ± 0.0966	56.8 ± 13.4	0.0071000	0.396 ± 0.118	54.7 ± 16.3	0.0071500
Oct	0.2970 ± 0.0498	43.00 ± 7.20	0.0068100	0.2980 ± 0.0755	41.5 ± 10.5	0.0071000	0.3130 ± 0.0682	43.70 ± 9.52	0.0070700	0.2510 ± 0.0782	34.7 ± 10.8	0.007140	0.2770 ± 0.0989	38.1 ± 13.6	0.0071900
Nov	0.2520 ± 0.0757	37.0 ± 11.1	0.006710	0.2660 ± 0.0962	36.8 ± 13.3	0.0071400	0.2630 ± 0.0503	37.10 ± 7.08	0.0070000	0.2540 ± 0.0809	35.2 ± 11.2	0.007120	0.2560 ± 0.0848	35.4 ± 11.7	0.007130
Dec	0.1430 ± 0.0183	20.50 ± 2.56	0.006890	0.1480 ± 0.0337	20.60 ± 4.67	0.007080	0.1590 ± 0.0697	22.10 ± 9.67	0.007080	0.1510 ± 0.0596	21.40 ± 8.44	0.006980	0.1530 ± 0.0595	21.00 ± 8.17	0.0072100
Detection frequency	12 of 12	12 of 12	12 of 12	10 of 10	10 of 10	10 of 10	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12
Median	0.139	20.6	0.00672	0.160	23.1	0.00708	0.148	21.0	0.00692	0.143	20.0	0.00712	0.152	21.0	0.00717
IQR (c)	0.176	29.5	0.000635	0.184	25.6	0.000170	0.176	27.9	0.000588	0.166	23.7	0.000115	0.157	24.2	0.000105
Maximum	0.412	64.8	0.00693	0.396	56.5	0.00724	0.445	68.2	0.00714	0.409	56.8	0.00717	0.396	54.7	0.00728
Median Percent of DCS	0.000065	0.0015	(d)	0.000075	0.0017	(d)	0.000069	0.0015	(d)	0.000067	0.0014	(d)	0.000071	0.0015	(d)
DCS	214000	1380000	(d)	214000	1380000	(d)	214000	1380000	(d)	214000	1380000	(d)	214000	1380000	(d)
Maximum Percent of DCS	0.00019	0.0047	(d)	0.00019	0.0041	(d)	0.00021	0.0049	(d)	0.00019	0.0041	(d)	0.00019	0.0040	(d)

Month	PSTL Uranium-235	PSTL Uranium-238	PSTL U235/U238 ratio	TCDF Uranium-235	TCDF Uranium-238	TCDF U235/U238 ratio	WCP Uranium-235	WCP Uranium-238	WCP U235/U238 ratio	WOBS Uranium-235	WOBS Uranium-238	WOBS U235/U238 ratio	Livermore composite Uranium-235	Livermore composite Uranium-238	Livermore composite U235/U238 ratio
Jan	0.1230 ± 0.0304	16.90 ± 4.15	0.007200	0.0894 ± 0.0191	12.20 ± 2.58	0.007230	0.05410 ± 0.00836	7.50 ± 1.14	0.007120	0.0553 ± 0.0132	7.71 ± 1.83	0.007080	0.06320 ± 0.00749	8.63 ± 1.02	0.0072300
Feb	0.1450 ± 0.0358	19.90 ± 4.91	0.0071900	0.09740 ± 0.00689	13.200 ± 0.900	0.007290	0.0617 ± 0.0124	9.33 ± 1.87	0.006530	0.05460 ± 0.00702	7.770 ± 0.971	0.006930	0.06960 ± 0.00552	9.410 ± 0.734	0.007310
Mar	0.0914 ± 0.0178	12.50 ± 2.41	0.007220	0.0697 ± 0.0120	9.39 ± 1.59	0.007330	0.0502 ± 0.0225	6.94 ± 3.10	0.007150	0.0394 ± 0.0146	5.45 ± 2.00	0.007140	0.04700 ± 0.00320	6.370 ± 0.422	0.007290
Apr	0.1900 ± 0.0481	26.20 ± 6.62	0.007150	0.0990 ± 0.0417	13.60 ± 5.72	0.007190	0.0681 ± 0.0240	9.63 ± 3.38	0.006980	0.0602 ± 0.0254	8.31 ± 3.50	0.007150	0.06830 ± 0.00633	9.380 ± 0.851	0.007190
May	0.265 ± 0.112	36.7 ± 15.5	0.007130	0.1830 ± 0.0452	25.00 ± 6.14	0.007210	0.1950 ± 0.0675	28.80 ± 9.94	0.006690	0.1070 ± 0.0373	15.30 ± 5.32	0.006920	0.0538 ± 0.0108	7.48 ± 1.49	0.007100
Jun	0.1440 ± 0.0706	19.60 ± 9.60	0.007250	0.1420 ± 0.0438	19.40 ± 5.97	0.007230	0.1240 ± 0.0264	18.90 ± 3.99	0.006480	0.0864 ± 0.0325	12.40 ± 4.66	0.0068800	0.2000 ± 0.0388	27.50 ± 5.30	0.007190
Jul	0.2120 ± 0.0662	29.30 ± 9.14	0.0071500	0.3190 ± 0.0904	43.8 ± 12.4	0.0071900	0.1780 ± 0.0352	26.70 ± 5.26	0.0065800	0.1370 ± 0.0214	19.60 ± 3.04	0.006910	0.07210 ± 0.00679	9.840 ± 0.907	0.007240
Aug	0.2710 ± 0.0602	37.10 ± 8.23	0.0072000	0.484 ± 0.163	66.4 ± 22.4	0.0072000	0.1870 ± 0.0542	29.30 ± 8.49	0.0063200	0.1470 ± 0.0456	21.70 ± 6.70	0.006710	0.1310 ± 0.0169	17.80 ± 2.29	0.0072400
Sep	0.437 ± 0.177	61.1 ± 24.8	0.007060	0.789 ± 0.274	108.0 ± 37.5	0.0072200	0.4430 ± 0.0907	67.1 ± 13.7	0.006530	0.339 ± 0.101	47.8 ± 14.3	0.0070100	0.2300 ± 0.0382	31.60 ± 5.24	0.0071800
Oct	0.369 ± 0.144	51.2 ± 20.0	0.0071200	0.544 ± 0.112	74.4 ± 15.3	0.0072200	0.2790 ± 0.0592	41.40 ± 8.77	0.0066600	0.2440 ± 0.0782	33.4 ± 10.7	0.0072100	0.2150 ± 0.0340	29.50 ± 4.66	0.0071900
Nov	0.353 ± 0.101	49.0 ± 14.0	0.0071100	0.4600 ± 0.0990	63.3 ± 13.6	0.0071800	0.3040 ± 0.0745	45.8 ± 11.2	0.0065600	0.2180 ± 0.0406	31.10 ± 5.79	0.0069300	0.1500 ± 0.0363	20.20 ± 4.87	0.007330
Dec	0.3500 ± 0.0787	47.7 ± 10.7	0.007240	0.2530 ± 0.0765	34.4 ± 10.4	0.0072600	0.1680 ± 0.0723	27.2 ± 11.7	0.0060900	0.1300 ± 0.0361	18.40 ± 5.08	0.006990	0.1690 ± 0.0398	23.50 ± 5.51	0.007080
Detection frequency	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12	12 of 12
Median	0.238	33.0	0.00717	0.218	29.7	0.00722	0.173	27.0	0.00657	0.118	16.8	0.00696	0.102	13.8	0.00721
IQR (c)	0.206	28.2	0.0000775	0.367	50.6	0.0000400	0.150	22.8	0.000245	0.106	15.9	0.000178	0.110	15.3	0.0000650
Maximum	0.437	61.1	0.00725	0.789	108	0.00733	0.443	67.1	0.00715	0.339	47.8	0.00721	0.230	31.6	0.00733
Median Percent of DCS	0.00011	0.0024	(d)	0.00010	0.0022	(d)	0.000081	0.0020	(d)	0.000055	0.0012	(d)	0.000047	0.0010	(d)
DCS	214000	1380000	(d)	214000	1380000	(d)	214000	1380000	(d)	214000	1380000	(d)	214000	1380000	(d)
Maximum Percent of DCS	0.00020	0.0044	(d)	0.00037	0.0078	(d)	0.00021	0.0049	(d)	0.00016	0.0035	(d)	0.00011	0.0023	(d)

(a) See *Environmental Report 2011*, figures 4-1, 4-2, and 4-3 for maps of sampling locations.

(b) Different sample dates occur when samples could not be collected on the same scheduled sampling interval due to access or weather, sampler malfunction, or power (GFI) is out

(c) IQR = Interquartile range

(d) Medians are not calculated for isotopic ratios

A.2.7 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore Valley downwind locations, 2011[(a)]

Date	Gross alpha AMON	Gross alpha CPET	Gross alpha PATT	Gross alpha TANK	Gross alpha ZON7
Jan 4	(b)	3.5 ± 21.0	3.5 ± 21.0	14.9 ± 26.2	73.3 ± 44.8
Jan 11	22.1 ± 18.4	-2.6 ± 20.1	16.7 ± 29.3	21.0 ± 28.9	10.3 ± 26.5
Jan 18	42.2 ± 42.6	17.2 ± 30.2	(b)	10.6 ± 27.3	17.4 ± 30.4
Jan 25	51.4 ± 42.9	10.7 ± 27.3	65.1 ± 46.6	43.3 ± 39.6	24.3 ± 33.6
Feb 1	17.1 ± 29.9	10.6 ± 27.2	30.3 ± 35.2	28.0 ± 38.5	17.1 ± 30.0
Feb 8	43.7 ± 39.6	-2.7 ± 20.2	10.6 ± 27.3	30.5 ± 35.3	17.3 ± 30.3
Feb 14	28.4 ± 36.8	(b)	(b)	(b)	(b)
Feb 15	(b)	34.7 ± 38.5	28.2 ± 36.4	8.1 ± 28.4	8.1 ± 28.6
Feb 22	-5.1 ± 21.3	-11.8 ± 17.3	8.1 ± 28.4	21.2 ± 33.6	8.1 ± 28.4
Mar 1	8.1 ± 28.4	34.6 ± 38.5	1.5 ± 25.3	1.5 ± 25.5	14.7 ± 31.2
Mar 8	-12.0 ± 17.5	8.1 ± 28.4	-5.1 ± 21.6	-11.8 ± 17.4	8.1 ± 28.3
Mar 15	-5.2 ± 21.8	-5.2 ± 21.8	28.2 ± 36.6	-5.1 ± 21.6	1.5 ± 25.5
Mar 22	8.0 ± 27.9	-11.7 ± 17.2	-5.1 ± 21.5	1.5 ± 25.3	8.1 ± 28.3
Mar 29	21.4 ± 33.9	1.5 ± 25.3	-5.1 ± 21.6	-5.1 ± 21.6	-11.8 ± 17.3
Apr 5	14.6 ± 31.0	-11.6 ± 17.1	21.0 ± 33.3	-5.1 ± 21.6	14.5 ± 30.9
Apr 12	1.5 ± 25.9	8.2 ± 28.8	8.3 ± 29.1	14.8 ± 31.3	49.2 ± 43.7
Apr 19	8.1 ± 28.4	21.3 ± 33.7	-5.1 ± 21.6	8.1 ± 28.3	1.5 ± 25.3
Apr 26	28.0 ± 36.3	1.5 ± 25.3	1.5 ± 25.2	1.5 ± 25.4	28.1 ± 36.3
May 3	47.7 ± 42.6	21.5 ± 34.0	14.8 ± 31.3	24.5 ± 31.7	27.6 ± 35.8
May 10	8.1 ± 28.3	14.6 ± 31.0	27.9 ± 36.1	9.4 ± 33.1	41.1 ± 40.7
May 17	21.4 ± 33.9	-5.2 ± 21.7	-11.8 ± 17.4	14.6 ± 31.0	8.1 ± 28.5
May 24	34.1 ± 37.7	8.1 ± 28.5	14.7 ± 31.2	-5.1 ± 21.6	28.0 ± 36.3
May 31	8.2 ± 28.7	1.5 ± 25.1	21.3 ± 33.7	(b)	-5.1 ± 21.6
Jun 1	(b)	(b)	(b)	1.3 ± 22.8	(b)
Jun 7	34.1 ± 38.1	-5.2 ± 21.7	-11.8 ± 17.4	-5.8 ± 24.3	1.5 ± 25.3
Jun 14	-12.0 ± 17.6	1.5 ± 25.3	-5.1 ± 21.6	(b)	1.5 ± 25.2
Jun 15	(b)	(b)	(b)	7.2 ± 25.1	(b)
Jun 21	47.7 ± 42.6	1.5 ± 25.2	1.5 ± 25.2	21.7 ± 34.4	14.8 ± 31.4
Jun 28	-5.1 ± 21.3	41.1 ± 40.3	-5.2 ± 21.8	(b)	8.0 ± 28.0
Jun 30	(b)	(b)	(b)	-4.5 ± 19.1	(b)
Jul 5	1.5 ± 26.0	1.5 ± 25.3	1.5 ± 26.0	10.9 ± 38.1	1.5 ± 25.6
Jul 12	14.5 ± 30.7	27.9 ± 36.1	1.4 ± 24.8	15.0 ± 31.7	66.6 ± 47.4
Jul 19	14.8 ± 31.4	-11.8 ± 17.4	8.2 ± 28.8	-5.2 ± 21.7	-5.2 ± 22.0
Jul 26	14.7 ± 31.2	21.3 ± 33.8	-5.1 ± 21.6	14.7 ± 31.2	1.5 ± 25.3
Aug 2	1.5 ± 25.2	-5.2 ± 21.8	14.8 ± 31.4	-5.1 ± 21.6	14.9 ± 31.5
Aug 9	8.2 ± 28.9	1.5 ± 25.3	1.5 ± 25.3	-5.1 ± 21.7	41.4 ± 40.7
Aug 16	8.0 ± 27.9	41.1 ± 40.3	21.2 ± 33.6	1.5 ± 25.3	14.7 ± 31.0
Aug 23	-11.8 ± 17.4	8.1 ± 28.5	1.5 ± 25.2	1.5 ± 25.2	8.1 ± 28.4
Aug 30	14.7 ± 31.2	27.9 ± 36.1	21.3 ± 33.7	28.0 ± 36.3	14.5 ± 30.8
Sep 6	41.8 ± 41.1	21.3 ± 33.8	28.1 ± 36.4	14.7 ± 31.1	41.8 ± 41.1
Sep 13	79.9 ± 51.1	14.8 ± 31.4	1.5 ± 25.3	14.7 ± 31.2	28.1 ± 36.4
Sep 20	41.1 ± 40.7	1.5 ± 25.2	34.0 ± 37.7	14.8 ± 31.4	21.3 ± 33.7
Sep 27	14.8 ± 31.3	28.0 ± 36.2	14.9 ± 31.6	8.1 ± 28.4	81.0 ± 51.4
Oct 4	48.5 ± 43.3	1.5 ± 25.2	54.8 ± 44.8	(b)	68.1 ± 48.5

A.2.7 Weekly gross alpha and gross beta concentrations (μBq/m3) from air particulate samples from the Livermore Valley downwind locations, 2011+A79

Date	Gross alpha AMON	Gross alpha CPET	Gross alpha PATT	Gross alpha TANK	Gross alpha ZON7
Oct 5	(b)	(b)	(b)	-4.6 ± 19.5	(b)
Oct 11	-	-11.3 ± 16.6	-5.0 ± 21.1	-5.0 ± 20.9	14.3 ± 30.3
Oct 12	13.0 ± 27.5	(b)	(b)	(b)	(b)
Oct 18	85.8 ± 57.7	1.5 ± 26.4	62.5 ± 47.7	71.8 ± 54.4	76.2 ± 51.1
Oct 25	28.0 ± 36.2	41.4 ± 40.7	-5.1 ± 21.6	(b)	28.0 ± 36.2
Oct 26	(b)	(b)	(b)	36.0 ± 35.4	(b)
Nov 1	128.0 ± 62.2	81.4 ± 51.8	121.0 ± 61.0	(b)	68.1 ± 48.5
Nov 2	(b)	(b)	(b)	81.0 ± 51.4	(b)
Nov 8	1.4 ± 24.6	34.2 ± 38.1	1.4 ± 24.6	1.7 ± 29.5	14.4 ± 30.5
Nov 15	47.7 ± 42.6	60.7 ± 46.2	35.2 ± 39.2	21.2 ± 33.6	61.8 ± 47.0
Nov 22	15.1 ± 32.0	21.6 ± 34.2	41.8 ± 41.1	34.9 ± 38.8	1.5 ± 25.5
Nov 29	33.7 ± 37.4	21.2 ± 33.5	-5.1 ± 21.5	24.3 ± 31.5	8.0 ± 28.1
Dec 6	48.8 ± 43.7	21.6 ± 34.3	41.4 ± 40.7	25.1 ± 39.6	28.1 ± 36.3
Dec 12	185.0 ± 67.3	184.0 ± 66.6	179.0 ± 66.2	(b)	119.0 ± 55.9
Dec 13	(b)	(b)	(b)	119.0 ± 51.8	(b)
Dec 20	97.3 ± 43.3	65.5 ± 37.0	59.6 ± 35.8	46.6 ± 32.1	65.5 ± 37.0
Dec 28	106.0 ± 53.3	77.0 ± 47.0	71.4 ± 45.5	(b)	106.0 ± 53.3
Detection frequency	16 of 51	8 of 52	9 of 51	6 of 51	14 of 52
Median	17.1	9.41	10.6	10.9	14.8
IQR (c)	34.8	26.4	26.8	21.6	33.1
Maximum	185	184	179	119	119

A.2.7 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore Valley downwind locations, 2011[+A111]

Date	Gross beta AMON	Gross beta CPET	Gross beta PATT	Gross beta TANK	Gross beta ZON7
Jan 4	(b)	199.0 ± 76.2	287.0 ± 85.1	213.0 ± 77.3	232.0 ± 79.6
Jan 11	581.0 ± 73.3	474 ± 110	477 ± 108	633 ± 114	651 ± 122
Jan 18	540 ± 125	555 ± 117	(b)	429 ± 107	451 ± 109
Jan 25	685 ± 128	536 ± 116	622 ± 124	599 ± 120	729 ± 131
Feb 1	855 ± 138	692 ± 127	696 ± 127	588 ± 132	607 ± 121
Feb 8	322.0 ± 96.6	310.0 ± 95.8	314.0 ± 95.8	332.0 ± 97.7	367 ± 101
Feb 14	562 ± 119	(b)	(b)	(b)	(b)
Feb 15	(b)	459 ± 109	448 ± 108	511 ± 113	422 ± 106
Feb 22	124.0 ± 74.4	121.0 ± 74.7	125.0 ± 75.5	130.0 ± 75.5	130.0 ± 76.2
Mar 1	251.0 ± 89.5	96.6 ± 71.8	179.0 ± 81.8	185.0 ± 83.2	145.0 ± 77.7
Mar 8	127.0 ± 76.6	116.0 ± 74.4	87.0 ± 70.7	131.0 ± 76.2	149.0 ± 78.4
Mar 15	195.0 ± 84.0	165.0 ± 80.7	175.0 ± 81.8	135.0 ± 76.6	185.0 ± 82.9
Mar 22	1270 ± 162	792 ± 134	921 ± 142	1040 ± 151	977 ± 146
Mar 29	1310 ± 167	1080 ± 153	1210 ± 161	1140 ± 156	1940 ± 198
Apr 5	533 ± 114	555 ± 116	500 ± 111	525 ± 114	592 ± 119
Apr 12	522 ± 116	396 ± 105	574 ± 120	514 ± 114	536 ± 117
Apr 19	222.0 ± 86.6	198.0 ± 83.6	207.0 ± 84.7	198.0 ± 83.6	223.0 ± 87.0
Apr 26	251.0 ± 89.5	203.0 ± 84.4	169.0 ± 80.7	218.0 ± 86.6	232.0 ± 87.7
May 3	164.0 ± 80.3	194.0 ± 83.6	174.0 ± 81.4	207.0 ± 77.0	224.0 ± 85.8
May 10	250.0 ± 89.5	234.0 ± 87.3	308.0 ± 95.1	152.0 ± 88.8	374 ± 101
May 17	107.0 ± 73.3	131.0 ± 76.2	184.0 ± 82.5	206.0 ± 84.4	251.0 ± 89.9
May 24	280.0 ± 91.8	174.0 ± 81.4	150.0 ± 78.4	212.0 ± 85.5	309.0 ± 95.5
May 31	137.0 ± 77.7	77.0 ± 69.2	130.0 ± 75.8	(b)	139.0 ± 77.0
Jun 1	(b)	(b)	(b)	127.0 ± 69.9	(b)
Jun 7	219.0 ± 85.5	159.0 ± 79.6	126.0 ± 75.8	130.0 ± 83.2	160.0 ± 79.9
Jun 14	289.0 ± 94.4	111.0 ± 74.0	226.0 ± 87.0	(b)	207.0 ± 84.7
Jun 15	(b)	(b)	(b)	282.0 ± 85.1	(b)
Jun 21	251.0 ± 89.5	265.0 ± 91.0	222.0 ± 86.6	231.0 ± 88.4	292.0 ± 94.4
Jun 28	294.0 ± 92.9	188.0 ± 82.5	185.0 ± 82.9	(b)	228.0 ± 86.2
Jun 30	(b)	(b)	(b)	166.0 ± 72.9	(b)
Jul 5	253.0 ± 91.4	213.0 ± 85.8	332.0 ± 99.5	370 ± 124	293.0 ± 94.7
Jul 12	294.0 ± 92.9	351.0 ± 99.2	280.0 ± 91.4	255.0 ± 91.0	411 ± 104
Jul 19	121.0 ± 75.1	67.7 ± 68.1	103.0 ± 73.6	24.4 ± 62.2	68.8 ± 69.2
Jul 26	246.0 ± 89.2	193.0 ± 83.2	251.0 ± 89.5	178.0 ± 81.8	299.0 ± 94.4
Aug 2	338.0 ± 98.0	296.0 ± 94.4	344.0 ± 99.2	284.0 ± 92.9	481 ± 111
Aug 9	270.0 ± 92.9	222.0 ± 86.6	208.0 ± 85.1	222.0 ± 86.6	261.0 ± 90.6
Aug 16	346.0 ± 97.7	355.0 ± 99.5	302.0 ± 94.4	347.0 ± 99.2	360.0 ± 99.9
Aug 23	357.0 ± 99.9	266.0 ± 91.4	323.0 ± 96.6	212.0 ± 85.1	361 ± 100
Aug 30	570 ± 118	448 ± 108	444 ± 107	477 ± 111	622 ± 121
Sep 6	718 ± 130	633 ± 123	562 ± 118	696 ± 127	777 ± 135
Sep 13	773 ± 132	651 ± 125	662 ± 125	592 ± 120	796 ± 135
Sep 20	722 ± 130	740 ± 131	585 ± 118	566 ± 118	988 ± 147
Sep 27	644 ± 124	592 ± 120	577 ± 120	703 ± 128	877 ± 140
Oct 4	353 ± 101	470 ± 110	344.0 ± 99.2	(b)	349.0 ± 99.5

A.2.7 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore Valley downwind locations, 2011[(a)]

Date	Gross beta AMON	Gross beta CPET	Gross beta PATT	Gross beta TANK	Gross beta ZON7
Oct 5	(b)	(b)	(b)	474 ± 103	(b)
Oct 11	(b)	111.0 ± 71.4	127.0 ± 74.0	196.0 ± 81.8	196.0 ± 81.8
Oct 12	153.0 ± 71.4	(b)	(b)	(b)	(b)
Oct 18	1110 ± 168	958 ± 149	973 ± 148	1010 ± 162	1090 ± 156
Oct 25	969 ± 146	821 ± 136	736 ± 131	(b)	881 ± 140
Oct 26	(b)	(b)	(b)	744 ± 121	(b)
Nov 1	1250 ± 164	1100 ± 154	981 ± 147	(b)	1160 ± 158
Nov 2	(b)	(b)	(b)	1140 ± 156	(b)
Nov 8	426 ± 104	462 ± 108	352.0 ± 97.7	366 ± 112	377.0 ± 99.9
Nov 15	932 ± 144	881 ± 139	906 ± 143	1060 ± 151	1060 ± 153
Nov 22	232.0 ± 89.2	214.0 ± 86.2	278.0 ± 92.9	326.0 ± 97.3	258.0 ± 91.0
Nov 29	666 ± 123	596 ± 120	411 ± 104	488 ± 102	562 ± 117
Dec 6	577 ± 120	533 ± 116	426 ± 107	403 ± 116	548 ± 117
Dec 12	2330 ± 198	2130 ± 189	2150 ± 191	(b)	2350 ± 199
Dec 13	(b)	(b)	(b)	2190 ± 180	(b)
Dec 20	1220 ± 127	1200 ± 126	1160 ± 124	1040 ± 116	1200 ± 125
Dec 28	1560 ± 167	1240 ± 151	1180 ± 148	(b)	1430 ± 161
Detection frequency	51 of 51	51 of 52	51 of 51	50 of 51	51 of 52
Median	353	353	332	347	376
IQR (c)	451	412	385	384	509
Maximum	2330	2130	2150	2190	2350

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.

(b) Different sample dates occur when samples could not be collected on the same scheduled sampling interval due to access or weather, sampler malfunction, or power (GFI) is out.

A.2.8 Tritium concentrations (mBq/m^3) in air, Livermore Valley, 2011[a]

Week	Month	AMON	CPET	FIRE	HOSP	PATT	VET	ZON7
1	Jan	27.1 ± 14.5	53.6 ± 15.1	41.8 ± 13.9	27.9 ± 13.9	49.2 ± 13.2	24.5 ± 13.0	16.2 ± 11.9
3	Jan	40.7 ± 15.7	41.8 ± 18.2	41.1 ± 16.0	22.5 ± 15.4	25.6 ± 12.2	42.2 ± 15.2	12.7 ± 13.1
5	Feb	25.3 ± 15.0	50.3 ± 17.6	45.1 ± 17.0	23.3 ± 15.2	25.3 ± 12.6	36.3 ± 14.3	22.9 ± 12.4
7	Feb	9.1 ± 11.8	20.4 ± 11.5	25.5 ± 16.2	10.1 ± 12.2	11.6 ± 10.7	27.5 ± 11.7	12.8 ± 11.0
9	Mar	17.7 ± 13.4	39.2 ± 12.9	21.6 ± 11.4	0.2 ± 12.8	15.7 ± 11.7	19.7 ± 12.9	23.5 ± 12.3
11	Mar	24.1 ± 17.2	81.8 ± 19.1	3.5 ± 13.4	5.5 ± 17.3	12.2 ± 15.8	30.1 ± 17.2	28.2 ± 16.7
13	Mar	24.8 ± 12.7	62.2 ± 14.8	1.63 ± 9.95	-0.1 ± 12.4	15.4 ± 11.7	11.3 ± 12.3	16.2 ± 12.6
15	Apr	13.7 ± 12.4	53.3 ± 14.4	11.00 ± 9.69	7.8 ± 12.5	4.9 ± 11.1	(b)	12.6 ± 12.4
17	Apr	9.9 ± 14.8	85.1 ± 19.0	-6.9 ± 11.3	-5.9 ± 15.9	-9.7 ± 12.8	7.6 ± 14.3	36.1 ± 18.8
19	May	12.7 ± 12.0	79.9 ± 15.8	17.5 ± 10.2	-0.5 ± 13.0	14.1 ± 11.0	17.9 ± 12.0	20.6 ± 12.4
21	May	16.7 ± 14.6	192.0 ± 23.0	-0.0 ± 13.7	-1.7 ± 12.6	7.7 ± 12.5	-1.4 ± 13.5	50.0 ± 15.4
23	Jun	11.0 ± 14.9	96.9 ± 22.1	1.6 ± 14.6	-4.2 ± 13.3	1.7 ± 12.5	4.5 ± 14.5	27.4 ± 15.4
25	Jun	13.1 ± 16.4	93.2 ± 18.1	0.6 ± 15.8	-4.0 ± 15.4	0.9 ± 12.4	4.1 ± 15.2	54.4 ± 18.8
27	Jul	14.4 ± 16.8	142.0 ± 20.0	15.8 ± 16.6	17.1 ± 16.7	21.1 ± 16.4	19.6 ± 17.4	43.3 ± 18.7
29	Jul	-18.5 ± 17.2	103.0 ± 22.5	-10.7 ± 19.4	9.7 ± 19.6	0.1 ± 18.6	1.2 ± 19.2	20.5 ± 20.2
31	Aug	3.7 ± 18.2	179.0 ± 25.3	-4.0 ± 18.1	4.1 ± 18.4	6.1 ± 17.7	-9.0 ± 18.2	40.3 ± 21.6
33	Aug	17.9 ± 18.0	102.0 ± 21.5	4.2 ± 17.3	2.8 ± 18.8	-3.0 ± 15.5	-1.6 ± 16.4	52.9 ± 20.5
35	Sep	9.5 ± 17.7	122.0 ± 22.6	-0.8 ± 16.9	-15.4 ± 17.2	15.3 ± 16.0	22.2 ± 18.0	55.1 ± 20.8
37	Sep	59.6 ± 18.8	336.0 ± 27.8	42.2 ± 17.0	24.2 ± 16.5	28.5 ± 13.9	28.9 ± 16.5	162.0 ± 23.1
39	Sep	85.5 ± 18.5	52.2 ± 18.2	13.8 ± 14.8	3.2 ± 14.5	42.9 ± 13.2	60.3 ± 17.8	13.2 ± 16.2
41	Oct	27.5 ± 23.2	147.0 ± 26.9	17.4 ± 21.2	1.4 ± 21.1	13.3 ± 19.9	13.7 ± 19.9	41.8 ± 21.2
43	Oct	(b)	109.0 ± 22.2	20.1 ± 16.7	40.0 ± 22.9	31.9 ± 17.1	42.6 ± 17.5	62.9 ± 18.8
45	Nov	23.1 ± 10.5	29.9 ± 15.4	19.4 ± 12.5	3.2 ± 11.1	19.0 ± 13.4	33.4 ± 14.2	19.5 ± 12.2
47	Nov	11.5 ± 13.5	32.0 ± 15.2	21.1 ± 15.5	-11.1 ± 13.4	-2.2 ± 13.8	15.8 ± 15.9	17.4 ± 15.0
49	Dec	23.00 ± 9.77	38.1 ± 11.1	32.0 ± 11.1	13.80 ± 9.58	10.70 ± 9.69	26.3 ± 11.2	35.1 ± 11.0
51	Dec	32.8 ± 11.8	40.7 ± 15.9	20.1 ± 11.0	10.90 ± 9.62	9.9 ± 10.4	29.7 ± 13.1	33.4 ± 11.0
	Median	17.7	80.8	16.6	3.69	12.8	19.7	27.8
	IQR[c]	13.8	63.6	19.9	13.5	15.4	22.1	25.0
	Median Percent of DCS[d]	0.00023	0.0010	0.00021	0.000047	0.00016	0.00025	0.00036
	Mean Dose (nSv)[e],[f]	5.14	22.0	<5	<5	<5	<5	8.59

(a) See *Environmental Report 2011,* Figure 4-2 for map of sampling locations.

(b) Data missing, lost sample or below detection limit.

(c) IQR = Interquartile range

(d) DCS = Deririved Concentration Standard of 7.8E+06 mBq/m3 for tritium in air. Percent of DCS is calculated from the median concentraton.

(e) The annual dose is calculated from the mean concentration and represents the effective dose equivalent from inhalation and skin absorption.

(f) When the mean dose is based on a concentration less than the lower limit of detection (about 25 mBq/m3), the dose is assumed to be less than that calculated from the lower limit of detection (5 nSv/yr).

A.2.9 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore Valley upwind locations and the special interest location, 2011[(a)]

Date	Gross alpha CHUR	Gross alpha FCC	Gross alpha FIRE	Gross alpha HOSP	Gross alpha LWRP
Jan 4	26.4 ± 30.6	3.4 ± 20.8	9.4 ± 24.3	15.1 ± 26.4	3.5 ± 21.0
Jan 11	22.9 ± 31.6	30.2 ± 35.0	24.3 ± 33.4	15.2 ± 26.5	(b)
Jan 18	-2.7 ± 20.2	30.6 ± 35.5	17.5 ± 30.7	-3.1 ± 23.2	12.7 ± 32.6
Jan 25	(b)	(b)	17.6 ± 30.8	10.6 ± 27.3	30.6 ± 35.4
Jan 26	44.0 ± 36.7	15.1 ± 26.4	(b)	(b)	(b)
Feb 1	20.3 ± 35.6	(b)	30.9 ± 35.9	10.5 ± 27.1	30.4 ± 35.2
Feb 8	4.0 ± 23.9	23.6 ± 21.5	4.0 ± 24.1	10.6 ± 27.3	-2.6 ± 20.1
Feb 15	1.5 ± 25.6	21.7 ± 34.4	8.1 ± 28.5	21.5 ± 34.0	41.4 ± 40.7
Feb 22	8.0 ± 28.0	14.5 ± 30.7	1.5 ± 25.2	-5.1 ± 21.6	8.1 ± 28.4
Mar 1	1.5 ± 25.2	21.3 ± 33.8	-5.1 ± 21.7	-5.1 ± 21.6	34.7 ± 38.5
Mar 8	8.1 ± 28.5	28.0 ± 36.3	-5.1 ± 21.6	1.5 ± 25.2	8.1 ± 28.3
Mar 15	8.2 ± 29.0	-5.2 ± 22.1	28.2 ± 36.5	-5.2 ± 22.1	-5.2 ± 21.9
Mar 22	14.4 ± 30.6	33.9 ± 37.7	1.5 ± 25.1	-5.1 ± 21.5	8.1 ± 28.3
Mar 29	-11.8 ± 17.4	21.4 ± 33.9	1.5 ± 25.2	1.5 ± 25.2	1.5 ± 25.3
Apr 5	-5.2 ± 21.8	21.2 ± 33.6	14.5 ± 30.7	1.4 ± 24.8	14.5 ± 30.6
Apr 12	15.1 ± 32.0	21.9 ± 34.6	8.3 ± 29.1	35.4 ± 39.6	8.3 ± 29.1
Apr 19	1.4 ± 24.8	7.9 ± 27.8	21.3 ± 33.8	8.1 ± 28.4	41.1 ± 40.7
Apr 26	15.0 ± 31.9	1.7 ± 29.5	1.5 ± 25.2	21.3 ± 33.8	8.1 ± 28.4
May 3	-11.8 ± 17.3	1.5 ± 25.2	8.1 ± 28.4	-5.2 ± 21.7	28.0 ± 36.3
May 10	-11.6 ± 17.1	8.0 ± 28.0	-5.1 ± 21.6	14.7 ± 31.2	27.9 ± 36.1
May 17	21.7 ± 34.4	1.5 ± 25.7	-5.2 ± 21.7	-5.2 ± 21.7	-5.2 ± 21.7
May 24	14.5 ± 30.7	-5.1 ± 21.3	1.5 ± 25.3	8.1 ± 28.4	-5.1 ± 21.7
May 31	28.0 ± 36.3	-11.8 ± 17.4	8.1 ± 28.3	8.1 ± 28.3	8.1 ± 28.3
Jun 7	-5.1 ± 21.6	-11.8 ± 17.3	14.8 ± 31.3	21.4 ± 33.9	1.5 ± 25.3
Jun 14	1.5 ± 25.3	14.7 ± 31.3	-5.1 ± 21.6	21.3 ± 33.7	14.7 ± 31.2
Jun 21	14.7 ± 31.0	21.2 ± 33.6	-5.1 ± 21.6	1.5 ± 25.2	21.3 ± 33.8
Jun 28	-11.8 ± 17.4	8.1 ± 28.5	-5.1 ± 21.5	1.5 ± 25.1	8.1 ± 28.2
Jul 5	1.5 ± 25.4	8.1 ± 28.6	-11.8 ± 17.4	-5.2 ± 21.8	1.5 ± 25.4
Jul 12	8.2 ± 28.8	15.0 ± 31.7	1.5 ± 25.2	21.0 ± 33.3	34.6 ± 38.5
Jul 19	-5.1 ± 21.3	-5.1 ± 21.2	-5.1 ± 21.6	1.5 ± 25.6	8.1 ± 28.4
Jul 26	1.5 ± 25.2	1.5 ± 25.2	-11.8 ± 17.3	-5.1 ± 21.7	8.1 ± 28.4
Aug 2	1.5 ± 25.3	8.1 ± 28.4	-5.2 ± 21.8	21.5 ± 34.0	41.4 ± 40.7
Aug 9	-5.2 ± 22.1	1.5 ± 25.7	14.8 ± 31.3	14.8 ± 31.3	8.1 ± 28.5
Aug 16	21.0 ± 33.2	27.5 ± 35.6	27.8 ± 36.0	21.2 ± 33.7	1.5 ± 25.1
Aug 23	1.5 ± 25.3	14.9 ± 31.7	-11.8 ± 17.3	9.3 ± 32.7	-5.1 ± 21.6
Aug 30	21.3 ± 33.8	41.1 ± 40.7	14.7 ± 31.1	-6.0 ± 25.0	-11.8 ± 17.3
Sep 6	14.8 ± 31.3	21.4 ± 33.9	28.1 ± 36.4	21.5 ± 34.0	21.5 ± 34.0
Sep 13	27.9 ± 36.2	34.6 ± 38.5	21.5 ± 34.0	1.5 ± 25.7	34.8 ± 38.5
Sep 20	-5.1 ± 21.6	21.4 ± 33.9	34.4 ± 38.1	21.0 ± 33.3	8.1 ± 28.2
Sep 27	34.7 ± 38.5	14.7 ± 31.2	2.80 ± 3.63	21.4 ± 33.9	21.4 ± 33.9
Oct 4	14.5 ± 30.8	53.6 ± 44.0	14.3 ± 30.4	20.8 ± 32.9	52.9 ± 43.3
Oct 11	(b)	(b)	14.8 ± 31.4	8.1 ± 28.6	-5.2 ± 21.8
Oct 12	1.3 ± 22.8	-4.7 ± 19.6	(b)	(b)	(b)
Oct 18	47.7 ± 47.0	61.0 ± 43.7	56.6 ± 50.7	63.3 ± 48.1	69.6 ± 49.6
Oct 25	40.7 ± 40.0	53.6 ± 43.7	47.7 ± 42.6	61.0 ± 46.6	41.4 ± 40.7
Nov 1	48.8 ± 43.7	35.4 ± 39.2	54.8 ± 44.8	28.2 ± 36.6	81.4 ± 51.8
Nov 8	47.7 ± 42.6	27.9 ± 36.1	14.5 ± 30.7	21.0 ± 33.3	8.0 ± 27.9
Nov 15	40.3 ± 39.6	14.4 ± 30.5	40.7 ± 40.0	34.2 ± 38.1	(b)
Nov 16	(b)	(b)	(b)	(b)	36.3 ± 35.7
Nov 22	28.7 ± 37.0	42.2 ± 41.8	34.4 ± 38.5	41.8 ± 41.4	78.8 ± 55.9
Nov 29	7.9 ± 27.6	46.6 ± 41.4	-5.1 ± 21.7	21.0 ± 33.2	(b)
Dec 6	62.5 ± 47.7	42.2 ± 41.4	28.8 ± 37.4	35.7 ± 39.6	(b)
Dec 12	135.0 ± 58.8	229.0 ± 73.6	190.0 ± 66.6	83.2 ± 47.7	222.0 ± 71.4
Dec 20	59.6 ± 42.2	36.2 ± 35.7	79.2 ± 39.6	15.8 ± 24.0	88.1 ± 41.4
Dec 28	88.8 ± 49.6	106.0 ± 53.3	102.0 ± 52.9	37.4 ± 36.7	132.0 ± 59.2
Detection frequency	10 of 52	11 of 51	7 of 52	5 of 52	12 of 49
Median	14.4	21.2	11.9	14.8	12.7
IQR	26.5	24.3	28.1	19.9	26.8
Maximum	135	229	190	83.2	222

A.2.9 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from the Livermore Valley upwind locations and the special interest location, 2011[a]

Date	Gross beta CHUR	Gross beta FCC	Gross beta FIRE	Gross beta HOSP	Gross beta LWRP
Jan 4	205.0 ± 76.2	179.0 ± 73.6	146.0 ± 71.4	160.0 ± 72.1	270.0 ± 83.6
Jan 11	603 ± 118	596 ± 120	437 ± 108	574 ± 109	(b)
Jan 18	514 ± 114	507 ± 114	525 ± 116	429 ± 117	629 ± 137
Jan 25	(b)	(b)	474 ± 112	500 ± 112	707 ± 128
Jan 26	747 ± 121	699 ± 118	(b)	(b)	(b)
Feb 1	688 ± 141	(b)	644 ± 125	470 ± 110	755 ± 131
Feb 8	289.0 ± 93.2	385.0 ± 69.6	315.0 ± 96.6	289.0 ± 93.6	599 ± 120
Feb 15	444 ± 109	338.0 ± 99.2	485 ± 111	330.0 ± 97.7	833 ± 138
Feb 22	90.3 ± 70.3	162.0 ± 78.8	135.0 ± 76.6	212.0 ± 85.5	62.9 ± 67.3
Mar 1	246.0 ± 89.2	265.0 ± 91.0	198.0 ± 84.0	227.0 ± 87.0	227.0 ± 87.3
Mar 8	107.0 ± 73.3	96.9 ± 72.1	116.0 ± 74.4	164.0 ± 79.9	140.0 ± 77.0
Mar 15	168.0 ± 81.8	177.0 ± 82.9	156.0 ± 79.6	266.0 ± 92.5	214.0 ± 86.2
Mar 22	988 ± 145	1180 ± 157	977 ± 146	1120 ± 155	1220 ± 161
Mar 29	1340 ± 168	1360 ± 169	1200 ± 160	1670 ± 185	1190 ± 159
Apr 5	470 ± 110	614 ± 121	536 ± 114	511 ± 112	710 ± 127
Apr 12	462 ± 111	350 ± 101	462 ± 111	514 ± 115	610 ± 123
Apr 19	165.0 ± 79.2	165.0 ± 79.2	289.0 ± 93.2	323.0 ± 96.6	332.0 ± 97.7
Apr 26	207.0 ± 86.2	198.0 ± 94.4	159.0 ± 79.6	309.0 ± 95.5	188.0 ± 82.9
May 3	184.0 ± 82.1	227.0 ± 87.0	179.0 ± 81.8	164.0 ± 80.3	203.0 ± 84.7
May 10	200.0 ± 83.2	238.0 ± 87.3	221.0 ± 86.2	477 ± 110	303.0 ± 94.7
May 17	128.0 ± 76.6	294.0 ± 95.1	169.0 ± 80.7	198.0 ± 84.0	165.0 ± 80.3
May 24	195.0 ± 82.5	285.0 ± 92.1	266.0 ± 91.0	261.0 ± 90.6	280.0 ± 92.5
May 31	116.0 ± 74.4	135.0 ± 77.0	130.0 ± 75.8	111.0 ± 73.6	149.0 ± 78.1
Jun 7	91.8 ± 71.0	197.0 ± 83.6	135.0 ± 77.0	77.7 ± 69.6	165.0 ± 80.3
Jun 14	159.0 ± 79.6	290.0 ± 93.6	188.0 ± 82.9	222.0 ± 86.2	265.0 ± 91.0
Jun 21	168.0 ± 80.3	287.0 ± 92.9	130.0 ± 76.2	203.0 ± 84.4	275.0 ± 92.1
Jun 28	92.1 ± 71.4	198.0 ± 84.0	149.0 ± 78.1	197.0 ± 83.2	259.0 ± 89.9
Jul 5	252.0 ± 90.3	377 ± 102	189.0 ± 83.2	276.0 ± 92.5	305.0 ± 95.5
Jul 12	147.0 ± 78.8	299.0 ± 95.5	299.0 ± 94.4	256.0 ± 89.2	309.0 ± 95.5
Jul 19	28.7 ± 61.4	114.0 ± 72.9	106.0 ± 72.9	68.8 ± 69.2	53.3 ± 65.9
Jul 26	174.0 ± 81.0	217.0 ± 85.8	174.0 ± 81.4	338.0 ± 98.0	155.0 ± 79.2
Aug 2	251.0 ± 89.5	474 ± 110	344.0 ± 99.2	388 ± 103	340.0 ± 98.8
Aug 9	246.0 ± 90.3	260.0 ± 91.8	165.0 ± 80.3	242.0 ± 88.8	184.0 ± 82.5
Aug 16	261.0 ± 89.5	385 ± 101	340.0 ± 98.0	370 ± 101	216.0 ± 85.5
Aug 23	242.0 ± 88.8	255.0 ± 90.6	208.0 ± 85.1	333 ± 108	280.0 ± 92.5
Aug 30	481 ± 111	507 ± 113	342.0 ± 98.4	363 ± 111	444 ± 107
Sep 6	411 ± 105	610 ± 121	514 ± 114	592 ± 120	592 ± 120
Sep 13	596 ± 120	718 ± 129	659 ± 125	725 ± 131	500 ± 112
Sep 20	488 ± 111	662 ± 125	651 ± 124	825 ± 135	644 ± 123
Sep 27	596 ± 120	821 ± 136	56.6 ± 11.8	796 ± 135	725 ± 130
Oct 4	433 ± 106	451 ± 108	403 ± 102	249.0 ± 87.7	462 ± 107
Oct 11	(b)	(b)	184.0 ± 82.5	233.0 ± 88.1	160.0 ± 79.9
Oct 12	131.0 ± 70.3	161.0 ± 74.0	(b)	(b)	(b)
Oct 18	873 ± 152	906 ± 134	733 ± 144	862 ± 142	1120 ± 158
Oct 25	758 ± 131	1010 ± 147	906 ± 142	1120 ± 155	944 ± 145
Nov 1	888 ± 142	1300 ± 168	906 ± 142	1050 ± 152	1250 ± 163
Nov 8	429 ± 106	451 ± 108	356.0 ± 98.8	455 ± 108	422 ± 105
Nov 15	877 ± 138	1220 ± 159	910 ± 141	1030 ± 149	(b)
Nov 16	(b)	(b)	(b)	(b)	1290 ± 154
Nov 22	262.0 ± 92.5	407 ± 106	298.0 ± 94.0	216.0 ± 87.0	353 ± 110
Nov 29	474 ± 108	644 ± 121	481 ± 111	327.0 ± 95.8	(b)
Dec 6	459 ± 111	514 ± 115	422 ± 108	540 ± 118	(b)
Dec 12	1990 ± 184	2860 ± 218	2010 ± 182	1110 ± 140	2290 ± 193
Dec 20	1230 ± 150	1660 ± 172	1100 ± 120	603.0 ± 93.6	1380 ± 133
Dec 28	1390 ± 159	1760 ± 177	1300 ± 155	762 ± 124	1480 ± 165
Detection frequency	51 of 52	51 of 51	52 of 52	51 of 52	47 of 49
Median	276	385	328	336	340
IQR	424	420	355	347	494
Maximum	1990	2860	2010	1670	2290

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.

(b) Different sample dates occur when samples could not be collected on the same scheduled sampling interval due to access or weather, sampler malfunction, or power (GFI) is out

(c) IQR = Interquartile Range

A.2.10 Plutonium-239+240 concentrations (nBq/m3) in air particulate samples from the Livermore Valley, 2011[(a)]

Month	Valley upwind CHUR	Valley upwind FCC	Valley upwind FIRE	Valley upwind HOSP	Valley downwind AMON	Valley downwind CPET	Valley downwind PATT	Valley downwind TANK	Valley downwind ZON7	Special interest LWRP
Jan	-7.29 ± 5.00	2.89 ± 4.96	1.48 ± 6.66	1.81 ± 4.88	3.02 ± 9.77	-2.17 ± 7.44	-6.59 ± 6.22	0.74 ± 2.82	-2.37 ± 6.22	12.3 ± 12.8
Feb	6.33 ± 8.81	-1.27 ± 8.73	-0.6 ± 10.7	12.4 ± 16.2	2.9 ± 16.7	8.0 ± 12.1	3.54 ± 9.10	0.4 ± 14.9	-3.60 ± 9.40	-7.9 ± 11.8
Mar	3.0 ± 13.5	-3.01 ± 8.33	-2.9 ± 14.5	-2.15 ± 7.81	2.42 ± 3.43	-3.55 ± 9.95	-9.95 ± 6.48	-2.8 ± 11.4	-11.50 ± 7.10	0.39 ± 6.29
Apr	1.94 ± 5.11	3.01 ± 9.14	-3.4 ± 11.4	0.6 ± 11.4	2.18 ± 5.74	-2.12 ± 5.85	8.14 ± 8.21	-11.70 ± 5.96	8.33 ± 5.18	5.62 ± 7.77
May	-25.7 ± 32.7	-33.3 ± 21.0	0 ± 1260	0.64 ± 6.29	0.33 ± 5.33	1.85 ± 7.84	11.7 ± 12.4	-37.4 ± 19.5	-1.01 ± 8.84	-6.9 ± 13.5
Jun	-36.90 ± 9.36	-13.10 ± 3.50	4.14 ± 3.74	-7.73 ± 3.92	-8.66 ± 4.48	15.5 ± 15.7	7.36 ± 9.03	-3.42 ± 4.85	-11.7 ± 19.5	16.70 ± 9.10
Jul	-0.73 ± 1.46	-1.16 ± 4.18	4 ± 781	2.65 ± 8.58	2.3 ± 10.3	-9.95 ± 7.81	-2.1 ± 11.3	-4.92 ± 4.40	0.32 ± 5.70	6 ± 781
Aug	3.32 ± 7.10	-2.13 ± 4.74	2.72 ± 5.85	-1.02 ± 7.77	-2.55 ± 6.44	0.00 ± 7.33	-2.37 ± 5.29	-5.70 ± 9.73	7.18 ± 7.58	8.95 ± 8.62
Sep	-0.31 ± 4.00	6.5 ± 12.1	1.41 ± 5.07	-1.53 ± 5.51	4.8 ± 10.2	7.47 ± 9.40	7 ± 777	-66 ± 107	48.5 ± 59.9	5.59 ± 6.88
Oct	17.6 ± 27.3	1.5 ± 10.3	13.6 ± 13.1	-3.88 ± 5.33	-3.34 ± 4.59	3.46 ± 8.21	5.11 ± 7.22	2.2 ± 14.4	0.76 ± 4.44	-1.81 ± 2.56
Nov	3.54 ± 7.25	2.65 ± 8.58	0.00 ± 7.07	2.07 ± 4.55	18.3 ± 28.4	3.49 ± 5.33	-14.00 ± 8.92	3.50 ± 7.51	0.32 ± 5.55	7.10 ± 8.77
Dec	7.40 ± 7.84	3.19 ± 4.88	-0.78 ± 5.88	3.44 ± 5.25	-9.88 ± 9.58	1.94 ± 4.26	4.00 ± 4.66	-1.33 ± 4.77	5.88 ± 7.44	8.73 ± 9.47
Detection frequency	0 of 12	0 of 12	2 of 12	0 of 12	0 of 12	0 of 12	0 of 12	0 of 12	1 of 12	2 of 12
Median	2.47	0.150	0.705	0.621	2.24	1.90	3.77	-3.12	0.320	5.75
IQR (b)	6.61	5.27	4.24	3.90	5.66	6.62	10.5	7.72	8.88	8.95
Maximum	17.6	6.55	13.6	12.4	18.3	15.5	11.7	3.50	48.5	16.7
Median Percent of DCS	0.000027	0.0000017	0.0000078	0.0000069	0.000025	0.000021	0.000042	-	0.0000036	0.000064
DCS	9000000	9000000	9000000	9000000	9000000	9000000	9000000	9000000	9000000	9000000

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) IQR = Interquartile range

A.2.11 Tritium concentrations (mBq/m3) in air, Site 300, 2011[a]

Week	Month	PSTL
1	Jan	16.0 ± 13.2
3	Jan	11.4 ± 14.8
5	Feb	6.8 ± 15.0
7	Feb	9.8 ± 12.5
9	Mar	11.0 ± 11.0
11	Mar	-5.0 ± 14.8
13	Mar	2.5 ± 10.5
15	Apr	9.0 ± 11.2
17	Apr	-13.2 ± 12.2
19	May	10.20 ± 9.84
21	May	-0.5 ± 12.0
23	Jun	-0.9 ± 13.5
25	Jun	-19.6 ± 14.2
27	Jul	7.9 ± 15.7
29	Jul	-13.8 ± 18.4
31	Aug	-2.9 ± 17.8
35	Aug	18.4 ± 15.1
37	Sep	9.6 ± 13.3
39	Sep	-0.5 ± 16.0
41	Oct	-7.9 ± 17.9
43	Oct	28.3 ± 16.2
45	Nov	8.9 ± 11.0
47	Nov	-10.7 ± 12.8
49	Dec	-0.56 ± 9.51
51	Dec	10.6 ± 10.1
	Median	6.77
	IQR [b]	13.1
	Median Percent of DCS [c]	0.000087
	Mean Dose (nSv) [d],[e]	<5

(a) See *Environmental Report 2011,* Figure 4-2 for map of sampling locations.

(b) IQR = Interquartile range

(c) DCS = Deririved Concentration Standard of 7.8E+06 mBq/m3 for tritium in air. Percent of DCS is calculated from the median concentraton.

(d) The annual dose is calculated from the mean concentration and represents the effective dose equivalent from inhalation and skin absorption.

(e) When the mean dose is based on a concentration less than the lower limit of detection (about 25 mBq/m3), the dose is assumed to be less than that calculated from the lower limit of detection (5 nSv/yr).

A.2.12 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from Site 300 onsite and offsite locations, 2011[a]

Date	Gross alpha TNK5	Gross alpha PSTL	Gross alpha ECP	Gross alpha EOBS	Gross alpha GOLF	Gross alpha NPS	Gross alpha WCP	Gross alpha WOBS	Gross alpha TCDF
Jan 5	-1.25 ± 9.43	-1.24 ± 9.40	11.1 ± 15.4	5.0 ± 12.7	8.0 ± 14.1	14.2 ± 16.5	8.1 ± 14.1	11.1 ± 15.4	5.0 ± 12.7
Jan 18	12.0 ± 16.5	25.5 ± 21.2	15.2 ± 17.6	31.8 ± 22.9	-1.3 ± 10.1	27.2 ± 22.6	15.2 ± 17.6	2.0 ± 12.0	28.5 ± 21.9
Feb 2	8.7 ± 15.2	31.9 ± 22.9	18.6 ± 18.8	38.5 ± 24.7	18.6 ± 18.8	32.7 ± 22.1	25.2 ± 20.9	12.0 ± 16.4	32.0 ± 29.2
Feb 16	10.7 ± 16.9	14.0 ± 18.1	10.7 ± 16.8	0.7 ± 12.5	0.7 ± 12.6	4.0 ± 14.1	10.6 ± 16.8	10.6 ± 16.8	40.3 ± 25.6
Mar 2	4.1 ± 14.4	0.7 ± 12.6	0.7 ± 12.7	14.1 ± 18.2	-5.88 ± 8.66	14.1 ± 18.2	-2.6 ± 10.9	10.7 ± 17.0	4.1 ± 14.3
Mar 16	10.8 ± 17.0	-2.6 ± 10.9	17.4 ± 19.3	-5.92 ± 8.70	7.4 ± 15.7	4.1 ± 14.2	10.7 ± 17.0	10.7 ± 17.0	10.7 ± 17.0
Mar 30	4.1 ± 14.2	4.1 ± 14.2	14.0 ± 18.1	-2.6 ± 10.8	-2.6 ± 10.8	-2.6 ± 10.8	4.1 ± 14.2	0.7 ± 12.6	0.7 ± 12.6
Apr 13	14.0 ± 18.1	27.3 ± 22.3	30.6 ± 23.2	30.6 ± 23.2	17.3 ± 19.2	17.3 ± 19.2	20.6 ± 20.3	17.3 ± 19.2	17.3 ± 19.2
Apr 27	7.4 ± 15.6	17.3 ± 19.2	4.0 ± 14.2	7.4 ± 15.6	14.0 ± 18.1	14.0 ± 18.1	4.1 ± 14.2	-2.6 ± 10.8	0.7 ± 12.6
May 11	18.3 ± 18.0	30.2 ± 23.0	30.2 ± 23.0	27.0 ± 22.1	10.6 ± 16.7	30.2 ± 23.0	17.1 ± 19.1	13.8 ± 17.9	17.3 ± 19.2
May 25	20.8 ± 20.5	37.7 ± 25.3	(b)	24.2 ± 21.5	10.8 ± 17.1	20.8 ± 20.5	(b)	4.1 ± 14.4	17.4 ± 19.3
Jun 8	0.7 ± 12.6	14.0 ± 18.1	(b)	17.3 ± 19.2	10.7 ± 16.9	17.3 ± 19.2	1.0 ± 16.4	7.4 ± 15.6	-2.6 ± 10.8
Jun 22	10.7 ± 16.9	0.7 ± 12.6	(b)	20.6 ± 20.3	14.0 ± 18.1	(b)	4.0 ± 14.2	14.0 ± 18.1	10.7 ± 16.9
Jun 23	(b)	(b)	(b)	(b)	(b)	25.5 ± 20.8	(b)	(b)	(b)
Jul 6	20.6 ± 20.3	10.8 ± 17.2	(b)	7.4 ± 15.6	20.6 ± 20.3	11.5 ± 18.2	24.0 ± 21.3	(b)	27.5 ± 22.5
Jul 7	(b)	(b)	(b)	(b)	(b)	(b)	(b)	9.9 ± 15.8	(b)
Jul 20	14.0 ± 18.1	10.7 ± 16.9	(b)	14.0 ± 18.1	7.4 ± 15.6	0.7 ± 12.6	0.7 ± 12.6	0.8 ± 13.6	10.7 ± 16.9
Aug 3	4.0 ± 14.2	7.4 ± 15.6	(b)	20.6 ± 20.3	0.7 ± 12.6	7.4 ± 15.6	7.4 ± 15.6	14.0 ± 18.1	7.4 ± 15.6
Aug 17	7.4 ± 15.6	17.3 ± 19.2	17.3 ± 19.2	27.3 ± 22.3	40.7 ± 25.8	30.6 ± 23.2	10.7 ± 16.9	23.9 ± 21.3	27.3 ± 22.3
Aug 31	33.9 ± 24.1	33.9 ± 24.1	27.3 ± 22.3	37.4 ± 25.0	23.8 ± 21.2	27.3 ± 22.3	10.7 ± 16.9	0.7 ± 12.7	33.9 ± 24.1
Sep 13	(b)	(b)	(b)	(b)	(b)	(b)	(b)	36.6 ± 26.0	(b)
Sep 14	33.8 ± 24.1	67.0 ± 31.7	47.0 ± 27.3	37.0 ± 24.9	34.0 ± 24.2	43.7 ± 26.6	37.4 ± 25.0	(b)	33.9 ± 24.1
Sep 28	47.0 ± 27.4	67.3 ± 31.8	30.6 ± 23.2	33.9 ± 24.1	20.6 ± 20.3	40.7 ± 25.8	50.3 ± 28.1	25.4 ± 20.8	70.3 ± 32.3
Oct 12	27.2 ± 22.3	17.3 ± 19.2	20.6 ± 20.3	27.2 ± 22.3	14.0 ± 18.1	20.6 ± 20.3	7.4 ± 15.6	17.3 ± 19.2	17.3 ± 19.2
Oct 26	87.0 ± 35.4	27.3 ± 22.3	40.3 ± 25.8	50.3 ± 28.2	30.6 ± 23.2	57.0 ± 29.6	37.0 ± 25.0	40.3 ± 25.8	107.0 ± 38.8
Nov 9	57.0 ± 29.5	50.3 ± 28.1	20.6 ± 20.2	37.0 ± 24.9	47.0 ± 27.2	30.5 ± 23.1	63.6 ± 31.0	30.6 ± 23.2	63.6 ± 30.9
Nov 22	40.0 ± 26.9	29.3 ± 24.0	40.0 ± 26.9	36.6 ± 26.0	22.3 ± 22.0	36.6 ± 26.0	32.8 ± 24.9	36.4 ± 25.9	54.4 ± 30.3
Dec 7	68.8 ± 30.8	31.6 ± 22.5	56.2 ± 28.3	62.5 ± 29.6	37.7 ± 24.1	50.3 ± 27.0	25.4 ± 20.8	28.5 ± 21.7	68.8 ± 30.8
Dec 21	117.0 ± 40.3	127.0 ± 42.2	130.0 ± 42.6	157.0 ± 46.2	80.3 ± 34.3	130.0 ± 42.6	123.0 ± 41.4	77.0 ± 33.6	160.0 ± 46.6
Detection frequency	12 of 26	13 of 26	11 of 20	17 of 26	10 of 26	15 of 26	10 of 25	8 of 26	13 of 26
Median	14.0	21.4	20.6	27.1	14.0	23.2	10.7	12.9	22.4
IQR (c)	26.2	21.1	18.1	22.9	15.9	18.2	18.0	17.0	28.0
Maximum	117	127	130	157	80.3	130	123	77.0	160

A.2.12 Weekly gross alpha and gross beta concentrations (µBq/m3) from air particulate samples from Site 300 onsite and offsite locations, 2011[(a)]

Date	Gross beta TNK5	Gross beta PSTL	Gross beta ECP	Gross beta EOBS	Gross beta GOLF	Gross beta NPS	Gross beta WCP	Gross beta WOBS	Gross beta TCDF
Jan 5	215.0 ± 51.1	252.0 ± 54.0	223.0 ± 51.4	252.0 ± 54.0	205.0 ± 49.9	214.0 ± 50.7	241.0 ± 53.3	239.0 ± 52.9	304.0 ± 58.1
Jan 18	418.0 ± 68.8	655.0 ± 83.6	470.0 ± 72.1	414.0 ± 68.4	644.0 ± 82.5	361.0 ± 67.7	366.0 ± 65.1	377.0 ± 65.9	814.0 ± 91.4
Feb 2	640.0 ± 82.5	588.0 ± 79.6	585.0 ± 79.2	655.0 ± 83.2	522.0 ± 75.5	588.0 ± 76.2	529.0 ± 75.8	525.0 ± 75.5	1250 ± 137
Feb 16	392.0 ± 67.0	309.0 ± 60.7	388.0 ± 66.6	347.0 ± 63.6	388.0 ± 66.6	418.0 ± 68.4	352.0 ± 64.0	422.0 ± 68.8	581.0 ± 78.4
Mar 2	139.0 ± 46.6	157.0 ± 48.1	133.0 ± 45.9	160.0 ± 48.5	140.0 ± 46.2	148.0 ± 47.4	121.0 ± 44.4	153.0 ± 47.7	199.0 ± 52.2
Mar 16	168.0 ± 49.2	165.0 ± 48.8	179.0 ± 49.9	196.0 ± 51.8	150.0 ± 47.4	162.0 ± 48.5	157.0 ± 48.1	119.0 ± 44.0	220.0 ± 53.6
Mar 30	770.0 ± 89.2	1020 ± 101	969.0 ± 99.2	925.0 ± 96.9	766.0 ± 89.2	895.0 ± 95.5	784.0 ± 89.9	870.0 ± 94.4	925.0 ± 96.9
Apr 13	403.0 ± 67.7	496.0 ± 73.6	625.0 ± 81.4	570.0 ± 78.1	418.0 ± 68.4	429.0 ± 69.2	396.0 ± 67.0	437.0 ± 69.9	466.0 ± 71.8
Apr 27	265.0 ± 57.4	253.0 ± 56.6	258.0 ± 57.0	229.0 ± 54.4	239.0 ± 55.1	188.0 ± 50.7	333.0 ± 62.5	231.0 ± 54.8	239.0 ± 55.1
May 11	256.0 ± 52.5	293.0 ± 59.2	327.0 ± 61.8	300.0 ± 59.9	217.0 ± 52.9	303.0 ± 59.9	205.0 ± 52.2	248.0 ± 55.5	219.0 ± 53.6
May 25	256.0 ± 57.0	241.0 ± 55.9	(b)	234.0 ± 55.1	246.0 ± 56.2	217.0 ± 53.6	(b)	377.0 ± 66.2	258.0 ± 57.0
Jun 8	113.0 ± 43.7	166.0 ± 48.8	(b)	174.0 ± 49.6	178.0 ± 49.9	169.0 ± 49.2	144.0 ± 56.2	162.0 ± 48.5	152.0 ± 47.4
Jun 22	241.0 ± 55.5	309.0 ± 61.0	(b)	316.0 ± 61.4	302.0 ± 60.3	(b)	260.0 ± 57.0	292.0 ± 59.6	246.0 ± 55.9
Jun 23	(b)	(b)	(b)	(b)	(b)	327.0 ± 59.6	(b)	(b)	(b)
Jul 6	292.0 ± 59.6	311.0 ± 61.4	(b)	407.0 ± 68.1	340.0 ± 63.3	332.0 ± 65.5	261.0 ± 57.0	(b)	360.0 ± 65.1
Jul 7	(b)	(b)	(b)	(b)	(b)	(b)	(b)	317.0 ± 58.8	(b)
Jul 20	167.0 ± 48.8	176.0 ± 49.6	(b)	219.0 ± 53.6	229.0 ± 54.4	229.0 ± 54.4	205.0 ± 52.5	148.0 ± 49.6	222.0 ± 53.6
Aug 3	369.0 ± 65.1	318.0 ± 61.4	(b)	451.0 ± 71.0	369.0 ± 65.1	381.0 ± 66.2	403.0 ± 67.7	385.0 ± 66.2	396.0 ± 67.3
Aug 17	370.0 ± 65.5	302.0 ± 60.3	385.0 ± 66.6	400.0 ± 67.3	335.0 ± 62.9	321.0 ± 61.8	297.0 ± 59.9	369.0 ± 65.1	411.0 ± 68.4
Aug 31	518.0 ± 75.1	481.0 ± 72.9	440.0 ± 70.3	622.0 ± 81.0	503.0 ± 74.0	492.0 ± 73.6	544.0 ± 76.6	503.0 ± 74.4	540.0 ± 76.6
Sep 13	(b)	(b)	(b)	(b)	(b)	(b)	(b)	758.0 ± 92.5	(b)
Sep 14	803.0 ± 90.6	833.0 ± 92.5	829.0 ± 92.1	903.0 ± 95.8	659.0 ± 83.6	814.0 ± 91.4	866.0 ± 94.4	(b)	777.0 ± 89.5
Sep 28	688.0 ± 85.1	707.0 ± 86.2	762.0 ± 88.8	740.0 ± 87.7	696.0 ± 85.5	733.0 ± 87.3	840.0 ± 92.9	733.0 ± 84.0	803.0 ± 91.0
Oct 12	309.0 ± 60.7	309.0 ± 60.7	320.0 ± 61.8	248.0 ± 55.9	289.0 ± 59.2	306.0 ± 60.7	301.0 ± 60.3	258.0 ± 57.0	350.0 ± 64.0
Oct 26	1090 ± 104	899.0 ± 95.8	1050 ± 103	962.0 ± 98.8	903.0 ± 95.8	1050 ± 102	1040 ± 102	855.0 ± 93.6	1160 ± 107
Nov 9	755.0 ± 88.4	692.0 ± 85.1	784.0 ± 89.9	751.0 ± 88.1	666.0 ± 83.2	703.0 ± 85.5	710.0 ± 86.2	740.0 ± 87.7	951.0 ± 98.0
Nov 22	588.0 ± 82.9	629.0 ± 85.1	692.0 ± 88.8	555.0 ± 81.0	610.0 ± 84.4	577.0 ± 82.1	618.0 ± 84.4	462.0 ± 74.7	781.0 ± 93.6
Dec 7	614.0 ± 77.7	596.0 ± 76.6	555.0 ± 74.4	529.0 ± 72.9	566.0 ± 75.1	507.0 ± 71.8	607.0 ± 77.3	551.0 ± 74.0	677.0 ± 81.0
Dec 21	1720 ± 130	1470 ± 120	1720 ± 130	1710 ± 129	1590 ± 125	1550 ± 123	1530 ± 122	1390 ± 117	1990 ± 139
Detection frequency	26 of 26	26 of 26	20 of 20	26 of 26	26 of 26	26 of 26	25 of 25	26 of 26	26 of 26
Median	381	314	512	410	378	371	366	381	438
IQR (c)	378	386	442	398	395	338	358	294	548
Maximum	1720	1470	1720	1710	1590	1550	1530	1390	1990

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.

(b) Different sample dates occur when samples could not be collected on the same scheduled sampling interval due to access or weather, sampler malfunction, or power (GFI) is out.

(c) IQR = Interquartile Range

A.2.13 Iodine-131 concentrations (µBq/m3) in air TEDA samples from the Livermore Valley, 2011[a]

Date	Iodine 131 FCC
Mar 31	4370 ± 211
Apr 7	1610 ± 195
Apr 14	1010 ± 799
Apr 21	124.0 ± 82.9
Apr 28	<170
May 5	<180
May 12	<99.2
May 19	<117
May 25	<551
Jun 2	<258
Jun 9	<269
Jun 16	<381
Jun 23	<618
Jul 1	<284
Jul 7	<673
Jul 14	<385
Jul 21	<217
Jul 28	110 ± 2630
Aug 4	<252
Aug 11	<189
Aug 18	<426
Aug 25	<237
Sep 1	<329
Sep 8	<106
Sep 15	<562
Sep 22	<944
Sep 29	<411
Oct 6	<400
Oct 13	<248
Oct 20	<201
Oct 27	<784
Nov 3	<214
Nov 10	<234
Nov 17	<268
Nov 23	<230
Dec 1	<142
Dec 8	<2310
Dec 15	<1920
Dec 28	<522
Detection frequency	4 of 39 [b]
Median	<269
IQR (c)	(c)
Maximum	4370
Median Percent of DCS	<0.00032
DCS	84000000
Maximum Percent of DCS	0.0052

(a) See *Environmental Report 2011,* figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) Iodine-131 detections were attributable to the Fukushima reactors (see chpater 4).
(c) IQR = Interquartile Range, which is calculated only when 6 or more values (see chapter 9).

A.2.14 Fukushima Daiichi Nuclear Power Plant related results in mBq/m3, 2011[a]

Date	Cs-134 LLNL Composite	Cs-134 Site 300 Composite	Cs-137 LLNL Composite	Cs-137 Site 300 Composite
Jan 15	<0.0006586	<0.0005439	<0.0006956	<0.0005735
Feb 15	<0.001347	<0.001251	<0.001347	<0.001369
Mar 15	0.06550 ± 0.00287	0.06470 ± 0.00264	0.07840 ± 0.00388	0.07330 ± 0.00388
Apr 15	0.02390 ± 0.00131	0.02190 ± 0.00163	0.02460 ± 0.00185	0.02380 ± 0.00429
May 15	0.00193 ± 0.00100	<0.00179	0.00305 ± 0.00330	0.003420 ± 0.000766
Jun 15	<0.000966	<0.00102	<0.00103	<0.000744
Jul 15	<0.000707	<0.00064	<0.000751	<0.000462
Aug 15	<0.00101	<0.00124	<0.00101	<0.0012
Sep 15	<0.00107	<0.00127	<0.00103	<0.00124
Oct 15	<0.00087	<0.00128	<0.000821	<0.125
Nov 15	<0.000988	<0.00125	<0.00105	<0.00128
Dec 15	<0.000792	<0.000796	<0.000788	<0.000792

(a) This data table represents site composite ambient air particulate monitoring. The cesium detections are attributable to the Fukushima reactors (see chapter 4)

A.3.1 Daily monitoring for tritium (mBq/ml) in the Livermore site sanitary effluent, 2011

Day	Jan Tritium (mBq/mL)	Feb Tritium (mBq/mL)	Mar Tritium (mBq/mL)	Apr Tritium (mBq/mL)	May Tritium (mBq/mL)	Jun Tritium (mBq/mL)	Jul Tritium (mBq/mL)	Aug Tritium (mBq/mL)	Sep Tritium (mBq/mL)	Oct Tritium (mBq/mL)	Nov Tritium (mBq/mL)	Dec Tritium (mBq/mL)
1	3.09 (<8.81)	-0.951 (<9.32)	4.44 (<9.21)	1.74 (<9.95)	0.818 (<9.03)	-	1.51 (<9.14)	-2.19 (<10.5)	5.77 (<9.55)	15.50 ± 5.86	-2.09 (<9.47)	3.77 (<9.51)
2	-0.766 (<9.18)	-3.77 (<9.03)	-1.54 (<8.99)	4.33 (<10.3)	4.51 (<8.84)	5.44 (<8.73)	13.80 ± 5.37	-5.03 (<10.8)	15.90 ± 5.74	36.00 ± 6.44	6.92 (<9.10)	3.77 (<9.10)
3	2.03 (<8.95)	2.13 (<8.73)	-1.14 (<8.84)	0.385 (<10.1)	22.30 ± 6.13	-0.681 (<9.03)	8.40 (<8.73)	4.62 (<10.0)	8.73 (<9.18)	7.18 (<9.32)	3.61 (<9.32)	-0.131 (<9.40)
4	-5.18 (<9.03)	-5.29 (<9.14)	5.03 (<8.84)	4.07 (<9.80)	-2.90 (<9.18)	4.29 (<8.99)	8.62 (<9.06)	0.411 (<9.84)	23.50 ± 6.27	2.40 (<9.44)	-6.59 (<10.2)	-1.56 (<9.44)
5	4.14 (<8.99)	-0.999 (<8.84)	3.70 (<8.66)	-0.206 (<10.2)	-1.42 (<9.29)	2.35 (<9.03)	3.88 (<9.06)	2.00 (<9.62)	16.20 ± 5.90	7.73 (<9.44)	1.49 (<9.66)	2.28 (<9.47)
6	-3.00 (<8.88)	0.670 (<8.99)	7.10 (<8.70)	0.244 (<10.1)	1.34 (<8.84)	3.56 (<8.99)	1.94 (<9.10)	11.80 ± 5.74	3.54 (<9.47)	6.99 (<9.58)	0.350 (<9.51)	2.65 (<9.44)
7	2.10 (<8.88)	1.92 (<9.18)	7.33 (<8.92)	1.72 (<8.62)	5.48 (<9.06)	-1.82 (<9.10)	2.69 (<8.95)	0.407 (<9.69)	3.24 (<9.44)	5.55 (<9.51)	-2.73 (<9.84)	-1.21 (<9.36)
8	-1.07 (<8.84)	-0.248 (<9.18)	-3.23 (<9.21)	-2.76 (<9.14)	7.99 (<8.88)	3.31 (<8.92)	18.70 ± 5.75	7.77 (<9.21)	11.00 ± 5.57	5.36 (<9.14)	0.0792 (<9.29)	-3.65 (<9.47)
9	3.47 (<8.58)	-1.37 (<9.21)	-4.40 (<9.29)	-0.0570 (<8.81)	-0.755 (<9.10)	5.55 (<8.73)	12.50 ± 5.66	6.40 (<9.44)	1.34 (<9.40)	14.50 ± 6.00	-1.50 (<9.32)	2.65 (<9.69)
10	-0.588 (<8.66)	5.40 (<8.70)	0.733 (<9.06)	0.388 (<8.88)	-3.74 (<9.10)	6.73 (<8.88)	13.70 ± 5.37	7.47 (<9.29)	12.50 ± 5.57	8.66 (<9.40)	2.59 (<9.44)	-0.592 (<9.66)
11	2.08 (<8.70)	-1.82 (<9.06)	2.24 (<8.73)	1.14 (<8.81)	4.92 (<8.47)	5.99 (<8.73)	6.03 (<8.99)	-2.08 (<9.77)	6.77 (<9.32)	15.50 ± 5.71	-3.53 (<9.58)	3.85 (<9.21)
12	-0.858 (<8.95)	1.83 (<9.06)	0.714 (<8.81)	-0.388 (<8.77)	3.57 (<8.92)	-1.15 (<9.10)	16.60 ± 5.67	0.477 (<9.44)	12.70 ± 5.71	11.70 ± 5.83	-3.96 (<9.58)	6.99 (<9.03)
13	-4.22 (<9.29)	5.74 (<8.70)	3.88 (<9.18)	-1.12 (<8.81)	2.29 (<8.99)	1.05 (<9.18)	9.55 ± 5.43	4.14 (<9.69)	1.74 (<9.58)	4.37 (<9.66)	-1.25 (<9.47)	-1.42 (<9.51)
14	6.92 (<9.14)	-3.65 (<9.10)	5.55 (<8.92)	0.0455 (<8.81)	-0.995 (<9.03)	7.33 (<8.81)	6.18 (<10.6)	7.14 (<9.06)	5.81 (<9.40)	2.58 (<9.58)	1.45 (<9.18)	4.44 (<9.21)
15	21.40 ± 5.84	5.70 (<8.44)	2.73 (<8.99)	37.40 ± 5.90	5.36 (<8.73)	8.51 (<8.70)	-0.0610 (<10.4)	8.77 (<8.99)	4.44 (<9.66)	7.96 (<9.25)	0.448 (<9.40)	-0.0633 (<9.36)
16	1.76 (<9.25)	0.429 (<9.03)	0.921 (<9.06)	10.10 ± 5.34	9.25 ± 5.34	-1.75 (<9.21)	7.22 (<10.2)	8.73 (<9.51)	3.42 (<9.44)	7.18 (<9.51)	-1.50 (<9.47)	-2.87 (<9.14)
17	4.66 (<9.03)	-4.59 (<9.29)	1.64 (<8.81)	6.66 (<8.84)	-1.44 (<8.95)	3.55 (<8.92)	2.50 (<10.5)	7.88 (<9.58)	8.21 (<9.40)	4.55 (<9.51)	-3.64 (<9.58)	-3.45 (<9.66)
18	-0.274 (<9.06)	1.79 (<9.14)	5.81 (<8.88)	3.81 (<8.92)	3.35 (<8.77)	0.755 (<8.95)	5.96 (<10.1)	5.92 (<9.29)	7.88 (<9.55)	-0.0906 (<9.55)	40.30 ± 6.37	4.33 (<9.06)
19	-0.688 (<9.06)	5.85 (<9.06)	0.588 (<9.03)	-1.41 (<8.81)	7.51 (<8.70)	2.69 (<9.32)	5.55 (<10.2)	3.88 (<9.51)	-0.718 (<9.80)	9.21 (<9.62)	16.70 ± 5.94	2.39 (<9.32)
20	-1.04 (<9.29)	5.70 (<8.95)	5.96 (<8.55)	1.66 (<8.81)	6.66 (<8.62)	4.88 (<8.70)	3.88 (<9.99)	14.10 ± 5.58	2.93 (<9.51)	4.00 (<9.44)	8.84 (<9.25)	-3.19 (<9.36)
21	-2.18 (<9.25)	-0.213 (<9.18)	2.34 (<8.95)	9.51 ± 5.18	1.39 (<9.10)	-1.68 (<9.10)	-0.566 (<9.06)	8.84 (<9.32)	2.37 (<9.36)	1.35 (<9.55)	3.07 (<9.10)	1.81 (<8.95)
22	-1.89 (<9.36)	0.496 (<9.21)	11.50 ± 5.36	2.96 (<9.03)	8.33 (<8.70)	-5.59 (<9.44)	5.92 (<8.73)	5.92 (<9.36)	8.25 (<9.62)	-1.34 (<9.47)	0.625 (<9.25)	1.52 (<9.51)
23	1.80 (<8.81)	1.76 (<8.88)	26.60 ± 6.07	-3.15 (<9.18)	4.44 (<8.77)	4.85 (<8.92)	6.03 (<9.06)	5.81 (<9.21)	10.90 ± 6.11	-0.607 (<9.80)	29.40 ± 6.17	8.95 (<9.29)
24	2.30 (<8.55)	4.33 (<8.66)	-0.884 (<9.06)	6.10 (<8.95)	-0.0881 (<9.32)	-2.25 (<9.29)	12.90 ± 5.46	5.99 (<9.88)	11.90 ± 5.66	-0.999 (<9.58)	12.00 ± 5.84	6.48 (<9.21)
25	-0.199 (<8.73)	-3.52 (<9.14)	5.70 (<8.73)	0.684 (<8.99)	(a)	5.88 (<8.88)	6.59 (<8.99)	12.70 ± 5.72	10.60 ± 5.31	3.45 (<9.29)	8.18 (<9.29)	3.65 (<9.51)
26	2.47 (<8.95)	3.74 (<8.84)	1.39 (<8.95)	-0.907 (<8.77)	-6.66 (<9.47)	0.562 (<9.25)	1.81 (<9.03)	9.58 ± 5.62	4.55 (<9.21)	4.33 (<9.21)	2.65 (<9.55)	-4.96 (<9.77)
27	-0.681 (<9.10)	-2.70 (<9.32)	2.31 (<8.88)	-3.46 (<9.29)	0.256 (<8.99)	5.66 (<8.84)	2.42 (<9.25)	7.77 (<9.44)	-0.422 (<9.84)	2.38 (<9.25)	7.99 (<9.32)	3.17 (<9.47)
28	-0.796 (<8.95)	11.60 ± 5.44	2.54 (<8.70)	-1.02 (<8.99)	1.86 (<8.99)	1.94 (<9.18)	3.92 (<10.3)	6.29 (<9.69)	3.64 (<9.62)	-6.14 (<9.69)	3.41 (<9.62)	-5.07 (<9.69)
29	2.04 (<9.03)	-	2.02 (<8.92)	-3.36 (<9.36)	1.61 (<9.03)	2.63 (<8.84)	-0.958 (<10.4)	2.19 (<9.66)	10.90 ± 5.62	-1.87 (<9.62)	2.49 (<9.21)	-1.78 (<9.77)
30	1.55 (<9.10)	-	4.55 (<8.95)	-3.36 (<9.32)	2.19 (<8.84)	2.64 (<8.88)	7.51 (<10.1)	0.659 (<9.36)	18.60 ± 5.97	1.90 (<9.44)	12.40 ± 5.58	4.74 (<9.36)
31	-1.84 (<9.25)	-	0.392 (<10.3)	-	-1.01 (<9.06)	-	6.77 (<10.1)	5.03 (<9.73)	-	-3.41 (<9.62)	-	5.92 (<9.14)

(a) No sample collected due to sampler malfunction

Note: The activities shown in this table are measured concentrations and their associated 2s counting errors. Mininum detectable concentration (MDC) is shown in parentheses when calculated concentration is less than the MDC.

A.3.2 Daily flow totals for Livermore site sanitary sewer effluent (ML), 2011

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.548	0.813	0.847	1.096	0.384	1.058	0.890	0.956	0.928	0.414	0.940	0.947
2	0.554	1.053	1.105	0.621	1.043	1.010	0.499	1.055	0.906	0.292	1.086	0.851
3	0.943	1.072	1.116	0.650	0.984	0.822	0.470	1.109	0.530	0.938	1.009	0.575
4	0.897	0.983	0.896	1.197	0.738	0.415	0.440	1.035	0.738	1.116	0.873	0.633
5	0.967	0.572	0.467	1.149	0.975	0.414	0.967	0.881	0.669	1.026	0.492	0.996
6	0.919	0.548	0.547	1.082	1.054	1.022	1.046	0.559	1.005	1.189	0.494	0.519
7	0.862	1.103	1.054	0.992	0.548	0.994	1.079	0.456	0.999	0.830	1.075	1.079
8	0.521	1.012	1.013	0.820	0.533	0.995	0.893	0.998	1.135	0.409	0.937	1.080
9	0.469	1.117	1.023	0.497	1.148	1.216	0.399	0.963	0.863	0.386	1.070	0.999
10	1.024	1.046	1.020	0.503	1.090	0.877	0.420	1.034	0.530	1.141	0.965	0.616
11	1.018	0.878	0.921	1.023	1.035	0.552	1.048	1.094	0.555	1.209	0.857	0.569
12	1.233	0.549	0.584	1.025	0.904	0.563	1.009	0.780	1.096	1.064	0.539	1.205
13	1.053	0.517	0.564	1.008	0.826	1.323	1.147	0.375	1.196	1.038	0.608	1.245
14	0.847	1.101	1.116	0.984	0.561	1.189	0.962	0.348	1.113	0.898	0.988	1.367
15	0.511	1.044	1.117	0.932	0.476	1.079	0.890	0.974	1.082	0.558	1.014	1.403
16	0.517	1.161	1.166	0.539	0.997	0.989	0.453	1.007	0.839	0.514	0.980	1.360
17	0.503	1.122	1.025	0.542	1.069	0.891	0.433	1.066	0.512	0.982	1.041	0.822
18	0.986	1.009	1.101	1.125	0.882	0.512	1.014	0.952	0.523	1.134	0.761	0.849
19	0.975	0.609	0.624	1.085	0.897	0.470	1.076	0.910	0.940	1.136	0.458	1.408
20	1.255	0.470	0.586	1.123	0.884	1.024	1.031	0.449	1.002	1.069	0.501	1.445
21	0.917	0.558	1.109	1.032	0.422	1.014	1.017	0.407	1.045	0.928	0.983	1.412
22	0.555	0.979	0.996	0.905	0.431	1.089	0.812	1.100	1.075	0.433	0.951	1.306
23	0.429	1.059	1.161	0.453	1.028	1.036	0.452	1.057	1.008	0.324	0.848	1.109
24	1.075	1.049	1.251	0.402	1.016	0.934	0.453	1.016	0.696	0.973	0.460	0.788
25	0.923	1.069	0.981	0.478	1.001	0.395	0.960	1.113	0.578	0.960	0.528	0.805
26	1.006	0.509	0.544	0.931	0.958	0.392	1.086	0.947	0.931	1.018	0.504	0.828
27	1.125	0.535	0.498	1.056	0.859	0.975	1.054	0.587	0.925	1.031	0.541	0.833
28	0.992	1.041	1.079	1.028	0.534	1.153	1.066	0.445	0.973	0.864	1.329	0.957
29	0.481	-	1.178	0.918	0.528	1.101	0.938	1.310	0.988	0.424	1.148	0.815
30	0.459	-	1.118	0.273	0.610	1.057	0.547	1.040	0.838	0.458	1.272	0.797
31	1.058	-	1.096	-	1.025	-	0.465	1.045	-	0.998	-	0.743

Weekend and holiday daily flow totals are shown in the shaded areas. The daily sample flow volume is for the 24 hours of the sampling day.

A.3.3 Monthly and annual flow summary statistics for Livermore site sanitary sewer effluent (ML), 2011

Period Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2011
Weekends & Holidays													
Total	6.234	6.178	6.118	7.054	5.688	5.398	6.773	5.488	6.722	5.758	5.012	8.660	75.083
Minimum	0.481	0.509	0.467	0.273	0.422	0.395	0.399	0.375	0.512	0.409	0.458	0.575	0.273
Maximum	0.992	1.069	1.101	1.096	1.054	0.934	0.938	0.947	1.008	0.928	0.873	1.360	1.360
Mean	0.693	0.772	0.765	0.705	0.711	0.675	0.677	0.686	0.747	0.640	0.626	0.866	0.715
Weekdays													
Total	19.388	18.400	22.785	18.415	19.752	21.163	18.243	21.580	19.496	19.996	20.240	21.701	241.159
Minimum	0.429	0.470	0.498	0.402	0.384	0.392	0.420	0.348	0.523	0.292	0.460	0.519	0.292
Maximum	1.255	1.161	1.251	1.197	1.148	1.323	1.147	1.310	1.196	1.209	1.329	1.445	1.445
Mean	0.881	0.920	0.991	0.921	0.859	0.962	0.869	0.938	0.928	0.909	0.920	1.033	0.928
All days													
Total	25.622	24.578	28.903	25.469	25.440	26.561	25.016	27.068	26.218	25.754	25.252	30.361	316.242
Minimum	0.429	0.470	0.467	0.273	0.384	0.392	0.399	0.348	0.512	0.292	0.458	0.519	0.273
Maximum	1.255	1.161	1.251	1.197	1.148	1.323	1.147	1.310	1.196	1.209	1.329	1.445	1.445
Mean	0.827	0.878	0.932	0.849	0.821	0.885	0.807	0.873	0.874	0.831	0.842	0.979	0.866

A.3.4 Monthly monitoring results for physical and chemical characteristics of the Livermore site sanitary sewer effluent, 2011

Sample type														
Analyte type	Analyte	EPA Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24-hour composite sample														
Nutrients (mg/L)	Total Organic Carbon (TOC)	415.1	28	26	36	36	26	32	34	26	30	30	57	32
Oxygen demand (mg/L)	Biochemical Oxygen Demand	SM17-5210B	110	73.0	84.0	81.0	66.0	71.0	97.0	73.0	170	89.0	380	83.0
Oxygen demand (mg/L)	Chemical Oxygen Demand	410.4	240	210	290	210	190	190	230	190	460	190	970	190
Solids (mg/L)	Settleable Solids	160.5	<0.5	<0.5	2.50	<0.5	<0.5	<0.5	<0.5	<0.5	23.0	<0.5	28.0	<0.5
Solids (mg/L)	Total dissolved solids (TDS)	160.1	250	220	260	410	480	330	350	250	370	270	320	600
Solids (mg/L)	Total suspended solids (TSS)	160.2	33.0	34.0	54.0	36.0	18.0	23.0	36.0	23.0	210	26.0	510	41.0
Solids (mg/L)	Volatile Solids	160.4	170	170	240	150	120	150	210	190	350	190	600	240
Grab sample														
Total oil and grease (mg/L)	Oil and Grease - 07:01 AM	1664HEM	26	-	-	-	-	-	-	-	-	-	-	-
Total oil and grease (mg/L)	Oil and Grease - 07:07 AM	1664HEM	-	-	-	-	-	-	31	-	-	-	-	-
Total oil and grease (mg/L)	Oil and Grease - 09:01 AM	1664HEM	18	-	-	-	-	-	-	-	-	-	-	-
Total oil and grease (mg/L)	Oil and Grease - 09:07 AM	1664HEM	-	-	-	-	-	-	35	-	-	-	-	-
Total oil and grease (mg/L)	Oil and Grease - 01:01 PM	1664HEM	35	-	-	-	-	-	-	-	-	-	-	-
Total oil and grease (mg/L)	Oil and Grease - 02:07 PM	1664HEM	-	-	-	-	-	-	20	-	-	-	-	-
Total oil and grease (mg/L)	Oil and Grease - 03:01 PM	1664HEM	26	-	-	-	-	-	-	-	-	-	-	-
Total oil and grease (mg/L)	Oil and Grease - 04:07 PM	1664HEM	-	-	-	-	-	-	23	-	-	-	-	-
Volatile organic compounds (µg/L)	1,1,1-Trichloroethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,1,2,2-Tetrachloroethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,1,2-Trichloroethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,1-Dichloroethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,1-Dichloroethene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,2-Dichlorobenzene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,2-Dichloroethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,2-Dichloroethene (total)	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,2-Dichloropropane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,3-Dichlorobenzene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	1,4-Dichlorobenzene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	2-Butanone	624	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Volatile organic compounds (µg/L)	2-Chloroethylvinylether	624	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Volatile organic compounds (µg/L)	2-Hexanone	624	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Volatile organic compounds (µg/L)	4-Methyl-2-pentanone	624	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Volatile organic compounds (µg/L)	Acetone	624	550	85	120	120	9400	340	93	19	81	44	25	96
Volatile organic compounds (µg/L)	Benzene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Bromodichloromethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Bromoform	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Bromomethane	624	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Volatile organic compounds (µg/L)	Carbon disulfide	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Carbon tetrachloride	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Chlorobenzene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Chloroethane	624	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Volatile organic compounds (µg/L)	Chloroform	624	9.7	6.6	6.1	5.0	8.3	2.1	4.5	2.9	5.2	7.1	3.4	2.5
Volatile organic compounds (µg/L)	Chloromethane	624	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Volatile organic compounds (µg/L)	Dibromochloromethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Dibromomethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Dichlorodifluoromethane	624	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Volatile organic compounds (µg/L)	Ethylbenzene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Freon 113	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Methylene chloride	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Styrene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Tetrachloroethene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

A.3.4 Monthly monitoring results for physical and chemical characteristics of the Livermore site sanitary sewer effluent, 2011

Sample type Analyte type	Analyte	EPA Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24-hour composite sample														
Volatile organic compounds (µg/L)	Toluene	624	1.2	<1	<1	<1	<1	1.6	1.7	<1	1.0	<1	25	1.3
Volatile organic compounds (µg/L)	Total xylene isomers	624	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Volatile organic compounds (µg/L)	Trichloroethene	624	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Volatile organic compounds (µg/L)	Trichlorofluoromethane	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	Vinyl acetate	624	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Volatile organic compounds (µg/L)	Vinyl chloride	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	cis-1,2-Dichloroethene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	cis-1,3-Dichloropropene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	trans-1,2-Dichloroethene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Volatile organic compounds (µg/L)	trans-1,3-Dichloropropene	624	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

A.3.5 Monthly monitoring results for gross alpha, gross beta, and tritium in the Livermore site sanitary sewer effluent, 2011

Month	Gross alpha (Bq/L)	Gross beta (Bq/L)	Tritium (Bq/L)
	B196	B196	B196
Jan	-0.0145 ± 0.0440	0.618 ± 0.209	2.53 ± 1.82
Feb	-0.0228 ± 0.0418	0.533 ± 0.201	1.74 ± 1.68
Mar	-0.0229 ± 0.0418	0.592 ± 0.208	4.14 ± 1.66
Apr	-0.0067 ± 0.0488	0.648 ± 0.218	-0.59 ± 2.59
May	-0.0066 ± 0.0477	0.688 ± 0.218	2.45 ± 2.74
Jun	-0.0388 ± 0.0349	0.592 ± 0.207	3.70 ± 1.98
Jul	-0.0066 ± 0.0481	0.511 ± 0.200	6.88 ± 1.91
Aug	0.0347 ± 0.0603	0.636 ± 0.214	5.70 ± 1.96
Sep	-0.0230 ± 0.0592	0.388 ± 0.262	8.21 ± 2.17
Oct	0.0269 ± 0.0588	0.629 ± 0.216	8.07 ± 2.20
Nov	-0.0067 ± 0.0485	0.725 ± 0.225	8.55 ± 2.10
Dec	0.0500 ± 0.0725	0.585 ± 0.240	1.00 ± 1.91

Note: The activities shown in this table are measured concentrations and their associated 2σ counting errors.

A.3.6 Weekly composite metals in Livermore site sanitary sewer effluent, 2011

Composite dates (a)	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Jan 5	<0.01	0.0033	<0.005	<0.01	0.045	<0.0002	<0.005	<0.002	0.10
Jan 12	<0.01	0.0020	<0.005	<0.01	0.027	<0.0002	<0.005	<0.002	0.062
Jan 19	<0.01	<0.002	<0.005	<0.01	0.026	<0.0002	<0.005	<0.002	0.056
Jan 26	<0.01	0.0027	<0.005	<0.01	0.036	<0.0002	<0.005	<0.002	0.085
Feb 2	<0.01	<0.002	<0.005	<0.01	0.031	<0.0002	<0.005	<0.002	0.064
Feb 9	<0.01	0.0034	<0.005	<0.01	0.037	<0.0002	<0.005	<0.002	0.079
Feb 16	<0.01	0.0022	<0.005	<0.01	0.036	<0.0002	<0.005	<0.002	0.085
Feb 23	<0.01	0.0020	<0.005	<0.01	0.028	<0.0002	<0.005	<0.002	0.060
Mar 2	<0.01	0.0030	<0.005	<0.01	0.028	<0.0002	<0.005	<0.002	0.067
Mar 9	<0.01	0.0053	<0.005	<0.01	0.038	<0.0002	<0.005	<0.002	0.090
Mar 16	<0.01	0.0037	<0.005	<0.05	0.048	<0.0002	<0.005	0.0029	0.090
Mar 23	<0.01	0.0026	<0.005	<0.01	0.034	<0.0002	<0.005	<0.002	0.091
Mar 30	<0.01	0.0059	<0.005	<0.01	0.054	<0.0002	<0.005	0.0021	0.14
Apr 6	<0.01	0.0039	<0.005	<0.01	0.042	<0.0002	<0.005	0.0025	0.098
Apr 13	<0.01	0.0031	<0.005	<0.01	0.031	0.00028	<0.005	<0.002	0.075
Apr 20	<0.01	0.0029	<0.005	<0.01	0.053	<0.0002	<0.005	0.0031	0.10
Apr 27	<0.01	0.0021	<0.005	<0.01	0.040	<0.0002	<0.005	<0.002	0.10
May 4	<0.01	0.0036	<0.005	<0.01	<0.01	<0.0002	<0.005	<0.002	0.066
May 11	<0.01	0.0027	<0.005	<0.01	0.030	<0.0002	<0.005	<0.002	0.055
May 18	<0.01	0.0030	<0.005	<0.01	0.027	<0.0002	<0.005	<0.002	0.056
May 25	<0.01	0.0026	<0.005	<0.01	0.033	<0.0002	<0.005	<0.002	0.056
Jun 1	<0.01	0.0025	<0.005	<0.01	0.044	<0.0002	<0.005	<0.002	0.056
Jun 8	<0.01	0.0023	<0.005	<0.01	0.043	<0.0002	<0.005	<0.002	0.069
Jun 15	<0.01	0.0030	<0.005	<0.01	0.038	<0.0002	<0.005	<0.002	<0.05
Jun 22	<0.01	0.0035	<0.005	<0.01	0.030	<0.0002	<0.005	<0.002	<0.05
Jun 29	<0.01	0.0035	<0.005	<0.01	0.037	<0.0002	<0.005	0.0031	0.055
Jul 6	<0.01	0.0032	<0.005	<0.01	0.044	<0.0002	<0.005	0.0030	0.056
Jul 13	<0.01	0.0034	<0.005	<0.01	0.035	<0.0002	<0.005	<0.002	<0.05
Jul 20	<0.01	0.0034	<0.005	<0.01	0.034	<0.0002	<0.005	<0.002	<0.05
Jul 27	<0.01	0.0025	<0.005	<0.01	0.039	<0.0002	<0.005	<0.002	0.055
Aug 3	<0.01	0.0036	<0.005	<0.01	0.035	<0.0002	<0.005	0.0025	<0.05
Aug 10	<0.01	0.0031	<0.005	<0.01	0.038	<0.0002	<0.005	0.0023	0.052
Aug 17	<0.01	0.0036	<0.005	<0.01	0.028	<0.0002	<0.005	<0.002	<0.05
Aug 24	<0.01	0.0040	<0.005	<0.01	0.038	<0.0002	<0.005	<0.002	0.052
Aug 31	<0.01	0.012	<0.005	<0.01	0.17	<0.0002	0.0064	0.012	0.24
Sep 7	<0.01	0.0065	<0.005	<0.01	0.11	0.0032	0.0051	0.0065	0.15
Sep 14	<0.01	0.0039	<0.005	<0.01	0.099	<0.0002	<0.005	0.0076	0.16
Sep 21	<0.01	0.0037	<0.005	<0.01	0.064	<0.0002	<0.005	0.0025	0.074
Sep 28	<0.01	0.0034	<0.005	<0.01	0.045	<0.0002	<0.005	<0.002	0.059
Oct 5	<0.01	0.0040	<0.005	<0.01	0.072	<0.0002	<0.005	0.0044	0.096
Oct 12	<0.01	0.0034	<0.005	<0.01	0.077	<0.0002	<0.005	0.023	0.089
Oct 19	<0.01	0.0029	<0.005	<0.01	0.052	<0.0002	<0.005	0.0052	0.076
Oct 26	<0.01	0.0034	<0.005	<0.01	0.096	<0.0002	<0.005	0.0096	0.15
Nov 2	<0.01	0.0035	<0.005	<0.01	0.069	<0.0002	<0.005	0.0029	0.073
Nov 9	<0.01	0.0037	<0.005	<0.01	0.066	<0.0002	<0.005	0.0035	0.12
Nov 16	<0.01	0.0046	<0.005	<0.01	0.046	<0.0002	<0.005	0.0046	0.071
Nov 23	<0.01	0.0028	<0.005	<0.01	0.043	0.00081	<0.005	0.0031	0.071
Nov 30	<0.01	0.0040	<0.005	<0.01	0.033	<0.0002	<0.005	<0.002	<0.05

A.3.6 Weekly composite metals in Livermore site sanitary sewer effluent, 2011

Composite dates (a)	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Dec 7	<0.01	0.0032	<0.005	<0.01	0.030	<0.0002	<0.005	<0.002	0.062
Dec 14	<0.01	0.0046	<0.005	<0.01	0.047	<0.0002	<0.005	<0.002	<0.05
Dec 21	<0.01	0.0026	<0.005	<0.01	0.031	<0.0002	<0.005	<0.002	<0.05
Dec 28	<0.01	0.0034	<0.005	<0.01	0.021	<0.0002	<0.005	<0.002	<0.05
Detection frequency	0 of 52	50 of 52	0 of 52	0 of 52	51 of 52	3 of 52	2 of 52	20 of 52	42 of 52
Minimum	<0.01	<0.002	<0.005	<0.01	<0.01	<0.0002	<0.005	<0.002	<0.05
Maximum	<0.01	0.012	<0.005	<0.05	0.17	0.0032	0.0064	0.023	0.24
Median	(b)	0.0034	(b)	(b)	0.038	<0.0002	<0.005	<0.002	0.066
IQR ©	(b)	0.0010	(b)	(b)	0.016	(d)	(d)	(d)	0.035
EPL (e)	0.2	0.06	0.14	0.62	1	0.01	0.61	0.2	3
Maximum Percent of EPL	<5.0	20	<3.6	<8.1	17	32	1.0	11	8.0

(a) Ending date of composite period
(b) Not applicable because there are no detections. See *Environmental Report 2010*, Chapter 9.
(c) IQR = Interquartile range
(d) Not applicable because of the large number of nondetections. See *Environmental Report 2010*, Chapter 9.
(e) EPL = Effluent pollutant limit

A.4.1 Metals detected in storm water runoff (µg/L), Livermore site, 2011

Analyte[a]	Date	Type	Arroyo Seco Site influent ASS2	Arroyo Seco Site effluent ASW	Arroyo Las Positas Site influent ALPE	Arroyo Las Positas Site influent ALPO	Arroyo Las Positas Site influent GRNE	Arroyo Las Positas Site effluent WPDC	Drainage Retention Basin DRB effluent CDBX
Beryllium	2/16	Total	<0.2	<0.2	0.8	(b)	<0.2	<0.2	<0.2
Beryllium	2/25	Total	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Beryllium	10/6	Total	<1	<1	<1	(b)	3.3	<1	(b)
Cadmium	2/16	Total	<0.2	<0.2	0.3	(b)	<0.2	1.0	<0.5
Cadmium	2/25	Total	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cadmium	10/6	Total	0.6	<0.5	<0.5	(b)	2.0	<0.5	(b)
Chromium(VI)	2/16	Total	<2	4	<2	(b)	<2	2	2
Chromium(VI)	2/25	Total	<2	<2	<2	<2	<2	<2	<2
Chromium(VI)	10/6	Total	<2	<2	<2	(b)	<2	<2	(b)
Copper	2/16	Total	10	6	57	(b)	6	4	<1
Copper	2/25	Total	5	7	10	6	7	5	<2
Copper	10/6	Total	23	19	34	(b)	160	21	(b)
Lead	2/16	Total	6	<5	35	(b)	<5	<5	<5
Lead	2/25	Total	<5	5	<5	<5	<5	<5	<5
Lead	10/6	Total	15	10	15	(b)	91	9	(b)
Mercury	2/16	Total	<0.2	<0.2	<0.2	(b)	<0.2	<0.2	<0.2
Mercury	2/25	Total	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Mercury	10/6	Total	<0.2	<0.2	<0.2	(b)	0.4	<0.2	(b)
Zinc	2/16	Total	100	65	260	(b)	100	44	<20
Zinc	2/25	Total	57	77	35	14	67	59	13
Zinc	10/6	Total	250	170	120	(b)	460	230	(b)

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.
(b) Analysis was not conducted for that sampling event.

A.4.2 Nonradioactive constituents (other than metals) detected in storm water runoff, Livermore site, 2011

Group Analyte	Date	Arroyo Seco Site influent ASS2	Arroyo Seco Site effluent ASW	Arroyo Las Positas Site influent ALPE	Arroyo Las Positas Site influent ALPO	Arroyo Las Positas Site influent GRNE	Arroyo Las Positas Site effluent WPDC	Drainage Retention Basin DRB influent CDB	Drainage Retention Basin DRB influent CDB2	Drainage Retention Basin DRB effluent CDBX
Physical (mg/L)[a]										
Chemical oxygen demand (mg O/L)	2/16	38	<25	190	(b)	25	29	(b)	(b)	<25
Chemical oxygen demand (mg O/L)	2/25	<25	<25	100	25	<25	46	(b)	(b)	25
Chemical oxygen demand (mg O/L)	10/6	<25	<25	72	(b)	160	61	(b)	(b)	(b)
Dissolved oxygen (mg O/L)	2/16	11	11	11	(b)	12	12	11	11	12
Dissolved oxygen (mg O/L)	2/25	11	11	10	11	11	11	11	11	11
Dissolved oxygen (mg O/L)	10/6	10	10	10	(b)	10	9	(b)	(b)	(b)
Total suspended solids	2/16	73	15	910	(b)	18	7	21	8	<1.1
Total suspended solids	2/25	10	20	32	4	37	10	36	8	2
Total suspended solids	10/6	150	180	390	(b)	3000	960	(b)	(b)	(b)
Total dissolved solids	2/16	29	220	69	(b)	96	210	120	47	510
Total dissolved solids	2/25	49	46	630	360	53	96	63	140	380
Total dissolved solids	10/6	19	22	190	(b)	190	89	(b)	(b)	(b)
pH (pH units)	2/16	6.60	7.92	7.66	(b)	7.36	7.89	7.77	6.88	8.47
pH (pH units)	2/25	7.08	7.42	7.80	7.84	7.26	7.59	7.49	7.57	8.15
pH (pH units)	10/6	6.85	6.96	8.02	(b)	8.58	7.66	(b)	(b)	(b)
Anions/General Minerals (mg/L)										
Nitrate (as NO3)	2/16	2.3	12	3.5	(b)	23	7.0	5.5	2.6	8.7
Nitrate (as NO3)	2/25	0.73	1.7	3.9	7.6	6.8	3.2	2.3	2.4	7.1
Nitrate (as NO3)	10/6	2.4	2.5	5.8	(b)	4.5	4.9	(b)	(b)	(b)
Ortho-Phosphate	2/16	0.40	0.38	0.34	(b)	0.57	0.29	0.12	0.50	<0.05
Ortho-Phosphate	2/25	0.54	0.33	1.7	0.72	0.53	0.26	0.089	0.95	0.15
Ortho-Phosphate	10/6	0.60	0.49	0.63	(b)	0.74	0.41	(b)	(b)	(b)
Total hardness (as CaCO3)	2/16	(b)	140	(b)	(b)	(b)	120	(b)	(b)	(b)
Total hardness (as CaCO3)	2/25	(b)	29	(b)	(b)	(b)	49	(b)	(b)	(b)
Total hardness (as CaCO3)	10/6	(b)	28	(b)	(b)	(b)	45	(b)	(b)	(b)
Herbicides (µg/L)[a]										
Bromacil	2/16	<0.5	<0.5	8.4	(b)	36	1.8	<0.5	<0.5	<0.5
Bromacil	2/25	<0.5	<0.5	<0.5	7.4	24	1.5	<0.5	<0.5	<0.5
Bromacil	10/6	<0.5	<0.5	<0.5	(b)	5.0	<0.5	(b)	(b)	(b)
Diazinon	2/16	<0.2	<0.2	<0.2	(b)	<0.2	<0.2	<0.2	<0.2	<0.2
Diazinon	2/25	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Diazinon	10/6	<0.2	<0.2	<0.2	(b)	<0.2	<0.2	(b)	(b)	(b)
Diuron	2/16	<1.1	<1.1	<1	(b)	<1	<1	<1	<1	<1.1
Diuron	2/25	<1	<1	<1	3.6	<1	<1	<1	<1	<1
Diuron	10/6	<1	<1	<1	(b)	<1	<1	(b)	(b)	(b)
Glyphosate	2/16	<20	28	<20	(b)	280	29	<20	150	<20
Glyphosate	2/25	<20	<20	<20	<20	82	<20	37	<20	<20
Glyphosate	10/6	97	34	26	(b)	77	<25	(b)	(b)	(b)
Miscellaneous organics (mg/L)[a]										
Oil and grease	2/16	<5	<5	5.1	(b)	<5	<5	<5	<5	<5
Oil and grease	2/25	<5.9	<5	<5	<5	<5	<6	<5	<5	<5
Oil and grease	10/6	<5	<5	<5	(b)	<5	<5	(b)	(b)	(b)
Total organic carbon	2/16	6.3	6.5	7.1	(b)	3.9	6.1	(b)	(b)	3.7
Total organic carbon	2/25	6.9	5.1	14	8.9	3.0	5.2	(b)	(b)	5.2
Total organic carbon	10/6	9.5	10	11	(b)	7.3	13	(b)	(b)	(b)

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.

(b) Analysis was not conducted for that sampling event.

A.4.3 Routine gross alpha, gross beta, and tritium sampling in storm water runoff, Livermore site, 2011

Parameter Date		Arroyo Seco Site influent ASS2	Arroyo Seco Site effluent ASW
Gross alpha (Bq/L)[a]			
	2/16	0.078 ± 0.053	0.160 ± 0.082
	2/25	0.011 ± 0.035	0.030 ± 0.041
	10/6	0.190 ± 0.083	0.100 ± 0.064
Gross beta (Bq/L)[a]			
	2/16	0.290 ± 0.086	0.180 ± 0.070
	2/25	0.043 ± 0.042	0.140 ± 0.069
	10/6	0.41 ± 0.10	0.260 ± 0.073
Tritium (Bq/L)[a]			
	2/16	1.5 ± 2.4	0.9 ± 2.3
	2/25	1.8 ± 2.2	1.4 ± 2.6
	10/6	0.4 ± 2.8	29.0 ± 7.4

Parameter Date		Arroyo Las Positas Site influent ALPE	Arroyo Las Positas Site influent ALPO	Arroyo Las Positas Site influent GRNE	Arroyo Las Positas Site effluent WPDC
Gross alpha (Bq/L)[a]					
	2/16	0.50 ± 0.15	(b)	0.051 ± 0.049	0.013 ± 0.030
	2/25	0.044 ± 0.047	0.100 ± 0.072	0.054 ± 0.044	0.003 ± 0.021
	10/6	0.190 ± 0.085	(b)	2.90 ± 0.74	0.67 ± 0.18
Gross beta (Bq/L)[a]					
	2/16	0.84 ± 0.17	(b)	0.130 ± 0.057	0.120 ± 0.063
	2/25	0.290 ± 0.083	0.150 ± 0.063	0.076 ± 0.046	0.080 ± 0.049
	10/6	0.390 ± 0.085	(b)	3.10 ± 0.55	0.94 ± 0.17
Tritium (Bq/L)[a]					
	2/16	-0.2 ± 2.2	(b)	1.1 ± 2.2	7.1 ± 3.0
	2/25	2.8 ± 2.3	1.3 ± 2.1	1.5 ± 2.2	5.9 ± 3.2
	10/6	0.5 ± 2.9	(b)	-1.4 ± 2.8	14.0 ± 4.7

Parameter Date		Drainage Retention Basin DRB influent CDB	Drainage Retention Basin DRB influent CDB2	Drainage Retention Basin DRB effluent CDBX
Gross alpha (Bq/L)[a]				
	2/16	0.080 ± 0.057	0.062 ± 0.048	0.075 ± 0.059
	2/25	-0.000 ± 0.029	0.040 ± 0.040	0.030 ± 0.040
	10/6	(b)	(b)	(b)
Gross beta (Bq/L)[a]				
	2/16	0.160 ± 0.068	0.110 ± 0.067	0.048 ± 0.053
	2/25	0.31 ± 0.10	0.120 ± 0.053	0.140 ± 0.061
	10/6	(b)	(b)	(b)
Tritium (Bq/L)[a]				
	2/16	2.0 ± 2.4	3.3 ± 2.6	8.6 ± 3.5
	2/25	1.9 ± 2.2	2.9 ± 2.4	7.3 ± 3.1
	10/6	(b)	(b)	(b)

(a) Nondetections of radioactive constituents are equal to or are less than the 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

(b) Analysis was not conducted for that sampling event.

A.4.4 Dioxins and furans in storm water (pg/L), Site 300, 2011

Analyte[a]	Date	Upstream location Influent CARW2	Effluent locations Effluent NLIN	Effluent locations Effluent NLIN2	Downstream location Downstream GEOCRK
2,3,7,8-TCDD	Mar 24	<0.63	<0.61	<0.58	<0.65
1,2,3,7,8-PeCDD	Mar 24	<0.58	<0.66	0.91	<0.8
1,2,3,4,7,8-HxCDD	Mar 24	<0.64	<0.69	<1.3	<0.69
1,2,3,6,7,8-HxCDD	Mar 24	<0.57	<0.62	4.3	<0.62
1,2,3,7,8,9-HxCDD	Mar 24	0.78	<0.62	4.7	<0.62
1,2,3,4,6,7,8-HpCDD	Mar 24	9.0	9.8	99	1.0
Octachlorinated dibenzo-p-dioxin	Mar 24	65	85	840	3.2
2,3,7,8-TCDF	Mar 24	0.64	<0.63	1.9	<0.76
1,2,3,7,8-PeCDF	Mar 24	<0.64	<0.63	<0.67	<0.71
2,3,4,7,8-PeCDF	Mar 24	<2.3	<1.9	2.7	2.2
1,2,3,4,7,8-HxCDF	Mar 24	<0.57	<0.58	3.4	<0.57
1,2,3,6,7,8-HxCDF	Mar 24	<0.55	<0.56	1.6	<0.55
2,3,4,6,7,8-HxCDF	Mar 24	<0.62	<0.63	<0.89	<0.62
1,2,3,7,8,9-HxCDF	Mar 24	<0.7	<0.7	<0.69	<0.7
1,2,3,4,6,7,8-HpCDF	Mar 24	<5.4	<3.4	<29	<1
1,2,3,4,7,8,9-HpCDF	Mar 24	<0.6	<0.65	2.1	<0.68
Octachlorinated dibenzo-furan	Mar 24	14	13	130	<1.1

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.

A.4.5 Polychlorinated biphenyls (PCBs) in storm water runoff (µg/L), Site 300, 2011

Inf/Eff Locations	PCB 1016[a]	PCB 1221[a]
	Mar 24	Mar 24
Influent		
CARW2	<0.5	<0.5
Effluent		
NLIN	<0.5	<0.5
NLIN2	<0.5	<0.5
Downstream		
GEOCRK	<0.5	<0.5

Inf/Eff Locations	PCB 1232[a]	PCB 1242[a]
	Mar 24	Mar 24
Influent		
CARW2	<0.5	<0.5
Effluent		
NLIN	<0.5	<0.5
NLIN2	<0.5	<0.5
Downstream		
GEOCRK	<0.5	<0.5

Inf/Eff Locations	PCB 1248[a]	PCB 1254[a]
	Mar 24	Mar 24
Influent		
CARW2	<0.5	<0.5
Effluent		
NLIN	<0.5	<0.5
NLIN2	<0.5	<0.5
Downstream		
GEOCRK	<0.5	<0.5

Inf/Eff Locations	PCB 1260[a]
	Mar 24
Influent	
CARW2	<0.5
Effluent	
NLIN	<0.5
NLIN2	<0.5
Downstream	
GEOCRK	<0.5

(a) PCB nondetections are shown as less than (<) the reporting limit for each analyte.

A.4.6 Metals in storm water runoff (µg/L), Site 300, 2011

Analyte[(a)]	Date	Type	Upstream location Influent CARW2	Effluent locations Effluent N883	Effluent locations Effluent NPT7	Effluent locations Effluent NLIN	Effluent locations Effluent NLIN2	Downstream location Downstream GEOCRK
Arsenic	3/24	Total	18	<2	<2	25	20	<2
Beryllium	3/24	Total	1.7	<0.8	<0.8	<0.8	2.4	<0.8
Cadmium	3/24	Total	0.8	<0.5	<0.5	<0.5	1.3	<0.5
Iron	3/24	Total	58000	120	4300	3000	64000	790
Lead	3/24	Total	20	<5	<5	<5	20	<5
Mercury	3/24	Total	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Selenium	3/24	Total	2	<2	<2	4	3	<2
Silver	3/24	Total	<1	<1	<1	<1	<1	<1

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.

A.4.7 Nonradioactive constituents detected in storm water runoff, Site 300, 2011

Group Analyte	Date	Upstream location	Effluent locations	Effluent locations	Effluent locations	Effluent locations	Downstream location
		CARW2	N883	NPT7	NLIN	NLIN2	GEOCRK
Physical (mg/L)[(a)]							
Chemical oxygen demand (mg O/L)	3/24	54	<25	<25	<25	120	<25
Total suspended solids	3/24	1100	7	16	63	1200	5
pH (pH units)	3/24	8.07	6.62	7.76	8.15	8.04	8.33
Conductivity (µS/cm)	3/24	512	9	68	867	358	692
Anions/General Minerals (mg/L)[(a)]							
Ammonia (as Nitrogen)	3/24	0.15	<0.1	<0.1	<0.1	0.24	<0.1
Calcium	3/24	62	(b)	(b)	57	44	55
Total hardness (as $CaCO_3$)	3/24	300	(b)	(b)	280	240	250
Cyanide	3/24	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Miscellaneous organics (mg/L)[(a)]							
Oil and grease	3/24	<5	<5	<5	<5	<5	<5
Explosive (µg/L)[(a)]							
HMX	3/24	<1	(b)	(b)	<1	<1	<1
RDX	3/24	<1	(b)	(b)	<1	<1	<1

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.

(b) Analysis was not conducted for that sampling event.

A.4.8 Radioactivity in storm water runoff, Site 300, 2011

Parameter Date	Method	Upstream location	Effluent locations	Effluent locations	Effluent locations	Effluent locations	Downstream location
		CARW2	N883	NPT7	NLIN	NLIN2	GEOCRK
Gross alpha (Bq/L)[(a)]							
3/24	E900	0.47 ± 0.15	0.062 ± 0.050	0.040 ± 0.043	0.240 ± 0.097	0.33 ± 0.11	0.061 ± 0.057
Gross beta (Bq/L)[(a)]							
3/24	E900	0.84 ± 0.17	0.160 ± 0.061	0.130 ± 0.055	0.300 ± 0.077	0.57 ± 0.12	0.220 ± 0.073
Tritium (Bq/L)[(a)]							
3/24	E906	-1.5 ± 2.0	1.4 ± 2.4	0.6 ± 2.3	-0.1 ± 2.2	0.3 ± 2.3	0.5 ± 2.2
Uranium-234+233 (mBq/L)[(a)]							
3/24	AS	59 ± 12	-0.04 ± 0.74	4.1 ± 1.9	160 ± 24	130 ± 22	24.0 ± 5.0
Uranium-235+236 (mBq/L)[(a)]							
3/24	AS	2.4 ± 2.2	0.63 ± 0.80	0.9 ± 1.0	5.9 ± 2.2	5.6 ± 3.1	1.00 ± 0.85
Uranium-238 (mBq/L)[(a)]							
3/24	AS	60 ± 12	0.71 ± 0.81	5.0 ± 1.9	120 ± 19	190 ± 31	24.0 ± 5.0

(a) Nondetections of radioactive constituents are equal to or are less than the 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.1 Livermore site metals surveillance wells, 2011

Type			
Constituents of concern	W-307	W-226	W-306
	May 5	Apr 27	Apr 14
Inorganic			
Field pH (pH units)	7.00	7.50	7.37
Field Conductivity (µS/cm)	1020	764	846
Water temperature (Degrees C)	23.8	21.9	17.6
Metals (µg/L)[(a)]			
Aluminum	<50	<50	<50
Antimony	<5	<5	<5
Arsenic	<2	2	<2
Barium	280	160	99
Beryllium	<0.2	<0.2	<0.2
Boron	610	520	1200
Cadmium	<0.5	<0.5	<0.5
Chromium	11	22	24
Chromium(VI)	11	19	28
Cobalt	<50	<50	<50
Copper	<2	<2	<2
Iron	<100	<100	<100
Lead	<5	<5	<5
Manganese	<30	<30	<30
Mercury	<0.2	<0.2	<0.2
Molybdenum	<25	<25	<25
Nickel	2	<2	<2
Selenium	<2	<2	<2
Silver	<1	<1	<1
Thallium	<1	<1	<1
Vanadium	<20	<20	<20
Zinc	<10	<10	<10

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

A.5.2 Livermore site Buildings 514 and 612 area surveillance wells, 2011

Type Constituents of concern	W-270	W-359	GSW-011
	Apr 14	Apr 14	Apr 18
Inorganic			
Field pH (pH units)	7.49	7.49	7.50
Field Conductivity (µS/cm)	828	653	772
Water temperature (Degrees C)	22.0	21.1	21.5
Radioactive (Bq/L)[a]			
Gross alpha	0.058 ± 0.047	0.057 ± 0.049	0.058 ± 0.049
Gross beta	0.014 ± 0.042	0.080 ± 0.045	0.057 ± 0.038
Tritium	-0.6 ± 2.0	4.3 ± 2.5	4.0 ± 2.7

(a) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.3 Livermore site near Decontamination and Waste Treatment Facility (DWTF) surveillance wells, 2011

Type Constituents of concern	W-007	W-593	W-594
	Apr 19	Apr 14	Apr 13
Inorganic			
Field pH (pH units)	6.85	6.89	7.46
Field Conductivity (µS/cm)	69.6	2440	1490
Water temperature (Degrees C)	20.7	18.4	17.5
Radioactive (Bq/L)[(a)]			
Tritium	1.0 ± 2.4	0.4 ± 2.1	-0.2 ± 2.2

(a) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.4 Livermore site East Traffic Circle Landfill surveillance wells, 2011

Type Constituents of concern	W-119	W-906	W-1303	W-1306	W-1308
	Jan 11	Jan 11	Jan 10	Jan 10	Jan 11
Inorganic					
Field pH (pH units)	7.98	7.39	7.54	7.39	7.47
Field Conductivity (µS/cm)	566	2180	1370	1660	1010
Water temperature (Degrees C)	15.4	18.0	16.9	19.8	18.7
Metals (µg/L)[(a)]					
Copper	<10	<10	<10	<10	<10
Lead	<50	<50	<50	<50	<50
Zinc	<20	<20	<20	<20	<20
Radioactive (Bq/L)[(b)]					
Tritium	5.8 ± 2.9	2.5 ± 2.4	7.4 ± 3.1	5.2 ± 2.8	9.4 ± 3.5

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

(b) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.5 Livermore site Tritium Facility surveillance wells, 2011

Area Location	Screened in HSU	Sampling date	Tritium (Bq/L)[(a)]
Upgradient of Tritium Facility			
W-305	2	Apr 19	6.9 ± 3.2
Downgradient of Tritium Facility			
W-101	1B	Apr 18	9.0 ± 3.5
W-147	1B	May 5	5.4 ± 3.0
W-148	1B	May 5	32.0 ± 7.6
W-148	1B	Dec 20	31.0 ± 6.7

(a) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.6 Livermore site perimeter off-site surveillance wells, 2011

Type Constituents of concern	14B1	W-121	W-151	W-571
	Jan 12	Jan 12	Jan 12	Jan 12
Inorganic				
Field pH (pH units)	7.68	7.89	7.62	7.56
Field Conductivity (µS/cm)	888	760	949	890
Water temperature (Degrees C)	10.0	17.4	18.9	18.7
General minerals (mg/L)[(a)]				
Bromide	<0.5	<0.5	<0.5	<0.5
Chloride	98	86	110	89
Fluoride	0.3	0.3	0.3	0.3
Nitrate	40	32	44	34
Ortho-Phosphate	0.3	0.2	0.2	0.2
Sulfate	38	39	42	32
Radioactive (Bq/L)[(b)]				
Gross alpha	0.140 ± 0.073	0.026 ± 0.043	0.056 ± 0.049	0.130 ± 0.073
Gross beta	0.072 ± 0.052	0.055 ± 0.044	0.027 ± 0.039	0.070 ± 0.039
Tritium	1.6 ± 2.2	0.4 ± 2.1	0.4 ± 2.1	1.9 ± 2.3

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

(b) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.7 Livermore site perimeter on-site surveillance wells, 2011

Type Constituents of concern	W-1012	W-556	W-373
	Jan 12	Jan 18	Jan 18
Inorganic			
Field pH (pH units)	7.46	7.46	7.50
Field Conductivity (µS/cm)	903	1080	987
Water temperature (Degrees C)	18.8	19.1	18.7
Metals (µg/L)			
Chromium(VI)	14	19	29
General minerals (mg/L)[(a)]			
Bromide	<0.5	0.9	1.0
Chloride	77	210	150
Fluoride	0.3	0.3	0.6
Nitrate	28	41	13
Ortho-Phosphate	0.2	0.2	0.1
Sulfate	37	37	61
Radioactive (Bq/L)[(b)]			
Gross alpha	0.083 ± 0.063	0.076 ± 0.059	0.074 ± 0.059
Gross beta	0.200 ± 0.067	0.097 ± 0.058	0.095 ± 0.059
Tritium	2.6 ± 2.4	1.1 ± 2.2	3.9 ± 2.5

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

(b) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.8 Livermore site near the National Ignition Facility (NIF) surveillance wells, 2011

Type Constituents of concern	W-653	W-1207
	Apr 21	Apr 18
Inorganic		
Field pH (pH units)	7.26	7.14
Field Conductivity (µS/cm)	1280	2300
Water temperature (Degrees C)	20.1	22.6
Radioactive (Bq/L)[(a)]		
Tritium	3.3 ± 2.7	1.0 ± 2.3

(a) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.9 Livermore site Taxi Strip surveillance wells, 2011

Type Constituents of concern	W-204	W-363
	Jan 11	Jan 18
Inorganic		
Field pH (pH units)	7.80	7.85
Field Conductivity (µS/cm)	510	505
Water temperature (Degrees C)	15.3	18.8
Metals (µg/L)[(a)]		
Copper	<10	<10
Lead	<50	<50
Zinc	<20	<20
Radioactive (Bq/L)[(b)]		
Tritium	2.2 ± 2.3	16.0 ± 4.7

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

(b) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.10 Livermore site background surveillance wells, 2011

Type			
Constituents of concern	W-008	W-221	W-017
	Jan 10	Jan 11	Jan 10
Inorganic			
Field pH (pH units)	7.57	7.31	7.69
Field Conductivity (µS/cm)	2540	1750	972
Water temperature (Degrees C)	17.3	17.7	16.9
General minerals (mg/L)[(a)]			
Bromide	2.6	1.9	0.8
Chloride	480	300	180
Fluoride	1.5	0.7	0.5
Nitrate	31	35	10
Ortho-Phosphate	<0.05	<0.05	0.1
Sulfate	330	120	28
Radioactive (Bq/L)[(b)]			
Gross alpha	0.180 ± 0.095	0.094 ± 0.063	0.035 ± 0.044
Gross beta	0.075 ± 0.061	0.062 ± 0.053	0.081 ± 0.045
Tritium	1.2 ± 2.2	27.0 ± 6.6	-0.8 ± 1.9

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

(b) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.5.11 Tritium activity in Livermore Valley wells, 2011

Location	Date	Tritium (Bq/L)[a]
16A2	Jun 15	2.3 ± 2.4
12D2	Jun 20	2.1 ± 2.5
8H18	Jul 19	1.6 ± 2.4
9Q1	Oct 27	1.6 ± 2.4
2R1	Jun 6	1.5 ± 2.4
11B1	Jun 20	1.3 ± 2.4
12A2	Jun 20	1.3 ± 2.4
7C2	Jun 20	1.3 ± 2.4
12G1	Jun 20	1.2 ± 2.4
9M3	Jun 14	1.0 ± 2.3
16L5	Jun 15	0.6 ± 2.2
1H3	Jun 6	0.6 ± 2.2
16B1	Oct 27	0.6 ± 2.3
9B1	Sep 9	0.2 ± 2.2
17D12	Sep 13	0.1 ± 2.2
7P3	Oct 19	-1.0 ± 2.1

(a) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

A.6.1 Site 300 annually monitored off-site surveillance wells, 2011

Type Constituents of concern [a]	MUL1 Aug 1	MUL2 Aug 1	STONEHAM1 Jul 18	VIE1 Aug 1	VIE2 Aug 18	W-35A-04 Feb 2	W-35A-04 May 9	W-35A-04 Aug 8	W-35A-04 Nov 16
Inorganic (µg/L)									
Arsenic	(b)	<2	<2	13	<2	3.7	(b)	4.3	3.9
Barium	(b)	<25	29	35	42	44	(b)	37	43
Beryllium	(b)	<0.5	<0.5	<0.5	<0.5	(b)	(b)	(b)	<0.5
Cadmium	(b)	<0.5	<0.5	<0.5	<0.5	<50	(b)	<50	<0.5
Chromium	(b)	<1	<1	<1	<1	1.4	(b)	1.1	1.0
Cobalt	(b)	<25	<25	<25	<25	(b)	(b)	(b)	<25
Copper	(b)	<10	<10	<10	<10	1.4	(b)	<1	<10
Lead	(b)	<2	<2	<2	<2	<5	(b)	<5	<2
Mercury	(b)	<0.2	<0.2	<0.2	<0.2	(b)	(b)	(b)	<0.2
Molybdenum	(b)	<25	<25	<25	<25	<25	(b)	<25	<25
Nickel	(b)	5.3	<5	<5	6.1	3.6	(b)	2.5	<5
Nitrate (mg/L)	(b)	8.7	1.5	(b)	22	11	13	13	12
Perchlorate (mg/L)	(b)	<0.004	<0.004	<0.004	<0.004	(b)	(b)	(b)	<0.004
Potassium (mg/L)	(b)	9.5	(b)	5.7	(b)	5.5	(b)	5.2	5.3
Selenium	(b)	4.0	<2	5.3	3.0	5.5	(b)	4.4	4.6
Silver	(b)	<0.5	<0.5	<0.5	<0.5	<10	(b)	<10	<0.5
Thallium	(b)	<1	<1	<1	<1	(b)	(b)	(b)	<1
Vanadium	(b)	<25	<25	<25	<25	<20	(b)	<20	<25
Zinc	(b)	<20	<20	<20	42	<20	(b)	<20	<20
Organic (µg/L) [c]									
EPA 502.2	(b)	0 of 60	0 of 60	0 of 60	0 of 60	(b)	(b)	(b)	1 of 60
Dibromochloromethane	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	2.1
Explosive (µg/L)									
HMX [d]	(b)	<0.68	<1	<0.67	<1	(b)	(b)	(b)	<1.2
RDX [e]	(b)	<0.68	5.0	<0.67	<1	(b)	(b)	(b)	<1.2
Radioactive (Bq/L) [f]									
Gross alpha	0.110 ± 0.068	0.020 ± 0.038	0.190 ± 0.087	0.084 ± 0.063	0.140 ± 0.069	(b)	(b)	(b)	0.170 ± 0.070
Gross beta	0.084 ± 0.042	0.190 ± 0.078	0.310 ± 0.087	0.240 ± 0.081	0.120 ± 0.058	(b)	(b)	(b)	0.270 ± 0.081
Tritium	0.5 ± 2.0	-0.5 ± 1.8	-0.4 ± 2.0	1.6 ± 2.0	-1.0 ± 2.3	(b)	(b)	(b)	1.0 ± 2.8
Uranium (calculated total)	-	0.0270 ± 0.0048	0.220 ± 0.033	0.120 ± 0.014	0.210 ± 0.028	(b)	(b)	(b)	0.160 ± 0.025

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) An analysis was not conducted for that sampling event.

(c) See *Environmental Report 2011,* Appendix B for EPA methods 502.2 and 625 constituents and their RLs.

(d) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

(e) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

(f) Nondetections of radioactive constituents are equal to or less than their 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.6.2 Site 300 off-site surveillance well CARNRW1, 2011 [(a, b, c)]

Type Constituents of concern	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1	CARNRW1
	Jan 3	Feb 1	Mar 2	Apr 5	May 2	Jun 1	Jul 28	Aug 2	Sep 7	Oct 4	Nov 1	Dec 1
Inorganic (µg/L)												
Perchlorate	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Organic (µg/L)												
EPA 601	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32
Radioactive (Bq/L)												
Tritium	-0.6 ± 1.9	-1.2 ± 2.3	-0.1 ± 2.6	0.2 ± 2.3	-0.2 ± 2.0	-0.8 ± 2.0	0.8 ± 2.0	2.3 ± 2.7	-2.8 ± 2.4	1.3 ± 2.2	0.1 ± 2.3	2.5 ± 2.4

(a) Constituent nondetections are shown as less than (<) the reporting limit (RL) for that analysis.

(b) See *Environmental Report 2011,* Appendix B, for EPA Method 601 constituents and RLS.

(c) Nondetections of radioactive constituents are equal to or less than their 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.6.3 Site 300 off-site surveillance well CARNRW2, 2011

Type Constituents of concern[a]	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2	CARNRW2
	Jan 3	Feb 1	Mar 2	Apr 5	May 2	Jun 1	Jul 6	Aug 2	Sep 7	Oct 4	Nov 1	Dec 1
Inorganic (µg/L)												
Arsenic	3.8	(b)	(b)	3.3	(b)	-	2.8	-	-	2.8	-	-
Barium	<25	(b)	(b)	<25	(b)	-	<25	-	-	<25	-	-
Beryllium	<0.5	(b)	(b)	<0.5	(b)	-	<0.5	-	-	<0.5	-	-
Cadmium	<0.5	(b)	(b)	<0.5	(b)	-	<0.2	-	-	<0.5	-	-
Chromium	<1	(b)	(b)	<1	(b)	-	<1	-	-	<1	-	-
Cobalt	<25	(b)	(b)	<25	(b)	-	<25	-	-	<25	-	-
Copper	<10	(b)	(b)	<10	(b)	-	<10	-	-	<10	-	-
Lead	<2	(b)	(b)	<2	(b)	-	<2	-	-	<2	-	-
Mercury	<0.2	(b)	(b)	<0.2	(b)	-	<0.2	-	-	<0.2	-	-
Molybdenum	26	(b)	(b)	25	(b)	-	26	-	-	<25	-	-
Nickel	<5	(b)	(b)	<5	(b)	-	<5	-	-	<5	-	-
Nitrate (mg/L)	0.89	1.1	1.3	<0.5	1.0	0.84	<0.5	<0.5	1.2	<0.5	<0.5	0.87
Perchlorate (mg/L)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Selenium	<2	(b)	(b)	<2	(b)	-	<2	-	-	<2	-	-
Silver	<0.5	(b)	(b)	<0.5	(b)	-	0.77	-	-	<0.5	-	-
Thallium	<1	(b)	(b)	<1	(b)	-	<1	-	-	<1	-	-
Vanadium	<25	(b)	(b)	<25	(b)	-	<25	-	-	<25	-	-
Zinc	<20	(b)	(b)	<20	(b)	-	<20	-	-	<20	-	-
Organic (µg/L) [c]												
EPA 502.2	3 of 60	(b)	(b)	0 of 60	(b)	-	0 of 60	-	-	0 of 60	-	-
Bromodichloromethane	0.77	(b)	(b)	(b)	(b)	-	-	-	-	-	-	-
Bromoform	7.8	(b)	(b)	(b)	(b)	-	-	-	-	-	-	-
Dibromochloromethane	3.1	(b)	(b)	(b)	(b)	-	-	-	-	-	-	-
Explosive (µg/L)												
HMX [d]	<1	(b)	(b)	<0.67	(b)	-	<0.83	-	-	<1	-	-
RDX[e]	<1	(b)	(b)	<0.67	(b)	-	<0.83	-	-	<1	-	-
Radioactive (Bq/L) [f]												
Gross alpha	0.014 ± 0.038	(b)	(b)	0.070 ± 0.041	(b)	-	-0.012 ± 0.027	-	-	0.030 ± 0.044	-	-
Gross beta	0.150 ± 0.059	(b)	(b)	0.340 ± 0.089	(b)	-	0.160 ± 0.061	-	-	0.140 ± 0.055	-	-
Tritium	0.8 ± 2.2	-0.1 ± 2.3	-0.3 ± 2.6	0.3 ± 2.3	-0.3 ± 2.0	0.3 ± 2.2	-0.1 ± 2.5	2.0 ± 2.7	-1.8 ± 2.5	0.3 ± 2.1	0.2 ± 2.3	0.8 ± 2.2
Uranium (calculated total)	0.0020 ± 0.0016	(b)	(b)	0.0023 ± 0.0021	(b)	-	0.0013 ± 0.0023	-	-	0.0011 ± 0.0017	-	-

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.
(b) An analysis was not conducted for that sampling event.
(c) See *Environmental Report 2011,* Appendix B for EPA methods 502.2 and 625 constituents and RLs.
(d) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
(e) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.
(f) Nondetections of radioactive constituents are equal to or less than their 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.6.4 Site 300 off-site surveillance well CDF1, 2011

Type	
Constituents of concern[a]	CDF1
	Jan 13
Inorganic (µg/L)	
Arsenic	5.6
Barium	26
Beryllium	<0.5
Cadmium	<0.5
Cobalt	<25
Copper	<10
Lead	<2
Nickel	<5
Vanadium	<25
Zinc	<20
Organic (µg/L)[b]	
EPA 502.2	0 of 60
Explosive (µg/L)	
HMX[c]	<0.77
RDX[d]	<0.77
Radioactive (Bq/L)[e]	
Gross alpha	-0.002 ± 0.037
Gross beta	0.250 ± 0.071
Tritium	0.6 ± 2.1

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) See *Environmental Report 2011,* Appendix B, for EPA Method 502.2 constituents and RLS.

(c) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

(d) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

(e) Nondetections of radioactive constituents are equal to or less than their 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.6.5 Site 300 off-site surveillance well CON1, 2011

Type	
Constituents of concern[a]	CON1
	Jan 13
Inorganic (µg/L)	
Arsenic	2.0
Barium	<25
Beryllium	<0.5
Cadmium	<0.5
Cobalt	<25
Copper	<10
Lead	<2
Nickel	<5
Vanadium	<25
Zinc	<20
Organic (µg/L)[b]	
EPA 502.2	0 of 60
Explosive (µg/L)	
HMX[c]	<1
RDX[d]	<1
Radioactive (Bq/L)[e]	
Gross alpha	-0.012 ± 0.037
Gross beta	0.290 ± 0.084
Tritium	0.3 ± 2.0

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) See *Environmental Report 2011,* Appendix B, for EPA Method 502.2 constituents and RLS.

(c) HMX is octahydro-1,3,5,6-tetranitro-1,3,5,7-tetrazocine.

(d) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

(e) Nondetections of radioactive constituents are equal to or less than their 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.6.6 Site 300 off-site surveillance well CON2, 2011

Type Constituents of concern	CON2 Jan 13	CON2 Feb 15	CON2 Mar 16	CON2 Apr 18	CON2 May 19	CON2 Jun 21	CON2 Jul 27	CON2 Aug 16	CON2 Sep 26	CON2 Oct 19	CON2 Nov 28	CON2 Dec 14
Organic (µg/L)[(a)]												
EPA 601	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32	0 of 32

(a) See *Environmental Report 2011,* Appendix B, for EPA Method 601 constituents and reporting limits.

A.6.7 Elk Ravine surveillance wells, Site 300, 2011

Type

Constituents of concern	NC7-61	NC7-61	NC7-69	K2-04D	K2-04S	NC2-12D	NC2-11D	812CRK (Spring 6)	812CRK (Spring 6)	NC2-07	NC2-07
	Apr 6	Nov 8	May 11	Apr 11	Apr 11	Apr 20	Apr 14	Apr 20	Aug 23	Apr 20	Oct 18
Inorganic (µg/L)											
Arsenic	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	37	38
Barium	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	41	41
Beryllium	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<0.5	<0.5
Cadmium	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<0.5	<0.5
Chromium	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<1	<1
Cobalt	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<25	<25
Copper	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<10	<10
Lead	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<2	<2
Mercury	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<0.2	<0.2
Molybdenum	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<25	<25
Nickel	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<5	<5
Selenium	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	3.6	4.2
Silver	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<0.5	<0.5
Thallium	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<1	<1
Vanadium	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	51	50
Zinc	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<20	<20
Explosive (µg/L)											
HMX	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<1	<0.77
RDX	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	<1	<0.77
Radioactive (Bq/L)											
Gross alpha	0.160 ± 0.074	(b)	0.027 ± 0.042	0.035 ± 0.028	0.130 ± 0.068	0.099 ± 0.059	0.130 ± 0.061	0.210 ± 0.081	(b)	0.190 ± 0.080	0.46 ± 0.14
Gross beta	0.260 ± 0.071	(b)	0.180 ± 0.077	0.140 ± 0.039	0.140 ± 0.063	0.160 ± 0.055	0.260 ± 0.072	0.190 ± 0.062	(b)	0.230 ± 0.064	0.290 ± 0.085
Tritium	810 ± 160	810 ± 160	(b)	(b)	(b)	(b)	(b)	0.4 ± 2.2	(b)	-0.1 ± 2.1	1.7 ± 2.4
Uranium (calculated total)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	0.220 ± 0.028	-	-

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) An analysis was not conducted for that sampling event.

(c) See *Environmental Report 2011,* Appendix B for EPA method 601 constituents and RLs.

(d) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

(e) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

(f) Nondetections of radioactive constituents are equal to or less than their 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.6.8 Site 300 off-site surveillance well GALLO1, 2011

Type Constituents of concern[a]	GALLO1	GALLO1	GALLO1	GALLO1	GALLO1	GALLO1
	Jan 12	Apr 27	May 18	Jul 20	Aug 16	Oct 19
Inorganic (µg/L)						
Arsenic	4.6	9.7	(b)	(b)	(b)	4.2
Barium	<25	<120	(b)	(b)	(b)	<25
Beryllium	<0.5	<0.5	(b)	(b)	(b)	<0.5
Cadmium	<0.5	<0.5	(b)	(b)	(b)	<0.5
Cobalt	<25	<25	(b)	(b)	(b)	<25
Copper	<10	<10	(b)	(b)	(b)	<10
Lead	<2	<2	(b)	(b)	(b)	<2
Nickel	<5	<5	(b)	(b)	(b)	<5
Nitrate (mg/L)	<0.5	(b)	<0.5	(b)	<0.5	<0.5
Perchlorate (mg/L)	<0.004	(b)	<0.004	(b)	<0.004	<0.004
Vanadium	<25	<25	(b)	(b)	(b)	<25
Zinc	95	1900	(b)	(b)	(b)	<20
Organic (µg/L)[c]						
EPA 502.2	0 of 60	0 of 60	(b)	(b)	(b)	1 of 60
Trichloroethene	(b)	(b)	(b)	(b)	(b)	0.55
Radioactive (Bq/L)[d]						
Gross alpha	0.009 ± 0.034	0.003 ± 0.033	(b)	-0.000 ± 0.036	(b)	0.006 ± 0.039
Gross beta	0.040 ± 0.042	-0.032 ± 0.037	(b)	0.052 ± 0.038	(b)	0.028 ± 0.035
Tritium	0.9 ± 2.1	-1.7 ± 2.1	(b)	-0.6 ± 2.0	(b)	-0.2 ± 2.2

(a) Constituent nondetections other than radioactive are shown as less than (<) reporting limit (RL) for that analysis.

(b) An analysis was not conducted for that sampling event.

(c) See *Environmental Report 2011,* Appendix B, for EPA Method 502.2 constituents and RLs.

(d) Nondetections of radioactive constituents are equal to or less than the 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.6.9 Site 300 potable supply well 18, 2011

Type Constituents of concern(a)	WELL18	WELL18	WELL18	WELL18	WELL18	WELL18	WELL18	WELL18
	Jan 12	Feb 16	Mar 15	Apr 27	May 18	Jun 28	Aug 17	Sep 28
Inorganic (µg/L)								
Nitrate (mg/L)	<0.5	<0.5	0.50	<0.5	<0.5	<0.5	<0.5	<0.5
Explosive (µg/L)								
HMX(b)	<1.3	<1	<1	<1	<1	<1	<1	<1
RDX(c)	<1.3	<1	<1	<1	<1	<1	<1	<1

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

(c) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

A.6.10 Site 300 potable supply well 20, 2011

Type Constituents of concern[(a)]	WELL20 Jan 12	WELL20 Feb 16	WELL20 Mar 15	WELL20 Apr 27	WELL20 May 18	WELL20 Jun 28	WELL20 Jul 20	WELL20 Aug 17	WELL20 Sep 28	WELL20 Oct 27	WELL20 Nov 29	WELL20 Dec 14
Inorganic (µg/L)												
Arsenic	<2	(b)	(b)	<2	(b)	(b)	(b)	(b)	(b)	<2	(b)	(b)
Barium	<25	(b)	(b)	<25	(b)	(b)	(b)	(b)	(b)	<25	(b)	(b)
Beryllium	<0.5	(b)	(b)	<0.5	(b)	(b)	(b)	(b)	(b)	<0.5	(b)	(b)
Cadmium	<0.5	(b)	(b)	<0.5	(b)	(b)	(b)	(b)	(b)	<0.5	(b)	(b)
Chromium	<1	(b)	(b)	<1	(b)	(b)	(b)	(b)	(b)	<1	(b)	(b)
Cobalt	<25	(b)	(b)	<25	(b)	(b)	(b)	(b)	(b)	<25	(b)	(b)
Copper	<10	(b)	(b)	<10	(b)	(b)	(b)	(b)	(b)	<10	(b)	(b)
Lead	<2	(b)	(b)	<2	(b)	(b)	(b)	(b)	(b)	<2	(b)	(b)
Mercury	<0.2	(b)	(b)	<0.2	(b)	(b)	(b)	(b)	(b)	<0.2	(b)	(b)
Molybdenum	<25	(b)	(b)	<25	(b)	(b)	(b)	(b)	(b)	<25	(b)	(b)
Nickel	<5	(b)	(b)	<5	(b)	(b)	(b)	(b)	(b)	<5	(b)	(b)
Nitrate (mg/L)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	(b)	<0.5	<0.5	<0.5	<0.5	<0.5
Selenium	<2	(b)	(b)	<2	(b)	(b)	(b)	(b)	(b)	<2	(b)	(b)
Silver	<0.5	(b)	(b)	<0.5	(b)	(b)	(b)	(b)	(b)	<0.5	(b)	(b)
Thallium	<1	(b)	(b)	<1	(b)	(b)	(b)	(b)	(b)	<1	(b)	(b)
Vanadium	<25	(b)	(b)	<25	(b)	(b)	(b)	(b)	(b)	<25	(b)	(b)
Zinc	<20	(b)	(b)	<20	(b)	(b)	(b)	(b)	(b)	<20	(b)	(b)
Organic (µg/L)[(c)]												
EPA 502.2	0 of 60	0 of 60	0 of 60	0 of 60	0 of 60	0 of 60	(b)	0 of 60	0 of 60	0 of 60	0 of 60	0 of 60
Explosive (µg/L)												
HMX[(d)]	<1.2	<1	<1.1	<1	<1	<1	(b)	<1	<1	<1	<1	<1
RDX[(e)]	<1.2	<1	<1.1	<1	<1	<1	(b)	<1	<1	<1	<1	<1
Radioactive (Bq/L)[(f)]												
Gross alpha	0.038 ± 0.045	(b)	(b)	0.005 ± 0.034	(b)	(b)	0.071 ± 0.055	(b)	(b)	-0.008 ± 0.036	(b)	(b)
Gross beta	0.200 ± 0.073	(b)	(b)	0.170 ± 0.063	(b)	(b)	0.220 ± 0.067	(b)	(b)	-0.013 ± 0.025	(b)	(b)
Tritium	1.0 ± 2.1	(b)	(b)	-0.1 ± 2.2	(b)	(b)	-1.7 ± 1.9	(b)	(b)	-1.0 ± 2.2	(b)	(b)

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) An analysis was not conducted for that sampling event.

(c) See *Environmental Report 2011,* Appendix B for EPA method 502.2 constituents and its RLs.

(d) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

(e) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

(f) Nondetections of radioactive constituents are equal to or less than their 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

A.7.1 Dry season (June 1 to September 30, 2011) monitoring data for releases from Lake Haussmann

	CDBX	CDBX	CDBX	CDBX	WPDC	WPDC	WPDC	WPDC
	Jun 7	Jul 20	Aug 16	Sep 20	Jun 7	Jul 20	Aug 16	Sep 20
Accute Toxicity (%)								
Fathead Minnow survival	100	100	100	100	100	100	100	100
Total Metals (mg/L)								
Antimony	0.00050	0.00028	0.00030	<0.005	0.00011	0.00016	0.00027	0.00011
Arsenic	0.0018	0.00065	0.0011	0.0012	<0.002	0.00095	0.00095	0.00068
Beryllium	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Boron	1.3	1.4	1.4	1.6	1.1	1.2	1.2	1.2
Cadmium	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00012
Chromium	0.0024	0.0025	0.0027	0.0019	0.0090	0.010	0.0090	0.0094
Hexavalent Chromium	0.0033	0.0014	0.0017	0.0019	0.0096	0.0070	0.0061	0.0081
Copper	0.00080	0.00054	0.00054	0.00092	0.0013	0.0014	0.0014	0.0013
Iron	0.020	<0.1	0.064	0.029	0.29	0.30	0.32	0.24
Lead	<0.005	<0.005	<0.005	0.00016	0.00023	<0.005	0.00025	0.00017
Manganese	0.011	0.17	0.036	0.016	0.0076	0.0098	0.0089	0.0049
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel	0.0020	0.0066	0.0035	0.0032	0.0021	0.0029	0.0028	0.0025
Selenium	0.0015	0.0011	0.0016	0.0015	0.0010	0.00072	0.0011	0.00070
Silver	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium	0.00014	<0.001	<0.001	<0.001	<0.001	<0.001	0.00013	0.00017
Zinc	0.0086	<0.02	<0.02	<0.02	0.016	0.012	0.0092	0.0076
Polychlorinated biphenyls (µg/L)								
PCB 1016	<0.5	<0.56	<0.5	<0.5	a	a	a	a
PCB 1221	<0.5	<0.56	<0.5	<0.5	a	a	a	a
PCB 1232	<0.5	<0.56	<0.5	<0.5	a	a	a	a
PCB 1242	<0.5	<0.56	<0.5	<0.5	a	a	a	a
PCB 1248	<0.5	<0.56	<0.5	<0.5	a	a	a	a
PCB 1254	<0.5	<0.56	<0.5	<0.5	a	a	a	a
PCB 1260	<0.5	<0.56	<0.5	<0.5	a	a	a	a
Miscellaneous (mg/L)								
pH (Units)	9.1	8.4	8.4	8.3	8.4	8.3	8.3	8.3
Total suspended solids	<1.1	<1.2	<2	2.5	12	14	14	5.0

(a) No sample required

A.7.2 Wet season monitoring data for releases from Lake Haussmann

	CDBX	CDBX	WPDC	WPDC
	Feb 16	Oct 11	Feb 16	Oct 11
Acute Toxicity (%)				
Fathead Minnow survival	(a)	100	100	100
Chronic Toxicity (%)				
Fathead Minnow survival	(a)	100	100	(a)
Fathead Minnow growth	(a)	100	100	(a)
Water Flea survival	(a)	100	(a)	(a)
Algae growth	(a)	100	(a)	(a)
General minerals (mg/L)				
Nitrate (as N)	(a)	5.6	(a)	(a)
Total Alkalinity (as CaCO3)	(a)	260	(a)	(a)
Nitrite (as N)	(a)	0.034	(a)	(a)
Total Metals (mg/L)				
Antimony	0.00045	<0.005	0.0013	0.00018
Arsenic	0.00096	0.00096	<0.002	<0.002
Beryllium	<0.0002	<0.0002	<0.0002	<0.0002
Boron	0.82	2.1	0.35	0.88
Cadmium	<0.0005	0.000095	0.0010	<0.0005
Chromium	0.0025	0.016	0.0046	0.014
Hexavalent Chromium	0.0021	0.0056	0.0017	0.0098
Copper	0.00087	0.0030	0.0037	0.0024
Iron	0.061	1.2	0.67	1.2
Lead	<0.005	0.00087	0.00051	0.00071
Manganese	0.0048	0.10	0.015	0.018
Mercury	<0.0002	<0.0002	0.000020	<0.0002
Nickel	0.0025	0.010	0.0029	0.0038
Selenium	0.0012	0.0039	<0.002	0.00083
Silver	<0.001	<0.001	<0.001	<0.001
Thallium	<0.001	<0.001	<0.001	<0.001
Zinc	<0.02	0.041	0.044	0.024
Volatile organic compounds (µg/L)				
Tetrachloroethene	<0.5	<0.5	(a)	(a)
Vinyl chloride	<0.5	<0.5	(a)	(a)
Polychlorinated biphenyls (µg/L)				
PCB 1016	<0.5	<0.5	(a)	(a)
PCB 1221	<0.5	<0.5	(a)	(a)
PCB 1232	<0.5	<0.5	(a)	(a)
PCB 1242	<0.5	<0.5	(a)	(a)
PCB 1248	<0.5	<0.5	(a)	(a)
PCB 1254	<0.5	<0.5	(a)	(a)
PCB 1260	<0.5	<0.5	(a)	(a)
Miscellaneous (mg/L)				
pH (Units)	8.5	8.6	7.9	8.3
Specific Conductance	a	1500	a	920
Total dissolved solids	510	650	210	630
Total organic carbon	3.7	3.8	6.1	a
Total suspended solids	<1.1	180	7.3	31
Chemical oxygen demand (mg O/L)	<25	23	29	(a)
Herbicides (µg/L)				
Bromocil	<0.5	<0.5	(a)	(a)
Diuron	<1.1	<1	<1	(a)

A.7.2 Wet season monitoring data for releases from Lake Haussmann

	CDBX	CDBX	WPDC	WPDC
	Feb 16	Oct 11	Feb 16	Oct 11
Glyphosate	<20	<25	29	(a)
Radioactive (Bq/L)				
Gross alpha	0.075 ± 0.059	0.150 ± 0.068	0.013 ± 0.030	(a)
Gross beta	0.075 ± 0.059	0.150 ± 0.068	0.013 ± 0.030	(a)
Tritium	0.075 ± 0.059	0.150 ± 0.068	0.013 ± 0.030	(a)

(a) No sample required

A.7.3 Tritium activities in rain water samples collected in the vicinity of the Livermore site, 2011[(a)]

Site Location	Feb 16	Feb 25	Feb 28	Oct 7
Livermore site				
SALV	-1.1 ± 2.0	(b)	1.5 ± 2.2	1.5 ± 2.9
MET	0.7 ± 2.2	1.6 ± 2.4	(b)	0.5 ± 2.6
DWTF	2.5 ± 2.5	4.8 ± 3.0	(b)	1.6 ± 2.6
SECO	-0.4 ± 2.0	1.2 ± 2.1	(b)	46 ± 10
Site 300				
ECP	(b)	(b)	(b)	-0.9 ± 2.7
PSTL	(b)	(b)	(b)	0.1 ± 2.8

(a) Nondetections of radioactive constituents are equal to or are less than the 2s uncertainty shown.
A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus.
(b) No sample taken

A.7.4 Radioactivity (Bq/L) in surface and drinking water in Livermore Valley, 2011[a]

Site Location	Date	Tritium	Gross alpha	Gross beta
Drinking waters				
GAS	1/20	0.87 ± 2.17	0.0293 ± 0.0246	0.0323 ± 0.0312
GAS	8/17	0.60 ± 2.55	0.0299 ± 0.0422	0.0414 ± 0.0448
TAP	1/20	-1.10 ± 1.91	0.01000 ± 0.00829	0.0063 ± 0.0139
TAP	8/17	0.20 ± 2.56	-0.01280 ± 0.00470	-0.0230 ± 0.0289
Surface waters				
CAL	8/17	-2.12 ± 1.91	0.0121 ± 0.0296	0.0253 ± 0.0367
DEL	8/17	0.59 ± 2.22	0.0103 ± 0.0243	0.0470 ± 0.0360
DUCK	8/17	0.59 ± 2.46	0.0359 ± 0.0444	0.0500 ± 0.0396
ALAG	8/17	-1.73 ± 1.90	0.0625 ± 0.0533	0.0699 ± 0.0437
SHAD	8/17	-1.17 ± 1.89	0.0142 ± 0.0332	0.1050 ± 0.0462
ZON7	8/17	-2.32 ± 1.82	0.0229 ± 0.0367	0.0374 ± 0.0381

(a) Nondetections of radioactive constituents are equal to or are less than the 2s uncertainty shown.
A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus.

A.8.1 Radionuclides in soils in the Livermore Valley, 2011

Area Location	Cesium-137	Potassium-40	Thorium-232	Uranium-235	Uranium-238	U235/U238	Gross alpha	Gross beta	Plutonium-238	Plutonium-239+240	Americium-241	Tritium (Bq/L)
Livermore Valley soil	(Bq/dry g)	(Bq/dry g)	(µg/dry g)	(µg/dry g)	(µg/dry g)	mass ratio (calculated)	(Bq/dry g)	(Bq/dry g)	(mBq/dry g)	(mBq/dry g)	(mBq/dry g)	(Bq/L)
L-AMON-SO	0.00280 ± 0.00023	0.5440 ± 0.0185	8.50 ± 0.20	0.0210 ± 0.0095	2.0 ± 1.7	0.010 ± 0.010	(d)	(d)	0.0028 ± 0.0017	0.085 ± 0.011	<0.96	(d)
L-CHUR-SO	0.00420 ± 0.00030	0.4920 ± 0.0148	8.60 ± 0.22	0.0200 ± 0.0090	2.4 ± 1.6	0.0083 ± 0.0067	(d)	(d)	0.0067 ± 0.0024	0.150 ± 0.018	<0.91	(d)
L-COW-SO	0.00049 ± 0.00020	0.4810 ± 0.0134	7.10 ± 0.23	0.0140 ± 0.0085	1.7 ± 1.6	0.0082 ± 0.0092	(d)	(d)	0.0021 ± 0.0015	0.0310 ± 0.0058	<0.75	(d)
L-ESB-SO	0.00086 ± 0.00025	0.4140 ± 0.0157	8.20 ± 0.20	0.0250 ± 0.0090	2.4 ± 1.1	0.0100 ± 0.0061	0.120 ± 0.083	0.31 ± 0.18	0.150 ± 0.017	1.50 ± 0.14	<0.92	10.0 ± 2.2
L-FCC-SO	0.00069 ± 0.00017	0.3700 ± 0.0119	6.60 ± 0.20	0.0150 ± 0.0094	1.6 ± 1.4	0.009 ± 0.010	(d)	(d)	0.0006 ± 0.0013	0.0250 ± 0.0054	<0.51	(d)
L-HOSP-SO	0.00150 ± 0.00024	0.36800 ± 0.00810	5.80 ± 0.13	0.0130 ± 0.0063	1.4 ± 1.2	0.0093 ± 0.0091	(d)	(d)	0.0034 ± 0.0017	0.0640 ± 0.0091	<0.58	(d)
L-MESQ-SO	0.00090 ± 0.00020	0.4700 ± 0.0150	6.80 ± 0.19	0.019 ± 0.010	2.6 ± 1.7	0.0073 ± 0.0061	(d)	(d)	0.0009 ± 0.0019	0.0340 ± 0.0062	<0.87	(d)
L-MET-SO	0.00140 ± 0.00023	0.5510 ± 0.0143	8.10 ± 0.21	0.022 ± 0.010	2.0 ± 1.0	0.0110 ± 0.0074	(d)	(d)	0.00063 ± 0.00097	0.0550 ± 0.0083	<0.81	(d)
L-NEP-SO	0.00150 ± 0.00019	0.4510 ± 0.0153	6.10 ± 0.15	0.0160 ± 0.0071	1.10 ± 0.83	0.015 ± 0.013	0.088 ± 0.073	0.10 ± 0.14	0.0029 ± 0.0018	0.087 ± 0.012	<0.55	4.5 ± 1.9
L-PATT-SO	0.00093 ± 0.00019	0.4770 ± 0.0105	7.40 ± 0.16	0.0180 ± 0.0074	1.6 ± 1.7	(g)	(d)	(d)	0.00072 ± 0.00089	0.0250 ± 0.0052	<1.9	(d)
L-SALV-SO	0.00140 ± 0.00020	0.39600 ± 0.00873	6.70 ± 0.13	0.0160 ± 0.0067	1.5 ± 1.9	(g)	0.110 ± 0.079	0.18 ± 0.16	0.0097 ± 0.0028	0.120 ± 0.014	<1.8	3.0 ± 1.8
L-TANK-SO	0.00220 ± 0.00018	0.3060 ± 0.0110	6.10 ± 0.13	0.0140 ± 0.0058	1.60 ± 0.80	0.0088 ± 0.0057	(d)	(d)	0.0029 ± 0.0020	0.099 ± 0.013	<0.53	(d)
L-VIS-SO	0.00100 ± 0.00020	0.3850 ± 0.0176	7.20 ± 0.22	0.019 ± 0.011	2.3 ± 2.4	(g)	0.100 ± 0.078	0.22 ± 0.17	0.0220 ± 0.0047	0.500 ± 0.050	<0.92	5.1 ± 2.0
L-ZON7-SO	0.00077 ± 0.00020	0.3850 ± 0.0146	8.20 ± 0.23	0.061 ± 0.011	7.8 ± 1.6	0.0078 ± 0.0021	(d)	(d)	0.0014 ± 0.0015	0.0410 ± 0.0073	<1	(d)
Median	0.0012	0.432	7.2	0.018	1.8	0.0093	0.11	0.20	0.0028	0.075	-	4.8
IQR	0.00063	0.0950	1.5	0.0055	0.77	0.0017	-	-	0.0049	0.079	-	-
Maximum	0.0042	0.551	8.6	0.061	7.8	0.015	0.12	0.31	0.15	1.5	<1.9	10
LWRP soil												
L-WRP1-SO	0.00380 ± 0.00029	0.4140 ± 0.0116	8.30 ± 0.20	0.0210 ± 0.0084	2.10 ± 0.98	0.0100 ± 0.0061	-	-	0.4400 ± 0.044	8.30 ± 0.77	2.90 ± 0.48	-
L-WRP3-SO	0.00041 ± 0.00021	0.3850 ± 0.0123	8.30 ± 0.23	0.020 ± 0.010	1.6 ± 1.0	0.012 ± 0.010	-	-	0.0290 ± 0.0054	0.580 ± 0.056	<0.78	-
L-WRP6-SO	0.00056 ± 0.00017	0.4510 ± 0.0153	8.10 ± 0.24	0.0190 ± 0.0073	2.10 ± 0.57	0.0090 ± 0.0043	-	-	0.0180 ± 0.0045	0.500 ± 0.050	<0.58	-
Median	(e)	(e)	(e)	(e)	(e)	(e)	(e)	(e)	(e)	(e)	(e)	(e)
IQR	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)	(f)
Maximum	0.0038	0.451	8.3	0.021	2.1	0.012	-	-	0.44	8.3	2.9	-

Note: Radioactivities are reported as the measured concentration and an uncertainty (± 2s counting error), or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See the *Environmental Report 2008,* Chapter 9.

(a) Thorium-232 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of thorium-232, i.e., 0.004044 Bq/µg or 0.1093 pCi/µg.

(b) Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of uranium-235, i.e., 0.080 Bq/µg or 2.16 pCi/µg.

provided in the table in µg/dry g by the specific activity of uranium-238, i.e., 0.01245 Bq/µg or 0.3367 pCi/µg.

(d) Analysis not required.

(e) Median not calculated because of small number of samples.

(f) Interquartile range not calculated because of small number of samples.

(g) Ratio not calculated when isotopic result less than its uncertainty.

A.8.2 Radionuclides and beryllium in soil at Site 300, 2011

Location	Cesium-137 (Bq/dry g)	Potassium-40 (Bq/dry g)	Thorium-232 (µg/dry g)	Uranium-235 (µg/dry g)	Uranium-238 (µg/dry g)	U235/U238 mass ratio (calculated)	Beryllium (mg/kg)
3-801N-SO	0.00095 ± 0.00018	0.4140 ± 0.0166	9.30 ± 0.19	0.0210 ± 0.0079	3.4 ± 1.1	0.0062 ± 0.0031	0.68
3-801W-SO	0.00140 ± 0.00026	0.43300 ± 0.00951	11.00 ± 0.19	0.0260 ± 0.0080	5.70 ± 0.93	0.0046 ± 0.0016	1.2
3-812N-SO	0.00130 ± 0.00025	0.3920 ± 0.0173	15.00 ± 0.39	0.250 ± 0.023	120.0 ± 9.0	0.00210 ± 0.00025	5.9
3-834W-SO	0.00320 ± 0.00026	0.42900 ± 0.00943	10.00 ± 0.18	0.0130 ± 0.0073	1.7 ± 1.2	0.0076 ± 0.0069	1.1
3-851N-SO	0.00120 ± 0.00018	0.4260 ± 0.0137	15.00 ± 0.32	0.028 ± 0.011	3.4 ± 1.5	0.0082 ± 0.0049	1.1
3-856N-SO	0.00160 ± 0.00019	0.3700 ± 0.0134	10.00 ± 0.29	0.023 ± 0.011	2.5 ± 1.5	0.0092 ± 0.0071	0.90
3-DSW-SO	0.00300 ± 0.00031	0.4400 ± 0.0167	9.50 ± 0.30	0.030 ± 0.011	3.1 ± 1.4	0.0097 ± 0.0056	0.55
3-EOBS-SO	0.00100 ± 0.00023	0.5070 ± 0.0173	11.00 ± 0.30	0.022 ± 0.013	2.6 ± 2.4	0.0085 ± 0.0093	0.78
3-EVAP-SO	0.00120 ± 0.00017	0.4140 ± 0.0141	11.00 ± 0.24	0.029 ± 0.010	3.8 ± 1.2	0.0076 ± 0.0036	0.66
3-NPS-SO	0.00290 ± 0.00025	0.5810 ± 0.0197	8.80 ± 0.28	0.022 ± 0.013	2.1 ± 1.3	0.0100 ± 0.0090	0.54
3-TNK5-SO	0.00130 ± 0.00025	0.4920 ± 0.0147	10.00 ± 0.25	0.018 ± 0.012	2.3 ± 1.9	0.0078 ± 0.0083	0.68
3-WOBS-SO	0.00350 ± 0.00029	0.4030 ± 0.0121	8.30 ± 0.23	0.0200 ± 0.0098	2.2 ± 1.1	0.0091 ± 0.0064	0.63
Median	0.0014	0.428	10	0.022	2.8	0.0080	0.73
IQR	0.0017	0.0418	1.6	0.0075	1.2	0.0019	0.45
Maximum	0.0035	0.581	15	0.25	120	0.010	5.9

Note: Radioactivities are reported as the measured concentration and an uncertainty (± 2s counting error), or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See the Environmental Report 2008, Chapter 9.

(a) Thorium-232 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of thorium-232, i.e., 0.004044 Bq/µg or 0.1093 pCi/µg.

(b) Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of uranium-235, i.e., 0.080 Bq/µg or 2.16 pCi/µg.

(c) Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of uranium-238, i.e., 0.01245 Bq/µg or 0.3367 pCi/µg.

A.9.1 Calculated dose from TLD environmental radiation measurements, Livermore site perimeter, 2011

Location [a]	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual Dose [b]
L-001-TD	0.138 ± 0.001	0.139 ± 0.006	0.142 ± 0.010	0.133 ± 0.011	0.552 ± 0.016
L-004-TD	0.143 ± 0.013	0.145 ± 0.003	0.152 ± 0.001	0.143 ± 0.004	0.583 ± 0.014
L-005-TD	0.151 ± 0.002	0.158 ± 0.006	0.162 ± 0.014	0.154 ± 0.010	0.625 ± 0.018
L-006-TD	0.147 ± 0.013	0.149 ± 0.008	0.169 ± 0.002	0.156 ± 0.013	0.621 ± 0.020
L-011-TD	0.138 ± 0.015	0.132 ± 0.005	0.147 ± 0.008	0.134 ± 0.006	0.551 ± 0.019
L-014-TD	0.134 ± 0.010	0.137 ± 0.010	0.145 ± 0.010	0.140 ± 0.005	0.556 ± 0.018
L-016-TD	0.130 ± 0.006	0.144 ± 0.010	0.148 ± 0.007	0.142 ± 0.010	0.564 ± 0.017
L-042-TD	0.134 ± 0.007	0.137 ± 0.012	0.146 ± 0.015	0.146 ± 0.010	0.563 ± 0.023
L-043-TD	0.130 ± 0.004	0.138 ± 0.006	0.144 ± 0.014	0.140 ± 0.008	0.552 ± 0.018
L-047-TD	0.123 ± 0.010	0.134 ± 0.004	0.142 ± 0.008	(c)	0.532 ± 0.017 [d]
L-052-TD	0.130 ± 0.003	0.138 ± 0.007	0.144 ± 0.006	(c)	0.549 ± 0.013 [d]
L-056-TD	0.136 ± 0.013	0.135 ± 0.008	0.144 ± 0.010	0.146 ± 0.016	0.561 ± 0.024
L-068-TD	0.136 ± 0.004	0.147 ± 0.006	0.151 ± 0.018	0.141 ± 0.006	0.575 ± 0.020
L-069-TD	0.134 ± 0.004	0.132 ± 0.007	0.148 ± 0.012	0.137 ± 0.009	0.551 ± 0.017
Mean [e]	0.136 ± 0.004	0.140 ± 0.004	0.149 ± 0.004	0.143 ± 0.004	0.567 ± 0.014

(a) See *Environmental Report 2011*, Figure 6-1 for location reference.

(b) The associated annual error is calculated as twice the rms location error.

(c) Data not available due to missing or damaged TLD.

(d) When TLD data is missing, the annual dose is calculated as four times the average of available quarterly data.

(e) The uncertainty associated with quarterly mean dose is represented by twice the Standard Error of the site-wide location averages.

A.9.2 Calculated dose from TLD environmental radiation measurements, Livermore Valley, 2011

Location [a]	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual Dose [b]
V-018-TD	0.108 ± 0.009	0.110 ± 0.003	0.119 ± 0.004	0.109 ± 0.003	0.446 ± 0.011
V-019-TD	0.132 ± 0.006	0.129 ± 0.012	0.143 ± 0.002	0.137 ± 0.010	0.541 ± 0.017
V-022-TD	0.139 ± 0.006	0.146 ± 0.005	0.158 ± 0.005	0.144 ± 0.006	0.587 ± 0.011
V-024-TD	0.147 ± 0.010	0.154 ± 0.004	0.150 ± 0.007	0.144 ± 0.014	0.595 ± 0.019
V-027-TD	0.124 ± 0.007	0.132 ± 0.010	-	0.144 ± 0.009	0.533 ± 0.020
V-028-TD	0.126 ± 0.004	0.133 ± 0.005	0.140 ± 0.007	0.135 ± 0.010	0.534 ± 0.014
V-030-TD	0.136 ± 0.002	0.143 ± 0.003	0.151 ± 0.009	0.146 ± 0.014	0.576 ± 0.017
V-032-TD	0.136 ± 0.009	0.142 ± 0.004	0.152 ± 0.003	0.139 ± 0.015	0.569 ± 0.018
V-033-TD	0.137 ± 0.001	0.152 ± 0.005	0.157 ± 0.012	0.147 ± 0.006	0.593 ± 0.014
V-035-TD	0.126 ± 0.004	0.134 ± 0.008	0.143 ± 0.004	0.129 ± 0.004	0.532 ± 0.011
V-037-TD	0.140 ± 0.005	0.145 ± 0.009	0.146 ± 0.003	0.159 ± 0.057	0.590 ± 0.058
V-045-TD	0.132 ± 0.008	0.135 ± 0.005	0.153 ± 0.007	0.149 ± 0.006	0.569 ± 0.013
V-057-TD	0.148 ± 0.008	0.144 ± 0.004	0.162 ± 0.009	0.158 ± 0.004	0.612 ± 0.013
V-060-TD	0.140 ± 0.002	(c)	0.135 ± 0.006	0.145 ± 0.007	0.560 ± 0.012 [d]
V-066-TD	0.136 ± 0.014	0.147 ± 0.023	0.155 ± 0.003	0.146 ± 0.008	0.584 ± 0.028
V-070-TD	0.142 ± 0.034	0.143 ± 0.011	0.148 ± 0.005	0.137 ± 0.004	0.570 ± 0.036
V-072-TD	0.156 ± 0.007	0.168 ± 0.008	0.168 ± 0.011	0.157 ± 0.004	0.649 ± 0.016
V-074-TD	0.127 ± 0.011	0.126 ± 0.004	0.139 ± 0.006	0.126 ± 0.011	0.518 ± 0.017
V-075-TD	0.118 ± 0.006	0.112 ± 0.009	0.117 ± 0.007	0.114 ± 0.021	0.461 ± 0.025
V-076-TD	0.134 ± 0.006	(c)	0.149 ± 0.002	0.132 ± 0.005	0.553 ± 0.011 [d]
V-077-TD	0.127 ± 0.002	0.141 ± 0.002	0.144 ± 0.013	0.133 ± 0.006	0.545 ± 0.015
V-122-TD	0.150 ± 0.010	0.160 ± 0.014	0.165 ± 0.005	0.166 ± 0.012	0.641 ± 0.022
Mean [e]	0.135 ± 0.005	0.140 ± 0.006	0.147 ± 0.006	0.141 ± 0.006	0.562 ± 0.021

(a) See Environmental Report 2011, Figure 6-2 for location reference.

(b) The associated annual error is calculated as twice the rms location error.

(c) Data not available due to missing or damaged TLD.

(d) When TLD data is missing, the annual dose is calculated as four times the average of available quarterly data.

(e)The uncertainty associated with quarterly mean dose is represented by twice the Standard Error of the site-wide location averages.

A.9.3 Calculated dose from TLD environmental radiation measurements, Site 300 vicinity, 2011

Area Location [(a)]	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual Dose [(b)]
Tracy					
3-092-TD	0.146 ± 0.010	0.149 ± 0.008	0.161 ± 0.012	0.150 ± 0.010	0.606 ± 0.020
3-093-TD	0.154 ± 0.009	0.159 ± 0.022	0.174 ± 0.014	0.158 ± 0.006	0.645 ± 0.028
Mean	0.150 ± 0.008	0.154 ± 0.010	0.168 ± 0.013	0.154 ± 0.008	0.625 ± 0.039
Other off-site					
3-090-TD	0.160 ± 0.018	0.179 ± 0.017	0.192 ± 0.011	0.176 ± 0.016	0.707 ± 0.031
3-099-TD	0.144 ± 0.006	0.145 ± 0.014	0.155 ± 0.008	0.147 ± 0.017	0.591 ± 0.024
Mean [(e)]	0.152 ± 0.016	0.162 ± 0.034	0.173 ± 0.037	0.161 ± 0.029	0.649 ± 0.116

(a) See Environmental Report 2011, Figure 6-3 for location reference.
(b) The associated annual error is calculated as twice the rms location error.
(c) Data not available due to missing or damaged TLD.
(d) When TLD data is missing, the annual dose is calculated as four times the average of available quarterly data.
(e) The uncertrepresented by twice the Standard Error of the site-wide location averages.

A.9.4 Calculated dose from TLD environmental radiation measurements, Site 300 perimeter, 2011

Location [a]	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual Dose [b]
3-078-TD	0.150 ± 0.003	0.141 ± 0.007	0.157 ± 0.014	0.154 ± 0.004	0.602 ± 0.016
3-081-TD	0.163 ± 0.005	0.164 ± 0.017	0.189 ± 0.009	0.168 ± 0.011	0.684 ± 0.023
3-082-TD	0.158 ± 0.014	(c)	0.176 ± 0.008	0.165 ± 0.011	0.665 ± 0.027 [d]
3-085-TD	0.144 ± 0.004	(c)	0.169 ± 0.012	0.159 ± 0.007	0.629 ± 0.019 [d]
3-086-TD	0.156 ± 0.006	0.168 ± 0.011	0.179 ± 0.009	0.165 ± 0.008	0.668 ± 0.017
3-088-TD	0.159 ± 0.012	0.156 ± 0.002	0.179 ± 0.016	0.160 ± 0.007	0.654 ± 0.021
3-089-TD	0.162 ± 0.013	0.183 ± 0.005	0.198 ± 0.004	0.185 ± 0.006	0.728 ± 0.016
3-091-TD	0.152 ± 0.010	0.175 ± 0.010	0.183 ± 0.008	0.176 ± 0.017	0.686 ± 0.024
3-121-TD	0.175 ± 0.019	0.179 ± 0.005	0.198 ± 0.016	0.176 ± 0.016	0.728 ± 0.030
Mean [e]	0.158 ± 0.006	0.167 ± 0.011	0.181 ± 0.009	0.168 ± 0.007	0.672 ± 0.028

(a) See Environmental Report 2011, Figure 6-3 for location reference.

(b) The associated annual error is calculated as twice the rms location error.

(c) Data not available due to missing or damaged TLD.

(d) When TLD data is missing, the annual dose is calculated as four times the average of available quarterly data.

(e) The uncerts represented by twice the Standard Error of the site-wide location averages.