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Lawrence Livermore National Laboratory

Environmental Report 2010

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Lawrence Livermore National Laboratory

Environmental Report 2010

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Subject: 2010 Annual Site Environmental Report for the Lawrence Livermore National Laboratory

The Annual Site Environmental Report was prepared by the Lawrence Livermore National Laboratory (LLNL) for the Department of Energy/National Nuclear Security Administration (NNSA)/Livermore Site Office. This report provides a comprehensive summary of the environmental program activities at LLNL for Calendar Year 2010. This report is prepared annually and is made available to relevant regulatory agencies and other interested organizations and individuals.

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.

Remediation activities continue to reduce contaminants at LLNL, and environmental monitoring of emission sources indicates compliance with environmental regulations.

LLNL continues to show commitment to protecting the environment by implementation of its Environmental Management System, which provides the framework for integrating environmental protection into its work planning processes.

Sincerely,

Heather Larson

Heather Larson
Assistant Manager for
Environment, Safety and Health

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Preface

The purposes of the *Lawrence Livermore National Laboratory Environmental Report 2010* 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 Protection Department. Submittal of the report satisfies requirements under DOE Order 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, 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 discuss the radiological impact on the public from LLNL operations (Chapter 7), LLNL's groundwater remediation program (Chapter 8), and quality assurance for the environmental monitoring programs (Chapter 9).

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, Debbie Stockdale, Suzanne Chamberlain, Nancy Blankenship, Connie Wells, Lisa Graves, Della Burruss, Beth Schad and Susan Lambaren. Special thanks to Rosanne Depue for helping with distribution.

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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 conducts 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 2010 the Laboratory had a staff of approximately 6400.

Purpose and Scope of the Environmental Report

The purposes of the *Environmental Report 2010* 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 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, 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 2010, LLNL had 8 active Lab-wide EMPs and initiatives on significant aspects, including waste generation, energy use, and cultural and ecological resource disturbance.

Pollution Prevention

A strong Pollution Prevention (P2) Program is an essential supporting element of LLNL's EMS. The P2 Program encompasses lab-wide environmental stewardship, including metrics and reporting on waste generation, environmentally preferable purchasing and resource conservation.

P2 promotes employee awareness through an internal website as well as through onsite and community outreach events.

Each year, the P2 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 operation.

In FY 2010, LLNL received three Environmental Stewardship awards: one in the NNSA Waste/Pollution Prevention category for the LLNL Ferrite Core and Power Conditioning Equipment Recovery and another for the NNSA Sustainable Design/Green Building category for water conservation efforts for the LLNL Water Conservation Test Bed project.

The third award the P2 Program received the California Integrated Waste Management Board's 2010 WRAP award. The WRAP 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.

P2 Program outreach events in 2010 included participation in the community Earth Day event sponsored by the City of Livermore and the Livermore Area Recreation and Park District, articles in the LLNL newspaper, training for Procurement staff, and maintenance of an internal P2 website.

Air Monitoring

LLNL operations involving radioactive materials had minimal impact on ambient air during 2010. 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 2010, radioactivity released to the atmosphere was monitored at six facilities on the Livermore site and one at Site 300. In 2010, 1339 GBq (36.2 Ci) of tritium was released from the Tritium Facility, and 44.4 GBq of tritium (1.2 Ci) was released from the Decontamination and Waste Treatment Facility and 14.9 GBq of tritium (0.403 Ci) was released from the National Ignition Facility (NIF). The Contained Firing Facility at Site 300 had 3737 Bq (101 nCi) of depleted uranium released in particulate form in 2010. None of the other facilities monitored for gross alpha and gross beta radioactivity had emissions in 2010.

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 2010 for the Livermore site and Site 300 were similar to 2009 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 2010, 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 2010, 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 2010, monitoring data under the LLNL Wastewater Permit #1250 (2010–2011) 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 2010, 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 28% 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 2010 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 1.9% 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 2010, 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 2010, 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 2010 was less than 1.2% of the drinking water standard.

LLNL's extensive network of thermoluminescent dosimeters measures the natural terrestrial and cosmogenic background; in 2010, as in recent years, no impact from LLNL operations was detected.

Biota

Through monitoring and compliance activities in 2010, 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 2010. Measures taken at the Livermore site to control bullfrogs, which are a significant threat to California red-legged frogs, included dispatching adults, removing egg masses, and allowing part of Arroyo Las Positas to dry out in November 2010. As in previous years, Site 300's invasive species control efforts have been focused largely on dispatching feral pigs, animals that threaten red-legged frog habitat.

The 2010 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 2010 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 2010 was 0.11 µSv (0.011 mrem) for the Livermore site and 5.7×10^{-6} µSv (5.7×10^{-7} 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 2010, concentrations continued to decrease in most of the Livermore site VOC plumes due to active remediation and the removal of more than 98.9 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 2010 and limited progress was made toward interior plume and source area clean up.

In 2010 at Site 300, perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 13 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 cleanup remedy for Building 850/Pit7 Complex OU was completely implemented in 2010, and the CERCLA pathway for the remaining OU is being negotiated with the regulatory agencies.

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 2010 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 6400, 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 7.2 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 6.7 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 2010 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 2010.

	Livermore Site		Site 300	
Temperature	**°C**	**°F**	**°C**	**°F**
Mean daily maximum	20.7	69.3	19.9	67.8
Mean daily minimum	8.4	47.2	11.9	53.5
Average	14.1	57.4	15.6	60.1
High	39.5	103.1	39.1	102.5
Low	–2.0	28.3	0.8	33.5
Rainfall	**cm**	**in.**	**cm**	**in.**
Total for 2010	40.2	15.8	38.5	15.1
Climatological normal[(a)]	34.8[(b)]	13.68[(b)]	27.3	10.76
Wind	**m/s**	**mph**	**m/s**	**mph**
Average speed	2.3	5.1	5.5	12.3
Peak gust speed	22.3	50.0	30.6	68.4

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

(b) Based on the mean, 1981–2010

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.

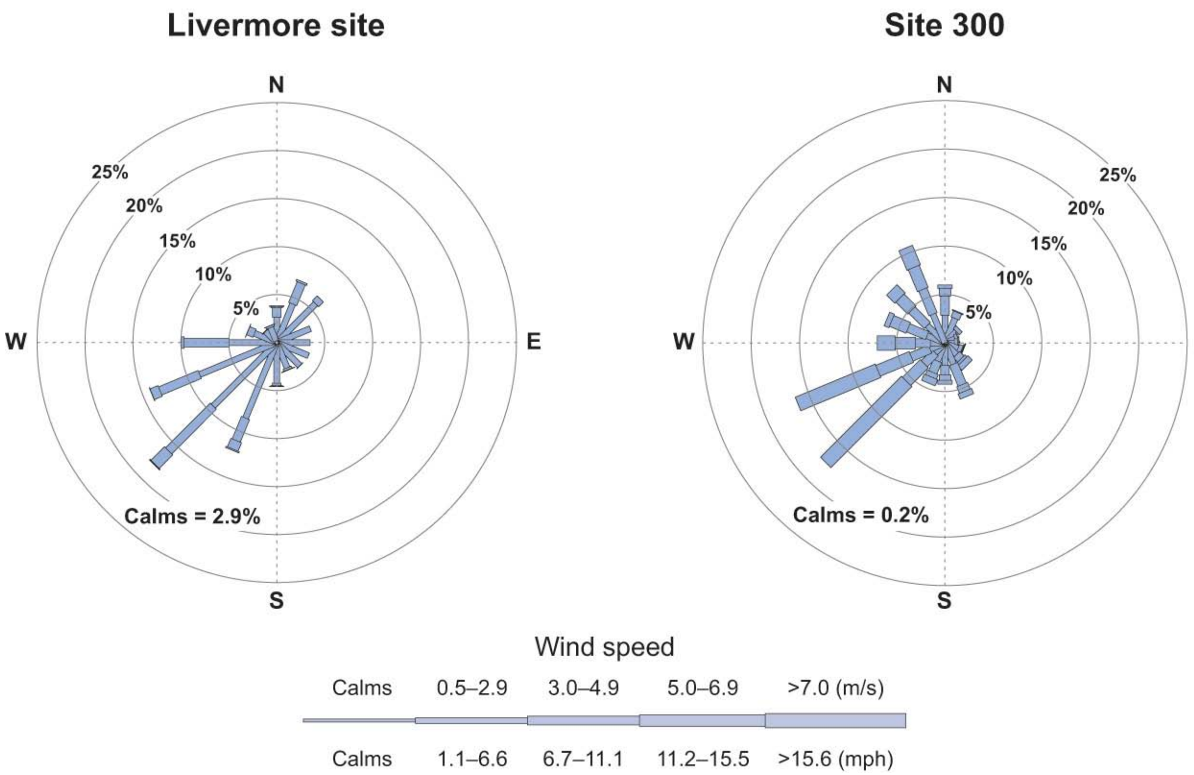

Figure 1-2. Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2010. The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes.

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.

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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 2010. **Table 2-1** is a summary of active permits in 2010 at the Livermore site and Site 300. **Table 2-2** lists environmental inspections and findings from them at both LLNL sites in 2010.

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 trichloroethene (TCE) and perchloroethylene (PCE).

During 2010, the Remedial Project Managers signed a Consensus Statement for Environmental Restoration of the Livermore site that included 19 Federal Facility Agreement milestones. The Livermore site environmental restoration project had 13 milestones scheduled for completion in 2010. The following deliverables were submitted to the regulatory agencies:

- Draft, Draft Final, and Final Work Plan for the Delineation of Mercury in Soil at the Building 212 Facility
- Fourth Quarter 2009 Self Monitoring Report

- 2009 Annual Report
- Plan for TFD Helipad *in situ* Bioremediation Treatability Test
- First, Second, and Third Quarter 2010 Self Monitoring Report
- Draft Focused Feasibility Study (FFS) for TF5475-1, TF5475-3, VTF5475 and TF518 North

The other regulatory milestones included:

- Receive regulatory comments on Draft Work Plan for the Delineation of Mercury in Soil at the Building 212 Facility
- Restart VTF518-PZ in current configuration (pre-upgrades)
- Neighborhood Meeting on the Treatment Facility A West Construction
- Receive regulatory comments on Draft FFS

All calendar year 2010 milestones were met.

During 2010, the Livermore site initiated three enhanced source area remediation (ESAR) treatability tests: (1) pneumatic fracturing at the Treatment Facility E Hotspot; (2) bioremediation at the Treatment Facility D Helipad; and (3) enhanced thermal remediation at the Treatment Facility E Eastern Landing Mat. The results of these treatability tests could potentially accelerate cleanup at the Livermore site. The pneumatic fracturing treatability test is scheduled for completion in 2011 while the bioremediation and thermal heating treatability tests are scheduled for completion in 2012.

In addition to these treatability studies, the Livermore site conducted extensive direct-push cone penetration testing (CPT) surveys to better delineate the Building 518 Perched Zone and Building 511/Building 419 source areas.

During 2010, six dual extraction wells, two ground water extraction wells, three soil-vapor extraction wells, and nine monitor wells were installed at the Livermore site. In addition, 90 obsolete wells in the Treatment Facility A Vadose Zone Observatory and Treatment Facility 406 Gas Pad areas were properly sealed. See Buscheck et al. (2011) for additional information on the current status of cleanup at the Livermore site.

Treatment Facilities. During 2010, the Livermore GWP maintained 29 groundwater and 9 soil vapor treatment facilities. The groundwater extraction wells and dual phase extraction wells extracted about 1,052 million L of groundwater during 2010. The dual-phase extraction wells and soil-vapor extraction wells together removed 1.7 million m^3 of soil vapor.

In 2010, the Livermore GWP treatment facilities removed about 98.9 kg of VOCs. Since remediation efforts began in 1989, more than 15.5 billion L of groundwater and approximately 12 million m^3 of soil vapor have been treated, removing about 2,876 kg of VOCs.

Community Relations. Livermore site community relations activities in 2010 included communication and meetings with neighbors (for example, the Neighborhood Meeting on the Treatment Facility A West Construction held in October 2010) and 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 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). 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.

Table 2-1. Active permits in 2010 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 13 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 2176.5 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 product storage tanks.	One operating permit covering three underground petroleum product 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 2-1 (cont.). Active permits in 2010 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 nonstorm 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 2010.

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 2-2. Inspections of Livermore site and Site 300 by external agencies in 2010

Site	Medium	Description	Agency	Date	Finding
Livermore site	Waste	Hazardous waste facilities Compliance Evaluation Inspection (CEI)	DTSC	6/21/10–6/23/10, and 6/29/10	Two minor violations and one Class I violation were issued. The first minor violation was issued for failure to include Hazardous Waste Report Management Method Codes on three manifests observed during the inspection, and the second minor violation was issued for failure to note a discrepancy when LLNL received hazardous waste accompanied by a manifest. The Class I violation was issued for LLNL's failure to inspect for and remedy the presence of beryllium contamination in the ductwork at Building 695, Room 1025. (Note: DTSC rescinded violations 1 & 3 per DTSC letter dated March 9, 2011.)
		Medical Waste Inspection	ACDEH	3/17/10	No violations
		Waste Tire Inspection	ACDEH	4/28/10	No violations

Table 2-2. (cont) Inspections of Livermore site and Site 300 by external agencies in 2010

	Air	Air pollutant emission sources	BAAQMD	1/21/10 2/24/10 3/25/10 4/29/10** 6/24/10 7/21/10 8/26/10* 9/30/10 11/17/10	No violations *A “Notice To Comply” was issued 8/30/10; one boiler was missing the required “Tune-up” record for CY2009. The boiler was in compliance as of CY2010 and at the time of inspection on 8/26/10. No further action was required. ** Two inspections occurred on April 29, 2010, one for the two permitted fuel dispensing facilities, and one for 14 other permitted and permit-exempt stationary sources.
		Asbestos	BAAQMD	4/20/10 5/20/10	No violations
		Synthetic Minor Operating Permit (SMOP)	BAAQMD	1/21/10 2/24/10 3/25/10 4/29/10 6/24/10 7/21/10 8/26/10 9/30/10 11/17/10	No violations
	Sanitary sewer	Categorical sampling/inspection Building 153 and Building 321C.	WRD	10/20/2010	No violations
		Annual compliance sampling at the Sewer Monitoring Complex	WRD	10/21/2010	No violations
		Building 432–Optic and Target Fabrication Shop Review	WRD	11/8/2010	No violations
		Building 581–Operational Support (OSB) of National Ignition Facility (NIF)	WRD	11/16/2010	No violations
		Café grease interceptor inspections, Buildings 123 and 471	WRD	11/10/2010	No violations

Table 2-2. (cont)

	Storage tanks	Compliance with underground storage tank requirements and operating permits	ACDEH	9/7/2010 9/14/2010	Three violations. 1) Designated Operator who performed monthly inspections did not possess the correct certification. LLNL hired a contractor who possessed the correct certification to perform the monthly inspections until LLNL staff were trained and certified and could resume this inspection function. 2) The company that services the cathodic protection system was not notified per the operating procedure when the system current went out of range. LLNL developed a Cathodic Protection Inspection Procedure that included a Compliance Criteria that defines the requirements for notification. The Compliance Criteria was posted on the cathodic protection panel. 3) Facility Employees for USTs were not trained by a certified Designated Operator. LLNL hired a contractor who possessed the correct certification to perform the training of the Facility Employees until LLNL staff were trained and certified and could resume this training function.
	Pesticides	Pest control records inspections	ACCDA	(a)	No violations.
Site 300	Waste	Permitted hazardous waste operational facilities: EWTF, EWSF (Building 816 and Magazine 2), Building 883 CSA and WAA. Hazardous waste generator areas: Buildings 801, 805, and 875. Review of hazardous waste-related documentation.	US EPA Region IX	6/24/2010	No violations were issued as a result of the 6/24/2010 inspections in the 8/27/2010 EPA Warning Letter and Return to Compliance. However, three potential violations were identified. 1) At Building 875, an empty aerosol can of brake parts cleaner was observed in a garbage can. The liquid product formerly in the empty container meets the RCRA hazardous waste characteristic of ignitability when declared a waste. However, the remaining propellant was carbon dioxide (CO2) which is not a hazardous waste. This information was not clearly documented at the time of the inspection so the can was removed from the garbage can. The potential violation was identified as "storage of hazardous waste without a permit" pursuant to 22 CCR 66262.34. The waste containers were removed from the metal cabinet and transferred to a waste storage area in compliance with 22 CCR 66262.34. No further follow up action was required. 2) Outside Building 875, two open containers which were labeled only as "compressor condensate" with small amounts of liquid inside were observed in a metal cabinet. The containers were not clearly identified as non-hazardous wastewater, although the compressor condensate is not a regulated hazardous waste. The potential violation was identified as "storage of hazardous waste without a permit" pursuant to 22 CCR 66262.34(c). The waste containers were removed from the metal cabinet and transferred to a waste storage area in compliance with 22 CCR 66262.34. No further follow up action was required. 3) Outside Building 875, one spent lead-acid vehicle battery was observed in a battery recycling storage container without the receipt date written on the battery. The potential violation was identified as "failure to properly manage lead-acid batteries" pursuant to 22 CCR 66266.81. The date the battery was received into the storage container was immediately written on the battery. Additionally, the battery terminals were taped with electrical tape. No further follow up action was required.

Table 2.2 (cont)

	Permitted hazardous waste operational facilities EWSF (Magazines 816, 2, 3, 4, and 5), Building 829 post-closure facility, EWTF (Control Room, Detonation Pad, Burn Pan, Burn Cage, one-year storage units by the Detonation Pad and Burn Units, Building 883 CSA, Building 883 WAA, Building 875 outside areas [former waste storage cabinet and current lead acid vehicle battery recycling storage container]) and a review of hazardous waste-related documentation.	DTSC	11/30/2010 12/1/2010	One minor violation was issued for failing to include the "Hazardous Waste Report Method Codes" [Handling Codes(s)] in field #19 on manifest # 00016789, which is required under 22 CCR 66564.71(a)(2)(b). The manifest was corrected on the same day that the "Summary of Violations" notice was issued. The final inspection report, dated 2/3/11, acknowledges the corrective action. No further follow up action was required.
	Hazardous waste generator areas: Building 899 Armory, Building 801 Contained Firing Facility, Building 875 Heavy Equipment, Building 883 WAA, Building 805 Process Area, Building 879 Fleet Management, and Building 874 Machine Shop.	San Joaquin County, Environmental Health Department, Certified, Unified Program Agency (CUPA).	3/31/2010	Two violations were issued: 1.Building 875 Heavy Equipment. Antifreeze that was declared as hazardous waste was observed in a secondary containment pallet. The violation was identified as a failure to maintain spill control equipment pursuant to 22 CCR 66265.33. The violation was corrected by removing the liquid, managing the liquid and paper wipes as hazardous waste and removing all liquid from the pallet prior to returning to service. The corrective actions and "Return to Compliance" Certification was submitted to San Joaquin CUPA on 4/26/2010. No further follow up action was required. 2. Universal Waste battery shipments from LLNL Site 300 to LLNL Livermore Site occurred without maintaining a record of each shipment at LLNL Site 300. The regulation cited was 22 CCR 66373.39. The violation was corrected by implementing a Universal Waste Battery Shipment Log for all Universal Waste battery shipments from LLNL Site 300 to LLNL Site 200 (Livermore site). The corrective action was described in the same "Return to Compliance" Certification submittal to San Joaquin CUPA on 4/26/2010. No further follow up action was required. Two non-compliance issues were described on the CUPA Inspection Report as "Notes:" 1. Outside Building 801 Container Firing Facility, four empty 55-gallon drums did not have the "emptied date" written on each drum. The issue was corrected during the inspection by writing the date the drums were emptied on each drum. The applicable regulation would be 22 CCR 66261.7(f). No further follow up action was required. 2. The Building 883 WAA Contingency Plan did not include the current phone number for the San Joaquin County Office of

Table 2.2 (cont)

					Emergency Services. The issue was corrected by writing the current phone number in the contingency plan. The applicable regulation would be 22 CCR 66265.52. No further follow up action was required.
	Air	Air pollutant emission sources	SJVAPCD BAAQMD	5/04/10 6/15/10 6/21/10	No violations
	Water	Permitted operations	CVRWQCB	4/29/2010	No violations
	Storage tanks	Compliance with underground storage tank requirements and operating permits	SJCEHD	8/30/2010	Two violations. 1) UST leak detector was not installed all the way to the bottom, so it would not detect a leak at the earliest opportunity. During the inspection the licensed contractor lowered the leak-detector probe to the bottom of the interstitial space so that it could detect a leak at the earliest opportunity. 2) Line leak detector did not pass the annual test until it was adjusted during the inspection and then passed.

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

(a) Inspection for 2010 records occurred 1/25/2010

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. See Dibley et al. (2011) for the current status of cleanup progress.

The Site 300 ERP milestones scheduled for 2010 were the submittal of the Draft, Draft Final, and Final Building 812 Proposed Plan and Draft Amendment to the Site-Wide Record of Decision for the Building 812 OU. The Building 812 milestones scheduled for completion in 2010 were put on hold while the CERCLA path forward for the Building 812 OU was renegotiated with the regulatory agencies. The regulatory agencies have agreed that additional characterization of the environmental contamination in the Building 812 OU is necessary before selecting a remedy. The characterization is scheduled for 2011 and 2012. The regulatory agencies also agreed to postpone the Proposed Plan and Draft Amendment to the Site-Wide Record of Decision for the Building 812 OU. A new schedule for these deliverables is being developed in concert with the regulators.

Treatment Facilities. During 2010, 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 36.7 million L of groundwater during 2010. The dual-phase extraction wells and soil-vapor extraction wells together removed 2.3 million m^3 of soil vapor.

In 2010, the Site 300 treatment facilities removed nearly 13 kg of VOCs, 0.12 kg of perchlorate, 1,400 kg of nitrate, 0.15 kg of the high explosive compound RDX, 0.0061 kg of silicone oils (TBOS/TKEBS), and 0.0078 kg of uranium in 2010. Since ground water remediation began in 1990, approximately 1,461 million L of ground water and over 16 million m^3 soil vapor has been treated, resulting in removal of more than 550 kg of VOCs, 1.0 kg of perchlorate, 9,400 kg of nitrate, 1.5 kg of RDX, 9.5 kg of silicone oils, and 0.0078 kg of uranium.

Remediation efforts in the Eastern GSA have successfully reduced concentrations of trichloroethylene (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. Environmental Protection Agency (EPA), Regional Water Quality Control Board (RWQCB), and California Department of Toxic Substances Control (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 2010. The Eastern GSA will begin the fifth year of post-shut monitoring in February 2011.

Community Relations. The Site 300 CERCLA Project maintains continuing communications with the community of Tracy and nearby neighbors. Community relations activities in 2010 included maintenance of information repositories and an administrative record; tours of site environmental activities; offsite, private, well-sampling activities; mailings to stakeholders; and providing responses to public and news media inquiries. LLNL hosted TAG meetings with Tri-Valley CAREs to provide a forum for focused discussions on CERCLA activities at Site 300.

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 2-3.**

Table 2-3. Compliance with EPCRA.

EPCRA section	Brief description of requirement	LLNL action
302	Notify SERC of presence of extremely hazardous substances.	Originally submitted 5/87.
303	Designate a facility representative to serve as emergency response coordinator.	Update submitted 1/28/09 to San Joaquin County for Site 300 and 2/27/09 to Alameda County for Livermore site. No changes for 2010.
304	Report releases of certain hazardous substances to SERC and LEPC.	No EPCRA-listed extremely hazardous substances were released above reportable quantities in 2010.
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 undisclosed hazardous material subject to Section 312 inventory requirements.
312	Submit hazardous chemical inventory to local administering agency (county).	Submitted to San Joaquin and Alameda counties on 1/29/10 and 3/1/10, 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 6/22/10; DOE forwarded it to U.S. EPA and California EPA 7/1/10.

On June 22, 2010, 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) 2009. 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 2009 TRI Form R for lead at Site 300 was submitted to DOE/NNSA on June 22, 2010. Over the past few years, the lead releases have decreased due to increased use of frangible bullets.

2.1.3 California Accidental Release Prevention (CalARP) Program

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 September 2009 to cover new processes that would be handling hydrofluoric acid above state threshold quantities. The Livermore site RMP now 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 Buildings 625, 693, 695, and 696 of 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

2009/2010, LLNL submitted several 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 Health Services (DHS) 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 EPD, 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 5400.5. 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 17 milestones during 2010, and of those, 4 had due dates in 2011.

LLNL requested and was granted an extension for one additional milestone to allow LLNL time to develop new procedures and work control documents for 0.0189 m^3 of waste.

LLNL removed approximately 53 m^3 of mixed waste from LLNL in 2010. An additional 51 m^3 of newly generated mixed waste was accepted into the approved storage facilities and added to the STP, reflecting an overall reduction of 2 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. All TSCA-regulated waste was disposed of in accordance with TSCA, state, and local disposal requirements with one exception. Radioactive polychlorinated biphenyl (PCB) waste is currently stored at one of LLNL's hazardous waste storage facilities until an approved facility accepts this waste for final disposal.

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 2010, LLNL operated 183 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 2010, LLNL also registered 38 natural gas boilers with the BAAQMD and maintained registrations for 83 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). California requires mandatory reporting of stationary-source air emissions from combustion of natural gas that exceed 25,000 metric tons per year of CO_2 equivalent emissions. For the previous three mandatory reporting years (CY2008, CY2009,and CY2010), 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 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. Beginning in CY2011, research facilities, such as LLNL, must submit an annual report describing the research uses of SF_6 and the measures taken to control the SF_6 emissions. LLNL must also report the amount of SF_6 contained in electrical switchgear and the amount of SF_6 that leaks from that switchgear.

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 2010 Annual Report* (Wilson et al. 2011), submitted to EPA, reported that the estimated maximum radiological doses that could have been received by a member of the public in 2010 were 0.11 μSv (0.011 mrem) for the Livermore site and 0.0000057 μSv (0.00000057 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 2-1**). 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 2010, no EISs or EAs were completed for LLNL. One categorical exclusion was completed: Mobile Hydrogen-Fueling Station and Use of Hydrogen Buses at LLNL. In 2010, DOE/NNSA also started preparation of a Supplement Analysis (SA) of the 2005 SWEIS, which will consider if the SWEIS should be supplemented, a new SWEIS should be prepared, or no further NEPA documentation is required. The SA will examine changes in programs, projects, or operations since the 2005 SWEIS; 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 will include two public informational meetings scheduled for April 2011.

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

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 consultation with the State Historic Preservation Officer (SHPO), DOE/NNSA formally determined that five archaeological resources, five individual buildings, two historic districts (encompassing 13 historic buildings), and selected objects in one 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 appendices. These plans describe specific resource management and treatment strategies that DOE/NNSA, in cooperation with LLNL, could implement to ensure that significant historic properties are managed in a manner that considers their historic value. As of the end of 2010, SHPO was still reviewing the draft PA and treatment plans.

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 2010.

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. LLNL works with regulators to protect special-status species. For example, on February 10, 2010, LLNL received an amendment to *The Arroyo Maintenance Project on Arroyo Las Positas at Lawrence Livermore National Laboratory Biological Opinion* from the U.S. Fish and Wildlife Service. This amendment describes potential impacts to California red-legged frogs that may occur during maintenance activities throughout the Livermore site. Additional conservation measures for the protection of California red-legged frogs during maintenance activities are also included.

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 Occurrences

Notification of environmental occurrences is required under a number of environmental laws and regulations as well as DOE Order 231.1A and DOE Manual 231.1-2. Table 2-4 provides a list of environmental incidents reportable under DOE Order 231.1A and DOE Manual 231.1-2 reporting requirements.

Table 2-4. Environmental Occurrences reported under the Occurrence Reporting System in 2010.

Date[a]	Occurrence category/ group	Description
3/31/10	Significance Category SC4 Occurrence under Group 9(2) OR 2010-0017	LLNL received a Notice of Violation (NOV) from the SJCEHD during the CUPA inspection of Site 300. The NOV identified two violations: 1) a small amount of antifreeze was observed in the secondary containment for product storage in B-875. 2) failure to keep records for the shipment of universal waste (used batteries). On March 31, 2010, antifreeze in the secondary containment pallet was removed immediately following the agency inspection. On April 1, 2010, the Site 300 Manager made announcements at the Site 300 Plan-of-the-Day and Plan-of-the-Week meetings that the current procedure (which uses LLNL in-house mail services) to mail universal waste batteries to the Livermore Site Battery Shop should be immediately discontinued. (Note: Since the Occurrence, LLNL has implemented a “Universal Waste Battery Shipment Log” that complies with the universal waste recordkeeping requirements in 22 CCR 66273.39.)
6/29/10	Significance Category SC4 Occurrence under Group 9(2) OR 2010-0026	LLNL initially received three violations from DTSC during the 2010 CEI: 1) one Class I violation for LLNL’s alleged failure to inspect and remedy for the presence of Beryllium contamination in ductwork at its hazardous waste facility, 2) one minor violation for missing waste handling codes on three manifests, and 3) one minor violation for LLNL’s alleged failure to record information on one manifest about a partially rejected shipment. DTSC rescinded violations 1 and 3, per DTSC’s letter dated March 9, 2011.
8/26/10	Significance Category SC4 Occurrence under Group 9(2) OR 2010-0040	LLNL received a Notice to Comply from the BAAQMD during a routine inspection for failure to complete an annual inspection and tune up for one boiler that had been tagged “out of service.” The next time the boiler is fired up, a "tune up" is necessary to comply with the BAAQMD Regulation 9, Rule 7.
8/30/10	Significance Category SC4 Occurrence under Group 9(2) OR 2010-0041	LLNL received a Notice of Violation (NOV) from the SJCEHD during the underground storage tank inspection of Site 300. The NOV identified two violations: 1) the secondary containment leak detection equipment on one tank was not properly adjusted to detect a leak at the earliest possible opportunity, 2) a mechanical line leak detector failed to detect a leak when tested. Both violations were corrected at the time of the inspection, and no response actions were required by the SJCEHD.
8/31/10	Significance Category SC4 Occurrence under Group 9(2)	LLNL received a NOV from the EPA for findings discovered during a hazardous waste compliance inspection of Site 300 conducted on

Date(a)	Occurrence category/ group	Description
	OR 2010-0042	6/24/10. The NOV identified three “potential” violations: 1. A mostly empty aerosol can of brake cleaner in a garbage can was found inside the heavy equipment area of B-875. 2. Two open, undated containers in/around B-875, which contained only small amounts of liquid waste, were labeled only as “compressor condensate” 3. A used lead-acid battery located in a storage container in the heavy equipment maintenance area in/around B-875 was not dated. (Note: Two of the potential violations were corrected at the time of the inspection. With regards to violation 1, the facility representative removed the aerosol can of brake cleaner from the garbage and placed the container in a nearby flammable storage locker. With regards to violation 3, the facility representative marked the date on the battery, covered the terminals with electrical tape, and relocated the battery to the appropriate storage container. Finally, documented proof including pictures was subsequently provided to EPA to show that the containers were emptied, dated, and properly disposed of.)
9/14/10	Significance Category SC4 Occurrence under Group 9(2) OR 2008-0048	LLNL received a NOV from the ACDEH for the underground storage tank inspection conducted on 9/7/10 and 9/14/10. Three violations were identified: 1) the individual performing monthly tank inspections did not have the correct certification. 2) Facility employees for USTs were not trained by a certified Designated Operator. 3) The tank cathodic corrosion protection equipment was below the minimum compliance range for four tanks, and the service company was not notified. Resolution is pending.
12/7/10	Significance Category SC4 Occurrence under Group 9(2) OR 2010-0060	LLNL received a minor violation from the DTSC during the CEI inspection at Site 300 conducted 11/30/10 through 12/1/10. One minor violation was identified: a hazardous waste manifest was missing the appropriate waste handling code. The hazardous waste manifest was corrected on the same day the "Summary of Violations" notice was issued.

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

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3. Environmental Program Information

Jennifer Doman, 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 the lead organizations that support LLNL's environmental stewardship and describes LLNL's Environmental Management System (EMS) and Pollution Prevention/Sustainability Program (P2S).

3.1 Environmental Protection Program

Three organizations lead the environmental protection program and provide environmental expertise to the Laboratory: Environmental Functional Area (EFA), Radioactive and Hazardous Waste Management (RHWM) Division, and Environmental Restoration Department (ERD). Spill response and energy, water, and fleet management are also key components of environmental protection and sustainability.

3.1.1 Environmental Functional Area

EFA is responsible for environmental monitoring and environmental regulatory interpretation and implementation guidance in support of LLNL's programs. EFA prepares and maintains environmental plans, reports, and permits; maintains the environmental portions of the *Environment, Safety, and Health* (*ES&H) Manual*; informs management about pending changes in environmental regulations pertinent to LLNL; represents LLNL in day-to-day interactions with regulatory agencies and the public; develops and provides institutional environmental training; and assesses the effectiveness of pollution control programs. A principal part of EFA's mission is to work with LLNL programs to ensure that operations are conducted in a manner that limits environmental impact and is in compliance with regulatory requirements. The LLNL EMS is managed within EFA through the EMS Team, which has representatives from each Principal Directorate and the Director's Office.

3.1.2 Radioactive and Hazardous Waste Management Division

RHWM manages all hazardous, radioactive, and mixed wastes generated at LLNL facilities in accordance with local, state, and federal requirements. RHWM processes, stores, packages, treats, and prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer. As part of its waste management activities, RHWM tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas (WAAs), which are typically located near the waste generator, to final disposition; develops and implements approved standard operating procedures; decontaminates LLNL equipment; ensures that containers for shipment of waste meet the specifications of the U.S. Department of Transportation (DOT) and other regulatory agencies; responds to emergencies; and participates in the cleanup of potential hazardous and radioactive spills at LLNL facilities. RHWM prepares numerous reports in support of its mission including those required by regulation and various guidance and management plans.

RHWM meets regulations for the treatment of LLNL's mixed waste in accordance with the requirements of the FFCA. The schedule for this treatment is negotiated with California and involves utilizing on-site treatment options as well as finding off-site alternatives.

3.1.3 Environmental Restoration Department

ERD evaluates and remediates soil and groundwater contaminated by past hazardous materials handling and disposal practices and from leaks and spills that have occurred at the Livermore site and Site 300 prior to and during LLNL operations. ERD conducts field investigations at both sites to characterize the existence, extent, and impact of contamination. ERD evaluates and develops various remediation technologies, makes recommendations, and implements actions for site restoration. ERD is responsible for managing remedial activities, such as soil removal and ground water and soil-vapor extraction and treatment, and for decontamination, decommissioning, and demolition of closed facilities in a manner that prevents environmental contamination and completes the facility life cycle. As part of its responsibility for CERCLA compliance issues, ERD plans, directs, and conducts assessments to determine both the impact of past releases on the environment and the restoration activities needed to reduce contaminant concentrations to protect human health and the environment.

3.1.4 Response to Spills and Other Environmental Emergencies

LLNL has an active spill response program to investigate and evaluate all spills and leaks (releases) at LLNL that are potentially hazardous to the environment. During working hours, incidents can be reported to the EPD environmental analysts supporting program areas or the LLNL Fire Dispatch for investigation and response. Off-hour incidents are reported to Fire Dispatch which notifies the Environmental Duty Officer (EDO) and the on-site Fire Department if required. The EDO, who is available 24 hours a day, seven days a week, maximizes efficient and effective emergency environmental response. The EDO and environmental analysts also notify and consult with LLNL management and have seven-day-a-week, 24-hour-a-day access to the Office of Laboratory Counsel for questions concerning regulatory reporting requirements.

3.1.5 Energy, Water and Fleet Management

The Facilities and Infrastructure Directorate implements Laboratory-wide programs for energy and water conservation, fleet management, high performance sustainable building, and renewable energy. These programs are designed to meet the requirements of DOE Order 430.2B, Departmental Energy, Renewable Energy and Transportation Management. The programs contribute to environmental protection through implementation of lab-wide reduction initiatives.

3.2 Environmental Management System

LLNL established its EMS to meet the requirements of International Organization for Standardization (ISO) 14001:1996 in June 2004. In 2006, LLNL enhanced its EMS to meet the requirements of ISO 14001:2004, and developed a number of Environmental Management Plans (EMPs) to address lab-wide significant environmental aspects. In October 2009, LLNL successfully achieved ISO 14001:2004 registration and has subsequently demonstrated continuous improvement through ongoing system enhancements and successful completion of two external surveillance audits.

3.2.1 Environmental Management Plans

In 2010, LLNL environmental aspects were re-evaluated and seven new institutional EMPs were implemented to address significant environmental aspects affected (or potentially affected) by Laboratory operations. An eighth EMP is currently being implemented to address environmental aspects associated with the use of hazardous materials and generation of hazardous waste. Previous directorate and institutional EMPs were closed; incomplete tasks from the previous EMPs were carried over to the new EMPs as appropriate.

The new institutional EMPs have been re-designed to increase focused efforts toward achieving measurable environmental objectives and targets and provide for continuous improvement. The new EMP template utilizes a two-part format: Part A documents senior management's commitment to high-level objectives and targets; Part B incorporates several project management elements to identify required resources, milestones, and timeframes. Part B also enhances progress reporting by providing a means of tracking task completion within the form. Contributory tasks and accomplishments can be added as they occur, allowing LLNL to recognize employee grass-roots and unplanned efforts in improving environmental stewardship. **Table 3-1** is a list of the active EMPs managed for LLNL through the EMS.

Table 3-1. Environmental Management Plans (EMP)

Title	Significant Aspect(s) Addressed	EMP Objective(s)
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 implement best purchasing practices
Municipal Waste Reduction	Municipal Waste Generation	Optimize use of printer/copier supplies and reduce municipal waste through recycling
Greenhouse Gas Emissions Reductions	Greenhouse Gas Emissions	Reduce LLNL greenhouse gas emissions through management of SF6 and fleet
Energy Conservation	Electrical Energy Use Greenhouse Gas Emissions Fossil Fuel Consumption	Meet or exceed DOE O 430.2B and EO 13514 energy conservation goals
Water Conservation	Water Use	Meet or exceed Performance Evaluation Plan (PEP) 7.5.3, DOE O 430.2B and EO 13514 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
Radioactive Materials use	Radioactive Materials Use	Reduce significantly the amount of radioactive materials on-site in accordance with PEP 7.3.1

3.2.2 EMS Audits and Reviews

The Laboratory successfully completed two external independent audits of its ISO 14001 EMS program (April 26-29 and September 7-10) with recommendations from the auditor to continue LLNL's ISO 14001:2004 registration. These independent audits were conducted by NSF International Strategic Registrations, an internationally recognized ISO auditor, and validated the Laboratory's strong commitment to environmental stewardship.

3.2.2.2 Internal Assessments and Reviews

In May 2010, 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 evaluated through reviews of internal assessments including Management Self Assessments; Management Observations, Verifications and Inspections (MOVIs); and walk-throughs and work-control assessments. In addition external agency inspections, assessments, and audits are considered in conjunction with the compliance and monitoring reports that are submitted to the various regulatory agencies. As a result of these reviews LLNL has identified areas for continuous improvement in the management of LLNL's environmental requirements. All the issues identified in these reviews have been corrected and LLNL continues to maintain its commitment to environmental compliance.

3.3 Pollution Prevention/Sustainability Program

LLNL's P2S Program (formerly known as Pollution Prevention, or P2) 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 PS2 Program supports institutional and directorate P2S activities via environmental teams, including implementation and facilitation of source reduction and/or reclamation, recycling, and reuse programs for hazardous and nonhazardous waste; facilitation of environmentally preferable procurement; and preparation of P2S opportunity assessments.

The P2S Program at LLNL strives to systematically reduce all types of waste generated and to 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 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.

3.3.1 Routine Hazardous, Transuranic, and Radioactive Waste

Routine waste listed in **Table 3-2** includes waste from ongoing operations produced by any type of production, analysis, and research and development taking place at LLNL.

Table 3-2. Routine hazardous waste at LLNL, FY 2007–2010.

Waste category	FY 2007	FY 2008	FY 2009	FY 2010
Routine hazardous waste generated (MT)	138	248	159	116

Table 3-3. Routine transuranic and radioactive waste at LLNL, FY 2010.

Waste category	FY 2009[(a)]	FY 2010
Routine low-level waste generated (m^3)	203.5	211.2
Routine mixed waste generated (m^3)	24.6	21.0
Routine TRU/mixed TRU waste generated (m^3)	9.4	0.6

(a) In FY 2009, a new volumetric calculation and reporting method was put in place for transuranic and radioactive wastes.

3.3.2 Diverted Waste

LLNL maintains an active waste-diversion program, encouraging recycling and reuse of both routine and nonroutine waste. During 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.

3.3.2.1 Municipal Solid Waste

Together, the Livermore site and Site 300 generated 2875 MT of routine nonhazardous solid waste in FY 2010. This volume includes diverted waste (e.g., material diverted through recycling and reuse programs) and landfill waste.

Both sites combined diverted a total 1991 MT of routine nonhazardous waste in FY 2010, which represents a diversion rate of 69%. The diverted routine nonhazardous waste includes waste recycled by RHWM and materials diverted through the surplus sales program. The portion of routine nonhazardous waste sent to landfill was 884 MT. See **Table 3-4**.

In 2010, LLNL transferred or donated for reuse 59 laptops and desktop computers and recycled 5,075 computers, monitors, and laptops, which were managed as universal waste.

LLNL recycled 55 MT of large and small batteries, which were also managed as universal waste.

Table 3-4. Routine municipal waste in FY 2010, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2010 (MT)
Diverted	Baled paper	51
	Beverage containers	5
	Corrugated Cardboard	104
	Cooking grease	13
	Mixed metals	911
	Office paper	165
	Tires and scrap	12
	Toner cartridges	10
	Greenwaste (chips, compost, mulch)	720
	TOTAL diverted	**1991**
Landfill	Compacted (landfill)	884
	TOTAL landfill	**884**
TOTAL routine nonhazardous waste		**2875**

3.3.2.2 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 5638 MT of waste related to construction and demolition activities in FY 2010.

In FY 2010, the two sites combined diverted 4601 MT of nonroutine nonhazardous solid waste through reuse or recycling, which represents a diversion rate of 82%. 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 2010, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2010 (MT)
Diverted	Class II cover soil (reused at landfill)	2802
	Class II concrete (reused at landfill)	1767
	Scrap metals (recycled)	32
	TOTAL diverted	**4601**
Landfill	Construction and demolition (noncompacted landfill)	1037
	TOTAL landfill	**1037**
TOTAL nonroutine nonhazardous waste		**5638**

(a) RHWM Waste Data Management System

3.3.3 Environmentally Preferable Purchasing

LLNL has a comprehensive Environmentally Preferable Purchasing (EPP) program that includes preferential purchasing of recycled content and biobased products. In 2010, the EPP program continued to include a preference for Electronic Product Environmental Assessment Tool (EPEAT) registered products. 69 % of all desktop electronics purchases in FY 2010 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.

3.3.4 Pollution Prevention/Sustainability Activities

3.3.4.1 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. In 2010, LLNL received three Environmental Stewardship awards.

The LLNL Ferrite Core and Power Conditioning Equipment Recovery project won in the Waste/Pollution prevention category for the reuse of over 800 ferrite cores and 50,000 pounds equipment from a decommissioned facility. Reusing the cores in another project saved over $2 million and diverted approximately 39,000 pounds of waste from the municipal waste stream.

The LLNL Water Conservation Test Bed project won an NNSA Environmental Stewardship award in the Sustainable Design/Green Building category and a DOE honorable mention for its water conservation efforts. The 3.5-acre Water Conservation Test Bed conserves the use of potable domestic water and includes an automated landscape water management feature to transport rainwater collected from a non-industrial rooftop to underground storage tanks for use in landscape irrigation. The volume of rainwater to be collected is expected to be between 90,000 and 210,000 gallons annually. The system design allows for future expansion to other nearby sources so that ultimately no potable water will be needed for irrigation.

The P2S Program received the California Integrated Waste Management Board's 2010 Waste Reduction Award Program (WRAP) award for recycling accomplishments during the 2009 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 third consecutive year that LLNL has won the WRAP award.

3.3.4.2 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 purpose and 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. In FY 2009 and FY2010, LLNL continued to expand green cleaning lab-wide, with the goal to implement green cleaning at all applicable locations.

Also in FY 2009, two existing buildings (EB) at the Livermore site were awarded USGBC LEED-EB Operations and Maintenance certification. Building 142 received Silver certification and LLNL's Terascale Simulation Facility (TSF) received a Gold certification. The Terascale Simulation Facility also won a 2009 DOE/NNSA Federal Energy Management Program award for its two-year effort to conserve energy in TSF computer rooms and is estimated to save $2.4 million annually in energy costs.

Another datacenter/office mixed-use building, Building 451, was submitted for USGBC LEED-EB Operations and Maintenance certification review in early FY11.

3.3.5 Pollution Prevention Employee Training and Awareness Programs

In 2010, LLNL partnered with Sandia National Laboratory California (Sandia/CA) for Earth Day. Jointly, the two sites conducted a number of activities to promote employee awareness of pollution prevention.

LLNL partnered with Sandia/CA to hold a recycled art contest for employees from both sites. Contest winners were announced during an onsite Earth Day event held at the LLNL central cafeteria. Also featured on Earth Day was a green business fair, including many vendors from LLNL's small business program.

Pollution prevention staff and volunteers from LLNL and Sandia/CA participated in the Livermore community Earth Day event. The event was sponsored by the City of Livermore and the Livermore Area Recreation and Park District, and included a community cleanup and a festival. Volunteer employees from LLNL and Sandia/CA staffed a table at the festival, which included a recycled art display. Information on LLNL, Sandia/CA and pollution prevention was also distributed to festival attendees.

The P2S Program conducted other awareness activities during the year. Articles on pollution prevention appeared in *Newsline* (the LLNL newspaper) and *NewsOnLine*. The P2S Program continues to conduct training for purchasing staff on Environmentally Preferable Purchasing 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, ask questions about PS2 planning and implementation, and find out about P2S current events.

The 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 • 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 5400.5; 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 5400.5.

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 2010, 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.

In 2010, a total of 1339 GBq (36.2 Ci) of measured tritium was released from the stack exhausts at the Tritium Facility. Of this, approximately 99% of tritium was released as vapor (HTO). The remaining 1% released was gaseous tritium (HT).

The DWTF released a total of 44.4 GBq (1.2 Ci) of measured tritium from the stack exhaust. The tritium released was approximately 76% vapor (HTO) and 24% gaseous tritium (HT).

The National Ignition Facility (NIF) released a total of 14.9 GBq (0.403 Ci) of measured tritium from the stack exhaust in 2010. A total of 3.8 GBq (0.104 Ci) was released as vapor (HTO), 11.1 GBq (0.299 Ci) as gaseous (HT), and 2.6×10^{-6} GBq (6.9×10^{-8} Ci) of tritiated particulate.

The Contained Firing Facility (CFF) at Site 300 had measured depleted uranium stack emissions in 2010. A total of 4.8×10^{-7} GBq (1.3×10^{-8} Ci) of uranium-234, 3.4×10^{-8} GBq (9.2×10^{-10} Ci) of uranium-235, and 3.2×10^{-6} GBq (8.7×10^{-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 2010. The data tables in **Appendix A, Section A.1** provide summary results of all air effluent monitored facilities and include upwind locations (control stations) 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 3.3×10^{-2} µSv/y (3.3×10^{-3} mrem/y); the dose from the DWTF (modeling HT emissions as HTO) was 3.8×10^{-4} µSv/y (3.8×10^{-5} mrem/y); the dose from the NIF (modeling HT emissions as HTO) was 7.5×10^{-5} µSv/y (7.5×10^{-6} mrem/y), and the dose from the CFF was 5.7×10^{-6} µSv/y (5.7×10^{-7} mrem/y).

All of the reported SW-MEI doses at the Livermore site and Site 300 are less than one-tenth of 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 2010 Annual Report* (Wilson et al. 2011) for a complete description of air effluent monitoring.

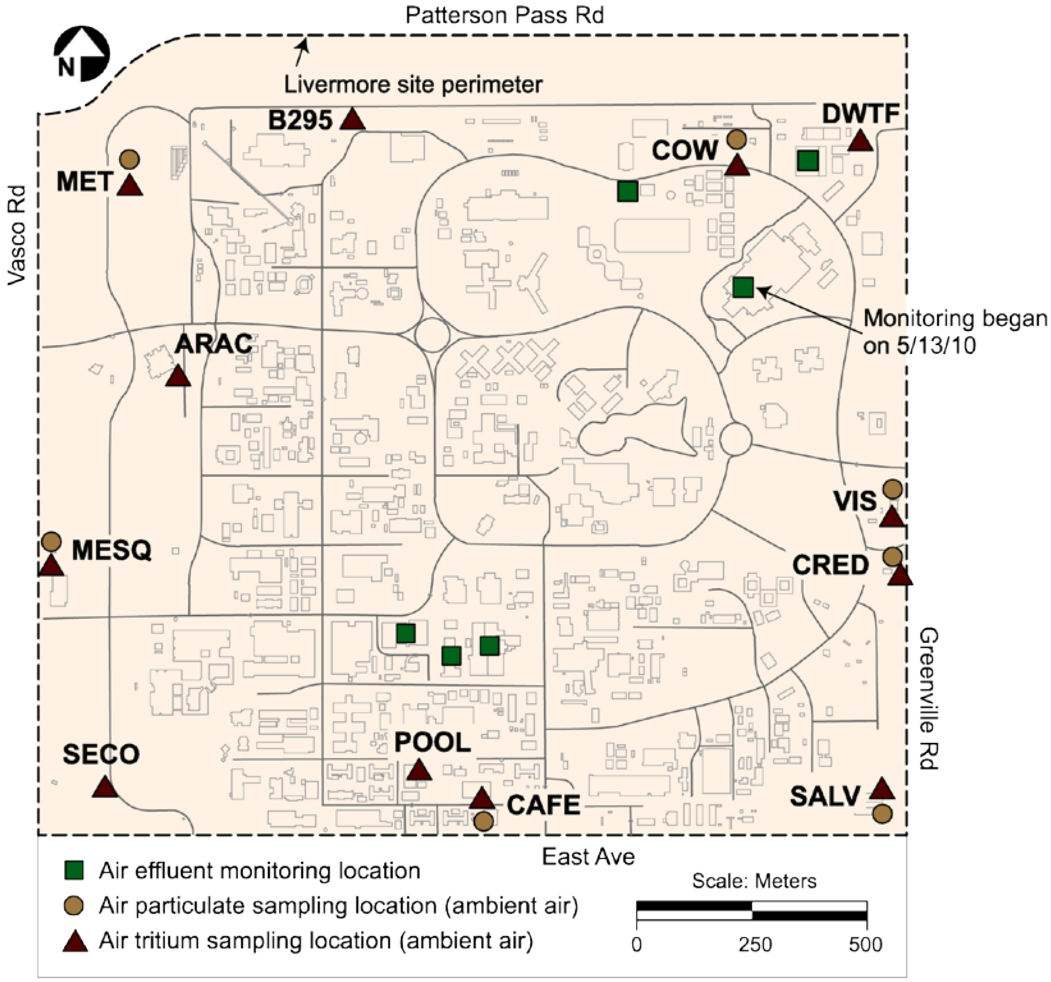

Figure 4-1. Air effluent and ambient air monitoring locations at the Livermore site, 2010.

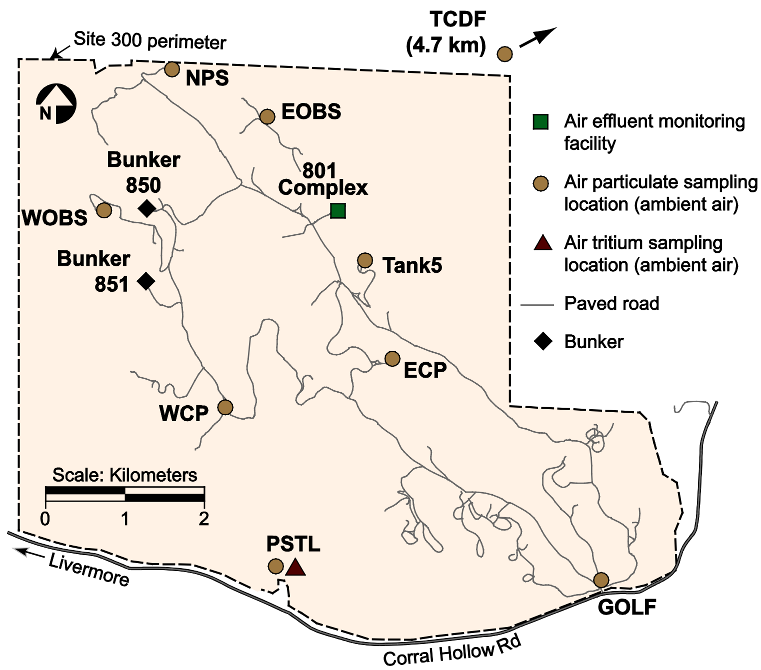

Figure 4-2. Air effluent and ambient air monitoring locations at Site 300, 2010.

4.1.2 Nonradiological Air Releases and Impact on the Environment

In 2010, the Livermore site emitted approximately 111 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, 2010.

	Estimated releases (kg/d)	
Pollutant	**Livermore site**	**Site 300**
ROGs/POCs	9.8	0.34
Nitrogen oxides	52.5	1.35
Carbon monoxide	43.1	0.29
Particulates (PM-10)	4.4	0.34
Sulfur oxides	1.4	0.11
Total	111.2	2.43

Livermore site air pollutant emissions were very low in 2010 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 3.76×10^5 kg/d, compared to the estimated daily release from the Livermore site of 52.5 kg/d, which is 0.014% of total Bay Area source emissions for NOx. The 2010 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was 2.83×10^5 kg/d, while the daily emission estimate for 2010 from the Livermore site was 9.8 kg/d, or 0.003% 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 2010 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 machine shop operations. Combustion pollutant emissions, such as NOx, CO, and SOx, decreased in 2010 primarily from the reduced usage of diesel-powered generators.

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 guides (DCGs) in DOE Order 5400.5 specify 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**.

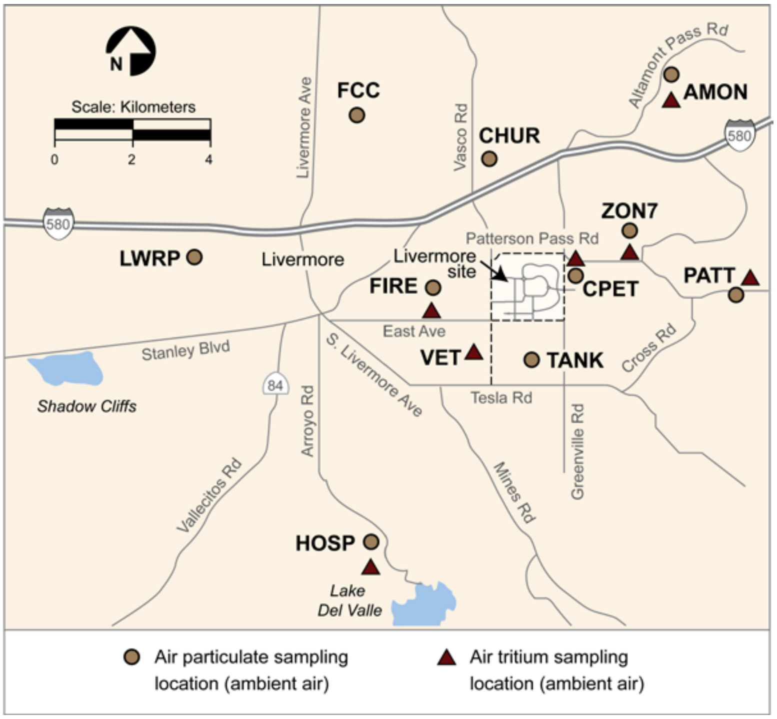

Figure 4-3. Air particulate and tritium monitoring locations in the Livermore Valley, 2010.

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 in 2010 were beryllium-7 (cosmogenic), lead-210, radium-226, and potassium-40, all of which are naturally occurring in the environment.

Composite samples were analyzed by alpha spectroscopy for plutonium-239+240, which was detected in 11 out of 216 samples taken in 2010. 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 DCG for the plutonium-239+240 detections were as follows:

- Livermore site perimeter: 69.2 nBq/m^3 (1.87 aCi/m^3); 0.0094% of the DCG
- Livermore off-site locations: 26.8 nBq/m^3 (0.72 aCi/m^3); 0.0036% of the DCG
- Site 300 composite: 6.14 nBq/m^3 (0.17 aCi/m^3); 0.00083% of the DCG

Plutonium-239+240 detections at Site 300 are calculated to be from resuspended fallout from historic aboveground nuclear testing. Site 300 does not use or store plutonium on site.

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 2010 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 DCG 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 very 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.

Table 4-2. Air tritium sampling summary for 2010.

Sampling locations	Detection frequency	Concentration (mBq/m^3)				Median % DCG[(a)]	Mean Dose (nSv)
		Mean	Median	IQR	Maximum		
Livermore site perimeter	286 of 309	143	91.4	117	2340	0.0025	30.1
Livermore Valley	122 of 182	52.8	23.4	47.9	966	0.00063	11.1
Site 300	5 of 26	2.86	3.58	14.3	30.2	0.000097	<5

(a) DCG = derived concentration guide of 3.7×10^6 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 2010 for airborne beryllium was 22 pg/m^3. This value is only 0.22% 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 2010 was 12 pg/m^3 and the highest value at the off-site location was 14 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 2010. 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 (DCG).

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 2010, the Livermore site discharged an average of 0.98 million L/d (260,000 gal/d) of wastewater to the City of Livermore sewer system or 3.7% 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 2010, Sandia/California generated approximately 26% 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, 2009/2010 and 2010/2011) 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 complementary (rather than overlapping) sections of the DOE Order 5400.5 and 10 CFR Part 20.

For sanitary sewer discharges, DOE Order 5400.5 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 DCGs) 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 5400.5 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 2010 combined release of alpha and beta sources was 0.23 GBq (0.006 Ci), which is 0.6% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The tritium total was 1.47 GBq (0.04 Ci), which is 0.9 % of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

Table 5-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2010.

Radioactivity	Estimate based on effluent activity (GBq)	Limit of sensitivity (GBq)
Tritium	1.47	0.71
Gross alpha	0.004	0.04
Gross beta	0.23	0.04

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 0.05 Bq/mL (1.36 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 2010 Report (Jones 2011). Cesium and plutonium results are from monthly composite samples of LLNL and LWRP effluent and from quarterly composites of LWRP sludge. For 2010, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCGs. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The highest plutonium concentration observed in 2010 sludge is 0.33mBq/g (0.009 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.

The historical levels for plutonium-239 observed in effluent since 2000 averaged approximately 1 μBq/mL (3×10^{-5} pCi/mL). The historical levels are generally 0.0003% of the DOE DCG for plutonium- 239. The highest plutonium and cesium concentrations are well below DOE DCGs.

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 2010, a total of 1.47 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, 2000–2010[(a)]

Year	Tritium (GBq)	Plutonium-239 (GBq)
2000	5.0	0.96×10^{-4}
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}

(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 2010 sanitary sewer effluent monitoring program are provided in **Appendix A**, **Section A.3**.)

During 2010, 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 2009 results. In **Table 5-3**, the 2010 maximum concentration for each metal is shown and compared with the EPL. These maximum values did not exceed 10% of their respective EPLs for seven of the nine regulated metals. Arsenic, with maximum values of 27% of its EPL, and copper, with maximum values that were 18% of its EPL weekly composite concentrations, were comparable to 2009 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, 2010.

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	61	96	77	N/A
	Solids (mg/L)							
	Total dissolved solids	12 of 12	1	None Specified	170	920	265	N/A
	Total suspended solids	12 of 12	1	None Specified	34	100	59	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	36 of 52	0.0020	0.06	<0.002	0.016	0.0023	27
	Cadmium	0 of 52	0.0050	0.14	<0.005	<0.005	n/a	<3.6
	Chromium	1 of 52	0.010	0.62	<0.01	0.01	<0.01	1.6
	Copper	52 of 52	0.010	1.0	0.023	0.18	0.034	18
	Mercury	0 of 52	0.00020	0.01	<0.0002	<0.0002	n/a	<2.0
	Nickel	5 of 52	0.0050	0.61	<0.005	0.0063	<0.005	1
	Lead	19 of 52	0.0020	0.20	<0.002	0.013	<0.002	6.5
	Zinc	39 of 52	0.050	3.00	<0.05	0.15	0.058	5

(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 2010, LLNL did not exceed either of these discharge limits. Results from the monthly TTO analyses for 2010 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**, **Section A.3**, 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 (<0.03 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 current year), which is administered by the WRD.

The processes at LLNL that are defined as categorical change as programmatic requirements dictate. During 2010, the WRD identified 15 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 2010, only two of the 15 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 2010, 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 2010 and January 2011 semiannual wastewater reports (Grayson et al. 2010, 2011).

The remaining 13 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.

As required in LLNL's wastewater discharge permit #1250, LLNL demonstrated compliance with permit requirements by semiannual sampling and reporting in 2010. In addition, WRD source control staff performed their required annual inspection and sampling of the two discharging categorical processes in October 2010. The compliance samples were analyzed for all regulated parameters, and the results demonstrated compliance with all federal and local pretreatment limits.

5.1.3 Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2009–2010) 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 2010, a total of 69,591 L (18,384 gal) of treated groundwater were discharged to the sanitary sewer. Of this entire volume, approximately 20% was associated with GWP sampling operations at well W-404, and 80% resulted from a discharge at Portable Treatment Unit-12. LLNL did not discharge groundwater from any other location to the sanitary sewer during 2010. All discharges were in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in Revelli (2011a).

5.1.4 Environmental Impact of Sanitary Sewer Effluent

During 2010, 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 2010 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 2010.

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 2010 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 2010).

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 5400.5. **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 2010 that their facilities complied with the provisions of LLNL's SWPPPs. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Revelli 2010a) and to the CVRWQCB (Revelli 2010b) 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 runoff monitoring network consists of nine sampling locations (see **Figure 5-1**). LLNL collected samples at eight of the nine locations on February 23, 2010. One location, ALPO, could not be sampled because there was no flow through that upstream location. Because stormwater seasons run from fall through spring, stormwater sampling events, which should occur twice during each stormwater season, may occur as often as four times to as rarely as not at all in any given calendar year. Only one complete set of storm water samples was collected at the Livermore site during calendar year 2010 because the first major storm of the 2009-2010 water year occurred on October 13, 2009, and there were no major storms during the last quarter of 2010 that were sampled for the 2010-2011 water year. Fish toxicity tests (both acute and chronic) are typically performed using the runoff samples from the first storm of the water year. Samples from the October 13, 2009 storm were used to perform acute toxicity testing; however due to pathogen-related mortality in the control group, the contract laboratory was unable to complete the chronic fish toxicity test using these samples. The contract laboratory failed to run the requested chronic toxicity test on samples collected during the February 23, 2010 storm, so LLNL collected samples from a subsequent storm (April 20, 2010) to fulfill the 2009–2010 water year requirement for chronic fish toxicity testing. No issues were identified in the results from either the acute or chronic toxicity analysis.

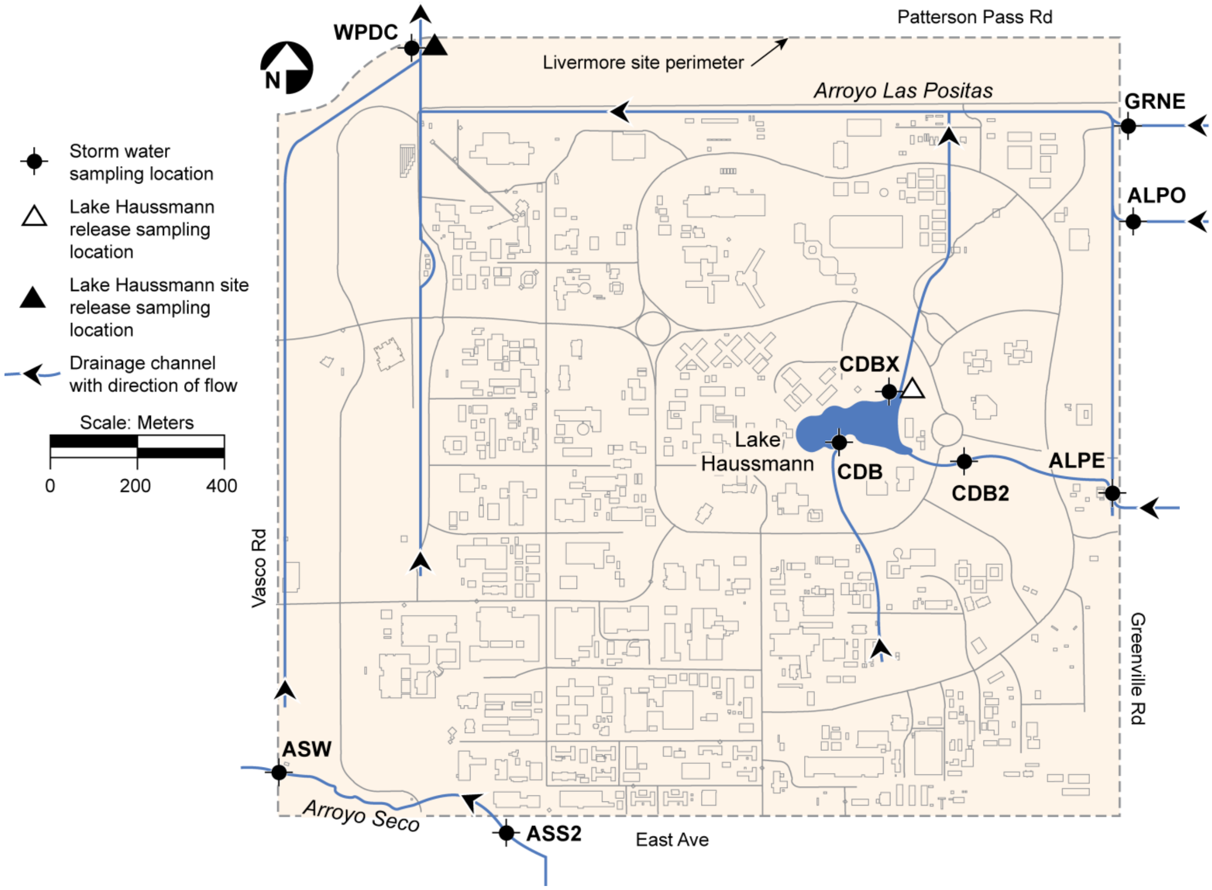

Figure 5-1. Storm water runoff and Lake Haussmann sampling locations, Livermore site, 2010.

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**.) Tritium activities at the site effluent sampling locations were approximately 1% of the maximum contaminant level (MCL). Gross alpha and gross beta radioactivity in the effluent storm water samples collected during 2010 were also generally low, less than 20% and 10% of their MCLs, respectively. These tritium, gross alpha, and gross beta activities were all below their respective LLNL site-specific thresholds listed in **Table 5-4**.

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 2010, 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, 2010.[a]

Parameter	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Minimum	1.1	0.006	0.050
Maximum	13.0	0.110	0.140
Median	1.6	0.058	0.100
Effluent			
Minimum	2.9	0.072	0.083
Maximum	8.4	0.086	0.110
Median	N/A[a]	N/A[a]	N/A[a]

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**. The only value above the site-specific thresholds for the Livermore site during 2010 was found at an influent tributary, GRNE, at a concentration approximately twice the corresponding effluent location, WPDC. These results suggest that current operations at the Livermore site during 2010 did not impact the quality of storm water runoff.

Table 5-6. Water quality parameters in storm water runoff above LLNL site-specific thresholds, Livermore site in 2010.

Radioactive/ Nonradioactive	Parameter	Date	Location	Influent / Effluent	Result	LLNL Threshold
Nonradioactive	Nitrate (NO_3) (mg/L)	2/23	GRNE	Influent	11	10

5.3.4 Site 300

On February 9, 2010, 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 (NLIN2, NPT7, and N883), an upstream off-site location (CARW2), and a downstream off-site location (GEOCRK) on the Corral Hollow Creek (**Figure 5-7**). One industrial activity location not shown in **Figure 5-7**, NLIN (approximately 0.25 km southeast of location NLIN2), was also sampled for selected analytes. 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 2010 because the first major storm of the 2009-2010 water year occurred on October 13, 2009, and there were no major storms during the last quarter of 2010 that would have been sampled for the 2010-2011 water year.

5.3.4.1 Radiological Monitoring Results

During 2010, 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**.)

5.3.4.2 Nonradiological Monitoring Results

No nonradiological constituents exceeded the site-specific thresholds listed in **Table 5-4** during 2010. 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 February 9, 2010, the total TEQs are shown in

Table 5-7. 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 5-7. Dioxin-specific water quality parameters in Site 300 storm water runoff, 2010.

Location	Total TEQ (pg/L) February 9
CARW2	3.9
NLIN2	5.2
GEOCRK	4.5

5.3.5 Environmental Impact of Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impact in 2010. 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 2010, 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 Wimborough 2006). 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 2010 from 16 of 18 water wells in the Livermore Valley (see **Figure 5-3**) and measured for tritium activity. Two wells (9B1 and 17D12) were out of service and could not be sampled during 2010.

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 12D2, located about 10 km (6.2 mi) west of LLNL (see **Figure 5-2**). The measured activity there was 1.5 Bq/L (40.5 pCi/L) in 2010, less than 0.25% of the MCL, and below background activity (1.9 Bq/L, 51.4 pCi/L) associated with this measurement.

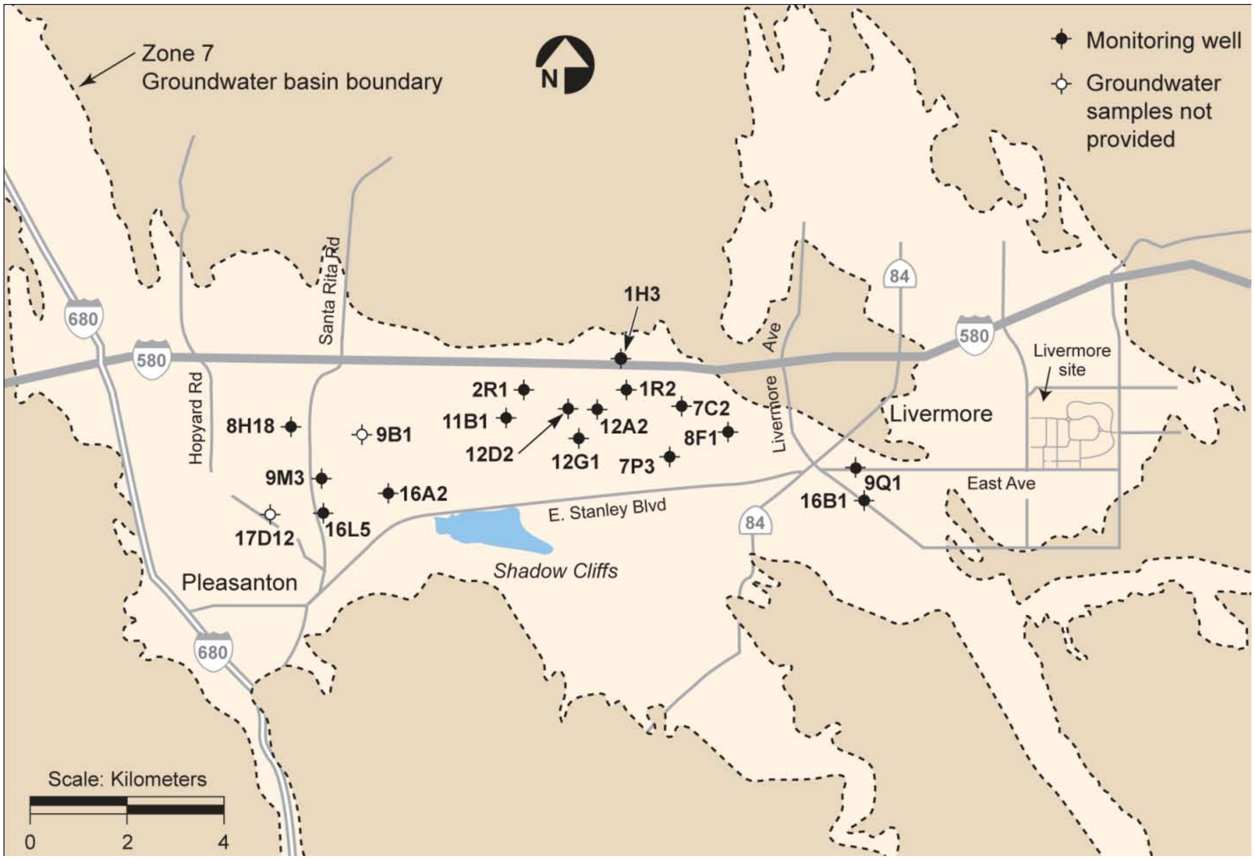

Figure 5-2. Off-site tritium monitoring wells in the Livermore Valley, 2010.

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 2010 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 2010 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 2010 sample from this location showed a concentration of 34 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 2010 sample from this well (30 mg/L) was again, as in the past five years, below the MCL. During 2010, concentrations of nitrate in on-site shallow background wells W-008 and W-221 were reported to be 31 mg/L and 37 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 2010, 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.

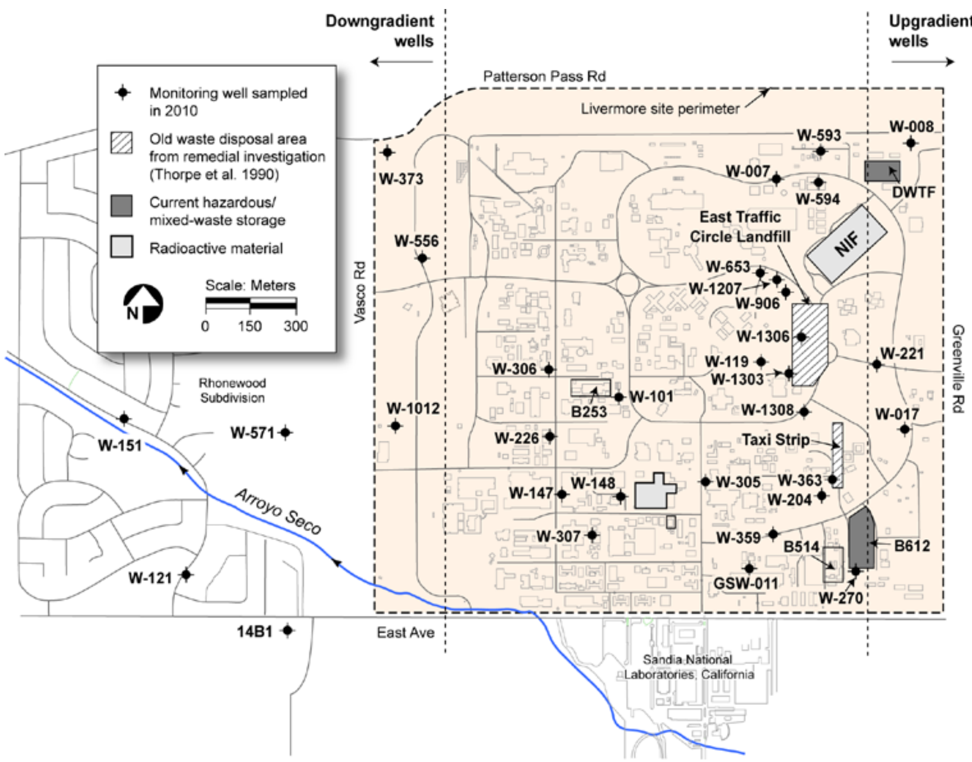

Figure 5-3. Routine surveillance groundwater monitoring wells at the Livermore site, 2010.

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 5-4**. All analytical results are provided in **Appendix A**, **Section A.5**.

The Taxi Strip and East Traffic Circle Landfill areas (see **Figure 5-4**) 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 2010 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 2010. Well W-1303 was also analyzed for plutonium-238 and plutonium-239+240, because a sample collected from that location in January 2009 showed plutonium-239+240 at a level above the minimum detectable activity; results for this 2010 sample showed no detectable plutonium activity.

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 2010, 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 2010 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 2010. 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 2010, 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 2010.

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 2010, 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 2010, 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, 2007, 2008, 2009, and 2010 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 2010 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.)

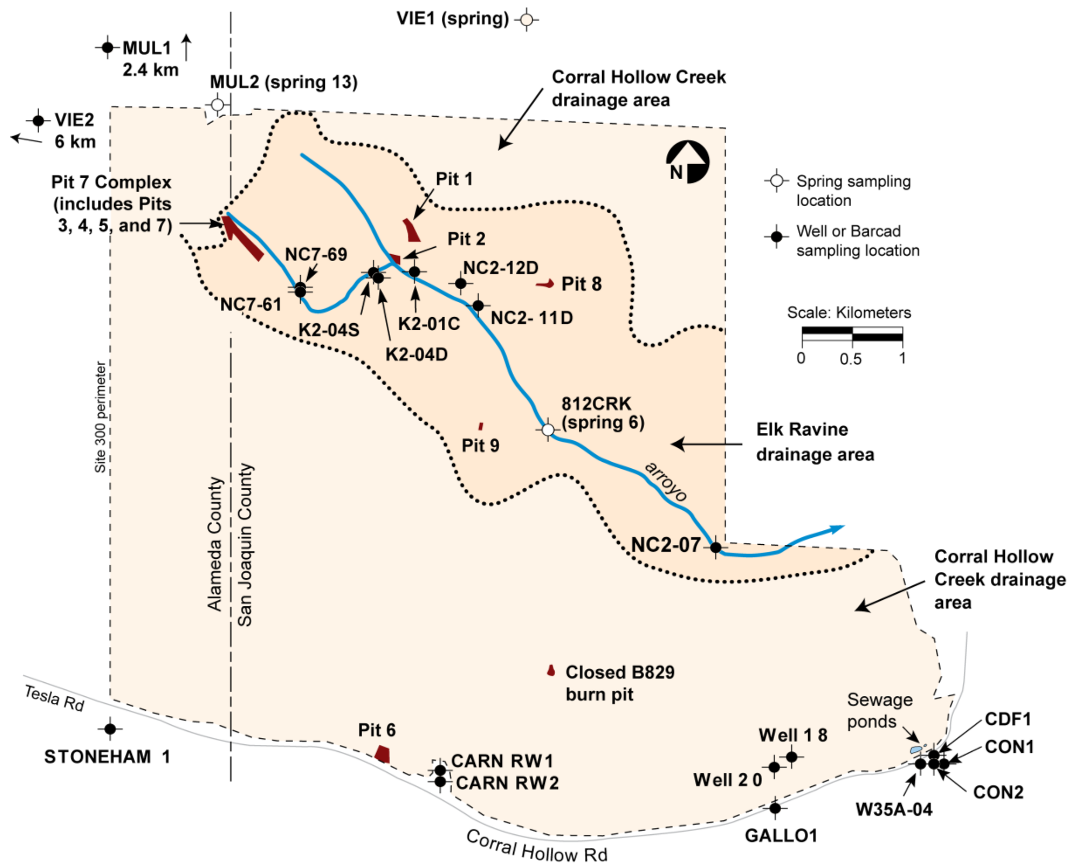

Figure 5-4. Surveillance groundwater wells and springs at Site 300, 2010.

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., 2009). 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 2010, including well locations, maps of the distribution of COCs in groundwater, and analytical data tables, see Dibley et al, 2011.

Elk Ravine. Groundwater samples were obtained on various dates in 2010 from the widespread Elk Ravine surveillance monitoring network shown in **Figure 5-4** (NC2-07, NC2-11D, NC2-12D, NC7-61, NC7-69, SPRING6 [812CRK], 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 2010. 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 results of tritium analysis for well NC7-61 were the same as 2009, with maximum values in both years of 1100 Bq/L. 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 2010 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 2010 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 2010; a detailed account of Pit 1 compliance monitoring during 2010, including well locations and tables and graphs of groundwater COC analytical data, is in Blake and MacQueen (2010).

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 obtained groundwater samples monthly, quarterly, semiannually, and annually during 2010 from specified Pit 6 monitoring wells. No new releases were detected at Pit 6 in 2010. A detailed account of Pit 6 compliance monitoring during 2010, including well locations, tables of groundwater analytical data, and maps showing the distribution of COC plumes, is in Blake and Valett (2010).

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 2010 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 2010, 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. 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 2010, including well locations and tables and graphs of groundwater COC analytical data, see Revelli (2011b).

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 (Tnbs1) 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 2010 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 2010 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 5-5)**. 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 2010 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 5400.5. 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 5-5**. During 2010, 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 2010, 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 2010, rain sampling continued at the same four locations on the Livermore site perimeter (see **Figure 5-6**) as in 2009. Some rainwater samples collected in calendar year 2010 showed maximum tritium activity greater than the minimum reporting limit of 3.7 Bq/L (100 Ci/L); this is consistent with historical values.

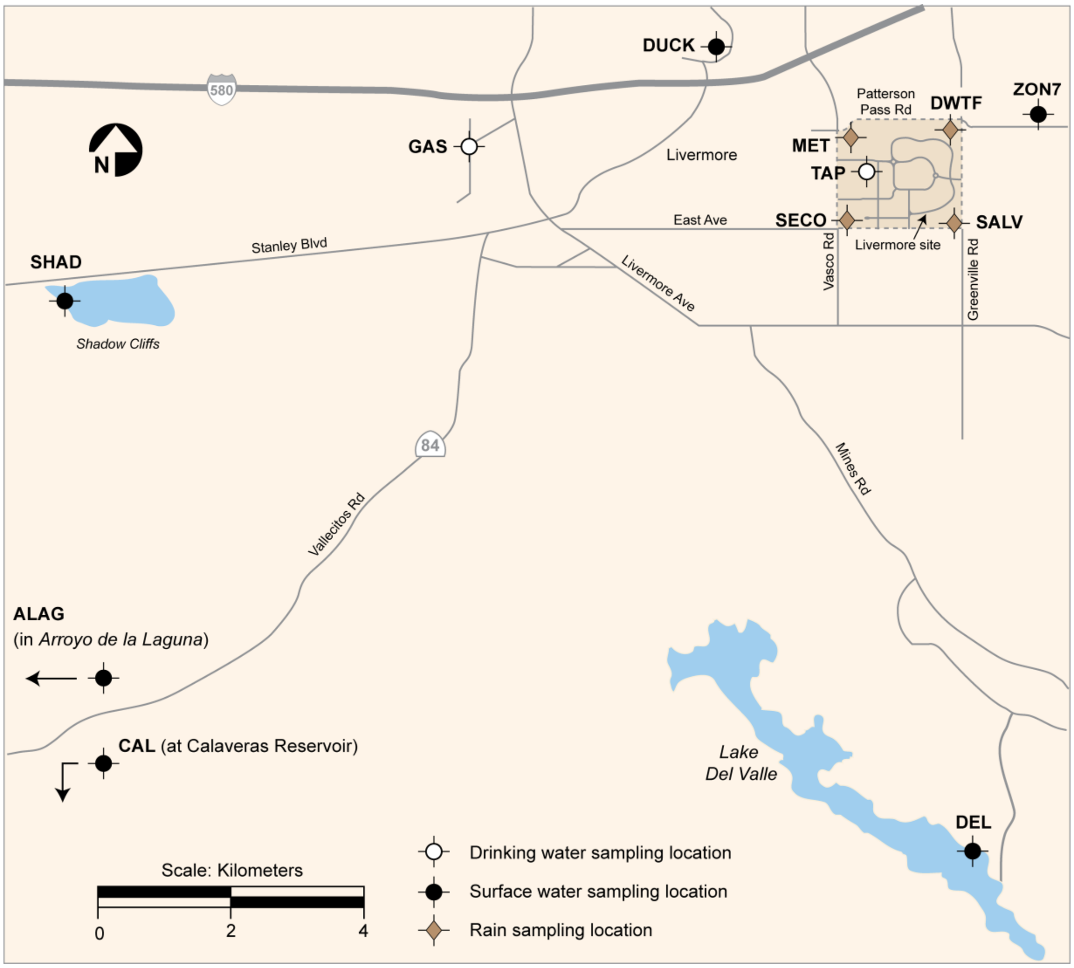

Figure 5-5. Livermore site and Livermore Valley sampling locations for rain, surface water, and drinking water, 2010.

5.5.1.2 Site 300 and Environs

During 2009, 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. 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 2010 show values below the minimum reporting limit of 3.7 Bq/L (100 pCi/L) .

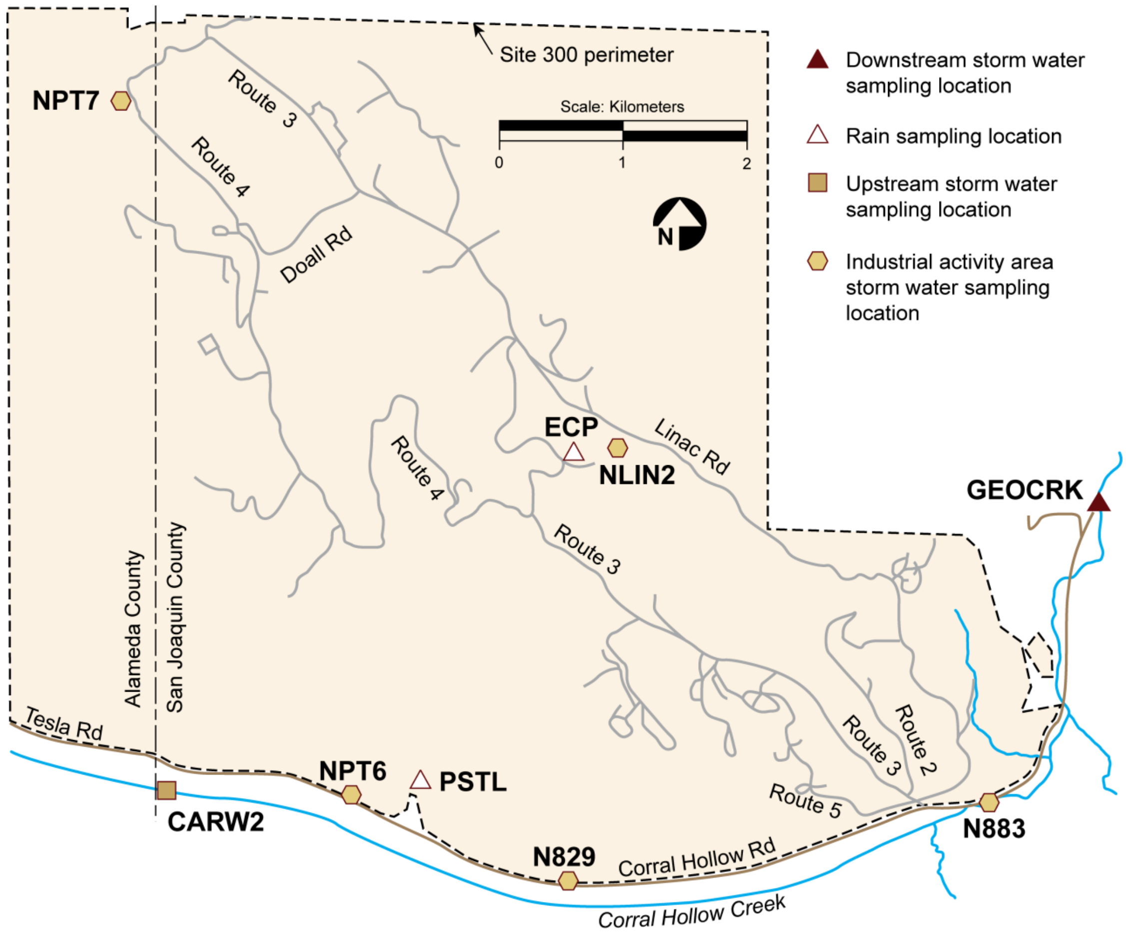

Figure 5-6. Storm water and rainwater sampling locations at Site 300, 2010.

5.5.2 Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5. Surface and drinking water near the Livermore site and in the Livermore Valley were sampled at the locations shown in **Figure 5-6** in 2010. 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 2010. 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 2010 was 2.35 Bq/L 63.5 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 TAP, while the maximum gross beta radioactivity occurred in a sample collected at DUCK. These maximum values (gross alpha at 0.152 Bq/L [4.11 pCi/L] and gross beta at 0.310 Bq/L [8.38 pCi/L]) were still less than 28% and 17% of their respective drinking water MCLs (see **Table 5-8**).

Table 5-8. Radioactivity in surface and drinking waters in the Livermore Valley, 2010.

Location	Metric	Tritium (Bq/L)[(a)]	Gross alpha (Bq/L)[(a)]	Gross beta (Bq/L)[(a)]
All locations	Median	0.80	0.0256	0.0561
	Minimum	0.34	-0.0008	-0.0226
	Maximum	2.35	0.1520	0.3100
	Interquartile range	0.86	0.0971	0.0823
Drinking water outlet locations	Median	0.59	0.0256	-0.0014
	Minimum	0.38	-0.0008	-0.0226
	Maximum	2.35	0.1520	0.0770
	Drinking water MCL	740	0.555	1.85

(a) A negative number means the sample radioactivity was less than the background radioactivity. 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 was the pH discharge limit of 8.5. Dry season and wet season pH has historically averaged 9.3 and 8.3, respectively. The higher pH readings seen in Lake Haussmann discharge samples during the dry season correspond to the peak of 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 reach surface water drainage courses. (In prior years, 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 2010 are detailed in the quarterly self-monitoring reports to the CVRWQCB. During the third quarter of 2010, LLNL conducted routine annual flushing of the drinking water system for water quality purposes (LLNL 2010X). 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. However, during 2010 all water discharged during planned releases from the Site 300 drinking water system soaked into the ground surface before reaching a surface water.

Two off-normal discharge events in 2010 did result in the release of drinking water that flowed across the site boundary. A line break near Building 818 on Sunday, June 30, 2010 resulted in an estimate of less than 500 gallons discharged from the site. Similarly, a valve malfunction at well W-18 on Saturday, July 24, 2010, resulted in an estimated 200-300 gallons discharged from the site. In both cases any discharged volumes would have had to flow approximately a quarter of a mile over relatively flat land consisting of soil and vegetation before reaching Corral Hollow Creek. There is no public access to Corral Hollow Creek in this area so whether or not the released water reached the creek bed could not be confirmed. Based on residual water observed in the area and the small volumes that left the Site 300 boundary, it is not likely that any discharge actually reached Corral Hollow Creek, the potential receiving water.

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 (2010).

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**)

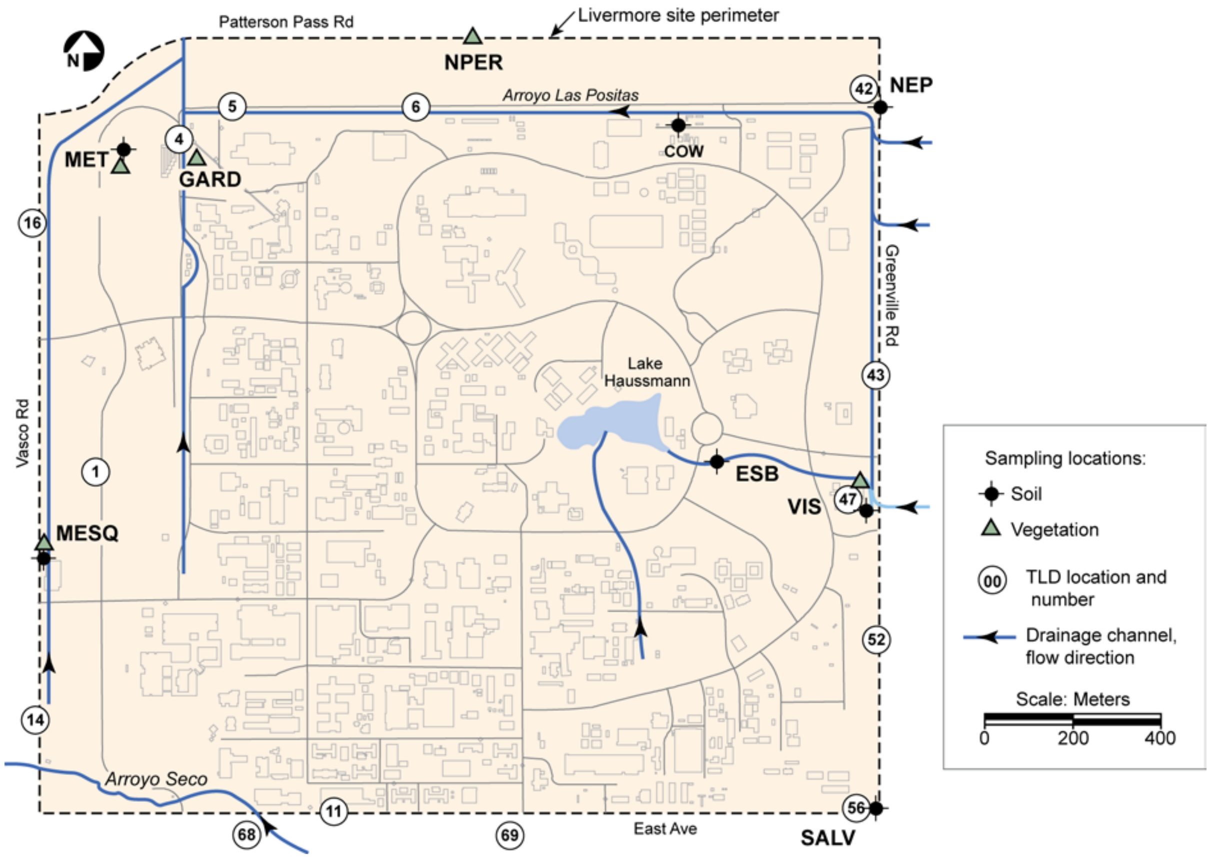

Figure 6-1. Soil and vegetation sampling locations and TLD locations, Livermore site, 2010.

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.

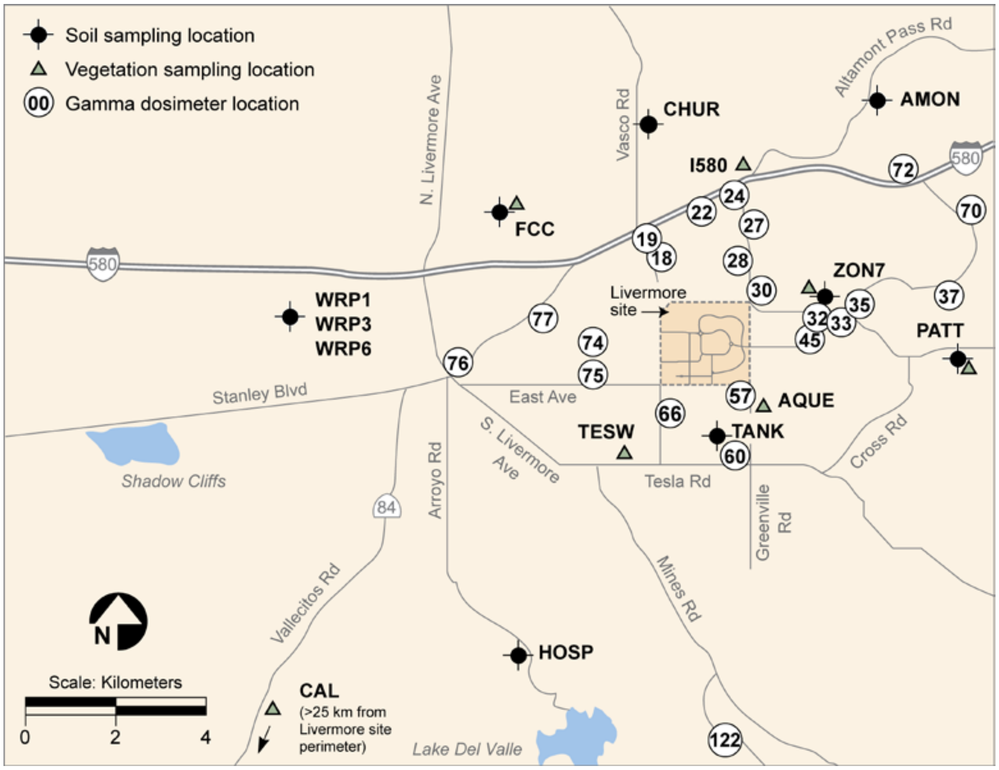

Figure 6-2. Soil and vegetation sampling locations and gamma dosimeter locations, Livermore Valley, 2010.

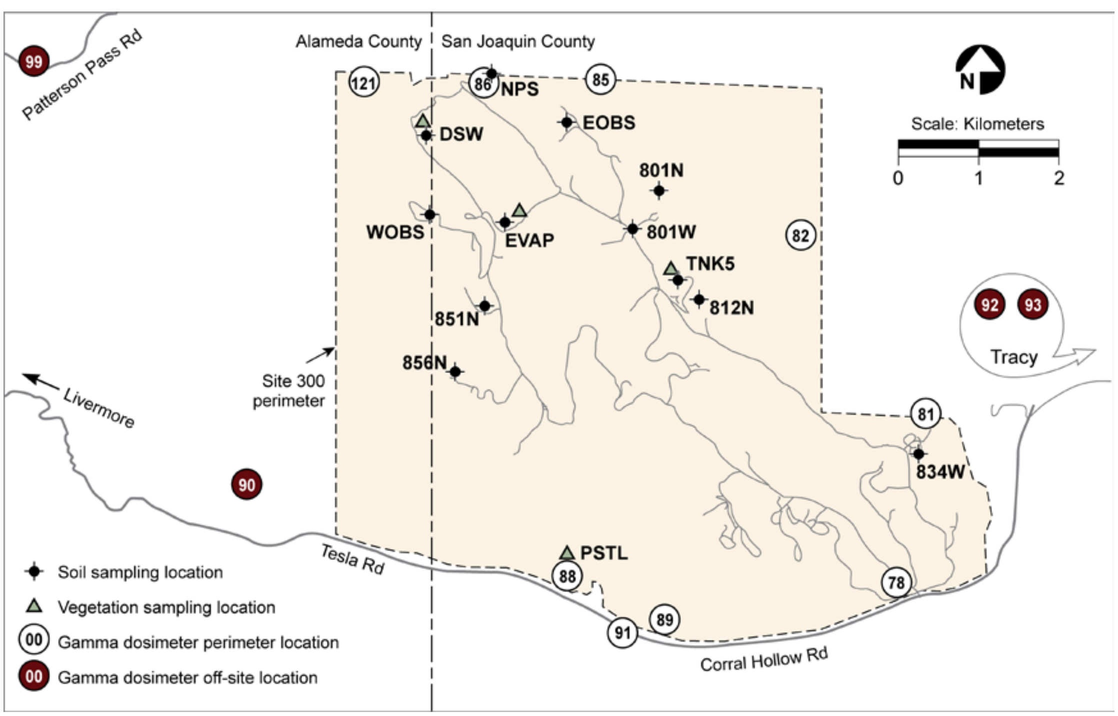

Figure 6-3. Soil and vegetation sampling locations and TLD locations, Site 300 and off-site, 2010.

In 2010, 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 2010 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 2010 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 2010 was 2.30 mBq/dry g (6.1×10^{-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 2010. The highest detected plutonium-239+240 value at the LWRP in 2010 was 8.8 mBq/dry g (2.4×10^{-1} pCi/dry g). In addition, americium-241 was detected in one LWRP sample at a concentration of 4.90 mBq/dry g (1.3×10^{-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 2010 (11.0 Bq/L [297 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 2010 are provided in **Appendix A**, **Section A.8**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2010 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 2010, the highest measured values for uranium-235 and uranium-238 in a single sample were 0.23 µg/g (0.018 Bq/g or 0.5 pCi/g) and 110 µg/g (1.4 Bq/g or 37 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 2010, 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 the next two years, 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 2010, 2.4 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 2010 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 2010 (8.8 mBq/dry g [0.24 pCi/dry g]), measured at LWRP, is 1.9% 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 2010 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 110 µg/g (1.4Bq/g or 37 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 2010 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 2010 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 2010 was 27 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 2010 was 17 Bq/L at DSW 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 both 14 Bq/L.

6.2.2 Wine Monitoring Results

Tritium concentrations in wines purchased in 2010 are shown in **Table 6-2**. The highest concentration in a Livermore Valley wine is 8.9 Bq/L (240 pCi/L) from a wine made from grapes harvested in 2007. The highest concentration in a California (other than the Livermore Valley) wine is 0.40 Bq/L (11 pCi/L) from a wine made from grapes harvested in 2008. The highest concentration in a Rhone Valley (France) wine is 14 Bq/L (390 pCi/L) from a wine made from grapes harvested in 2009.

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 2010. The table includes mean annual ingestion doses calculated for 2010.

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	1.7	1.8	<10[b]
	GARD	3	3.6	18
	MESQ	1.7	1.7	<10[b]
	MET	1.4	1.8	<10[b]
	NPER	3.6	10	49
	VIS	23	27	130
INTERMEDIATE (1–5 km from Livermore site perimeter)	I580	1.9	2.5	12
	PATT	0.098	0.28	<10[b]
	TESW	1.2	1.3	<10[b]
	ZON7	3.8	6.3	31
FAR (>5 km from Livermore site perimeter)	CAL	-0.48	-0.44	<10[b]
	FCC	1.2	0.99	<10[b]
Site 300	DSW[c]	14	17	[d]
	EVAP[c]	14	13	[d]
	PSTL	0.063	-0.16	[d]
	TNK5	0.64	0.55	[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 2005, 2007, 2008 and 2009; the California wines represent vintages from 2007 and 2008; and the Rhone Valley wines represent vintage from 2006 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 2010, decay-corrected concentrations for Livermore Valley wine samples ranged from 0.67 to 11 Bq/L; for the two California wine samples, 0.45 and -0.07 Bq/L; and for the two Rhone Valley wine samples, 6.5 and 16 Bq/L.

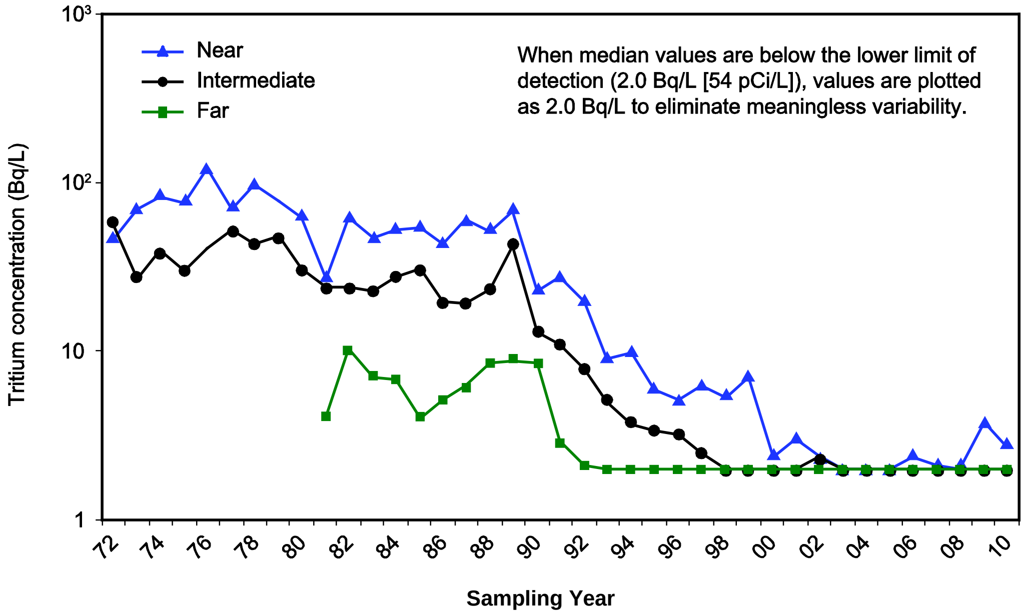

Figure 6-4. Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2010.

Table 6-2. Tritium in retail wine, 2010[(a,b)]

Sample	Concentration by area of production (Bq/L)		
	Livermore Valley	California	Europe
1	0.49 ± 0.37	0.40 ± 0.37	5.1 ± 0.44
2	3.3 ± 0.41	-0.06 ± 0.27	14 ± 0.54
3	8.9 ± 0.48		
4	6.5 ± 0.45		
5	1.2 ± 0.38		
6	3.8 ± 0.42		
Dose (nSv/y)[(c)]	11	0.49	17

(a) Radioactivities are 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 2010 sampling. Concentrations are those measured in March 2011.

(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 2010, was 130 nSv (13 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 2010, including OBT, is 260 nSv/y (26 µrem/y). This maximum dose is about 1/12,000 of the average annual background dose in the United States from all natural sources and about 1/39 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 2010, the highest concentration of tritium (8.9 Bq/L [240 pCi/L]) was just 1.2% 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 2010 would have resulted in a dose of 76 nSv/y (7.6 µrem/y). A more realistic dose estimate, based on moderate drinking (one liter per week)[1] at the mean of the Livermore Valley wine concentrations (4.0 Bq/L [108 pCi/L]) would have been 4.9 nSv/y (0.49 µrem/y). Both doses explicitly account for the added contribution of OBT.[2]

The potential dose from drinking Livermore Valley wines in 2010, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/133 of a single dose from a panoramic dental x- ray.

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

(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. Dose coefficients for HTO and OBT are those of the International Commission on Radiological Protection (1996).

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.

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 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 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).

To compare LLNL dose contributions with the natural background, the analysis is divided into three groups:

- Comparison of the average quarterly dose (mSv) for the Livermore site, Livermore Valley, and Site 300 locations for the five-year period from 2006 to 2010
- Comparison of the average quarterly dose (mSv) for the Livermore site and Livermore Valley locations in 2010
- Comparison of average quarterly dose (mSv) for Site 300, city of Tracy, and Site 300 vicinity in 2010

The results of these comparisons 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).

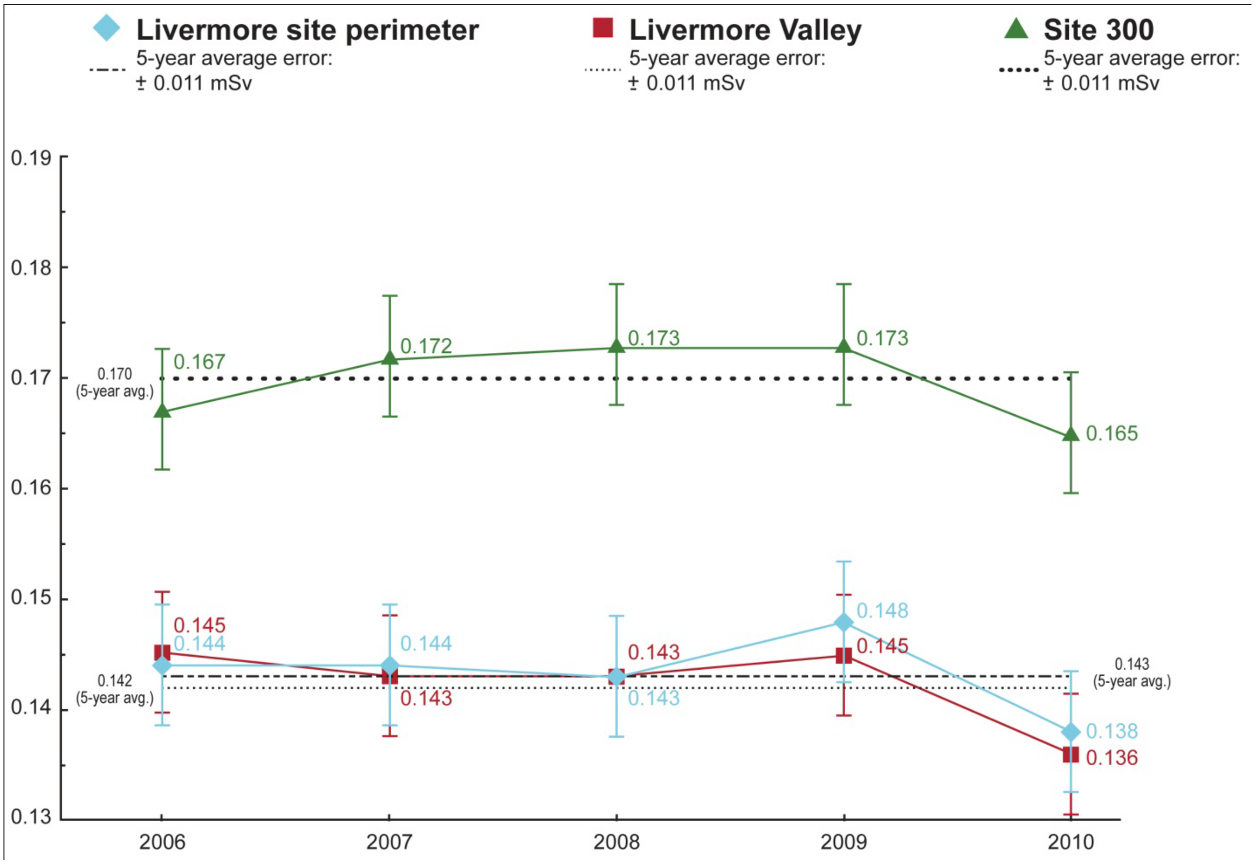

Figure 6-5. Comparison of the average quarterly dose for the Livermore site perimeter, Livermore Valley, and Site 300 monitoring locations from 2006 to 2010.

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 and Site 300. 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 2010 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 2006 to 2010 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 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 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.

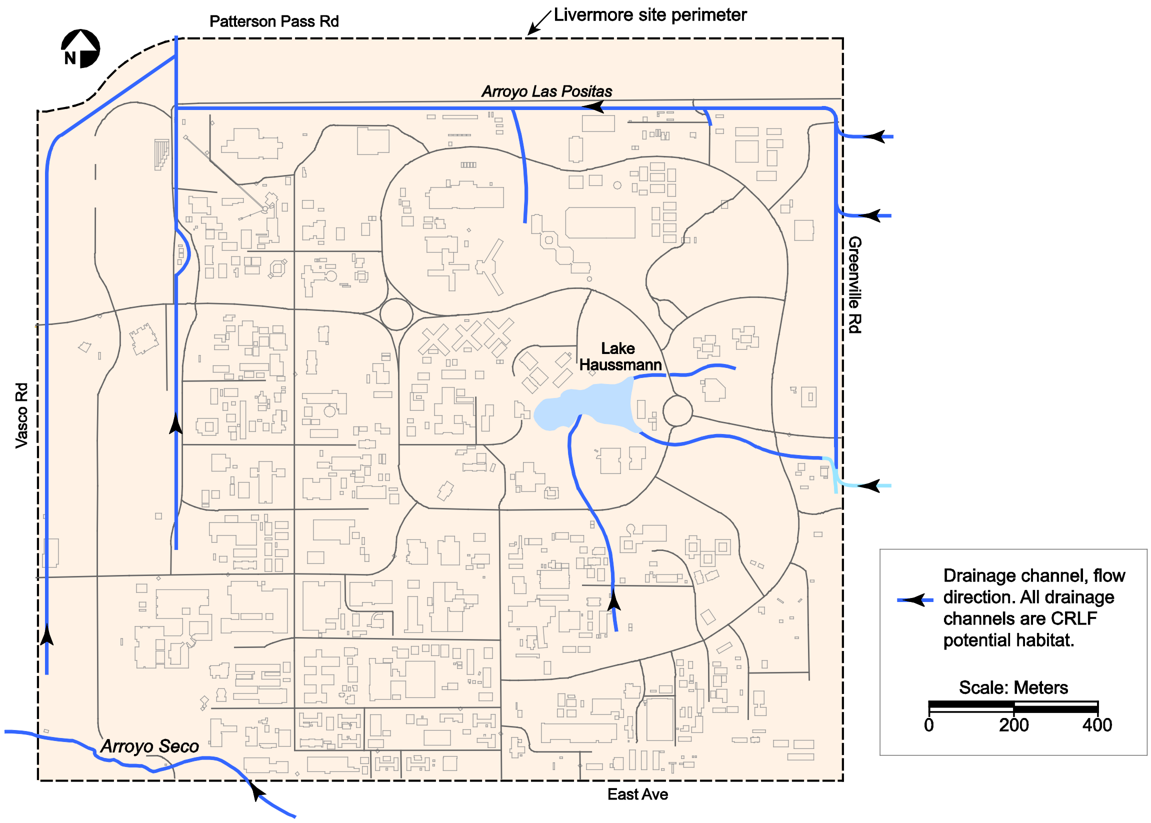

Figure 6-6. Populations of the California red-legged frog, Livermore site, 2010.

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).

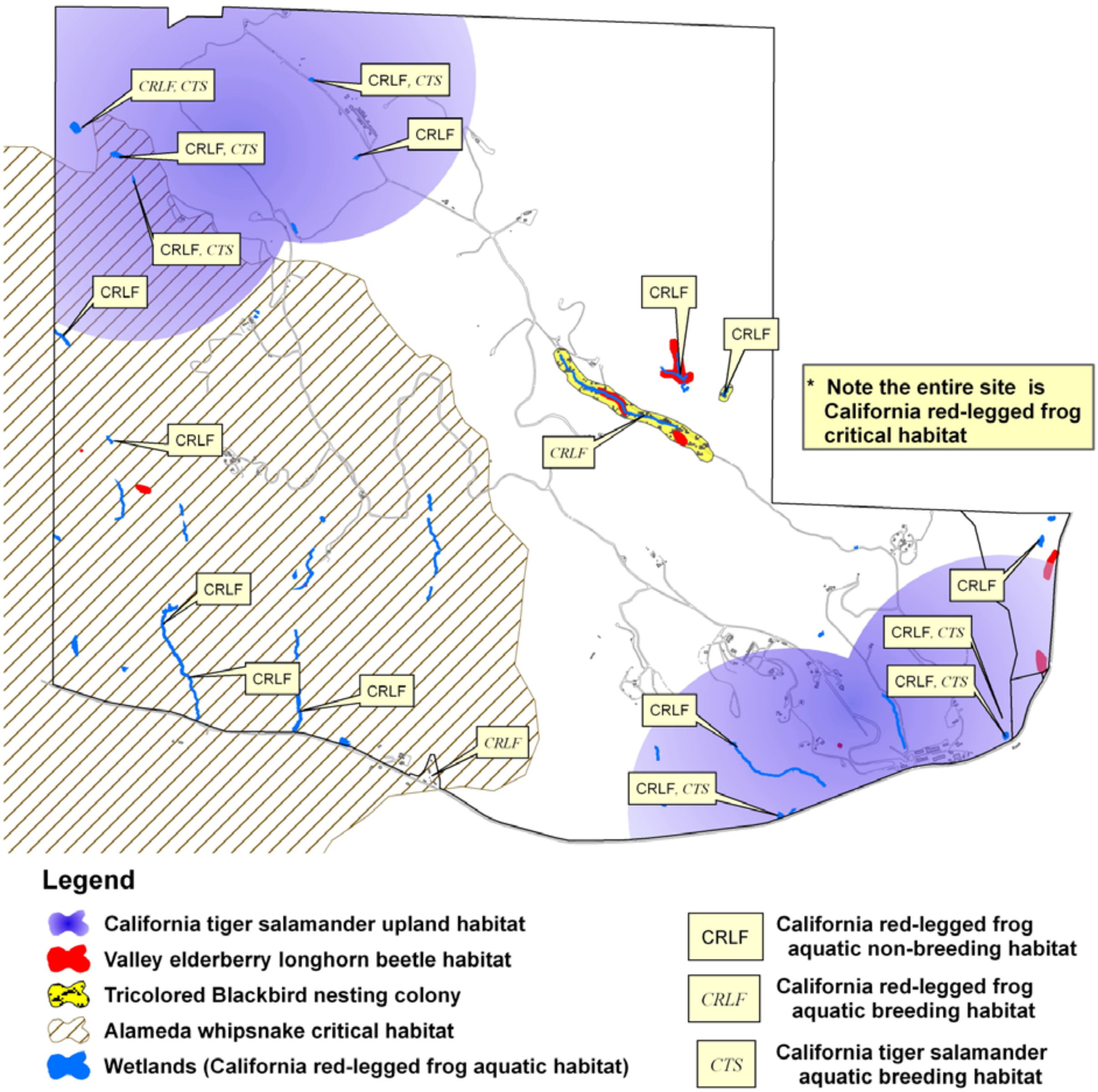

Figure 6-7. Distribution of special status wildlife, Site 300, 2010.

6.4.1 Compliance Activities

6.4.1.1 Building 850 Remediation

On November 17, 2008, the DOE/NNSA requested consultation with the USFWS to amend the Opinion for Routine Maintenance and Operations Projects at the Lawrence Livermore National Laboratory, Site 300 Experimental Test Site. This consultation analyzed potential impacts to California tiger salamanders and California red-legged frogs that could result from the environmental clean-up activities for the Building 850 area involving removal of PCB-, dioxin-, and furan-contaminated soil from the hillsides surrounding the former explosives test facility. The resulting Opinion addressed impacts of the clean-up operation on California tiger salamander and California red-legged frog, and issued a conference opinion on the proposed California red-legged frog critical habitat within the action area.

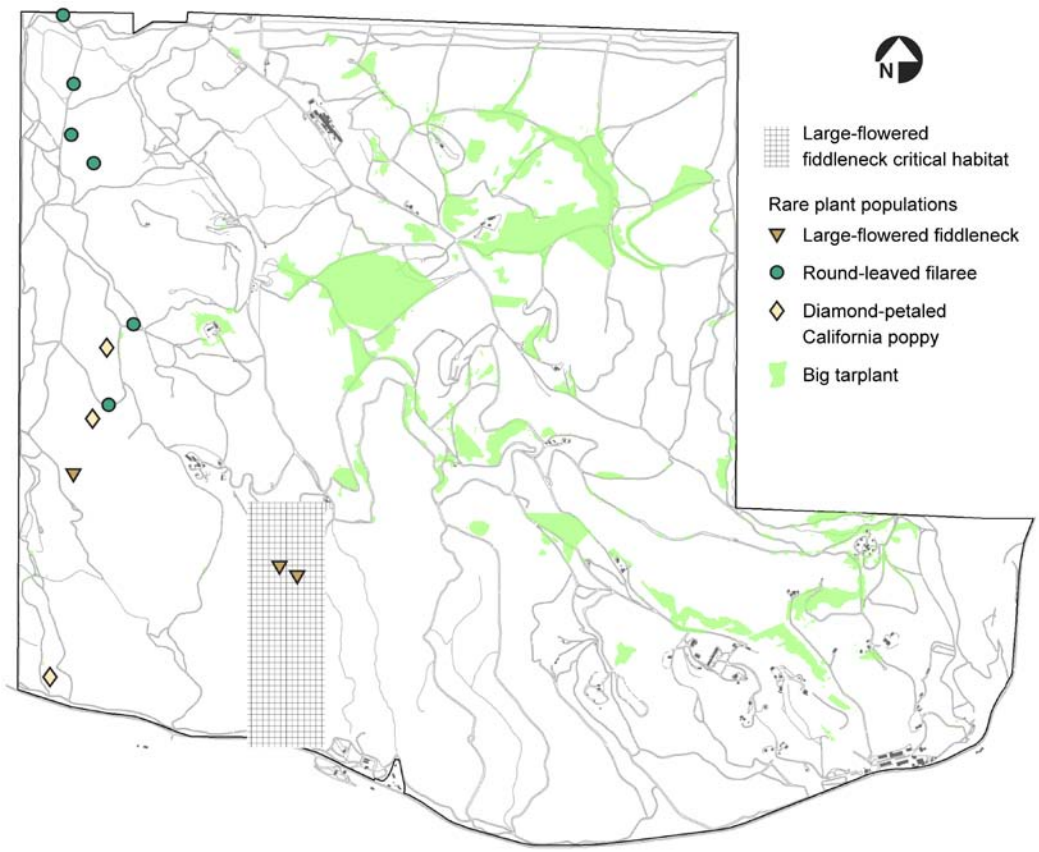

Figure 6-8. Distribution of special status plants, Site 300, 2010.

No California red-legged frogs or California tiger salamanders were discovered at the Building 850 project site during the pre-construction, developmental, or post-construction intervals. No special status species were observed in the project area or nearby during the duration of the project. All construction personnel received the required natural resource education briefing and did not report seeing any species of concern.

The BO amendment for this project requires onsite mitigation for potential impacts to California tiger salamander and California red-legged frog habitat. Two breeding pool enhancement sites are considered as potential mitigation areas. One site would ultimately be deepened to allow sufficient hydroperiod for survival of California tiger salamander larvae. The compensation plan for this project also includes protection of upland habitat for the two species around an enhanced (deepened) breeding pool that currently acts as a limit to population recruitment. The proposed wildlife habitat compensation site related to this project is anticipated to be completed during the summer of 2011 or 2012.

6.4.1.2 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 2010. In 2010, a total of 20 to 25 California red-legged frog egg masses were observed in the Upper and Lower Mid-Elk Ravine pools.

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 bred and metamorphosed from the 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, Pool M2 did fill and California tiger salamanders were able to successfully reproduce at this location.

6.4.1.3 Oasis and Round Valley Culvert Replacement Projects

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 2010 winters to pool and afford potential breeding habitat for amphibians.

6.4.1.4 Building 438 Drainage Channel Maintenance

On January 16, 2010 during drainage channel maintenance at LLNL's Livemore site, one California red-legged frog was crushed by a backhoe and died shortly after it was discovered.

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. The USFWS and California Department of Fish and Game (CDFG) were notified of this incidental take. LLNL biologists conducted pre-activity surveys prior to work at this site, and monitored all work within the drainage channel.

A total of 30 California red-legged frogs and 34 Pacific tree frogs were safely relocated from the project site to suitable habitat on site in Arroyo las Positas and the habitat enhancement pool portion of Lake Haussmann. Many of these frogs were found while clearing vegetation by hand prior to the use of heavy equipment

6.4.1.5 California red-legged frog Incidental Take

A California red-legged frog was inadvertently killed during lawn maintenance conducted in December of 2010 in an area located approximately 700 feet from Lake Haussmann. This incidental take is authorized through the 2007 and 2010 amendments to the 1998 *Formal Consultation on the Proposed Arroyo Maintenance Project on Arroyo las Positas at Lawrence Livermore National Laboratory*. The USFWS and CDFG were notified of this incidental take. LLNL has voluntarily implemented the following measures to protect California red-legged frogs during lawn maintenance in this area: All landscape crew received training on the ecological and behavior of California red-legged frogs and regulations protecting natural resources at LLNL; landscaping crew will inspect the lawn area before maintenance, and maintenance at this site will occur in the afternoon when frogs are more likely to have left the lawn area to seek cover.

6.4.1.6 Arroyo Seco Restoration

Arroyo Seco crosses the southeast corner of the Livermore site. In 2005, an extensive erosion control and restoration project was completed in the LLNL reach of Arroyo Seco. Prior to this project, Arroyo Seco flowed through a very steep incised channel as it crossed the Livermore site. Erosion also occurred in locations where storm water flowed over the banks of the arroyo. This project included measures to repair existing erosion damage, prevent future erosion, and restore the stream banks to a more natural topography. Where space allowed, the stream banks were cut back to decrease their slope and meanders were added to the channel to decrease the rate of flow through the site. Space did not allow the addition of meanders in the upstream portion of the project site, so vegetated geogrids were installed in this area to prevent future erosion. The vegetated geogrids were constructed of folds of soil held in place on the stream banks by erosion control fabric, and further stabilized with willow plantings.

In 2010, LLNL conducted the fifth year of the five-year monitoring plan required by USFWS and ACOE for the restoration of the Arroyo Seco Management Plan project site. Results of this monitoring are documented in Paterson (2011). Monitoring at this site includes annual measurements of the survivorship of plants that were installed as part of the restoration and estimates of the percent cover of grasses and forbs, shrubs, and trees at the project site. Percent cover measurements were recorded separately for four monitoring zones (north bank, south bank, north terrace, and south terrace) and three vegetated geogrids. The mitigation and monitoring plan for this project lists annual success criteria based on the percent cover of grasses, shrubs, and trees at the project site, and requires LLNL to replace all trees and shrubs that do not survive during the first five years of monitoring.

In 2010, the fifth year after construction, the project site met the success criteria for grasses and shrubs in all four monitoring zones. The percent cover of trees in three (north bank, south bank, and north terrace) of the four monitoring zones was lower than the required success criteria, but when the percent cover of trees was averaged for all banks and all terraces the project site does meet the final success criteria.

This site has met the specific requirements of the Mitigation and Monitoring Plan for the Arroyo Seco Management Plan project. In addition to meeting the specific requirements of the plan, the site has achieved the intent of the plan through the control of erosion on the stream banks and the establishment of native vegetation at the project site that is similar to the vegetation naturally present in intermittent arroyos near the project site. Native trees, shrubs, and perennials are now abundant at the site which was largely vegetated by ruderal species prior to construction and erosion in the channel and on the stream banks is decreased compared to pre-project condition.

6.4.1.7 Arroyo Mocho Boulder Removal and Erosion Control Project

LLNL operates a pumping plant that draws water from the Hetch Hetchy aqueduct located in the Arroyo Mocho Canyon. Several large boulders fell into the channel of Arroyo Mocho below the pumping plant, potentially forcing the flow of the arroyo toward the hillside that the pumping plant is located on and resulting in an erosion hazard to this hillside and the pumping plant. The 2004 BO for the Arroyo Mocho Road Improvement and Anadromous Fish Passage project has been amended to include the boulder removal project. The 2004 BO was amended again in 2009 to include additional erosion control efforts at the pump station and along the access road.

Arroyo Mocho and the surrounding area are habitat for California red-legged frog, California tiger salamander, and Alameda whipsnake. In 2007 and 2008, boulders were removed from Arroyo Mocho to mitigate erosion hazards and monitoring was conducted as required by the BO amendments. No boulder removal or erosion control work was necessary at the Arroyo Mocho site in 2009 or 2010.

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 *(Rana 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 Livemore site.

At the Livermore site, bullfrog control measures were implemented between May and September of 2010. 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 November of 2010 by temporarily halting groundwater discharges to the arroyo. No largemouth bass were observed at the Livermore site in 2010.

6.4.3 Surveillance Monitoring

6.4.3.1 Wildlife Monitoring and Research

Fairy Shrimp. LLNL was directed by USFWS (BO Conservation Measure #17 iii) to "conduct USFWS protocol-level branchiopod surveys to determine whether listed brachiopod species are present within the compensation area," prior to enhancement work conducted as part of compensation for potential impacts to California tiger salamander and California red-legged frog habitat during the Building 850 remediation project (see Section 6.4.1.1).

Surveys for listed branchiopods were performed in the 2009-2010 wet season to determine the presence of federally-listed branchiopods in the two pools. A dry season sampling effort followed the wet season surveys in the summer of 2010. No listed branchiopod species were discovered at either potential mitigation site. Future efforts by LLNL will decide which site will be chosen for enhancement purposes.

Alameda Whipsnake. Since 2002, LLNL has participated in a study, in cooperation with the USFWS and four other agencies, to determine the effects of prescribed burns on the Alameda whipsnake. The USFWS issued a BO for this study that outlined the general conditions for conducting prescribed burns and gathering information about potential impacts to Alameda whipsnakes. Participation in this study allowed LLNL to obtain USFWS approval to conduct prescribed burns necessary for Site 300 operations in areas that support Alameda whipsnakes. Previous LLNL Environmental Reports document the study area and baseline conditions, and early results.

LLNL implemented the study in two adjacent areas (a burn site and a control site) of Coastal Scrub vegetation at Site 300. A prescribed burn was conducted at the burn site in the summer of 2003, and the post-burn monitoring has been conducted starting in the fall of 2003 through the spring 2009. Both the burn and control sites were impacted by a wildfire in 2005. Although no whipsnake fatalities were documented during post-burn surveys conducted immediately following the 2005 wildfire, both trapping areas were burned severely and little remnant vegetation was left in the shrubland.

No whipsnakes were captured during the spring 2009 trapping period. 2009 was the final year of trapping at Site 300 conducted as part of this study; no trapping was conducted in 2010. Although the effects of the prescribed burn and subsequent impacts of the wildfire on the whipsnake are not yet determined, both the whipsnake and its habitat are adapted to periodic fire events, and both the snake and vegetation are expected to recover from the fire in subsequent years.

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 Egg Mass Surveys. LLNL continued diurnal visual surveys for California red-legged frog egg mass at the Livermore site in Arroyo Las Positas and in the habitat enhancement portion of Lake Haussmann. No egg masses were observed in Arroyo Las Positas in 2010. Although, no egg masses were observed in the Habitat Enhancement portion of Lake Haussmann in 2010, 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 2010.

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 a nearby ranch. 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 2010.

LLNL established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. The size of the experimental population fluctuates as a result of seed bank enhancement efforts conducted in this population. The experimental population contained 217 large-flowered fiddleneck plants in 2010. The increase from 26 plants observed in 2009 is a result of seeding conducted in December of 2009.

In December of 2010, in an attempt to further boost numbers of large-flowered fiddleneck in the experimental population, 100 large-flowered fiddleneck seeds were planted in each of the 11 plots in the experimental population.

Big Tarplant. The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September through November of 2010. It is estimated that between 80,000 and 214,000 individual big tarplant occurred at Site 300 in 2010. This species is abundant at Site 300, especially in or near areas where prescribed burns are routinely conducted and where wildfires have occurred, although it is rare outside of Site 300. 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.

Diamond-Petaled California Poppy. Currently three populations of this species are known to occur at Site 300; the population locations are referred to as Site 1, Site 2, and Site 3. 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. A census of the three Site 300 populations was conducted in April 2010. In 2010, 1107 diamond-petaled California poppy plants were found at Site 300. The most recently discovered population, Site 3, contained by far the largest number (1068 plants). Numbers of plants at Sites 1 and 2 have been very small in recent years. In 2010, Site 1 had 23 plants, and Site 2 had 16 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

2010, 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 more than 7010 plants. In 2010, the majority of these plants (5390) occurred in the two grassland populations that are not located in fire trails.

6.4.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2010, LLNL has been able to avoid most impacts to special status wildlife and plants. Although Livermore site projects did result in the authorized incidental take of two California red-legged frogs, 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 the monitoring programs. .

7. Radiological Dose Assessment

Nicholas A. Bertoldo • Gretchen M. Gallegos

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 2010, 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 2010.

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. Thus, the SW-MEI dose is not received by any actual individual and is a conservative estimate of the highest possible dose that might be received by any member of the public predicated on the exposure conditions specified above.

In 2010, 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 2010 Radiological Dose Assessment

This section summarizes the doses to the most exposed public individuals from LLNL operations in 2010, 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.

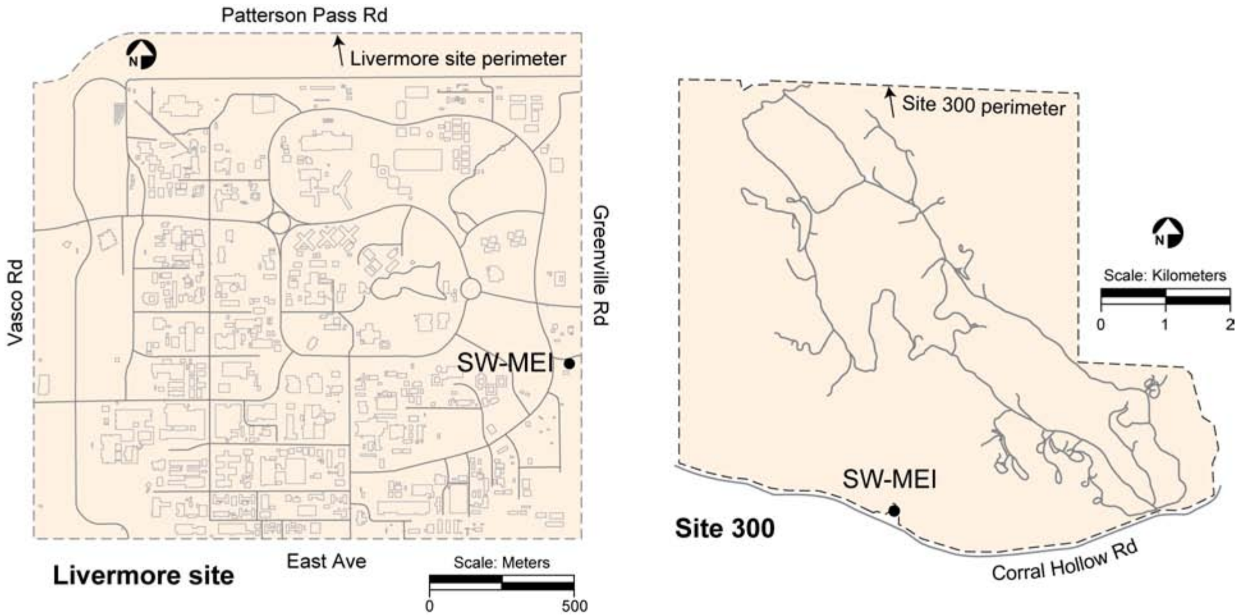

Figure 7-1. Location of the SW-MEI at the Livermore site and Site 300, 2010.

7.3.1 Total Dose to Site-Wide Maximally Exposed Individuals

The total dose to the SW-MEI from Livermore site operations in 2010 was 0.11 μSv/y (0.011 mrem/y). Of this, the dose attributed to diffuse emissions (area sources) were 0.074 μSv (0.0074 mrem) or 69% 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 2010. 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 2010 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 2010 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 (5.7×10^{-6} μSv/y) [5.7×10^{-7} mrem/y] was due to (3.2×10^{-6} GBq) [8.7×10^{-8} Ci] of uranium-238, (3.4×10^{-8} GBq) [9.2×10^{-10} Ci] uranium-235, and (4.8×10^{-7} GBq) [1.3×10^{-8} 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 2010.

Site	Facility (source category)	CAP88-PC dose (μSv/y)[a]	CAP88-PC contribution to total dose[b]
Livermore Site	Tritium Facility stacks (point source)	3.3×10^{-2}	31%
	Building 331 WAA, Building 612 Yard (diffuse sources)	6.6×10^{-2}	62%
	Southeast quadrant soil resuspension (diffuse source)	7.4×10^{-3}	7%
Site 300	Contained Firing Facility	5.7×10^{-6}	100%

(a) 1 μSv = 0.1 mrem

(b) Contributions from B695 and B581 Stacks account for < 1% each 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 10% 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 2010.

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 7.22 million residents included for the Livermore site collective dose determination and 6.7 million for Site 300. The populations were derived using ORNL LANDSCAN™ 2007 data and ESRI ARCMAP software.

The CAP88-PC result for potential maximum collective dose attributed to 2010 Livermore site operations was 0.0057 person-Sv (0.57 person-rem); the corresponding collective dose from Site 300 operations was 1.9×10^{-6} person-Sv (1.9×10^{-4} 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 2010.

Site	Year	Annual Dose (μSv)[(a)]	Site	Year	Annual Dose (μSv)[(a)]
Livermore site	2010	0.11	Site 300	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 2010 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, 2010.

Location/source	Category	Individual dose[a] (μSv)[c]	Collective dose[b] (person-Sv)[d]
LLNL			
Livermore site sources	Atmospheric emissions	0.11	0.0057
Site 300 sources	Atmospheric emissions	5.7×10^{-6}	1.9×10^{-6}
Other sources[e] (background)	Natural radioactivity[f,g]		
	Cosmic radiation	300	2,170
	Terrestrial radiation	300	2,170
	Internal (food and water consumption)	400	2,888
	Radon	2,000	14,440
	Medical radiation (diagnostic procedures)[f]	530	3,827
	Weapons test fallout[f]	10	72
	Nuclear fuel cycle	4	29

(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 6.7 million for Site 300), calculated with respect to distance and direction from each site. The Livermore site population estimate of 7.22 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 2010.

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
Livermore SW-MEI	Tritium	56	0.037	1.6×10^{-1}(a)	2.9×10^{-3}
Livermore SW-MEI	Plutonium-239	7.4×10^{-5}	1.9×10^{-8}	1.1×10^{-8}	1.5×10^{-4}
Site 300 SW-MEI	Uranium-238	3.07×10^{-4}	1.1×10^{-9}	1.1×10^{-6}	3.6×10^{-3}(b)

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) The ratio for the mean uranium-235 and uranium-238 concentrations for 2010 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 2010, radionuclides contributing to dose to biota were americium-241, cesium-137, tritium, plutonium-238, plutonium-239, thorium-232, uranium-234, uranium-235, and uranium-238. In the 2010 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. 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). Radionuclide concentrations in each medium 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), the site has passed the screening analysis and biota are assumed to be protected.

In 2010, the sum of the fractions for the aquatic system was 0.0331, and the sum for the terrestrial system was 0.320 with a total of 0.353 for the combined fraction. The predominant contribution is due to uranium in the Site 300 soil.

7.5 Environmental Impact

The annual radiological doses from all emissions at the Livermore site and Site 300 in 2010 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 2010 were:

- Livermore site: 0.11 μSv (0.011 mrem)—31% from point-source emissions; 69% from diffuse-source emissions.
- Site 300: 5.7×10^{-6} μSv (5.7×10^{-7} 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 2010 was estimated to be 0.0057 person-Sv (0.57 person-rem) for the Livermore site and 1.9×10^{-6} person-Sv (1.9×10^{-4} person-rem) for Site 300. These doses include potentially exposed populations of 7.22 million people for the Livermore site and 6.7 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 2010 were insignificant compared to both the federal standard and the dose received from natural background sources. The collective doses from LLNL operations in 2010 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 2010.

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8. Groundwater Investigation and Remediation

Valerie Dibley

During 2010, groundwater investigations and remediation under CERCLA continued at both the Livermore site and Site 300. 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 Ground Water 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 2010, LLNL maintained and operated 25 groundwater treatment facilities. The groundwater extraction wells and dual (groundwater and soil vapor) extraction wells produced more than 278 million gal or 1,052 million L of groundwater and the treatment facilities removed nearly 54.4 kg of VOCs. Since remediation began in 1989, approximately 4,083 million gal or 15.5 billion L of groundwater have been treated, resulting in removal of more than 1,440 kg of VOCs. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2011).

LLNL also maintained and operated 8 soil vapor treatment facilities in 2010. The soil vapor extraction wells and dual extraction wells produced more than 60 million ft^3 or 1.7 million m^3 of soil vapor and the treatment facilities removed more than 44.5 kg of VOCs. Since initial operation, over 432 million ft^3 or 12 million m^3 of soil vapor has been extracted and treated, removing more than 1,436 kg of VOCs from the subsurface. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2011).

One ground water treatment facility (Treatment Facility A-West) remained offline during 2010 while a remedial design is completed to connect the offsite well, W-404 to the 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. Three ground water treatment facilities (Treatment Facility 518-North and Treatment Facilities 5475-1 and

T5475-3) and one soil vapor treatment facility (Vapor Treatment Facility 5475) were offline during 2010 due mixed waste generation and disposal issues. A draft Focused Feasibility Study (FFS) was submitted to the regulatory agencies to meet the September 2010 milestone ; this document discussed potential treatment system modifications to address the mixed waste issues. The regulatory agencies agreed to delay the draft final and final FFS milestones until several Livermore Site treatability studies have been completed. These treatability studies could provide additional alternatives for addressing the mixed waste issues.

The Livermore Site initiated three enhanced source area remediation (ESAR) treatability tests: (1) pneumatic fracturing at the Treatment Facility E Hotspot; (2) bioremediation at the Treatment Facility D Helipad; and (3) enhanced thermal remediation at the Treatment Facility E Eastern Landing Mat. The results of these treatability tests could potentially accelerate cleanup at the Livermore Site. The pneumatic fracturing treatability test is scheduled for completion in 2011 while the bioremediation and thermal heating treatability tests are scheduled for completion in 2012.

In addition to these treatability studies, the Livermore Site conducted extensive direct-push cone penetration testing (CPT) surveys to better delineate the Building 518 Perched Zone and Building 511/Building 419 source areas.

During 2010, six dual extraction wells, two ground water extraction wells, three soil vapor extraction wells, and nine monitor wells were installed at the Livermore Site. In addition, 90 obsolete wells in the Treatment Facility A Vadose Zone Observatory and Treatment Facility 406 Gas Pad areas were properly sealed.

During 2010, the Livermore Site submitted a Work Plan to the regulatory agencies for the delineation of mercury in soil at the former Building 212 location in April 2010. Free-phase mercury was identified in soil during demolition of Building 212 in April 2008. Removal of soil containing mercury was performed by LLNL at that time. However, confirmation sampling indicated that mercury remained in subsurface soil, and the extent of mercury was not fully defined. Results from additional field investigations performed during June 2010 indicate that mercury concentrations in surficial and shallow soil in the vicinity of Building 212 are less than the U.S. EPA Industrial Screening Level. A status report will be submitted to the regulatory agencies in 2011. During 2010, the Remedial Project Managers signed a Consensus Statement for Environmental Restoration of the Livermore Site that included 19 Federal Facility Agreement milestones. The Livermore Site environmental restoration project had thirteen milestones scheduled for completion in 2010. 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 2010. There is little to no evidence of measureable contaminant plume migration as a result of treatment facilities not operating during late 2008 and early 2009. Hydraulic containment along the western and southern boundaries of the site was fully re-established and progress was made toward interior plume and source area clean up. See Buscheck et al. (2011) 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 CERCLA 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) 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 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.

In 2010, the Site 300 ERP operated 15 groundwater and 5 soil vapor treatment facilities. About 9.7 million gal or 36.7 million L of groundwater were extracted and treated during 2010. The dual and soil vapor extraction wells together removed 80 million ft^3 or 2.3 million m^3 of contaminated soil vapor. The Site 300 treatment facilities removed nearly 13 kg of VOCs, 0.12 kg of perchlorate, 1,400 kg of nitrate, 0.15 kg of the high explosive compound RDX, 0.0061 kg of silicone oils (TBOS/TKEBS), and 0.0078 kg of uranium in 2010. Since groundwater remediation began in 1990, approximately 386 million gal or 1,461 million L of groundwater and over 574 million ft^3 or 16 million m^3 soil vapor have been treated, resulting in removal of more than 550 kg of VOCs, 1.0 kg of perchlorate, 9,400 kg of nitrate, 1.5 kg of RDX, 9.5 kg of silicone oils, and 0.0078 kg of uranium. Tritium in ground water continues to decay, reducing tritium activities in Site 300 ground water. Detailed flow and mass removal by OU is presented in Dibley et al. (2011).

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 Building 850/Pit 7 Complex OU became fully implemented in 2010. Three regulatory milestones were met in 2010: (1) submittal of as-built drawings for the Pit 7 Complex remedial action; (2) submittal of as-built drawings for the Building 850 Removal Action; and (3) submittal of the Building 850/Pit 7 Complex OU Remedial Action Completion Report. These documents were submitted to the regulatory agencies in May 2010. The CERCLA pathway for the last OU, Building 812, is being negotiated with the regulatory agencies.

Groundwater concentration and hydraulic data collected and analyzed for Site 300 during 2010 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 2010 is available in the *2010 Annual Compliance Monitoring Report for LLNL Site 300* (Dibley et al. 2011).

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 of contaminated soil, and hydraulic drainage diversion; and monitored natural attenuation, monitoring, and institutional controls.

9. Quality Assurance

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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. There were no laboratory 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 EFA are DOE-qualified vendors and are NELAP certified (or equivalent). LLNL has qualified auditors under the DOECAP program in the areas of quality assurance, organic chemistry, inorganic chemistry, radiochemistry, 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 FY2010, the laboratories certified by the State of California operating at LLNL as government owned and contractor operated were not internally assessed or qualified by EFA 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 2010, LLNL had Blanket Service Agreements (BSAs) with six commercial analytical laboratories and used two on-site analytical laboratories. 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 2010, all contracted commercial labs were successful in participation in performance evaluation studies.

Although laboratories are also required to participate in laboratory intercomparison programs, permission to publish their results for comparison purposes was not granted for 2010. To obtain 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 similar 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 similar 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 detections (see **Section 9.4**). **Table 9-3** is based on data pairs in which either or both values are nondetections.

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

Media	Analyte	N[a]	%RSD[b]	Slope	r^{2}[c]	Intercept
Air	Gross beta	66	16.6	0.847	0.92	5.69×10^{-5} (Bq/m^3)
	Beryllium	13	12.1	1.01	0.88	0.0583 (pg/m^3)
	Uranium-235	11	7.75	1.04	0.99	-9.61×10^{-10} (µg/m^3)
	Uranium-238	11	7.88	1.05	0.98	-1.92×10^{-7} (µg/m^3)
	Tritium	32	26.8	0.881	0.92	0.0072 (Bq/m^3)
Dose (TLD)	90-day radiological dose	32	2.93	0.906	0.87	1.36 (mrem)
Groundwater	Gross alpha[d]	12	15.6	0.556	0.39	0.0491 (Bq/L)
	Gross beta[d]	37	29.3	0.706	0.43	0.0998 (Bq/L)
	Arsenic	24	6.42	1.01	0.99	-0.000397 (mg/L)
	Barium[e]	16	3.69	0.877	0.74	0.00159 (mg/L)
	Chloride	12	0.712	0.945	0.99	7.35 (mg/L)
	Fluoride	12	3.6	0.992	0.99	0.00377 (mg/L)
	Nitrate (as NO_3)	19	2.61	0.935	0.97	0.652 (mg/L)
	pH	10	0.374	1.15	0.89	-1.12 (units)
	Potassium	12	3.33	1.07	1	-0.554 (mg/L)
	Selenium	10	5.68	1	0.98	0.000298 (mg/L)
	Sodium	14	1.74	1	0.98	–0.367 (mg/L)
	TDS[e]	12	2.22	1.22	0.51	-130 (mg/L)
	Specific conductance	10	0.909	0.957	0.96	56.1 (umhos/cm)
	Sulfate	12	1.82	1.03	1	–6.77 (mg/L)
	Tritium	11	18	1.03	1	-0.925 (Bq/L)
	Uranium-234+ uranium-233	13	16.4	0.886	0.92	0.000232 (Bq/L)
	Uranium-238	12	8.05	0.948	0.98	0.00108 (Bq/L)

(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 r^2 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 detection limit.

Media	Analyte	N[a]	Mean ratio	Minimum ratio	Maximum ratio
Air	Gross alpha	5	1.1	0.79	1.6
Air	Plutonium 239+240	1	0.71	0.71	0.71
Aqueous	Gross alpha	1	1.2	1.2	1.2
Aqueous	Gross beta	1	0.86	0.86	0.86
Groundwater	Radium-226	1	0.53	0.53	0.53
Groundwater	Uranium 235+236	6	1.2	0.82	1.8
Runoff (from rain)	Gross alpha	1	0.84	0.84	0.84
	Gross beta	1	0.97	0.97	0.97
	Tritium	1	1.6	1.6	1.6
	Uranium-234 + 233	1	0.96	0.96	0.96
	Uranium-235 + 236	1	1.6	1.6	1.6
	Uranium 238	1	0.93	0.93	0.93
Soil	Gross alpha	1	0.88	0.88	0.88
	Gross beta	1	0.91	0.91	0.91
	Cesium-137	3	0.93	0.82	1.1
	Tritium	1	0.94	0.94	0.94
	Potassium-40	3	0.97	0.92	1
	Plutonium-238	2	1	1	1
	Plutonium-239+240	2	1.3	0.96	1.6
	Radium-226	3	0.8	0.5	0.98
	Radium-228	3	0.89	0.71	1
	Thorium-228	3	0.92	0.72	1
	Uranium-235	3	0.92	0.67	1.1
	Uranium-238	3	1.1	0.38	1.7
Sewer	Gross beta	7	0.99	0.88	1.1
Sewer	Tritium	1	1.1	1.1	1.1
Sewer	Tritium	1	0.83	0.83	0.83
Vegetation	Tritium	4	1.2	0.99	1.7

(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 detection limit.

Media	Analyte	No. inconsistent pairs[(a)]	No. pairs	Percent inconsistent pairs
Air	Gross alpha	2	64	3.1
Air	Tritium	1	14	7.1
Groundwater	Gross alpha	1	26	3.8
	Arsenic	1	8	12
	Nitrate (as NO^3)	1	7	14

(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 averaged; 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 27% or better; 75% have %RSD of 13% 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.

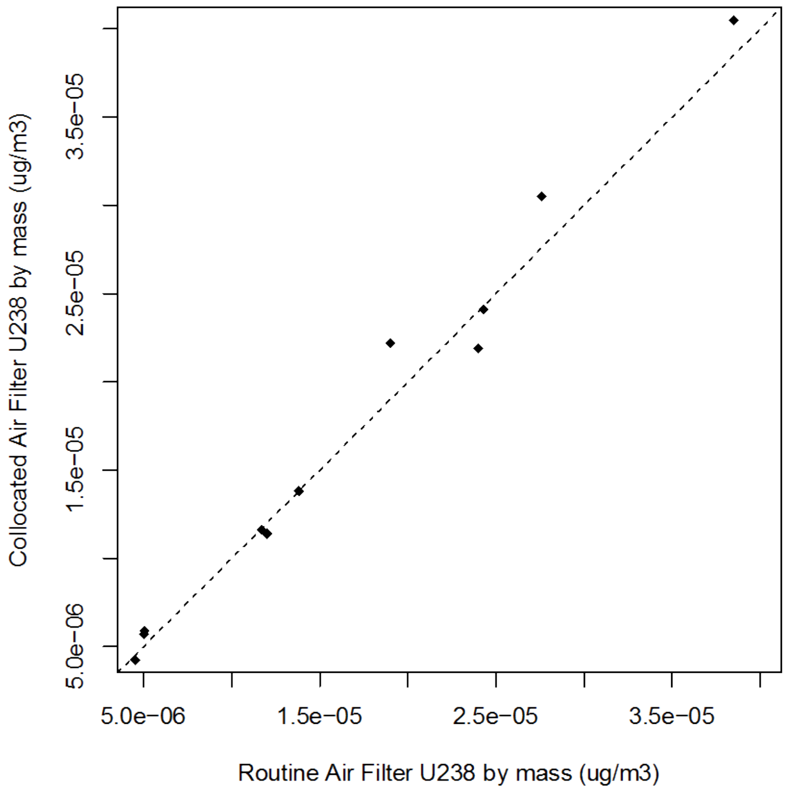

Figure 9-1. Example of data points that demonstrate good agreement between collocated sample results using uranium-238 concentrations in air filters

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 23 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.

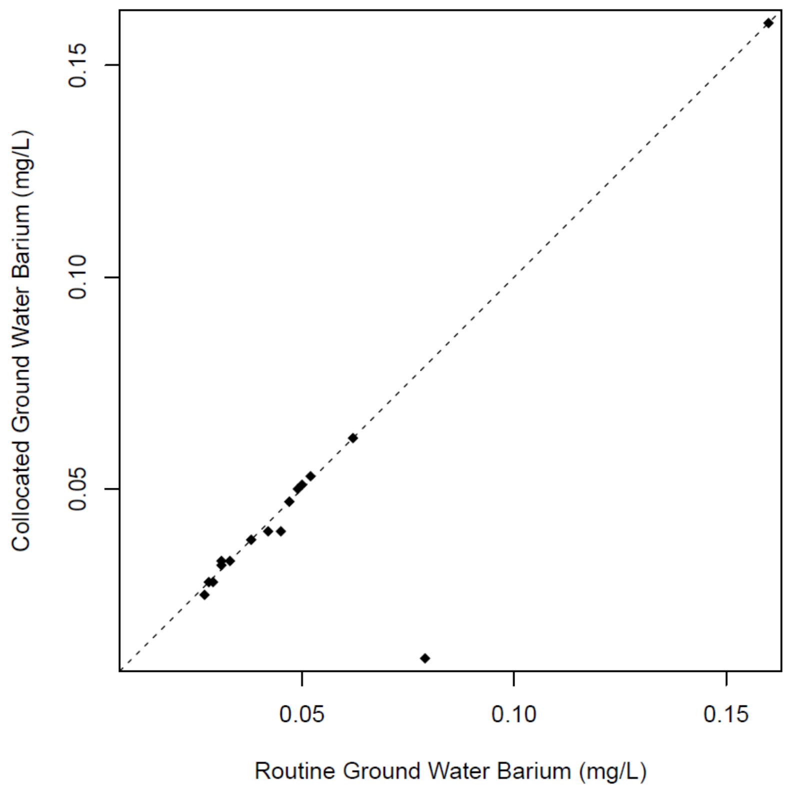

Figure 9-2. Example of data with one outlier using collocated groundwater barium concentrations

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 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 23 data sets listed in **Table 9-1**, two 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 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.

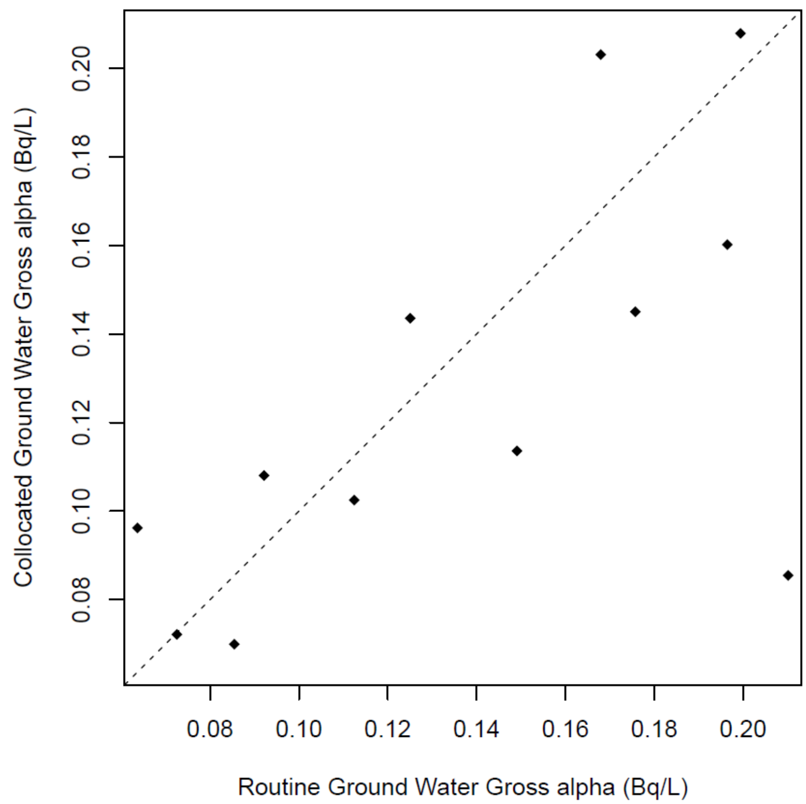

Figure 9-3. Example of variability using collocated groundwater gross alpha concentrations

9.4.1 Radiological Data

Most of the data tables in **Appendix A** display radiological data as a 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 follows the IEEE Standard 754- 1985, 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 2010 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 *Environmental Report 2009*.

References

Arnold, R.A. (2002). *Report on the Threatened Valley Elderberry Longhorn Beetle and Its Elderberry Food Plant at the Lawrence Livermore National Laboratory – Site 300*. Pleasant Hill, CA: Entomological Consulting Services, Ltd.

ATSDR. (2002). *Health Consultation, Tritium Releases and Potential Offsite Exposure, Lawrence Livermore National Laboratory (U.S. DOE), Livermore, Alameda County, California, EPA Facility ID: CA2890012584; and Lawrence Livermore National Laboratory (U.S. DOE); Tracy, San Joaquin County, California, EPA Facility ID: CA2890090002; and Savannah River Site (U.S. DOE), Aiken, Aiken, Barnwell and Allendale Counties, South Carolina, EPA Facility ID: SC1890008989.* Atlanta: Agency for Toxic Substances Disease Registry.

ATSDR. (2003). *ATSDR Final Public Health Assessment Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community, Lawrence Livermore National Laboratory, Main Site (USDOE) Livermore, Alameda County, California, EPA Facility ID: CA2890012584.* Atlanta: Agency for Toxic Substances Disease Registry.

Avalos, G. (2005). "Vintners toast triumph as Supreme Court uncorks potential for out-of-state sales." *Contra Costa Times*, May 17.

Bertoldo, N., G. Gallegos, D. MacQueen, A. Wegrecki, and K. Wilson. (2010). *LLNL NESHAPs 2009 Annual Report.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-TR-113867-10.

Blake, R. and D. H. MacQueen (2010). *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2009*, Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-10191-09-4.

Blake, R. and J. Vallet (2010). *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill Annual Report 2009*, Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-10191-09-4.

Blake, R.G., C.M. Noyes, and M.P. Maley. (1995). *Hydrostratigraphic Analysis—The Key to Cost-Effective Ground Water Cleanup at Lawrence Livermore National Laboratory.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-JC-120614.

Bowen, B.M. (2007). *1958–2006 Precipitation Climatology for Lawrence Livermore National Laboratory Livermore Site and Site 300*, Livermore, CA: Lawrence Livermore National Laboratory, UCRL-TR-228582.

Burkholder, L. (2008). Personal communication with L. Paterson, wildlife biologist, Lawrence Livermore National Laboratory, Livermore, CA.

Buscheck, M., P. McKereghan, M. Dresen, and E. Folsom (2010). *LLNL Ground Water Project 2009 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126020-09.

Campbell, C.G., K. Folks, S. Mathews, and R. Martinelli. (2004). "Investigating Sources of Toxicity in Stormwater: Algae Mortality in Runoff Upstream of the Lawrence Livermore National Laboratory." *Environmental Practice* 6(1): 23–35. LLNL-UCRL-JC-147164.

Campbell, C.G. and S. Mathews. (2006). *An Approach to Industrial Stormwater Benchmarks: Establishing and Using Site-Specific Threshold Criteria at Lawrence Livermore National Laboratory.* CASQA Stormwater 2006 Conference, Sacramento, CA, September 25, 2006–September 27, 2006, UCRL-CONF-224278.

Clark, H.O., D.A. Smith, B.L. Cypher, and P.A. Kelly. (2002). *Mesocarnivore Surveys on Lawrence Livermore National Laboratory Site 300.* California State University, Stanislaus, Endangered Species Recovery Program, Fresno, CA.

CNPS. (2009). *Inventory of Rare and Endangered Plants, 7th Edition*. California Native Plant Society. Published on-line at http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi.

CVRWQCB. (1993). *Waste Discharge Requirements for Post-Closure Monitoring Requirements for Two Class I Landfills.* Order No. 93-100.

CVRWQCB. (1998). *Monitoring and Reporting Program No. 93-100, Revision 2*.

Dibley, V., L. Ferry, and M. Bruscheck, (2010). *2009 Annual Compliance Monitoring Report for Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-206319-09.

References

Dibley, V., L. Ferry, S. Gregory, L. Hall, V. Madrid, L. Martello, E. Shiroma, M. Taffet, and K. Wells (2009), Compliance Monitoring Plan and Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-411239).

Dibley, V., L. Ferry, and M. Bruscheck, (2011). *2010 Annual Compliance Monitoring Report for Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-206319-10.

Dresen, M. D., J.P. Ziagos, A.J. Boegel, and E.M. Nichols (Eds.) (1993). *Remedial Action Implementation Plan for the LLNL Livermore Site*, Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-110532.

DTSC. (2003). *Transmittal of Documents Relating to the Final Post Closure Permit Decision for Lawrence Livermore National Laboratory, Site 300.* Berkeley: Department of Toxic Substances Control, EPA ID No. CA-2890090002 (letter, February 21).

Ferry, L., M. Dresen, Z. Demir, V. Dibley, V. Madrid, M. Taffet, S. Gregory, J. Valett, and M. Denton. (2006). *Final Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-220391.

Ferry, L., R. Ferry, W. Isherwood, R. Woodward, T. Carlsen, Z. Demir, R. Qadir, and M. Dresen. (1999). *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-132609.

Ferry, L., T. Berry, and D. MacQueen. (1998). *Post-Closure Plan for the Pit 6 Landfill Operable Unit, Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-128638.

Ferry, R., L. Ferry, M. Dresen, and T. Carlsen. (2002). *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-147570.

Gallegos, G., ed. (2009). *Environmental Monitoring Plan.* Livermore, CA: Lawrence Livermore National Laboratory, Operation and Regulatory Affairs Division, Environmental Protection Department, UCRL-ID-106132, Rev. 5.

Goodrich, R. and J. Wimborough. (2006). *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs).* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-109115 Rev. 12.

Gouveia, F. and K.R. Chapman. (1989). *Climatology of Lawrence Livermore National Laboratory.* Livermore, CA: Lawrence Livermore National Laboratory, UCID-21686.

Grayson, A. (2009). *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements Order No. R5-2008-0148, Annual/Second Semester Report 2009*, Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-411431-10-3.

Grayson A., K. Brunckhorst, and C. Foster. (2009). *Lawrence Livermore National Laboratory Livermore Site Semiannual Wastewater Point-Source Monitoring Report.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-10204-09-2.

Grayson A. and C. Foster. (2010). *Lawrence Livermore National Laboratory Livermore Site Semiannual Wastewater Point-Source Monitoring Report.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-10204-10-1.

Harrach, R.J., R.A. Failor, G.M. Gallegos, P.J. Tate, E. Christofferson, E.R. Brandstetter, J.M. Larson, A.H. Biermann, R.A. Brown, B.C. Fields, L.M. Garcia, and A.R. Grayson. (1996). *Environmental Report 1995.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-95. Accessible at https://saer.llnl.gov/.

Harrach, R.J., G.M. Gallegos, R.A. Failor, E. Christofferson, P.J. Tate, E.R. Brandstetter, J.M. Larson, J. McIntyre, B.C. Fields, R.A. Brown, L.M. Garcia, and A.R. Grayson. (1995). *Environmental Report 1994.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-94. Accessible at https://saer.llnl.gov/.

Harrach, R.J., G.M. Gallegos, P.J. Tate, E. Christofferson, E.R. Brandstetter, J.M. Larson, A.H. Biermann, B.C. Fields, L.M. Garcia, and K.A Surano. (1997). *Environmental Report 1996*, Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-96. Accessible at https://saer.llnl.gov/.

Hoffman, F., R.G. Blake, Z. Demir, R.J. Gelinas, P.F. McKereghan, and C.D. Noyes. (2003). "A Conceptual Model and Remediation Strategy for Volatile Organic Compounds in Unconsolidated Sediments: A Lawrence Livermore National Laboratory Case Study." *Environmental & Engineering Geoscience* 9 (February 2003), no. 1:83–94.

ICRP. (2005). “2005 Recommendations of the International Commission on Radiological Protection (Draft for Consultation),” International Commission on Radiological Protection. Accessible at http://www.icrp.org/docs/2005_recs_CONSULTATION_Draft1a.pdf

International Commission on Radiological Protection. (1996). “Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5. Compilation of Ingestion and Inhalation Dose Coefficients.” *Annals of the ICRP*, Vol. 26, No. 1, pp. 1–91.

Jackson, C.S. to Naomi Feger, San Francisco Bay RWQCB (2002), Letter: "Drainage Retention Basin Monitoring Plan Change," Lawrence Livermore National Laboratory, Livermore, CA, WGMG02:175:CSJ:RW:kh, (December 6, 2002).

Jones, H. (2010). *Monthly Sewer Monitoring Report for LLNL Main Site*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-1355026-10-02.

LLNL. (2001). *Revisions to the Post-Closure Permit Application for the Building 829 HE Open Burn Treatment Facility—Volume 1* (Revised, December 2001). Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-139697-01.

LLNL. (2002). Personal communication with J. Woollett and M. van Hattem, wildlife biologists, Lawrence Livermore National Laboratory, Livermore, CA.

LLNL. (2003). *LLNL Avian Monitoring Program Variable Circular Plot Point Count and Constant Effort Mist Netting*. Livermore, CA: Lawrence Livermore National Laboratory.

LLNL. (2009). *Radioactive Waste Management Basis.* Livermore, CA: Lawrence Livermore National Laboratory, LLNL-TR-402476-REV-2.

Mathews, S., and M. Taffet. (1997). *Final Closure Plan for the High-Explosives Open Burn Facility at Lawrence Livermore National Laboratory Experimental Test Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-111753 Rev. 1.

Mathews, S., N.A. Bertoldo, R.A, Brown, C.G. Campbell, S. Cerruti, C.L. Conrado, A.R. Grayson, H.E. Jones, J.A. Karachewski, G. Kumamoto, J. Larson, D.H. MacQueen, L. Paterson, S.R. Peterson, M.A. Revelli, D. Rueppel, M.J. Taffet, K. Wilson, and J. Woollett. (2007). *Environmental Report 2006.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-06.

NCRP. (1987a). *Ionizing Radiation Exposure of the Population of the United States.* Washington, DC: National Council on Radiation Protection and Measurements, Report No. 93.

NCRP. (1987b). *Recommendations on Limits of Exposure to Ionizing Radiation.* Washington, DC: National Council on Radiation Protection and Measurements, Report No. 91.

NCRP. (1995). *Principles and Application of Collective Dose in Radiation Protection.* Bethesda, MD: National Council on Radiation Protection and Measurements, NCRP Report No. 121.

NCRP. (1999). *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies.* Bethesda, MD: National Council on Radiation Protection and Measurements, NCRP Report No. 129.

Noyes, C., W. Sicke, R. Ruiz, Z. Demir, C. Quinly, S Bourne, E. Folson, P. McKereghan, R. Nagar, and M. Dresen (2009). *Treatability Study Summary and Proposed Cleanup Alternatives for the TFA West Area, Lawrence Livermore National Laboratory, Livermore Site*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-416970, September 2009.

Orloff, S. (1986). *Wildlife Studies of Site 300 Emphasizing Rare and Endangered Species: Lawrence Livermore National Laboratory, San Joaquin County, California.* Sausalito, CA: BioSystems Analysis, Inc.

Parks, B.S. (1992). *User’s Guide for CAP88-PC, Version 1.* Las Vegas: U.S. Environmental Protection Agency, Office of Radiation Programs, EPA 402-B-92-001.

Paterson, L.E. (2010a). *Lawrence Livermore National Laboratory (LLNL) Arroyo Mocho Road Improvement and Fish Passage Project Final Monitoring Report*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-423462.

Paterson, L.E. (2010b). *Lawrence Livermore National Laboratory (LLNL) Arroyo Seco Management Plan 2009 Monitoring Report*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-422342, January 2010.

Preston, R.E. (1997). *Delineation of Waters of the United States for Arroyo Las Positas, Lawrence Livermore National Laboratory, Alameda County, California.* Sacramento: Jones & Stokes.

Preston, R.E. (2002). *Special-status Plant Species Surveys and Vegetation Mapping at Lawrence Livermore National Laboratory.* Sacramento: Jones & Stokes.

Rainey, B. (2003). Personal communication to L. Paterson, Environmental Protection Department, Lawrence Livermore National Laboratory, July.

Revelli, M. A. (2009a). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174 Annual Report 2008-2009*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126783-09.

Revelli, M. (2009b). *Lawrence Livermore National Laboratory Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-144362-09.

Revelli, M.A. (2010a). *Groundwater Discharge Annual Self-Monitoring Report for 2009.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-143911-09.

Revelli, M.A. (2010b). *Lawrence Livermore National Laboratory Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2009.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-143121-09.

Rogers/Pacific Corporation. (1990). *Lawrence Livermore National Laboratory Site 300 Resource Conservation and Recovery Act Closure and Post-Closure Plans—Landfill Pits 1 and 7, Vols. I and II*. Van Nuys, CA, EPA No. CA2890090002.

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, CA: Lawrence Livermore National Laboratory, UCRL-50027-02.

SFBRWQCB. (1995). *Waste Discharge Requirements and National Pollutant Discharge Elimination System (NPDES) Storm Water Permit for: U.S. Department of Energy and Lawrence Livermore National Laboratory.* Oakland: San Francisco Bay Regional Water Quality Control Board, Order No. 95-174, NPDES No. CA030023.

Silver, W.J., C.L. Lindeken, J.W. Meadows, W.H. Hutchin, and D.R. McIntyre. (1974). *Environmental Levels of Radioactivity in the Vicinity of the Lawrence Livermore Laboratory, 1973 Annual Report.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-51547.

Site 300 U.S. DOE (2007), Amendment to the Interim Site-Wide Record of Decision for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-222569).

N. Sugiura and T. Kosako (2000). "Discussion on the Collective Dose in the Application to Radioactive Waste Management." 10th Congress of the International Radiation Protection Association (IRPA) Hiroshima, Japan. May10. Accessible at http://www,2000.ipa.net/irpa10/cdrom/01082.pdf.

Swaim, K. (2002). *Results of Surveys for Special Status Reptiles at the Site 300 Facilities of Lawrence Livermore National Laboratory.* Livermore, CA: Swaim Biological Consulting.

SWRCB. (1997). *Waste Discharge Requirements and National Pollutant Discharge Elimination System (NPDES) Discharges of Storm Water Associated with Industrial Activities Excluding Construction Activities.* Sacramento: State Water Resources Control Board, Order No. 97-03-DWQ, General Permit No. CAS000001.

SWRCB. (1999). *Waste Discharge Requirements for Discharges of Storm Water Runoff Associated with Construction Activity.* NPDES General Permit No. CAS000002, Order No. 99-08-DWQ.

Taffet, M.J., L. Green-Horner, L.C. Hall, T.M. Carlsen, and J.A. Orberdorfer. (1996). *Addendum to Site-Wide Remedial Investigation Report, Building 850/Pit 7 Complex Operable Unit, Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-108131, Add. 1.

Taffet, M., V. Dibley, T. Carlsen, V. Madrid, Z. Demir, B. Daily, and L. Ferry. (2008). *Draft Building 812 Remedial Investigation/Feasibility Study Lawrence Livermore National Laboratory, Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-404981-DRAFT.

Thorpe, R.K., W.F. Isherwood, M.D. Dresen, and C.P. Webster-Scholten. (1990). *CERCLA Remedial Investigation Report for the LLNL Livermore Site, Vols. 1–5*. Livermore, CA: Lawrence Livermore National Laboratory, UCAR-10299.

U.S. DOE. (1991). *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance.* Washington, DC: U.S. Department of Energy, DOE/EH-0173T.

U.S. DOE. (2002). *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. Washington, DC: U.S. Department of Energy, DOE-STD-1153-2002.

U.S. DOE/NNSA (2005). *Final Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement.* U.S. Department of Energy/National Nuclear Security Administration, Washington, D.C. March 2005. (DOE/EIS-0348; DOE/EIS-0236-S3). Accessible at: https://www-envirinfo.llnl.gov/enviroRecent.php

U.S. DOE and UC. (1992). *Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories.* Livermore, CA: Lawrence Livermore National Laboratory, DOE/EIS-0157, SCH90030847.

U.S. EPA. (1987). *Data Quality Objectives for Remedial Response Activities: Development Process*. Washington, DC: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, EPA 540/G-87/003, OSWER Directive 9355-0.

U.S. EPA. (2000). "Notice: Final Reissuance of National Pollutant Discharge Elimination System (NPDES) Storm Water Multi-Sector General Permit for Industrial Activities." *Federal Register*, Volume 65, No. 210, October 30.

USFWS. (1998). *Recovery Plan for Upland Species of the San Joaquin Valley, California*. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Region 1.

U.S. NRC. (1977). *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluation Compliance with 10 Code of Federal Regulations, Part 50, Appendix 1*. Washington, DC: U.S. Nuclear Regulatory Commission, Regulatory Guide 1.109.

U.S. NRC/U.S. EPA (2004), *Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP)*, U.S. Nuclear Regulatory Commission/U.S. Environmental Protection Agency, July 2004 (NUREG-1576, EPA 402-B-04-001A, NTIS PB2004-105421).

Van Hattem, M. (2005). Personal communication with L. Paterson, wildlife biologist, Lawrence Livermore National Laboratory, Livermore, CA.

Weber, W. (2002). *2001–2002 Wet Season Branchiopod Survey Report, University of California, Lawrence Livermore National Laboratory, Site 300, Alameda and San Joaquin Counties*. Hayward, CA: Condor Country Consulting.

Webster-Scholten, C.P., ed. (1994). *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory, Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-108131.

West, E. (2002). *2002 Small Mammal Inventory at Lawrence Livermore National Laboratory, Site 300*. Sacramento: Jones & Stokes.

Woollett, J. (2005). Personal communication with L. Paterson, wildlife biologist, Lawrence Livermore National Laboratory, Livermore, CA.

Ziagos, J., and E. Reber-Cox. (1998). *Ground Water Tritium Plume Characterization Summary Report for the Building 850/Pits 3 and 5 Operable Unit, Site 300.* Livermore, CA: Lawrence Livermore National Laboratory.

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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
BO	biological opinion
BSA	Blanket Service Agreement
BSL	Biosafety Level
CAA	Clean Air Act
CalARP	California Accidental Release Prevention
CAMP	Corrective Action Monitoring Plan
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

DCG	derived concentration guide (*See also* definition in **Key Terms** section.)
DHS	(California) Department of Health Services
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
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
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

	From metric unit to U.S. customary equivalent unit		From U.S. customary unit to metric equivalent unit	
Category	**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 guide (DCG). 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.1.1 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from the monitored emission point at Livermore site, Building 235, 2010

A.1.2 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from the monitored emission point at Livermore site, Building 491, 2010

A.1.3 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2010

A.1.4 Summary of tritium (Bq/m^3) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2010

A.1.5 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from the monitored emission points at Livermore site, Building 332, 2010

A.1.6 Summary of tritium in air effluent samples (Bq/m^3) from the monitored emission points at Livermore site, Building 331, 2010

A.1.7 Summary of gross alpha and gross beta (μBq/m^3) in air effluent samples from the monitored emission point at Site 300, Building 801, 2010

A.1.8 Summary of tritiated particulate (μBq/m^3) in air effluent samples from the monitored emission point at Livermore site, Building 581, 2010

A.1.9 Summary of Iodine-131 (μBq/m^3) in air effluent samples from the monitored emission point at Livermore site, Building 581, 2010

A.1.10 Summary of representative gamma suite for radioactive particulate (uBq/m3) in air effluent samples from the monitored emission points at Livermore site, Building 581, 2010

A.1.11 Summary of gross alpha and gross beta (uBq/m3) in air effluent samples from the monitored emission point at Livermore site, Building 581, 2010

A.1.12. Summary of tritium in air effluent samples (Bq/m3) from the monitored emission points at Livermore, Building 581 2010

A.2 Ambient Air (Chapter 4)

A.2.1 Weekly gross alpha and gross beta concentrations (μBq/m^3) from air particulate samples from the Livermore perimeter locations, 2010

A.2.2 Tritium concentrations (mBq/m^3) in air on the Livermore site, 2010

A.2.3 Beryllium concentration (pg/m^3) in air particulate samples at the Livermore site and Site 300, 2010

A.2.4 Beryllium-7 concentrations (mBq/m^3) composite for Livermore site and Site 300 air particulate samples, 2010

A.2.5 Plutonium-239+240 concentrations (nBq/m^3) in air particulate samples from the Livermore perimeter and Site 300 perimeter composite, 2010

A.2.6 Uranium mass concentrations (pg/m^3) in air particulate samples from Site 300 onsite and offsite locations, and the Livermore site (composite), 2010

A.2.7 Weekly gross alpha and gross beta concentrations (μBq/m^3) from air particulate samples from the Livermore Valley downwind locations, 2010

A.2.8 Tritium concentrations (mBq/m^3) in air, Livermore Valley, 2010

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

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

Constituent of concern	Reporting limit (µg/L)[a,b]
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

Constituent of concern	Reporting limit (μg/L)[(a,b)]
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	*Bufo boreas*		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

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, 2009–2010

Revelli, M.A. (2010). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174, Annual Report 2008–2009*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-126783-10.

LLNL Ground Water Project Annual Report, 2010

Buscheck, M., P. McKereghan, M. Dresen, and E. Folsom (2011). *LLNL Ground Water Project 2010 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126020-10.

LLNL NESHAPs Annual Report, 2010

Wilson, K., G. Gallegos, D. MacQueen, A. Wegrecki, and N. Bertoldo. (2011). *LLNL NESHAPs 2010 Annual Report.* Livermore, California: Lawrence Livermore National Laboratory, UCRL-TR-113867-10.

Site 300 Building 829 Compliance Monitoring Annual Report, 2010

Revelli, M.A. (2011). *Lawrence Livermore National Laboratory Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2010.* Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-143121-10.

Site 300 Compliance Monitoring Annual Report, 2010

Dibley, V. (2010). *2010 Annual Monitoring Compliance Report for Lawrence Livermore National Laboratory Site 300.* Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-206319-10.

Site 300 Storm Water Monitoring for Waste Discharge Requirements 97-03-DWQ Annual Report, 2010

Revelli, M. (2010). *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-144362-10.

Site 300 Compliance Monitoring for Water Discharge Requirement Order No. R5-2008-0148 Annual Report, 2010

Blake, R. (2011). *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements Order No. R5-2008-0148, Annual/Second Semester Report 2010*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-411431-11-3.

Site 300 Pit 6 Compliance Monitoring Annual Report, 2010

Blake, R, and J. Vallet. (2011). *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report 2010*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-132057-10-4.

Site 300 Pit 1 Compliance Monitoring Annual Report, 2010

Blake, R. (2011). *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pit 1, Annual Report for 2010*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-10191-10-4.

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.

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 2010 can be accessed at https://saer.llnl.gov/.

Record of Changes to Environmental Report 2009

The following changes have been made to the Internet version of *Environmental Report 2009*.

- **Page vii, Preface**: The web link in the second paragraph was changed to https://saer.llnl.gov.
- **Page 3-7, Table 3-3:** FY 2009 value changed from 164 to 159 metric tons.
- **Page 3-7, Table 3-4:** FY 2009 data changed to 203.5 (m^3) for routine low-level waste, 24.6 (m^3) for routine mixed waste and 9.4 (m^3) for routine TRU/mixed TRU waste.
- **Page 5-17, Figure 5-3:** The legend was changed from 2008 to 2010.