2013 Site Annual Environmental Report

Lawrence Livermore National Laboratory

UCRL-TR-50027-13

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Lawrence Livermore National Laboratory

Environmental Report 2013

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Preface

The purposes of the *Lawrence Livermore National Laboratory Environmental Report 2013* are to record Lawrence Livermore National Laboratory's (LLNL's) compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring at the two LLNL sites—the Livermore Site and Site 300. The report is prepared for the U.S. Department of Energy (DOE) by LLNL's Environmental Functional Area. Submittal of the report satisfies requirements under DOE Order 231.1B, "Environment, Safety and Health Reporting," and DOE Order 458.1, "Radiation Protection of the Public and Environment."

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

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

The majority of the report covers LLNL's environmental monitoring programs and monitoring data for 2013: effluent and ambient air monitoring and dose assessment (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). The remaining two chapters discuss LLNL's groundwater remediation program (Chapter 7), and quality assurance for the environmental monitoring programs (Chapter 8). Complete monitoring data, which are summarized in the body of the report, are provided in Appendix A.

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

The report is the responsibility of LLNL's Environmental Functional Area. Monitoring data were obtained through the combined efforts of the Environmental Functional Area; Environmental Restoration Department; Physical and Life Sciences Environmental Monitoring Radioanalytical Laboratory; and the Hazards Control Department.

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

Contents

Appendices

Figures

Tables

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Executive Summary

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

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

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

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

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore Site," which occupies 1.3 square miles; and a rural Experimental Test Site, referred to as "Site 300," near Tracy, California, which occupies 10.9 square miles. In 2013 the Laboratory had a staff of approximately 6,300.

Purpose and Scope of the Environmental Report

The purposes of the Environmental Report 2013 are to record LLNL's compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring. Specifically, the report discusses LLNL's Environmental Management System; describes significant accomplishments in pollution prevention; presents the results of air, water, vegetation, and foodstuff monitoring; reports radiological doses from LLNL operations; summarizes LLNL's activities involving special status wildlife, plants, and habitats; and describes the progress LLNL has made in remediating groundwater contamination.

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

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

Regulatory Permitting and Compliance

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

Integrated Safety Management System and Environmental Management System

LLNL established its Environmental Management System (EMS) to meet the requirements of the International Organization for Standardization (ISO) 14001:1996 in June 2004. In June 2006, LLNL upgraded its EMS to meet the requirements of ISO 14001:2004. During 2006 and 2007, LLNL developed Environmental Management Plans (EMPs) that address lab-wide and programmatic significant aspects. During 2008, more focus was placed on raising lab-wide awareness of EMS and on continued development of EMPs. In October 2009, LLNL became ISO 14001:2004 certified. In 2013, LLNL had 8 active Lab-wide EMPs and initiatives on significant aspects, including sustainable acquisition, municipal waste reduction, greenhouse gas reductions, hazardous material use/waste generation, ecological resources disturbances, energy conservation, water conservation and fossil fuel consumption.

Pollution Prevention

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

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

In 2013, LLNL received three NNSA Sustainability awards and was recognized by U.S. EPA's Federal Green Challenge (FGC) program.

The P2S Program outreach efforts in 2013 included participation in a community Earth Day event, assisting LLNL and Sandia in a Farmers Market, publishing articles in the LLNL newspaper, and maintaining of an internal P2S website and a green hotline for all LLNL employees. Also new in 2013 LLNL launched an internal Craigslist-like service called ReUseIt to encourage reuse of property and material.

Air Monitoring

LLNL operations involving radioactive materials had minimal impact on ambient air during 2013. 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 2013, radioactivity released to the atmosphere was monitored at six facilities on the Livermore Site and one at Site 300. In 2013, 1857 GBq (50.2 Ci) of tritium was released from the Tritium Facility, and 47.7 GBq of tritium (1.29 Ci) was released from the National Ignition Facility (NIF). For the Contained Firing Facility at Site 300 a total of 8.1×10^{-7} GBq (2.2×10^{-8} Ci) of uranium-234, 7.4×10^{-8} GBq (2.0×10^{-9} Ci) of uranium-235, and 6.3×10^{-6} GBq (1.7×10^{-7} Ci) of uranium-238 was released in particulate form. The dose to the hypothetical, site-wide maximally exposed individual (SW-MEI) member doses at the Livermore Site and Site 300 are less than one percent of the annual National Emissions Standards for Hazardous Pollutants (NESHAPs), which is 100 µSv/y (10 mrem/y) total site effective dose equivalent. None of the other facilities monitored for gross alpha and gross beta radioactivity had emissions in 2013.

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 2013 for the Livermore Site and Site 300 were similar to 2012 levels with the exception of combustion pollutant emissions, such as NOx, CO, and ROGs/POCs, which increased in 2013 primarily due to the site-wide power outage at Site 300 that occurred on October 30, 2013, and lasted for 21 hours necessitating the start-up and continuous operation of all emergency standby diesel engine generators for the duration of the power outage. 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 2013, ambient air monitoring data confirmed estimated releases from monitored stacks and was 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 2013, 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 2013, monitoring data under the LLNL Wastewater Permit #1250 (2012–2013, 2013–2014) 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 upstream and downstream from both the Livermore Site and Site 300. In the calendar year 2013, there were three storms at the Livermore Site but no storms at Site 300 that met the criteria for a qualifying event as defined in Permit WDR 95-174 (SFBRWQCB 1995) for the Livermore Site and the General Industrial Storm Water Permit (97-03-DWQ) for Site 300. The data for all three Livermore Site storm events were within acceptable levels as defined in our permit WDR 95-174.

In addition to the CERCLA-driven monitoring (i.e., for volatile organic compounds [VOCs]) conducted by LLNL’s Environmental Restoration Department (ERD), extensive surveillance 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 the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) compliance, the constituents of all off-site samples collected at both the Livermore Site and Site 300 were below allowable limits for drinking water.

Surface waters and drinking water are analyzed for tritium and gross alpha and gross beta radioactivity. In the Livermore Valley, the maximum tritium activity was less than 1% of the drinking water standard, and the maximum gross alpha and gross beta measurements were less than 5% of their respective drinking water standards. 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 2013 was insignificant. Soil is analyzed for plutonium, gamma-emitting radionuclides and tritium. Plutonium concentrations in soil at the Livermore Water Reclamation Plant continued to be high relative to other sampled locations, but even this concentration was only 2.1% 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 2013, 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 2013, the median of concentrations in all off-site vegetation samples was below the lower limit of detection of the analytical method. For Livermore Valley wines purchased in 2013, the highest concentration of tritium was just 0.64% of the EPA's standard for maximal permissible level of tritium in drinking water.

LLNL's extensive network of thermoluminescent dosimeters measures the natural terrestrial and cosmogenic background; in 2013, as in recent years, no impact from LLNL operations was detected.

Biota

Through monitoring and compliance activities in 2013, 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 2013. Measures taken at the Livermore Site to control bullfrogs, which are a significant threat to California red-legged frogs, 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 September of 2013 by temporarily halting groundwater discharges to the arroyo.

The 2013 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 2013 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 2013 was 1.8×10^{-2} µSv (1.8×10^{-3} mrem) for the Livermore Site and 4.0×10^{-7} µSv (4.0×10^{-8} mrem) at Site 300. These doses are well below the federal National Emissions Standards for Hazardous Air Pollutants of 100 µSv (10 mrem) and are significantly less than the doses from natural background radiation. In 2013, there was an unplanned deuterium-tritium release of 4.0 GBq (0.109 Ci), which was 0.11% of the U.S. EPA Reportable Quantities (40 CFR 302). The release did not significantly add to LLNL's dose impact.

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 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 2013, concentrations continued to decrease in most of the Livermore Site VOC plumes due to active remediation and the removal of more than 43 kg of VOCs from both groundwater and soil vapor. Groundwater concentration and hydraulic data indicate subtle but consistent declines in the VOC concentrations and areal extent of the contaminant plumes in 2013.

In 2013 at Site 300, perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 11 kg of VOCs. Each Site 300 OU has a different profile of contaminants, but overall, groundwater and soil vapor extraction and natural attenuation continue to reduce the mass of contaminants in the subsurface. Cleanup remedies have been fully implemented and are operational at eight of the nine OUs at Site 300. The CERCLA pathway for the last OU, Building 812, was negotiated with the regulatory agencies in 2011. All milestones were met or renegotiated with the regulatory agencies (see Chapter 2).

Conclusion

LLNL's Environmental Management System provides a framework that integrates environmental protection into all work planning processes. The success of EMS is evidenced by LLNL's certification to the ISO 14001:2004 standard, 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 2013 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.

1. Introduction

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

As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory, with a staff of approximately 6,300, 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 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, LLNL's general research site, is within the eastern limits of Livermore, a city with a population of about 82,000 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 cities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 7.7 million people within 50 mi of the Laboratory, only about 10% are within 20 mi.

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

The city of Tracy, with a population of over 84,000, is approximately 6 mi to the northeast of Site 300 (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 7.1 million people who live within 50 mi of Site 300, 95% are more than 20 mi away in distant metropolitan areas such as Oakland, San Jose, and Stockton.

1.2 Meteorology

Meteorological towers at both the Livermore Site and Site 300 continuously gather data including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature. Mild, rainy winters and warm-to-hot, dry summers characterize the climate at both sites. For a detailed review of the climatology at LLNL, see Gouveia and Chapman (1989).

Both wind and rainfall exhibit strong seasonal patterns at both sites. 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 strongly influenced by higher elevation and more pronounced topological relief.

Temperature, rainfall, and wind speed data for the Livermore Site and Site 300 towers during 2013 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 2013.

	Livermore Site		Site 300	
Temperature	**°C**	**°F**	**°C**	**°F**
Mean daily maximum	22.2	71.9	21.5	70.7
Mean daily minimum	8.3	47.0	12.8	55.0
Average	14.6	58.2	16.8	62.3
High	39.6	103.4	40.4	104.7
Low	–3.7	25.4	-2.9	26.8
Rainfall	**cm**	**in.**	**cm**	**in.**
Total	10.6	4.2	9.7	3.8
Climatological normal [a]	34.8 [b]	13.7 [b]	27.3	10.7
Wind	**m/s**	**mph**	**m/s**	**mph**
Average speed	2.3	5.1	5.7	12.7
Peak gust speed	17.7	39.7	38.1	85.2

[a] Climatological normal is calculated for a 30-year period (1981–2010).

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

1.3 Topography

The Livermore Site is located in the southeastern portion of the Livermore Valley, a prominent topographic and structural depression oriented east–west within the Diablo Range. The most prominent valley in the Diablo Range, the Livermore Valley is bounded on the west by the 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 highest elevation of the valley floor is 720 ft above sea level along its eastern margin near the Altamont Hills; it descends 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 separated by intervening ravines is oriented along a generally northwest–southeast trend. 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 1,740 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.

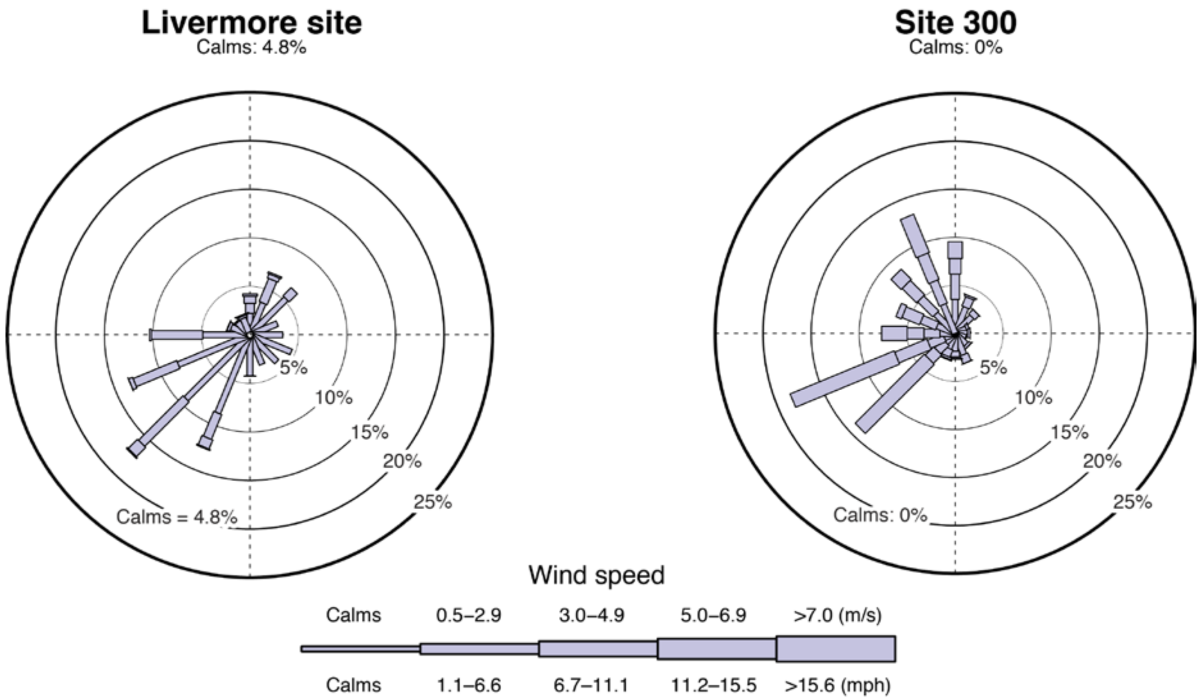

Figure 1-2. Wind roses showing wind direction and speed frequency at the Livermore Site and Site 300 during 2013. The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes.

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 2013.

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 7** for more information on the activities and findings of the investigations.

2.1.1.1 Livermore Site Ground Water Project

The Livermore Site came under CERCLA in 1987 when it was placed on the National Priorities List. The Livermore Site Ground Water Project (GWP) complies with provisions specified in a Federal Facility Agreement (FFA) entered into by the U.S. Environmental Protection Agency (EPA), DOE, the California EPA's Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). As required by the FFA, the GWP addresses compliance issues by investigating potential contamination source areas (e.g., suspected old release sites, solvent-handling areas, leaking underground tank systems), monitoring water quality through an extensive network of wells, and remediating contaminated soil and groundwater. The primary soil and groundwater contaminants (constituents of concern) are common volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE). Background information on LLNL Livermore Site environmental characterization and restoration activities are presented in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990). The *LLNL Ground Water Project 2013 Annual Report* (Buscheck et al. 2014) presents the current status of clean up at the Livermore Site.

Regulatory Milestones. The Livermore Site environmental restoration project had 9 milestones scheduled for completion in calendar year 2013. The following deliverables were submitted to the regulatory agencies:

- Fourth Quarter 2012 Self-Monitoring Report
- 2012 Annual Report
- First, Second, and Third Quarter 2013 Self-Monitoring Report
- Draft and Draft Final Explanation of Significant Differences for Institutional Controls

The Final Explanation of Significant Differences for Institutional Controls was scheduled for 2013. However, it has been delayed due to regulatory comments.

The other regulatory milestones included the following:

- Receive regulatory comments on Draft Explanation of Significant Differences for Institutional Controls

All other calendar year 2013 milestones were met.

Treatment Facilities. During 2013, the Livermore GWP maintained 28 groundwater and 9 soil vapor treatment facilities. The groundwater extraction wells and dual phase extraction wells extracted about 1,132 million L of groundwater during 2013. The dual-phase extraction wells and soil-vapor extraction wells together removed 1.7 million m^3 of soil vapor.

In 2013, the Livermore GWP treatment facilities removed about 43 kg of VOCs. Since remediation efforts began in 1989, more than 18.8 billion L of groundwater and approximately 16.9 million m^3 of soil vapor have been treated, removing about 3,117 kg of VOCs.

Livermore Site restoration activities in 2013 were focused on enhancing and optimizing ongoing operations at treatment facilities. Evaluation of technologies that may accelerate cleanup of the Livermore Site contaminant source areas and address areas of co-mingled VOC and low-level tritium plumes, also continued. Beneath the site, groundwater concentration and hydraulic data indicate subtle but consistent declines in VOC concentrations and areal extent of contaminant plumes in 2013. Hydraulic containment along the western and southern boundaries of the site was fully maintained in 2013, and progress was made toward interior plume and source area clean up. See Buscheck et al. (2014) for more information.

Community Relations. Livermore Site community relations activities in 2013 included maintenance of information repositories and an administrative record; and two meetings (May and December 2013) 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); for Tri-Valley CAREs (May 2013) and Alliance for Nuclear Accountability (November 2013). In addition, DOE/LLNL environmental documents, letters, and public notices were posted on a public website: http://www-envirinfo.llnl.gov.

2.1.1.2 Site 300 Environmental Restoration Project

Remedial activities are ongoing at Site 300, which became a CERCLA site in 1990 when it was placed on the National Priorities List. Remedial activities are overseen by the EPA, the Central Valley Regional Water Quality Control Board (CVRWQCB), and DTSC, under the authority of an FFA for the site. Contaminants of concern at Site 300 include VOCs (primarily TCE), high-explosive compounds, tritium, depleted uranium, silicone-based oils, nitrate, perchlorate, polychlorinated biphenyls, dioxins, furans, and metals. The contaminants present in environmental media vary within the different environmental restoration operable units (OUs) at the site. See Webster-Scholten (1994) and Ferry et al. (1998) for background information on LLNL environmental characterization and restoration activities at Site 300. The *LLNL Site 300 2013 Annual Compliance Monitoring Report* (Dibley et al. 2014) presents the current status of clean up at Site 300.

Regulatory Milestones. The Site 300 environmental restoration project had 12 milestones scheduled for completion in calendar year 2013. The following deliverables were submitted to the regulatory agencies:

- Annual 2012 Compliance Monitoring Report
- Draft and Draft Final Building 854 Five-Year Review
- Draft Final and Final Operable Units 3 and 8 Five-Year Review
- First Semester 2013 Compliance Monitoring Report
- Draft Building 865 Technical Memorandum in Support of a Record of Decision (ROD) Amendment (TMSRA), also called the Draft Building 865 Remedial Investigation/Feasibility Study

The other regulatory milestones included:

- Regulatory comments due on Draft Building 865 TMSRA
- Regulatory comments due on Draft Building 854 Five-Year Review

All calendar year 2013 milestones were met or renegotiated with the regulatory agencies. The submittal dates for the Draft Final and Final Building 865 TMSRA and the Final Building 854 Five-Year Review were delayed to address regulatory comments.

Four non-milestone deliverables were submitted to the regulatory agencies during 2013 including:

- Addendum to the Compliance Monitoring Plan and Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300
- Exposure Parameters for the Deer Mouse and Rock Wren at Lawrence Livermore National Laboratory Site 300
- Mammalian and Avian Toxicity Reference Values for use in the Building 812 Baseline Ecological Risk Assessment at Lawrence Livermore National Laboratory Site 300
- Technical Memorandum for Additional Characterization of the Building 812 Operable Unit at the Lawrence Livermore National Laboratory Site 300

Treatment Facilities. During 2013, the Site 300 Environmental Restoration Project (ERP) operated 15 groundwater and 5 soil vapor treatment facilities at Site 300. The groundwater extraction wells and dual-phase extraction wells extracted about 42.6 million L of groundwater during 2013. The dual-phase extraction wells and soil-vapor extraction wells together removed 2.8 million m^3 of soil vapor.

In 2013, the Site 300 treatment facilities removed nearly 11 kg of VOCs, 0.12 kg of perchlorate, 1,400 kg of nitrate, 0.17 kg of the high explosive compound RDX, 0.0017 kg of silicone oils (TBOS/TKEBS), and 0.024 kg of uranium. Since ground water remediation began in 1990, approximately 1,581 million L of ground water and 23.2 million m^3 soil vapor have been treated, resulting in removal of more than 590 kg of VOCs, 1.4 kg of perchlorate, 14,000 kg of nitrate, 1.9 kg of RDX, 9.5 kg of silicone oils, and 0.041 kg of uranium.

Site 300 restoration activities in 2013 were focused on enhancing and optimizing ongoing operations at treatment facilities, continuing bioremediation treatability studies, and characterization in the Building 812 Operable Unit. Groundwater concentration data indicate declines in contaminant concentrations in 2013 and progress toward offsite and onsite plume and source area cleanup. See Dibley et al. (2014) for more information.

Community Relations. Site 300 community relations activities in 2013 included maintenance of information repositories and an administrative record, two meetings (May and December 2013) with members of Tri-Valley CAREs and the organization's scientific advisor as part of the activities funded by an EPA TAG, and tours of site environmental activities. In addition, DOE/LLNL environmental documents, letters, and public notices were posted on a public website: http://www-envirinfo.llnl.gov.

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

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

LLNL has reported lead release data via the Form R for Site 300 since 2002. The Form R is used for reporting TRI chemical releases and includes information about waste management and waste minimization activities. Over 99 percent of lead releases are associated with activities at the Site 300 Small Firearms Training Facility (SFTF). Data for the 2012 TRI Form R for lead at Site 300 was submitted to DOE/NNSA on June 17, 2013. Over the past several years, the lead releases have decreased due to increased use of frangible bullets.

Table 2-1. Compliance with EPCRA.

EPCRA section	Brief description of requirement	LLNL action
302	Notify State Emergency Response Commission (SERC) of presence of extremely hazardous substances.	Originally submitted 5/87.
303	Designate a facility representative to serve as emergency response coordinator.	Update submitted 10/4/13 to San Joaquin County for Site 300 and 9/23/13 to the Livermore-Pleasanton Fire Department for Livermore Site.
304	Report releases of certain hazardous substances to SERC and Local Emergency Planning Committee (LEPC).	No EPCRA-listed extremely hazardous substances were released above reportable quantities in 2013.
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 County and the Livermore-Pleasanton Fire Department on 1/8/13 and 2/15/13, 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 submitted to DOE on 6/17/13; DOE forwarded it to U.S. EPA and California EPA on 6/17/13.

2.1.3 California Accidental Release Prevention 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. The purpose of the CalARP program is to prevent accidental releases of substances that can cause serious harm to the public and the environment, to minimize the damage if releases do occur, and to satisfy Community Right-to-Know laws. The CalARP program is implemented at the local government level by Certified Unified Program Agencies (CUPAs). The related federal regulations are the Clean Air Act 112(r) and Title 40 of the Code of Federal Regulations (CFR), Part 68.

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. On August 29, 2013, LLNL submitted a de-registration of the LLNL Site 300 water treatment system to the SJCOES. The SJCOES visited Site 300 on September 11, 2013 to verify that the chlorine gas cylinders had been removed.

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

2.1.4 Resource Conservation and Recovery Act

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 and CUPA to comply with these regulations and obtain hazardous waste permits.

The hazardous waste management facilities at the Livermore Site consist of permitted units in Area 612 and Building 625 plus Buildings 693, 695, and 696, which make up the Decontamination and Waste Treatment Facility (DWTF). Permitted waste-management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction). LLNL submitted the permit renewal application to DTSC in April 2009, followed by submittal of the human health risk assessment (HHRA) in December 2010 as part of the permit renewal process. Furthermore, DTSC regulated closure of Building 419 was achieved in November 2013. Post-closure care of groundwater shall be conducted under CERCLA.

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, as well as the Building 829 post-closure permit. Transportation of hazardous or mixed waste over public roads occurs by DTSC-registered transporters, including LLNL.

2.1.5 California Medical Waste Management Act

All LLNL medical waste management operations are conducted in accordance with the California Medical Waste Management Act (CMWMA). The program is administered by the California Department of Public Health (DPH) and is enforced by the Alameda County Department of Environmental Health (ACDEH). LLNL’s medical waste permit is renewed on an annual basis and covers medical waste generation and treatment activities for the six Biosafety Level (BSL) 2 facilities, and the BSL 3 facility at Building 368. During 2013, LLNL started updating the required Medical Waste Management Plans (BSL 2 and BSL 3) and it will be submitted to ACDEH in the first half of 2014.

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.

2.1.7 Release of Property

LLNL does not release to the public property (e.g., vehicles, equipment, or other materials) with residual radioactivity above the limits specified in DOE Order 458.1. Pursuant to written procedures, items that are potentially contaminated or activated are either surveyed prior to the release to the public, or a process knowledge evaluation is conducted to verify that the material has not been exposed to radioactive material or to energy capable of inducing radioactivity in the material. In some cases, both a radiological survey and a process knowledge evaluation are performed. Excessed items that meet the requirements for unrestricted-release are either donated to interested state agencies, federal agencies, or universities; redeployed to other onsite users; or released to LLNL’s Donation, Utilization and Sales group. In 2013, approximately 1,800 equipment release swipes were processed by LLNL’s Radiological Measurements Laboratory; the equipment may have subsequently been used on-site or released to the public. Utilizing a graded approach, LLNL only keeps track of high value released items (e.g., those items worth greater than $100,000). In 2013, no such high value items were released.

DOE issued a moratorium in January 2000 prohibiting the release of volume-contaminated metals and subsequently suspended the release of metals for recycling purposes from DOE radiological areas in July 2000. No metals subject to the moratorium or suspension were released from LLNL in 2013.

Excess property with residual radioactivity above the limits in DOE Order 458.1 is either transferred to other DOE facilities for reuse, or transferred to LLNL’s Radioactive and Hazardous Waste Management for disposal as radioactive waste. There were no releases of real property to the public in 2013.

2.1.8 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 5 milestones during 2013. An additional 22.3 m^3 of newly generated mixed waste was accepted into the approved storage facilities and added to the STP. LLNL removed approximately 32.9 m^3 of mixed waste from LLNL in 2013.

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.

2.1.9 Toxic Substances Control Act

The Federal Toxic Substances Control Act (TSCA) and implementing regulations found in Title 40 of the Code of Federal Regulation, Parts 700–789 (40 CFR 700–789) govern the uses of newly developed chemical substances and TSCA-governed waste. In 2013, LLNL generated TSCA PCB/Low Level Radioactive waste that was containerized in two 55-gallon steel drums. The two drums were accepted for final disposal by Energy Solutions in Clive, Utah on January 16, 2014.

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 2013, LLNL operated 149 permitted air-pollutant emission sources at the Livermore Site and 39 permitted air-pollutant emission sources at Site 300. In addition, LLNL maintained the registrations for 33 natural gas boilers with the BAAQMD at the Livermore Site and continued the registrations for 79 in-use off-road diesel vehicles with CARB at the Livermore Site and Site 300.

In 2013, LLNL continued to maintain a Synthetic Minor Operating Permit (SMOP) to ensure that actual emissions of regulated air pollutant from a total 281 solvent evaporation sources, fuel dispensing sources, remediation and wastewater sources, and combustions sources at the Livermore Site did not exceed federal Clean Air Act (CAA) Title V emission limits. LLNL was initially issued the SMOP by the BAAQMD in 2002 after it was determined that LLNL had the potential to emit regulated air pollutants in excess of federal CCA Title V emission limits, if all emission sources at the Livermore Site were to operate at maximum capacity. As a result, LLNL agreed to receive federally enforceable permit conditions in the SMOP that reflect actual emissions of regulated air pollutants from sources rather than potential emissions from sources. As such, LLNL has been able to demonstrate through extensive monitoring and record keeping practices of emissions for sources, and meeting significantly reduced air pollutant emissions limits in the SMOP that its actual emissions are well below CCA Title V emission limits, and thus, LLNL does not have any “major sources” of air pollutant emissions per 40 CFR 70.2.

Under the authority of California Assembly Bill 32 (AB32), the State of California has adopted several new regulations regarding emissions of greenhouse gases (GHG). Initially, California required the mandatory reporting of stationary emission sources from combustion of natural gas that exceeded 25,000 metric tons per year of CO_2 equivalent emissions. For the mandatory reporting years of CY2009, CY2010, and CY2011, the Livermore Site was slightly below the reporting threshold. Beginning in CY2012, California lowered the mandatory reporting threshold to 10,000 metric tons per year of CO_2 equivalent emissions, and consequently LLNL started reporting emissions for CY2012 and CY 2013. LLNL continues to implement reductions and controls to minimize CO_2 emissions. LLNL is replacing diesel engines, boilers and hot water heaters on a continuing basis, and the new equipment is more efficient than the replaced equipment, in terms of fuel use and air emissions, such as CO_2. LLNL Site 300 emissions of CO_2 are much lower than Livermore Site emissions, and there is no natural gas service at Site 300 that would generate CO_2 emissions.

Also under the authority of AB32, California has adopted special regulations pertaining to sulfur hexafluoride (SF_6), because of its high GHG potential. In CY2012 and CY 2013, LLNL was required to submit an annual report to CARB describing the research uses of SF_6 and the measures taken to control the SF_6 emissions from such research activities, and was required to keep records on the amounts of SF_6 contained in and used for electrical switchgear. The reduction of greenhouse gases has been further encouraged by Executive Order 13514, which establishes an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal agencies.

In addition, the federal EPA has a mandatory reporting regulation for stationary emission sources, similar to California's regulation. LLNL is currently below the mandatory reporting threshold for EPA of 25,000 metric tons per year 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 potential dose to the public. The *LLNL NESHAPs 2013 Annual Report* (Wilson et al. 2014) reported that the estimated maximum radiological dose from radioactive air emissions were 0.018 µSv (0.0018 mrem) for the Livermore Site and 4.0×10^{-7} µSv (4.0×10^{-8} mrem) for Site 300. The totals are well below the 100 µSv/y (10 mrem/y) site-wide dose limits defined by the NESHAPs regulation. The *LLNL NESHAPs 2013 Annual Report* is located in Appendix D of this report.

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 the appropriate regulatory agencies whose mission is to protect water quality.

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

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

2.4 Other Environmental Statutes

2.4.1 National Environmental Policy Act and Floodplains and Wetland Assessments

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

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

In 2013, no other EISs, or EAs were completed. Five Categorical Exclusions under DOE NEPA Regulations (10 CFR 1021) were completed for:

- Relocation of the Central General Services Area (GSA) Operating Unit (OU) Misting Towers (NA-13-01)
- Expansion of the LLNL Mobile Analytical Laboratory (MAL) Support Operations (NA-13-02)
- Experimental Detector Construction and Operation (NA-13-05)
- Pool M1a and b Habitat Enhancement Project, Site 300 (NA-13-11)
- M2 Pool Habitat Enhancement Project, Site 300 (NA-13-12)

There were no proposed actions at LLNL that required separate DOE floodplain or wetlands assessments under DOE regulations in 10CFR Part 1022.

2.4.2 National Historic Preservation Act

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

In 2005, in consultation with DOE/NNSA, the California State Historic Preservation Officer (SHPO) formally determined that five archaeological resources, five individual buildings, two historic districts (encompassing 13 non-contiguous individual buildings), and selected objects in another building at LLNL are eligible for listing in the National Register of Historic Places (NRHP). To assist DOE and SHPO in developing an agreement as to how to manage the NRHP-eligible properties, LLNL prepared a draft Programmatic Agreement (PA), which includes a draft Archaeological Resources Treatment Plan and a draft Historic Buildings Treatment Plan as attachments. These plans describe specific and optional resource management and treatment strategies that DOE/NNSA, in cooperation with LLNL, could implement to ensure that NRHP-eligible historic properties under LLNL's jurisdiction are managed and maintained in a way that considers the preservation of historic values in compliance with Sections 106 of the NHPA. In 2012, DOE/NNSA invited the Advisory Council on Historic Preservation (ACHP) to be a signatory to the PA. As of the end of 2013, the draft PA and treatment plans were being reviewed by ACHP and SHPO.

In 2011, LLNL completed a five-year re-evaluation of the historic building assessment originally completed in 2004 (published in 2007). The five-year cycle of re-evaluations for NRHP-eligibility is a requirement of the draft PA. Final recommendations from the re-evaluation include removing Building 391 from the list of NRHP-eligible buildings and allowing Building 332 to evolve as needed, eventually losing integrity for its period of historic significance and therefore not be considered NRHP-eligible. These two buildings have been preserved via recordation, a mitigation option identified in the draft Historic Buildings Treatment Plan. Two buildings, B810A and B865E, were recommended for addition to the inventory of NRHP-eligible buildings. As of the end of 2013, consultation of the five-year re-evaluation report with SHPO has not been initiated.

2.4.3 Antiquities Act of 1906

The Antiquities Act provides 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 2013.

2.4.4 Endangered Species Act and Sensitive Natural Resources

LLNL meets the requirements of the Federal and State Endangered Species Acts (ESAs), the Eagle Protection Act, the Migratory Bird Treaty Act, and other applicable regulations as they pertain to endangered species, threatened species, and other special-status species (including their habitats) and designated critical habitats that exist at the LLNL sites. The following list highlights 2013 compliance activities:

- On March 29, 2013, DOE/NNSA requested formal consultation with the U.S. Fish and Wildlife Service (FWS) regarding infill construction and redevelopment at the Livermore Site. The FWS issued a Biological Opinion (BO) for this project on August 1, 2013.
- On July 9, 2013, DOE/NNSA re-initiated formal consultation with the FWS for the Pool M2 habitat enhancement project at Site 300. On November 22, 2013, the FWS issued a BO amendment for long-term maintenance activities at the site. (Pool M2 was originally enhanced to benefit California tiger salamanders as mitigation for the closure of the explosives wastewater surface impoundments.)
- On June 17, 2013, DOE/NNSA requested re-initiation of formal consultation for the mitigation, monitoring, and reporting plan for the Building 850 PCB-bearing soil removal project. A BO amendment is anticipated by summer of 2014.

2.4.5 Federal Insecticide, Fungicide, and Rodenticide Act

LLNL complies with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which provides federal control of the distribution, sale, and use of pesticides and requires that commercial users of pesticides are certified pesticide applicators. The California Department of Pesticide Regulation (DPR) has enforcement responsibility for FIFRA in California; DPR has in turn given enforcement responsibility to county departments of agriculture. All pesticides at LLNL are applied, stored, and used in compliance with FIFRA and other California, Alameda County, and San Joaquin County regulations governing the use of pesticides. The staff of the Landscape and Pest Management Shop at the Livermore Site and the Laborer/Gardener Shop at

Site 300 includes certified pesticide applicators. These shops ensure that all storage and use of pesticides at LLNL is in accordance with applicable regulations. LLNL also reviews pesticide applications to ensure they do not result in impacts to water quality or special status species.

2.5 Environmental Permits, Inspections, and Occurrences

LLNL's various missions require a variety of permits. **Table 2-2** is a summary of active permits in 2013 at the Livermore Site and Site 300. The external agencies that issue the permits may also perform inspections required by the permits. **Table 2-3** lists environmental inspections and findings from both LLNL sites in 2013.

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

Table 2-2. Active permits in 2013 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. LPFD permit 092811-10697. Hazardous Waste Generator Program, Hazardous Materials Business Program, Above Ground Petroleum Tank Program, CA Accidental Release Program, and Underground Storage Tank Program. Permit Valid – September 20, 2013–September 19, 2018.	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 BSL 2 facilities, and the BSL 3 facility at Building 368.	NA
Air	BAAQMD issued 136 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 5 Asbestos Removal and Demolition Permits. CARB issued 7 permits for the operation of portable diesel air compressors and generators.	SJVAPCD issued 35 permits for operation of various types of equipment. SJVAPCD approved a Prescribed Burn Plan for the burning of 2,176.5 acres of grassland. BAAQMD issued 1 permit for the operation of an emergency diesel generator. CARB issued 1 permit for the operation of portable diesel air compressor BAAQMD approved a Prescribed Burn Plan for the burning of 139.1 acres of grassland.
Storage tanks	One operating permit covering 10 underground petroleum storage tanks.	One operating permit covering 3 underground petroleum storage tanks assigned individual permit numbers.
Sanitary sewer	Discharge Permit 1250[b] for discharges of wastewater to the sanitary sewer. Permit 1510G for discharges of groundwater from CERCLA restoration activities.	WDR R5-2008-0148 for operation of sewage evaporation pond.

Table 2-2. (cont.) Active permits in 2013 at the Livermore Site and Site 300.

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

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

(a) Numbers of permits are based on actual permitted units or activities maintained and/or renewed by LLNL during 2013.

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

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

Table 2-3. Inspections of Livermore Site and Site 300 by external agencies in 2013.

Medium	Description	Agency	Date	Finding
Waste	CUPA Inspection (Livermore Site)	LPFD	09/17/13 – 09/19/13	One minor violation related to hazardous waste labeling in B231 was found on 9/19/13. Two observations: faded hazardous waste labels in B132 and update Cal ARP risk management program (RMP).
	Medical Waste Inspection (Livermore Site)	ACDEH	07/25/13	Three Areas of Concern were a small bag of biohazardous waste (labeled with date) inside metal trash can without required red plastic bag; 1 box of pipettes labeled biohazardous but missing biohazardous symbol, which was immediately corrected; and B361 R1634 PLS Autoclave calibration ran for 29 minutes but was not corrected because it required 30 minutes. No violations.
	Waste Tire and Heavy Equipment Tire Storage Inspection Main Site	ACDEH	04/14/13	No violations
	Waste Tire Inspection at Site 300	CalRecycle	05/06/13	No violations
	Independent External Audit for NNSSWAC		08/12-15/13	No findings
Air	Air pollutant emission sources (Livermore Site)	BAAQMD	01/21/13 02/21/13 04/25/13 05/22/13 06/25/13 06/27/13 09/19/13 11/21/13	No violations
	Synthetic Minor Operating Permit (SMOP) (Livermore Site)	BAAQMD	01/21/13 02/21/13 04/25/13 05/22/13 08/22/13 09/19/13 11/21/13	No violations
Sanitary sewer	Annual Inspection of the Sewer Monitoring Complex, Livermore Site	WRD, State Water Resources Board, EPA Contractors	1/29/2013	No violations
	Inspection of Categorical Processes at Buildings 153 and 321C.	WRD, State Water Resources Board, EPA Contractors	1/29/2013	No violations

Table 2-3. (cont.) Inspections of Livermore Site and Site 300 by external agencies in 2013.

Medium	Description	Agency	Date	Finding
Sanitary sewer	Inspection of DWTF at B695	WRD	10/02/2013	No violations
	Categorical sampling/inspection Building 153 and Building 321C. (Livermore Site)	WRD	10/01/2013	No violations
	Annual compliance sampling at the Sewer Monitoring Complex (Livermore Site)	WRD	10/02/2013	No violations
	Café grease interceptor inspections, Buildings 123 and 471 (Livermore Site)	WRD	10/01/2013	No violations
	Quarterly BOD/TSS sampling at Outfall (Livermore Site)	WRD	03/13/2013 06/26/2013 08/20/2013 12/03/2013	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits (Livermore Site)	LPFD	08/13/13 & 08/20/13	Two violations: **1.** The S2 High Level Liquid Leak Sensor on the 611-G3U1 (E85) UST did not alarm when tested. The defective sensor was replaced during the inspection and was tested and passed. No follow up was required by LLNL. **2.** A leak in the 611-G3U1 (E85) UST Turbine Sump's secondary containment caused the food grade interstitial monitoring fluid to leak out and the leak sensor was in alarm. LLNL submitted a Corrective Action Plan to repair the Turbine Sump leak, the leak was repaired on 12/23/2013, and the Turbine Sump was returned to service.
Pesticides	Pest control records inspections (Livermore Site)	ACCDA	1/3/13	No violations
Waste	Hazardous waste facilities Compliance Evaluation Inspection (CEI) (Site 200)	DTSC	04/29/13, 05/01/13, 05/02/13 & 05/07/13	No violations.
Air	Air pollutant emission sources (Site 300)	SJVAPCD	04/11/13 10/02/13	No violations
Water	Permitted operations (Site 300)	CVRWQCB	01/23/13 11/17/13	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits (Site 300)	SJCEHD	08/06/13	No violations

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

Table 2-4. Environmental Occurrences reported under the Occurrence Reporting System in 2013.

Date(a)	Occurrence category/group	Description
2/04/13	Significance Category SC4 Occurrence under Group 5A(2) OR 2013-0003	On February 2, 2013, sewage water was observed flowing out a sewer manhole cover, across an asphalt walkway and into a nearby storm drain. Additionally, sewage water was observed flowing along the curb parallel to Avenue B. The sewage overflow continued to the Arroyo via the storm drain and eventually flowed offsite before the release could be controlled. During the investigation it was determined that approximately 9,000 gallons of sewage water were released. This release was immediately reportable to the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB).
02/12/13	Significance Category SC3 Occurrence under Group 5A(2) and OR 2013-0005	On February 12, 2013, an incident occurred at Site 300 in Building 827D Room 105. Workers wearing safety glasses and butyl acid gloves were adding approximately 2 liters of 20% fuming sulfuric acid to a mixture of 2,6-diaminopyrazine-1-oxide in 12 liters of concentrated (95-98%) sulfuric acid. The result of the addition of the 20% fuming sulfuric acid was an increase of pressure in a 100-liter glass reaction vessel, which caused the spraying of acid onto three people resulting in two significant injuries and one minor exposure. The San Joaquin County Environmental Health Department and the California Environmental Management Agency (CalEMA) were promptly notified of the incident.
04/25/13	Significance Category SC4 Occurrence under Group 5A(2) OR 2013-0017	On April 24, 2013, a broken plastic elbow was discovered on a 2" city water-supply line providing water to an eye wash station. The water sprayed onto asphalt and ran approximately 20 feet to a storm drain. The storm drain leads to a culvert that terminates at the Arroyo Las Positas. It is estimated that 500 gallons of water flowed into Arroyo Las Positas, and subsequently left the LLNL site. This release was reported to the SFBRWQCB.
08/12/13	Significance Category SC4 Occurrence under Group 9(1) OR 2013-0031	On August 12, 2013, LLNL received a Notice of Violation (NOV) from the City of Livermore, CA, concerning co-mingling of categorical aqueous waste with non-categorical waste prior to treatment and release to the sanitary sewer. Upon review of the July 2013, LLNL Wastewater Point-Source Monitoring Report, the City of Livermore, CA, issued a NOV for eight instances that were found to be in violation of Federal Categorical Pretreatment Standards, 40 CFR Part 403, and/or the conditions specified in LLNL Wastewater Discharge Permit #1250. Specifically, the NOV cites the following violation: 1) Comingling of Categorical Wastes: RHWM co-mingled regulated categorical waste with non-regulated waste streams prior to treatment, compliance monitoring, and discharge to the sanitary sewer on 3 occasions. 2) Incorrect Analytical Methods Utilized for Self-Monitoring Samples: The Livermore Site Semiannual Monitoring report indicates that Methods SW846 E901 C (cyanide), SW846 8260 B (ITO), and SW846 601 B (Metals) were utilized to determine compliance with sanitary sewer discharge limits for regulated waste from Buildings 153 and 322. The Wastewater Discharge Permit #1250 issued to Lawrence Livermore National Laboratory requires that the following methods be utilized to determine compliance with sanitary sewer discharge limits: Standard Method 4500-CN-E (Cyanide), EPA Methods 624 and 625 (ITO), and EPA Method 200.7 (Metals), (3 incidents of non-compliance). 3) Failure to Monitor for Cyanide: The Livermore Site Semiannual Report indicates that the required cyanide analysis was not performed on the regulated discharges from Building 322 (Metal Finishing, 40 CFR 433) on 06/19/12 and 09/05/12. The Wastewater Discharge Permit #1250 issued to Lawrence Livermore National Laboratory and 40 CFR Part 433 requires that cyanide analysis be performed on all process related discharges to the sanitary sewer (2 incidents of non-compliance)..

Table 2-4. (cont.) Environmental Occurrences reported under the Occurrence Reporting System in 2013.

Date[(a)]	Occurrence category/group	Description
08/27/13	Significance Category SC4 Occurrence under Group 9(1) OR 2013-0034	A California Department of Public Health (CDPH) enforcement letter was transmitted to LLNL on August 27, 2013, confirming that the Lawrence Livermore National Laboratory, Site 300, had not been operating in accordance to their domestic water supply permit. During an August 6, 2013 inspection by the CDPH, it was noted that a new method of treatment, sodium hypochlorite, had been introduced to the Site 300 water distribution system without being approved or permitted by the CDPH. Section 116550(a) of the California Health and Safety Code specifies: "No person operating a public water system shall modify, add or change his or her source of supply or method of treatment of, or change his or her distribution system as authorized by a valid existing permit issued to him or her by the department unless the person first submits an application to the department and receives an amended permit as provided in this chapter authorizing the modification, addition, or change in his or her source of supply or method of treatment." Although Site 300 had submitted a permit amendment application in May 2013, a subsequent request from the CDPH to submit a chlorination plan for the new equipment/treatment method being installed had not been fulfilled by LLNL. Thus, the water treatment system modification/operations/activities noted during the August 6, 2013 inspection were found not to be in accordance with the existing domestic water-supply permit.
09/03/13	Significance Category SC4 Occurrence under Group 5A(2) OR 2013-0035	On September 3, 2013, irrigation water was observed overflowing the landscaped area on the southwest side of Building 482. LLNL staff responded and discovered that an irrigation line was stuck open from 2 am to 2 pm on September 3, 2013. The irrigation water was not originally noticed because it was being discharged into shrubs located around the building. In the twelve-hour period that the valve was stuck open, approximately 17,300 gallons of irrigation water was discharged. Although some of the water absorbed into a landscaped area, once the ground was saturated, water flowed into storm water catch basins. The water then flowed into a storm drainage channel and finally into Arroyo Las Positas. It is estimated that approximately 13,000 gallons of water flowed offsite. This release was reported to the SFBRWQCB.
09/09/13	Significance Category SC4 Occurrence under Group 9(1) OR 2013-0036	LLNL received a letter on August 29, 2013 from the Federal Aviation Administration (FAA) that they had conducted a recent inspection of hazardous materials shipment to determine compliance with the Hazardous Materials Regulations (HMR) as found in Title 49, Code of Federal Regulations (49 CFR), parts 171-180 (49 CFR 171-180). Based on the information obtained during this inspection on July 25, 2013, the FAA concluded that a possible violation of the HMR may have occurred. Specifically, Lawrence Livermore National Laboratory located at 7000 East Avenue in Livermore, CA offered a hazardous materials shipment to FedEx Express on July 24, 2013. The shipment was transported by air to Bradley International Airport in E. Windsor Locks, CT on Flight 1747 for delivery to ZYGO Corp in Middlefield, CT. This shipment, air waybill 487174095464, was prepared by a LLNL employee and contained 5 liters of UN2922, corrosive liquid, toxic, n.o.s (Polyoxyproplenetriamine), 8(6.1), III. This liquid shipment was in a UN specification drum that appeared to be meant for solid shipments of hazardous material.

Table 2-4. (cont.) Environmental Occurrences reported under the Occurrence Reporting System in 2013.

Date(a)	Occurrence category/group	Description
09/19/13	Significance Category SC4 Occurrence under Group 9(1) OR 2013-0040	On September 19, 2013, LLNL received a Notice of Violation (NOV) from the Livermore/Pleasanton Fire Department (LPFD) following a Certified Unified Program Agency (CUPA) inspection. The NOV concerned a label on a one-gallon hazardous waste container that was not properly filled out (pursuant to regulation 22 CCR § 66262.32). The container was an appropriate type for the waste and sealed properly. The violation was found during the CUPA inspection of LLNL facilities that took place between September 17-19, 2013. The label on the container when found stated only "used solvent wipes." The incorrect label was immediately removed and replaced with a fully completed hazardous waste label, in the presence of the CUPA inspector.
10/21/13	Significance Category SC4 Occurrence under Group 9(1) OR 2013-0045	On October 21, 2013, LLNL received an inspection report from the LPFD Underground Storage Tank (UST) CUPA. The inspection was performed in August of 2013 and sited two violations at the underground gasoline storage tanks near Building 611. The two violations were noted in the inspection report as follows: 1) Failure of the Site 200 UST # 611-G3U1 (E85) S2 Sensor to alarm when tested. The defective liquid leak sensor was replaced during the inspection by the certified contractor and was tested and passed. 2) A leak was observed in the turbine sump secondary containment. A Corrective Action Plan was submitted and the repairs completed in December 2013.

(a) Date the occurrence was categorized not discovered.

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3. Environmental Program Information

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

3.1 Environmental Management System

LLNL continues to enhance its EMS through systematic process improvements and increased focus on establishing specific environmental objectives and performance measures contained in Environmental Management Plans (EMPs). Progress toward goals is regularly measured and provided to senior management and other interested parties through a variety of means including periodic senior management reports and the yearly update of this Environmental Report. The Laboratory's EMS has successfully maintained its International Organization for Standardization (ISO) 14001 registration since 2009 and is audited annually by a third-party internationally recognized ISO registrar for continued conformance and certification.

3.1.1 Environmental Management Plans

EMPs are designed and implemented to address the Laboratory's most significant environmental effects (aspects) and to achieve environmental objectives and performance measures (targets) that substantively reduce these. EMPs are updated annually to incorporate new initiatives and effectively demonstrate LLNL's commitment to continuous improvement. **Table 3-1** lists the eight EMPs for FY 2013, along with the significant environmental aspects each addresses, the Lab-wide environmental objectives, and the related DOE sustainability goals. LLNL's status towards meeting each of the DOE sustainability goals listed in **Table 3-1**, along with planned actions to ensure continued progress towards attaining these goals can be found in the *LLNL FY14 Site Sustainability Plan* in **Appendix D**.

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

Title	Significant Environmental Aspect(s) Addressed	EMP Objective(s)	Related DOE Sustainability Goal(s)
Sustainable Acquisition	• Nonhazardous Materials Use • Municipal Waste Generation	Promote lab-wide sustainable acquisition to meet Site Sustainability Goal 6.1 and to support DOE in meeting its EO 13514 requirements by including necessary provisions and clauses to affect new purchases, such as ensuring a procurement preference for EPEAT-registered electronic products.	6.1: Procurements meet sustainability requirements and include sustainable acquisition clause (95% each year).
Municipal Waste Reduction	• Municipal Waste Generation	Divert at least 50% of non-hazardous solid waste (including construction and demolition debris) by FY2015 to meet Site Sustainability Goals 5.1 and 5.2 and increase recycling.	5.1: Divert at least 50% of nonhazardous solid waste, excluding construction and demolition debris by FY15. 5.2: Divert at least 50% of construction and demolition materials and debris by FY15.
Greenhouse Gas Reduction	• Greenhouse Gas Emissions	Reduce Scope 1 & 2 GHG by 28% by FY20 from the FY08 baseline to meet Site Sustainability Goal 1.1. Reduce Scope 3 GHG by 13% by FY20 from the FY08 baseline to meet Site Sustainability Goal 1.2.	1.2: 13% Scope 3 GHG reduction by FY20 from a FY08 baseline. 3.2: 2% annual reduction in fleet petroleum consumption by FY20 relative to a FY05 baseline. 3.4: Reduce fleet inventory of non-mission critical vehicles by 35% by FY13 relative to a FY05 baseline. 7.3: Electronic Stewardship - 100% of eligible PCs, laptops, and monitors with power management actively implemented and in use by FY12.

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

Title	Significant Environmental Aspect(s) Addressed	EMP Objective(s)	Related DOE Sustainability Goal(s)
Hazardous Materials Use and Hazardous Waste Generation	• Hazardous Materials Use Hazardous Waste Generation	Reduce the use and inventory of hazardous materials. Minimize the generation of routine hazardous, mixed low-level, and/or low-level waste.	n/a
Ecological Resources Disturbances	Ecological Resources Disturbances	Protect native species, sensitive wetland areas, and prohibit the release of invasive species in support of DOE/NNSA's compliance and long-term natural resource stewardship responsibilities.	n/a
Energy Conservation	• Electrical Energy Use • Greenhouse Gas Emissions Fossil Fuel Consumption	Reduce energy intensity (BTU per gross square foot) by 30% by FY15 from the FY03 baseline to meet Site Sustainability Goal 2.1.	2.5: 15% of existing buildings greater than 5,000 gross square feet (GSF) are compliant with the Guiding Principles (GPs) of HPSB by FY15. 2.6: All new construction, major renovations, and alterations of buildings greater than 5,000 GSF must comply with the GPs and where the work exceeds $5 million, each are LEED® certified. 7.2: Maximum annual weighted average Power Utilization Effectiveness (PUE) of 1.4 by FY15. 7.3: Electronic Stewardship - 100% of eligible PCs, laptops, and monitors with power management actively implemented and in use by FY12.

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

Title	Significant Environmental Aspect(s) Addressed	EMP Objective(s)	Related DOE Sustainability Goal(s)
Water Conservation	• Water Use	Reduce potable water intensity (Gal per gross square foot) by 26% by FY20 from the FY07 baseline to meet Site Sustainability Goal 4.1.	4.1: 26% potable water intensity (gallons per gross square foot) reduction by FY20 from a FY07 baseline. 4.2: 20% water consumption (gal) reduction of industrial, landscaping, and agricultural (ILA) water by FY20 from a FY10 baseline.
Fossil Fuel Consumption	• Fossil Fuel Consumption	Reduce fleet petroleum consumption by 2% annually by FY20 relative to the FY05 baseline to meet Site Sustainability Goal 3.2.	3.1: 10% annual increase in fleet alternative fuel consumption by FY15 relative to a FY05 baseline. 3.2: 2% annual reduction in fleet petroleum consumption by FY20 relative to a FY05 baseline. 3.3: 100% of light duty vehicle purchases must consist of alternative fuel vehicles (AFV) by FY15 and thereafter (75% FY2000–2015).

3.1.2 EMS Audits and Reviews

The Laboratory successfully completed one external third-party independent audit of its ISO 14001 EMS program (March 2013) with recommendations from the auditor to continue LLNL's ISO 14001 registration. This independent audit was conducted by NSF International Strategic Registrations and validated the Laboratory's solid commitment to environmental stewardship.

3.1.2.2 Internal Assessments and Reviews

In January and August 2013, Senior Management Reviews of the EMS were conducted, reaffirming management commitment to the Lab's environmental policy and stewardship through the implementation of EMS.

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

3.2 Pollution Prevention/Sustainability Program

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

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

3.2.1 Routine Hazardous, Transuranic, and Radioactive Waste

Routine waste listed in **Tables 3-2 and 3-3** includes waste from ongoing operations produced by any type of production, analysis, and research and development taking place at LLNL. The increase in routine hazardous waste in 2012 was due to an evaporator unit that was out of commission for part of the year and roofing debris from various projects. The increase in routine Low-Level Waste (LLW) volumes beginning in 2011 are due to NIF, PLS and WCI activities (largely wipe cleaning wastes and personal protective equipment (PPE) disposal). NIF implemented several improvements that reduced its contribution to the LLW between FY12 and FY13 sixty-five percent.

Table 3-2. Routine hazardous waste at LLNL, FY 2009–2013.

Waste category	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Routine hazardous waste generated (MT)	159	116	143	232	131

Table 3-3. Routine transuranic and radioactive waste at LLNL, FY 2009–2013.

Waste category	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Routine LLW generated (m^3)	203.5	211.2	678.3	861.7	741
Routine mixed waste generated (m^3)	24.6	21.0	27.4	45.9	32
Routine TRU/mixed TRU waste generated (m^3)	9.4	0.6	0.4	4.8	7.5

3.2.2 Diverted Waste

LLNL maintains an active waste-diversion program, encouraging recycling and reuse of both routine and non-routine waste which prevents waste from going to the landfill. In 2010, DOE changed the annual reporting requirements for waste diversion in response to Executive Order 13514, issued October 5, 2009. This change required separate accounting for construction/demolition and municipal solid wastes and is reflected in **Tables 3-4 and 3-5**.

3.2.2.1 Municipal Solid Waste

Together, the Livermore Site and Site 300 generated 2,638 MT of routine nonhazardous solid waste in FY 2013. This volume includes diverted waste (e.g., material diverted through recycling and reuse programs) and landfill waste.

Both sites combined diverted a total 1,994 MT of routine nonhazardous waste in FY 2013, which represents a diversion rate of 76%. The portion of routine nonhazardous waste sent to landfill was 644 MT. See **Table 3-4**. In 2013, LLNL recycled 6,459 computers, monitors, and laptops, which were resold or managed as universal waste. LLNL recycled 24MT of large and small batteries, which were also managed as universal waste.

LLNL continued to expand recycling opportunities for plastics beyond the comingled recycling program. In 2013, 11.4 MT of plastics were recycled, this is up from 2.5 MT in 2012. The comingled recycling and composting program initiated in May 2011 was continued during 2013, diverting 44 MT of comingled recycling and 65 MT of compostable material from the landfill.

Table 3-4. Routine municipal waste in FY 2013, Livermore Site and Site 300 combined.

Destination	Waste description	Amount in FY 2013 (MT)
Diverted	Baled paper	81
	Corrugated cardboard	74.2
	Cooking grease (including grease traps)	29
	Mixed metals	748
	Scrap lead (Pb)	3
	Plastic (new in 2012)	11.4
	Office paper	187
	Scrap tires	2
	Toner cartridges	8.4
	Greenwaste (chips, compost, mulch)	605
	Wood	136
	Comingled recycling	44
	Compost (food scraps, paper towels, food containers)	65
	TOTAL diverted	**1,994**
Landfill	Compacted (landfill)	644
	TOTAL landfill	**644**
TOTAL routine nonhazardous waste		**2,638**

3.2.2.2 Construction and Demolition (C&D) Waste

C&D wastes include excavated soils, wastes and metals from construction, decontamination and demolition activities. The Livermore Site and Site 300 generated a total of 2,161 MT of waste related to construction and demolition activities in FY 2013. The two sites combined diverted 1,626 MT of non-routine nonhazardous solid waste through reuse or recycling, which represents a diversion rate of 75% in FY 2013. Diverted C&D waste includes soil and concrete reused either on site for other projects or as cover at Class II landfills. See **Table 3-5**.

Table 3-5. Construction and Demolition waste in FY 2013, Livermore Site and Site 300 combined.

Destination	Waste description	Amount in FY 2013 (MT)
Diverted	Class II cover soil (reused at landfill)	949
	Class II concrete (reused at landfill)	669
	Scrap metals (recycled)	8
	TOTAL diverted	**1,626**
Landfill	Construction and demolition (non-compacted landfill)	535
	TOTAL landfill	**535**
	TOTAL non-routine non-hazardous waste	**2,161**

3.2.3 Sustainable Acquisition

LLNL has a comprehensive Sustainable Acquisition program that includes preferential purchasing of recycled content and bio-based products. In 2013, the Sustainable Acquisition program continued to include a preference for Electronic Product Environmental Assessment Tool (EPEAT) registered computers and monitors, as well as products in two new EPEAT categories; imaging equipment and televisions. Standards for imaging equipment and televisions were finalized in 2012 and EPEAT qualified products in these categories became available in early 2013. Ninety-five percent of all desktop electronics, imaging equipment, and television purchases in FY 2013 were EPEAT Bronze, EPEAT Silver or EPEAT Gold, indicating that the products meet or exceed the Institute of Electrical and Electronics Engineers (IEEE) 1680-2009; 2012 environmental performance standard for electronic products.

To further support sustainable acquisition, LLNL launched a new internal Craigslist-like service called ReUseIt to encourage reuse of property and material. Employees are encouraged to check ReUseIt before purchasing products. Additional sustainable acquisition highlights can be found in the *LLNL FY14 Site Sustainability Plan* in **Appendix D**.

3.2.4 Pollution Prevention/Sustainability Activities

3.2.4.1 Environmental Stewardship Accomplishments and Awards

Each year, the P2S Program submits nominations for the NNSA environmental awards program, which recognizes exemplary performance in integrating environmental stewardship practices to reduce risk, protect natural resources, and enhance site operations. P2S also submits nominations for various other awards recognizing excellence in P2S projects. In 2013, LLNL received three NNSA Sustainability awards and was recognized by U.S. EPA’s Federal Green Challenge (FGC) program.

"Active Risk Management at LLNL's National Ignition Facility Results in Lower Consumption and Less Waste" won an NNSA 2013 Best in Class Award in the Waste Reduction and Pollution Prevention category for significantly reducing low-level radiological waste generation, product use, and costs and time spent managing hazards. When NIF introduced radioactive fuel (tritium) to the facility in September 2010, hazard management protocols emphasized safety. As the program progressed, NIF collected data from more than 10,000 surveys to verify the effectiveness of engineering controls and also ensured the workforce was properly trained to manage hazards. With a better understanding of radiological risks and refinement of employee's skills, NIF was able to identify and implement several program adjustments to right-size safety protocols with actual hazards to improve overall operational efficiency. This 'active risk management' approach resulted in a reduction of an estimated 12,240 cubic feet of radiological waste per year, $1.3 million in consumables and 40,000 person-hours per year of time spent managing NIF hazards.

"Getting Connected to Build a Holistic Waste Reduction Program" won an NNSA Best in Class Award in the Innovation and Holistic Approach category for developing a holistic cross-disciplinary program to expand reuse and recycling opportunities and benefits across the site.

With the P2s at the hub, ties were made with individuals representing internal programs, as well as committees directing related Lab initiatives. Connections also went beyond LLNL's boundaries to tap into local and regional entities, and the greater DOE complex. All of these links made it possible to expand the types of items recycled and promote a culture that considers reuse first.

To evaluate the effectiveness of this approach, a database was established to track reuse transactions and special recycling projects. To date, an estimated $524,000 has been saved through reuse activities, and over 30,000 pounds of items for which a recycling pathway was not previously available, were recycled. The reuse and cost savings data also provided valuable evidence to support development of an internal 'Craigslist' application to facilitate reuse exchanges site-wide and better manage reuse of property.

"LLNL's Sustainable Landscape" won an NNSA Environmental Stewardship Award in the Water category for implementing sustainable landscape practices. LLNL has taken several measures to reduce irrigation water use by implementing 'smart' irrigation controllers and drought tolerant planting schemes that are compatible with the local climate. In FY11, LLNL developed a Sustainable Landscape Concept Plan to incorporate sustainability recommendations and guidelines in landscaping and irrigation practices on site, augmenting the existing Landscape Architecture Master Plan and the Laboratory's landscape program.

The plan provides design directions and a planting palette for future projects and also earmarks existing areas for lawn reduction and drought tolerant planting conversion improvements as funding allows. To date, 14 satellite irrigation controllers have been installed on site to use water more effectively, and in FY12 LLNL tackled its largest xeriscaping project to date by replacing a 20,000 square foot lawn with drought tolerant and native plants. Each controller provides an estimated 30 percent water savings, and landscape modifications from the FY12 project are expected to save more than 400,000 gallons of water per year.

LLNL received accolades for its 2012 achievements in waste reduction and green purchasing as part of its participation in the Federal Green Challenge (FGC). The FGC is a voluntary partnership program sponsored by the EPA that challenges federal agencies to reduce their greenhouse gas emissions. FGC participants commit to a minimum 5 percent reduction in two of six target areas: Energy, electronics, purchasing, transportation, water and waste.

3.2.4.2 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 goal of the Policy is to reduce the* usage of potentially hazardous cleaning chemicals and their adverse impact on indoor air quality, occupant health, and the environment. LLNL continues to expand green cleaning lab-wide, with the goal to implement green cleaning at all applicable locations. Alternative solutions are evaluated as the industry improves and more green products that perform effectively become available. In FY 2012, the program identified additional products for floor care, making 98% of the products purchased for floor care Green Seal certified. The new floor care products have been used in 99% of facilities.

Due to the unavailability of funding for the continuation of the High Performance Sustainable Building (HPSB) Assessments in FY2014, no new buildings were studied and assessed using the HPSB Assessment tool. In FY 2015, assessments for Buildings 1879, 5627, 1739, and 6925 will be completed, and nine additional buildings have been targeted for study.

3.2.5 Pollution Prevention/Sustainability Employee Training and Awareness Programs

In celebration of Earth Day 2013, P2S staff offered a week's worth of earth friendly events, including showings of the award-winning documentary Bag It, a low cost on-site document shredding for employee's personal documents, a preview to the monthly Farmers' Market, and an inspiring presentation and book signing by Beth Terry author of *Plastic Free: How I Kicked the Plastic Habit and How You Can Too*. Neighboring SNL/CA Laboratories employees were invited to participate in the Earth Week activities.

LLNL and SNL/CA Laboratories also worked together to continue a monthly Farmers' Market held May through October. The P2S Program collaborated with the Farmers' Market project team to incorporate sustainability measures into the market events. P2S staff continued the recycling and composting program for the market and worked with vendors to provide more sustainable packaging options.

The P2S Program conducted other awareness activities during the year. Articles on pollution prevention were published in NewsLine (LLNL's internal online newsletter), and the P2S Program continued to provide support for implementation of green events. Four large site-wide and four program area green events were held in 2013 and resulted in diversion of over 1,300 pounds of compostable waste and 155 pounds of recyclable waste. Waste diversion at events was enhanced by use of a single Waste Station approach including specific signage and compost and recycling bins to provide a universal system that is easily recognizable by employees and provides consistent messaging at LLNL events. The P2S Program continues to conduct training for purchasing staff on Sustainable Acquisition requirements.

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

4. Air Monitoring and Dose Assessment

Kent Wilson • • Nicholas A. Bertoldo • Steven Cerruti • Wilfred Montemayor

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

The EPA Region 9 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 Appendix D for the *LLNL 2013 NESHAPs Annual Report* (Wilson et al. 2014).

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

In 2013, 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.

Three facilities had measureable emissions in 2013. A total of 1857 GBq (50.2 Ci) of measured tritium was released from the stack exhausts at the Tritium Facility. Of this, approximately 75% of tritium was released as vapor (HTO). The remaining 25% released was gaseous tritium (HT).

The National Ignition Facility (NIF) released a total of 47.7 GBq (1.29 Ci) of tritium from the stack exhaust in 2013. Of this, approximately, 78% of tritium was released as vapor (HTO). The remaining 22% was released as gaseous tritium (HT).

The Contained Firing Facility (CFF) at Site 300 had measured depleted uranium stack emissions in 2013. A total of 8.1×10^{-7} GBq (2.2×10^{-8} Ci) of uranium-234, 7.4×10^{-8} GBq (2.0×10^{-9} Ci) of uranium-235, and 6.3×10^{-6} GBq (1.7×10^{-7} Ci) of uranium-238 was released in particulate form.

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

One unplanned air effluent release occurred at the Livermore Site in 2013:

On September 13, 2013, tritium was inadvertently released in Building 298. An experiment involving deuterium-tritium (DT) in an experimental container was not proceeding as expected. During the process of trying to identify the source of excess heat in an assembly, a valve was opened that caused an unexpectedly high pressure reading on a vacuum gauge. The valve was closed; however, DT gas from the experiment was emitted. The estimated amount of DT gas released was 4.0 GBq (0.109 Ci), which was 0.11% of the U.S. EPA Reportable Quantities (40 CFR 302).

CAP88-PC version 4.0.0.570 was used to model the DT source term. The MEI member of the public having highest potential dose consequence was located at 264 meters north-northeast relative to Building 298. The modeled dose was 0.00058 µSv (0.000058 mrem). This dose is well below the NESHAPs 100 µSv/y (10 mrem/y) site-wide standard dose to public.

None of the other facilities monitored for radionuclides had reportable emissions in 2013. The data tables in **Appendix A, Section A.1** provide summary results of all air effluent monitored facilities and include upwind locations (control stations) which are used for gross alpha and gross beta background comparison to stack effluent gross alpha and gross beta results.

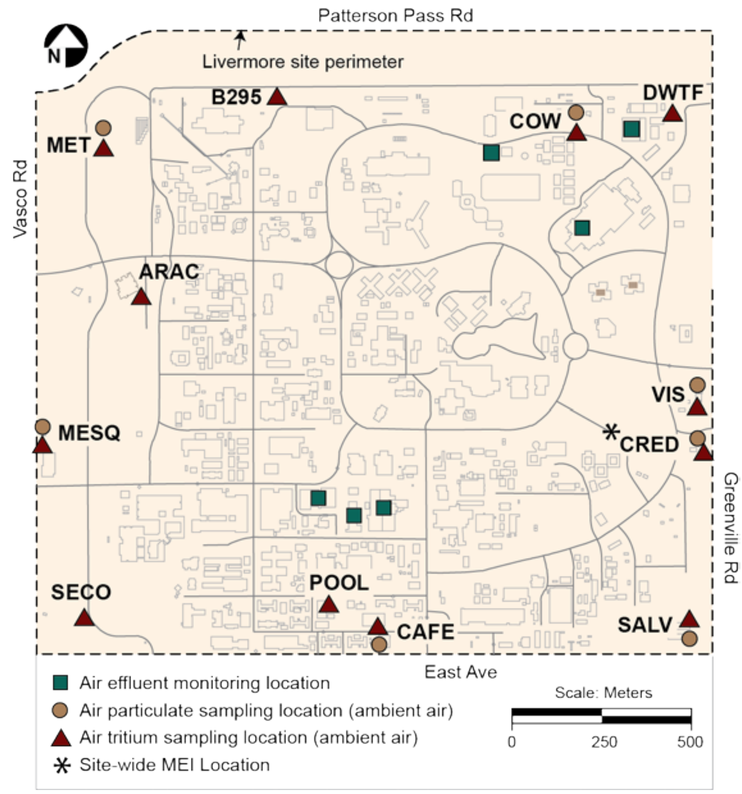

Figure 4-1. Air effluent and ambient air monitoring locations at the Livermore Site, 2013.

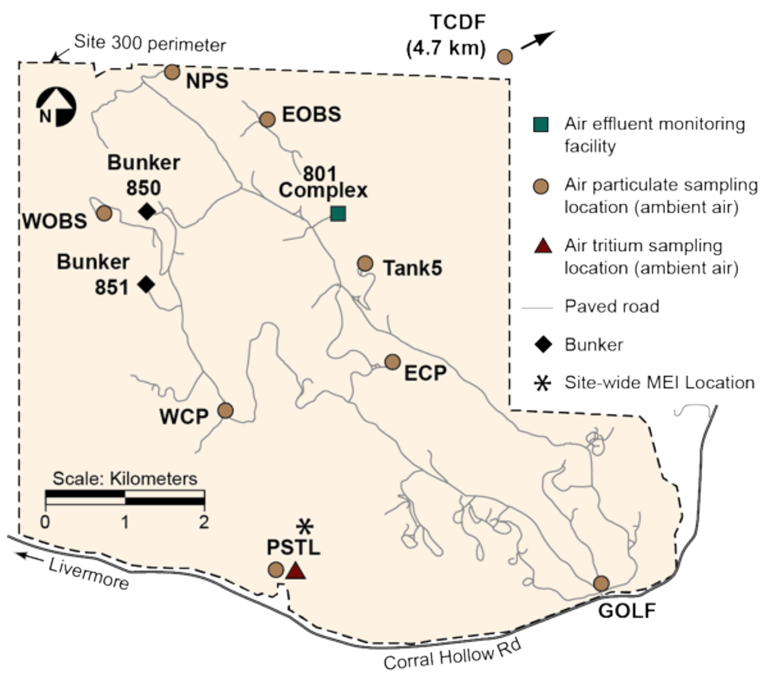

Figure 4-2. Air effluent and ambient air monitoring locations at Site 300, 2013.

4.1.2 Nonradiological Air Releases and Impact on the Environment

In 2013, the Livermore Site emitted approximately 100.2 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, 2013.

	Estimated releases (kg/d)	
Pollutant	**Livermore Site**	**Site 300**
ROGs/POCs	11.3	0.26
Nitrogen oxides	42.7	2.88
Carbon monoxide	40.5	0.67
Particulates (PM-10)	4.5	0.39
Sulfur oxides	1.2	0.17
Total	100.2	4.37

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

Livermore Site air pollutant emissions were very low in 2013 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 3.0×10^5 kg/d, compared to the estimated daily release from the Livermore Site of 42.7 kg/d, which is 0.014% of total Bay Area source emissions for NOx. The 2013 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was approximately 2.36×10^5 kg/d, while the daily emission estimate for 2013 from the Livermore Site was 11.3 kg/d, or 0.005% 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 2013 from operations (permitted and exempt stationary sources) at Site 300 are listed in **Table 4-1**. The stationary emission sources that release the greatest amounts of regulated air pollutants at Site 300 include internal combustion engines (such as diesel-powered generators), a gasoline-dispensing facility, and general research operations. Combustion pollutant emissions, such as NOx, CO, and ROGs/POCs, increased in 2013 primarily due to the site-wide power outage at Site 300 that occurred on October 30, 2013, and lasted for 21 hours necessitating the startup and continuous operation of all emergency standby diesel engine generators for the duration of the power outage.

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.

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**.

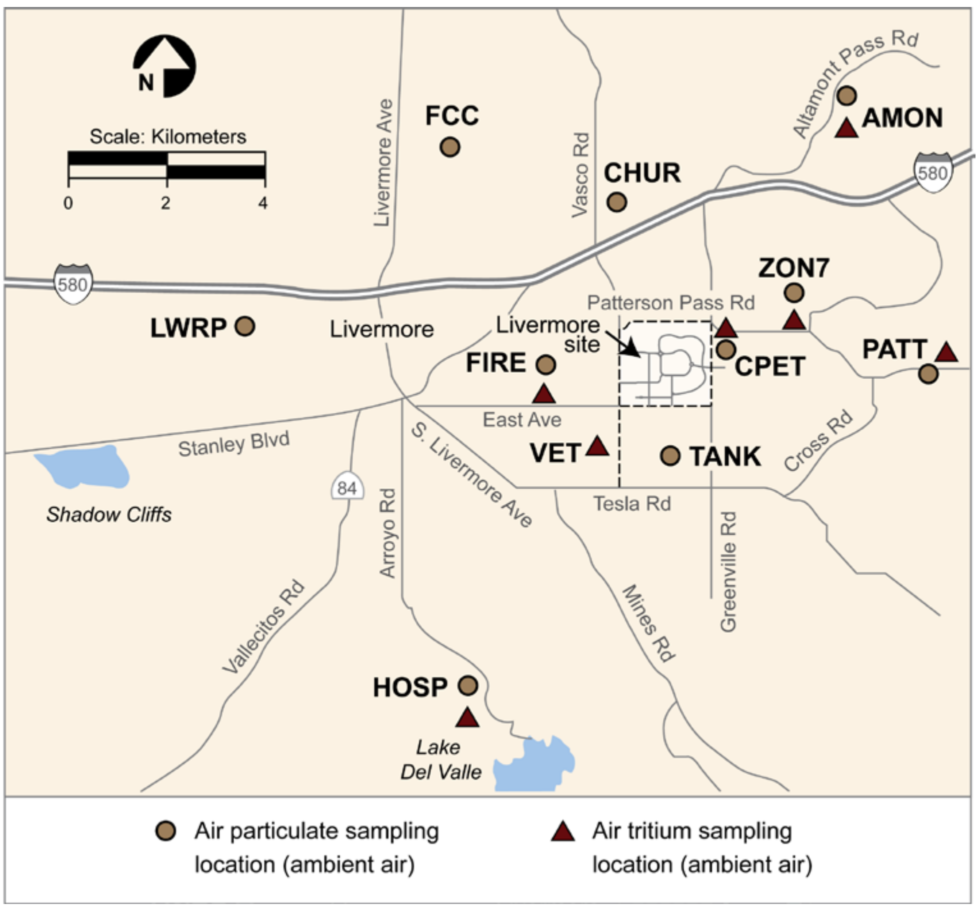

Figure 4-3. Air particulate and tritium monitoring locations in the Livermore Valley, 2013.

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 2013 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 4 out of 214 samples taken in 2013. 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, or from resuspended fallout.

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

The Derived Concentration Standards were formerly published in DOE Order 5400.5 in 1993. The current radiation protection standards approach, which has changed from the previously adopted 1993 guidance, uses age and gender specific attributes for the population subgroups of members of the public subject to exposure incorporating more sophisticated biokinetic and dosimetric information from the International Commission on Radiological Protection (ICRP).

The highest values and percentage of the DCS for the plutonium-239+240 detections were as follows:

- Livermore Site perimeter: There were no detections in 2013.
- Livermore off-site locations: 9.8 nBq/m^3 (0.26 aCi/m^3), 0.00011 % of the DCS
- Site 300 composite: 15.3 nBq/m^3 (0.41 aCi/m^3), 0.00017% of the DCS.

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. The annual median uranium-235/uranium-238 isotopic ratios for 2013 were as follows:

- Livermore Site perimeter composite: 0.00726
- Site 300 sample locations: 0.00719
- Site 300 off-site location: 0.00727

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 tenth of one percent of the DCS as shown in **Appendix A**, **Section A.2**.

Gross alpha and gross beta were sampled for at all locations. The primary sources of alpha and beta activities are naturally occurring radioisotopes. Routine isotopic gamma results indicate the activities are the result of naturally occurring isotopes (uranium, radium, 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. LLNL does not directly measure diffuse emissions. The approach used to characterize these emission sources is stated in the *LLNL NESHAPs 2013 Annual Report* (Wilson et al. 2014); a copy of this report is in **Appendix D**.

Table 4-2. Air tritium sampling summary for 2013.

Sampling locations	Detection frequency	Concentration (mBq/m^3) Mean	Median	IQR	Maximum	Median as % of DCS	Mean Dose (nSv)
Livermore Site perimeter	235 of 299	44.5	38.1	31.0	570	0.00049	10.2
Livermore Valley	71 of 171	15.8	10.2	21.3	125	0.00013	<5
Site 300	5 of 25	3.51	4.59	12.0	27.4	0.000059	<5

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

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

4.2.3 Ambient Air Beryllium Concentrations and Impact on the Environment

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 2013 for airborne beryllium was 17 pg/m^3. This value is only 0.17% 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 2013 was 15 pg/m^3 and the highest value at the off-site location was 25 pg/m^3. These data are similar to data collected from previous years.

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 samplers. 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.

4.3 Radiological Air Dose Assessment

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.

In 2013, the SW-MEI at the Livermore Site was located at the UNCLE Credit Union, about 10 m outside the site's controlled eastern perimeter. The SW-MEI at Site 300 was located on the site's south-central perimeter, which borders the Carnegie State Vehicular Recreation Area. The two SW-MEI locations are shown in **Figures 4-1 and 4-2**.

Table 4-3 shows average doses received in the United States from exposure to natural background radiation and other sources of radiation.

Table 4-3. Radiation doses from background (natural and man-made) and other sources of radiation.

Sources [(a)] (background)	Category	Individual dose (μSv) [(b)]	Collective dose [(c)] (person-Sv) [(d)]
	Natural radioactivity [(e,f)]		
	Cosmic radiation	300	2,330
	Terrestrial radiation	300	2,330
	Internal (food and water consumption)	400	3,110
	Radon	2,000	15,500
	Medical radiation (diagnostic procedures) [(f)]	530	4,120
	Weapons test fallout [(f)]	10	78
	Nuclear fuel cycle	4	31

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

(b) 1 μSv = 0.1 mrem.

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

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

(e) These values vary with location.

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

The annual radiological doses from all air emissions at the Livermore Site and Site 300 in 2013 were found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs 10 mrem/y site-wide standard. Using an EPA-mandated computer model and actual LLNL meteorology appropriate to the two sites, the doses to the LLNL SW-MEI members of the public from LLNL operations in 2013 were:

- Livermore Site: 1.8×10^{-2} μSv (1.8×10^{-3} mrem)
- Site 300: 4.0×10^{-7} μSv (4.0×10^{-8} mrem)

The collective EDE attributable to LLNL airborne emissions in 2013 was calculated to be 0.0018 person-Sv (0.18 person-rem) for the Livermore Site and 6.0×10^{-8} person-Sv (6.0×10^{-6} person-rem) for Site 300. These doses include potentially exposed populations of 7.77 million people for the Livermore Site and 7.11 million people for Site 300 living within 80 km of the site centers.

The doses to the SW-MEI, which represent the maximum doses that could be received by members of the public, resulting from Livermore Site and Site 300 operations in 2013 were less than 1% of the NESHAPS 100 µSv/y (10 mrem/y) site-wide standard.

LLNL operations involving radioactive materials had minimal impact on ambient air during 2013. The measured radionuclide particulate and tritium concentrations in ambient air at the Livermore Site and Site 300 were all less than one percent of the DOE primary radiation protection standard for the public (DCS). The SW-MEI doses from both sites for 2013 in comparison to the dose from radon shown in **table 4-3**, is less than one-tenth of one percent to naturally occurring radiation.

See the *LLNL NESHAPs 2013 Annual Report* (Wilson et al. 2014) for a complete description of dose (individual and collective), air dispersion modeling, and air monitoring; the NESHAPs report is located in **Appendix D**.

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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 water. 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 2012). 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 2013, the Livermore Site discharged an average of 0.88 million L/d (233,000 gal/d) of wastewater to the City of Livermore sewer system or 3.4% 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 2013, Sandia/California generated approximately 5.5% 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 effluent contains both domestic waste 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 retention tanks and discharged to LLNL's collection system following characterization and approval from LLNL's EFA Water Team staff Wastewater Discharge Authorization Requirement (WDAR) approval process.

5.1.1 Livermore Site Sanitary Sewer Monitoring Complex

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

5.1.1.1 Radiological Monitoring Results

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

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

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

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

LLNL determines the total radioactivity contributed by tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. As shown in **Table 5-1**, the 2013 combined release of alpha and beta sources was 0.17 GBq (0.005 Ci), which is 0.5% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The tritium total was 1.94 GBq (0.05 Ci), which is 1.1 % of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

Table 5-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2013.

Radioactivity	Estimate based on effluent activity (GBq)	MDC[(a)] (GBq)
Tritium	1.94	0.76
Gross alpha	0.01	0.02
Gross beta	0.16	0.05

(a) Minimum detectable concentration

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 0.08 Bq/mL (2.16 pCi/mL) was far below the permit discharge limit of 12 Bq/mL (333 pCi/mL).

Complete calendar year 2013 data for 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 March 2013 Report (Jones 2013). Cesium and plutonium results are from monthly composite samples of LLNL and LWRP effluent and from quarterly composites of LWRP sludge. For 2013, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCTSs. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The highest plutonium concentration observed in 2013 sludge is 0.6 mBq/g (0.016 pCi/g), which is many times lower than the National Council on Radiation Protection and Measurements (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for commercial or industrial property.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-2** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2013, a total of 1.94 GBq (0.05 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, 2003–2013.

Year	Tritium (GBq)	Plutonium-239 (GBq)
2003	1.11	0.51×10^{-4}
2004	1.34	1.16×10^{-5}
2005	3.12	9.64×10^{-6}
2006	19.9	7.56×10^{-6}
2007	2.83	6.24×10^{-6}
2008	0.83	5.52×10^{-6}
2009	1.01	5.93×10^{-6}
2010	1.47	5.25×10^{-6}
2011	1.37	2.00×10^{-6}
2012	1.57	7.00×10^{-6}
2013	1.94	5.91×10^{-5}

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.

A summary of the analytical results from the permit-specified monthly composite sampling program 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. (Results from LLNL's 2013 sanitary sewer effluent monitoring program are provided in **Appendix A**, **Section A.3**.)

During July 2013, the permit changed how metals are sampled. Metals are no longer measured weekly. Metals are now measured with a 24-hour composite sample collected twice annually in April and October. All of the metals samples in 2013 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, 2013.

Sample	Parameter	Detection frequency[a]	PQL[b]	Minimum	Maximum	Median
Monthly 24-hour Composite	Biochemical oxygen demand (mg/L)	12 of 12	2	64	150	82
	Solids (mg/L)					
	Total dissolved solids	12 of 12	1	200	620	260
	Total suspended solids	12 of 12	1	26	67	36

(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).

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 2013, LLNL did not exceed either of these discharge limits. Results from the monthly TTO analyses for 2013 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 with the exception of methylene chloride which was measured at 40 µg/L and reported in the December LWRP report. This value is well below the regulatory reporting limit of 1 mg/l. 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 for semi-annual samples in April (<0.02 mg/L) and October (<0.02 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), which is administered by the WRD.

The processes at LLNL that are determined to be regulated under the Categorical Standards may change as programmatic requirements dictate. During 2013, the WRD identified 14 wastewater-generating processes at LLNL that are defined under either 40 CFR Part 469 or 40 CFR Part 433.

Only processes that discharge to the sanitary sewer require semiannual sampling, inspection, and reporting. During 2013, two of the 14 processes discharged wastewater to the sanitary sewer: semiconductor processes located in the Building 153 microfabrication facility, and the abrasive jet machining located in Building 321C. In 2013, LLNL analyzed compliance samples for all regulated parameters from both processes and demonstrated compliance with all federal categorical and local 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 2013 and January 2014 semiannual wastewater reports (Rosene, 2013, 2014).

In addition, WRD source control staff performed their required annual inspection and sampling of the two discharging categorical processes in October 2013. The compliance samples were analyzed for all regulated parameters, and the results demonstrated compliance with all federal and local pretreatment limits.

The remaining 12 processes, if they were to discharge wastewater to the sanitary sewer, would be regulated under 40 CFR Part 433. Wastewater from these processes is either recycled onsite or contained for eventual removal and appropriate disposal by RHWM.

5.1.3 Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2013–2014) 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 2013, there were no discharges (from on-site or off-site locations) to the sanitary sewer from Environmental Restoration Department (ERD) GWP activities. When such discharges occur, permit compliance is maintained by Treatment Facility Operators through the systematic use of engineering and administrative controls, including Wastewater Discharge Authorization Records (WDARs) generated for each discharge. This information was reported to the City of Livermore (Revelli 2014a).

5.1.4 Environmental Impact of Sanitary Sewer Effluent

During 2013, 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 2013 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 (2012).

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. Occasionally, 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 2013.

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.

Under the terms of this Monitoring and Reporting Program (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 2013 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 2013).

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 observations also meet 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). The Energy Independence and Security Act, Section 438 specifically calls for federal development that has a footprint that exceeds 5,000 square feet to maintain or restore predevelopment hydrology. Storm water monitoring at both sites also follows the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) and meets the applicable requirements of DOE Order 458.1. **Appendix B** includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

LLNL permits require sample collection and analysis at the sample locations specified in the permits two times per rainy season if specific criteria are met and the sampling window coincides with regular working hours. 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 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 2013 that their facilities complied with the provisions of LLNL's SWPPPs. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Lee 2013a) and to the CVRWQCB (Lee 2013b) 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, if necessary, summarize the inspections.

In the calendar year 2013, there were three storms at the Livermore Site that met the criteria for a qualifying event (in January, February, and November) as defined in Permit WDR 95-174 (SFBRWQCB 1995) but no storms at Site 300 met the criteria for a qualifying event as defined in the General Industrial Storm Water Permit (97-03-DWQ) for Site 300. LLNL will continue to monitor the nine sampling locations at the Livermore Site and the seven sampling locations at Site 300 that characterize runoff from on-site industrial activities, as well as upstream off-site locations when there are permit-qualifying storms that generate sufficient runoff to collect samples during regular working hours.

5.3.2 Storm Water Compliance

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. 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.

The data for all three Livermore Site storm events, i.e., January, February, and November 2013, were within acceptable levels as defined in our permit WDR 95-174.

Storm water visual observations and best management practices inspections indicated that LLNL’s storm water program continues to protect water quality.

A full report of storm water runoff samples for the period of July 2012 to June 2013 is available in the Annual Storm Water Reports for the Livermore Site and Site 300 (**Appendix D**).

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 2012).

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 7**. 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 2013, representative samples of groundwater were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures* (Goodrich and Lorega 2012). 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 (tritiated water) is potentially the most mobile groundwater contaminant from LLNL operations. Groundwater samples were obtained during 2013 from 17 water wells in the Livermore Valley (see **Figure 5-1**) and measured for tritium activity.

Tritium measurements of Livermore Valley groundwater are provided in **Appendix A**, **Section A.5**. The measurements continue to show very low 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 16B1, located about 3.5 km (2.2 mi) west of LLNL (see **Figure 5-1**). The measured activity there was 2.3 Bq/L (62.2 pCi/L) in 2013, less than 0.35% of the MCL.

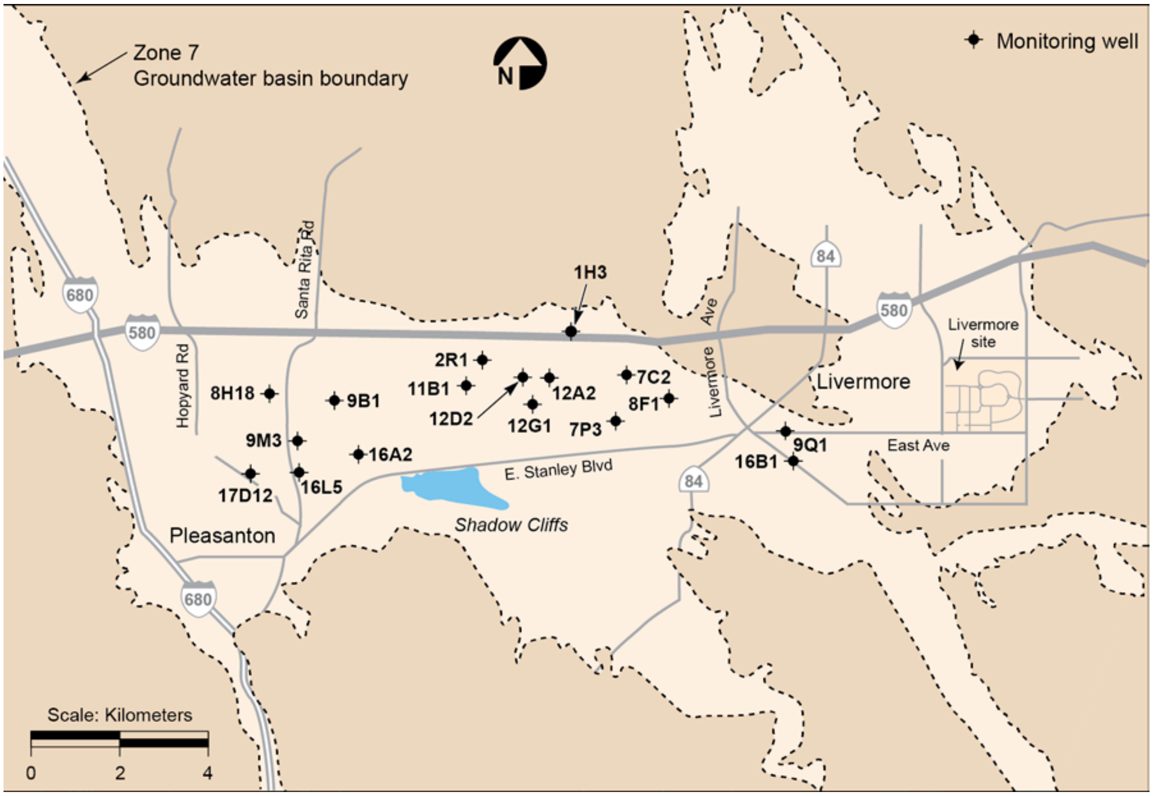

Figure 5-1. Off-site tritium monitoring wells in the Livermore Valley, 2013.

5.4.1.2 Livermore Site Perimeter

LLNL's groundwater surveillance monitoring program was designed to complement the Livermore Site Ground Water Project (GWP (see **Chapter 7**). 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 5-2**). As discussed in **Chapter 7**, the alluvial sediments have been divided into nine hydrostratigraphic units (HSUs—water bearing zones that exhibit similar hydraulic 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 2013 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 2013 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 2013 sample from this location showed a concentration of 37 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 2013 from the nearby wells W-556 and W-1012, also along the western perimeter of the LLNL site, showed chromium (VI) concentrations of 18 µg/L and 12 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 2013 sample from this well (25 mg/L) was again, as in the past eight years, below the MCL. During 2013, concentrations of nitrate in on-site shallow background wells W-008 and W-221 were both reported to be 30 mg/L. Detected concentrations of nitrate in western perimeter wells ranged from 13 mg/L (in well W-373) to 45 mg/L (in well 14B1).

During 2013, 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.

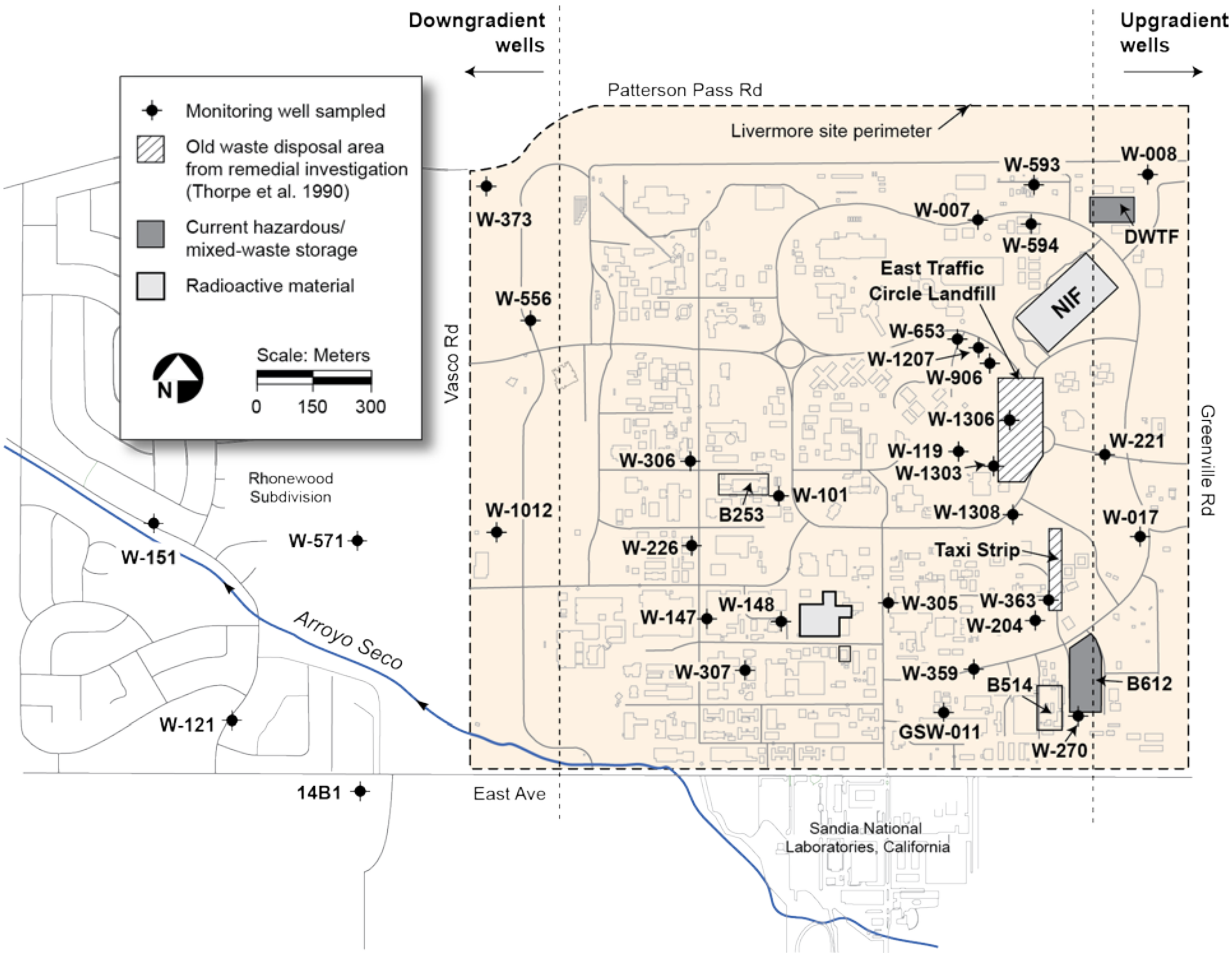

Figure 5-2. Routine surveillance groundwater monitoring wells at the Livermore Site, 2013.

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 5-2**. All analytical results are provided in **Appendix A**, **Section A.5**.

The Taxi Strip and East Traffic Circle Landfill areas (see **Figure 5-2**) 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 2013 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 at all seven locations, and none of the trace metals (copper, lead, zinc) were detected in six of these seven monitoring wells during

2013. The single exception is well W-1306, where a zinc concentration of 73 µg/L was reported in the January 2013 sample. This location had been out of service (pending pump replacement) for most of 2012 and showed low concentrations of copper (11 µg/L) and zinc (68 µg/L) when sampled (November 2012) after repairs had been completed. Although these levels are above the non-detections more recently reported for this location, they are comparable to values reported in 1997; when the well was first developed and the original pump was brought into service. LLNL will continue to monitor this location to determine if the results might be attributable to contaminants associated with the installation of new hardware.

Near the National Ignition Facility (NIF), LLNL measures pH, conductivity, and tritium concentration of nearby groundwater to establish a baseline. During 2013, 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 2013 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 2013. 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 2013, 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 2013.

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 2013, with the exception of manganese, the monitoring results for well W-307 showed only slight variations from the concentrations reported last year. Historically, manganese had not been detected above the analytical reporting limit at this location. The April 2013 sample from well W-307 showed a manganese concentration of 81 µg/L, while the two samples collected at W-307 in May and August of 2012 showed manganese concentrations of 220 µg/L and <10 µg/L (non-detect), respectively. LLNL will continue to track these results as additional data become available to monitor the fluctuation of manganese concentrations at this location.

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 2013, 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 soil 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; however, well W-101 was dry and could not be sampled in 2013. In August 2000, elevated tritium activity was detected in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L [3100 ± 135 pCi/L]). The activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater in this area had remained at or near the same level through 2005, but samples collected from well W-148 in 2006 through 2013 have shown significantly lower values—a downward trend ranging from approximately one-half to one-quarter 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 2013 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 5-3**). 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 **Chapter7** for a review of groundwater monitoring in this drainage area conducted under CERCLA.)

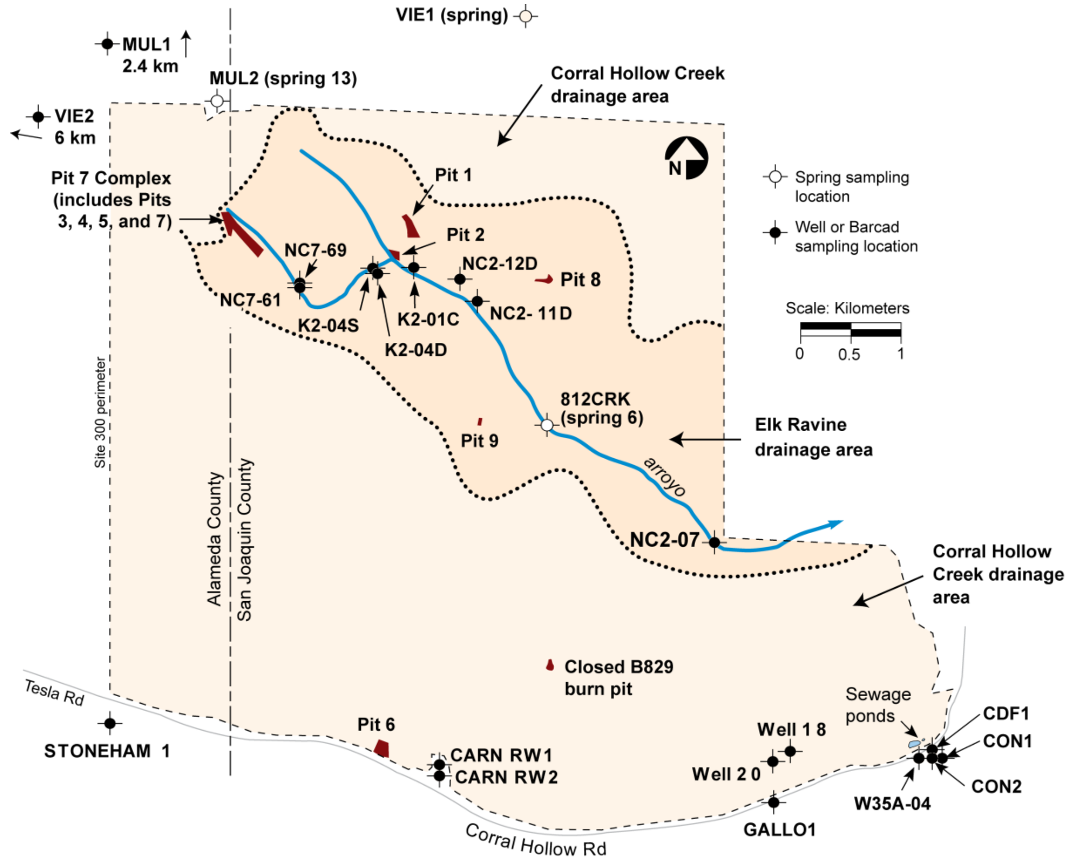

Figure 5-3. Surveillance groundwater wells and springs at Site 300, 2013.

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 (Site 300 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 for the Pit 7 complex 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 2013 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 2013, including well locations, maps of the distribution of COCs in groundwater, and analytical data tables, see Dibley et al, 2013.

Elk Ravine. Groundwater samples were obtained on various dates in 2013 from the widespread Elk Ravine surveillance monitoring network shown in **Figure 5-4** (NC2-07, NC2-11D, NC2-12D, NC7-61, NC7-69, 812CRK [SPRING6], K2-04D, K2-04S, K2-01C). Samples from NC2-07 were analyzed for inorganic constituents (mostly metallic elements), general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX). Samples from the remaining wells were analyzed only for general radioactivity.

No new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2013. 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 highest result of tritium analysis for well NC7-61 was 760 Bq/L in 2013, down from 780 Bq/L in 2012. 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 2013 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 2013 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 2013; a detailed account of Pit 1 compliance monitoring during 2013, including well locations and tables and graphs of groundwater COC analytical data, is in Blake (2013).

5.4.2.2 Corral Hollow Creek Drainage Area

Pit 6. Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in Ferry et al. (1998, 2002). Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Plan (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Plan (CAMP), which monitors the movement and fate of historical releases. To comply with monitoring requirements, LLNL collected groundwater samples monthly, quarterly, semiannually, and annually during 2013 from specified Pit 6 monitoring wells. Groundwater wells were analyzed for VOCs, tritium, beryllium, mercury, total uranium, gross alpha/beta, perchlorate, and nitrate.

During 2013, no new releases were detected at Pit 6. A detailed account of Pit 6 compliance monitoring during 2013, including well locations, tables of groundwater analytical data, and maps showing the distribution of COC plumes, is displayed in the CERCLA Annual Compliance Report that was submitted by the LLNL Environmental Restoration Department (Dibley 2013).

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 2013 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 2013, 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 one-third 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 2013, including well locations and tables and graphs of groundwater COC analytical data, see Revelli (2014b).

Water Supply Well. Water supply well 20, located in the southeastern part of Site 300 (**Figure 5-4**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer ($Tnbs_1$) and can produce up to 1,500 L/min (396 gal/min) of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2013 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 2013 LLNL obtained groundwater samples from two off-site springs (MUL2 and VIE1) and ten off-site wells (MUL1, VIE2, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04) **(Figure 5-4)**. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at a private residence 6 km west of the site. It represents a typical potable water supply well in the Altamont Hills.

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

Groundwater samples were obtained once (annually) during 2013 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 by EPA 906.0 which is a modified method in support of DOE Order 458.1. Rainwater is collected in rain gauges at fixed locations from both Livermore Site and Site 300. The tritium activity of each sample is measured and the analytical results compared to the MCL of 740 Bq/L (20,000 pCi/L) established by the EPA for drinking water. In calendar year 2013, the rain gauges were placed at the sample locations SALV, MET, DWTF, and SECO as shown in Appendix A, Section A.X. The sample collection for calendar year 2013 ranged from January 24, 2013 to November 21, 2013.

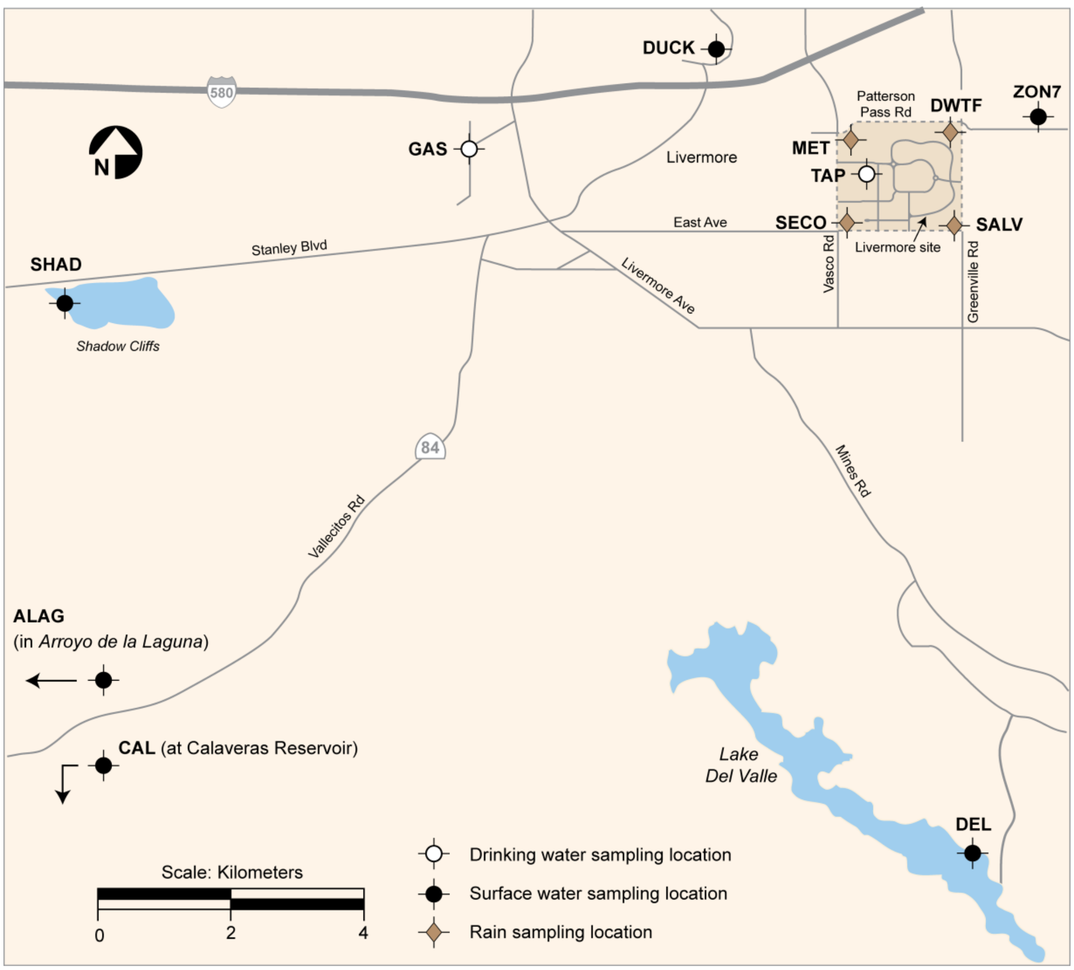

Figure 5-4. Livermore Site and Livermore Valley sampling locations for rain, surface water, and drinking water, 2013.

The highest tritium activity reported was for the January 24 storm at the SECO location with an activity of 11 Bq/L. The activity ranged from 0.4 Bq/L to 3.5 Bq/L for the remaining locations with the exception of the SECO location for the February 20 storm reported as a non-detect.

5.5.1.2 Site 300 and Environs

During 2010, LLNL positioned two rain gauges at on-site locations ECP and PSTL (see **Figure 5-5**) to collect rainfall to measure tritium activity at Site 300. Rainfall samples are usually collected at the same time storm water samples are collected. However, the 2013 rain season did not produce a sufficient amount of precipitation for Site 300 stormwater sampling and no rain samples were collected in calendar year 2013.

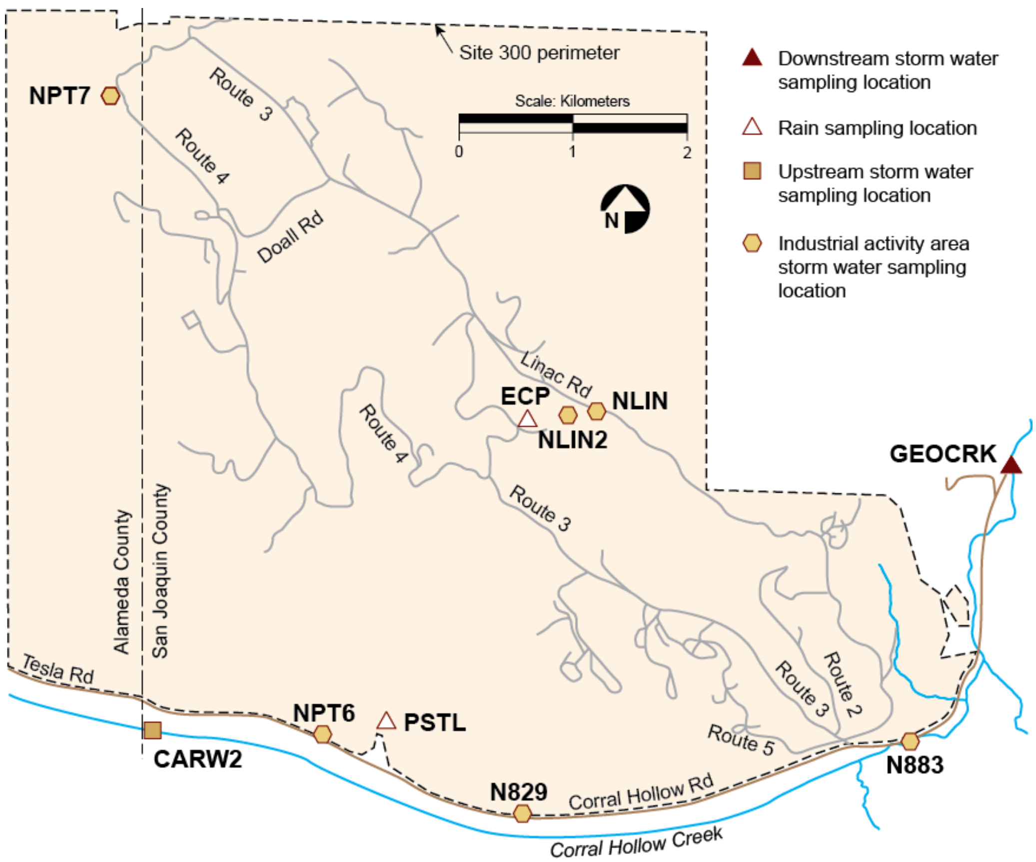

Figure 5-5. Storm water and rainwater sampling locations at Site 300, 2013.

5.5.2 Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 458.1. Surface and drinking water near the Livermore Site and in the Livermore Valley were sampled at the locations shown in **Figure 5-4** in 2013. 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 5-4**).

Samples are analyzed according to written, standardized procedures summarized in Gallegos (2012). LLNL sampled the two drinking water outlets semiannually and the other locations annually in 2013. 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 2013 was 1.77 Bq/L 47.8 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, and the maximum gross beta radioactivity also occurred in a sample collected at TAP. These maximum values (gross alpha at 0.070 Bq/L [1.89 pCi/L] and gross beta at 0.131 Bq/L [3.54 pCi/L]) were still less than 13% and 8% of their respective drinking water MCLs (see **Table 5-4**).

Table 5-4. Radioactivity in surface and drinking waters in the Livermore Valley, 2013.

Location	Metric	Tritium (Bq/L)[(a)]	Gross alpha (Bq/L)[(a)]	Gross beta (Bq/L)[(a)]
All locations	Median	0.37	0.0027	0.0679
	Minimum	-2.19	-0.1670	0.0121
	Maximum	1 .77	0.0703	0.1310
	Interquartile range	1.99	0.0417	0.0212
Drinking water outlet locations	Median	1.20	0.0107	0.0742
	Minimum	0.67	-0.0169	0.0121
	Maximum	1.77	0.0703	0.1310
	Drinking water MCL	740	0.555	1.85

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

5.5.3 Lake Haussmann Monitoring

Lake Haussmann, which was formerly called the Drainage Retention Basin, 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. LLNL initiated monitoring changes during the 2013 calendar year based on monitoring redundancy, regulatory drivers, and consistent historical data confirming water quality. LLNL revised the two wet and four dry season release samples per year to collect two wet season samples at CDBX, CDB, and CDB2 as currently performed under LLNL's Industrial Storm Water Program. Storm Water Compliance and Surveillance Monitoring information is in Section 5.3 of this report.

5.5.4 Site 300 Drinking Water System Discharges

LLNL currently maintains coverage under General Order R5-2013-0074-025, NPDES Permit No. CAG995001 for occasional large volume discharges from the Site 300 drinking water system that reaches surface water drainage courses. (Prior to 2013, this coverage was provided by the now superseded WDR R5-2008-0081.) 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 2013 are detailed in the quarterly self-monitoring reports to the CVRWQCB. During the third quarter of 2013, LLNL conducted routine annual flushing of the drinking water system for water quality purposes. In accordance with the CVRWQCB requirements and the LLNL *Pollution Prevention and Monitoring and Reporting Program* (PPMRP), LLNL monitored one flush per pressure zone of drinking water discharged. However, during 2013 all water discharged during planned releases from the Site 300 drinking water system soaked into the ground surface before reaching a surface water.

One off-normal discharge event in 2013 did result in the release of drinking water that flowed across the site boundary. On Wednesday, May 22, 2013, a defective valve in the irrigation line near the Site 300 Main Gate resulted in an estimate of less than 500 gallons discharged from the site. 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 volume that left the Site 300 boundary, it is not likely that any discharge actually reached Corral Hollow Creek, the potential receiving water.

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6. Terrestrial Monitoring

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

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 and is used to compare the impact of operations.

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 (see Chapter 4). 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 is calculated using a screening model that requires knowledge of radionuclide concentrations in soils and surface water, which is explained under the *Biota Dose* section below.

Sampling for all media is conducted according to written, standardized procedures summarized in Gallegos (2012).

LLNL also 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**)

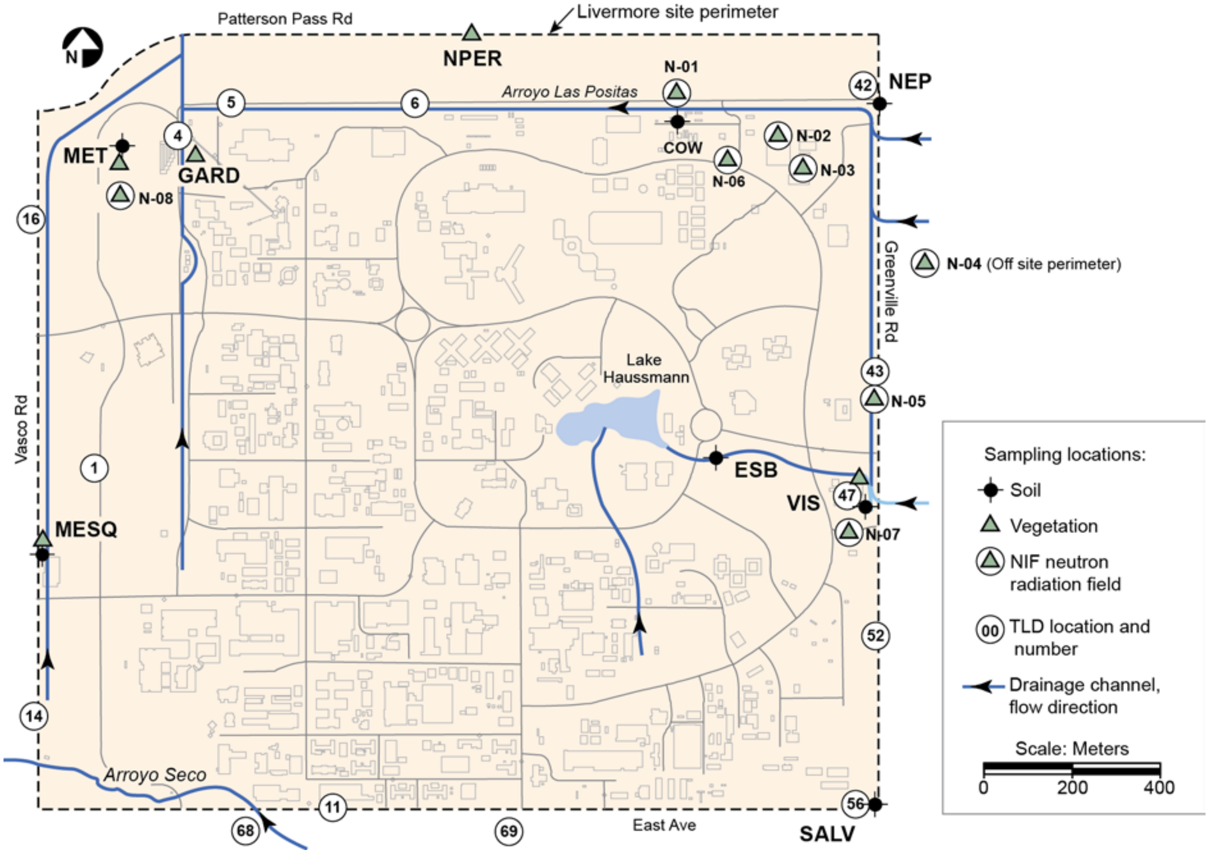

Figure 6-1. Soil and vegetation sampling locations and TLD locations, Livermore Site.

These locations were selected to represent both background concentrations (distant locations unlikely to be affected by LLNL activities) and areas that have 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 using an 8.25-cm-diameter, stainless steel core sampler.

Additional samples are collected for tritium, gross alpha, gross beta, and metals analyses. At four sample locations a 15-cm deep sample is taken for tritium analysis at one of the subsample grid points; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis.

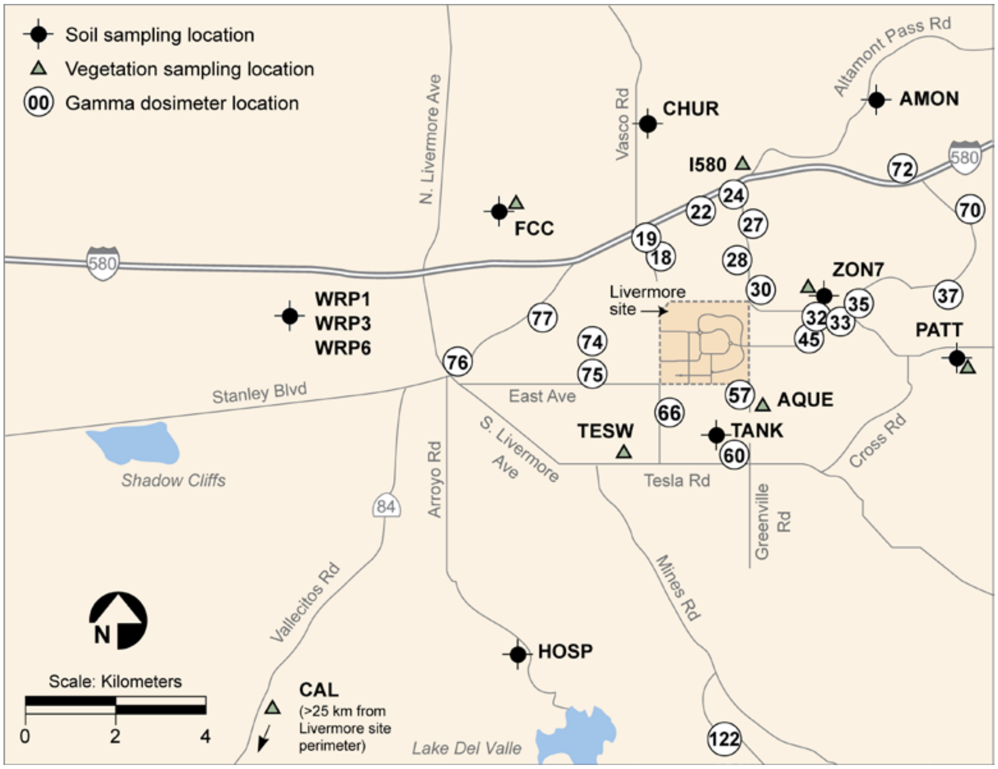

Figure 6-2. Soil and vegetation sampling locations and TLD locations, Livermore Valley.

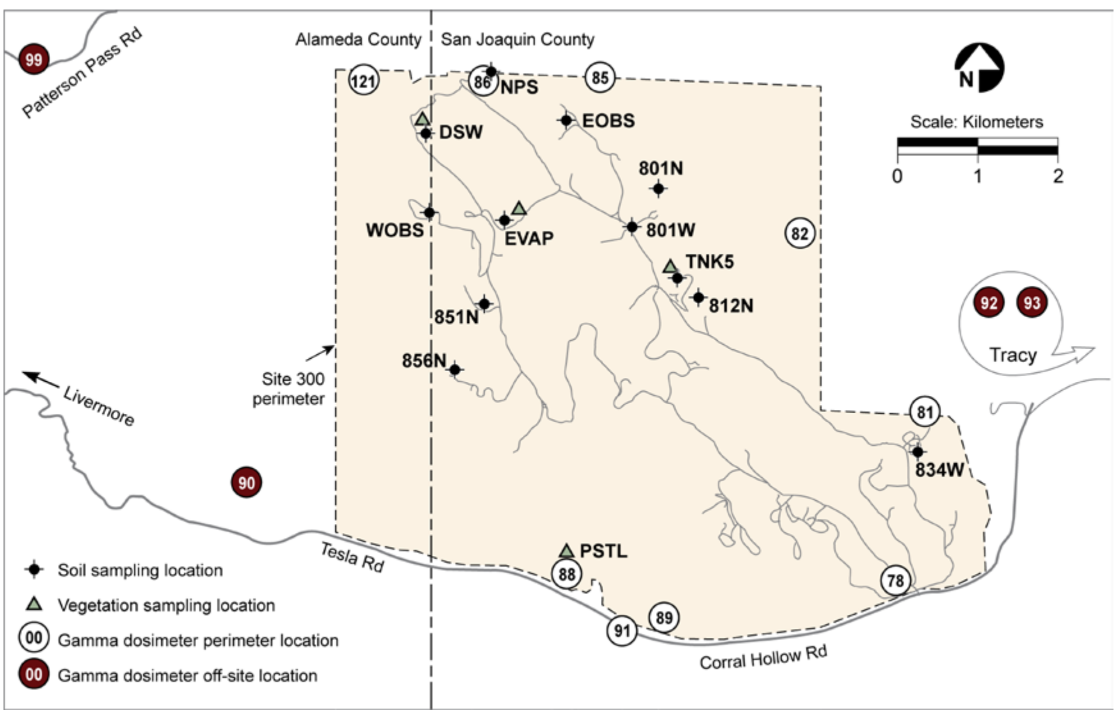

Figure 6-3. Soil and vegetation sampling locations and TLD locations, Site 300 and offsite.

In 2013, 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 a suite of 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.

6.1.1 Radiological Monitoring Results

The 2013 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 2013 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 2013 was 0.35 mBq/dry g (9.5×10^{-3} 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 2013. The highest detected plutonium-239+240 value at the LWRP in 2013 was 10 mBq/dry g (2.7×10^{-1} pCi/dry g). In addition, americium-241 was detected in one LWRP sample at a concentration of 5.0 mBq/dry g (1.4×10^{-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 2013 (16 Bq/L [432 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 2013 are provided in **Appendix A**, **Section A.8**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2013 lie within the ranges reported in previous years. 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 due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. In 2013, the highest measured values for uranium-235 and uranium-

238 in a single sample were 0.0.049 µg/g (0.0039 Bq/g or 0.11 pCi/g) and 9.5 µg/g (0.12 Bq/g or 3.2 pCi/g), respectively. The uranium-235 to uranium-238 ratio in this sample was 0.0053, which at the upper end range of analytical uncertainty is consistent with the ratio for natural occurring uranium; at the lower end range of the analytical uncertainty, the presence of depleted uranium is indicated. Depleted uranium values at Site 300 result from the previous use of depleted uranium in atmospheric explosive experiments.

6.1.2 Nonradiological Monitoring Results

Nonradiological monitoring for beryllium at Site 300 is sampled at all locations (see **fig. 6-3**). The beryllium results for soils at Site 300 were within the ranges reported since sampling began in 1991. The highest value in 2013, 1.1 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 range of results reflects the varied concentrations of beryllium in the soil from previous explosives testing.

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 2013 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 2013 (10 mBq/dry g [0.27 pCi/dry g]), measured at LWRP, is 2.1% 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 2013 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 dispersed depleted uranium from historical testing. The highest measured uranium-235 concentration was 0.0.049 µg/g (0.0039 Bq/g or 0.11 pCi/g) and was well below the NCRP-recommended screening level for commercial sites (8.2 µg/g [0.65 Bq/g or 17.5 pCi/g]). The highest measured uranium-238 concentration was 9.5 µg/g (0.12 Bq/g or 3.2 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]).

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 7**). In 2011, ERD began characterization as a means to address soil and groundwater contamination cleanup in the Building 812 OU. However, further characterization activities may be necessary and may therefore delay remediation. See **Chapter 7** for further details regarding this project.

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 2013 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 2013 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 2013 was 4.3 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 2013 was 37 Bq/L at EVAP located in an area where the groundwater is contaminated with tritium.

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

At Site 300, the median concentrations of tritium in vegetation at locations PSTL and TNK5 were below the detection limit. The median concentration of tritium in vegetation at EVAP was 8.3 Bq/L.

6.2.2 Wine Monitoring Results

Tritium concentrations in wines purchased in 2013 are shown in **Table 6-2**. The highest concentration in a Livermore Valley wine is 4.7 Bq/L (127 pCi/L) from a wine made from grapes harvested in 2011. The highest concentration in a California (other than the Livermore Valley) wine is 3.0 Bq/L (81 pCi/L) from a wine made from grapes harvested in 2009. The highest concentration in a Rhone Valley (France) wine is 4.4 Bq/L (120 pCi/L) from a wine made from grapes harvested in 2010.

Analysis of the wines purchased annually since 1977 have typically 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 2013. The table includes mean annual ingestion doses calculated for 2013.

Sampling locations		Concentration of tritium in plant water (Bq/L)		Mean annual ingestion dose (a) (nSv/y)
		Median	Mean	
NEAR (on-site or <1 km from Livermore Site perimeter)	AQUE	1.9	4.0	20
	GARD	1.9	1.7	<10(b)
	MESQ	2.4	3.2	16
	MET	1.2	2.1	10
	NPER	1.6	2.5	12
	VIS	4.6	4.3	21
INTERMEDIATE (1–5 km from Livermore Site perimeter)	I580	2.6	2.3	11
	PATT	1.0	0.86	<10(b)
	TESW	2.1	2.8	14
	ZON7	3.9	4.0	20
FAR (>5 km from Livermore Site perimeter)	CAL	0.62	0.57	<10(b)
	FCC	1.1	1.2	<10(b)
Site 300	DSW(c)	(d)	1.6	(e)
	EVAP(c)	8.3	37	(e)
	PSTL	1.2	1.6	(e)
	TNK5	0.05	0.44	(e)

(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) Median not calculated because only three values are available for DSW.

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

The Livermore Valley wines represent vintages from 2010, 2011 and 2012; the California wines represent vintages from 2007 and 2011; and the Rhone Valley wines represent vintages from 2010 and 2012. 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 2013, decay-corrected concentrations for Livermore Valley wine samples ranged from 2.5 to 5.4 Bq/L; for the two California wine samples, 3.0 and 4.3 Bq/L; and for the two Rhone Valley wine samples, 4.6 and 5.4 Bq/L.

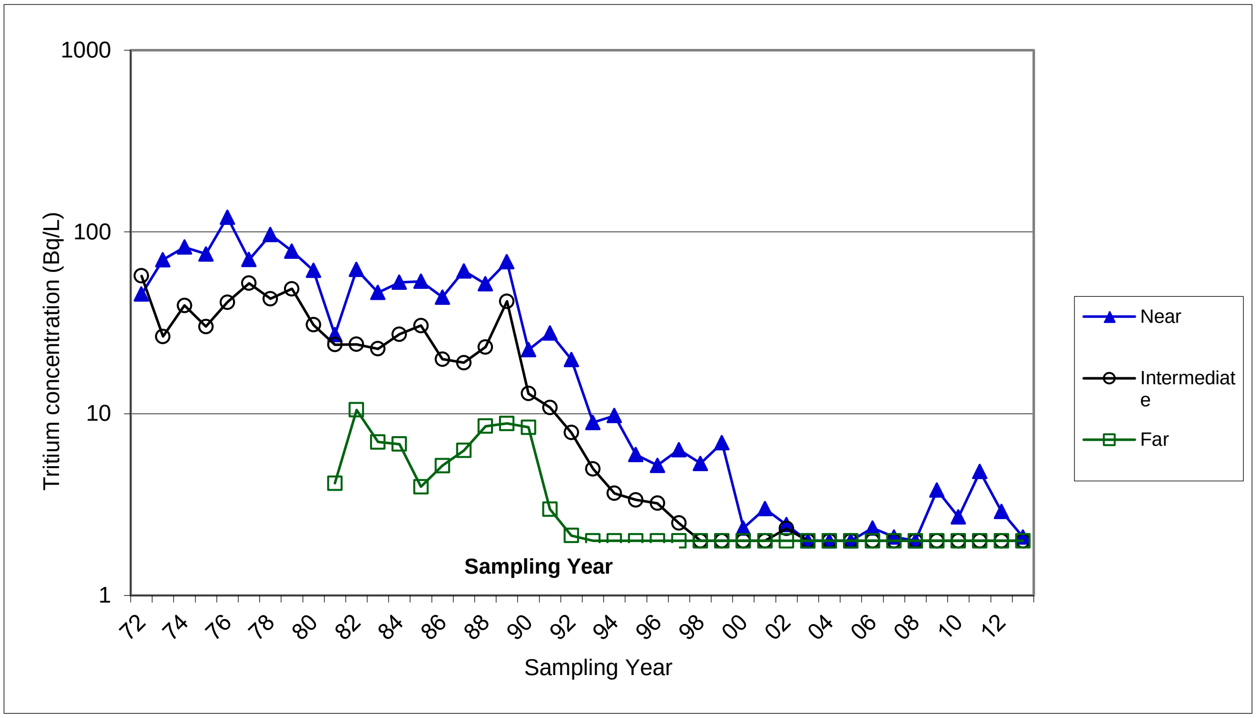

Figure 6-4. Median tritium concentrations in Livermore Site and Livermore Valley plant water samples, 1972 to 2013.

Table 6-2. Tritium in retail wine, 2013[a, b].

	Concentration by area of production (Bq/L)		
Sample	**Livermore Valley**	**California**	**Europe**
1	3.0 ± 0.70	2.6 ± 0.82	4.2 ± 0.72
2	3.6 ± 0.71	3.0 ± 0.83	4.4 ± 0.73
3	2.1 ± 0.67		
4	3.0 ± 0.70		
5	4.7 ± 0.88		
6	3.1 ± 0.84		
Dose (nSv/y)[c]	5.7	3.6	5.3

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

(b) Wines from a variety of vintages were purchased and analyzed for the 2013 sampling. Concentrations are those measured in March or April 2014.

(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 2013, was 21 nSv (2.1 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 × concentration in air (Bq/m^3)
Drinking water	0.013 × concentration in drinking water (Bq/L)
Food ingestion	0.0049 × 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 2013, including OBT, is 42 nSv/y (4.2 µrem/y). This maximum dose is about 1/71,000 of the average annual background dose in the United States from all natural sources and about 1/240 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 2013, the highest concentration of tritium (4.7 Bq/L [127 pCi/L]) was just 0.64% 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 2013 would have resulted in a dose of 40 nSv/y (4.0 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 (3.3 Bq/L [88 pCi/L]) would have been 4.0 nSv/y (0.40 µrem/y).

(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. The dose coefficient for HTO is 1.8×10^{-11} Sv/Bg per the International Commission on Radiological Protection (1996).

Both doses explicitly account for the added contribution of OBT.(2)

The potential dose from drinking Livermore Valley wines in 2013, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/250 of a single dose from a panoramic dental x-ray.

6.3 Biota Dose

In 2013, 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 was used to assess dose to biota in 2013.

6.3.1 Estimate of Dose to Biota

Biota (flora and fauna) also needs to be protected from potential radiological exposure from LLNL operations because their exposure pathways are unique to their environment (e.g., a burrowing animal may be exposed by 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 2013, radionuclides contributing to dose to biota were americium-241, cesium-137, tritium (HTO), potassium-40, plutonium-238, plutonium-239, thorium-232, uranium-235, and uranium-238, as well as plutonium-239 based on gross alpha and strontium-90 based on gross beta.

In the 2013 LLNL assessment, the maximum concentration of each radionuclide measured in soil and the storm water run-off samples were used in the dose screening calculations for the terrestrial and aquatic fractions respectively. This approach resulted in an assessment that is extremely conservative, given that the maximum concentrations in the media are distributed over a large area. It accounts for the exposure at both the Livermore Site and Site 300 individually and no plant or animal would likely be exposed to both simultaneously.

In the RESRAD-BIOTA code, each radionuclide in each medium (e.g., soil, sediment, and surface water) is assigned a Biota Concentration Guide (BCG). Measured radionuclide concentrations in the soil and water media are divided by the BCG, and the resulting fractions (concentration ratios) for each nuclide and medium are summed as a ratio for the fraction affecting the aquatic animals and terrestrial plants and animals of each ecosystem (aquatic and terrestrial) and presented in **Table 6.3**. For aquatic and riparian animals, the sum of the fractions for water exposure is added to the sum of the fractions for sediment exposure. Similarly, fractions for water and soil exposures are summed for terrestrial animals. If the sums of the fractions for the aquatic and terrestrial systems are both less than 1 (i.e., the dose to the biota does not exceed the screening limit), then the site has passed the screening analysis for protection of the biota.

At the Livermore Site in 2013, the sum of the water fractions for the Aquatic and Riparian animal are 6.15×10^{-2} due to the contribution from storm water runoff. The sum of the soil fraction for the terrestrial animal and plant was 4.38×10^{-1}, primarily due to gross beta with the remainder due to Cs-137, and K-40. The predominant concentrations of radioactivity measured in the aquatic ecosystem were due to gross alpha with a ratio of concentration to BCG of 2.17×10^{-2} for the aquatic animal and the gross beta ratio of concentration to BCG of 3.98×10^{-2} for the riparian animal.

At Site 300 in 2013 soil fraction for the terrestrial animal was 1.27×10^{-1} with a total ratio of 1.27×10^{-1} for the ecosystem based solely on soil measurements as there was no run-off sampling of storms at Site 300 for 2013. The dose to biota at Site 300 is primarily due to natural potassium-40 in the soil with a ratio of 1.19×10^{-1} and the remainder primarily Cs-137, Th-232, and U-238.

Table 6-4. Biota dose summary.

Biota Dose Concentration Ratio				
	Aquatic Animal	**Riparian Animal**	**Terrestrial Plant**	**Terrestrial Animal**
Livermore Site	2.17×10^{-2}	3.98×10^{-2}	(NA)	4.38×10^{-1}
Sum of Ratio For Ecosystem	Water 6.15×10^{-2}		Soil 4.38×10^{-1}	
Site 300	(NA)	(NA)	(NA)	1.27×10^{-1}
Sum of Ratio For Ecosystem	Water (NA)		Soil 1.27×10^{-1}	

6.4 Ambient Radiation Monitoring

LLNL’s ambient radiation monitoring program compares changes in the natural radiation field that may be attributable to LLNL operations to long-term averages. 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.

The eight background locations for the National Ignition Facility (NIF) neutron radiation field dosimeters are shown in **Figure 6.1**, designated by N-# e.g., N-01. Data from these dosimeters in 2013 were below detection limits of this dosimeter type of 100 μSv (10 mrem). NIF TLDs are deployed monthly.

6.4.1 Methods and Reporting

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

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

The TLD measurements are corrected in the following way for reporting: the results of the TLD measurement process are normalized to 90-day quarters from their actual exposure period, and 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. Similar comparisons are made for TLDs at Site 300 and 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 milli-roentgen (mR).

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

The results of these comparisons of the Livermore Site to Livermore Valley and Site 300 to the Site 300 vicinity (which includes the City of Tracy), are shown in **Table 6-4.**

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 with the dose in milli-sievert (mSv; 1 mSv = 100 mrem).

Table 6-5. Annual average ambient radiation doses (mSv) represented as calculated average (standard deviation, N) where N is the number of site-specific samples in the year.

	Dose (mSv)				
Location	**2009**	**2010**	**2011**	**2012**	**2013**
Livermore Site	0.147 (0.009, 55)	0.138 (0.007, 55)	0.142 (0.009, 54)	0.141 (0.008, 56)	0.145 (0.009, 56)
Livermore Valley	0.145 (0.013, 86)	0.137 (0.012, 86)	0.141 (0.014, 85)	0.141 (0.014, 88)	0.140 (0.030, 88)
Site 300	0.173 (0.012, 36)	0.165 (0.010, 34)	0.168 (0.014, 34)	0.157 (0.040, 36)	0.173 (0.015, 36)
Site 300 Vicinity and Tracy	0.164 (0.012, 16)	0.154 (0.010, 15)	0.159 (0.014, 16)	0.158 (0.012, 16)	0.161 (0.014, 16)

6.4.2 Gamma Monitoring Results

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

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

6.4.3 Environmental Impact from Laboratory Operations

TLD measurements for 2013 indicate there were no detectable elevations in the ambient radiation field as a result of LLNL operations. Radiation dose trends remain consistent with annual average levels for each sample location and synonymous to natural background levels. As depicted in Tabl**e 6-5**, the annual average gamma radiation dose for the Livermore Site perimeter and the Livermore Valley from 2008 to 2012 is statistically equivalent and shows no discernible impact due to operations conducted at LLNL.

6.5 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 Wildlife [CDFW] 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 6-5**). 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 known historic or occupied breeding habitat for the California tiger salamander at the Livermore Site.

Five species that are listed under the federal Endangered Species Act (ESA) are known to occur at Site 300—the California tiger salamander, California red-legged frog, Alameda whipsnake (*Masticophus lateralis euryxanthus),* valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and the large-flowered fiddleneck (*Amsinckia grandiflor*a). Although there are no recorded observations of the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*) at Site 300, this species is known to have historically occurred in the adjacent Carnegie and Tracy Hills areas (USFWS 1998). Because of the proximity of known observations of San Joaquin kit fox to Site 300, it is necessary to consider potential impacts to San Joaquin kit fox during activities at Site 300. California threatened Swainson's Hawks (*Buteo swainsoni*) and California-endangered Willow Flycatchers (*Empidonax traillii*) have also been observed at Site 300. The willow flycatcher is not known to nest at Site 300.

Current and historic observations of the five listed species, a California Fully Protected Species (White-tailed Kite [*Elanus leucurus*]), and two avian California Species of Special Concern (Western Burrowing Owl [*Athene cunicularia*] and Tricolored Blackbird [*Agelaius tricolor*]) at Site 300 are shown in **Figures 6-6** and **6-7**. 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.

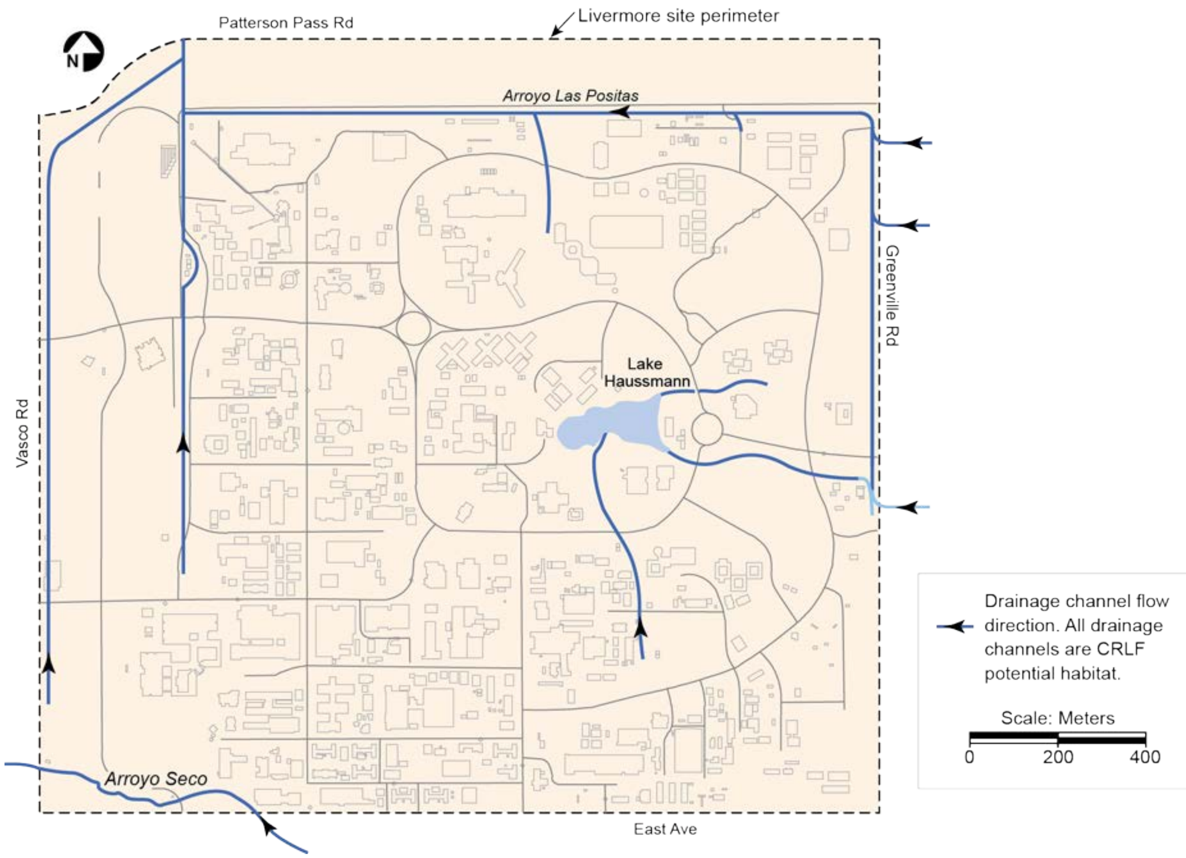

Figure 6-5. Potential California red-legged frog aquatic habitat, Livermore Site.

Including the federally endangered large-flowered fiddleneck, five rare plant species and three uncommon plant species are known to occur at Site 300. The five rare species—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*), the round-leaved filaree *(California macrophylla),* the diamond-petaled California poppy (*Eschscholzia rhombipetala*)—all have a California Rare Plant Rank (CRPR) of 1B (CNPS 2014). Adobe navarretia (*Navarretia nigelliformis* ssp. *radians*) was found to occur at Site 300 during the 2009 through 2012 biological review completed in January of 2014 (Paterson and Woollett 2014). 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 6-7**.

The three uncommon plant species—California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperevax caulescens*)—have a CRPR of 4 (CNPS 2014). Past surveys have failed to identify any rare plants on the Livermore Site (Preston 1997, 2002).

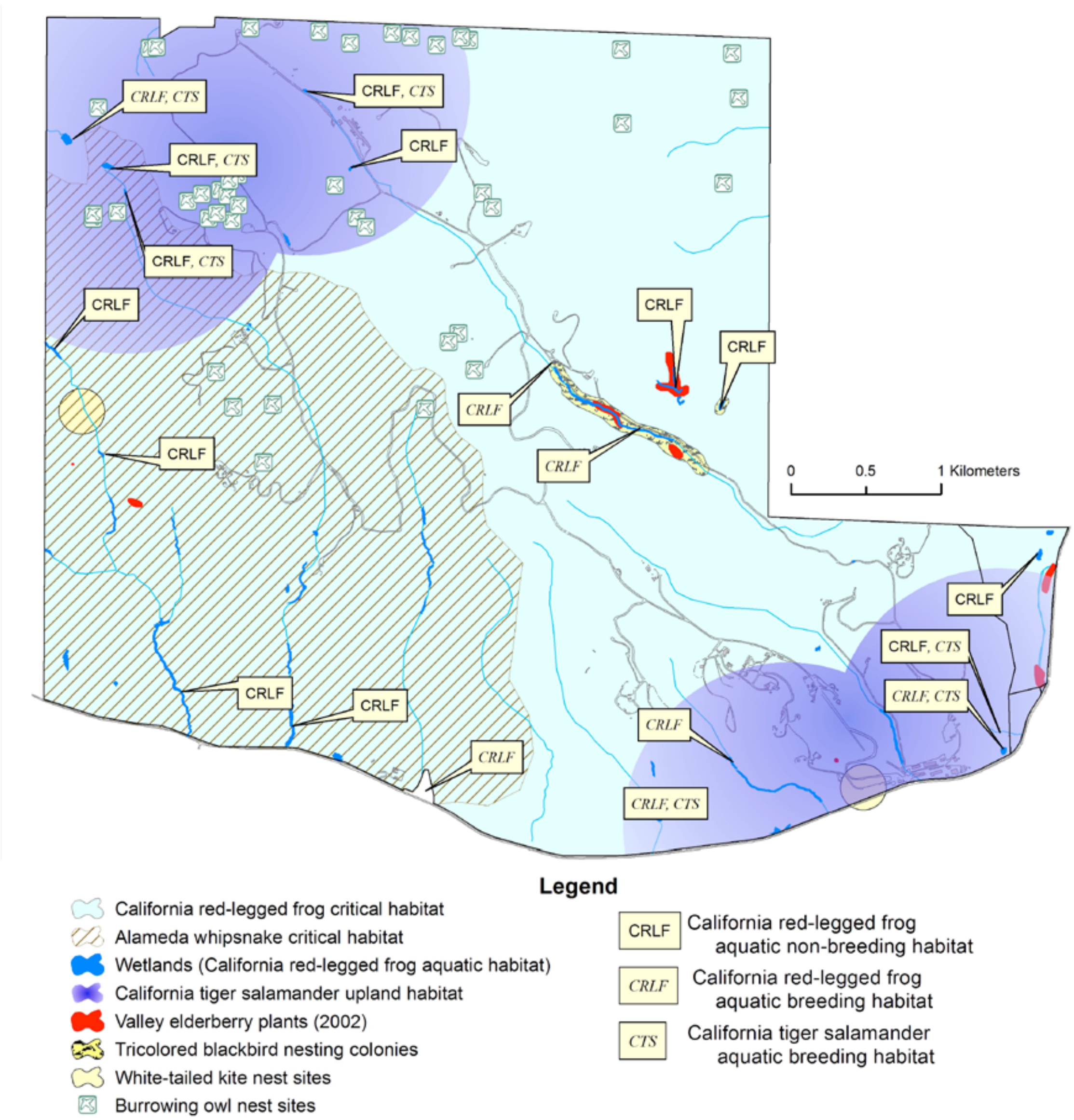

Figure 6-6. Distribution of special status wildlife, Site 300.

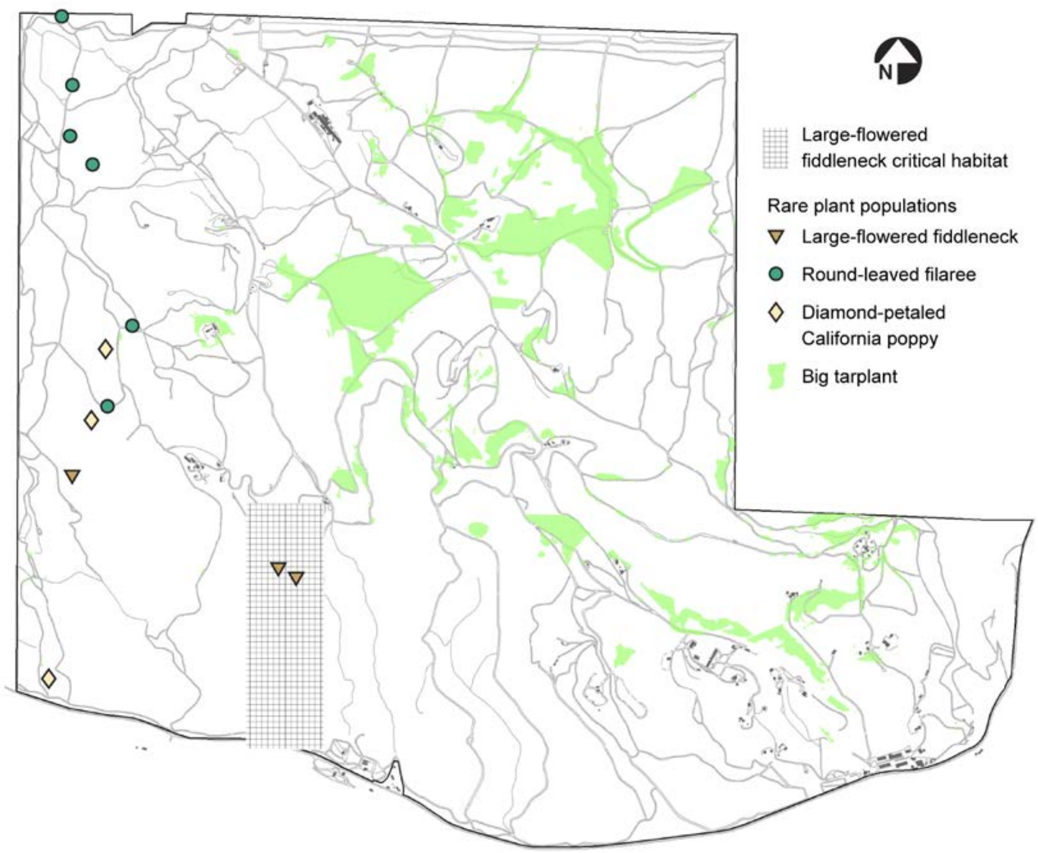

Figure 6-7. Distribution of special status plants, Site 300.

6.5.1 Habitat Enhancement Projects and Compliance Activities

6.5.1.1 Elk Ravine Habitat Enhancement Pools

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 through 2012.

6.5.1.2 Pool M2

In 2006, 2010, and 2011, Pool M2 filled and California tiger salamanders were able to successfully reproduce at this location. In 2007, 2008, 2009, 2012, and 2013 the pool received inadequate inundation and evaporated before the salamander larvae could reach maturity and leave the pool. An additional habitat enhancement project was conducted at the Pool M2 in 2013. The clay liner of this pool was augmented in the fall of 2013 in an effort to limit infiltration or loss of water through the bottom of the pool.

6.5.1.3 Oasis and Round Valley Pools

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 protected 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 2012 winters to pool and afford potential breeding habitat for amphibians.

An additional habitat enhancement project was conducted at the Round Valley Pool in 2012. The clay liner of this pool was augmented in the fall of 2012 in an effort to limit infiltration or loss of water through the bottom of the pool.

6.5.1.4 Power Pole Modifications for Migratory Bird Protection

To minimize adverse impacts to migratory birds, Site 300 implemented an avian protection policy to support avian-friendly transmission lines, insulators, power poles and other features that are designed to minimize collision and electrocution fatalities of birds of prey. Between June and November 2011, seven power poles onsite caused bird of prey deaths by electrocution.

Five of the seven poles received multiple perch deterrents, gray pvc triangles that were designed to fully discourage perching birds of prey on the crossarm arrays (and withstand the ambient UV rays). Additionally, to allow alternative, safe perch sites for birds, non-energized poles (stand-alone) with crossarm arrays in multiple directions were placed within roughly 25 feet of the original pole. Poles were purchased that lacked chemical treatments and were at least 6 feet taller in stature than the original pole (to support the viewshed perspective of the birds). No additional birds of prey have been electrocuted on these power poles since the modifications were performed.

6.5.2 Invasive Species Control Activities

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

At the Livermore Site, bullfrog control measures were implemented between May through September of 2013. 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 September of 2013 by temporarily halting groundwater discharges to the arroyo.

6.5.3 Surveillance Monitoring

6.5.3.1 Wildlife Monitoring and Research

Nesting Bird Surveys. Nesting bird surveys 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. At Site 300 in 2013, two red-tailed hawk pairs received protected buffer zones around their respective nest tree to avoid impacts relative to the annual prescription burn.

California Red-Legged Frog Nocturnal Surveys. LLNL continued nocturnal visual surveys for California red-legged frogs in Lake Haussmann and Arroyo Las Postias. No egg masses were observed in Arroyo Las Positas in 2013. Despite this, adult California red-legged frogs were observed in Arroyo Las Positas and Lake Haussmann in 2013.

6.5.3.2 Rare Plant Research and Monitoring

Large-Flowered Fiddleneck. This species is currently known to exist naturally in only two locations—at the Site 300 Drop Tower and on nearby conservation property owned by the Contra Costa Water District. A third population occurs in Draney Canyon at Site 300, but no large-flowered fiddleneck have been observed at this location since a landslide that occurred at the population site in 1997. The Drop Tower and Draney Canyon native population contained no large-flowered fiddleneck plants in 2013.

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

In November of 2012, 100 large-flowered fiddleneck seeds were planted in each of the 20 plots in the experimental population, and the experimental population contained 715 large-flowered fiddleneck plants at flowering in 2013. These plants are a result of seeds produced from plants present in the population in 2012 and previous years and the 2012 seed bank enhancement efforts.

Big Tarplant. The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September through November of 2013. It is estimated that between 46,000 and 158,000 individual big tarplants occurred at Site 300 in 2013. While this species is extremely rare throughout its range, it can be abundant at Site 300, especially in or near areas where prescribed burns are routinely conducted and where wildfires have occurred. As is typical with annual plant species, the abundance of big tarplant varies greatly between years depending on environmental conditions. For example in 2009, the Site 300 big tarplant population was estimated to contain no more than 22,000 individual plants while up to 214,000 big tarplants were found at Site 300 in 2010.

Diamond-Petaled California Poppy. Although the species is not listed under the federal or California ESAs, it is extremely rare and is currently known to occur only at Site 300 and in Contra Costa and San Luis Obispo Counties. Currently three populations of this species are known to occur at Site 300; these population locations are referred to as Site 1, Site 2, and Site 3.

The most recently discovered population, Site 3, is the largest and typically contains the largest population of this rare species. As with the big tarplant and other annual plants, the number of diamond-petaled California poppy plants present in these populations is expected to vary from year to year.

A spring census of these three populations has been conducted annually between 2000 and 2013. During this time, the largest diamond-petaled California poppy populations were observed in 2012. Between 20,000 and 45,000 diamond-petaled California poppies were observed at Site 300 in 2012. The relatively large diamond-petaled California poppy population in 2012 was likely attributable to annual grass cover in 2012, which was much less dense than average. The number of diamond-petaled California poppies observed in 2011 was the lowest seen since surveys began (a total of only 46 plants). A census of the three Site 300 populations was conducted in April 2013. A total of approximately 10,850 diamond-petaled California poppies were observed at Sites 1, 2, and 3 during 2013.

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. Only two of the six round-leaved filaree populations were surveyed in 2013 due to drought conditions. These two populations combined were estimated to contain 1,809 plants in 2013.

6.5.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2013, LLNL has been able to avoid impacts to special status wildlife and plants. Habitat enhancement, avian protection, and invasive species control efforts resulted in benefits to protected species. LLNL continues to monitor and maintain several restoration sites, habitat enhancements, and conservation set asides that are beneficial to native plants and animals at the Livermore Site or Site 300 and ensures the protection of listed and special status species.

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7. Groundwater Investigation and Remediation

Valerie Dibley

Lawrence Livermore National Laboratory samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology and nature and extent of the contamination and its source. Where necessary, remediation strategies are developed and evaluated through 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.

7.1 Livermore Site Environmental Restoration Project

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

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

7.1.1 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 1,000 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.

7.1.2 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.

7.1.3 Remediation Activities and Monitoring Results

In 2013, LLNL maintained and operated 28 groundwater treatment facilities. The groundwater extraction wells and dual (groundwater and soil vapor) extraction wells produced more than 1,132 million L of groundwater and the treatment facilities removed 43 kg of VOCs. Since remediation began in 1989, approximately 18.8 billion L of groundwater have been treated, resulting in removal of more than 1,585 kg of VOCs. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2014).

LLNL also maintained and operated 9 soil vapor treatment facilities in 2013. The soil vapor extraction wells and dual extraction wells produced more than 1.7 million m^3 of soil vapor and the treatment facilities removed 27 kg of VOCs. Since initial operation, nearly 16.9 million m^3 of soil vapor has been extracted and treated, removing more than 1,532 kg of VOCs from the subsurface. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2014).

Seven treatment facilities remained offline in 2013:

Treatment Facility A-East

- VTFD Helipad
- VTFD Hotspot
- TF5475-1
- TF5475-3
- VTF5475
- TF518 North

TFA East remained off-line due to the lack of groundwater in extraction well W-254, the sole extraction well for this facility. VTFD Helipad remained off-line in support of the *in situ* bioremediation Enhanced Source Area Remediation (ESAR) treatability test at the TFD Helipad Source area. VTFD Hotspot was not operated during 2013 as cyclic groundwater extraction from the TFD Hotspot extraction wells continued. Per regulatory agreement, VTFD Hotspot was permanently removed from service as of August 2013. Groundwater extracted from the TFD Hotspot wells is treated at TFD Main. The four remaining facilities were discussed in LLNL (2009). With the U.S. EPA concurrence, restart of these four facilities has been deferred pending the results of ESAR treatability tests. DOE/LLNL continues to monitor groundwater for VOCs and tritium. See Buscheck et al. (2014) for more information on the Livermore Site groundwater and soil vapor treatment facilities.

Restoration activities in 2013 at the Livermore Site were primarily focused on enhancing and optimizing ongoing operations at treatment facilities, while continuing to evaluate technologies that could be used to accelerate cleanup of the Livermore Site source areas and to address the mixed-waste management issue discussed in the draft Focused Feasibility Study of Methods to Minimize Mixed Hazardous and Low Level Radioactive Waste from Soil Vapor and Ground Water Treatment Facilities at the Lawrence Livermore National Laboratory Site (Bourne et al. 2010).

In 2013, the ESAR treatability tests continued at TFD Helipad (*in situ* bioremediation) and at TFE Eastern Landing Mat (thermally enhanced remediation). Analysis of the results of the TFE Hotspot (pneumatic fracturing) treatability tests completed in 2010 and 2011 continued. At the Trailer 5475 source area, additional sampling was performed to monitor the current subsurface conditions, including changes in tritium activities. Preliminary investigation of the TFC Hotspot source area to assess the efficacy of combining pneumatic fracturing with *in situ* chemical reduction using zero valent iron (ZV) also continued. The results of the treatability tests may identify alternative remedial approaches for other Livermore Site source areas.

Additional Livermore Site environmental restoration activities performed in 2013 included:

- Abandonment of three piezometers in the TFC area and redevelopment of extraction wells at TF406 Northwest and at TFA.
- Implementing treatment facility upgrades and remedial wellfield expansions at TFD Southshore, TFE Southwest and TFE West, as well as planning upgrades at TFD South and TFG-1.
- Activities conducted in support of the Resource Conservation and Recovery Act (RCRA) closure of Building 419.

The Livermore Site environmental restoration project had 9 milestones scheduled for completion in 2013. All milestones were met or rescheduled (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 2013. Hydraulic containment along the western and southern boundaries of the site was fully maintained in 2013, and progress was made toward interior plume and source area clean up. See Buscheck et al. (2014) for the current status of cleanup progress.

7.1.4 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.

7.2 Site 300 Environmental Restoration Project

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

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in Webster-Scholten (1994), *Final Remedial Investigation/Feasibility Study for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300* (Taffet et al., 2005), and the *Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2006). Another source of background information is https://www-erd.llnl.gov/library/index.html.

7.2.1 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.

7.2.2 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.

7.2.3 Remediation Activities and Monitoring Results

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

- Operating up to 20 groundwater and soil vapor extraction and treatment facilities.
- Capping and closing four landfills, six high explosives rinse water lagoons and one high explosives burn pit.

- Removal and/or closure of numerous dry wells throughout the site.
- Removal of contaminated soil from source areas throughout the site.
- Installation of a drainage diversion system at the Pit 7 Complex to prevent groundwater from rising into the landfills and releasing contaminants in the waste.
- Remediation (consolidation and solidification) of 29,000 cubic yards of PCB-, dioxin-, and furan-contaminated soil in a Corrective Action Management Unit (CAMU) at Building 850.
- Treatability studies for the *in situ* bioremediation of VOCs and perchlorate in groundwater.
- Installation and sampling of over 680 groundwater monitor wells to track plume migration and remediation progress.

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

In 2013, the Site 300 Environmental Restoration Project operated 15 groundwater and 5 soil vapor treatment facilities extracting and treating approximately 42.6 million L of groundwater and 2.8 million m^3 of contaminated soil vapor. The Site 300 treatment facilities removed nearly 11 kg of VOCs, 0.12 kg of perchlorate, 1,400 kg of nitrate, 0.17 kg of the high explosive compound RDX, 0.0017 kg of silicone oils (TBOS/TKEBS), and 0.024 kg of uranium in 2013. Since groundwater remediation began in 1990, approximately 1,581 million L of groundwater and over 23.2 million m^3 soil vapor have been treated, resulting in removal of more than 590 kg of VOCs, 1.4 kg of perchlorate, 14,000 kg of nitrate, 1.9 kg of RDX, 9.5 kg of silicone oils, and 0.041 kg of uranium. Tritium in groundwater continues to decay on site, reducing tritium activities in Site 300 groundwater. Detailed flow and mass removal by OU is presented in Dibley et al. (2014).

Cleanup remedies have been fully implemented and are operational in eight of the nine OUs at Site 300 to date (Operable Unit 8 and General Services Area, Building 834, Pit 6 Landfill, High Explosives Process Area, Building 850/Pit 7 Complex, Building 854, and Building 832 Canyon OUs). The CERCLA pathway for the last OU, Building 812, was negotiated with the regulatory agencies in 2011. Building 812 characterization activities were initiated in 2011 and continued in 2012 and 2013. These activities included:

- Sampling surface soil for laboratory analysis.
- Hand augering additional boreholes and conducting High Purity Germanium (HPGe) detector gamma surveying for uranium-238 in subsurface soil to better determine the vertical extent of uranium in subsurface soil.
- Continuing gamma radiation surveying to better define the extent of uranium-238 in Building 812 surface soil.

The results of the characterization activities are being analyzed and will be incorporated in a Remedial Investigation/Feasibility Study for the Building 812 OU.

Additional Site 300 Environmental Restoration Project activities performed in 2013 included:

- Installing one new groundwater monitor well and two groundwater injection wells.
- Inspecting and maintaining the Pit 7 drainage diversion system and Building 850 Corrective Action Management Unit.
- Continuing the Building 850 *In Situ* Perchlorate Bioremediation Treatability Test.
- Finalizing the Mammalian and Avian Toxicity Reference Values for use in the Building 812 Baseline Ecological Risk Assessment at Lawrence Livermore National Laboratory Site 300.
- Relocating and upgrading the Central General Services Area misting towers.
- Completing the Addendum to the Compliance Monitoring Plan and Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory Site 300.
- Submitting the Technical Memorandum for Additional Characterization of the Building 812 Operable Unit at the Lawrence Livermore National Laboratory Site 300.

The Site 300 environmental restoration project had 12 milestones scheduled for completion in calendar year 2013. All milestones were met or renegotiated with the regulatory agencies (see Chapter 2).

Groundwater concentration and hydraulic data collected and analyzed for Site 300 during 2013 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 2013 is available in the *2013 Annual Compliance Monitoring Report for LLNL Site 300* (Dibley et al. 2014).

7.2.4 Environmental Impacts

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

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8. Quality Assurance

Donald H. MacQueen • Gene Kumamoto

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

8.1 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) and Environmental Restoration Department (ERD) track 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 regulatory reports, integrity of samples, or data, and that are not covered by other reporting or tracking mechanisms. Nonconformances involving the EFA are captured and used to provide trending information for environmental compliance evaluations. There were no laboratory data nonconformances affecting the quality of data used for reporting purposes documented in 2013. Many minor sampling or data problems are resolved without generating an ITS item. The LLNL quality assurance requirements stipulate that laboratories generating data must have a formal nonconformance program to track and document issues in their analyses. Such programs are separate from the LLNL Institutional Tracking System.

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 DOECAP requirements under The NELAC Institute (TNI). All commercial laboratories used by LLNL are LLNL-qualified vendors and are National Environmental Laboratory Accreditation Program (NELAP) certified or California Department of Health Services Environmental laboratory accredited. Audit reports, checklists, and Corrective Action Plans are maintained under the DOECAP program for commercial labs.

The following six areas pertain to the services provided by a particular external analytical laboratory:

- QA management systems and general laboratory practices
- Organic analyses
- Inorganic and wet chemistry analyses
- Radiochemical analyses
- Laboratory information management systems and electronic deliverables
- Hazardous and radioactive materials management

LLNL has qualified auditors under the national DOECAP program in the areas of quality assurance, organic chemistry, inorganic chemistry, laboratory information management, and hazardous material management.

In FY2013, the laboratories certified by the State of California operating at LLNL as government owned and contractor operated were not internally assessed, but are by the State of California under the Environmental Laboratory Accreditation Program (ELAP).

Analytical laboratories routinely perform QC tests to document and assess the quality and validity of their sample results. Each set of data received from the analytical laboratory is systematically evaluated and compared to establish measurement-quality objectives before the results can be authenticated and accepted into the monitoring database. Categories of measurement quality objectives include accuracy, precision, and comparability. When possible, quantitative criteria are used to define and assess data quality.

8.2 Analytical Laboratories and Laboratory Intercomparison Studies

In 2013, LLNL had Blanket Service Agreements (BSAs) with seven commercial 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/QC objectives are maintained.

LLNL uses the results of nationally recognized 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

2013, all contracted commercial labs were successful in participation in performance evaluation studies and where there were individual failures to perform, the commercial labs were verified to have corrective actions in place.

Although laboratories are also required to participate in laboratory intercomparison programs, permission to publish their accreditation results for comparison purposes was not granted for 2013. To obtain DOE Mixed Analyte Performance Evaluation Program (MAPEP) reports that include the results from all participating laboratories, see http://www.inl.gov/resl/mapep/reports.html. MAPEP is a DOE program and the results are publicly available from laboratories that choose to participate.

8.3 Duplicate Analyses

Duplicate (collocated) samples are distinct samples of the same matrix collected as closely as possible to the same point in space and time. Collocated samples that are processed and analyzed by the same laboratory provide information about the precision of the entire measurement system, including sampling, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples that are processed and analyzed by different laboratories provide information about the precision of the entire measurement system that also captures interlaboratory variation (U.S. EPA 1987). Collocated samples may also identify errors such as mislabeled samples or data entry errors. **Tables 8-1**, **8-2**, and **8-3** 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 8-1** and **8-2** are based on data pairs in which both values are above the analytical contract reporting limit (referred to as "detections"); see **Section 8.4**). **Table 8-3** is based on data pairs in which either or both values are below the analytical contract reporting limit (referred to as nondetections).

Table 8-1. Quality assurance collocated sampling: Summary statistics for analytes with more than eight pairs in which both results were above the reporting limit.

Media	Analyte	N [(a)]	%RSD [(b)]	Slope	r^2 [(c)]	Intercept
Air	Gross alpha [(d)]	18	27.2	0.737	0.26	1.46×10^{-5} Bq/m^3
Air	Gross beta	52	14.7	0.881	0.85	3.17×10^{-5} Bq/m^3
Air	Beryllium	16	11.2	1.21	0.93	-1.08 pg/m^3
Air	Uranium 235 by mass measurement	12	4.25	1.13	1	-1.4×10^{-8} µg/m^3
Air	U238 by mass	12	5.35	1.13	1	-1.84×10^{-6} µg/m^3
Air	Tritium	26	24.2	0.895	0.83	0.00107 Bq/m^3
Direct radiation	90 day Rad dose	32	3.56	1	0.89	0.108 mrem
Groundwater	Gross alpha [(d)]	12	31	0.72	0.55	0.043 Bq/L
Groundwater	Gross beta [(d)]	35	39.1	0.627	0.49	0.136 Bq/L
Groundwater	Total Alkalinity (as $CaCO_3$)	9	0	1.02	0.99	-4.96 mg/L
Groundwater	Arsenic	30	17.6	1.11	0.96	-0.0014 mg/L
Groundwater	Barium	15	2.85	1	1	-0.0012 mg/L
Groundwater	Calcium	10	1.39	1	1	-0.0883 mg/L
Groundwater	Chloride	15	0	0.999	1	0.2 mg/L
Groundwater	cis-1,2-Dichloroethene [(e)]	16	11	1.68	0.98	-16.5 µg/L

Table 8-1(cont.). Quality assurance collocated sampling: Summary statistics for analytes with more than eight pairs in which both results were above the reporting limit.

Media	Analyte	N [(a)]	%RSD [(b)]	Slope	r^{2} [(c)]	Intercept
Groundwater	1,2-Dichloroethene (total) [(e)]	13	17.5	1.7	0.99	-23.1 µg/L
Groundwater	Fluoride	16	5.42	0.984	0.99	-0.00451 mg/L
Groundwater	Magnesium	10	1.22	1.02	1	-0.264 mg/L
Groundwater	Nitrate (as NO3)	72	11.2	1.02	0.99	-0.0344 mg/L
Groundwater	Perchlorate	23	6.27	1.05	0.99	-0.943 µg/L
Groundwater	pH	13	0.808	0.986	0.92	0.103 Units
Groundwater	Potassium	15	1.28	1.06	0.99	-0.421 mg/L
Groundwater	Selenium	10	14.6	1.28	0.86	-0.000537 mg/L
Groundwater	Sodium	16	1.89	1.01	0.99	-1.58 mg/L
Groundwater	TDS	10	4.97	0.907	0.97	69.5 mg/L
Groundwater	Specific Conductance	13	1	0.985	1	17.2 µmhos/cm
Groundwater	Sulfate	15	0	0.999	1	0.325 mg/L
Groundwater	Total Hardness (as CaCO3)	9	1.4	1.01	1	-1.25 mg/L
Groundwater	Trichloroethene	70	8.57	1.1	1	-55.1 µg/L
Groundwater	Tritium	26	6.88	1.03	1	-2.78 Bq/L
Groundwater	U234+U233	21	10.4	0.887	1	0.0101 Bq/L
Groundwater	U235	14	36.8	0.991	0.9	0.00168 Bq/L
Groundwater	U238	21	10.7	0.911	1	0.00414 Bq/L
Sewer	Gross beta (d)	12	18	0.549	0.18	0.000256 Bq/mL

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

(b) 75th percentile of percent relative standard deviations (%RSD) where %RSD = $\left(\frac{200}{\sqrt{2}}\right)\frac{|x_1 - x_2|}{x_1 + x_2}$
and 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 high variability.

(e) Outside acceptable range of slope or r^2 because of outliers.

Table 8-2. Quality assurance collocated sampling: Summary statistics for selected analytes with eight or fewer pairs in which both results were above the reporting limit.

Media	Analyte	N [(a)]	Minimum ratio	Maximum ratio
Aqueous	Gross alpha	1	0.94	0.94
Aqueous	Gross beta	1	1.2	1.2
Aqueous	Uranium 234 and Uranium 233	1	0.55	0.55
Aqueous	Uranium 235 and Uranium 236	1	0.68	0.68
Aqueous	Uranium 238	1	0.68	0.68
Groundwater	Radium 226	2	0.95	1
Groundwater	Uranium 235 by mass measurement	2	1	1
Groundwater	Uranium 238 by mass measurement	2	1	1
Other water	Gross beta	1	0.98	0.98
Runoff (from rain)	Gross alpha	2	1.7	3.6
Runoff (from rain)	Gross beta	3	0.36	3.4
Runoff (from rain)	Tritium	1	1.4	1.4
Soil	Cesium 137	3	0.86	1
Soil	Potassium 40	3	0.94	1
Soil	Plutonium 239+240	2	1	2
Soil	Radium 226	3	0.95	1
Soil	Radium 228	3	0.94	0.98
Soil	Thorium 228	3	0.87	1

Table 8-2 (cont.). Quality assurance collocated sampling: Summary statistics for selected analytes with eight or fewer pairs in which both results were above the reporting limit.

Media	Analyte	N (a)	Minimum ratio	Maximum ratio
Soil	Uranium 235	3	0.7	0.93
Soil	Uranium 238	2	0.79	0.92
Sewer	Tritium	5	0.78	1.2
Vegetation	Tritium	4	0.62	1.6

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

Table 8-3. Quality assurance collocated sampling: Summary statistics for analytes with at least four pairs in which one or both results were below the reporting limit.

Media	Analyte	Number of inconsistent pairs (a)	Number of pairs	Percent of inconsistent pairs
Air	Gross alpha	1	35	2.9
Groundwater	Barium	1	26	3.8
Groundwater	Nitrate (as NO3)	1	75	1.3
Groundwater	Perchlorate	1	126	0.79
Groundwater	RDX	1	66	1.5
Groundwater	Trichlorofluoromethane	2	223	0.9
Groundwater	Uranium 235 and Uranium 236	2	22	9.1
Groundwater	Uranium 235 and Uranium 236	2	22	9.1

(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 8-1**. When there were eight or fewer data pairs with both results considered detections, the ratios of the individual data pairs for selected analytes were calculated; the minimum and maximum ratios are given in **Table 8-2**. 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 8-3** 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 8-1** are the 75th percentile of the individual precision values. Routine and collocated sample results show good %RSD—90% of the pairs have %RSD of 24% 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 8-1**. 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.

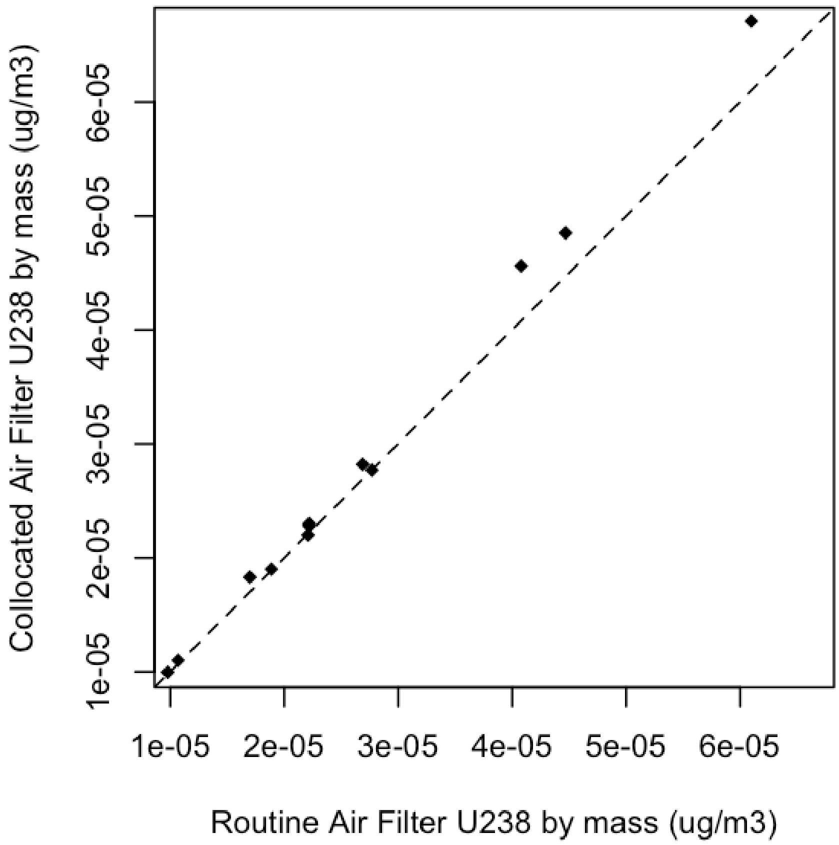

Figure 8-1. Example of good agreement between collocated sample results using uranium-238 concentrations in air.

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 34 data sets reported in **Table 8-1**, two did not meet the criterion for acceptability because of outliers. **Figure 8-2** illustrates a set of collocated pairs with one outlier.

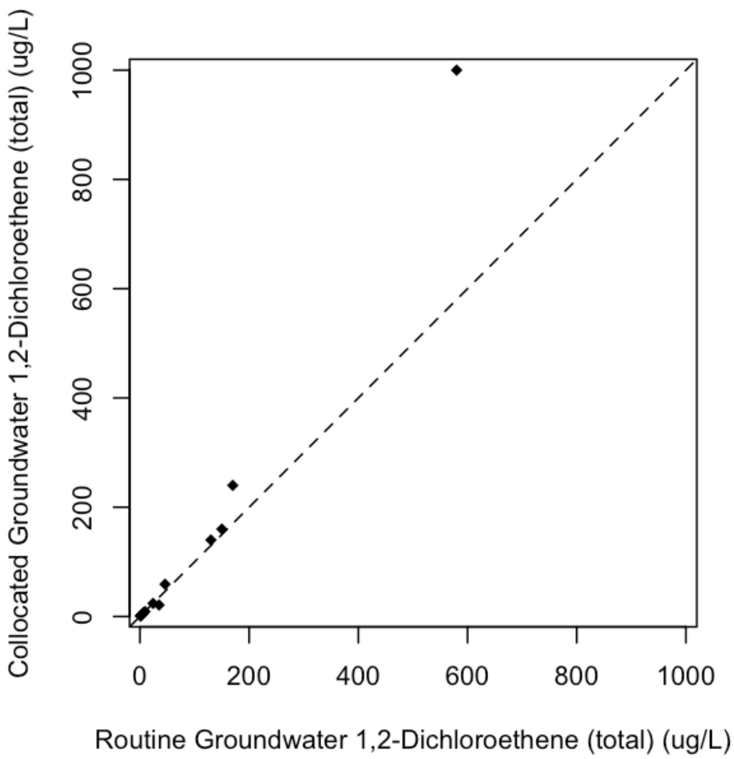

Figure 8-2. Example of data with one outlier using collocated air filter groundwater total 1,2-DCE concentrations.

The second category, high variability, occurs when the measurement process inherently has substantial variability (see **Figure 8-3** for an example). It tends to occur at extremely low environmental concentrations. Low concentrations of radionuclides on particulates in air highlight this effect because a small change in the number of radionuclide-containing particles on an air filter can significantly affect results. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 34 data sets listed in **Table 8-1**, four show sufficient variability in the results to make them fall outside the acceptable range.

8.4 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, organize the data into rows and columns, and present a draft table. The tables are then reviewed by the responsible analyst before inclusion in the Appendix. 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.

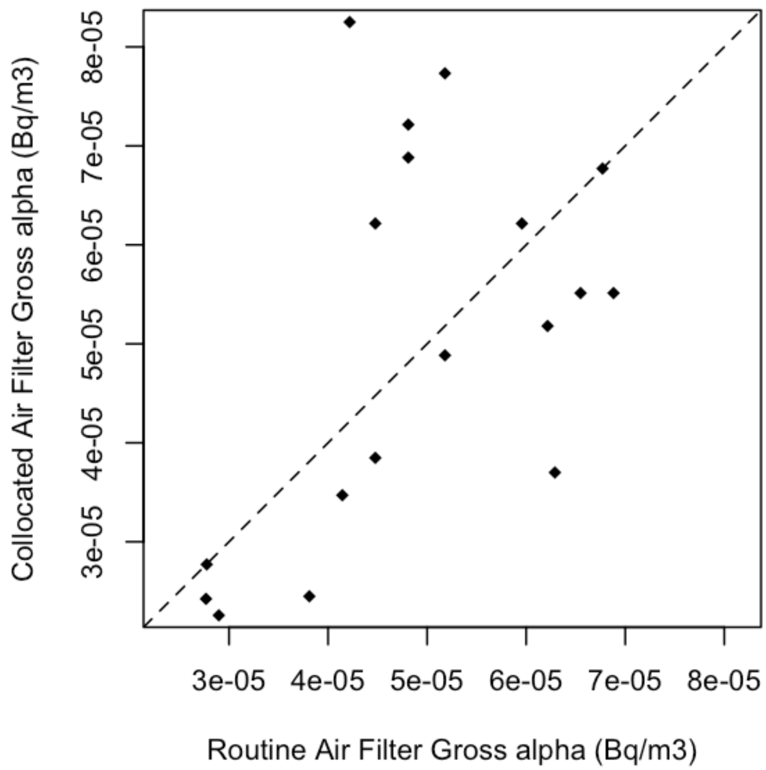

Figure 8-3. Example of high variability using collocated air filter gross alpha concentrations.

8.4.1 Radiological Data

Most of the data tables in **Appendix A** that have radiological data display the result plus or minus (±) an associated 2σ (two 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 8.6**). 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. In such cases, samples with a concentration at or near background sometimes have more background counts than sample counts, and thus 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.

8.4.2 Nonradiological Data

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

8.5 Statistical Comparisons and Summary Statistics

Standard statistical 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 statistical 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 (2012). 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, 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 (Bqs), and are then rounded to an appropriate number of significant digits. The calculation of summary statistics may be affected by the presence of nondetections. A nondetection of the form "less than the reporting limit" indicates that no specific measured value is available; instead, the best information available is that the actual value is less than the contract reporting limit. Adjustments to the calculation of the median and IQR for data sets that include such 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.

8.6 Reporting Uncertainty in Data Tables

Measurement uncertainties associated with results from analytical laboratories are represented in two ways. The first of these, significant digits, derives from 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 1,000. The value 1,000 is exact; it has no uncertainty and therefore the concept of significant digits does not apply.

The second 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 additional digits that are not significant and should not be shown in data tables (for example, 5.3 pCi/g × 0.037 Bq/pCi = 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 used to prepare the data tables implements the ISO/IEC/IEEE 60559:2011 rule, which is "go to the even digit." For example, 2.45 would be rounded down to 2.4, and 2.55 would be rounded up to 2.6.

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

8.7 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 8.4**, 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 2013 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.

8.8 Errata

Appendix E contains the protocol for errata in LLNL *Environmental Reports* and the errata for *LLNL Site Annual Environmental Report 2012*.

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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
ACHP	Advisory Council on Historic Preservation
ACOE	Army Corps of Engineers
AFV	alternative fuel vehicle
ALARA	as low as reasonably achievable
APHIS	Animal and Plant Health Inspection Service
ATSDR	Agency for Toxic Substances and Disease Registry
BAAQMD	Bay Area Air Quality Management District (*See also* definition in **Key Terms** section.)
BCG	Biota Concentration Guide
BGS	Below Ground Surface
BO	biological opinion
BSA	Blanket Service Agreement
BSL	Biosafety Level
CAA	Clean Air Act
CalARP	California Accidental Release Prevention
CAMP	Corrective Action Monitoring Plan
CAMU	Corrective Action Management Unit
CARB	California Air Resources Board
CCR	California Code of Regulations
CDC	Centers for Disease Control
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
CWG	Community Working Group
DCS	Derived Concentration Technical Standard
DMP	Detection Monitoring Plan
DMT	Data Management Team
DOE	(U.S.) Department of Energy (*See also* definition in **Key Terms** section.)
DOECAP	(U.S.) Department of Energy Consolidated Auditing Program
DOT	(U.S.) Department of Transportation
DPH	Department of Public Health
DPR	(California) Department of Pesticide Regulation
DRB	Drainage Retention Basin
DTSC	(California Environmental Protection Agency) Department of Toxic Substances Control
DWTF	Decontamination and Waste Treatment Facility
E85	Vehicle fuel, 85% ethanol and 15% gasoline
EA	environmental assessment
EDE	effective dose equivalent (*See also* definition in **Key Terms** section.)
EDO	Environmental Duty Officer
EFA	Environmental Functional Area
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.)
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
FGC	Federal Green Challenge
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FY	fiscal year (*See also* definition in **Key Terms** section.)
GHG	greenhouse gases
GPS	global positioning system
GPs	Guiding principles
GSA	(U.S.) General Services Administration
GSF	Gross square feet
GWP	(Livermore site) Ground Water Project

HAP	hazardous air pollutant
HHRA	Human health risk assessment
HPGe	high-purity germanium
HSU	hydrostratigraphic unit
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
ILA	industrial, landscaping, and agricultural
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
LLW	Low Level Waste
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
MOVIs	Management, Observation, Verification and Inspections
MRP	Monitoring and Reporting Program
MSAs	Management Self Assessments
MSDS	material safety data sheet
NCRP	National Council on Radiation Protection and Measurements
NELAP	National Environmental Laboratory Accreditation Program
NEPA	National Environmental Policy Act (*See also* definition in **Key Terms** section.)
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NOx	nitrous oxides
NPDES	National Pollutant Discharge Elimination System (*See also* definition in **Key Terms** section.)
NRHP	National Register of Historic Places
OBT	organically bound tritium
ODS	ozone depleting substance
ORNL	Oak Ridge National Laboratory
OU	operable unit
P2S	pollution prevention/sustainability
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
POCs	Precursor organic compounds (*See also* definition in **Key Terms** section.)

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
PUE	Power Utilization Effectiveness
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
ROD	Record of Decision
ROGs	reactive organic gases (*See also* definition in **Key Terms** section.)
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.)
TNI	The NELAC Institure
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)
UCD	under dispenser containment
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)	28.3 gram (g)
	1 kilogram (kg)	2.21 pounds (lb)	1 pound (lb)	0.454 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
y	yocto	10^{-24}	da	deca	10^{1}
z	zepto	10^{-21}	h	hecto	10^{2}
a	atto	10^{-18}	k	kilo	10^{3}
f	femto	10^{-15}	M	mega	10^{6}
p	pico	10^{-12}	G	giga	10^{9}
n	nano	10^{-9}	T	tera	10^{12}
µ	micro	10^{-6}	P	peta	10^{15}
m	milli	10^{-3}	E	exa	10^{18}
c	centi	10^{-2}	Z	zetta	10^{21}
d	deci	10^{-1}	Y	yotta	10^{24}

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

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

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

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

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

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

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

Effluent. Liquid or gaseous waste discharged to the environment.

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

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

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

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

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

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

Freon-11. Trichlorofluoromethane.

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

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

Groundwater. All subsurface water.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Part A permit. Application submitted by generators in the RCRA permitting process.

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**.

Reactive organic gases/precursor organic compounds (ROGs/POCs). Classes of chemicals that are precursors to the production of ozone and the photochemical formation of smog.

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.

APPENDIX A
Data Tables

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

A.1 Air Effluent (Chapter 4)

A.2 Ambient Air (Chapter 4)

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APPENDIX B
EPA Methods of Environmental Water Analysis

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

Constituent of concern		Analytical method	Reporting limit[(a,b)]
Metals and minerals (mg/L)	All alkalinities	SM 2310	1
	Aluminum	EPA 200.7 or 200.8	0.05 or 0.2
	Ammonia nitrogen (as N)	EPA 350.1 or SM 4500-NH3	0.03 or 0.1
	Antimony	200.8	0.005
	Arsenic	200.8	0.002
	Barium	200.8	0.025 or 0.01
	Beryllium	200.8 or SM 3113B	0.0005 or 0.0002
	Boron	EPA 200.7	0.05
	Bromide	EPA 300.0	0.5
	Cadmium	EPA 200.8	0.0005
	Calcium	EPA 200.7	0.5
	Chloride	EPA 300.0	1 or 0.5
	Chlorine (residual)	SM-4500-CL	0.1
	Chromium	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	200.7 or 200.8	0.001, 0.01 or 0.05
	Cyanide	EPA 335.4 or 4500-CN	0.02
	Fluoride	EPA 300	0.05
	Hardness, total (as $CaCO_3$)	SM 2320B	1
	Iron	EPA 200.7 or 200.8	0.1
	Lead	EPA 200.8	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	0.002
	Silver	EPA 200.8	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 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
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).

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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
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
Amphibians	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
	California red-legged frog	*Rana draytonii*	FT, CASSC	LLNL 2002
	Northern Pacific treefrog	*Pseudacris regilla*		LLNL 2002
	Western spadefoot toad	*Spea hammondii*	CASSC	LLNL 2002
	California toad	*Anaxyrus boreas halophilus*		LLNL 2002
Reptiles	Pacific pond turtle	*Actinemys marmorata*	CASSC	Woollett 2005
	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
	Silvery legless lizard	*Anniella pulchra pulchra*	CASSC	Swaim 2002
	Common 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
	California Gilbert's skink	*Eumeces gilberti*		LLNL 2002; Swaim 2002
	California alligator lizard	*Elgaria multicarinata multicarinata*		LLNL 2002; Swaim 2002
	Western Yellow-bellied Racer	*Coluber constrictor*		LLNL 2002; Swaim 2002
	Gopher snake	*Pituophis catenifer*		LLNL 2002; Swaim 2002
	California kingsnake	*Lampropeltis getula californiae*		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

C. Wildlife Survey Results

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Reptiles Cont.	Western black-headed snake	*Tantilla planiceps*		Swaim 2002
	Pacific ring-necked snake	*Diadophis punctatus amabilis*		Woollett 2005
	California striped racer	*Masticophis lateralis lateralis*		LLNL 2002; Swaim 2002
	Northern Pacific rattlesnake	*Crotalus oreganus oreganus*		LLNL 2002; Swaim 2002
Birds	Pied-billed Grebe	*Podilymbus podiceps*	MBTA	LLNL 2003
	Double-crested Cormorant	*Phalacrocorax auritus*	MBTA, DFWWL	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*		LLNL 2003
	Red-shouldered Hawk	*Buteo lineatus*	MBTA	LLNL 2003
	Osprey	*Pandion haliaetus*	MBTA, DFWWL	LLNL 2003
	Golden Eagle	*Aquila chrysaetos*	BGEPA MBTA, CAFPS	LLNL 2003
	Rough-legged Hawk	*Buteo lagopus*	MBTA	LLNL 2003
	Ferruginous Hawk	*Buteo regalis*	MBTA, DFWWL	LLNL 2003
	Red-tailed Hawk	*Buteo jamaicensis*	MBTA	LLNL 2003
	Swainson's Hawk	*Buteo swainsoni*	MBTA, ST	LLNL 2003
	White-tailed Kite	*Elanus leucurus*	MBTA, CAFPS	LLNL 2003
	Cooper's Hawk	*Accipiter cooperii*	MBTA, DFWWL	LLNL 2003
	Sharp-shinned Hawk	*Accipiter striatus*	MBTA, DFWWL	LLNL 2003
	Northern Harrier	*Circus cyaneus*	MBTA, CASSC	LLNL 2003
	Prairie Falcon	*Falco mexicanus*	MBTA, DFWWL,	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
	Sora	*Porzana carolina*	MBTA	Woollett 2009
	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

Taxa	Common Name	Scientific Name	Regulatory Status(a)	Source
Birds Cont.	Greater Roadrunner	*Geococcyx californianus*	MBTA	LLNL 2003
	Barn Owl	*Tyto alba*	MBTA	LLNL 2003
	Short-eared Owl	*Asio flammeus*	MBTA, CASSC	LLNL 2003
	Great Horned Owl	*Bubo virginianus*	MBTA	LLNL 2003
	Burrowing Owl	*Athene cunicularia*	BCC, MBTA, CASSC	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*	BCC, 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
	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*	BCC, MBTA, SE,	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*	BCC, MBTA, CASSC,	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	*Baeolophus 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

C. Wildlife Survey Results

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Birds Cont.	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 cedrorum*	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 brewsteri*	BCC, MBTA, CASSC,	LLNL 2003
	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*	MBTA, CASSC	LLNL 2003
	Rufous Crowned Sparrow	*Aimophila ruficeps*	MBTA	LLNL 2003
	Lazuli Bunting	*Passerina amoena*	MBTA	LLNL 2003
	Blue Grosbeak	*Passerina caerulea*	MBTA	LLNL 2003

Taxa	Common Name	Scientific Name	Regulatory Status[(a)]	Source
Birds Cont.	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*	BCC, MBTA, CASSC	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
	Merlin	*Falco columbarius*	MBTA	Woolett 2011
	Long-eared owl	*Asio otus*	MBTA, CASSC	LLNL 2003
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

C. Wildlife Survey Results

Taxa	Common Name	Scientific Name	Regulatory Status[a]	Source
Mammals Cont.	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
	Black-tailed deer	*Odocoileus hemionus*		LLNL 2002; Clark et al. 2002
	Wild pig	*Sus scrofa*		LLNL 2002; Clark et al. 2002
	Yuma myotis	*Myotis yumanensis*		Rainey 2003
	Broad-footed mole	*Scapanus latimanus*		Woollett 2011

(a) FT = Threatened under the Federal Endangered Species Act

BCC = U.S. Fish and Wildlife Service Birds of Conservation Concern (US Fish and Wildlife Service 2008)

BGEPA = Bald and Golden Eagle Protection Act

MBTA = Migratory Bird Treaty Act

SE = Endangered under the State Endangered Species Act

ST = Threatened under the State Endangered Species Act

CAFPS = California Department of Fish and Wildlife Fully Protected Species (CA Fish and Game Code Section 3511)

CASSC = California Species of Special Concern (CA Dept. of Fish and Wildlife, Special Animals List, January 2011)

DFWWL = California Department of Fish and Wildlife Taxa to Watch

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.

LLNL Livermore Site Storm Water Monitoring for Waste Discharge Requirements 95-174: 2012–2013

Lee, G. (2013). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174, Annual Report 2012–2013* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126783-13.

LLNL FY14 Site Sustainability Plan

Stremel, G. (2013). *Lawrence Livermore National Laboratory Fy13 Site Sustainability Plan*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-603352.

LLNL Ground Water Project Annual Report, 2013

Buscheck, M., P. McKereghan and M. Dresen (2013). *LLNL Ground Water Project 2013 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126020-13.

LLNL NESHAPs Annual Report, 2013

Wilson, K., G. Gallegos, D. MacQueen, A. Wegrecki, and N. Bertoldo (2014). *LLNL NESHAPs 2013 Annual Report.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-TR-113867-13.

Site 300 Compliance Monitoring Program for the Closed Building 829 Facility Annual Report 2013

Revelli, M.A. (2014). *Lawrence Livermore National Laboratory Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2013.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-143121-13.

Site 300 Compliance Monitoring Annual Report, 2013

Dibley, V. (2014). *2013 Annual Monitoring Compliance Report for Lawrence Livermore National Laboratory Site 300.* Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-206319-13.

Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ 2013

Lee, G. (2013). *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-144362-13.

Site 300 Compliance Monitoring for Water Discharge Requirement Order No. R5-2008-0148 Second Semester/Annual Report 2013

Blake, R. (2014). *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements Order No. R5-2008-0148, Second Semester/Annual Report 2013*. Livermore, CA: Lawrence Livermore National Laboratory, LLNL-AR-411431-14-3.

Site 300 Pit 1 Compliance Monitoring Fourth Quarter/Annual Report for 2013

Blake, R. (2014). *LLNL Experimental Test Site 300 Compliance Monitoring Program for Closed Pit 1 Landfill, Fourth Quarter Report for 2013*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-10191-13-4.

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

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APPENDIX E
Errata

Protocol for Errata in LLNL Environmental Reports

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

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

LLNL environmental reports from 1994 through 2012 can be accessed at https://saer.llnl.gov/.

Record of Changes to Environmental Report 2012

The following changes have been made to the Internet version of *Environmental Report 2012*.

- Change the electronic version of 2012 report: "Title of Section 2.1.3 changed from "Resource Conservation and Recovery Act and Related State Laws" to "California Accidental Release Prevention Program"