LAWRENCE LIVERMORE NATIONAL LABORATORY

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# Environmental Report 2009

G. M. Gallegos, N. A. Bertoldo, C. G. Campbell, S. Cerruti, J. Coty, V. Dibley, J. Domain, A. R. Grayson, H. E. Jones, G. Kumamoto, D. H. MacQueen, J. C. Nelson, L. Paterson, M. A Revelli, A. M. Wegrecki, K. Wilson, J. Woollett

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This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Lawrence Livermore National Laboratory

# Environmental Report 2009

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## Lawrence Livermore National Laboratory

# Environmental Report 2009


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Subject: 2009 Annual Site Environmental Report for the Lawrence Livermore National Laboratory

The Annual Site Environmental Report was prepared by the Lawrence Livermore National Laboratory (LLNL) for the Department of Energy/National Nuclear Security Administration (NNSA)/Livermore Site Office. This report provides a comprehensive summary of the environmental program activities at LLNL for Calendar Year 2009. This report is prepared annually and is made available to relevant regulatory agencies and other interested organizations and individuals.

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

LSO appreciates that LLNL is committed to achieving continuous improvement in environmental performance through pollution prevention, energy efficiency, and other related measures; and is committed to conducting its operations in an environmentally safe and sound manner. Remediation activities continue to reduce contaminants at both Livermore Site and Site 300.

The environmental protection and compliance programs at LLNL are implemented to ensure the health and safety of employees, and the residents of neighboring communities, in addition to the preservation of the environment.

Sincerely,

Michael G. Brown
Assistant Manager for
Environmental Stewardship

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# Preface

The purposes of the *Lawrence Livermore National Laboratory Environmental Report 2009* are to record Lawrence Livermore National Laboratory's (LLNL's) compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring at the two LLNL sites—the Livermore site and Site 300. The report is prepared for the U.S. Department of Energy (DOE) by LLNL's Environmental Protection Department. Submittal of the report satisfies requirements under DOE Order 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, Radiation Protection of the Public and Environment.

The report is distributed electronically and is available at https://saer.lln.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 2009: effluent and ambient air (Chapter 4); waters, including wastewater, storm water runoff, surface water, rain, and groundwater (Chapter 5); and terrestrial, including soil, sediment, vegetation, foodstuff, ambient radiation, and special status wildlife and plants (Chapter 6). Complete monitoring data, which are summarized in the body of the report, are provided in Appendix A.

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

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

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

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 Foster, Steven Hall, Renee Needens, Terrance W. Poole, and Robert Williams; and to the data management personnel—Kimberley A. Swanson, Debbie Stockdale, Suzanne Chamberlain, Nancy Blankenship, Connie Wells, Lisa Graves, Della Burruss, and Susan Lambaren. Special thanks to Rosanne Depue for helping with distribution.

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# Executive Summary

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

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

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

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

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore site," which occupies 1.3 square miles; and a rural Experimental Test Site, referred to as "Site 300," near Tracy, California, which occupies 10.9 square miles. In 2009 the Laboratory had a staff of approximately 6400.

## Purpose and Scope of the Environmental Report

The purposes of the *Environmental Report 2009* 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 EPD's acceptance standards.

This report is prepared for DOE by LLNL's Environmental Protection Department. Submittal of the report satisfies requirements under DOE Order 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, Radiation Protection of the Public and Environment. The report is distributed 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 place on raising lab-wide awareness of EMS and on continued development of EMPs. In 2009, LLNL had 38 active programmatic EMPs and 8 active Lab-wide EMPs and initiatives on significant aspects, including waste generation, energy use, and cultural and ecological resource disturbance. In October 2009, LLNL became ISO 14001:2004 certified.

## Pollution Prevention

A strong Pollution Prevention (P2) Program is an essential supporting element of LLNL's EMS. The P2 Program encompasses lab-wide environmental stewardship, including metrics and reporting on waste generation, environmentally preferable purchasing and resource conservation. P2 promotes employee awareness through an internal website as well as through onsite and community outreach events.

Each year, the P2 Program submits nominations for the NNSA environmental awards program, which recognizes exemplary performance in integrating environmental stewardship practices to reduce risk, protect natural resources, and enhance site operation.

In FY 2009, LLNL received two Environmental Stewardship awards: one in the Waste/Pollution Prevention category and the other for Sustainable Design/Green Building. A water conservation project at Site 300 was also submitted in 2009 as a noteworthy accomplishment.

Also in 2009, LLNL's Terascale Computing Facility won an NNSA Federal Energy Management Program award for energy conservation in computer rooms. The Terascale facility was the first LLNL building submitted for U.S. Green Building Council's LEED Gold certification.

The P2 Program received the California Integrated Waste Management Board's 2009 WRAP award. This is the second consecutive year that LLNL has received this award. The WRAP award recognizes California businesses and organizations that have made outstanding efforts to reduce nonhazardous waste by implementing resource-efficient practices, aggressive waste reduction, reuse and recycling activities, and procurement of recycled-content products.

P2 Program outreach events in 2009 included participation in the community Earth Day event sponsored by the City of Livermore and the Livermore Area Recreation and Park District, articles in the LLNL newspaper, training for Procurement staff, and maintenance of an internal P2 website.

## Air Monitoring

LLNL operations involving radioactive materials had minimal impact on ambient air during 2009. 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 2009, radioactivity released to the atmosphere was monitored at five facilities on the Livermore site and one at Site 300. In 2009, 618 GBq (16.7 Ci) of tritium was released from the Tritium Facility, and 1.7 GBq of tritium (46 mCi) was released from the Decontamination and Waste Treatment Facility. The Contained Firing Facility at Site 300 had 3300 Bq (89 nCi) of depleted uranium released in particulate form in 2009. None of the other facilities monitored for gross alpha and gross beta radioactivity had emissions in 2009.

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 2009 for the Livermore site and Site 300 were similar to 2008 levels. Nonradiological releases from LLNL continue to be a very small fraction of releases from all sources in the Bay Area or San Joaquin County.

In addition to air effluent monitoring, LLNL samples ambient air for tritium, radioactive particles, and beryllium. Some samplers are situated specifically to monitor areas of known contamination; some monitor potential exposure to the public; and others, distant from the two LLNL sites, monitor the natural background. In 2009, ambient air monitoring data confirmed estimated releases from monitored stacks and were used to determine source terms for resuspended plutonium-contaminated soil and tritium diffusing from area sources at the Livermore site and resuspended uranium-contaminated soil at Site 300. In 2009, 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 2009, monitoring data under the LLNL Wastewater Permit #1250 (2010–2011) demonstrated full compliance with all discharge limits, and most of the measured values were a fraction of the allowed limits. All discharges to the Site 300 sewage evaporation pond and percolation ponds were within permitted limits, and groundwater monitoring related to this area showed no measurable impacts.

Storm water is sampled for constituents such as radioactivity, metals, oxygen, dioxins, polychlorinated biphenyls (PCBs), and nitrate both upstream and downstream from both the Livermore site and Site 300. In 2009, no issues were identified as a result of acute or chronic toxicity tests in runoff waters, and data showed that the quality of Livermore site storm water effluent was similar to that entering the site (influent). Storm water sampling at Site 300 revealed low concentrations of radioactivity, consistent with the background concentrations of naturally occurring radionuclides, and low levels of dioxins continue to be observed. Storm water visual observations and best management practices inspections indicated that LLNL’s storm water program continues to protect water quality.

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

Surface waters and drinking water are analyzed for tritium and gross alpha and gross beta radioactivity. In the Livermore Valley, the maximum tritium activity was less than 1% of the drinking water standard, and the maximum gross alpha and gross beta measurements were less than 45% of their respective drinking water standards. For Lake Haussmann (formerly called the Drainage Retention Basin) on the Livermore site, levels of gross alpha, gross beta, tritium, metals, and pesticides were below discharge limits, and organics and PCBs were below detection limits. Aquatic bioassays for acute and chronic toxicity showed no effects in water discharged from Lake Haussmann. At Site 300, maintenance and the operation of drinking water and cooling systems resulted in permitted discharges without adverse impact on surrounding waters.

## Terrestrial Radiological Monitoring

The impact of LLNL operations on surface soil in 2009 was insignificant. Soil is analyzed for plutonium, gamma-emitting radionuclides, tritium, and PCBs as appropriate. Plutonium concentrations at the Livermore Water Reclamation Plant continued to be high relative to other sampled locations, but even this concentration was only 1.6% 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 2009, 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 2009, the median of concentrations in all off-site vegetation samples was below the lower limit of detection of the analytical method. The highest concentration of tritium in Livermore Valley wines sampled in 2009 was less than 0.8% of the drinking water standard.

LLNL's extensive network of thermoluminescent dosimeters measures the natural terrestrial and cosmogenic background; in 2009, as in recent years, no impact from LLNL operations was detected.

## Biota

Through monitoring and compliance activities in 2009, 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 2009. Measures taken at the Livermore site to control bullfrogs, which are a significant threat to California red-legged frogs, included dispatching adults, removing egg masses, and allowing part of Arroyo Las Positas to dry out in November 2009. As in previous years, Site 300's invasive species control efforts have been focused largely on dispatching feral pigs, animals that threaten red-legged frog habitat.

The 2009 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 2009 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 2009 was 0.042 µSv (0.0042 mrem) for the Livermore site and $2.7 \times 10^{-6}$ µSv ($2.7 \times 10^{-7}$ mrem) at Site 300. These doses are well below the federal National Emissions Standards for Hazardous Air Pollutants of 100 µSv (10 mrem) and are significantly less than the doses from natural background radiation. There were no unplanned releases of radionuclides to the atmosphere at the Livermore site or at Site 300.

## Groundwater Remediation

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

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

In 2009, concentrations continued to decrease in most of the Livermore site VOC plumes due to active remediation and the removal of more than 85.7 kg of VOCs from both groundwater and soil vapor. Although the large budget shortfall in 2008 resulted in the non-operation of many Livermore site groundwater remediation facilities, there is little to no evidence of measurable contaminant plume migration while these facilities where not operating. Hydraulic containment along most portions of the western and southern boundaries of the site was fully re-established in 2009 and limited progress was made toward interior plume and source area clean up.

In 2009 at Site 300, perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 16 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 seven of the nine OUs at Site 300; the cleanup remedy for Building 850/Pit7 Complex OU will be completely implemented in 2010, and the CERCLA pathway for the remaining OU is being negotiated with the regulatory agencies.

## Conclusion

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

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# 1. Introduction

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

As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory, with a staff of approximately 6400, serves as a scientific resource to the U.S. government and a partner to industry and academia.

## 1.1 Location

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


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

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

Within a 50-mi radius of the Livermore site are communities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 7.2 million people within 50 mi of the Laboratory, only about 10% are within 20 mi.

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

The city of Tracy, with a population of over 80,000, is approximately 6 mi to the northeast (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 6.7 million people who live within 50 mi of Site 300, 95% are more than 20 mi away in distant metropolitan areas such as Oakland, San Jose, and Stockton.

## 1.2 Meteorology

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

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

Temperature, rainfall, and wind speed data for the Livermore site and Site 300 towers during 2009 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 2009.

| | Livermore Site | | Site 300 | |
|---|---|---|---|---|
| **Temperature** | **°C** | **°F** | **°C** | **°F** |
| Mean daily maximum | 21.7 | 71.0 | 20.8 | 69.5 |
| Mean daily minimum | 8.4 | 47.1 | 12.6 | 54.7 |
| Average | 14.4 | 57.9 | 16.5 | 61.6 |
| High | 41.6 | 106.9 | 39.5 | 103.2 |
| Low | –4.3 | 24.2 | –2.2 | 28.0 |
| **Rainfall** | **cm** | **in.** | **cm** | **in.** |
| Total for 2009 | 31.1 | 12.2 | 21.4 | 8.44 |
| Climatological normal[a] | 34.6[b] | 13.62[b] | —[c] | —[c] |
| **Wind** | **m/s** | **mph** | **m/s** | **mph** |
| Average speed | 2.3 | 5.2 | 5.8 | 13.0 |
| Peak gust speed | 18.7 | 41.9 | 33.9 | 75.9 |

(a) Climatological normal is calculated for a 30 year period (e.g., 1971–2000).

(b) Based on the mean, 1971–2000

(c) Normal values not available because of brief measurement history at new tower.

## 1.3 Topography

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

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

Creek, an ephemeral stream that drains toward the San Joaquin Basin, runs along the southern and eastern boundaries of Site 300.

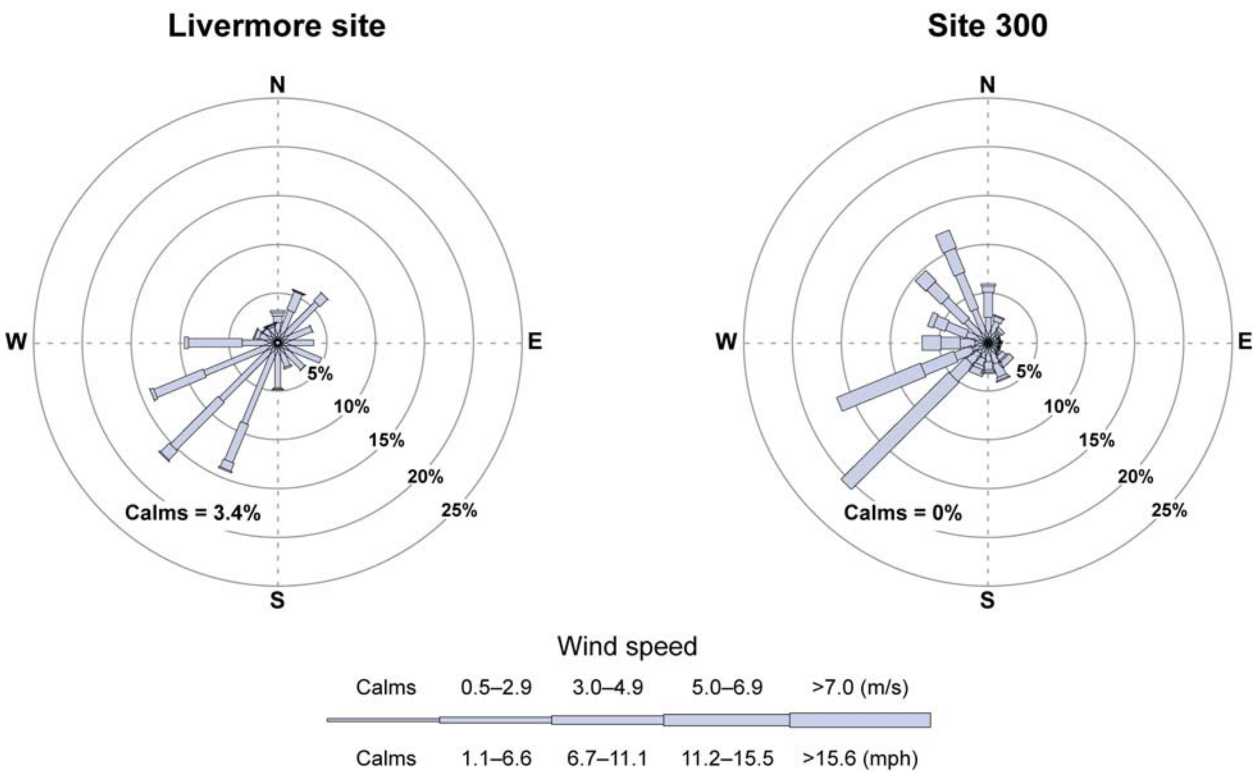


**Figure 1-2.** Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2009. The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes.

## 1.4 Hydrogeology

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

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

## Contributing Authors

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# 2. Compliance Summary

LLNL activities comply with federal, state, and local environmental regulations, internal requirements, Executive Orders, and DOE orders as specified in Contract DE-AC52-07NA27344. This chapter provides an overview of LLNL's compliance programs and activities during 2009. **Table 2-1** is a summary of active permits in 2009 at the Livermore site and Site 300. **Table 2-2** lists environmental inspections and findings from them at both LLNL sites in 2009.

## 2.1 Environmental Restoration and Waste Management

### 2.1.1 Comprehensive Environmental Response, Compensation and Liability Act

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

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

#### *2.1.1.1 Livermore Site Ground Water Project*

The Livermore site came under CERCLA in 1987 when it was placed on the National Priorities List. The Livermore Site Ground Water Project (GWP) complies with provisions specified in a Federal Facility Agreement (FFA) entered into by the U.S. Environmental Protection Agency (EPA), DOE, the California EPA's Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). As required by the FFA, the GWP addresses compliance issues by investigating potential contamination source areas (e.g., suspected old release sites, solvent-handling areas, leaking underground tank systems), monitoring water quality through an extensive network of wells, and remediating contaminated soil and groundwater. The primary soil and groundwater contaminants (constituents of concern) are common volatile organic compounds (VOCs), primarily trichloroethene (TCE) and perchloroethylene (PCE).

During 2009, restoration activities at the Livermore site were primarily focused on restoring operations at treatment facilities that were shut down or required repair due to the fiscal year 2008 budget shortfall. In December 2008 EPA expressed concern about the lengthy process to restart components of the CERCLA remedy and issued an enforcement letter to DOE dated January 6, 2009, assessing penalties for violations of the CERCLA Section 120 FFA. This was followed by a series of meetings and negotiations with the Remedial Project Managers (RPMs) to discuss the issues and constraints associated with restart of treatment facilities and to identify actions needed to meet CERCLA requirements. EPA and DOE reached a settlement of this enforcement action in March 2009 and the RPMs signed a Consensus Statement.

Also in 2009, Table 5 of the Remedial Action Implementation Plan was amended to include 32 new FFA milestones (Dresen et al. 1993). The Livermore GWP met all 2009 regulatory and DOE milestones on schedule including restarting 23 treatment facilities that were shutdown due to the fiscal year 2008 budget reduction. In addition, the Livermore site GWP submitted the following deliverables to the regulatory agencies:

- Building 212 Soil Removal Project Status Report
- Resolution of Mixed Waste Management Issues Associated with Operation of Soil Vapor and Ground Water Treatment Facilities at LLNL, Livermore Site
- Schedules for the bioremediation treatability test at TFD/VTFD Helipad, upgrades for TF5475-2, TF518-PZ, and VTF518-PZ, and focused feasibility study for TF518 North, TF5475-1, TF5475-3, and VTF5475
- Treatability Study Summary and Proposed Cleanup Alternatives for TFA West
- Quarterly and Annual Self Monitoring Reports

Other work conducted in 2009 included Enhanced Source Area Remediation (ESAR) related work that was mostly limited to minor modifications to the facilities that will be part of the ESAR activities to accommodate field treatability tests. These modifications included instrumentation of treatability test wells with level transducers to observe the influence of nearby pumping at the Treatment Facility (TF) D Helipad and limited testing of a pump that can withstand high temperatures at the Vapor Treatment Facility (VTF) E Eastern Landing Mat ESAR site. In addition, two new extraction wells were drilled and constructed in the TFB area located near the western border of the Livermore site where concentrations remain above the maximum contaminant level (5 micrograms per liter) for trichloroethene (TCE). See Buscheck et al. (2010) for the current status of cleanup progress.

***Treatment Facilities.*** During 2009, the Livermore GWP maintained 29 groundwater and 9 soil vapor treatment facilities. The groundwater extraction wells and dual phase extraction wells extracted about 832 million L of groundwater during 2009. The dual phase extraction wells and soil vapor extraction wells together removed 999 thousand $m^3$ of soil vapor.

In 2009, the Livermore GWP treatment facilities removed about 86 kg of VOCs. Since remediation efforts began in 1989, more than 14.3 billion L of groundwater and approximately 10.5 million $m^3$ of soil vapor have been treated, removing about 2792 kg of VOCs.

***Community Relations.*** Livermore site community relations activities in 2009 included communication and meetings with neighbors and local, regional, and national interest groups and other community organizations; public presentations; maintenance of information repositories and an administrative record; tours of site environmental activities; and responses to public and news media inquiries. In addition, DOE/LLNL met with members of Tri-Valley Communities Against a Radioactive Environment (Tri-Valley CAREs) and the organization’s scientific advisor as part of the activities funded by an EPA Technical Assistance Grant (TAG). Community questions were also addressed via electronic mail, and project documents, letters, and public notices were posted on a public website: http://www-envirinfo.llnl.gov.

**Table 2-1.** Active permits in 2009 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.<br>Registered Hazardous Waste Hauler authorized to transport wastes from Site 300 to the Livermore site. Permit number 1351.<br>Conditionally Exempt Specified Wastestream Permit to mix resin in Unit CE231-1.<br>Conditional Authorization Permit to operate sludge dewatering unit in Building 322A.<br>PT0305819. RCRA large-quantity hazardous waste generation facility—ACDEH. | EPA ID No. CA2890090002. Hazardous Waste Facility Permit—CSA (Building 883) and EWSF.<br>Hazardous Waste Facility Permit —EWTF.<br>Hazardous Waste Facility Post-Closure Permit—Building 829 High Explosives Open Burn Treatment Facility.<br>PT0010318. Hazardous waste generation facility—SJCEHD. |
| Medical waste | ACDEH issued a permit that covers medical waste generation and treatment activities for the six BSL 2 facilities, and the BSL 3 facility at Building 368. | NA |
| Air | BAAQMD issued 164 permits for operation of various types of equipment.<br>BAAQMD issued a revision to the SMOP, 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.<br>BAAQMD issued 7 Asbestos Removal Permits and 3 Demolition Permits.<br>CARB issued 6 permits for the operation of portable diesel air compressors and generators. | SJVAPCD issued 36 permits for operation of various types of equipment.<br>SJVAPCD approved a Prescribed Burn Plan for the burning of 2176.5 acres of grassland.<br>BAAQMD issued 1 permit for the operation of an emergency diesel generator.<br>BAAQMD approved a Prescribed Burn Plan for the burning of 139.1 acres of grassland. |
| Storage tanks | Seven operating permits covering 10 underground petroleum product and hazardous waste storage tanks. | One operating permit covering three underground petroleum product tanks assigned individual permit numbers. |
| Sanitary sewer | Discharge Permit 1250[b] for discharges of wastewater to the sanitary sewer.<br>Permit 1510G for discharges of groundwater from CERCLA restoration activities. | WDR R5-2008-0148 for operation of sewage evaporation pond. |

**Table 2-1 (cont.).** Active permits in 2009 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]<br>NPDES Permit No. CA0030023 for discharges of storm water associated with industrial activities and low-threat nonstorm water discharges to surface waters.<br>NPDES General Permit No. CAS000002,) for discharges of storm water associated with construction activities affecting 0.4 hectares (1 acre) or more.<br>FFA for groundwater investigation/remediation. | WDR No. 93-100 for post-closure monitoring requirements for two Class I landfills.<br>WDR R5-2008-0148 for discharges to percolation pits and septic systems.<br>NPDES General Permit No. CAS000001 for discharge of storm water associated with industrial activities.<br>NPDES Regional General Permit No. CAG995001 for large volume discharges from the drinking water system.<br>FFA for groundwater investigation/remediation.<br>33 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 2009.

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

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

**Table 2-2.** Inspections of Livermore site and Site 300 by external agencies in 2009.

| Site | Medium | Description | Agency | Date | Finding |
|---|---|---|---|---|---|
| **Livermore site** | Waste | Hazardous waste facilities Compliance Evaluation Inspection (CEI) | DTSC | 4/29/09<br>5/5/09 –5/6/09<br>5/14/09 | No violations |
| | | Certified Unified Program Agency (CUPA) Inspection | ACDEH | 8/26/09<br>8/28/09 | Final inspection report not yet received. |
| | | Medical Waste Inspection | ACDEH | 2/19/09 | No violations |
| | Air | Air pollutant emission sources | BAAQMD | 12/3/09<br>12/14/09<br>12/17/09 | No violations |
| | | Asbestos | BAAQMD | 8/27/09 | No violations |
| | | SMOP | BAAQMD | 12/3/09<br>12/14/09<br>12/17/09 | No violations |
| | Sanitary sewer | Categorical sampling/inspection Building 153 and Building 321C. Café grease interceptor inspections. | WRD | 9/24/09 | No violations |
| | | Annual compliance sampling at the Sewer Monitoring Complex | WRD | 9/29/09–<br>9/30/09 | No violations |
| | Storage tanks | Compliance with underground storage tank requirements and operating permits | ACDEH | 9/9/09<br>9/15/09 | No violations |
| | Pesticides | Pest control records inspections | ACCDA | 12/15/09 | No violations |
| **Site 300** | Waste | Permitted hazardous waste operational facilities: EWTF, EWSF, Building 883 CSA, and hazardous waste generator areas: B801 photo processing rooms 115 and 116,B875 Heavy Equipment Maintenance Area and a review of hazardous waste-related documentation | US EPA Region IX | 7/28/09 | No violations were issued; however, two potential violations were identified in the US EPA Inspection Report: (1) At Building 875, a 55-gallon drum containing used oil was incorrectly described on the hazardous waste label as “waste oil.” The label was removed in the presence of the inspector and replaced with a corrected label with “Used Oil” written in the waste description field on the hazardous waste label, and (2) an empty container in Building 801 room 115 (photo processing area) was identified as a California-only potential violation because it did not have a completed hazardous label affixed to the container. This was not a potential violation that required corrective action because the new container was empty. New, empty, and clean containers are not subject to federal or state hazardous waste regulation. |
| | Air | Air pollutant emission sources | SJVAPCD | 4/14/09<br>4/16/09<br>4/27/09 | No violations |

**Table 2-2 (cont.).** Inspections of Livermore site and Site 300 by external agencies in 2009.

| Site | Medium | Description | Agency | Date | Finding |
|---|---|---|---|---|---|
| **Site 300 (cont.)** | Water | Permitted operations | CVRWQCB | 4/9/09<br>11/9/09 | No violations |
| | Storage tanks | Compliance with underground storage tank requirements and operating permits | SJCEHD | 3/23/09<br>9/21/09 | No violations |

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

### 2.1.1.2 Site 300 Environmental Restoration Project

Remedial activities are ongoing at Site 300, which became a CERCLA site in 1990 when it was placed on the National Priorities List. Remedial activities are overseen by the EPA, the Central Valley Regional Water Quality Control Board (CVRWQCB), and DTSC, under the authority of an FFA for the site. Contaminants of concern at Site 300 include VOCs (primarily TCE), high explosive compounds, tritium, depleted uranium, silicone-based oils, nitrate, perchlorate, polychlorinated biphenyls, dioxins, furans, and metals. The contaminants present in environmental media vary within the different environmental restoration operable units (OUs) at the site. See Webster-Scholten (1994), and Ferry et al. (1999) for background information on LLNL environmental characterization and restoration activities at Site 300. See Dibley et al. (2010) for the current status of cleanup progress. In 2009, the Site 300 Environmental Restoration Project (ERP) met all regulatory and DOE milestones on schedule including submitting the semiannual Compliance Monitoring Reports, draft final and final Building 854 Final 5-Year Review, and the draft, draft final, and final Compliance Monitoring Plan/Contingency Plan. In addition, the Site 300 ERP completed the cleanup of polychlorinated biphenyl (PCB)-, dioxin-, and furan-contaminated soil surrounding the Building 850. Prior to PCBs becoming regulated substances, capacitors were destroyed on the Building 850 Firing Table during experiments. Dioxins and furans were created by the combustion of the PCBs during these experiments. Cleanup was necessary to mitigate cancer risk to on-site workers resulting from the potential inhalation or ingestion of re-suspended particulates and direct dermal exposure to contaminated surface soil as well as to mitigate potential hazard to burrowing owls. Approximately 22,172 $m^3$ of PCB-contaminated soil were excavated from the hillsides, solidified using Portland cement, and placed in the former Corporation yard of Building 850.

The Building 812 milestones scheduled for completion in 2009 were put on hold while the CERCLA path forward for the Operable Unit was renegotiated with the regulatory agencies.

***Treatment Facilities.*** During 2009, the Site 300 ERP operated 13 groundwater and 5 soil vapor treatment facilities at Site 300. The groundwater extraction wells and dual phase extraction wells extracted about 33 million L of groundwater during 2009. The dual phase extraction wells and soil vapor extraction wells together removed 2.6 million $m^3$ of soil vapor.

In 2009, the Site 300 treatment facilities removed about 16 kg of VOCs, 0.12 kg of perchlorate, 1500 kg of nitrate, 0.14 kg of the high explosive compound RDX, and 0.0031 kg of silicone-based oil. Since remediation efforts began in 1990, more than 1423 million L of groundwater and approximately 14 million $m^3$ of soil vapor have been treated, removing about 540 kg of VOCs, 0.91 kg of perchlorate, 8100 kg of nitrate, 1.3 kg of RDX, and 9.5 kg of silicone-based oil.

***Community Relations.*** The Site 300 CERCLA Project maintains continuing communications with the community of Tracy and nearby neighbors. Community relations activities in 2009 included maintenance of information repositories and an administrative record; participation in community meetings and workshops; tours of site environmental activities; offsite, private, well-sampling activities; mailings to stakeholders; and providing responses to public and news media inquiries. LLNL hosted TAG meetings with Tri-Valley CAREs to provide a forum for focused discussions on CERCLA activities at Site 300.

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

Title III of SARA, known as the Emergency Planning and Community Right-to-Know Act (EPCRA), requires owners and operators of facilities who handle certain hazardous chemicals on site to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management, directs all federal agencies to comply with the requirements of the EPCRA, including SARA, Section 313, the Toxic Release Inventory (TRI) Program. EPCRA requirements and LLNL compliance are summarized in **Table 2-3.**

**Table 2-3.** Compliance with EPCRA.

| EPCRA section | Brief description of requirement | LLNL action |
|---|---|---|
| 302 | Notify SERC of presence of extremely hazardous substances. | Originally submitted 5/87. |
| 303 | Designate a facility representative to serve as emergency response coordinator. | Update submitted 1/28/09 to San Joaquin County for Site 300 and 2/27/09 to Alameda County for Livermore site. |
| 304 | Report releases of certain hazardous substances to SERC and LEPC. | No EPCRA-listed extremely hazardous substances were released above reportable quantities in 2009. |
| 311 | Submit MSDSs or chemical list to SERC, LEPC, and Fire Department. | Update submitted 3/31/09. |
| 312 | Submit hazardous chemical inventory to local administering agency (county). | Submitted to San Joaquin and Alameda counties on 1/28/09 and 2/27/09, respectively. |
| 313 | Submit Form R to U.S. EPA and California EPA for toxic chemicals released above threshold levels. | Form R for lead for Site 300 and mercury for Livermore site submitted to DOE on 6/23/09 and 6/17/09, respectively; DOE forwarded it to U.S. EPA and California EPA 6/29/09. |

On June 17, 2009, LLNL submitted to DOE/NNSA the TRI Form R for mercury for the Livermore site detailing environmental release estimates for calendar year (TRI reporting year) 2008. Form R is used for reporting TRI chemical releases and includes information about waste management and waste minimization activities.

LLNL has reported lead release data for Site 300 since 2002. Over 99 percent of lead releases are associated with activities at the Site 300 Small Firearms Training Facility (SFTF). Data for the 2008 TRI Form R for lead at Site 300 was submitted to DOE/NNSA on June 23, 2009. Over the past few years the lead releases have decreased due to increased use of frangible bullets.

### 2.1.3 California Accidental Release Prevention (CalARP) Program

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

In June 2000, LLNL Site 300 submitted a risk management plan (RMP) to the San Joaquin County, Office of Emergency Services (SJCOES). The RMP described the systems in place to prevent or mitigate the hazards associated with chlorine used in the LLNL Site 300 water treatment system. In accordance with the Final CalARP Program Regulations in the California Code of Regulations (Title 19, Division 2, Chapter 4.5), the LLNL Site 300 RMP was updated in August 2005. It has been determined that the Site 300 water treatment system falls under CalARP Program Level 2. This plan is updated at least every five years.

LLNL submitted a revised Livermore site CalARP Level 1 RMP in September 2009 to cover new processes that would be handling hydrofluoric acid above state threshold quantities. The Livermore site RMP now includes lithium hydride, nitric acid and hydrofluoric acid.

### 2.1.4 Resource Conservation and Recovery Act and Related State Laws

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

The hazardous waste management facilities at the Livermore site consist of permitted units in Area 612 and Buildings 693, 695, and 696 of the Decontamination and Waste Treatment Facility (DWTF). Permitted waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction). LLNL submitted the permit renewal application to DTSC in April 2009 and is currently updating the health risk assessment (HRA) as part of the permit renewal process. DTSC approved the Building 419 Closure Plan in October 2009. Closure activities at Building 419 have commenced and will continue through September 2011. During 2008/2009, LLNL submitted several permit modification requests to DTSC, all of which been approved and implemented.

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

### 2.1.5 California Medical Waste Management Act

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

### 2.1.6 Radioactive Waste and Mixed Waste Management

LLNL manages radioactive waste and mixed waste in compliance with applicable sections of DOE Order 435.1, and the LLNL-developed *Radioactive Waste Management Basis for the Lawrence Livermore National Laboratory* (LLNL 2009), which summarizes radioactive waste management controls relating to waste generators and treatment and storage facilities. Additional information on the management of radioactive and mixed wastes, prepared by EPD, is available to LLNL employees in the *Environment, Safety and Health (ES&H) Manual*. LLNL does not release to the public any property with residual radioactivity above the limits specified in DOE Order 5400.5. Excess property of this type is either transferred to other DOE facilities for reuse or transferred to LLNL's Radioactive and Hazardous Waste Management Division for disposal.

### 2.1.7 Federal Facility Compliance Act

LLNL continues to work with DOE to maintain compliance with the Federal Facilities Compliance Act (FFCA) Site Treatment Plan (STP) for LLNL, which was signed in February 1997. LLNL completed 22 milestones during 2009, and of those, 12 had due dates beyond 2009 (ranging from 2010 to 2011).

LLNL requested and was granted an extension for one additional milestone to allow LLNL time to develop new procedures and work control documents for 1.12 $m^3$ of waste.

LLNL removed approximately 38 $m^3$ of mixed waste from LLNL in 2009. An additional 32 $m^3$ of newly generated mixed waste was accepted into the approved storage facilities and added to the STP, reflecting an overall reduction of 6 $m^3$ of mixed waste being stored by LLNL.

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

### 2.1.8 Toxic Substances Control Act

The Federal Toxic Substances Control Act (TSCA) and implementing regulations found in Title 40 of the Code of Federal Regulation, Parts 700–789 (40 CFR 700-789) govern the uses of newly developed chemical substances and TSCA-governed waste. All TSCA-regulated waste was disposed of in accordance with TSCA, state, and local disposal requirements with one exception. Radioactive polychlorinated biphenyl (PCB) waste is currently stored at one of LLNL's hazardous waste storage facilities until an approved facility accepts this waste for final disposal.

## 2.2 Air Quality and Protection

### 2.2.1 Clean Air Act

All activities at LLNL are evaluated to determine the need for air permits. 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. Both agencies are overseen by the California Air Resources Board (CARB), which also oversees statewide permitting for portable diesel fuel-driven equipment such as portable generators and portable air compressors. In addition, CARB oversees the state-wide registration of In-use Off-road Diesel Vehicles, such as diesel powered forklifts, loaders, backhoes, graders, and cranes.

In 2009, LLNL operated 180 permitted air emission sources at the Livermore site and 37 permitted air emission sources at Site 300. In addition, the Livermore site continues to maintain a Synthetic Minor Operating Permit (SMOP), which was issued by the BAAQMD in 2002, to ensure the Livermore site does not emit regulated air pollutants in excess of federal Clean Air Act (CAA) Title V limits. As such, LLNL is able to demonstrate that it does not have any major sources of air pollutant emissions per 40 CFR 70.2. In 2009, LLNL also registered 86 In-use Off-road Diesel Vehicles with CARB.

Under the authority of California Assembly Bill 32 (AB32), the State of California has adopted several new regulations regarding emissions of greenhouse gases (GHG). California requires "mandatory reporting" of stationary source air emissions from combustion of natural gas that exceed 25,000 metric tons per year of $CO_2$ equivalent emissions. For the previous two mandatory reporting years (CY2008 and CY2009), the Livermore site has been slightly below the reporting threshold. LLNL continues to implement reductions and controls that should reduce $CO_2$ emissions in future years. LLNL Site 300 emissions of $CO_2$ are much lower than Livermore site emissions, and there is no natural gas service at Site 300 that would generate $CO_2$ emissions.

Also under the authority of AB32, California has adopted special regulations pertaining to sulfur hexafluoride ($SF_6$), because of its high GHG potential. Beginning in CY2011, research facilities, such as LLNL, must submit an annual report describing the research uses of $SF_6$ and the measures taken to control the $SF_6$ emissions. LLNL must also report the amount of $SF_6$ contained in electrical switchgear and the amount of $SF_6$ that leaks from that switchgear.

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

### 2.2.2 National Emission Standards for Hazardous Air Pollutants, Radionuclides

To demonstrate compliance with 40 CFR Part 61, Subpart H (National Emission Standards for Hazardous Air Pollutants [NESHAPs] for radiological emissions from DOE facilities), LLNL monitors certain air release points and evaluates the maximum possible dose to the public. The *LLNL NESHAPs 2009 Annual Report* (Bertoldo et al. 2010), submitted to EPA, reported that the estimated maximum radiological doses that could have been received by a member of the public in 2009 were 0.042 µSv (0.0042 mrem) for the Livermore site and 0.0000027 µSv (0.00000027 mrem) for Site 300. The totals are well below the 100 µSv/y (10 mrem/y) dose limits defined by the NESHAPs regulations.

## 2.3 Water Quality and Protection

LLNL complies with requirements of the federal Clean Water Act (CWA), Porter-Cologne Water Quality Control Act, and Safe Drinking Water Act (SDWA); the California Aboveground Petroleum Storage Act, Water Code, and Health and Safety Code; and City of Livermore ordinances, by complying with regulations and obtaining permits issued by several agencies whose mission is to protect water quality.

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

The CWA and California Aboveground Petroleum Storage Act require LLNL to have and implement Spill Prevention Control and Countermeasure (SPCC) plans for aboveground, oil-containing containers. The ACDEH and the San Joaquin County Environmental Health Department (SJCEHD) also issue permits for operating underground storage tanks containing hazardous materials or hazardous waste (see **Table 2-1**). LLNL's permitted underground storage tanks, for which permits are required, contain diesel fuel, gasoline, and used oil; aboveground storage tanks, for which permits are not required, contain fuel, insulating oil, and process wastewater.

## 2.4 Other Environmental Statutes

### 2.4.1 National Environmental Policy Act and Floodplains and Wetland Assessments

The National Environmental Policy Act (NEPA) of 1969 is the U.S. government's basic environmental charter. When considering a proposed project or action at LLNL, DOE/NNSA must (1) consider how the action would affect the environment and (2) make certain that environmental information is available to public officials and citizens before decisions are made and actions are taken. The results of the evaluations and notice requirements are met through publication of “NEPA documents”, such as environmental impact statements (EISs) and environmental assessments (EAs) under DOE NEPA Implementing Procedures in 10 CFR 1021. In 2005 DOE/NNSA completed the *Final Site-Wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (U.S. DOE/NNSA 2005). In 2009, no EISs or EAs were completed for LLNL; however, there were three categorical exclusions completed in 2009—(1) Offsite Compact Proton Therapy Accelerator, (2) Lead Removal for Recycling at the Small Firearms Training Facility, and (3) Site 300 Rifle Range Improvements. Moreover, NEPA values were incorporated in a CERCLA document for *Treatability Study Summary and Proposed Cleanup Alternatives for the TFA West Area, Lawrence Livermore National Laboratory, Livermore Site* (Noyes et al. 2009). There were no proposed actions at LLNL that required separate DOE floodplain or wetlands assessments under DOE regulations in 10 CFR Part 1022.

### 2.4.2 National Historic Preservation Act

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

In consultation with the State Historic Preservation Officer (SHPO), DOE/NNSA formally determined that five archaeological resources, five individual buildings, two historic districts (encompassing 13 historic buildings), and selected objects in one building at LLNL are eligible for listing in the National Register of Historic Places (NRHP). To assist DOE and SHPO in developing an agreement as to how to manage the NRHP-eligible properties, LLNL prepared a draft Programmatic Agreement (PA), which includes a draft archaeological resources treatment plan and a draft historic buildings treatment plan as appendices. These plans describe specific resource management and treatment strategies that DOE/NNSA, in cooperation with LLNL, could implement to ensure that significant historic properties are managed in a manner that considers their historic value. As of the end of 2009, SHPO was still reviewing the draft PA and treatment plans.

### 2.4.3 Antiquities Act of 1906

Provisions of the Antiquities Act provide for protection of items of antiquities (i.e., archaeological sites and paleontological remains). The five NRHP-eligible archaeological sites noted in Section 2.4.2 are protected under the Antiquities Act. No paleontological remains subject to the provisions of the Antiquities Act were identified in 2009.

### 2.4.4 Endangered Species Act and Sensitive Natural Resources

LLNL meets the requirements of the federal and state Endangered Species Act (ESA), the Eagle Protection Act, the Migratory Bird Treaty Act, and other applicable regulations as they pertain to endangered species, threatened species, and other special-status species (including their habitats) and designated critical habitats that exist at the LLNL sites. The following list highlights 2009 compliance activities.

- On November 17, 2008, LLNL submitted a Biological Assessment to the U.S. Fish and Wildlife Service (USFWS) for the Building 850 Polychlorinated Biphenyls-Bearing Soil Removal Project. An amendment to the 2002 Biological Opinion for the *Formal Consultation on the Routine Maintenance and Operations Project at LLNL, Site 300 Experimental Test Site* for this project was received on April 9, 2009. Construction associated with the project was completed in 2009. Mitigation measures required by the 2009 amendment will be implemented in 2010 and 2011.
- On May 21, 2009, the *Biological Opinion for the Proposed Arroyo Mocho Road Improvement and Anadomous Fish Passage Project* was amended to include routine erosion control projects along the Arroyo Mocho access road and at the pumping station.

### 2.4.5 Federal Insecticide, Fungicide, and Rodenticide Act

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

## 2.5 Environmental Occurrences

Notification of environmental occurrences is required under a number of environmental laws and regulations as well as DOE Order 231.1A and DOE Manual 231.1-2. In 2009, no environmental incidents were reportable under DOE Order 231.1A and DOE Manual 231.1-2 reporting requirements.

### Contributing Authors

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# 3. Environmental Program Information

*Jennifer Doman*

LLNL is committed to enhancing its environmental stewardship and to reducing any impacts its operations may have on the environment. This chapter describes the lead organizations that support the LLNL's environmental stewardship and describes LLNL's Environmental Management System (EMS) and Pollution Prevention (P2) program.

## 3.1 Environmental Protection Program

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

### 3.1.1 Environmental Protection Department

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

### 3.1.2 Radioactive and Hazardous Waste Management Division

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

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

### 3.1.3 Environmental Restoration Department

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

### 3.1.4 Response to Spills and Other Environmental Emergencies

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

### 3.1.5 Energy, Water and Fleet Management

The Facilities and Infrastructure Directorate implements Laboratory-wide programs for energy and water conservation, fleet management, high performance sustainable building, and renewable energy. These programs are designed to meet the requirements of DOE Order 430.2B, Departmental Energy, Renewable Energy and Transportation Management. The programs contribute to environmental protection through implementation of lab-wide reduction initiatives (see **Table 3-2**).

## 3.2 Environmental Management System

LLNL established its EMS to meet the requirements of International Organization for Standardization (ISO) 14001:1996 in June 2004. In 2006, LLNL upgraded its EMS to meet the requirements of ISO 14001:2004, and developed a number of Environmental Management Plans (EMPs) that address lab-wide significant aspects. During FY 2007, the EMS expanded to incorporate EMPs at the programmatic level. During FY 2008, more focus was placed on raising lab-wide awareness of the EMS, and on continued development of EMPs at both the institutional and programmatic levels. In October 2009, LLNL became ISO 14001:2004 certified.

### 3.2.1 Environmental Management Plans

EMS representatives from each program area continue to develop EMPs and associated objectives and targets, based on program-specific aspects. Directorates select aspects to pursue considering which ones they could reasonably affect, based on budget and mission. During 2009, the directorate EMPs listed in **Table 3-1** were active. In addition, a number of EMPs and initiatives address Lab-wide environmental aspects (see **Table 3-2**).

**Table 3-1.** LLNL Directorate Environmental Management Plans active in 2009

| Principal Directorate | Aspect(s) addressed | Environmental Management Plan(s) and Program(s) |
|---|---|---|
| Operations & Business | • Water use | • Water Conservation |
| | • Municipal waste generation | • Municipal Waste Generation |
| | • Municipal waste generation | • Recycling of Beverage Containers (closed in 2009) |
| | • Municipal waste generation<br>• Nonhazardous materials use | • Office Paper Use Reduction and Recycling |
| | • Nonhazardous materials use | • Nonhazardous Materials Use |
| | • Electrical energy use<br>• Fossil fuel consumption | • IMF (Institutionally Managed Facilities) Energy Conservation |
| Weapons & Complex Integration | • Cultural resource disturbance | • Archaeological Resources |
| | • Ecological resource disturbance | • Ecological Resources |
| | • Electrical energy use | • Electrical Energy Use |
| | • Fossil fuel consumption | • Fossil Fuel Consumption |
| | • Hazardous materials use | • Hazardous Materials Use |
| | • Municipal waste generation | • Municipal Waste Generation |
| | • Nonhazardous materials use | • Nonhazardous Materials Use |
| | • Radioactive materials use | • Radioactive Materials Use |
| | • Renewable energy use | • Renewable Energy Use |
| Science & Technology | • Municipal waste generation<br>• Nonhazardous materials use | • Computer Packaging Material Recycling Plan |
| | • Nonhazardous materials use | • Minimizing Outdoor Equipment Storage |
| | • Hazardous materials use<br>• Waste reduction | • Preventing the Formation of Lead Oxide by Sealing Lead Shielding |

**Table 3-1 (cont.).** LLNL Directorate Environmental Management Plans active in 2009

| Principal Directorate | Aspect(s) addressed | Environmental Management Plan(s) and Program(s) |
|---|---|---|
| Science & Technology (cont.) | • All environmental aspects | • EMS Integration into Work Control Process |
| | • Electrical energy use | • Server Energy Efficiency Opportunities (closed in 2009) |
| | • Radioactive materials use | • Minimizing Radioactive Sealed Sources and Reducing Exposure Hazards |
| | • Municipal waste generation | • Office Paper Use Reduction and Recycling (closed in 2009) |
| | • Municipal waste generation | • Computer Packaging Material Recycling for B453 |
| | • Municipal waste generation | • Evaluation of Beverage Container Recycling Opportunities in the S&T PAD (closed in 2009) |
| | • Nonhazardous materials | • Minimizing Outdoor Equipment Storage |
| | • Electrical energy use | • B453 Electrical Energy Conservation |
| | • Hazardous waste generation<br>• Industrial waste generation | • Engineering Shop Consolidation |
| Global Security | • Water use<br>• Electrical energy use | • Optimizing Autoclave Water & Energy Use within Global Security (closed in 2009) |
| | • Hazardous waste generation<br>• Industrial waste generation | • Waste & Chemical Usage Evaluation (closed in 2009) |
| Director's Office | • Municipal waste generation<br>• Nonhazardous materials use | • Office Paper Use Reduction and Recycling |
| | • Hazardous waste generation | • Hazardous and Industrial Waste Evaluation |
| | • Waste reduction<br>• Hazardous materials use | • Hazardous/Toxic Chemicals/Materials Evaluation |
| | • Hazardous materials use<br>• Hazardous waste generation<br>• Fossil fuel conservation<br>• Municipal waste generation | • Environmental Stewardship at Small Arms Training Facility |
| | • Hazardous materials use | • Hazardous Materials Use Reduction |
| NIF & Photon Science | • Hazardous waste generation<br>• Municipal waste generation | • Legacy Waste Management |
| | • Hazardous waste management<br>• Hazardous waste generation<br>• Hazardous materials use | • Online Service Request Button<br>• Waste and Chemical Usage Evaluation |
| | • Municipal waste generation | • NIF Dedication & Family Days Environmental Stewardship: Recycling (closed in 2009) |

**Table 3-2.** LLNL Environmental Management Plans and Initiatives for Lab-wide aspects active in 2009

| Environmental aspect | Objective summary | Status |
|---|---|---|
| Ecological resource disturbance | • Establish an LLNL policy prohibiting the introduction of exotic species<br>• Educate LLNL employees about the consequences of exotic species introduction<br>• Control exotic species, e.g., feral pig, largemouth bass | Ongoing |
| Cultural resource disturbance | • Support DOE/NNSA in working with the California State Historic Preservation Officer to sign and then implement a new Programmatic Agreement | Ongoing |
| Electrical energy use[(a)] | • Meet the energy use intensity goals outlined in DOE Order 430.2B, Departmental Energy, Renewable Energy and Transportation Management | Energy use intensity was reduced by 12.7% over the FY 2003 baseline, exceeding the 12% cumulative four-year goal. |
| Fossil fuel consumption/ renewable energy use[(a)] | • Meet the Vehicle Fleet Management objectives outlined in DOE Order 430.2B, Departmental Energy, Renewable Energy and Transportation Management | The E85 fuel station continued operation in 2009. LLNL has 317 E85 compatible alternative fuel vehicles (AFV) on-site and 65 electric vehicles (GEMS). Fleet Management continues to replace conventional fuel vehicles with AFVs per the General Services Administration (GSA) replacement schedule. |
| Hazardous materials use | • Evaluate biobased alternatives for use by Fleet Management<br>• Increase awareness of green chemistry resources. | Fleet adopted use of selected biobased lubricating oils. EMS and P2 internal web pages include information on chemical alternatives and links to green chemistry resources. |
| Water use[(a)] | • Meet the water conservation goals outlined in DOE Order 430.2B, Departmental Energy, Renewable Energy and Transportation Management | Achieved a water use reduction of 5.2% from FY 2007 levels, exceeding the cumulative two-year goal of 4.0%. |
| Construction and building maintenance[(a)] | • Achieve Leadership in Energy & Environmental Design for Existing Buildings (LEED-EB) certification for 15% of site's existing building square footage by FY 2015 | Submitted two buildings for U.S. Green Building Council (USGBC) LEED-EB operations and maintenance certification review. |
| Renewable energy use[(a)] | • Meet the renewable energy goals outlined in DOE Order 430.2B, Departmental Energy, Renewable Energy and Transportation Management | Achieved compliance with Renewable Energy requirements through purchase of Renewable Energy Credits (RECs). |

(a) Aspect is addressed as part of the DOE Order 430.2B Executable Plan.

### 3.2.2 EMS Audits and Reviews

*3.2.2.1 External Audits:*

An external EMS audit conducted by the DOE Livermore Site Office on April 20–24 indentified two major nonconformances and six minor nonconformances. A path forward to enable the Laboratory to self certify in accordance with DOE Order 450.1A in June was implemented with the preparation of a Corrective Action Plan. The Laboratory self certified with acceptance by DOE on May 27, 2009.

The Laboratory successfully completed an external independent audit of its ISO 14001 EMS program (September 21–24), the fourth and final phase in a series of audits required to achieve formal registration of the LLNL ISO 14001 Environmental Management System. Registration was formally conferred on October 31, 2009. The registration recognizes that Laboratory organizations and employees meet all the goals in environmental compliance programs, processes, and practices.

This independent audit was conducted by NSF International Strategic Registration, an internationally recognized ISO auditor, and validated the Laboratory's strong commitment to environmental stewardship.

*3.2.2.2 Internal Assessments and Reviews:*

In May a Senior Management Review was conducted and senior management reaffirmed its commitment to environmental stewardship through the implementation of EMS.

In November 2009 an internal EMS audit was performed to address corrective actions resulting from the April DOE independent assessment and to comply with the ISO 14001:2004 internal audit requirements. Five minor nonconformances were identified and are in the process of being addressed both at the institutional and programmatic level.

## 3.3 Pollution Prevention Program

LLNL's P2 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 P2 accomplishments, and fostering of P2 awareness through presentations, articles, and events. The P2 Program supports institutional and directorate P2 activities via environmental teams, including implementation and facilitation of source reduction and/or reclamation, recycling, and reuse programs for hazardous and nonhazardous waste; facilitation of environmentally preferable procurement; and preparation of P2 opportunity assessments.

The P2 Program at LLNL strives to systematically reduce all types of waste generated, and to eliminate or minimize pollutant releases to all environmental media from all aspects of the operations at the Livermore site and Site 300. These efforts help protect public health and the environment by reducing or eliminating waste, improving resource usage, and reducing inventories and releases of hazardous chemicals. These efforts also benefit LLNL by reducing compliance costs and minimizing the potential for civil and criminal liabilities under environmental laws. In accordance with EPA guidelines and DOE policy, the P2 Program uses a hierarchical approach to waste reduction (i.e., source elimination or reduction, material substitution, reuse and recycling, and treatment and disposal), which is applied, where feasible, to all types of waste. Waste generation is tracked using RHWM's HazTrack database. By reviewing the information in this database, program managers and P2 Program staff can monitor and analyze waste streams to determine cost-effective improvements to LLNL operations.

LLNL continues its efforts to phase-out Class I ozone depleting substances (ODSs). These efforts include recovery and recycling activities, refrigerant and coolant substitutions, preventative maintenance, leak detection programs, and equipment replacement. LLNL uses minimal quantities of ODSs for mission-critical laboratory research, under the "laboratory exemption" provided for in 40 CFR Part 82, Subpart A, Appendix G.

### 3.3.1 Routine Hazardous, Transuranic, and Radioactive Waste

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

Beginning in FY 2009, a new volumetric calculation and reporting method is in place for transuranic and radioactive wastes. Because of this change, a comparison between FY 2009 and past years' data will not accurately reflect actual changes in generated volume. Therefore, the table for transuranic and radioactive wastes (**Table 3-4**) is limited to 2009. The multi-year table format will resume with the addition of FY 2010 data next year.

**Table 3-3.** Routine hazardous waste at LLNL, FY 2006–2009.

| Waste category | FY 2006 | FY 2007 | FY 2008 | FY 2009 |
|---|---|---|---|---|
| Routine hazardous waste generated (MT) | 153 | 138 | 248 | 164 |

**Table 3-4.** Routine transuranic and radioactive waste at LLNL, FY 2009.

| Waste category | FY 2009[(a)] |
|---|---|
| Routine low-level waste generated ($m^3$) | 210.4 |
| Routine mixed waste generated ($m^3$) | 25.4 |
| Routine TRU / mixed TRU waste generated ($m^3$) | 9.7 |

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

### 3.3.2 Diverted Waste

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

#### *3.3.2.1 Routine Waste*

Together, the Livermore site and Site 300 generated 3654 MT of routine nonhazardous solid waste in FY 2009. This volume includes diverted waste (e.g., material diverted through recycling and reuse programs) and landfill waste.

Both sites combined diverted a total 2502 MT of routine nonhazardous waste in FY 2009, which represents a diversion rate of 68%. The diverted routine nonhazardous waste includes waste recycled by RHWM and materials diverted through the surplus sales program. The portion of routine nonhazardous waste sent to landfill was 1152 MT. See **Table 3-5**.

In 2009, LLNL transferred or donated for reuse 50 laptops and monitors and recycled 4055 computers, monitors, and laptops, which were managed as universal waste.

**Table 3-5.** Routine nonhazardous waste in FY 2009, Livermore site and Site 300 combined.

| Destination | Waste description | Amount in FY 2009 (MT) |
|---|---|---|
| Diverted | Batteries[(a)] | 31 |
| | Baled paper | 78 |
| | Beverage containers | 5 |
| | Corrugated Cardboard | 78 |
| | Cooking grease | 21 |
| | Engine oils | 8 |
| | Fluorescent lights[(a)] | 6 |
| | Magazines, newspapers, phone books | 20 |
| | Mixed metals[(b)] | 1352 |
| | Office paper | 80 |
| | Tires and scrap | 5 |
| | Toner cartridges | 8 |
| | Wood (chips, compost) | 810 |
| | **TOTAL diverted** | **2502** |
| Landfill | Compacted (landfill) | 1152 |
| | **TOTAL landfill** | **1152** |
| **TOTAL routine nonhazardous waste** | | **3654** |

(a) Batteries and fluorescent lights are managed as universal waste.

(b) Mixed scrap metals, including 12.76 MT of lead.

*3.3.2.2 Nonroutine Waste*

Nonroutine nonhazardous solid wastes include excavated soils, wastes and metals from construction, and decontamination and demolition activities. The Livermore site and Site 300 generated a total of 7525 MT of nonroutine nonhazardous solid waste in FY 2009.

In FY 2009, the two sites combined diverted 4912 of nonroutine nonhazardous solid waste through reuse or recycling, which represents a diversion rate of 65%. Diverted nonroutine nonhazardous solid waste includes soil reused either on site for other projects or as cover soil at Class II landfills. See **Table 3-6**.

**Table 3-6.** Nonroutine nonhazardous waste in FY 2009, Livermore site and Site 300 combined.

| Destination | Waste description | Amount in FY 2009 (MT) |
|---|---|---|
| Diverted | Class II cover soil (reused at landfill) | 186 |
| | Class II concrete (reused at landfill) | 4726 |
| | **TOTAL diverted** | **4912** |
| Landfill | Construction demolition (noncompacted landfill) | 2613 |
| | **TOTAL landfill** | **2613** |
| **TOTAL nonroutine nonhazardous waste** | | **7525** |

(a) RHWM Waste Data Management System

## 3.3.3 Environmentally Preferable Purchasing

LLNL has a comprehensive Environmentally Preferable Purchasing (EPP) program that includes preferential purchasing of recycled content and biobased products. In 2009, the EPP program continued to include a preference for Electronic Product Environmental Assessment Tool (EPEAT) registered products. 97 % of all desktop electronics purchases in FY 2009 were EPEAT Silver or EPEAT Gold, indicating that the products meet or exceed the Institute of Electrical and Electronics Engineers (IEEE) 1680-2006 environmental performance standard for electronic products.

## 3.3.4 Pollution Prevention Activities

*3.3.4.1 Environmental Stewardship Accomplishments and Awards*

Each year, the P2 Program submits nominations for the NNSA environmental awards program, which recognizes exemplary performance in integrating environmental stewardship practices to reduce risk, protect natural resources, and enhance site operations. In FY 2009, LLNL received two Environmental Stewardship awards: one in the Waste/Pollution Prevention category and the other in the Sustainable Design/Green Building category.

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

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

The P2 Program also submitted an accomplishment to the NNSA for the beneficial reuse of wastewater at Site 300. Site 300 is converting from existing well water to a public water supply system. The conversion effort generated wastewater from flushing out the lines as part of the connection process. LLNL received permission from regulatory authorities to use this water to maintain proper treatment parameters for the site's sewage evaporation pond and to provide some of the water to neighboring Carnegie State Vehicular Recreation Area for dry season dust control. This effort allowed the beneficial reuse of over 400,000 gallons of non-potable water, and reduced the demand for well water at both sites.

The P2 Program received the California Integrated Waste Management Board's 2009 WRAP award for recycling accomplishments during the 2008 calendar year. The award recognizes California businesses and organizations that have made outstanding efforts to reduce nonhazardous waste by implementing resource-efficient practices, aggressive waste reduction, reuse and recycling activities, and procurement of recycled-content products. This is the second consecutive year that LLNL has won the WRAP award.

#### *3.3.4.2 High Performance Sustainable Buildings and Energy Conservation*

The Facilities and Infrastructure Directorate manages the implementation of DOE Order 430.2B objectives related to sustainable building materials and practices. In FY 2008, a Green Cleaning Policy was developed that meets the U. S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) requirements. The purpose and goal of the Policy is to reduce the usage of potentially hazardous cleaning chemicals and their adverse impact on indoor air quality, occupant health, and the environment. In FY 2009, LLNL continued to expand green cleaning lab-wide, with the goal to implement green cleaning at all applicable locations.

Also in FY 2009, two buildings at the Livermore site were submitted for USGBC LEED-EB Operations and Maintenance certification review. Building 142 was submitted to USGBC for

LEED-EB Operations and Maintenance Silver certification. LLNL's Terascale Simulation Facility (TSF) won a 2009 DOE/NNSA Federal Energy Management Program award for its two-year effort to conserve energy in TSF computer rooms. The TSF was also submitted to USGBC for LEED-EB Operations and Maintenance Gold certification and is estimated to save $2.4 million annually in energy costs.

### 3.3.5 Pollution Prevention Employee Training and Awareness Programs

In 2009, LLNL conducted a number of activities to promote employee awareness of pollution prevention. LLNL participated in a community Earth Day event, held April 18, 2009. The event was sponsored by the City of Livermore and the Livermore Area Recreation and Park District, and included a creek cleanup and a festival. The P2 Program and volunteers from the LLNL Environmental Protection Department staffed a table at the festival, which included a poster display of LLNL waste diversion activities. Information on LLNL and pollution prevention was also distributed to festival attendees.

The P2 Program conducted other awareness activities during the year. Articles on pollution prevention appeared in *Newsline* (the LLNL newspaper) and *NewsOnLine*. The P2 Program continues to conduct training for purchasing staff on Environmentally Preferable Purchasing requirements.

The P2 Program maintains an internal P2 website for LLNL employees, which was redesigned in 2009. The website is a resource for employees who have questions regarding pollution prevention, energy efficiency, reuse and recycling of materials, green building, and other environmental topics. Employees can also use the site to suggest P2 ideas, ask questions about P2 planning and implementation, and find out about P2 current events.

The P2 Program's Earth Hotline was merged into an EPD-wide Green Hotline in 2009. The Green Hotline provides support for employees with questions, suggestions, or ideas regarding LLNL's pollution prevention and waste diversion endeavors, as well as other environmental issues

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# 4. Air Monitoring Programs

*Kent Wilson • Nicholas A. Bertoldo • Steven Cerruti*

Lawrence Livermore National Laboratory performs continuous air sampling to evaluate its compliance with local, state, and federal laws and regulations and to ensure that human health and the environment are protected. Federal environmental air quality laws and U.S. DOE regulations include 40 CFR 61, Subpart H—the NESHAPs section of the Clean Air Act; applicable portions of DOE Order 5400.5; and ANSI standards. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) provides the guidance for implementing DOE Order 5400.5.

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

## 4.1 Air Effluent Monitoring

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

Currently, the air effluent sampling program measures only radiological emissions. For LLNL operations with nonradiological discharges, LLNL obtains permits from local air districts (i.e., BAAQMD and SJVAPCD) for stationary emission sources, and from the CARB for portable emission sources such as diesel air compressors and generators. Current permits do not require monitoring of air effluent but do require monitoring of equipment usage, material usage, and 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. Air Monitoring Programs

### 4.1.1 Air Effluent Radiological Monitoring Results and Impact on the Environment

In 2009, LLNL measured releases of radioactivity from air exhausts at five facilities at the Livermore site and at one facility at Site 300. Air effluent monitoring locations at the Livermore site and Site 300 are shown in **Figures 4-1** and **4-2**, respectively.

In 2009, a total of 618 GBq (16.7 Ci) of measured tritium was released from the Tritium Facility. Of this, approximately 544 GBq (14.7 Ci) of tritium was released as vapor (HTO). The remaining tritium released, 74 GBq (2.0 Ci), was gaseous tritium (HT).

The DWTF released a total of 1.7 GBq ($4.59 \times 10^{-2}$ Ci) of measured tritium from the stack exhaust. Approximately 85% of the tritium was released as vapor (HTO) and the remaining 15% as gaseous tritium (HT).

The Contained Firing Facility (CFF) at Site 300 had measured depleted uranium emissions in 2009. A total of $1.2 \times 10^{-6}$ GBq ($3.3 \times 10^{-8}$ Ci) of uranium-234, $6.7 \times 10^{-8}$ GBq ($1.8 \times 10^{-9}$ Ci) of uranium-235, and $2.0 \times 10^{-6}$ GBq ($5.4 \times 10^{-8}$ Ci) of uranium-238 was released in particulate form.

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

None of the other facilities monitored for radionuclides had reportable emissions in 2009. The data tables in **Appendix A, Section A.1** provide summary results of all air effluent monitored facilities and include upwind locations (control stations) for gross alpha and gross beta background comparison to stack effluent gross alpha and gross beta results.

The dose to the hypothetical, site-wide maximally exposed individual (SW-MEI) member of the public caused by the measured air emissions from the Tritium Facility (modeling HT emissions as HTO as required by EPA) was $1.5 \times 10^{-2}$ μSv/y ($1.5 \times 10^{-3}$ mrem/y); the dose from the DWTF (modeling HT emissions as HTO) was $1.3 \times 10^{-5}$ μSv/y ($1.3 \times 10^{-6}$ mrem/y); and the dose from the CFF was $2.7 \times 10^{-6}$ μSv/y ($2.7 \times 10^{-7}$ mrem/y).

All of the reported SW-MEI doses at the Livermore site and Site 300 are less than one-tenth of one percent of the annual NESHAPs standard, which is 100 μSv/y (10 mrem/y) total site effective dose equivalent. As shown in **Chapter 7**, the estimated radiological dose caused by measured air emissions from LLNL operations was minimal. See also the *LLNL NESHAPs 2009 Annual Report* (Bertoldo et al. 2010) for a complete description of air effluent monitoring.

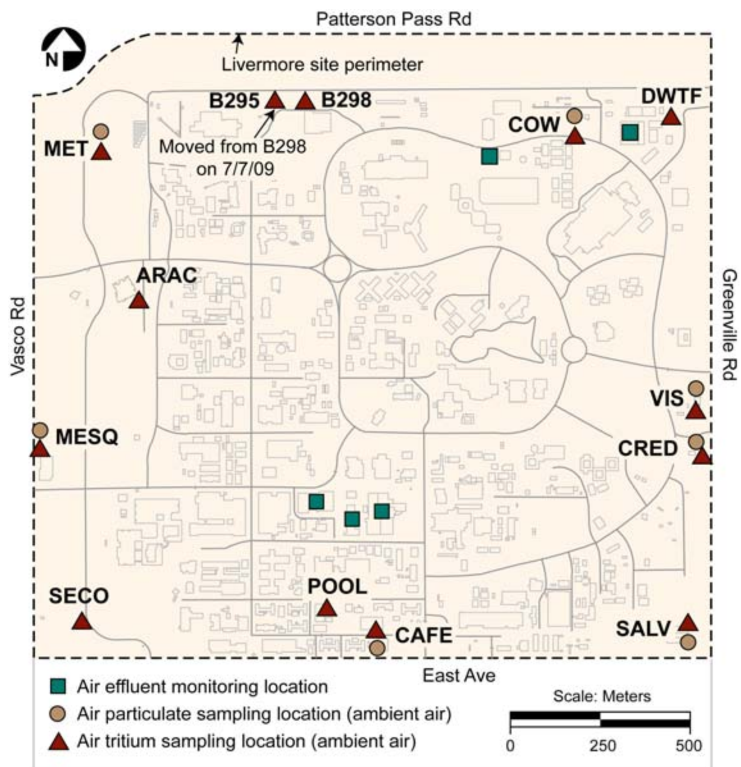


**Figure 4-1.** Air effluent and ambient air monitoring locations at the Livermore site, 2009.

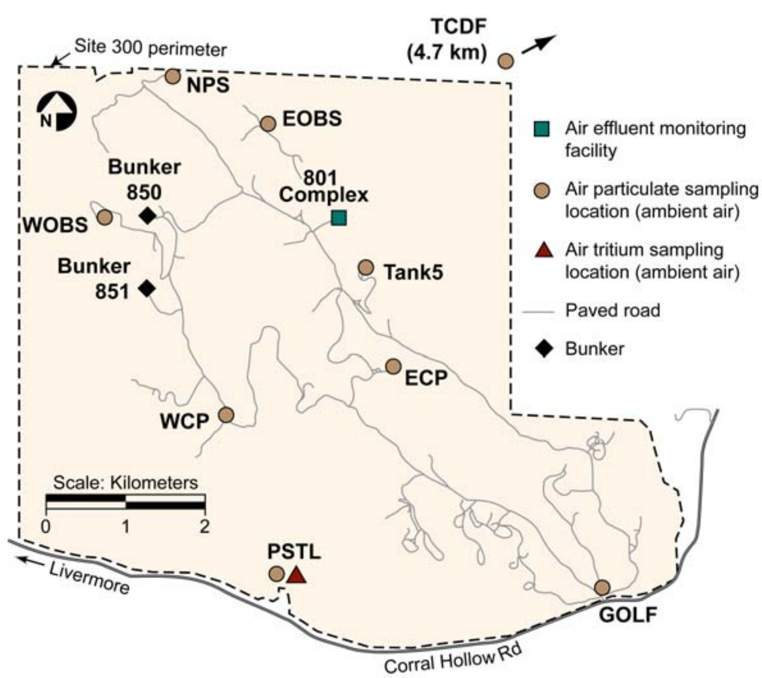


**Figure 4-2.** Air effluent and ambient air monitoring locations at Site 300, 2009.

### 4.1.2 Nonradiological Air Releases and Impact on the Environment

In 2009, the Livermore site emitted approximately 123 kg/d of regulated air pollutants as defined by the Clean Air Act, including nitrous oxides (NOx), sulphur 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, 2009.

| | Estimated releases (kg/d) | |
|---|---|---|
| **Pollutant** | **Livermore site** | **Site 300** |
| ROGs/POCs | 9.9 | 0.42 |
| Nitrogen oxides | 59.3 | 2.14 |
| Carbon monoxide | 46.8 | 0.46 |
| Particulates (PM-10) | 5.2 | 0.32 |
| Sulfur oxides | 1.5 | 0.17 |
| **Total** | 122.7 | 3.51 |

Livermore site air pollutant emissions were very low in 2009 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 $4.18 \times 10^5$ kg/d, compared to the estimated daily release from the Livermore site of 59.3 kg/d, which is 0.014% of total Bay Area source emissions for NOx. The 2009 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was $3.13 \times 10^5$ kg/d, while the daily emission estimate for 2009 from the Livermore site was 9.9 kg/d, or 0.003% of the total Bay Area source emissions for ROGs/POCs.

Certain operations at Site 300 require permits from the SJVAPCD. The estimated daily air pollutant emissions during 2009 from operations (permitted and exempt stationary sources) at Site 300 are listed in **Table 4-1**. The stationary emission sources that release the greatest amounts of regulated air pollutants at Site 300 include internal combustion engines (such as diesel-powered generators), a gasoline-dispensing facility, and general machine shop operations. Combustion pollutant emissions, such as NOx, CO, SOx, and PM 10, decreased in 2009 primarily from the reduced usage of diesel-powered generators.

## 4.2 Ambient Air Monitoring

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

The derived concentration guides (DCGs) in DOE Order 5400.5 specify the concentrations of a radionuclide that can be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public, which is 1 mSv/y (100 mrem/y) effective dose equivalent.

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

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

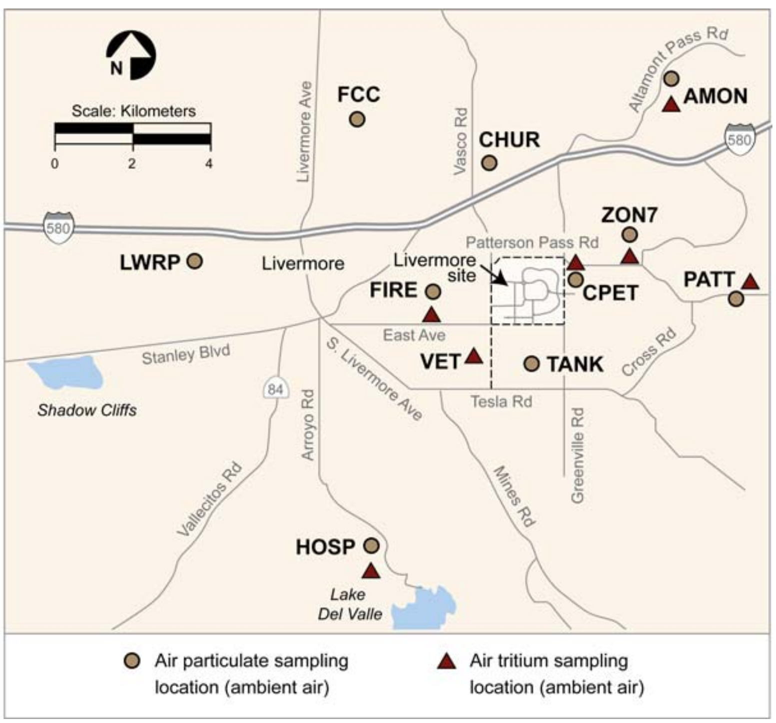


**Figure 4-3.** Air particulate and tritium monitoring locations in the Livermore Valley, 2009.

### 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 2009 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 17 out of 216 samples taken in 2009. 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. Plutonium-239+240 detections at Site 300 are calculated to be from resuspended fallout from historic aboveground nuclear testing. Site 300 does not use or store plutonium on site.

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

- Livermore site perimeter: 119 nBq/m$^3$ (3.2 aCi/m$^3$); 0.016% of the DCG
- Livermore off-site locations: 238 nBq/m$^3$ (6.4 aCi/m$^3$); 0.032% of the DCG
- Site 300 composite: 3.0 nBq/m$^3$ (0.081 aCi/m$^3$); 0.00041% of the DCG

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

Uranium-235 and uranium-238 were detected at all sample locations. Uranium ratios are used to determine the type of uranium present in the environment. Natural uranium has a mathematical uranium-235/uranium-238 ratio of 0.00725, and depleted uranium has a uranium-235/uranium-238 ratio of 0.002. Uranium isotopes are naturally occurring. The annual median uranium-235/uranium-238 isotopic ratios for 2009 were as follows:

- Livermore site perimeter composite: 0.0072
- Site 300 sample locations: 0.0071
- Site 300 off-site location: 0.0073

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 DCG as shown in **Appendix A**, **Section A.2**.

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

### 4.2.2 Ambient Air Tritium Concentrations

The biweekly air tritium data that are provided in **Appendix A**, **Section A.2** are summarized in **Table 4.2**. Area (diffuse) sources include stored containers of tritium waste or tritium-contaminated equipment from which HTO diffuses into the atmosphere.

Because HTO air concentrations observed at the Livermore site sample locations are very low, the concentrations at remote sample locations are readily predicted to be below the minimum detectable concentration (MDC). However, some samples from these remote locations yielded results greater than the MDC. These results are attributed to the inability to discriminate between a true signal and a background signal in the observed data.

**Table 4-2.** Air tritium sampling summary for 2009.

| Sampling locations | Detection frequency | Concentration ($mBq/m^3$) | | | | Median % DCG[(a)] | Dose (nSv) |
|---|---|---|---|---|---|---|---|
| | | Mean | Median | IQR | Maximum | | |
| Livermore site perimeter | 277 of 310 | 88.1 | 44.0 | 43.0 | 3160 | 0.0012% | 18.6 |
| Livermore Valley | 115 of 181 | 26.1 | 18.7 | 21.6 | 315 | 0.00051% | 5.50 |
| Site 300 | 9 of 25 | 6.42 | 5.11 | 11.1 | 32.7 | 0.00014% | 1.35 |

(a) DCG = derived concentration guide of $3.7 \times 10^6$ $mBq/m^3$ for tritium in air.

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

### 4.2.3 Ambient Air Beryllium Concentrations

LLNL measures the monthly concentrations of airborne beryllium at the Livermore site, Site 300, and at the off-site sampler northeast of Site 300. The highest value recorded at the Livermore site perimeter in 2009 for airborne beryllium was 16 $pg/m^3$. This value is only 0.16% 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 2009 was 11 $pg/m^3$ and the highest value at the off-site location was 12 $pg/m^3$. These data are similar to data collected from previous years.

### 4.2.4 Impact of Ambient Air Releases on the Environment

LLNL operations involving radioactive materials had minimal impact on ambient air during 2009. The measured radionuclide particulate and tritium concentrations in air at the Livermore site and Site 300 were all less than one-tenth of one percent of the DOE primary radiation protection standard for the public (DCG).

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

# 5. Water Monitoring Programs

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

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

## 5.1 Sanitary Sewer Effluent Monitoring

In 2009, the Livermore site discharged an average of 0.90 million L/d (238,266 gal/d) of wastewater to the City of Livermore sewer system, or 3.3% of the total flow into the City's system. This volume includes wastewater generated by Sandia/California and a very small quantity from Site 300. In 2009, Sandia/California generated approximately 18.8% of the total effluent discharged from the Livermore outfall. Wastewater from Sandia/California and Site 300 is discharged to the LLNL collection system and combined with LLNL sewage before it is released at a single point to the municipal collection system.

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

### 5.1.1 Livermore Site Sanitary Sewer Monitoring Complex

LLNL's sanitary sewer discharge permit (Permit 1250, 2008/2009 and 2009/2010) requires continuous monitoring of the effluent flow rate and pH. Samplers at the Sewer Monitoring Station (SMS) collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, total toxic organics, and other water-quality parameters.

### *5.1.1.1 Radiological Monitoring Results*

DOE orders and federal regulations establish the standards of operation at LLNL (see **Chapter 2**), including the standards for sanitary sewer discharges. Primarily the standards for radioactive material releases are contained in complementary (rather than overlapping) sections of the DOE Order 5400.5 and 10 CFR Part 20.

For sanitary sewer discharges, DOE Order 5400.5 provides the criteria DOE has established for the application of best available technology to protect public health and minimize degradation of the environment. These criteria (the DCGs) limit the concentration of each radionuclide discharged to publicly owned treatment works. If the measured monthly average concentration of a radioisotope exceeds its concentration limit, LLNL is required to improve discharge control measures until concentrations are again below the DOE limits.

The 10 CFR Part 20 sanitary sewer discharge numerical limits include the following annual discharge limits for radioactivity: tritium, 185 GBq (5 Ci); carbon-14, 37 GBq (1 Ci); and all other radionuclides combined, 37 GBq (1 Ci). The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq [5 Ci]) takes precedence over the DOE Order 5400.5 concentration-based limit for tritium for facilities that generate wastewater in large volumes, such as LLNL. In addition to complying with the 10 CFR Part 20 annual mass-based discharge limit for tritium and the DOE monthly concentration-based discharge limit for tritium, LLNL also complies with the daily effluent concentration-based discharge limit for tritium established by WRD for LLNL. The WRD limit is smaller by a factor of 30 than the DOE monthly limit so the limits are therefore essentially equivalent; however, the WRD limit is more stringent in the sense that it is daily rather than monthly. 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 2009 combined release of alpha and beta sources was 0.21 GBq (0.006 Ci), which is 0.6% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The tritium total was 1.01 GBq (0.03 Ci), which is 0.6 % of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

**Table 5-1.** Estimated total radioactivity in LLNL sanitary sewer effluent, 2009.

| Radioactivity | Estimate based on effluent activity (GBq) | Limit of sensitivity (GBq) |
|---|---|---|
| Tritium | 1.01 | 0.73 |
| Gross alpha | 0.002 | 0.04 |
| Gross beta | 0.21 | 0.06 |

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 0.07 Bq/mL (1.94 pCi/mL) was far below the permit discharge limit of 12 Bq/mL (333 pCi/mL).

Measured concentrations of cesium-137 and plutonium-239 in the sanitary sewer effluent from LLNL, the LWRP, and in LWRP sludge are reported in the LLNL February 2010 Report (Jones 2010). Cesium and plutonium results are from monthly composite samples of LLNL and LWRP effluent and from quarterly composites of LWRP sludge. For 2009, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCGs. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The highest plutonium concentration observed in 2009 sludge is 2.74 mBq/g (0.074 pCi/g), which is many times lower than the National Council on Radiation Protection and Measurements (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for commercial or industrial property.

The historical levels for plutonium-239 observed in effluent since 1999 averaged approximately 1 µBq/mL ($3 \times 10^{-5}$ pCi/mL). The historical levels are generally 0.0003% of the DOE DCG for plutonium-239. The highest plutonium and cesium concentrations are well below DOE DCGs.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-2** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2009, a total of 1.02 GBq (0.03 Ci) of tritium was discharged to the sanitary sewer, an amount that is well within environmental protection standards and is comparable to the amounts discharged during the past 20 years.

**Table 5-2.** Historical radioactive liquid effluent releases from the Livermore site, 1999–2009[a]

| Year | Tritium (GBq) | Plutonium-239 (GBq) |
|---|---|---|
| 1999 | 7.1 | $0.68 \times 10^{-4}$ |
| 2000 | 5.0 | $0.96 \times 10^{-4}$ |
| 2001 | 4.9 | $1.1 \times 10^{-4}$ |
| 2002 | 0.74 | $0.42 \times 10^{-4}$ |
| 2003 | 1.11 | $0.51 \times 10^{-4}$ |
| 2004 | 1.34 | $1.16 \times 10^{-5}$ |
| 2005 | 3.12 | $9.64 \times 10^{-6}$ |
| 2006 | 19.9 | $7.56 \times 10^{-6}$ |
| 2007 | 2.83 | $6.24 \times 10^{-6}$ |
| 2008 | 0.83 | $5.52 \times 10^{-6}$ |
| 2009 | 1.01 | $5.93 \times 10^{-6}$ |

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

#### *5.1.1.2 Nonradiological Monitoring Results*

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

A summary of the analytical results from the permit-specified monthly and weekly composite sampling programs is presented in **Table 5-3**. The permit also requires that grab samples of effluent be collected on a monthly and semiannual basis, and analyzed for total toxic organic (TTO) compounds and cyanide, respectively. (Complete results from LLNL's 2009 sanitary sewer effluent monitoring program are provided in **Appendix A**, **Section A.3**.)

During 2009, concentrations of the regulated metals show generally good agreement between the monthly composite samples and the corresponding weekly composite samples, and these results closely resemble the 2008 results. In **Table 5-3**, the 2009 maximum concentration for each metal is shown and compared with the EPL. These maximum values did not exceed 10% of their respective EPLs for seven of the nine regulated metals. Arsenic, with maximum values of 15% and 67% of its EPL (monthly and weekly composite concentrations, respectively) and copper, with maximum values that were 11% of its EPL for both monthly and weekly composite concentrations, were comparable to 2008 results. All of the monthly 24-hour composite and weekly composite samples were in compliance with LLNL's wastewater discharge permit limits.

**Figure 5-1** presents historical trends for the monthly 24-hour composite sample results from 2002 through 2009 for eight of the nine regulated metals; cadmium is not presented because this metal was not detected above the practical quantitation limit (PQL) in any of the 2002 through 2009 monthly sampling events. (Typical PQLs for the regulated metals in LLNL sanitary effluent are shown in **Table 5-3**.) The 2009 results routinely show concentrations of arsenic, copper, lead, and zinc at levels above their respective PQLs; nickel showed only one detection above its PQL. These observations are generally consistent with the 2001 through 2004 data; however, with the exception of arsenic, the concentrations of those metals detected in 2005 through 2009 have shown an overall downward trend. The range of monthly 24-hour composite concentrations reported for arsenic in 2009, although never exceeding 15% of its EPL, has not shown a similar downward trend. Note the maximum weekly value for arsenic was 67% of EPL. Analysis of the daily archive samples for this week do not support this value. Sediment contamination is the probable cause for the above average weekly arsenic value.

**Table 5-3.** Summary of analytical results for permit-specified composite sampling of the LLNL sanitary sewer effluent, 2009.

| Sample | Parameter | Detection frequency[(a)] | PQL[(b)] | EPL[(c)] | Minimum | Maximum | Median | Maximum % of EPL |
|---|---|---|---|---|---|---|---|---|
| **Monthly 24-hour Composite** | **Oxygen demand (mg/L)** | | | | | | | |
| | Biochemical oxygen demand | 12 of 12 | 2 | None Specified | 59 | 140 | 86 | N/A |
| | **Solids (mg/L)** | | | | | | | |
| | Total dissolved solids | 12 of 12 | 1 | None Specified | 190 | 890 | 255 | N/A |
| | Total suspended solids | 12 of 12 | 1 | None Specified | 38 | 84 | 69 | N/A |
| | **Total metals (mg/L)** | | | | | | | |
| | Silver | 0 of 12 | 0.010 | 0.20 | <0.01 | <0.01 | <0.01 | <5.0 |
| | Arsenic | 11 of 12 | 0.0020 | 0.06 | <0.002 | 0.0087 | 0.0034 | 15 |
| | Cadmium | 0 of 12 | 0.0050 | 0.14 | <0.005 | <0.005 | <0.005 | <3.6 |
| | Chromium | 0 of 12 | 0.010 | 0.62 | <0.01 | <0.01 | <0.01 | <1.6 |
| | Copper | 12 of 12 | 0.010 | 1.0 | 0.027 | 0.11 | 0.045 | 11 |
| | Mercury | 0 of 12 | 0.00020 | 0.01 | <0.0002 | <0.0002 | <0.0002 | <2.0 |
| | Nickel | 0 of 12 | 0.0050 | 0.61 | <0.005 | <0.005 | <0.005 | <0.8 |
| | Lead | 7 of 12 | 0.0020 | 0.20 | <0.002 | 0.013 | .0025 | 6.5 |
| | Zinc | 12 of 12 | 0.050 | 3.00 | 0.070 | 0.12 | 0.089 | 4.0 |
| **Weekly Composite** | **Total metals (mg/L)** | | | | | | | |
| | Silver | 0 of 52 | 0.010 | 0.20 | <0.01 | <0.01 | <0.01 | <5.0 |
| | Arsenic | 44 of 52 | 0.0020 | 0.06 | <0.002 | 0.040 | 0.0028 | 67 |
| | Cadmium | 0 of 52 | 0.0050 | 0.14 | <0.005 | <0.005 | <0.005 | <3.6 |
| | Chromium | 1 of 52 | 0.010 | 0.62 | <0.01 | 0.13 | <0.01 | 2.1 |
| | Copper | 51 of 52 | 0.010 | 1.0 | <0.010 | 0.11 | 0.030 | 11 |
| | Mercury | 2 of 52 | 0.00020 | 0.01 | <0.0002 | 0.00022 | <0.0002 | 2.2 |
| | Nickel | 4 of 52 | 0.0050 | 0.61 | <0.005 | 0.010 | <0.005 | 1.6 |
| | Lead | 26 of 52 | 0.0020 | 0.20 | <0.002 | 0.031 | <0.002 | 16 |
| | Zinc | 43 of 52 | 0.050 | 3.00 | <0.05 | 0.064 | 0.024 | 8.3 |

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

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

(c) EPL = Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2008/2009 and 2009/2010).

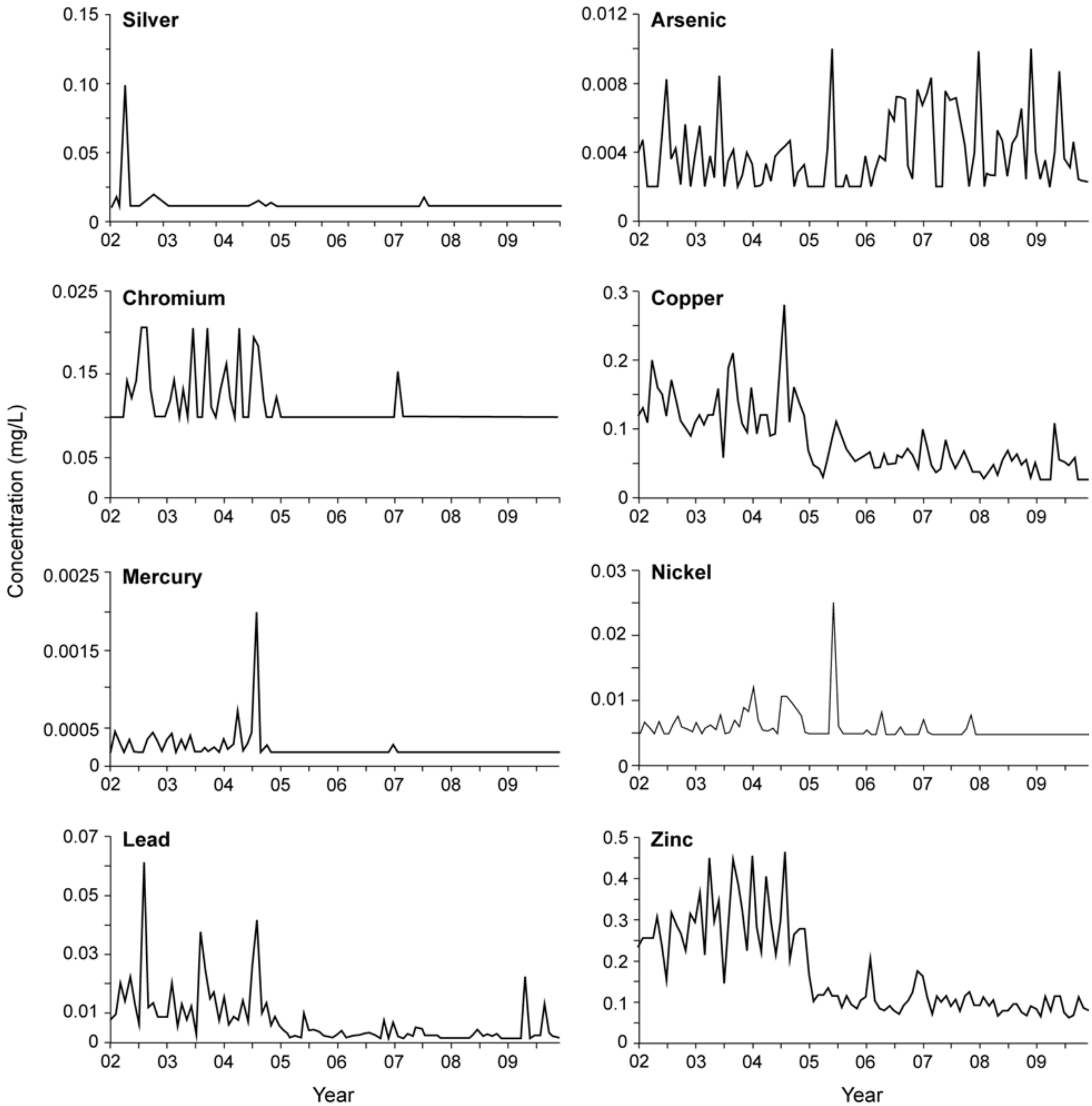


**Figure 5-1.** Monthly 24-hour composite sample concentrations for eight of the nine regulated metals in LLNL sanitary sewer effluent showing historical trends

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 2009, LLNL did not exceed either of these discharge limits. Results from the monthly TTO analyses for 2009 show that no priority pollutants, listed by the EPA as toxic organics, were identified in LLNL effluent above the 10 µg/L permit-specified reporting limit. As shown in **Appendix A**, **<u>Section A.3</u>**, one non-regulated organic compound, acetone, was identified in monthly grab samples at concentrations above the 10 µg/L permit-specified reporting limit. Cyanide was below the analytical detection limit in April (<0.02 mg/L) and October (<0.03 mg/L).

### 5.1.2 Categorical Processes

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

The processes at LLNL that are defined as categorical change as programmatic requirements dictate. During 2009, 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 2009, 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 2009, LLNL analyzed compliance samples for all regulated parameters from both processes and demonstrated compliance with all federal categorical discharge limits. As a further environmental safeguard, LLNL sampled the wastewater in each categorical wastewater tank prior to each discharge to the sanitary sewer. These monitoring data were reported to the WRD in July 2009 and January 2010 semiannual wastewater reports (Grayson et al. 2009, 2010).

The remaining 12 processes, which do not discharge wastewater to the sanitary sewer, are regulated under 40 CFR Part 433. Wastewater from these processes is either recycled or contained for eventual removal and appropriate disposal by RHWM. Because the processes do not discharge directly or indirectly to the sanitary sewer, they are not subject to the monitoring and reporting requirements contained in the applicable standard. (See Grayson et al. 2008, 2009).

As required in LLNL's wastewater discharge permit, LLNL demonstrated compliance with permit requirements by semiannual sampling and reporting in 2009. In addition, WRD source control staff performed their required annual inspection and sampling of the two discharging categorical processes in September 2009. The compliance samples were analyzed for all regulated parameters, and the results demonstrated compliance with all federal and local pretreatment limits.

### 5.1.3 Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2009–2010) allows treated groundwater from the Livermore site GWP to be discharged in the City of Livermore sanitary sewer system (see **Chapter 8** for more information on the GWP). During 2009, a total of 13,900 L (3676 gal) of treated groundwater were discharged to the sanitary sewer. This entire volume was associated with GWP sampling operations at well W-404. LLNL did not discharge groundwater from any other location to the sanitary sewer during 2009. All discharges were in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in Revelli (2010a).

### 5.1.4 Environmental Impact of Sanitary Sewer Effluent

During 2009, 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 2009 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 from the influent to the sewage evaporation pond, within the sewage evaporation pond, and flow to the sewage percolation pond were obtained in accordance with the written, standardized procedures summarized in Gallegos (2009).

### 5.2.1 Sewage Evaporation and Percolation Ponds

Sanitary effluent (nonhazardous wastewater) generated at buildings in the General Services Area at Site 300 is disposed of through a lined evaporation pond. However, during winter rains, treated wastewater may discharge into an unlined percolation pond where it enters the ground and the shallow groundwater. Although this potential exists, it did not occur during 2009.

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. This new WDR puts in place new monitoring requirements for additional systems at Site 300. LLNL implemented the elements of MRP R5-2008-0148 beginning fourth quarter 2008. In addition, a revised Monitoring and Reporting Program (MRP) was issued on November 23, 2009, and will be initiated in the following year.

Under the terms of WDR R5-2008-0148, LLNL submits semiannual and annual monitoring reports regarding not only discharges of domestic and wastewater effluent to the sewage evaporation and percolation ponds in the General Services Area, but also septic system groundwater monitoring at Buildings 812, 834, 850, and 899; cooling tower blow down to a septic system at Building 825; cooling tower blow down to percolation pits at Buildings 801, 809, 812, 817A, and 851; and septic systems and mechanical equipment discharges at Buildings 806, 827A, 827C, 827D, and 827E.

The monitoring data collected for the 2009 fourth quarter/annual report 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 (Grayson 2009).

## 5.3 Storm Water Compliance and Surveillance Monitoring

LLNL monitors storm water at the Livermore site in accordance with Permit WDR 95-174 (SFBRWQCB 1995) and at Site 300 in accordance with the California NPDES General Permit for Storm Water Discharges Associated with Industrial Activities (WDR 97-03-DWQ) (SWRCB 1997). Site 300 storm water monitoring also meets the requirements of the *Post-Closure Plan for the Pit 6 Landfill Operable Unit* (Ferry et al. 1998). For construction projects that disturb one acre of land or more, LLNL also meets storm water compliance monitoring requirements of the California NPDES General Permit for Storm Water Discharges Associated with Construction Activity (WDR 99-08-DWQ) (SWRCB 1999). Storm water monitoring at both sites also follows the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) and meets the applicable requirements of DOE Order 5400.5. **Appendix B** includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

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

### 5.3.1 LLNL Site-Specific Storm Water

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

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

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

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

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

(c) EPA benchmark

(d) California and EPA drinking water action level

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

### 5.3.2 Storm Water Inspections

Each principal directorate at LLNL conducts an annual inspection of its facilities to verify implementation of the Storm Water Pollution Prevention Plans (SWPPPs) and to ensure that measures to reduce pollutant discharges to storm water runoff are adequate. LLNL's principal associate directors certified in 2009 that their facilities complied with the provisions of LLNL's SWPPPs. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Revelli 2009a) and to the CVRWQCB (Revelli 2009b) with the results of sampling, observations, and inspections.

For each construction project permitted by WDR 99-08-DWQ, LLNL conducts visual monitoring of construction sites before, during, and after storms to assess the effectiveness of the best management practices. Annual compliance certifications summarize the inspections.

### 5.3.3 Livermore Site

The Livermore site storm water runoff monitoring network consists of nine sampling locations (see **Figure 5-2**). LLNL collected samples at all nine of these locations on three occasions during 2009; January 22 and February 17, 2009, for the two required storms of the 2008–2009 water year, and October 13, 2009, for the first required storm of the 2009–2010 water year. (The second storm of the 2009–2010 water year was sampled on February 23, 2010.) Fish toxicity tests (both acute and chronic) are typically performed using the runoff samples from the first storm of the water year and no issues were identified in either toxicity analysis performed on the samples from the January 22, 2009, storm. Similarly, there were no issues identified in the acute toxicity analysis on samples from the October 13, 2009 storm. Due to pathogen-related mortality in the control group, however, the contract laboratory was unable to run the chronic fish toxicity test using samples from this first storm of the 2009–2010 water year. LLNL collected samples from a subsequent storm (April 20, 2010) to fulfill the 2009–2010 water year requirement for chronic fish toxicity testing.

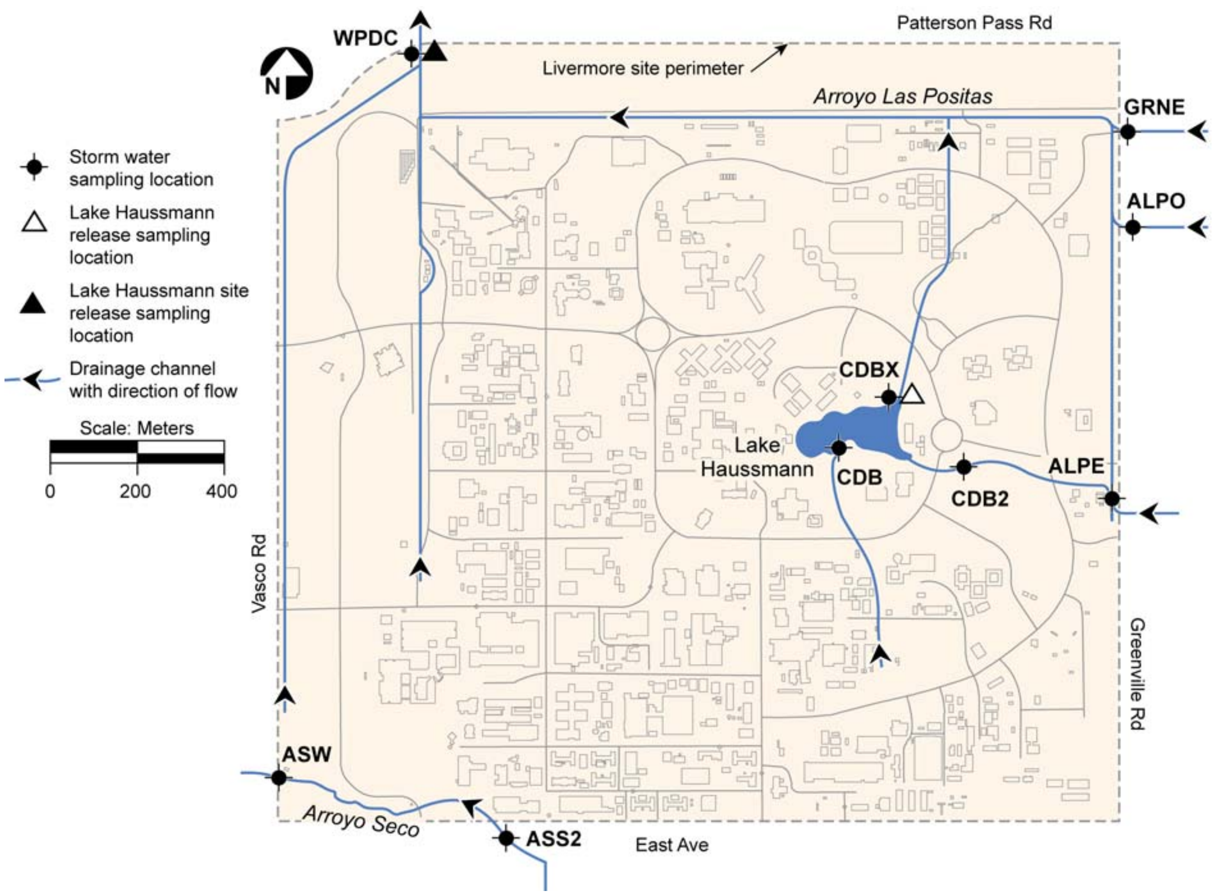


**Figure 5-2.** Storm water runoff and Lake Haussmann sampling locations, Livermore site, 2009.

### *5.3.3.1 Radiological Monitoring Results*

Storm water tritium, gross alpha, and gross beta results are summarized in **Table 5-5**. (Complete analytical results are provided in **Appendix A**, **Section A.4**.) Tritium activities at the site effluent sampling locations were less than 1% of the maximum contaminant level (MCL). Gross alpha and gross beta radioactivity in the effluent storm water samples collected during 2009 were also generally low, less than 60% and 12% of their MCLs, respectively. These tritium, gross alpha, and gross beta activities were all below their respective LLNL site-specific thresholds listed in **Table 5-4**.

LLNL began analyzing for plutonium in storm water in 1998. Current storm water sampling locations for plutonium are the Arroyo Seco and the Arroyo Las Positas effluent locations (ASW and WPDC, respectively). In 2009, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.10 pCi/L).

**Table 5-5.** Radioactivity in storm water from the Livermore site, 2009.[(a)]

| Parameter | Tritium (Bq/L) | Gross Alpha (Bq/L) | Gross Beta (Bq/L) |
|---|---|---|---|
| MCL | 740 | 0.555 | 1.85 |
| Influent | | | |
| Minimum | –2.9 | 0.002 | 0.015 |
| Maximum | 4.2 | 0.740 | 1.000 |
| Median | 1.2 | 0.061 | 0.190 |
| Effluent | | | |
| Minimum | –0.5 | 0.015 | 0.110 |
| Maximum | 6.0 | 0.330 | 0.210 |
| Median | 2.9 | 0.072 | 0.140 |

### *5.3.3.2 Nonradiological Monitoring Results*

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

Constituents that exceeded site-specific thresholds for effluent and/or influent storm water sampling locations are listed in **Table 5-6**. With the exception of the ASW effluent sample collected on October 13, 2009, all locations with water quality parameters above the site-specific thresholds for the Livermore site during 2009 were influent tributaries. Although the nitrate result for the October 13, 2009, ASW effluent sample was comparable to nitrate levels found in influent samples (ALPE and ALPO) collected on that same day, the source of the nitrate at ASW was attributed to the application of fertilizer to nearby lawns only a few weeks prior to this early season storm. The presence of diuron (an herbicide used for roadside vegetation management) in runoff flowing onto the LLNL site has been documented by Campbell et al. (2004). These results suggest that current operations at the Livermore site during 2009 did not impact the quality of storm water runoff.

**Table 5-6.** Water quality parameters in storm water runoff above LLNL site-specific thresholds, Livermore site in 2009.

| Radioactive/ Nonradioactive | Parameter | Date | Location | Influent / Effluent | Result | LLNL Threshold |
|---|---|---|---|---|---|---|
| **Radioactive** | Gross Alpha (Bq/L) | 1/22 | ALPE | Influent | 0.74 | 0.34 |
| | | 10/13 | ALPO | Influent | 0.44 | 0.34 |
| | | 10/13 | GRNE | Influent | 0.38 | 0.34 |
| | Gross Beta (Bq/L) | 10/13 | ALPO | Influent | 1.00 | 0.48 |
| | | 10/13 | GRNE | Influent | 0.53 | 0.48 |
| **Nonradioactive** | Diuron (µg/L) | 10/13 | ALPE | Influent | 100 | 14 |
| | | 10/13 | GRNE | Influent | 130 | 14 |
| | Lead (µg/L) | 2/17 | ALPE | Influent | 18 | 15 |
| | | 10/13 | ALPO | Influent | 17 | 15 |
| | Nitrate ($NO_3$) (mg/L) | 1/22 | ALPO | Influent | 12 | 10 |
| | | 1/22 | GRNE | Influent | 17 | 10 |
| | | 10/13 | ASW | Effluent | 15 | 10 |
| | | 10/13 | ALPE | Influent | 17 | 10 |
| | | 10/13 | ALPO | Influent | 12 | 10 |

### 5.3.4 Site 300

On three occasions during 2009 LLNL collected and analyzed samples from all locations that normally have storm water flow at Site 300. These sampling locations characterize runoff from on-site industrial activities (NLIN2, NPT7, and N883), an upstream off-site location (CARW2), and a downstream off-site location (GEOCRK) on the Corral Hollow Creek (**Figure 5-7**). No significant runoff was detected at two similar on-site sampling locations (NPT6 and N829). Sample collection dates were January 22 and February 17, 2009, for the two required storms of the 2008–2009 water year, and October 13, 2009, for the first required storm of the 2009–2010 water year. (The second storm of the 2009–2010 water year was sampled on February 9, 2010.)

#### *5.3.4.1 Radiological Monitoring Results*

In 2009, storm water sampling and analysis were performed for gross alpha and gross beta radioactivity, uranium isotopes, and tritium, and results were compared with the site-specific thresholds listed in **Table 5-4**. (Complete analytical results are provided in **Appendix A**, **Section A.4**.) No concentrations of tritium or gross beta radioactivity in the storm water samples collected from any location exceeded LLNL's site-specific thresholds. Gross alpha radioactivity, exceeding Site 300's threshold concentration, was detected in the October 13, 2009, storm water sample from the upstream location CARW2 at 1.5 Bq/L (40.5 pCi/L) (see **Table 5-7**). Previous environmental sampling has shown that suspended sediments from this area contain significant quantities of naturally occurring uranium and its daughter decay products that account for the elevated gross alpha and beta radioactivity.

**Table 5-7.** Water quality parameters in storm water runoff above LLNL site-specific thresholds, Site 300 in 2009.

| Radioactive/ Nonradioactive | Parameter | Date | Location | Upstream/, Downstream/ Effluent | Result | LLNL Threshold |
|---|---|---|---|---|---|---|
| **Radioactive** | Gross alpha (Bq/L) | 10/13/09 | CARW2 | Upstream | 1.5 | 0.90 |
| **Nonradioactive** | Beryllium (mg/L) | 2/17/09 | CARW2 | Upstream | 0.0080 | 0.0016 |
| | | 2/17/09 | NLIN2 | Effluent | 0.0029 | 0.0016 |
| | | 2/17/09 | GEOCRK | Downstream | 0.0040 | 0.0016 |
| | Lead (mg/L) | 2/17/09 | CARW2 | Upstream | 0.083 | 0.030 |
| | | 2/17/09 | GEOCRK | Downstream | 0.043 | 0.030 |
| | | 10/13/09 | N883 | Effluent | 0.290 | 0.030 |
| | Chemical oxygen demand (mg/L) | 2/17/09 | CARW2 | Upstream | 370 | 200 |
| | | 10/13/09 | N883 | Effluent | 440 | 200 |
| | | 10/13/09 | NLIN2 | Effluent | 430 | 200 |
| | Total suspended solids (mg/L) | 2/17/09 | CARW2 | Upstream | 3500 | 1700 |
| | | 2/17/09 | GEOCRK | Downstream | 2100 | 1700 |

#### *5.3.4.2 Nonradiological Monitoring Results*

Storm water samples collected at Site 300 in 2009 were analyzed for nonradiological water quality parameters, and sample results were compared with the site-specific thresholds listed in **Table 5-4**. Constituents that exceeded the thresholds for sampled locations are listed in **Table 5-7**. (Complete analytical results are provided in **Appendix A**, **Section A.4**.)

During the February 17, 2009, storm, concentrations of beryllium and lead collected from upstream location CARW2 and downstream location GEOCRK, and of beryllium collected from effluent location NLIN2 exceeded their respective Site 300 threshold comparison values. Also during this storm, the parameter TSS exceeded its site-specific threshold for the samples collected at CARW2 and GEOCRK and the TSS value at NLIN2 was elevated (but remained below the threshold value). High TSS concentrations are not unusual in large storms generating runoff in this area, and it is likely that the metals concentrations are associated with particulates carried in the storm water runoff. Lead was also reported above its site-specific threshold in the October 13, 2009, sample collected at location N883. However, this result (0.29 mg/L, which is almost one order of magnitude above the threshold value) does not appear to be representative because a duplicate quality control sample collected approximately fifteen minutes later showed a more typical concentration (0.0097 mg/L).

Three 2009 storm water samples from Site 300 showed chemical oxygen demand concentrations above the threshold value (200 mg/L); the CARW2 sample collected on February 17, 2009, and the N883 and NLIN2 samples both collected on October 13, 2009. The CARW2 sample represents upstream conditions and is not related to LLNL activities. As noted above, a duplicate sample (collected at the N883 location on October 13, 2009) suggests that the initial result may not be representative. The chemical oxygen demand value for the N883 initial sample was 440 mg/L, while the reported value for the N883 duplicate sample was 150 mg/L. In 2005, LLNL moved previous monitoring location NLIN upstream nearly 2 km to present location NLIN2 for logistical reasons to avoid delays in sample collection. The chemical oxygen demand concentrations reported for the NLIN2 location includes contributions from organic material, mobilized by runoff from a wetland area immediately upstream of this sample location.

As in the past, low concentrations of dioxins were detected in water samples from storm runoff at Site 300. The federal MCL for dioxin and furans (dioxin-like compounds) is for the most toxic congener 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (2,3,7,8-tetraCDD). The other dioxin and furan congeners have varying degrees of toxicity. EPA has assigned toxicity equivalency factors (TEFs) to specific dioxin and furan congeners. The congeners 2,3,7,8-tetraCDD and 1,2,3,7,8-pentaCDD have an assigned TEF of 1; the other dioxin and furan congeners have TEFs of <1. The toxicity equivalency (TEQ) is determined by multiplying the concentration of a dioxin and furan congener by its TEF. See **Appendix A**, **Section A.4**, for the concentrations of dioxin and furan compounds that have non-zero TEFs. To calculate the total TEQ for each sampling event at a given location, LLNL used the approach of multiplying the dioxin and furan congener concentrations by their respective TEFs, adding them together, and conservatively including those congeners reported to be less than their detection limits as half the reported detection limit. For the three runoff events sampled at Site 300 during 2009, the total TEQs are shown in **Table 5-8**. All dioxins detected were below the equivalent federal MCL of 30 pg/L. LLNL will continue to monitor storm water concentrations to determine whether trends are emerging.

**Table 5-8.** Dioxin-specific water quality parameters in storm water runoff

| Location | Total TEQ (pg/L) | | |
|---|---|---|---|
| | **January 22** | **February 17** | **October 13** |
| CARW2 | N/A (no flow) | 3.7 | 16.4 |
| NLIN2 | 2.2 | 27.1 | 8.5 |
| GEOCRK | 1.6 | 2.0 | 0.9 |

### 5.3.5 Environmental Impact of Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impact in 2009. Tritium activities in storm water runoff effluent were <1% of the drinking water MCL. Gross alpha and gross beta activities in effluent samples at the Livermore site were both less than their respective MCLs. Site 300 storm water monitoring continues to show low concentrations of dioxins.

## 5.4 Groundwater

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

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

The WDRs and post-closure plans specify wells and effluents 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 2009, representative samples of groundwater were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures* (Goodrich and Wimborough 2006). The procedures cover sampling techniques and information concerning the chemicals that are routinely analyzed for in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps or had to be bailed. All of the chemical and radioactivity analyses of groundwater samples were performed by California-certified analytical laboratories. For comparison purposes only, some of the results were compared with drinking water limits (MCLs).

### 5.4.1 Livermore Site and Environs

#### *5.4.1.1 Livermore Valley*

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. HTO is potentially the most mobile groundwater contaminant from LLNL operations. Groundwater samples were obtained during 2009 from 17 of 18 water wells in the Livermore Valley (see **Figure 5-3**) and measured for tritium activity. One well could not be sampled during 2009.

Tritium measurements of Livermore Valley groundwaters are provided in **Appendix A**, **Section A.5**. The measurements continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) MCL established for drinking water in California. The maximum tritium activity measured off site was in the groundwater at well 7C2, located about 7.2 km (4.5 mi) west of LLNL (see **Figure 5-3**). The measured activity there was 1.5 Bq/L (40.5 pCi/L) in 2009, less than 0.25% of the MCL, and below background activity (1.8 Bq/L, 48.6 pCi/L) associated with this measurement.

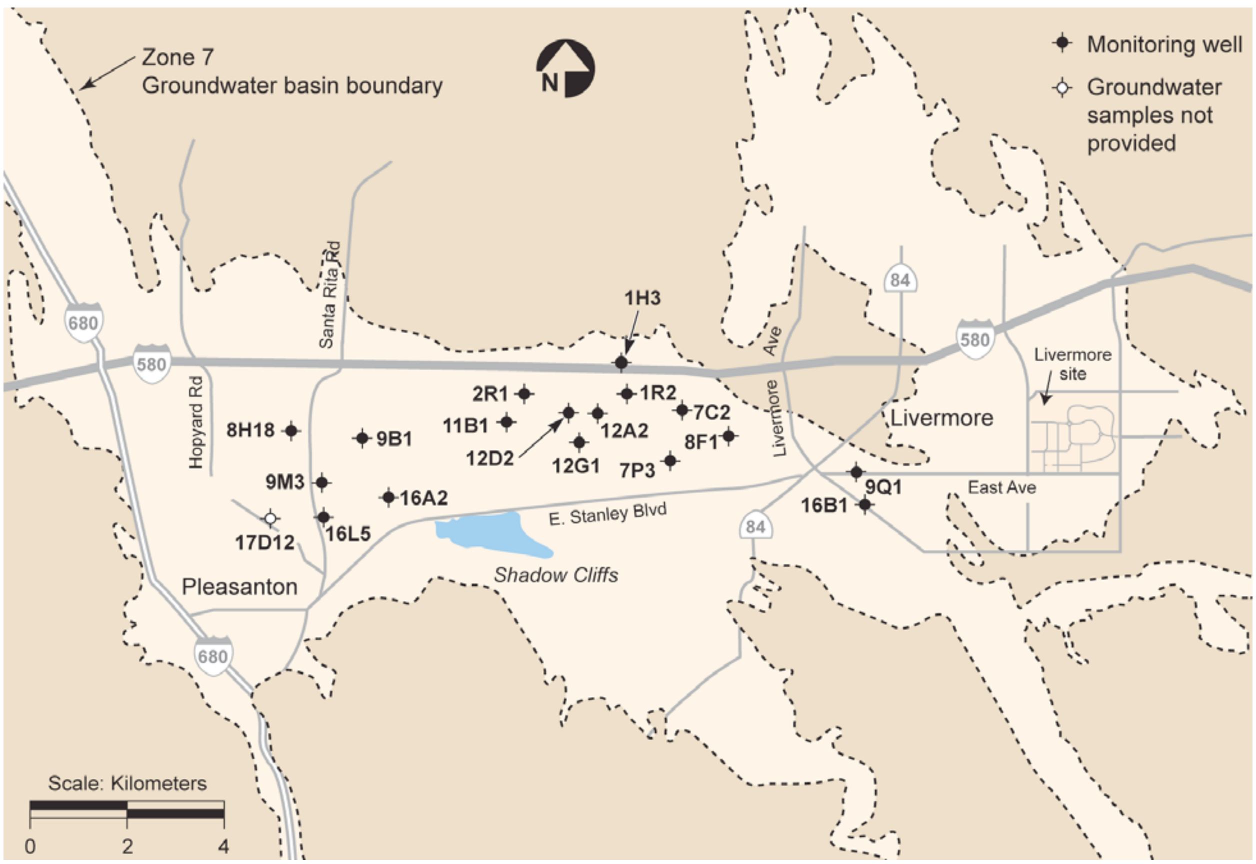


**Figure 5-3.** Off-site tritium monitoring wells in the Livermore Valley, 2009.

### *5.4.1.2 Livermore Site Perimeter*

LLNL's groundwater surveillance monitoring program was designed to complement the Livermore Site GWP (see **Chapter 8**). The intent of the program is to monitor for potential groundwater contamination from LLNL operations. The perimeter portion of the surveillance groundwater monitoring network uses three upgradient (background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven downgradient monitoring wells located near the western boundary (wells 14B1, W-121, W-151, W-1012, W-571, W-556, and W-373) (see **Figure 5-4**). As discussed in **Chapter 8**, the alluvial sediments have been divided into nine hydrostratigraphic units (HSUs) 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 2009 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 2009 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, the 2009 sample from this location showed a chromium(VI) concentration of 5 µg/L, continuing the overall downward trend that first dropped below the MCL in 2002. Groundwater samples collected in 2009 from the nearby wells W-556 and W-1012, also along the western perimeter of the LLNL site, both showed chromium(VI) concentrations of 17 µg/L.

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 concentrations detected in samples from this well during 2009 (32 and 29 mg/L) were again, as in the past four years, below the MCL. During 2009, concentrations of nitrate in on-site shallow background wells W-008 and W-221 were reported to be 29 mg/L and 31 mg/L, respectively. Detected concentrations of nitrate in western perimeter wells ranged from 29 mg/L (in well W-1012) to 41 mg/L (in well W-151).

During 2009, gross alpha, gross beta, radium-226, 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.

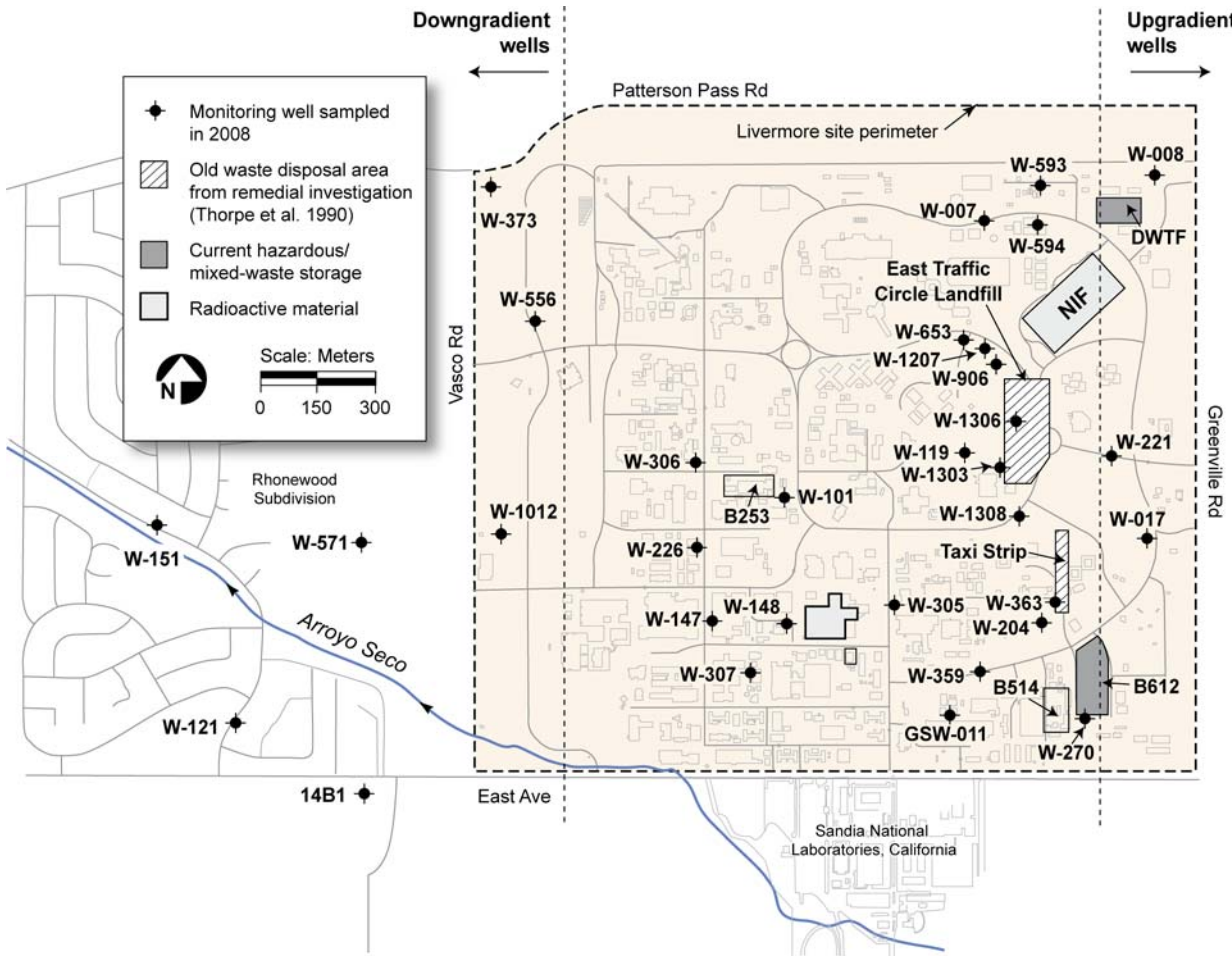


**Figure 5-4.** Routine surveillance groundwater monitoring wells at the Livermore site, 2009.

### *5.4.1.3 Livermore Site*

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past, where previously detected COCs have low concentrations that do not require CERCLA remedial action, and where baseline information needs to be gathered for the area near a new facility or operation. Wells selected for monitoring are screened in the uppermost aquifers and are downgradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 5-4**. All analytical results are provided in **Appendix A**, **Section A.5**.

The Taxi Strip and East Traffic Circle Landfill areas (see **Figure 5-4**) are two potential sources of historical groundwater contamination. Samples from monitoring wells screened in HSU-2 (W-204) and HSU-3A (W-363) downgradient from the Taxi Strip area were analyzed in 2009 for copper, lead, zinc, plutonium-238, plutonium-239+240, 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, plus radium-226 and radium-228. With one exception (discussed below), there were no concentrations of plutonium or radium radioisotopes detected above the radiological laboratory's minimum detectable activities. Only the plutonium-239+240 activity in a sample from well W-1303, collected in January 2009, was reported at a level above the minimum detectable activity. This result, however, remained below a comparable activity reported for these isotopes in a sample collected from this same location in March 2004. Concentrations of tritium remained well below the drinking water MCLs. None of the trace metals (copper, lead, zinc) were detected in any of these seven monitoring wells during 2009.

Although the National Ignition Facility (NIF) has not yet begun full operations, LLNL measures pH, conductivity, and tritium concentration of nearby groundwater to establish a baseline. During 2009, 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 2009 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 2009. 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 2009, groundwater from these wells was sampled and analyzed for gross alpha, gross beta, americium-241, plutonium-238, plutonium-239+240, and tritium. No significant contamination was detected in the groundwater samples collected downgradient from these areas in 2009.

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 2009, the monitoring results for well W-307 showed only slight variations from the concentrations reported in recent years.

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 2009, 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 last year.

Additional surveillance groundwater sampling locations, established in 1999, are in areas surrounding the Plutonium Facility and Tritium Facility. Potential contaminants include plutonium and tritium from these facilities, respectively. Plutonium is much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, can migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU-2; downgradient wells W-101, W-147, and W-148 are screened in HSU-1B. Groundwater samples collected from these wells during 2009 showed no detectable concentration, above the limit of sensitivity for the analytical method, of either plutonium-238 or plutonium-239+240.

In August 2000, elevated tritium activity was detected in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L [3100 ± 135 pCi/L]). The activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater in this area had remained at or near the same level through 2005, but samples collected from well W-148 in 2006, 2007, 2008, and 2009 have shown significantly lower values—a downward trend ranging from approximately one-half to one-third of the August 2000 value. LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that tritium and plutonium 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 2009 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 5-5**). Storm water runoff in the Elk Ravine drainage area collects in arroyos and quickly infiltrates into the ground. Groundwater from wells in the Elk Ravine drainage area is monitored for COCs to determine the impact of current LLNL operations on the system of underground flows that connects the entire Elk Ravine drainage area. The area contains eight closed landfills, known as Pits 1 through 5 and 7 through 9, and firing tables where explosives tests are conducted. None of these closed landfills has a liner, which is consistent with the disposal practices when the landfills were constructed. The following descriptions of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See **Chapter 8** for a review of groundwater monitoring in this drainage area conducted under CERCLA.)

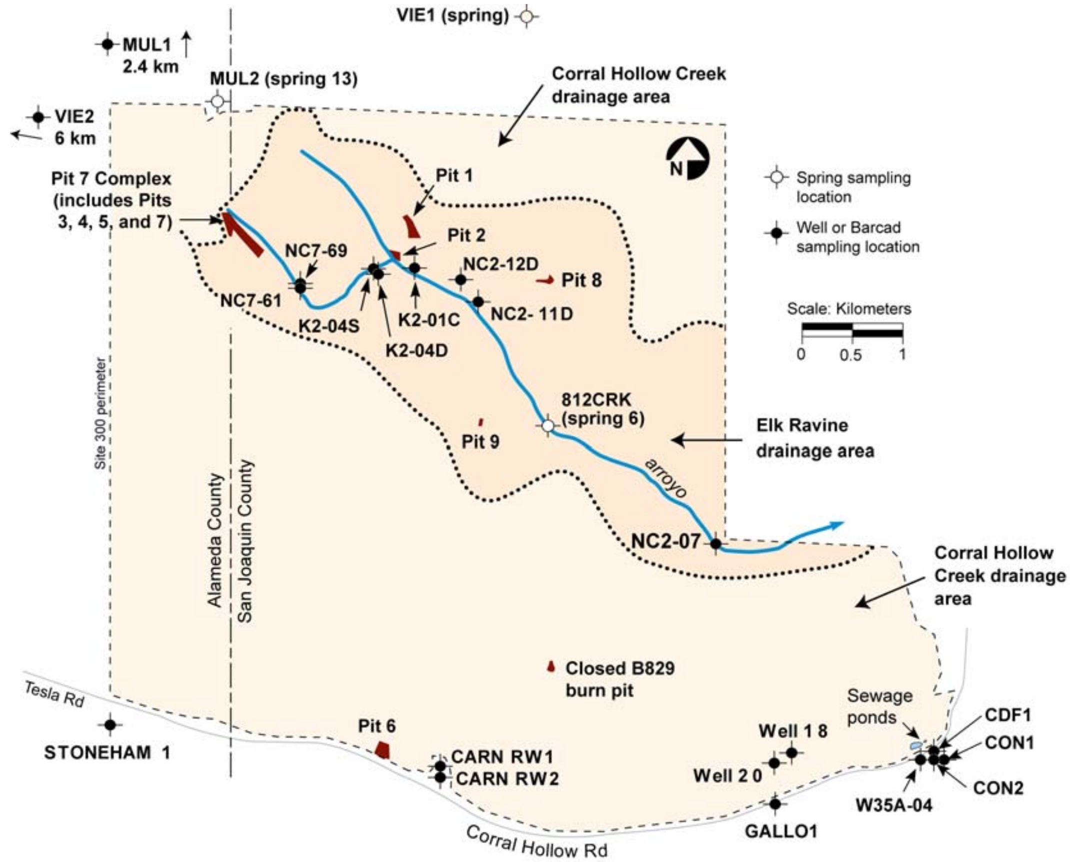


**Figure 5-5.** Surveillance groundwater wells and springs at Site 300, 2009.

***Pit 7 Complex.*** The Pit 7 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 in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990). The main objective of this monitoring is the early detection of any new release of COCs from Pit 7 to groundwater.

For compliance purposes, LLNL obtained groundwater samples quarterly during 2009 from the Pit 7 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. For a detailed account of Pit 7 compliance monitoring during 2009, including well locations and tables and graphs of groundwater COC analytical data, see Blake and MacQueen (2010).

***Elk Ravine.*** Groundwater samples were obtained on various dates in 2009 from the widespread Elk Ravine surveillance monitoring network shown in **Figure 5-5** (NC2-07, NC2-11D, NC2-12D, NC7-61, NC7-69, SPRING6 [812CRK], K2-04D, K2-04S, K2-01C). Samples from NC2-07 were analyzed for inorganic constituents (mostly metallic elements), general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX). Samples from the remaining wells were analyzed only for general radioactivity.

No new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2009. The major source of contaminated groundwater beneath Elk Ravine is from historical operations in the Building 850 firing table area (Webster-Scholten 1994; Taffet et al. 1996). Constituents that are measured as part of the Elk Ravine drainage area surveillance monitoring network are listed in **Appendix B**.

The results of tritium analysis for well NC7-61 were the same as 2008, with maximum values in both years of 1100 Bq/L. This tritium activity remains elevated with respect to the background concentrations. Tritium, as HTO, has been released in the past in the vicinity of Building 850. The majority of the Elk Ravine surveillance network tritium measurements made during 2009 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 all 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 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 2009 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 2009; a detailed account of Pit 1 compliance monitoring during 2009, including well locations and tables and graphs of groundwater COC analytical data, is in Blake and MacQueen (2010).

#### *5.4.2.2 Corral Hollow Creek Drainage Area*

***Pit 6.*** Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in Ferry et al. (1998, 2002). Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Plan (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Plan (CAMP), which monitors the movement and fate of historical releases. To comply with monitoring requirements, LLNL obtained groundwater samples monthly, quarterly, semiannually, and annually during 2009 from specified Pit 6 monitoring wells. No new releases were detected at Pit 6 in 2009. A detailed account of Pit 6 compliance monitoring during 2009, including well locations, tables of groundwater analytical data, and maps showing the distribution of COC plumes, is in Blake and Valett (2010).

***Building 829 Closed High Explosives Burn Facility.*** Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in Mathews and Taffet (1997), and in LLNL (2001), as modified by DTSC (2003). As planned for compliance purposes, LLNL obtained groundwater samples during 2009 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 2009, there were no confirmed COC detections above their respective statistical limits in groundwater samples from any of the Building 829 network monitoring wells. Among the inorganic constituents, perchlorate was not detected above its reporting limit in any sample. With the exception of barium in well W-892-15 (which remains below its statistical limit, but at a level approximately twice the originally calculated background concentration) and manganese in well W-829-1938 (which exhibits a low of approximately half the originally calculated background concentration), the metal COCs that were detected showed concentrations that are not significantly different from background concentrations for the deep aquifer beneath the High Explosives Process Area. There were no organic or explosive COCs detected above reporting limits in any samples. With one exception, all results for the radioactive COCs (gross alpha and gross beta) were below their statistical limit values. The gross beta activity in one sample from well W-829-1938 was initially reported to be above its statistical limit; however, this result was subsequently invalidated. For a detailed account of compliance monitoring of the closed burn pit during 2009, including well locations and tables and graphs of groundwater COC analytical data, see Revelli (2010b).

***Water Supply Well.*** Water supply well 20, located in the southeastern part of Site 300 (**Figure 5-5**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer (Tnbs1) and can produce up to 1500 L/min (396 gal/min) of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2009 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 2009 LLNL obtained groundwater samples from two off-site springs (MUL2 and VIE1) and ten off-site wells (MUL1, VIE2, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04) **(Figure 5-5)**. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at a private residence 6 km west of the site. It represents a typical potable water supply well in the Altamont Hills.

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

Groundwater samples were obtained once (annually) during 2009 from the remaining off-site surveillance monitoring locations: MUL1, MUL2, and VIE1 (north of Site 300); VIE2 (west of Site 300); and STONEHAM1, CON1, CDF1, and W-35A-04 (south of Site 300). Samples were analyzed for inorganic constituents (metals, nitrate, and perchlorate), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs, and extractable organic compounds (EPA Method 625).

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

## 5.5 Other Monitoring Programs

### 5.5.1 Rainwater

Rainwater is sampled and analyzed for tritium activity in support of DOE Order 5400.5. Rainwater is collected in rain gauges at fixed locations. The tritium activity of each sample is measured and all analytical results are provided in **Appendix A**, **Section A.7**.

#### 5.5.1.1 Livermore Site and Environs

Rain sampling locations are shown in **Figure 5-6**. During 2009, LLNL collected rainwater samples following all three rain events in the Livermore Valley. All of the rainwater sampling dates correspond to storm water runoff sampling. During 2009, no on-site measurement of tritium activity was above the MCL of 740 Bq/L (20,000 pCi/L) established by the EPA for drinking water. A 2007 internal analysis of the LLNL rain sampling network demonstrated that current discharges were not likely to produce activities greater than the analytical laboratory detection limit in rainwater beyond the Livermore site perimeter. In 2009, rain sampling continued at the same four locations on the Livermore site perimeter (see **Figure 5-6**) as in 2008. Some rainwater samples collected in calendar year 2009 showed maximum tritium activity greater than the minimum reporting limit of 3.7 Bq/L (100 Ci/L); this is consistent with historical values.

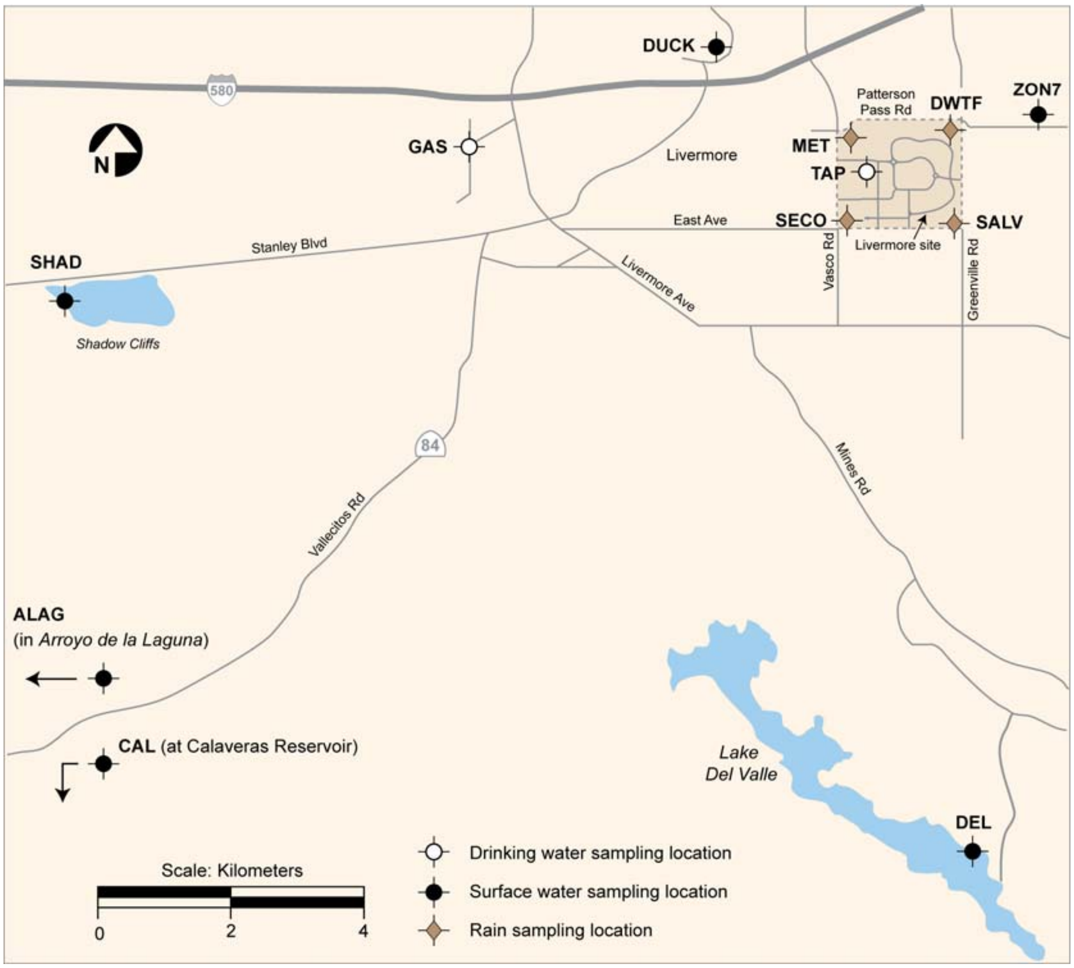


**Figure 5-6.** Livermore site and Livermore Valley sampling locations for rain, surface water, and drinking water, 2009.

### *5.5.1.2 Site 300 and Environs*

During 2009, LLNL positioned two rain gauges at on-site locations ECP and PSTL (see **Figure 5-7**) to collect rainfall to measure tritium activity at Site 300. Rainfall samples are collected at the same time storm water samples are collected. The maximum tritium activity measured in Site 300 rainwater samples during 2009 show values below the minimum reporting limit of 3.7 Bq/L (100 pCi/L) .

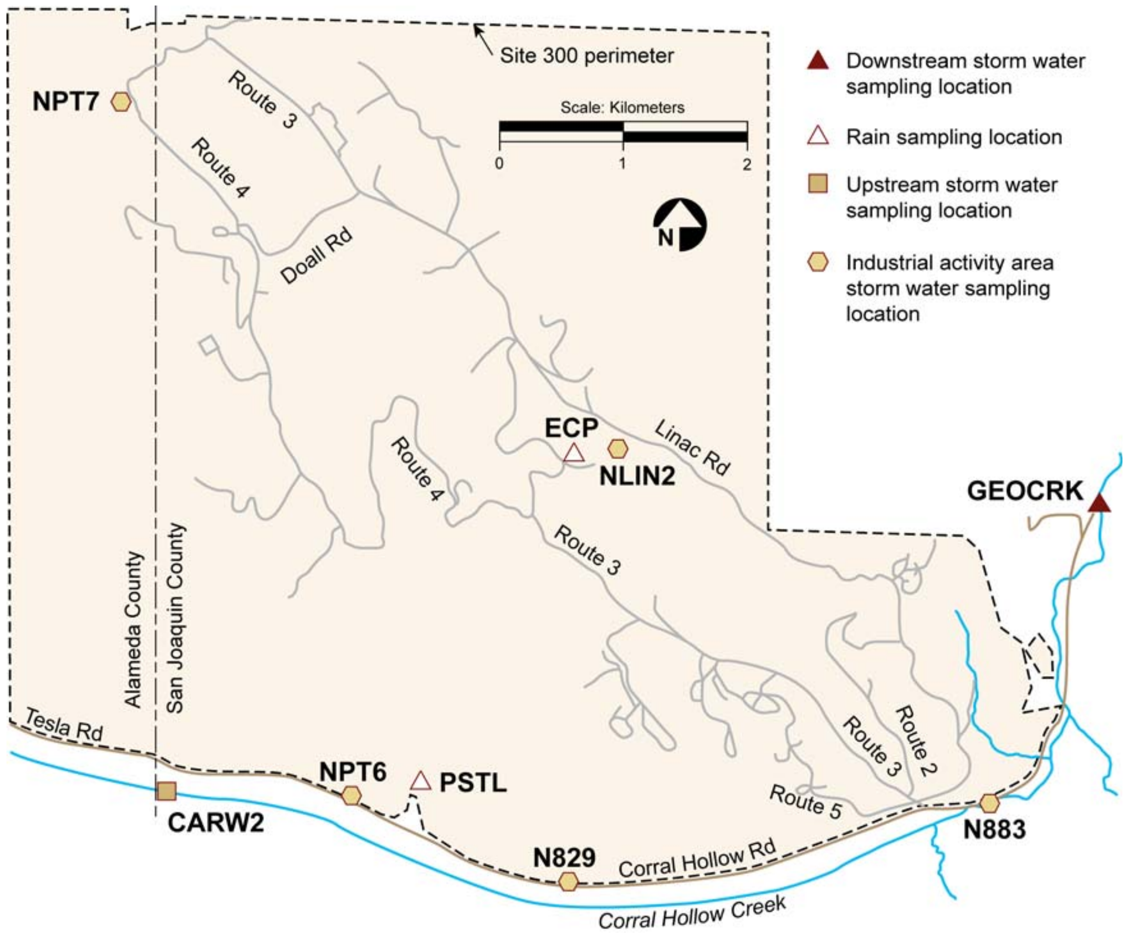


**Figure 5-7.** Storm water and rainwater sampling locations at Site 300, 2009.

### 5.5.2 Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5. Surface and drinking water near the Livermore site and in the Livermore Valley were sampled at the locations shown in **Figure 5-6** in 2009. Off-site sampling locations CAL, DEL, DUCK, ALAG, SHAD, and ZON7 are surface water bodies; of these, CAL, DEL, and ZON7 are also drinking water sources. GAS and TAP are drinking water outlets; radioactivity data from these two sources are used to calculate drinking water statistics (see **Table 5-9**).

Samples are analyzed according to written, standardized procedures summarized in Gallegos (2009). LLNL sampled the two drinking water outlets semiannually and the other locations annually in 2009. 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 2009 was 1.85 Bq/L (50 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. Maximum activities detected for gross alpha and gross beta radioactivity both occurred in samples collected at DUCK. Although DUCK is not a drinking water source sampling location, these maximum values (gross alpha at 0.233 Bq/L [6.30 pCi/L] and gross beta at 0.385 Bq/L [10.41 pCi/L]) were still less than 42% and 21% of their respective drinking water MCLs (see **Table 5-9**).

**Table 5-9.** Radioactivity in surface and drinking waters in the Livermore Valley, 2009.

| Location | Metric | Tritium (Bq/L)[a] | Gross alpha (Bq/L)[a] | Gross beta (Bq/L)[a] |
|---|---|---|---|---|
| All locations | Median | 0.00 | 0.017 | 0.088 |
| | Minimum | –0.77 | –0.010 | 0.003 |
| | Maximum | 1.85 | 0.233 | 0.385 |
| | Interquartile range | 0.79 | 0.057 | 0.041 |
| Drinking water outlet locations | Median | 1.01 | 0.016 | 0.057 |
| | Minimum | –0.08 | –0.010 | 0.003 |
| | Maximum | 1.85 | 0.072 | 0.097 |
| | Drinking water MCL | 740 | 0.555 | 1.85 |

(a) A negative number means the sample radioactivity was less than the background radioactivity. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

### 5.5.3 Lake Haussmann Release

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

The only limit exceeded for samples collected at CDBX and WPDC was the pH discharge limit of 8.5. Dry season and wet season pH has averaged 9.3 and 8.3, respectively, since 1992. The higher pH readings seen in Lake Haussmann discharge samples during the dry season correspond to the peak of the summer algal bloom (i.e., increased photosynthesis) within Lake Haussmann. While some metals were detected, no metals were above discharge limits. All organics and PCBs were below analytical detection limits. Pesticides, gross alpha, gross beta, and tritium levels were well below discharge limits, and acute and chronic toxicity tests were above minimum limits.

### 5.5.4 Site 300 Drinking Water System Discharges

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

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

Complete monitoring results from 2009 are detailed in the quarterly self-monitoring reports to the CVRWQCB. During the third quarter of 2009, 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. At each location the monitored parameters were in compliance with the effluent limits. All 2009 releases from the Site 300 drinking water system quickly percolated into the drainage ditches or streambed and did not reach Corral Hollow Creek, the potential receiving water.

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# 6. Terrestrial Monitoring

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*Lisa Paterson • Anthony M. Wegrecki • Jim Woollett*

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

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

Terrestrial pathways from LLNL operations leading to potential radiological dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air. Wine is the most important agricultural product in the Livermore Valley, representing a multi-million dollar annual industry, based on sales, and is sampled annually for tritium analysis. Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground-level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota (see **Chapter 7**) is calculated using a screening model that requires knowledge of radionuclide concentrations in soils and surface water.

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

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

## 6.1 Soil Monitoring

The number of soil sampling locations are 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**)

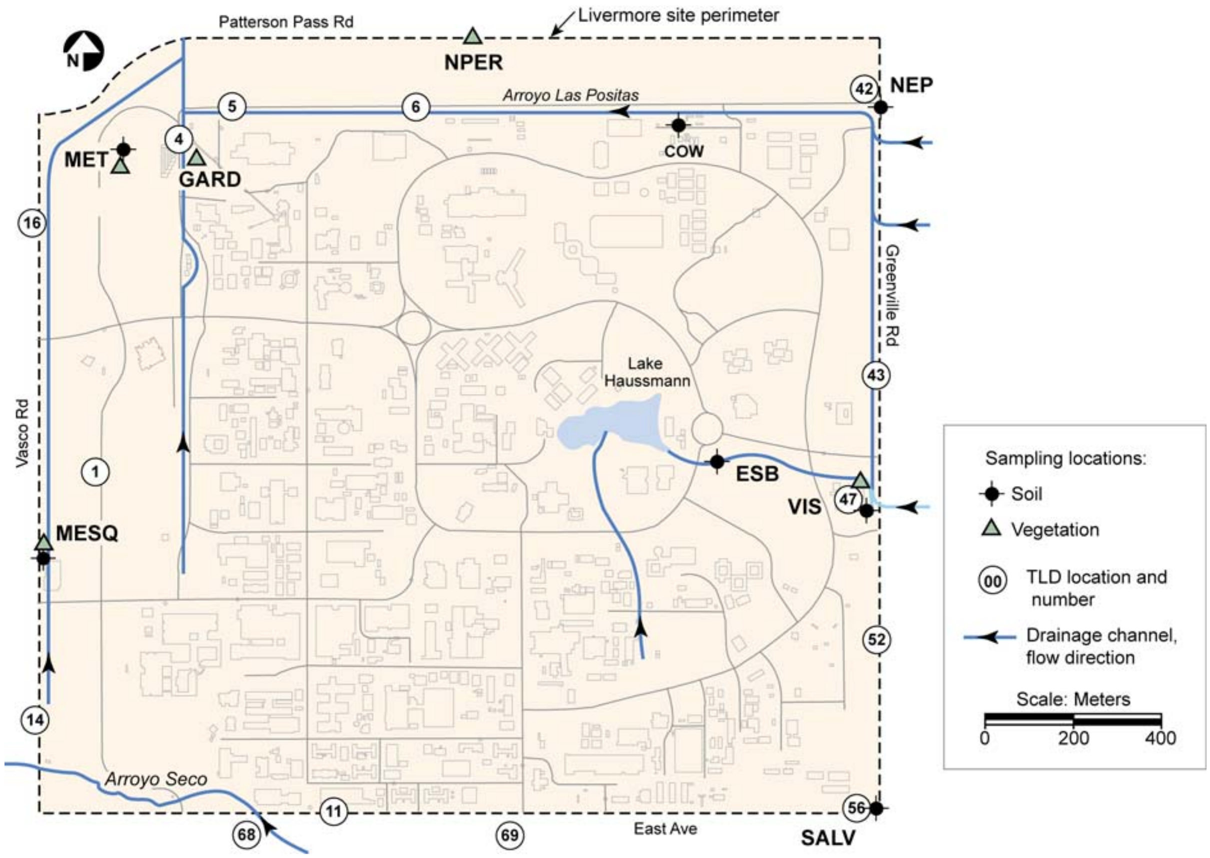


**Figure 6-1.** Soil and vegetation sampling locations and TLD locations, Livermore site, 2009.

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

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

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

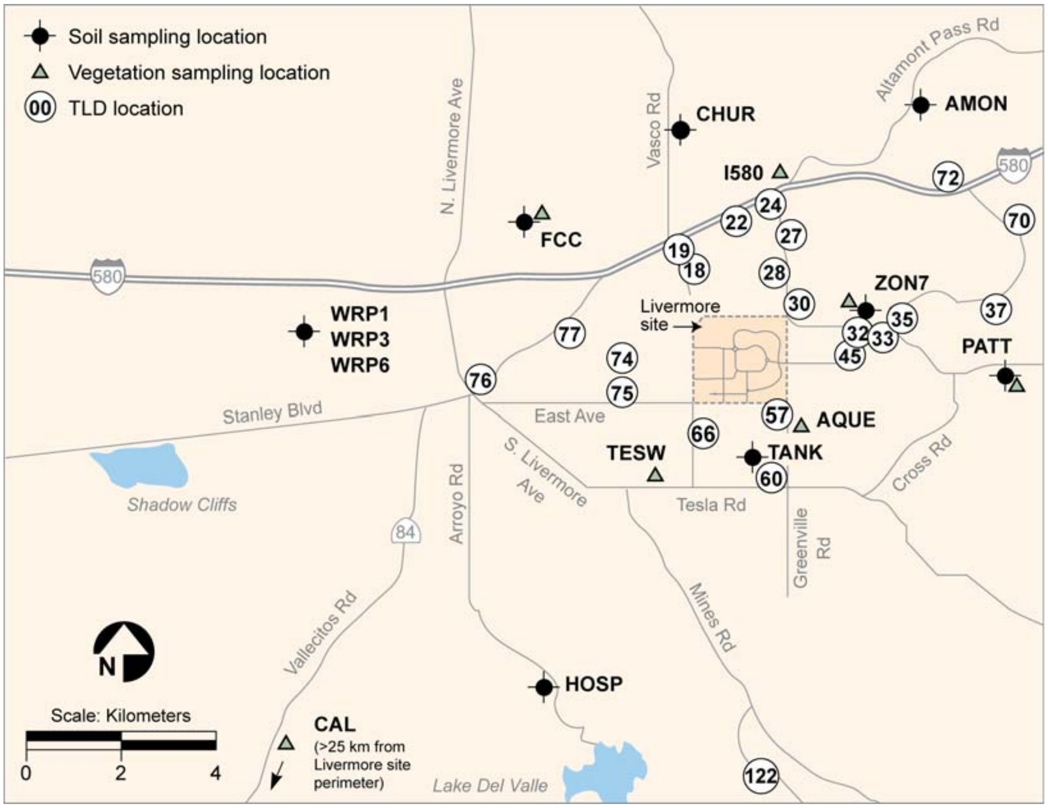


**Figure 6-2.** Soil and vegetation sampling locations and TLD locations, Livermore Valley, 2009.

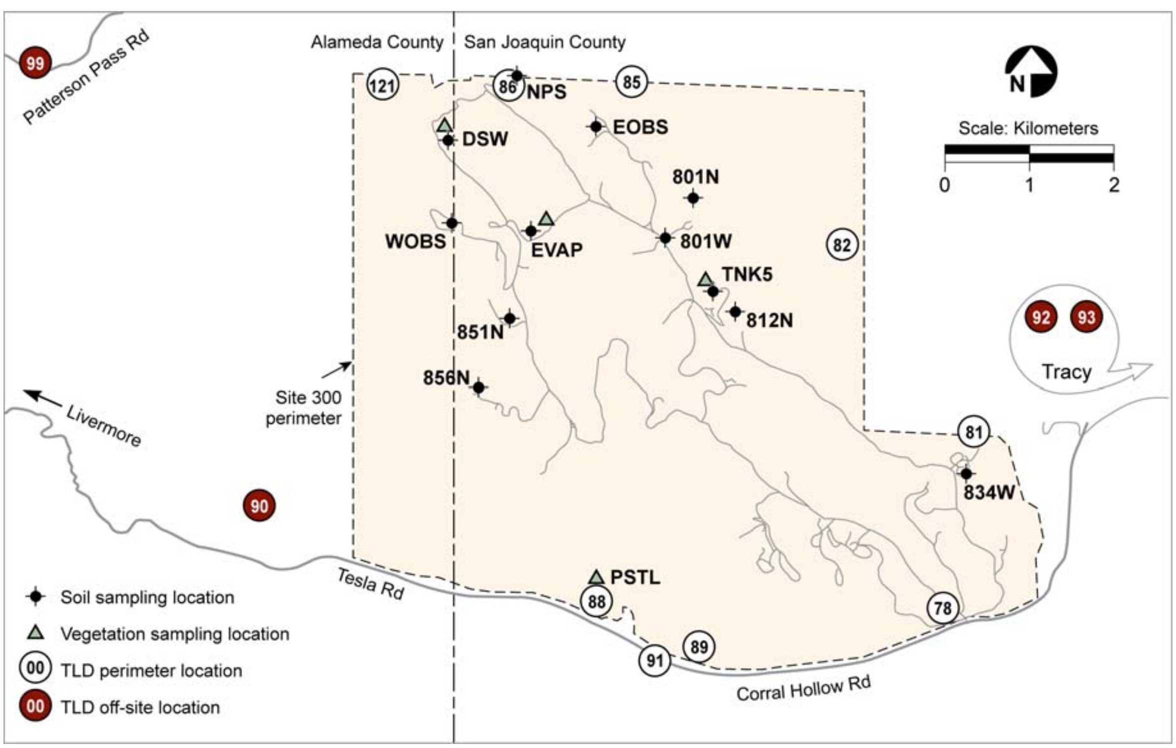


**Figure 6-3.** Soil and vegetation sampling locations and TLD locations, Site 300 and off-site, 2009.

In 2009, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides; samples at selected locations were analyzed for tritium, gross alpha, and gross beta. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium.

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

### 6.1.1 Radiological Monitoring Results

The 2009 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 2009 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 2009 was 2.0 mBq/dry g ($5.4 \times 10^{-2}$ pCi/dry g). Elevated levels of plutonium-239+240 resulting from an estimated $1.2 \times 10^{9}$ Bq (32 mCi) plutonium release to the sanitary sewer in 1967 and earlier releases were again detected at LWRP sampling locations in 2009. The highest detected plutonium-239+240 value at the LWRP in 2009 was 7.8 mBq/dry g ($2.1 \times 10^{-1}$ pCi/dry g). In addition, americium-241 was detected in one LWRP sample at a concentration of 4.3 mBq/dry g ($1.1 \times 10^{-1}$ 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 2009 (5.0 Bq/L [135 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 2009 are provided in **Appendix A**, **Section A.8**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2009 lie within the ranges reported in all years since monitoring began. At 10 of the 12 sampling locations, the ratio of uranium-235 to uranium-238 reflects the natural ratio of 0.00725. There is significant uncertainty in calculating the ratio, however, due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. The highest measured values for uranium-235 and uranium-238 in a single sample were 0.23 µg/g (0.018 Bq/g or 0.5 pCi/g) and 110 µg/g (1.4 Bq/g or 37 pCi/g), respectively. The uranium-235 to uranium-238 ratio in this sample is 0.0021, which at the levels of uncertainty associated with the analysis equals the ratio for depleted uranium of 0.002. Such values at Site 300 result from the use of depleted uranium in explosive experiments.

### 6.1.2 Nonradiological Monitoring Results

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

Aroclor 1260, a PCB, has been detected at location ESB since surveillance for PCBs began at this location in 2000. In 2009, samples analyzed for PCBs were found to be below regulatory reporting limits. The presence of PCBs suggests residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see **Chapter 5**). The previously detected concentrations are below the federal and state hazardous waste limits. LLNL will continue to consistently monitor for the next three years, unless the results continue to be below the regulatory reporting limits, at which time the need for PCB monitoring will be reassessed.

Beryllium results for soils at Site 300 were within the ranges reported since sampling began in 1991. The highest value in 2009, 3.1 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 differing results reflect the particulate nature of the contamination.

### 6.1.3 Environmental Impact on Soil

#### *6.1.3.1 Livermore Site*

Routine surface soil sample analyses indicate that the impact of LLNL operations on this medium in 2009 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 2009 (7.8 mBq/dry g [0.21 pCi/dry g]), measured at LWRP, is 1.6% 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 2009 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occurred near the firing tables. They result from the fraction of the firing table operations that disperse depleted uranium. The highest measured uranium-238 concentration was 110 µg/g (1.4Bq/g or 37 pCi/g) and was well below the NCRP-recommended screening level for commercial sites (313 µg/g [3.9 Bq/g or 105 pCi/g]). These values occurred near Bunker 812 and are a result of historic operations at that location. In 2008, a Remedial Investigation/Feasibility Study was submitted for the Building 812 operating unit (OU) (Taffet et al. 2008). This Investigation/Feasibility Study specifies the nature and extent of contamination, risk assessment, and remedial alternatives for CERCLA cleanup of the site (see **Chapter 8**). Cleanup remedies to address soil and groundwater contamination in the Building 812 OU are being negotiated with the regulatory agencies.

## 6.2 Vegetation and Foodstuff Monitoring

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

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

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

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

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

Wines for sampling in 2009 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 2009 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 2009 was 13 Bq/L at the Near location MESQ located on the west-central perimeter of the Livermore site. For Site 300, the highest mean concentration for 2009 was 90 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 DSW, PSTL, and TNK5 were below detection limit. The median concentration of tritium in vegetation at EVAP was 4.6 Bq/L.

### 6.2.2 Wine Monitoring Results

Tritium concentrations in wines purchased in 2009 are shown in **Table 6-2**. The highest concentration in a Livermore Valley wine is 5.7 Bq/L (150 pCi/L) from a wine made from grapes harvested in 2006. The highest concentration in a California (other than the Livermore Valley) wine is 270 Bq/L (7300 pCi/L) from a wine made from grapes harvested in 2006. The highest concentration in a Rhone Valley (France) wine is 3.8 Bq/L (100 pCi/L) from a wine made from grapes harvested in 2007.

Analysis of the wines purchased annually since 1977 have demonstrated the following relationship between the Livermore Valley, California, and the Rhone Valley wines: Tritium concentrations in the Rhone Valley wines are typically higher than tritium concentrations in the Livermore Valley wines. Tritium concentrations in the California (other than the Livermore Valley) wines are typically lower than tritium concentrations in the Livermore Valley wines. However, one of the two California wines sampled in 2008 did not follow this relationship and contained a higher level of tritium (320 Bq/l) than in wines sampled in past years. To further investigate the much higher level of tritium, the same wine (i.e., the same winery, vintage and type of wine) was purchased and analyzed in 2009. The results show a tritium level (270 Bq/L) similar to the level presented in the *Environmental Report 2008*.

**Table 6-1.** Median and mean concentrations of tritium in plant water for the Livermore site, Livermore Valley, and Site 300 sampled in 2009. The table includes mean annual ingestion doses calculated for 2009.

| 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 | 4.5 | 4.2 | 21 |
| | GARD | 2.5 | 2.5 | 12 |
| | MESQ | 5.6 | 13 | 64 |
| | MET | 3.8 | 3.8 | 19 |
| | NPER | 4.4 | 4.9 | 24 |
| | VIS | 5.3 | 5.8 | 28 |
| INTERMEDIATE (1–5 km from Livermore site perimeter) | I580 | 4.6 | 4.4 | 22 |
| | PATT | 0.66 | 0.73 | <10[(b)] |
| | TESW | 1.6 | 1.8 | <10[(b)] |
| | ZON7 | 1.7 | 2.2 | 11 |
| FAR (>5 km from Livermore site perimeter) | CAL | 0.5 | 0.46 | <10[(b)] |
| | FCC | 0.86 | 0.72 | <10[(b)] |
| Site 300 | DSW[(c)] | 0.64 | 0.8 | (d) |
| | EVAP[(c)] | 4.6 | 90 | (d) |
| | PSTL | 0.46 | 0.51 | (d) |
| | TNK5 | 0.57 | 0.58 | (d) |

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

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

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

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

The Livermore Valley wines represent vintages from 2003, 2004, 2006, 2007, and 2008; the California wines represent vintages from 2006 and 2007; and the Rhone Valley wines represent vintage from 2007. 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 2009, decay-corrected concentrations for Livermore Valley wine samples ranged from 0.15 to 6.9 Bq/L; for the two California wine samples, 330 and 0.66 Bq/L; and for the two Rhone Valley wine samples, 1.0 and 5.0 Bq/L.

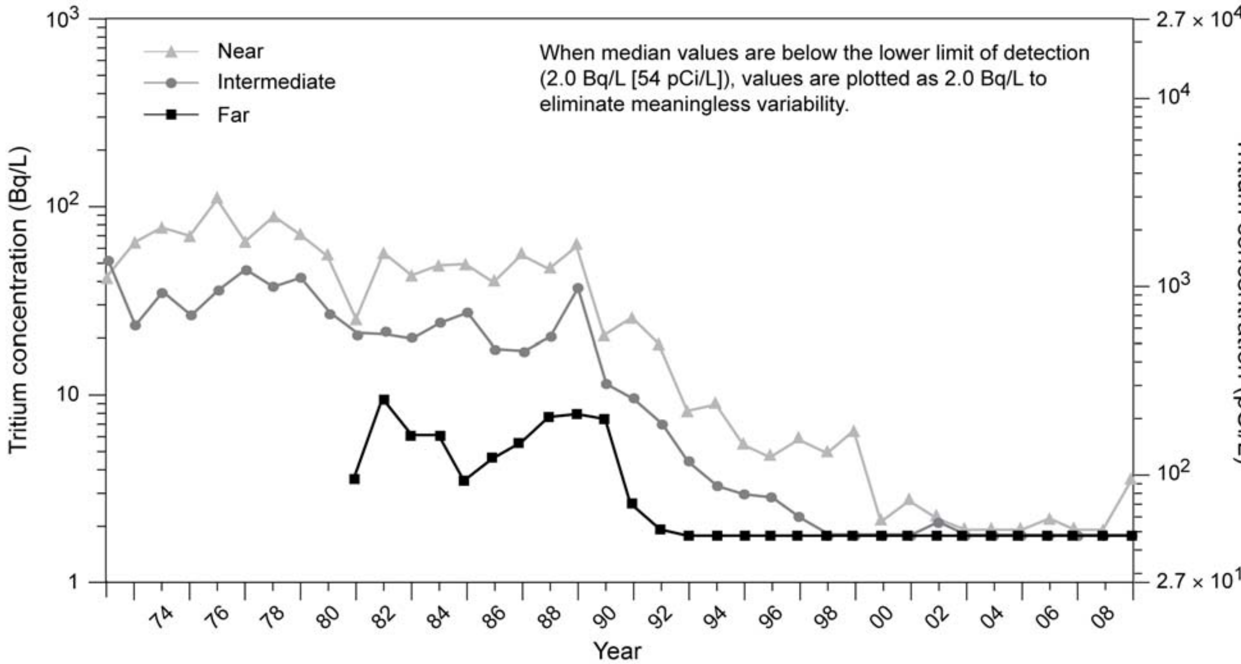


**Figure 6-4.** Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2009.

**Table 6-2.** Tritium in retail wine, 2009(a,b)

| Sample | Concentration by area of production (Bq/L) | | |
|---|---|---|---|
| | **Livermore Valley** | **California** | **Europe** |
| 1 | 5.7 ± 1.8 | 0.57 ± 1.6 | 0.79 ± 1.6 |
| 2 | 1.7 ± 1.6 | 270 ± 6.3 | 3.8 ± 1.7 |
| 3 | 0.11 ± 1.6 | | |
| 4 | 1.3 ± 1.6 | | |
| 5 | 3.3 ± 1.7 | | |
| 6 | 2.2 ± 1.6 | | |
| Dose (nSv/y)(c) | 6.9 | 330 | 4.6 |

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

(b) Wines from a variety of vintages were purchased and analyzed for the 2009 sampling. Concentrations are those measured in April 2010.

(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 2009, was 64 nSv (6.4 μrem).

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

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

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

Doses calculated based on Regulatory Guide 1.109 neglect the contribution from organically bound tritium (OBT). However, according to a panel of tritium experts, “the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this” (ATSDR 2002, p. 27). Thus, the maximum estimated ingestion dose from LLNL operations for 2009, including OBT, is 128 nSv/y (12.8 μrem/y). This maximum dose is about 1/23,000 of the average annual background dose in the United States from all natural sources and about 1/79 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 2009, the highest concentration of tritium (5.7 Bq/L [150 pCi/L]) was just 0.77% 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 2009 would have resulted in a dose of 49 nSv/y (4.9 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 (2.4 Bq/L [64 pCi/L]) would have been 2.9 nSv/y (0.29 μrem/y). Both doses explicitly account for the added contribution of OBT.[2]

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

(2) Dose from wine was calculated based on the measured concentration of HTO multiplied by 1.3 to account for the potential contribution of OBT that was removed so that the tritium in wine could be counted using liquid scintillation counting. Dose coefficients for HTO and OBT are those of the International Commission on Radiological Protection (1996).

The potential dose from drinking Livermore Valley wines in 2009, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/210 of a single dose from a panoramic dental x‑ray.

## 6.3 Ambient Radiation Monitoring

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

### 6.3.1 Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter that absorbs it. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thulium-activated calcium sulfate ($CaSO_4$:Tm), to measure environmental gamma exposure. The TLD measurements are corrected in the following way for reporting: the results of the TLD measurement process are normalized to 90-day quarters from their actual exposure period, and the measurement units are converted from absorbed exposure units to reported dose units. These corrections allow the TLDs measurements to be representative of external exposure to the public at these sample locations. Comparisons are made for LLNL perimeter locations to those of the Livermore Valley (background location) for the purposes of determining an elevated radiation field. This is similarly done for Site 300 and its nearby locations.

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

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

- comparison of the average quarterly dose (mSv) for the Livermore site, Livermore Valley, and Site 300 locations for the five-year period from 2005 to 2009
- comparison of the average quarterly dose (mSv) for the Livermore site and Livermore Valley locations in 2009

- comparison of average quarterly dose (mSv) for Site 300, city of Tracy, and Site 300 vicinity in 2009

The results of these comparisons are shown in **Figure 6-5**.

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

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

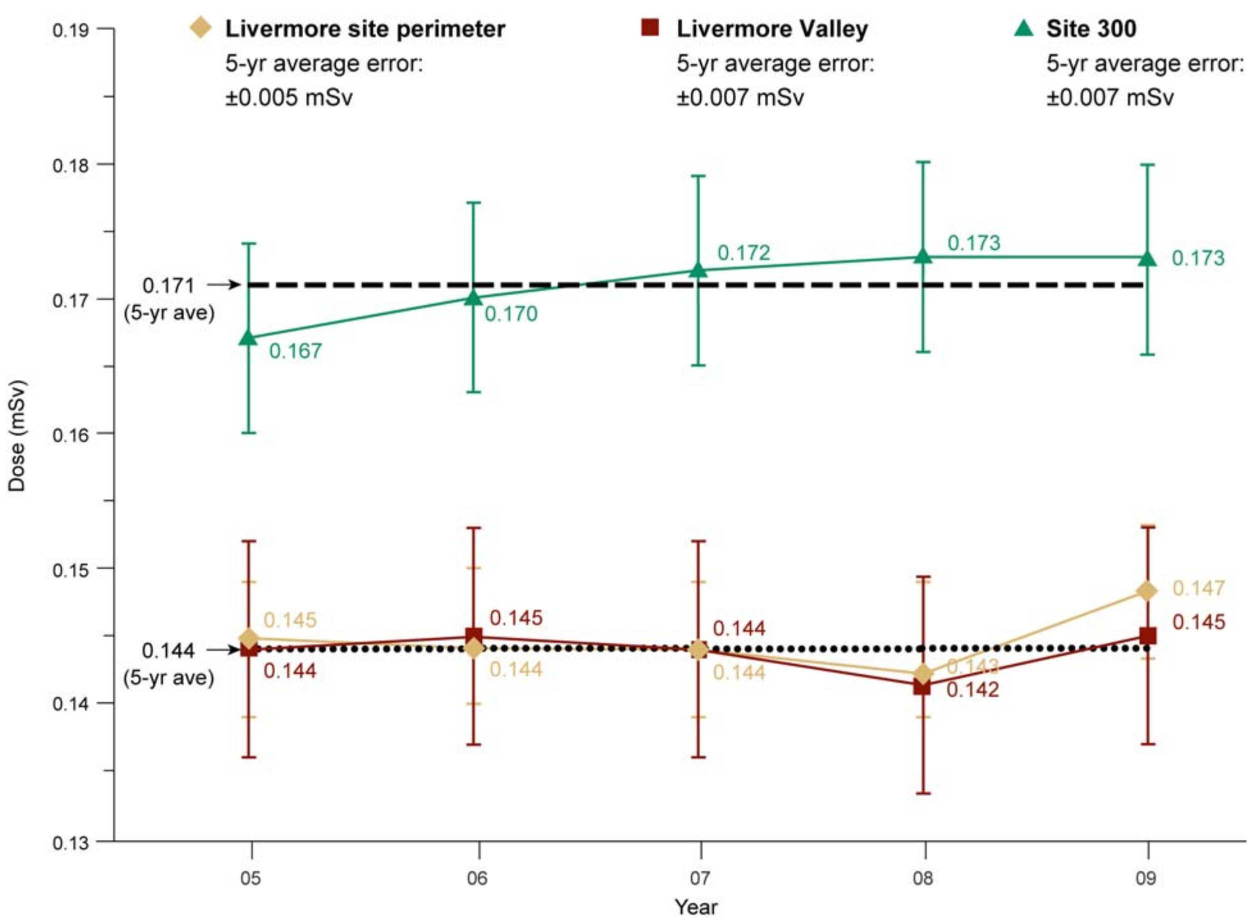


**Figure 6-5.** Comparison of the average quarterly dose for the Livermore site perimeter, Livermore Valley, and Site 300 monitoring locations from 2005 to 2009.

## 6.3.2 Monitoring Results

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

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

### 6.3.3 Environmental Impact from Laboratory Operations

There is no increased ambient radiation field produced as a direct result of LLNL operations for 2009 as measured by this network. Radiation dose trends remain consistent with annual average levels for each sample location and synonymous to natural background levels. As depicted in **Figure 6-5**, the annual average gamma radiation dose for the LLNL site perimeter and the Livermore Valley from 2005 to 2009 are statistically equivalent and show no discernible impact due to operations conducted at LLNL.

## 6.4 Special Status Wildlife and Plants

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

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

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

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

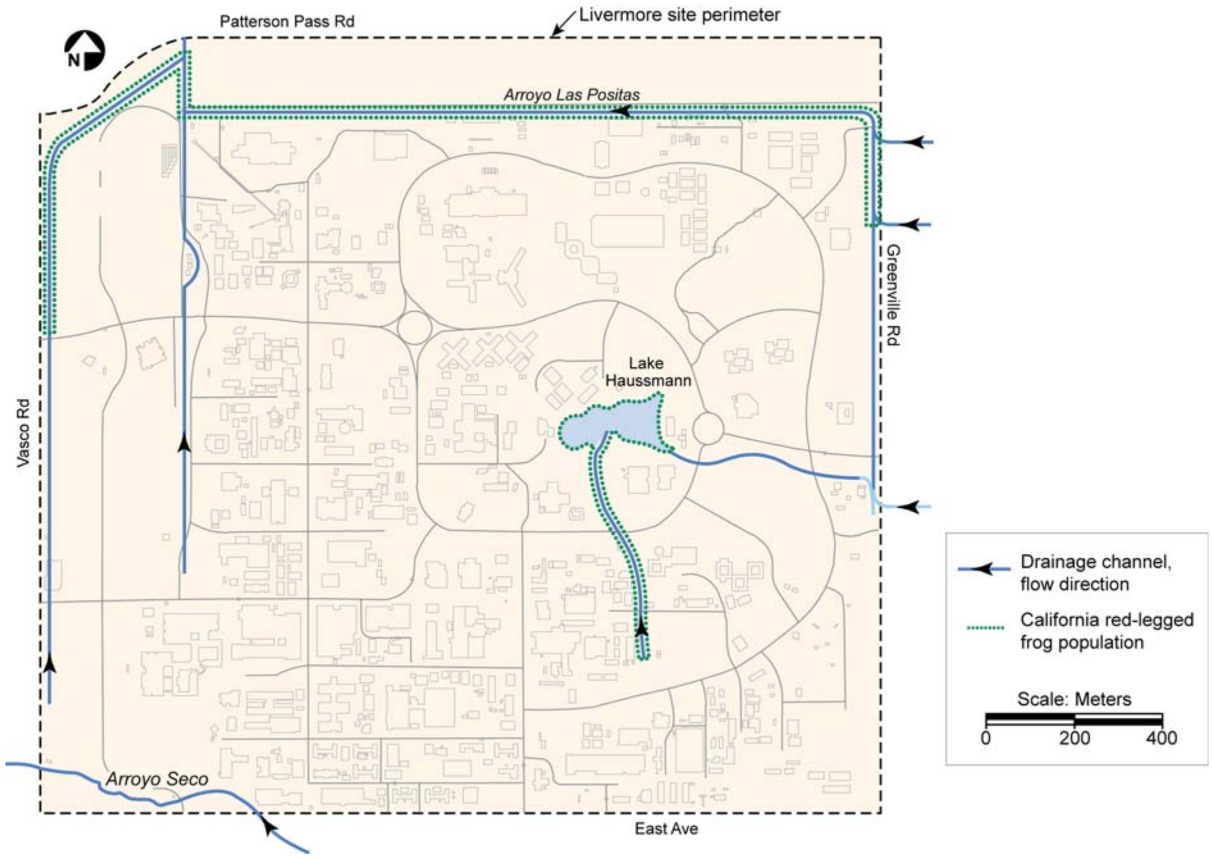


**Figure 6-6.** Populations of the California red-legged frog, Livermore site, 2009.

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

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

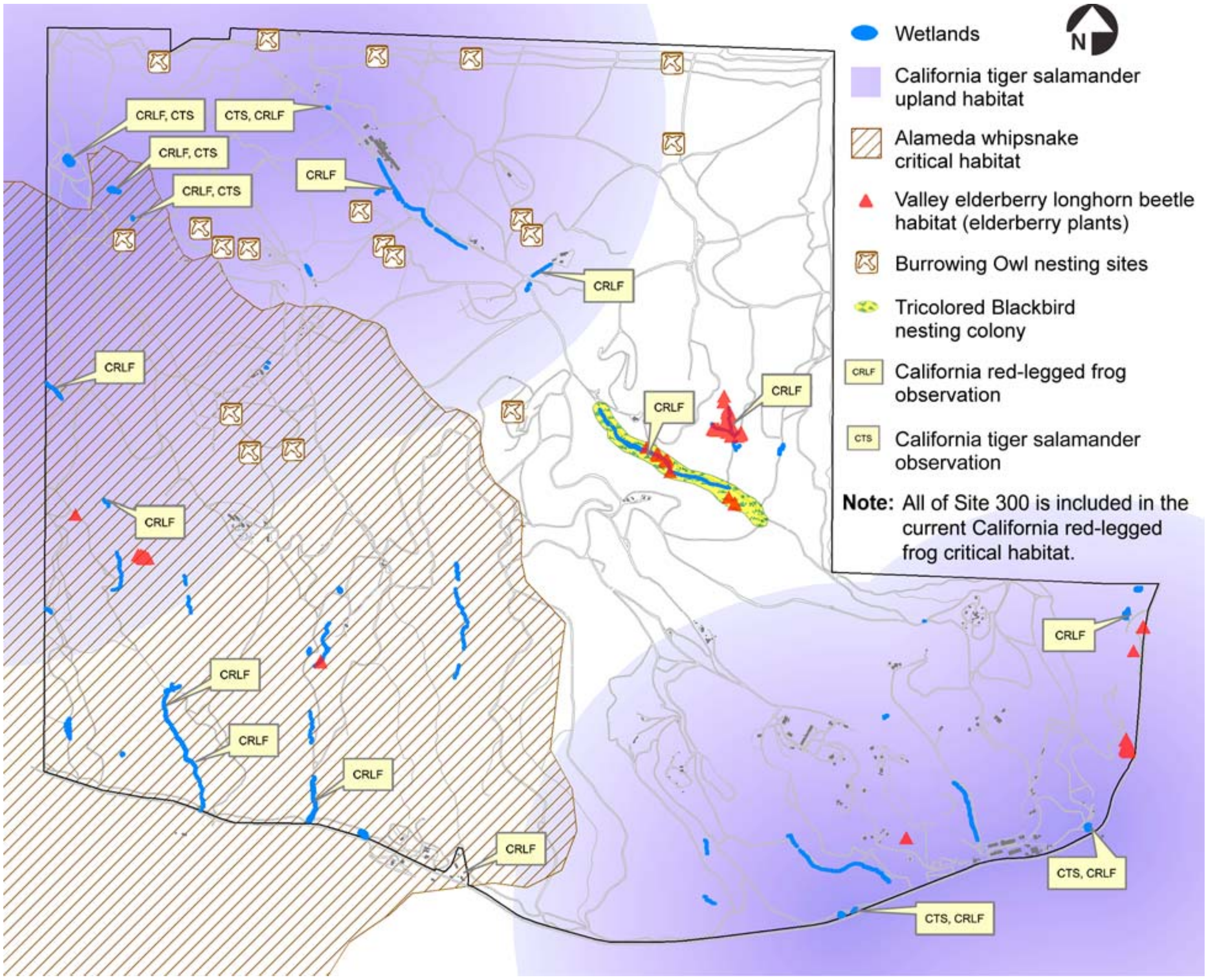


**Figure 6-7.** Distribution of special status wildlife, Site 300, 2009.

## 6.4.1 Compliance Activities

### *6.4.1.1 Building 850 Remediation*

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

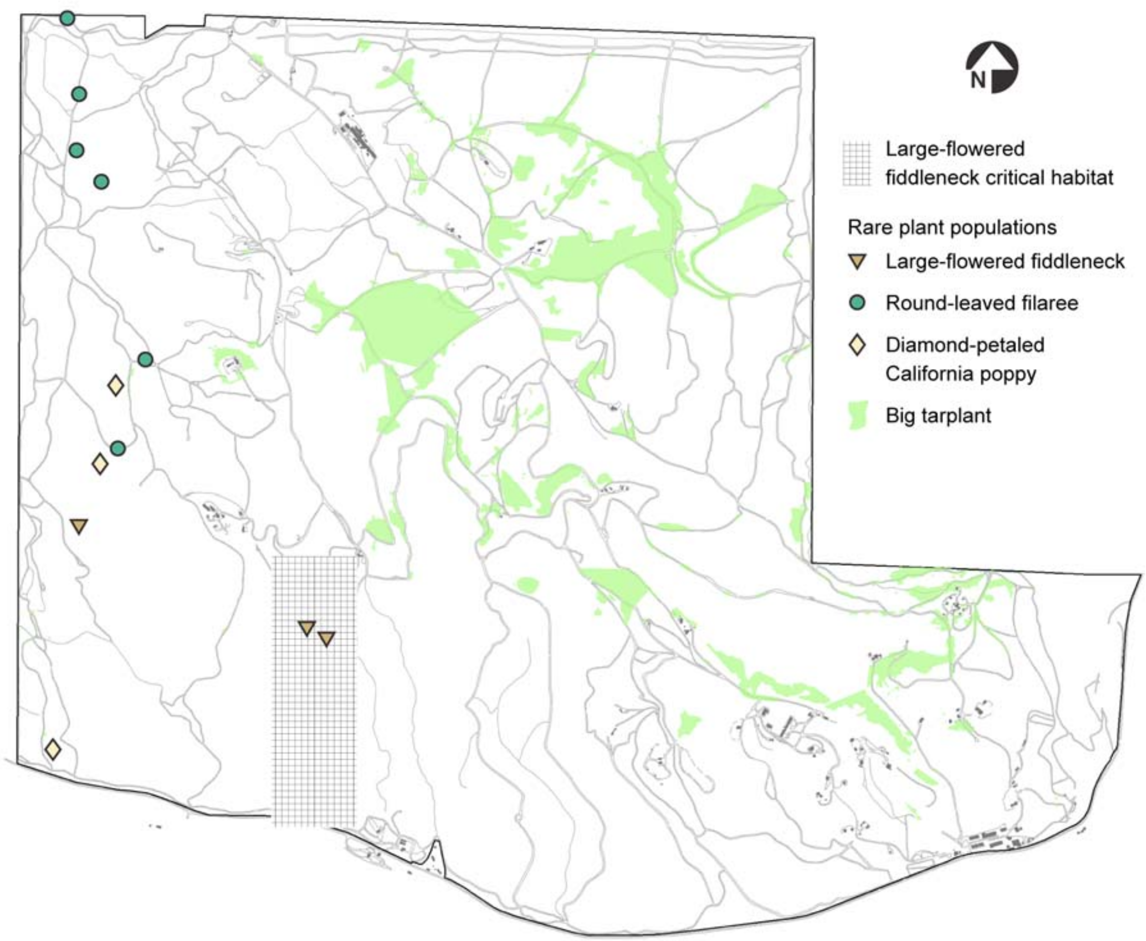


**Figure 6-8.** Distribution of special status plants, Site 300, 2009.

No California red-legged frogs or California tiger salamanders were discovered at the Building 850 project site during the pre-construction, developmental, or post-construction intervals. No special status species were observed in the project area or nearby during the duration of the project. All construction personnel received the required natural resource education briefing and did not report seeing any species of concern. To ensure wildlife did not enter the work area, perimeter exclusionary fencing surrounding the entire construction site was maintained between April 2009 and December 2009.

The proposed wildlife habitat compensation site related to this project is anticipated to be completed during the summer of 2011. The compensation site mitigates potentially adverse impacts to the California red-legged frog and California tiger salamander as a result of the Building 850 construction. It protects upland habitat for the two species around an enhanced (deepened) breeding pool that currently acts as a limit to population recruitment.

#### *6.4.1.2 Habitat Enhancement Project*

In late August 2005, LLNL implemented a habitat enhancement project for California red-legged frogs at Site 300 in accordance with a 2002 USFWS biological opinion (BO) and ACOE and RWQCB permits. California red-legged frogs were translocated to the new habitat enhancement pools in February and March of 2006. Monitoring demonstrated that California red-legged frogs successfully reproduced in these pools in 2006, 2007, 2008, and 2009. In 2009, a total of 20 to 25 California red-legged frog egg masses were observed in the Upper and Lower Mid-Elk Ravine pools.

In fall 2005, a depression in the northwest corner of Site 300 below Harrier pool was deepened and expanded to serve as mitigation for California tiger salamander habitat lost as a result of closing two man-made, high explosives rinse water ponds in the Process Area. In 2006, California tiger salamanders successfully bred and metamorphosed from the pool. In 2007, 2008, and 2009 the pool received inadequate inundation and evaporated before the salamander larvae could reach maturity and leave the pond.

#### *6.4.1.3 Oasis and Round Valley Culvert Replacement Projects*

In 2006, LLNL completed culvert replacement projects at two Site 300 locations (the Oasis and Round Valley) where unpaved fire trails crossed intermittent drainages. The Round Valley project included the creation of a pool upstream of the project area in part as mitigation for the impacts at the Oasis site and to serve as enhanced habitat for amphibian species. These projects were completed under the USFWS BO for maintenance and operations of Site 300 and ACOE and RWQCB permits. The Round Valley pool did not receive enough water during the 2007/2008 and 2008/2009 winters to pool and afford potential breeding habitat for amphibians.

#### *6.4.1.4 Arroyo Seco Restoration*

In 2009, LLNL conducted the fourth year of the five-year monitoring plan required by USFWS and ACOE for the restoration of the Arroyo Seco Management Plan project site. Arroyo Seco crosses the southeast corner of the Livermore site. Monitoring at this site includes annual measurements of the survivorship of plants that were installed as part of the restoration and estimates of the percent cover of grasses and forbs, shrubs, and trees at the project site. Percent cover measurements were recorded separately for four monitoring zones (north bank, south bank, north terrace, and south terrace) and three vegetated geogrids. The geogrids are slopes that are stabilized by erosion control fabric and planted willows. Results of this monitoring are documented in Paterson (2010a). The mitigation and monitoring plan for this project lists annual success criteria based on the percent cover of grasses, shrubs, and trees at the project site, and requires LLNL to replace all trees and shrubs that do not survive during the first five years of monitoring.

In 2009, the project site met the success criteria for grasses and shrubs in all four monitoring zones. The percent cover of trees in three (north bank, south bank, and north terrace) of the four monitoring zones was lower than the required success criteria. As a result, additional trees were planted in March 2010. However, trees have been very successful on the geogrids. In the spring of 2009, the percent cover of trees on the three geogrids ranged from 65% to 100%.

#### *6.4.1.5 Arroyo Mocho Boulder Removal and Erosion Control Project*

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

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

#### *6.4.1.6 Arroyo Mocho Restoration*

In 2009, LLNL implemented the fifth year of a five-year mitigation and monitoring plan for the restoration of the 2004 Arroyo Mocho Road Improvement and Anadromous Fish Passage project. This mitigation and monitoring plan is a requirement of the ACOE permit for this project. Success criteria for this restoration are based on the number of native species present and the percent cover of these species within three monitoring communities (low flood plain, sloping terrace, and upland) at the project site. The project site currently includes a diverse collection of native riparian and upland plants. In all years of monitoring including 2009, the number of native species observed at the site far exceeded the success criteria for species richness.

The low flood plain and upland communities both exceed the success criteria described in the mitigation plan for percent cover of native plants. The sloping terrace community did not meet the recommended success criteria for the percent cover of native species.

The mitigation plan for this project recommends a ratio of 3.5 square feet of wetland habitat restored for every 1 square foot of habitat temporarily impacted during construction. In January 2010, 3.2 square feet of wetland habitat were present at the project site for every 1 square foot of wetland vegetation that was temporarily impacted. Wetland vegetation is naturally expanding to fill all suitable areas at the project including the area that was previously covered by the concrete low-water crossing. The increase in wetland habitat at the project site is largely the result of natural colonization of the project site and is expected to continue over the next three to five years, eventually meeting the 3.5 to 1 goal.

In an attempt to control exotic plants, as specified in the mitigation and monitoring plan, and increase the cover of native plants at the site, hand weeding of exotic species including yellow star thistle and bull thistle was conducted in 2009. The results of the monitoring are documented in Paterson (2010b).

Army Corp of Engineers biologists visited the project site in March of 2010, and determined that LLNL has successfully met mitigation requirements for the Corps permit for this project. No further monitoring or maintenance action is required for this restoration site.

### 6.4.2 Invasive Species Control Activities

Invasive species control is an important part of LLNL's effort to protect special status species at both sites. Prevention of the downstream dissemination of invasive species is also important to protect native species throughout our region. The bullfrog *(Rana catesbeiana)* and the largemouth bass *(Micropterus salmoides)* are significant threats to California red-legged frogs at the Livermore site, and the feral pig (*Sus scrofa*) threatens California red-legged frog habitat at Site 300.

In 2009, to mitigate threats to California red-legged frog habitat, feral pigs were dispatched at Site 300. At the Livermore site, bullfrog control measures were implemented between May and September of 2009. Bullfrog control measures included dispatching adults and removing egg masses in Lake Haussmann and Arroyo Las Positas. To remove bullfrog tadpoles and invasive fish, the LLNL reach of Arroyo Las Positas was allowed to dry out in November of 2009 by temporarily halting groundwater discharges to the arroyo.

### 6.4.3 Surveillance Monitoring

#### *6.4.3.1 Wildlife Monitoring and Research*

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

A prescribed burn was conducted at the burn site in the summer of 2003, and the post-burn monitoring has been conducted starting in the fall of 2003 through the spring 2009. Both the burn and control sites were impacted by a wildfire in 2005. Although no whipsnake fatalities were documented during post-burn surveys, both trapping areas were burned severely and little remnant vegetation was left in the shrubland.

No whipsnakes were captured during the spring 2009 trapping period. Although the effects of the prescribed burn and subsequent impacts of the wildfire on the whipsnake are not yet determined, both the whipsnake and its habitat are adapted to periodic fire events, and both the snake and vegetation are expected to recover from the fire in subsequent years.

***Nesting Bird Surveys.*** LLNL conducts nesting bird surveys to ensure LLNL activities comply with the Migratory Bird Treaty Act and do not result in impacts to nesting birds. White-tailed Kites frequently nest in the trees along the north, east, and south perimeters of the Livermore site. LLNL staff surveyed potential White-tailed Kite nesting sites during the spring of 2009. One pair of White-tailed Kites attempted to nest, but the nest was abandoned before any eggs were hatched. No other pairs of White-tailed Kites were observed nesting at the Livermore site in 2009. Although White-tailed Kites are also known to occasionally nest at Site 300, site-wide kite surveys were not conducted at Site 300 in 2009 because kites do not typically nest in areas where they may be affected by programmatic activities.

***California Red-Legged Frog Egg Mass Surveys.*** LLNL continued diurnal visual surveys for California red-legged frog egg mass at the Livermore site in Arroyo Las Positas and in the habitat enhancement portion of Lake Haussmann. No egg masses were observed in Arroyo Las Positas in 2009. Although, no egg masses were observed in the Habitat Enhancement portion of Lake Haussmann in 2009, several newly metamorphosed California red-legged frogs were observed in the Habitat Enhancement Pool and nearby areas indicating that California red-legged frogs did successfully breed in Lake Haussmann or the Habitat Enhancement Pool in 2009.

#### *6.4.3.2 Rare Plant Research and Monitoring*

***Large-Flowered Fiddleneck.*** This species is known to exist naturally in only two locations—at the Site 300 Drop Tower and on a nearby ranch. The Drop Tower native population contained no large-flowered fiddleneck plants in 2009, and fewer than 20 plants each year for the past seven years.

LLNL established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. The size of the experimental population fluctuates as a result of seed bank enhancement efforts conducted in this population. The experimental population contained 28 large-flowered fiddleneck plants in 2009.

In December of 2009, in an attempt to increase the numbers of large-flowered fiddleneck in the experimental population, 100 large-flowered fiddleneck seeds were planted in each of the 20 plots in the experimental population.

***Big Tarplant.*** The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September and October of 2009. It is estimated that between 6,000 and 22,000 individual big tarplant occurred at Site 300 in 2009. This species is abundant at Site 300, especially in or near areas where prescribed burns are routinely conducted and where wildfires have occurred, although it is rare outside of Site 300. The abundance of big tarplant varies greatly between years depending on environmental conditions.

***Diamond-Petaled California Poppy.*** Currently three populations of this species are known to occur at Site 300; the population locations are referred to as Site 1, Site 2, and Site 3. Although the species is not listed under the federal or California ESAs, it is extremely rare and is currently known to occur only at Site 300 and in one location in San Luis Obispo County. A census of the three Site 300 populations was conducted in April 2009. In 2009, 452 plants were found at Site 300. The most recently discovered population, Site 3, contained the largest number (405 plants). Numbers of plants at Sites 1 and 2 have been very small in recent years. In 2009, Site 1 had 40 plants, and Site 2 had 7 plants.

***Round-Leaved Filaree.*** Six populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwest portion of the site. This species thrives in the disturbed soils of the annually graded fire trails at Site 300, but also occurs infrequently in grasslands. Of the six populations, four occur on fire trails and two occur in grasslands. During the spring of 2009, the extent of the six populations was mapped using a handheld GPS, and the size of each population was estimated. The six populations combined were estimated to contain more than 5300 plants. In 2009, the majority of these plants (5170) occurred in the two grassland populations that are not located in fire trails.

### 6.4.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2009, LLNL has been able to avoid most impacts to special status wildlife and plants. In addition, LLNL continues to monitor and maintain several restoration sites and habitat enhancements that are beneficial to native plants and animals at the Livermore site and Site 300. Invasive species continue to be one of the largest threats to California red-legged frogs at the Livermore site and Site 300, and LLNL continued its program to remove invasive exotic species of amphibians and fish from the Livermore site, and feral pigs from Site 300 in 2009.

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# 7. Radiological Dose Assessment

*Nicholas A. Bertoldo • Gretchen M. Gallegos*

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

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

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

In 2009, the radionuclides measured and modeled that contributed to individual and collective doses were tritium and plutonium 239+240 at the Livermore site and uranium-234, uranium-235, and uranium-238 at Site 300. All radionuclides measured at the Livermore site and Site 300 were used to assess dose to biota in 2009.

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

## 7.1 Air Dispersion and Dose Models

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

## 7.2 Identification of Key Receptors

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

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

In 2009, the SW-MEI at the Livermore site was located at the UNCLE Credit Union, about 10 m outside the site's controlled eastern perimeter, and 957 m east-northeast of the Tritium Facility. The SW-MEI at Site 300 was located on the site's south-central perimeter, which borders the Carnegie State Vehicular Recreation Area. The location was 3170 m south–southeast of the firing table at Building 851. The two SW–MEI locations are shown in **Figure 7-1**.

## 7.3 Results of 2009 Radiological Dose Assessment

This section summarizes the doses to the most exposed public individuals from LLNL operations in 2009, shows the temporal trends compared with previous years, presents the potential doses to the populations residing within 80 km of either the Livermore site or Site 300, and places the potential doses from LLNL operations in perspective with doses from other sources.

(1) Calculated for tritium only.

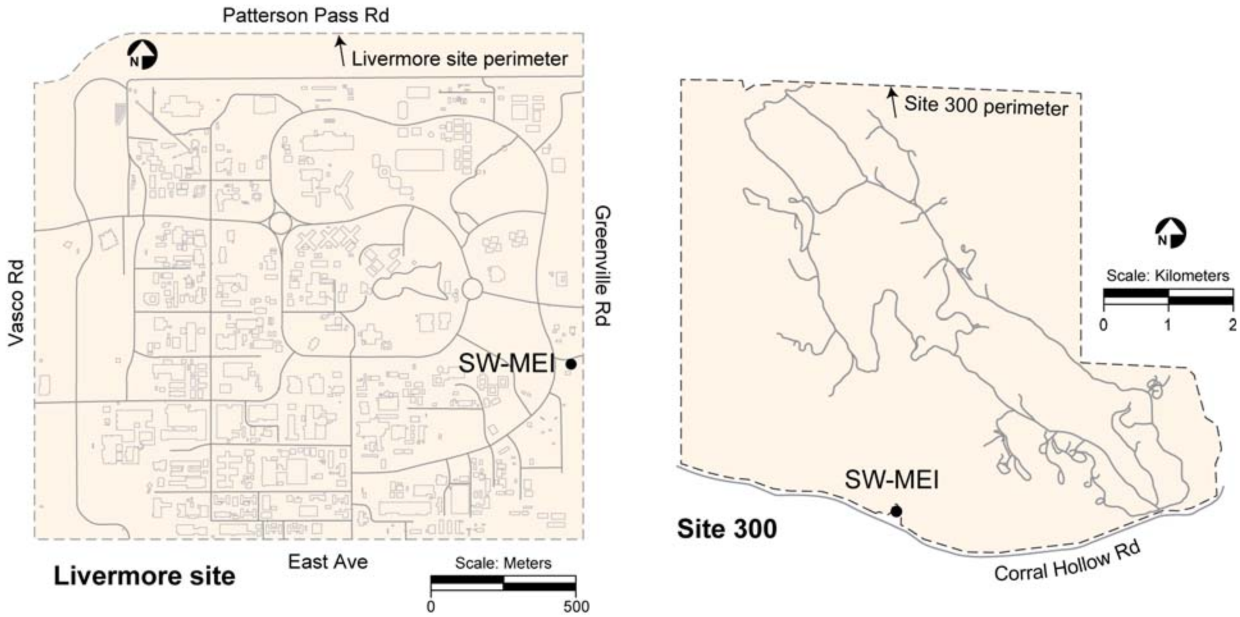


**Figure 7-1.** Location of the SW-MEI at the Livermore site and Site 300, 2009.

### 7.3.1 Total Dose to Site-Wide Maximally Exposed Individuals

The total dose to the SW-MEI from Livermore site operations in 2009 was 0.042 µSv/y (0.0042 mrem/y). Of this, the dose attributed to diffuse emissions (area sources) totaled 0.027 µSv (0.0027 mrem) or 64%; the dose due to point sources was 0.015 µSv 0.0015 mrem) or 36% of the total. The point source dose includes Tritium Facility elemental tritium gas (HT) emissions modeled as tritiated water (HTO), as directed by EPA Region IX.

**Table 7-1** shows the facilities or sources that accounted for nearly 100% of the dose to the SW-MEI for the Livermore site and Site 300 in 2009. Although LLNL has nearly 150 sources with the potential to release radioactive material to air according to NESHAPs prescriptions, most are very minor. Nearly the entire radiological dose to the public in 2009 from LLNL operations came from no more than six sources. LLNL uses, with permission from EPA, surveillance monitoring in place of inventory-based modeling to account for dose contributions from the numerous minor sources.

In 2009 at Site 300, there were no outdoor firing table explosive experiments using depleted uranium to produce any emissions. No resuspension of depleted uranium was detected at the SW-MEI location from pre-existing concentrations. Radioactive emissions from Site 300 were solely from the Contained Firing Facility. The calculated dose to the SW-MEI ($2.7 \times 10^{-6}$ µSv/y [$2.7 \times 10^{-7}$ mrem/y]) was due to the isotopes uranium-238, uranium-235, and uranium-234.

**Table 7-1.** List of facilities or sources whose combined emissions accounted for nearly 100% of the SW-MEI doses for the Livermore site and Site 300 in 2009.

| Site | Facility (source category) | CAP88-PC dose (μSv/y)[(a)] | CAP88-PC contribution to total dose |
|---|---|---|---|
| Livermore Site | Tritium Facility stacks (point source) | $1.5 \times 10^{-2}$ | 35.7% |
| | Building 331 WAA, Building 612 Yard (diffuse sources) | $1.7 \times 10^{-2}$ | 40% |
| | Southeast quadrant soil resuspension (diffuse source) | $1.0 \times 10^{-2}$ | 23.8% |
| Site 300 | Contained Firing Facility | $2.7 \times 10^{-6}$ | 100% |

(a) 1 μSv = 0.1 mrem

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

### 7.3.2 Doses from Unplanned Releases

There were no unplanned atmospheric releases of radionuclides at the Livermore site or Site 300 in 2009.

### 7.3.3 Collective Dose

Collective dose for both LLNL sites was calculated using CAP88-PC for a radius of 80 km from the site centers. Population centers affected by LLNL emissions within the 80-km radius include the nearby communities of Livermore and Tracy; the more distant metropolitan areas of Oakland, San Francisco, and San Jose; and the San Joaquin Valley communities of Modesto and Stockton. Within the 80-km radius specified by DOE, there are 7.22 million residents included for the Livermore site collective dose determination and 6.7 million for Site 300. The populations were derived using ORNL LandScan 2007 data and ESRI ARCMAP software.

The CAP88-PC result for potential collective dose attributed to 2009 Livermore site operations was 0.002 person-Sv ( 0.2 person-rem); the corresponding collective dose from Site 300 operations was $5.11 \times 10^{-7}$ person-Sv ($5.11 \times 10^{-5}$ person-rem).

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

**Table 7-2.** Doses calculated for the SW-MEI for the Livermore site and Site 300, 1990 to 2009.

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

(a) 1 μSv = 0.1 mrem

### 7.3.4 Doses to the Public Placed in Perspective

As a frame of reference to gauge the size of the LLNL doses, **Table 7-3** compares them to average doses received in the United States from exposure to natural background radiation and other sources. The collective dose is high even though the individual dose is very small. This is due to the high population density in the 80-km radius. Moreover, the overall contribution of dose from LLNL operations in 2009 is overshadowed by natural radiation.

**Table 7-3.** Comparison of radiation doses from LLNL sources to average doses from background (natural and man-made) radiation, 2009.

| Location/source | Category | Individual dose[a] (μSv)[c] | Collective dose[b] (person-Sv)[d] |
|---|---|---|---|
| LLNL | | | |
| Livermore site sources | Atmospheric emissions | 0.042 | 0.002 |
| Site 300 sources | Atmospheric emissions | $2.7 \times 10^{-6}$ | $5.1 \times 10^{-7}$ |
| Other sources[e] (background) | Natural radioactivity[f,g] | | |
| | Cosmic radiation | 300 | 2,170 |
| | Terrestrial radiation | 300 | 2,170 |
| | Internal (food and water consumption) | 400 | 2,888 |
| | Radon | 2,000 | 14,440 |
| | Medical radiation (diagnostic procedures)[f] | 530 | 3,827 |
| | Weapons test fallout[f] | 10 | 72 |
| | Nuclear fuel cycle | 4 | 29 |

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

(b) The collective dose is the combined dose for all individuals residing within an 80-km radius of LLNL (approximately 7.22 million people for the Livermore site and 6.7 million for Site 300), calculated with respect to distance and direction from each site. The Livermore site population estimate of 7.22 million people was used to calculate the collective doses for “Other sources.”

(c) 1 μSv = 0.1 mrem

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

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

(f) These values vary with location.

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

## 7.4 Special Topics on Dose Assessment

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

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

**Table 7-4.** Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2009.

| Location | Nuclide | EPA concentration standard ($Bq/m^3$) | Detection limit (approximate) ($Bq/m^3$) | Mean measured concentration ($Bq/m^3$) | Measured concentration as a fraction of the standard |
|---|---|---|---|---|---|
| Livermore SW-MEI | Tritium | 56 | 0.037 | $5.9 \times 10^{-2}$(a) | $1.1 \times 10^{-3}$ |
| Livermore SW-MEI | Plutonium-239 | $7.4 \times 10^{-5}$ | $1.9 \times 10^{-8}$ | $1.44 \times 10^{-8}$(b) | $1.9 \times 10^{-4}$ |
| Site 300 SW-MEI | Uranium-238 | $3.1 \times 10^{-4}$ | $1.1 \times 10^{-9}$ | $7.4 \times 10^{-7}$(c) | $2.4 \times 10^{-3}$ |

Note: 1 Bq = $2.7 \times 10^{-11}$ Ci

(a) The measured tritium value includes contributions from all minor sources (including the Building 612 Yard and the Building 331 Outside Yard), Tritium Facility, and DWTF; it is not possible to differentiate the contributions of the Tritium Facility and DWTF from those of the minor sources.

(b) The mean measured concentration is less than the detection limit.

(c) The ratio for the mean uranium-235 and uranium-238 concentrations for 2008 is 0.00725, which is equal to the ratio of these isotopes for naturally occurring uranium. This value for uranium-238 is from naturally occurring uranium resuspended in the soil.

### 7.4.1 Estimate of Dose to Biota

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

Limits on absorbed dose to biota are 10 mGy/d (1 rad/d) for aquatic animals and terrestrial plants, and 1 mGy/d (0.1 rad/d) for terrestrial animals. At LLNL in 2009, radionuclides contributing to dose to biota were americium-241, cesium-137, tritium, plutonium-238, plutonium-239, thorium-232, uranium-234, uranium-235, and uranium-238. In the 2009 LLNL assessment, the maximum concentration of each radionuclide measured in soils and surface waters was used in the dose screening calculations. This approach resulted in an assessment that is extremely conservative, given that the maximum concentrations in the media are distributed over a very large area. Specifically, it accounts for the exposure at both the Livermore site and Site 300 and no plant or animal would likely be exposed to both. Furthermore, although biota would most likely live in and near permanent bodies of water (i.e., surface water), measurements of storm water runoff were used for the assessment because higher concentrations of radionuclides are measured in runoff than in surface waters.

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

In 2009, the sum of the fractions for the aquatic system was 0.0714, and the sum for the terrestrial system was 0.0243 with a total of 0.0957 for the combined fraction. The predominant contribution is due to uranium in the Site 300 soil.

## 7.5 Environmental Impact

The annual radiological doses from all emissions at the Livermore site and Site 300 in 2008 were found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs standard. This standard limits to 100 µSv/y (10 mrem/y) the EDE to any member of the public arising as a result of releases of radioactive material to air from DOE facilities. Using an EPA-mandated computer model and actual LLNL meteorology appropriate to the two sites, potential doses to the LLNL SW-MEI members of the public from LLNL operations in 2009 were:

- Livermore site: 0.042 µSv (0.0042 mrem)—36% from point-source emissions; 64% from diffuse-source emissions.
- Site 300: $2.7 \times 10^{-6}$ µSv ($2.7 \times 10^{-7}$ mrem)—100% from the point source emissions.

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

The collective EDE attributable to LLNL operations in 2009 was estimated to be 0.002 person-Sv (0.2 person-rem) for the Livermore site and $5.1 \times 10^{-7}$ person-Sv ($5.1 \times 10^{-5}$ person-rem) for Site 300. These doses include potentially exposed populations of 7.22 million people for the Livermore site and 6.7 million people for Site 300 living within 80 km of the site centers.

The doses to the SW-MEI, which represent the maximum doses that could be received by members of the public, resulting from Livermore site and Site 300 operations in 2009 were insignificant compared to both the federal standard and the dose received from natural background sources. The collective doses from LLNL operations in 2009 reflect the large population within the 80-km range of the Livermore site and Site 300.

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

Potential radiological doses from LLNL operations were well below regulatory standards and were very small compared with doses normally received from natural background radiation sources, even though highly conservative assumptions were used in the determination of LLNL doses. The potential maximum doses to the public indicate that LLNL's use of radionuclides had no credible impact on public health during 2009.

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# 8. Groundwater Investigation and Remediation

*Valerie Dibley*

During 2009, groundwater investigations and remediation under CERCLA continued at both the Livermore site and Site 300. Lawrence Livermore National Laboratory samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology and nature and extent of the contamination and its source. Where necessary, remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each area is developed in consultation with the regulatory agencies and the community.

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

## 8.1 Livermore Site Ground Water Project

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

An analysis of all environmental media showed that groundwater and both saturated and unsaturated soils are the only media that require remediation (Thorpe et al. 1990). Compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards (MCLs) are TCE, PCE, 1,1-dichloroethylene, chloroform, 1,2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, trichlorotrifluoroethane (Freon-113), trichlorofluoromethane (Freon-11), and carbon tetrachloride. PCE is also present at low concentrations slightly above the MCL in off-site plumes that extend from the southwestern corner of the Livermore site. LLNL operates groundwater extraction wells in both on-site and off-site areas. In addition, LLNL maintains an extensive network of groundwater monitoring wells in the off-site area west of Vasco Road.

### 8.1.1 Physiographic Setting

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

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

### 8.1.2 Hydrogeology of the Livermore Site

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

### 8.1.3 Remediation Activities and Monitoring Results

In 2009, LLNL maintained 29 groundwater treatment facilities. The groundwater extraction wells and dual (groundwater and soil vapor) extraction wells produced more than 832 million L of groundwater and the treatment facilities removed nearly 46.3 kg of VOCs. Since remediation began in 1989, approximately 14.3 billion L of groundwater have been treated, resulting in removal of more than 1399 kg of VOCs. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2010).

LLNL also maintained 9 soil vapor treatment facilities in 2009. The soil vapor extraction wells and dual extraction wells produced more than 999,000 $m^3$ of soil vapor and the treatment facilities removed more than 39.4 kg of VOCs. Since initial operation, over 10 million $m^3$ of soil vapor has been extracted and treated, removing more than 1393 kg of VOCs from the subsurface. Detailed flow and mass removal by treatment facility area is presented in Buscheck et al. (2010).

During 2009, the Remedial Project Managers signed a Consensus Statement for Environmental Restoration of the Livermore Site that included 32 new Federal Facility Agreement milestones. The majority of these milestones included the restoration of treatment facility operations that were shut down or required repair due to the fiscal year 2008 budget shortfall. Enhanced Source Area Remediation (ESAR) related work was mostly limited to minor modifications to the facilities that will be part of the ESAR activities to accommodate field treatability tests. These modifications included instrumentation of treatability test wells with level transducers to observe the influence of nearby pumping at the Treatment Facility (TF) D Helipad and limited testing of a pump that can withstand high temperatures at the Vapor Treatment Facility (VTF) E Eastern Landing Mat ESAR site. In addition, two new extraction wells were drilled and constructed in the TFB area located near the western border of the Livermore site where concentrations remain above the maximum contaminant level (5 micrograms per liter) for trichloroethene (TCE). See Buscheck et al. (2010) for the current status of cleanup progress.

Groundwater concentration and hydraulic data indicate very little change in the VOC concentrations and areal extent of the contaminant plumes in 2009. This lack of significant change is primarily attributable to active remediation at several groundwater treatment facilities that operated during the entire calendar year, and also to remediation that was restarted at many facilities prior to September 2009. There is little to no evidence of measureable contaminant plume migration while many treatment facilities were not operating during late 2008 and early 2009. Hydraulic containment along most portions of the western and southern boundaries of the site was fully re-established and limited progress was made toward interior plume and source area clean up.

### 8.1.4 Environmental Impacts

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

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

## 8.2 Site 300 CERCLA Project

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

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in Webster-Scholten (1994) and the *Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2006).

### 8.2.1 Physiographic Setting and Geology of Site 300

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

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

### 8.2.2 Contaminant Hydrogeology of Site 300

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

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

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

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

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

### 8.2.3 Remediation Activities and Monitoring Results

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

- Operating up to 20 groundwater and soil vapor extraction and treatment facilities.
- Capping and closing four landfills, six high explosives rinse water lagoons and one high explosives burn pit.
- Removal and/or closure of numerous dry wells throughout the site.
- Removal of contaminated soil from source areas throughout the site.
- Installation and sampling of over 680 groundwater monitor wells to track plume migration and remediation progress.

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

In 2009, the Site 300 ERP operated 13 groundwater and 5 soil vapor treatment facilities. About 33 million L of groundwater were extracted and treated during 2009. The dual and soil vapor extraction wells together removed 2.6 million $m^3$ of contaminated soil vapor. The Site 300 treatment facilities removed nearly16 kg of VOCs, 0.12 kg of perchlorate, 1500kg of nitrate, 0.14 kg of the high explosive compound RDX and 0.0031 kg of silicone oils (TBOS/TKEBS) in 2009. Since groundwater remediation began in 1990, approximately 1423 million L of groundwater has been treated, resulting in removal of more than 540 kg of VOCs, 0.91 kg of perchlorate, 8100 kg of nitrate, 1.3 kg of RDX, and 9.5 kg of silicone oils. Detailed flow and mass removal by OU is presented in Dibley et al. (2010).

Cleanup remedies have been fully implemented and are operational in seven 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 854, and Building 832 Canyon OUs). The Building 850/Pit 7 Complex OU will be fully implemented in 2010. The CERCLA pathway for the last OU, Building 812, is being negotiated with the regulatory agencies.

Cleanup of polychlorinated biphenyl (PCB), dioxin, and furan-contaminated soil surrounding Building 850 was completed in 2009. Prior to PCBs becoming regulated substances, capacitors were destroyed on the Building 850 Firing Table during experiments. Dioxins and furans were created by the combustion of the PCBs during these experiments. Cleanup was necessary to mitigate cancer risk to on-site workers resulting from the potential inhalation or ingestion of resuspended particulates and direct dermal exposure to contaminated surface soil, as well as to mitigate potential hazard to burrowing owls. Approximately 22,172 $m^3$ of PCB-contaminated soil were excavated from the hillsides, solidified using portland cement, and placed in the former Corporation yard of Building 850.

Groundwater concentration and hydraulic data collected and analyzed for Site 300 during 2009 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 2009 is available in the *2009 Annual Compliance Monitoring Report for LLNL Site 300* (Dibley et al. 2010).

### 8.2.4 Environmental Impacts

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

# 9. Quality Assurance

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

## 9.1 Quality Assurance Activities

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

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

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

LLNL participates in the Department of Energy Consolidated Auditing Program (DOECAP). Annual, on-site visits to commercial laboratories under contract to LLNL are part of the auditing program to ensure that accurate and defensible data are generated. The audit program is based on National Environmental Laboratory Accreditation Program (NELAP) requirements. All commercial laboratories used by LLNL EPD are DOE-qualified vendors and are NELAP certified (or equivalent). LLNL has qualified auditors under the DOECAP program in the areas of quality assurance, organic chemistry, inorganic chemistry, radiochemistry, laboratory information management, and hazardous material management. Audit reports, checklists, and Corrective Action Plans are maintained under the DOECAP program for qualified commercial labs. In FY2009, the laboratories certified by the State of California operating at LLNL as government owned and contractor operated were not internally assessed or qualified by EPD due to budgetary and staff limitations, but were recertified by the State of California under the Environmental Laboratory Accreditation Program (ELAP).

## 9.2 Analytical Laboratories and Laboratory Intercomparison Studies

In 2009, LLNL had Blanket Service Agreements (BSAs) with nine commercial analytical laboratories and used two on-site analytical laboratories. All analytical laboratory services used by LLNL are provided by facilities certified by the State of California. LLNL works closely with these analytical laboratories to minimize problems and ensure that QA objectives are maintained.

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

Although laboratories are also required to participate in laboratory intercomparison programs, permission to publish their results for comparison purposes was not granted for 2009. To obtain Mixed Analyte Performance Evaluation Program (MAPEP) reports that include the results from all participating laboratories, see http://www.inl.gov/resl/mapep/reports.html. MAPEP is a DOE program and the results are publicly available from laboratories that choose to participate.

## 9.3 Duplicate Analyses

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

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

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

| Media | Analyte | N[a] | %RSD[b] | Slope | $r^2$[c] | Intercept |
|---|---|---|---|---|---|---|
| Air | Gross beta | 85 | 20.1 | 0.963 | 0.83 | $1.04 \times 10^{-5}$ (Bq/m$^3$) |
| | Beryllium[d] | 14 | 14.6 | 0.7 | 0.87 | 1.22 (pg/m$^3$) |
| | Uranium-235 | 12 | 9.07 | 0.966 | 0.91 | $1.5 \times 10^{-8}$ (µg/m$^3$ |
| | Uranium-238 | 12 | 10.3 | 0.985 | 0.89 | $2.29 \times 10^{-6}$ (µg/m$^3$) |
| | Tritium | 35 | 22.5 | 0.763 | 0.93 | 0.00663 (Bq/m$^3$) |
| Dose (TLD) | 90-day radiological dose[e] | 30 | 3.54 | 0.97 | 0.69 | 0.393 (mrem) |
| Groundwater | Gross alpha | 10 | 44.9 | 1.11 | 0.81 | –0.0291 (Bq/L) |
| | Gross beta[e] | 44 | 24.3 | 0.792 | 0.59 | 0.0503 (Bq/L) |
| | Arsenic | 24 | 16.8 | 0.955 | 0.98 | 0.000406 (mg/L) |
| | Barium | 21 | 3.63 | 1.05 | 0.97 | –0.00165 (mg/L) |
| | Chloride | 9 | 0.718 | 0.985 | 1 | 3.41 (mg/L) |
| | Fluoride | 9 | 4.56 | 1.01 | 1 | –0.00389 (mg/L) |
| | Nitrate (as $NO_3$) | 24 | 4.35 | 0.842 | 0.99 | 2.9 (mg/L) |
| | Potassium | 10 | 0 | 1 | 1 | $4.49 \times 10^{-15}$ (mg/L) |
| | Sodium | 10 | 0 | 1.02 | 1 | –1.27 (mg/L) |
| | TDS | 9 | 1.79 | 0.991 | 1 | 35.6 (mg/L) |
| | Sulfate | 9 | 1.79 | 0.989 | 1 | –1.52 (mg/L) |
| | Tritium | 13 | 6.44 | 0.998 | 1 | 2.38 (Bq/L) |
| | Uranium-234+ uranium-233 | 18 | 12.4 | 0.966 | 0.99 | 0.000564 (Bq/L) |
| | Uranium-235 | 12 | 22.5 | 0.889 | 0.95 | 0.000751 (Bq/L) |
| | Uranium-238 | 17 | 12.7 | 1 | 0.99 | 0.000222 (Bq/L) |
| Sewer | Gross alpha[e] | 11 | 31.4 | 1.31 | 0.92 | $-1.97 \times 10^{-5}$ (Bq/mL) |
| | Gross beta | 52 | 11.7 | 0.81 | 0.8 | 0.000149 (Bq/mL) |
| | Acetone[d] | 10 | 53.3 | 0.101 | 0.28 | 118 (µg/L) |
| | Chloroform[d] | 9 | 48.1 | 1.08 | 0.53 | 2.32 (µg/L) |

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

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

(c) Coefficient of determination.

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

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

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

| Media | Analyte | N[(a)] | Mean ratio | Minimum ratio | Maximum ratio |
|---|---|---|---|---|---|
| Air | Gross alpha | 4 | 1.3 | 0.81 | 2.1 |
| Groundwater | Radium-226 | 6 | 1.4 | 0.92 | 1.7 |
| OW | Gross beta | 1 | 0.82 | 0.82 | 0.82 |
| Rain | Tritium | 3 | 0.83 | 0.66 | 1.1 |
| Release water | Tritium | 1 | 0.77 | 0.77 | 0.77 |
| Runoff (from rain) | Gross alpha | 4 | 1.5 | 0.73 | 2.1 |
| | Gross beta | 5 | 1.1 | 0.79 | 1.2 |
| | Tritium | 1 | 1 | 1 | 1 |
| | Uranium-234 + 233 | 2 | 0.7 | 0.35 | 1 |
| | Uranium-235 + 236 | 1 | 0.83 | 0.83 | 0.83 |
| | Uranium 238 | 1 | 1 | 1 | 1 |
| Soil | Gross alpha | 1 | 1.5 | 1.5 | 1.5 |
| | Gross beta | 1 | 0.81 | 0.81 | 0.81 |
| | Cesium-137 | 3 | 0.97 | 0.89 | 1 |
| | Tritium | 1 | 1.1 | 1.1 | 1.1 |
| | Potassium-40 | 3 | 0.98 | 0.9 | 1.1 |
| | Plutonium-238 | 1 | 0.0014 | 0.0014 | 0.0014 |
| | Plutonium-239+240 | 2 | 0.0014 | 0.0011 | 0.0016 |
| | Radium-226 | 3 | 0.91 | 0.84 | 0.96 |
| | Radium-228 | 3 | 0.96 | 0.91 | 1 |
| | Thorium-228 | 3 | 0.95 | 0.93 | 0.98 |
| | Uranium-235 | 3 | 1 | 0.95 | 1.1 |
| | Uranium-238 | 3 | 1 | 0.65 | 1.3 |
| Sewer | Tritium | 2 | 1 | 0.89 | 1.2 |
| Vegetation | Tritium | 3 | 0.91 | 0.69 | 1.2 |

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

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

| Media | Analyte | No. inconsistent pairs[(a)] | No. pairs | Percent inconsistent pairs |
|---|---|---|---|---|
| Air | Gross beta | 2 | 13 | 15 |
| Groundwater | Gross alpha | 3 | 37 | 8.1 |
| | Acetone | 1 | 20 | 5 |
| | Chloromethane | 1 | 43 | 2.3 |
| | Copper | 1 | 39 | 2.6 |
| | Naphthalene | 1 | 32 | 3.1 |
| | Trichloroethene | 1 | 38 | 2.6 |
| | Zinc | 2 | 36 | 5.6 |
| Sewer | Gross alpha | 9 | 41 | 22 |
| | 2-Butanone | 1 | 10 | 10 |
| Vegetation | Tritium | 1 | 8 | 12 |

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

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

Precision is measured by the percent relative standard deviation (%RSD); see the EPA's *Data Quality Objectives for Remedial Response Activities: Development Process*, Section 4.6 (U.S. EPA 1987). Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, lower values represent better precision. The results for %RSD given in **Table 9-1** are the 75th percentile of the individual precision values. Routine and collocated sample results show good %RSD—90% of the pairs have %RSD of 32% or better; 75% have %RSD of 16% or better.

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

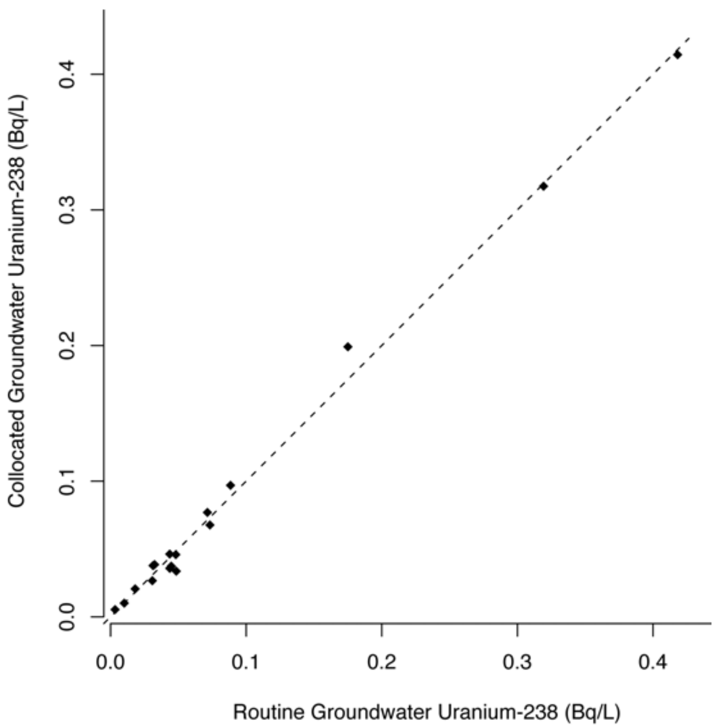


**Figure 9-1.** Example of data points that demonstrate good agreement between collocated sample results using uranium-238 concentrations in groundwater

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

Data sets that do not meet LLNL regression analysis criteria fall into one of two categories: outliers and high variability. Outliers can occur because of data transcription errors, measurement errors, or real but anomalous results. Of the 25 data sets reported in **Table 9-1**, three did not meet the criterion for acceptability because of outliers. **Figure 9-2** illustrates a set of collocated pairs with one outlier.

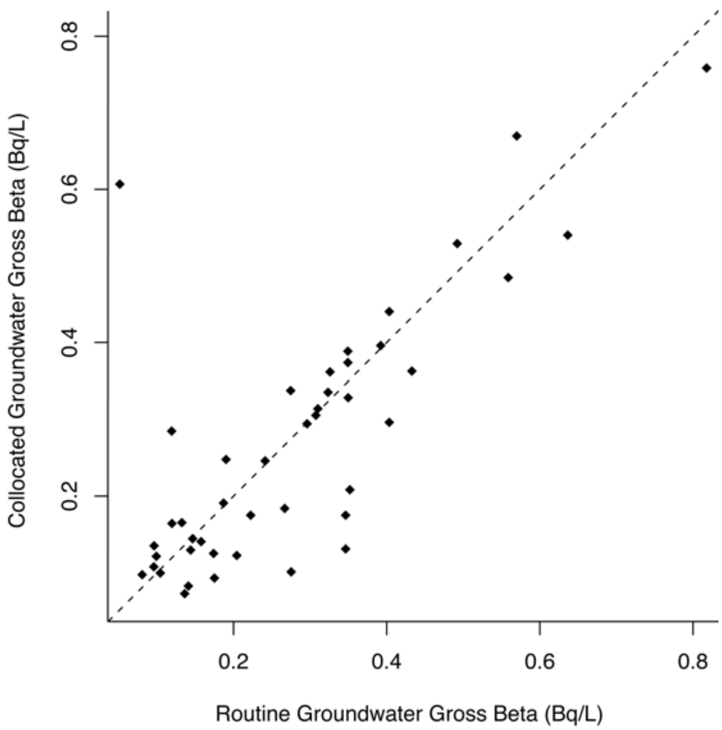


**Figure 9-2.** Example of data with one outlier using collocated groundwater gross beta concentrations

The second category, high variability, occurs when the measurement process inherently has substantial variability (see **Figure 9-3** for an example). It also tends to occur at extremely low environmental concentrations. Low concentrations of radionuclides on particulates in air highlight this effect because a small 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 25 data sets listed in **Table 9-1**, three show sufficient variability in the results to make them fall outside the acceptable range.

## 9.4 Data Presentation

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

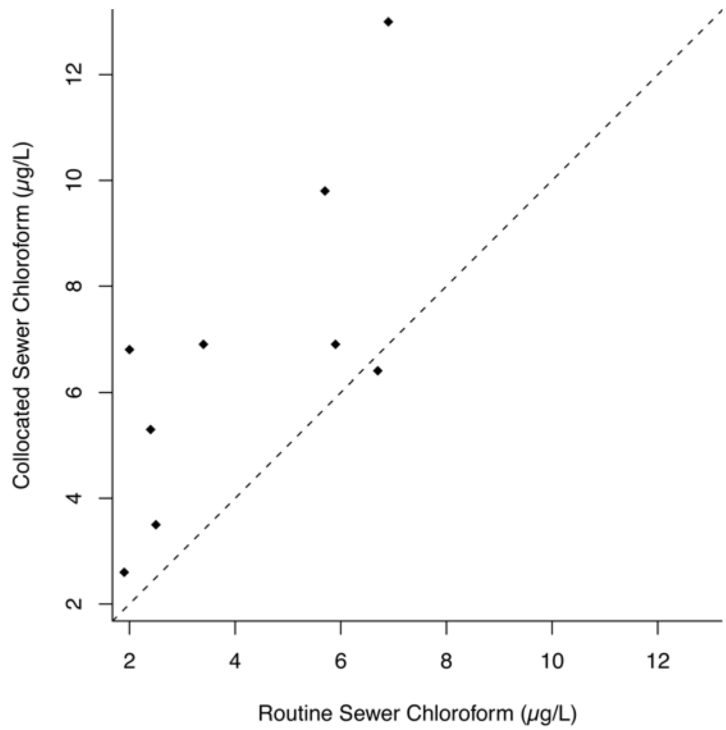


**Figure 9-3.** Example of variability using collocated sewer chloroform concentrations

### 9.4.1 Radiological Data

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

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

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

### 9.4.2 Nonradiological Data

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

## 9.5 Statistical Comparisons and Summary Statistics

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

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

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

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

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

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

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

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

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

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

## 9.6 Reporting Uncertainty in Data Tables

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

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

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

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

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

When rounding a value with a final digit of "5," the software that was used to prepare the data tables follows the IEEE Standard 754-1985, which is "go to the even digit." For example, 2.45 would be rounded down to 2.4, and 2.55 would be rounded up to 2.6.

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

## 9.7 Quality Assurance Process for the Environmental Report

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

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

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

For this 2009 environmental report, LLNL staff checked tables and figures in the body of the report. Forms to aid in the QC of tables and figures were distributed along with the appropriate figure, table, and text, and a coordinator kept track of the process. Items that were checked included clarity and accuracy of figure captions and table titles; data accuracy and completeness; figure labels and table headings; units; significant digits; and consistency with text. Completed QC forms and the corrected figures or tables were returned to the report editor, who, in collaboration with the responsible author, ensured that corrections were made.

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

## 9.8 Errata

**Appendix E** contains the protocol for errata in LLNL *Environmental Reports* and the errata for LLNL *Environmental Report 2008*.

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# Acronyms and Glossary

## Symbols and Units of Measure

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

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

## Acronyms and Abbreviations

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

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

| | |
|---|---|
| IQR | Interquartile range (*See also* definition in **Key Terms** section.) |
| ISMS | Integrated Safety Management System |
| ISO | International Organization for Standardization |
| ITS | Institutional Tracking System |
| LEED | Leadership in Energy and Environmental Design |
| LEED-EB | Leadership in Energy and Environmental Design for Existing Buildings |
| LEPC | Local Emergency Planning Committee |
| LLNL | Lawrence Livermore National Laboratory |
| LLNS | Lawrence Livermore National Security, LLC |
| LWRP | Livermore Water Reclamation Plant |
| MAPEP | Mixed Analyte Performance Evaluation Program |
| MARLAP | Multi-Agency Radiological Laboratory Analytical Protocols |
| MCL | maximum contaminant level (*See also* definition in **Key Terms** section.) |
| MDC | minimum detectable concentration |
| MRP | Monitoring and Reporting Program |
| MSDS | material safety data sheet |
| NCRP | National Council on Radiation Protection and Measurements |
| NELAP | National Environmental Laboratory Accreditation Program |
| NEPA | National Environmental Policy Act (*See also* definition in **Key Terms** section.) |
| NESHAPs | National Emissions Standards for Hazardous Air Pollutants |
| NHPA | National Historic Preservation Act |
| NIF | National Ignition Facility |
| NNSA | National Nuclear Security Administration |
| NOx | nitrous oxides |
| NPDES | National Pollutant Discharge Elimination System (*See also* definition in **Key Terms** section.) |
| NRHP | National Register of Historic Places |
| OBT | organically bound tritium |
| ODS | ozone depleting substance |
| ORNL | Oak Ridge National Laboratory |
| OU | operable unit |
| P2 | pollution prevention |
| PA | Programmatic Agreement |
| PCB | polychlorinated biphenyl |
| PCE | perchloroethylene (or perchloroethene); also called tetrachloroethylene or tetrachloroethene |
| PM-10 | particulate matter with diameter equal to or less than 10 micrometer |
| PPMRP | Pollution Prevention and Monitoring and Reporting Program |
| PQL | practical quantitation limit (*See also* definition in **Key Terms** section.) |
| PRAD | (LLNL) Permits and Regulatory Affairs Division |
| QA | quality assurance (*See also* definition in **Key Terms** section.) |
| QC | quality control (*See also* definition in **Key Terms** section.) |
| RCRA | Resource Conservation and Recovery Act of 1976 (*See also* definition in **Key Terms** section.) |
| REC | Renewable Energy Credit |
| RHWM | (LLNL) Radioactive and Hazardous Waste Management Division |
| RL | reporting limit |
| RMP | risk management plan |
| ROG/POC | reactive organic gases/precursor organic compounds |
| RPM | Remedial Project Managers |
| RWQCB | Regional Water Quality Control Board (*See also* definition in **Key Terms** section.) |
| SARA | Superfund Amendment and Reauthorization Act of 1986 (*See also* definition in **Key Terms** section.) |

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

## Metric and U.S. Customary Unit Equivalents

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

## Multipying Prefixes

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

## Key Terms

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

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

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

**Alluvium.** Sediment deposited by flowing water.

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

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

**Analyte.** Specific component measured in a chemical analysis.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Effluent.** Liquid or gaseous waste discharged to the environment.

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

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

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

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

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

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

**Freon-11.** Trichlorofluoromethane.

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

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

**Groundwater.** All subsurface water.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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# APPENDIX A
# Data Tables

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

## A.1 Air Effluent (Chapter 4)

A.1.1 Summary of gross alpha and gross beta (µBq/m$^{3)}$ in background locations for comparison to monitored air effluent emission points in 2009

A.1.2 Summary of gross alpha and gross beta (µBq/m$^3$) in air effluent samples from the monitored emission point at Livermore site, Building 235, 2009

A.1.3 Summary of gross alpha and gross beta (µBq/m$^3$) in air effluent samples from the monitored emission point at Livermore site, Building 491, 2009

A.1.4 Summary of gross alpha and gross beta (µBq/m$^3$) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2009

A.1.5 Summary of tritium (Bq/m$^3$) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2009

A.1.6 Summary of gross alpha and gross beta (µBq/m$^3$) in air effluent samples from the monitored emission points at Livermore site, Building 332, 2009

A.1.7 Summary of tritium in air effluent samples (Bq/m$^3$) from the monitored emission points at Livermore site, Building 331, 2009

A.1.8 Summary of gross alpha and gross beta (µBq/m$^3$) in air effluent samples from the monitored emission point at Site 300, Building 801, 2009

## A.2 Ambient Air (Chapter 4)

A.2.1 Weekly gross alpha and gross beta concentrations (µBq/m$^3$) from air particulate samples from the Livermore perimeter locations, 2009

A.2.2 Tritium concentrations (mBq/m$^3$) in air on the Livermore site, 2009

A.2.3 Beryllium concentration (pg/m$^3$) in Livermore site and Site 300 air particulate samples, 2009

A.2.4 Beryllium-7 concentrations (mBq/m$^3$) composite for Livermore site and Site 300 air particulate samples, 2009

A.2.5 Plutonium-239+240 concentrations (nBq/m$^3$) in air particulate samples from the Livermore perimeter and Site 300 perimeter composite, 2009

A.2.6 Uranium mass concentrations (pg/m$^3$) in air particulate samples from Site 300 onsite and offsite locations, and the Livermore site (composite), 2009

A.2.7 Weekly gross alpha and gross beta concentrations (µBq/m$^3$) from air particulate samples from the Livermore Valley downwind locations, 2009

A.2.8 Tritium concentrations (mBq/m$^3$) in air, Livermore Valley, 2009

A.2.9 Weekly gross alpha and gross beta concentrations (µBq/m$^3$) from air particulate samples from Livermore Valley upwind location and the special interest location, 2009

A.2.10 Plutonium-239+240 concentrations (nBq/m$^3$) in air particulate samples from the Livermore Valley, 2009

A.2.11 Tritium concentrations (mBq/m$^3$) in air, Site 300, 2009

A.2.12 Weekly gross alpha and gross beta concentrations (µBq/m$^3$) from air particulate samples from Site 300 onsite and offsite locations, 2009

## A.3 Livermore Site Wastewater (Chapter 5)



## A.4 Storm Water (Chapter 5)



## A.5 Livermore Site Groundwater (Chapter 5)



## A.6 Site 300 Groundwater (Chapter 5)

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# APPENDIX B
# EPA Methods of Environmental Water Analysis

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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# APPENDIX D
# Extra Resources

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

## Livermore Site Storm Water Monitoring for Waste Discharge Requirements 95-174, 2008–2009

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

## LLNL Ground Water Project Annual Report, 2009

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

## LLNL NESHAPs Annual Report, 2009

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

## Site 300 Building 829 Compliance Monitoring Annual Report, 2009

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

## Site 300 Compliance Monitoring Annual Report, 2009

Dibley, V. (2010). *2009 Annual Monitoring Compliance Report for Lawrence Livermore National Laboratory Site 300.* Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-206319-09.

## Site 300 Storm Water Monitoring for Waste Discharge Requirements 97-03-DWQ Annual Report, 2009

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

## Site 300 Compliance Monitoring for Water Discharge Requirement Order No. R5-2008-0148 Annual Report, 2009

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

## Site 300 Pit 6 Compliance Monitoring Annual Report, 2009

Blake, R, and J. Vallet. (2010). *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report 2009*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-132057-09-4.

## Site 300 Pits 1 and 7 Compliance Monitoring Annual Report, 2009

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

## Supplementary Topics on Radiological Dose

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

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# APPENDIX E
# Errata

## Protocol for Errata in LLNL Environmental Reports

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

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

LLNL environmental reports from 1994 through 2009 can be accessed at https://saer.llnl.gov/.

## Record of Changes to Environmental Report 2008

The following changes have been made to the Internet version of *Environmental Report 2008*.

- **Page 5-16, Section 5.4.1.2, second paragraph:** Last sentence was changed to "…concentrations of 17 µg/L and 16 µg/L, respectively."
- **Page 5-20, Pit 7 Complex section:** First sentence was changed to "The Pit 7 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 in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990)."
- **Page 5-21, continuation of Elk Ravine section, second full paragraph:** First sentence was changed to "The maximum result for tritium analysis for well NC7-61 was the same as 2007 within the limits of counting uncertainty, with a maximum value in 2008 of 1100 Bq/L."
- **Page 5-21, Pit 1 section:** First sentence was changed to "The Pit 7 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 in Rogers/Pacific Corporation (1990)."

- **Page 6-4, Section 6.1.1, third paragraph:** “Location COW” was changed to “Location ESB”.

# Data Workbooks

AF-LOWVOL [uBq/m3]   2009 data    (created 2010-03-24 07:09:22, Oracle) (epprd02.llnl.gov)

**A.1.1  Summary of gross alpha and gross beta (μBq/m$^3$) in background locations for comparison to monitored air effluent emission points in 2009[a]**

| Analyte<br>Location | No. > MDC[b] | Minimum | Median | Maximum |
|---|---|---|---|---|
| Gross alpha | | | | |
| FCC | 4 of 51 | -6.92 | 30.8 | 156 |
| HOSP | 4 of 51 | -22 | 33.9 | 180 |
| WCP | 5 of 50 | -6.48 | 36.6 | 197 |
| Gross beta | | | | |
| FCC | 46 of 51 | 79.2 | 540 | 1850 |
| HOSP | 46 of 51 | 87.7 | 603 | 1810 |
| WCP | 49 of 50 | 135 | 655 | 2330 |

a  See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
b  MDC = minimum detection concentration

**A.1.2 Summary of gross alpha and gross beta (µBq/m$^3$) in air effluent samples from the monitored emission point at Livermore site, Building 235, 2009**

| Analyte<br>Emission Point | No. > MDC[(a)] | Minimum | Median | Maximum |
|---|---|---|---|---|
| Gross alpha | | | | |
| PAM_1 | 0 of 52 | -9.51 | -5.53 | 89.5 |
| Gross beta | | | | |
| PAM_1 | 0 of 52 | -149 | -14.9 | 142 |

(a) MDC = minimum detectable concentration

**A.1.3 Summary of gross alpha and gross beta (μBq/m$^3$) in air effluent samples from the monitored emission points at Livermore site, Building 491, 2009**

| Analyte<br>Emission Point | No. > MDC[a] | Minimum | Median | Maximum |
|---|---|---|---|---|
| Gross alpha | | | | |
| PAM_1 | 0 of 25 | -3.46 | -1.38 | 21.7 |
| Gross beta | | | | |
| PAM_1 | 0 of 25 | -44.8 | 12.1 | 70.7 |

(a) MDC = minimum detectable concentration

AE-695 [uBq/m3]   2009-2010 data    (created 2010-03-24 07:09:56, Oracle) (epprd02.llnl.gov)

**A.1.4  Summary of gross alpha and gross beta (μBq/m$^3$) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2009**

| Analyte<br>Emission Point | No. > MDC[(a)] | Minimum | Median | Maximum |
|---|---|---|---|---|
| Gross alpha | | | | |
| PAM_1 | 1 of 51 | -6.51 | -1.86 | 825 |
| Gross beta | | | | |
| PAM_1 | 0 of 50 | -429 | -6.25 | 170 |

(a)  MDC = minimum detectable concentration

**A.1.5 Summary of tritium (Bq/m$^3$) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2009**

| Analyte<br>Emission Point | No. > MDC[(a)] | Minimum | Median | Maximum |
|---|---|---|---|---|
| HT[(b)] | | | | |
| BUBBLER1 | 3 of 51 | -15.5 | 0.89 | 7.56 |
| HTO[(c)] | | | | |
| BUBBLER1 | 11 of 51 | -11.5 | 4.26 | 9.16 |

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

**A.1.6 Summary of gross alpha and gross beta (μBq/m$^3$) in air effluent samples from the monitored emission points at Livermore site, Building 332, 2009**

| Analyte<br>Emission Point | No. > MDC[(a)] | Minimum | Median | Maximum |
|---|---|---|---|---|
| Gross alpha | | | | |
| SP-1A | 0 of 52 | -5.81 | -3.9 | 44.8 |
| SP-1B | 0 of 52 | -6.73 | -4 | 44.8 |
| SP-2B | 0 of 52 | -5.81 | -3.26 | 42.6 |
| SP-2A | 0 of 52 | -6.66 | -4 | 53.6 |
| SP-3 | 0 of 52 | -6.73 | -4 | 43.7 |
| SP-4 | 0 of 52 | -6.73 | -4.74 | 44.8 |
| SP-6A | 0 of 52 | -5.81 | -3.79 | 66.6 |
| SP-6B | 0 of 52 | -6.66 | -4 | 43.3 |
| SP-7B | 0 of 52 | -6.73 | -4 | 34.6 |
| SP-7A | 0 of 52 | -6.66 | -3.88 | 42.9 |
| SP-8 | 0 of 45 | -6.73 | -4 | 19.3 |
| SP-9 | 0 of 45 | -6.73 | -3.27 | 34.6 |
| SP-10 | 0 of 52 | -5.81 | -4.11 | 42.9 |
| SP-11 | 0 of 52 | -6.73 | -4.35 | 42.9 |
| SP-12 | 0 of 52 | -6.7 | -3.98 | 42.9 |
| Gross beta | | | | |
| SP-1A | 0 of 52 | -81.8 | -4.29 | 95.8 |
| SP-1B | 0 of 52 | -80.7 | -3.77 | 73.6 |
| SP-2B | 1 of 52 | -121 | -4.82 | 246 |
| SP-2A | 0 of 52 | -103 | -4.22 | 94.7 |
| SP-3 | 0 of 52 | -110 | -9.5 | 116 |
| SP-4 | 0 of 52 | -104 | -2.81 | 126 |
| SP-6A | 0 of 52 | -62.9 | -9.62 | 81.4 |
| SP-6B | 0 of 52 | -89.2 | -9.62 | 96.6 |
| SP-7B | 0 of 52 | -79.2 | -11.4 | 88.4 |
| SP-7A | 0 of 52 | -87.7 | 7.03 | 102 |
| SP-8 | 0 of 45 | -120 | -10.6 | 101 |
| SP-9 | 0 of 45 | -89.2 | -4.29 | 163 |
| SP-10 | 0 of 52 | -78.8 | -2.84 | 85.8 |
| SP-11 | 0 of 52 | -89.5 | -4.12 | 112 |
| SP-12 | 0 of 52 | -89.5 | -8.2 | 73.3 |

(a) MDC = minimum detectable concentration

**A.1.7 Summary of tritium in air effluent samples (Bq/m$^3$) from the monitored emission points at Livermore site, Building 331, 2009**

| Analyte Emission Point | equip.id | No. > MDC[(a)] | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| HT[(b)] | | | | | |
| Stack1 | BUBBLER1 | 51 of 51 | 56.1 | 108 | 5100 |
| Stack2 | BUBBLER2 | 3 of 51 | -9.91 | 4.35 | 18.5 |
| HTO[(c)] | | | | | |
| Stack1 | BUBBLER1 | 51 of 51 | 151 | 321 | 99000 |
| Stack2 | BUBBLER2 | 40 of 51 | -3.77 | 34.2 | 72.5 |

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

AE-801 [uBq/m3]   2009 data    (created 2010-03-24 07:10:03, Oracle) (epprd02.llnl.gov)

**A.1.8  Summary of gross alpha and gross beta (µBq/m$^3$) in air effluent samples from the monitored emission point at Site 300, Building 801, 2009**

| Analyte<br>Emission Point | No. > MDC[(a)] | Minimum | Median | Maximum |
|---|---|---|---|---|
| Gross alpha | | | | |
| PAM_1 | 6 of 35 | -4.92 | 8.84 | 189 |
| Gross beta | | | | |
| PAM_1 | 25 of 35 | 8.44 | 117 | 714 |

(a)  MDC = minimum detectable concentration

**A.2.1 Weekly gross alpha and gross beta concentrations (uBq/m$^3$) from air particulate samples from the Livermore perimeter locations, 2009[(a)]**

| Date | Gross alpha CAFE | Gross alpha COW | Gross alpha CRED | Gross alpha MESQ | Gross alpha MET | Gross alpha SALV | Gross alpha VIS |
|---|---|---|---|---|---|---|---|
| 6-Jan | 19.7 ± 28.2 | 8.5 ± 23.5 | 13.9 ± 25.7 | 2.8 ± 20.5 | 31.0 ± 32.2 | 14.1 ± 25.9 | 19.7 ± 28.1 |
| 13-Jan | 16.9 ± 31.1 | -10.2 ± 16.4 | 3.3 ± 24.2 | 37.0 ± 38.5 | 30.6 ± 36.5 | -3.5 ± 21.4 | 16.6 ± 30.6 |
| 20-Jan | 42.6 ± 39.2 | 9.8 ± 27.1 | 29.6 ± 35.3 | 42.2 ± 39.2 | 9.8 ± 27.2 | 56.2 ± 44.0 | 44.4 ± 41.1 |
| 27-Jan | 9.8 ± 27.0 | -3.3 ± 20.7 | (b) | 35.7 ± 37.0 | 16.5 ± 30.4 | 29.7 ± 35.4 | 10.1 ± 27.9 |
| 3-Feb | 3.3 ± 24.2 | 41.8 ± 38.8 | 29.9 ± 35.6 | 9.8 ± 27.3 | 9.6 ± 26.7 | -3.2 ± 20.0 | 3.3 ± 24.5 |
| 10-Feb | 43.7 ± 40.3 | 10.2 ± 28.4 | 9.8 ± 27.2 | 23.1 ± 33.0 | 23.9 ± 34.1 | 51.4 ± 43.3 | 16.5 ± 30.3 |
| 17-Feb | -3.3 ± 20.6 | -9.9 ± 15.9 | -9.9 ± 15.9 | 9.8 ± 27.3 | 3.3 ± 24.2 | 9.9 ± 27.5 | 3.3 ± 24.5 |
| 24-Feb | 16.4 ± 30.1 | -9.9 ± 15.8 | 16.4 ± 30.2 | 16.2 ± 29.9 | 3.3 ± 24.0 | 3.3 ± 24.3 | 17.3 ± 31.8 |
| 3-Mar | 3.3 ± 24.4 | -3.3 ± 20.4 | -3.3 ± 20.3 | -3.3 ± 20.2 | 9.8 ± 27.3 | 9.9 ± 27.4 | 16.6 ± 30.5 |
| 10-Mar | -3.4 ± 20.8 | -3.4 ± 20.8 | 3.3 ± 24.5 | 9.9 ± 27.5 | -10.0 ± 16.0 | -3.3 ± 20.7 | -10.1 ± 16.2 |
| 17-Mar | 3.3 ± 24.3 | 3.4 ± 25.2 | 3.3 ± 24.2 | 3.4 ± 24.8 | -3.3 ± 20.5 | 10.1 ± 27.9 | -10.0 ± 16.0 |
| 24-Mar | -3.2 ± 20.1 | -3.3 ± 20.3 | 10.1 ± 28.1 | -9.9 ± 15.9 | 3.3 ± 24.0 | 9.6 ± 26.5 | 3.4 ± 24.6 |
| 31-Mar | -3.5 ± 21.6 | 22.7 ± 32.4 | 9.5 ± 26.4 | 16.5 ± 30.3 | 3.2 ± 23.8 | -3.3 ± 20.7 | 9.8 ± 27.1 |
| 7-Apr | 29.9 ± 35.7 | -3.4 ± 21.2 | 10.4 ± 28.7 | 16.8 ± 30.9 | -3.3 ± 20.5 | 3.3 ± 24.3 | 10.2 ± 28.2 |
| 14-Apr | -3.5 ± 21.4 | -10.2 ± 16.3 | 9.5 ± 26.3 | 17.5 ± 32.2 | -6.0 ± 36.9 | 23.0 ± 32.9 | 9.5 ± 26.3 |
| 21-Apr | 3.3 ± 24.4 | -3.3 ± 20.6 | 3.5 ± 25.5 | 16.8 ± 30.9 | 0.99 ± 2.76 | 3.9 ± 28.1 | 10.5 ± 29.2 |
| 28-Apr | 22.4 ± 31.9 | 34.9 ± 36.2 | 16.2 ± 29.8 | 3.2 ± 23.6 | 28.5 ± 34.0 | 43.3 ± 40.0 | 29.2 ± 34.9 |
| 4-May | 11.9 ± 33.0 | -4.0 ± 24.9 | 3.9 ± 28.6 | 20.2 ± 37.0 | 20.0 ± 36.8 | 11.9 ± 33.0 | 11.8 ± 32.6 |
| 12-May | 31.7 ± 32.9 | 20.5 ± 29.3 | -2.9 ± 18.2 | 9.0 ± 24.9 | 8.8 ± 24.4 | 20.1 ± 28.7 | -3.0 ± 18.2 |
| 19-May | 37.7 ± 39.2 | 3.3 ± 24.3 | 23.2 ± 33.1 | 3.4 ± 24.6 | 56.2 ± 44.0 | 22.8 ± 32.5 | 23.3 ± 33.3 |
| 26-May | -3.3 ± 20.6 | 9.9 ± 27.5 | 36.4 ± 37.7 | -3.4 ± 20.8 | 29.8 ± 35.5 | 23.2 ± 33.1 | 29.9 ± 35.7 |
| 2-Jun | 3.3 ± 24.0 | 3.3 ± 24.0 | 3.3 ± 24.1 | 29.9 ± 35.6 | 29.4 ± 35.1 | 10.3 ± 28.5 | 16.5 ± 30.3 |
| 9-Jun | 28.9 ± 34.4 | 10.0 ± 27.8 | 9.8 ± 27.0 | 3.4 ± 25.0 | 23.4 ± 33.4 | -3.2 ± 19.8 | 42.2 ± 39.2 |
| 16-Jun | 17.4 ± 31.9 | 16.6 ± 30.5 | 3.3 ± 24.0 | 9.9 ± 27.6 | -3.3 ± 20.6 | -10.0 ± 16.0 | 16.4 ± 30.2 |
| 23-Jun | 22.3 ± 31.9 | -3.2 ± 19.8 | 23.9 ± 34.1 | 9.6 ± 26.5 | 9.6 ± 26.5 | 3.2 ± 23.3 | 10.2 ± 28.3 |
| 29-Jun | -4.0 ± 24.9 | 12.3 ± 34.0 | 50.7 ± 47.0 | 12.1 ± 33.4 | 4.1 ± 30.0 | 28.2 ± 40.3 | -3.9 ± 24.2 |
| 7-Jul | 26.2 ± 31.2 | 25.8 ± 30.7 | 14.4 ± 26.5 | 14.5 ± 26.8 | 20.1 ± 28.7 | 2.9 ± 21.2 | 25.9 ± 30.9 |
| 14-Jul | 36.5 ± 37.7 | 3.3 ± 24.3 | -9.9 ± 15.9 | 16.6 ± 30.5 | -3.3 ± 20.5 | -3.3 ± 20.6 | -9.9 ± 15.9 |
| 21-Jul | 9.9 ± 27.5 | -3.3 ± 20.5 | 16.6 ± 30.5 | -3.3 ± 20.5 | 23.2 ± 33.1 | -3.3 ± 20.5 | 36.4 ± 37.7 |
| 28-Jul | -3.3 ± 20.6 | -10.0 ± 15.9 | -10.0 ± 16.0 | -3.3 ± 20.6 | -9.9 ± 15.9 | 9.8 ± 27.2 | 10.0 ± 27.7 |
| 4-Aug | 16.5 ± 30.3 | 3.3 ± 24.2 | 9.9 ± 27.3 | 16.5 ± 30.3 | 9.9 ± 27.4 | 10.1 ± 27.9 | 9.9 ± 27.3 |
| 11-Aug | 23.3 ± 33.2 | 29.9 ± 35.7 | 16.6 ± 30.6 | 16.6 ± 30.6 | 23.3 ± 33.2 | 36.0 ± 37.4 | 10.0 ± 27.7 |
| 19-Aug | 31.8 ± 33.1 | 8.7 ± 24.0 | 43.3 ± 36.7 | -2.9 ± 17.9 | 26.0 ± 31.1 | 14.2 ± 26.2 | 8.7 ± 24.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 25-Aug | 73.6 ± 53.6 | 25.8 ± 36.9 | 55.5 ± 47.0 | 65.9 ± 51.4 | 34.8 ± 41.4 | 4.0 ± 29.0 | 25.9 ± 37.0 |
| 1-Sep | 42.2 ± 39.2 | 16.6 ± 30.5 | 36.4 ± 37.7 | 22.7 ± 32.4 | 35.7 ± 37.0 | -9.7 ± 15.6 | 42.9 ± 40.0 |
| 8-Sep | 3.4 ± 24.7 | 3.4 ± 25.2 | 44.8 ± 41.4 | 3.4 ± 24.8 | 50.7 ± 42.9 | -3.0 ± 18.4 | 31.0 ± 36.9 |
| 15-Sep | 3.2 ± 23.3 | 9.5 ± 26.4 | 9.5 ± 26.4 | -3.2 ± 19.7 | 28.7 ± 41.1 | 3.7 ± 27.3 | 28.6 ± 34.1 |
| 22-Sep | 16.6 ± 30.6 | 3.5 ± 25.5 | 31.2 ± 37.4 | 3.3 ± 24.4 | 10.0 ± 27.7 | 20.9 ± 29.9 | 31.2 ± 37.4 |
| 29-Sep | 36.4 ± 37.7 | 15.9 ± 29.3 | 28.6 ± 34.1 | 16.4 ± 30.1 | 16.4 ± 30.1 | 18.6 ± 34.3 | 22.3 ± 31.8 |
| 6-Oct | 17.2 ± 31.6 | 31.0 ± 37.0 | 3.4 ± 25.2 | 17.4 ± 31.9 | 17.1 ± 31.4 | 30.8 ± 36.7 | -3.4 ± 21.3 |
| 12-Oct | 19.7 ± 36.2 | 3.9 ± 28.4 | 34.9 ± 41.4 | 19.4 ± 35.6 | 19.8 ± 36.5 | 26.6 ± 38.1 | 42.6 ± 44.4 |
| 20-Oct | -8.7 ± 13.9 | -8.7 ± 13.9 | 8.5 ± 23.5 | -2.9 ± 17.9 | -2.9 ± 18.0 | 2.9 ± 20.9 | 2.8 ± 20.7 |
| 27-Oct | 3.2 ± 23.8 | 16.2 ± 29.8 | 9.9 ± 27.4 | 22.7 ± 32.4 | 3.2 ± 23.8 | 30.0 ± 35.7 | -3.3 ± 20.4 |
| 3-Nov | 23.0 ± 32.8 | 9.9 ± 27.5 | 10.1 ± 28.1 | 29.9 ± 35.6 | 9.9 ± 27.5 | 10.1 ± 27.9 | 10.1 ± 27.9 |
| 10-Nov | -3.3 ± 20.3 | 22.7 ± 32.4 | -3.2 ± 19.9 | 16.2 ± 29.7 | 42.2 ± 39.2 | 3.3 ± 23.9 | 16.3 ± 30.0 |
| 17-Nov | 10.1 ± 28.1 | 29.7 ± 35.4 | 37.7 ± 39.2 | -3.3 ± 20.4 | 23.1 ± 32.9 | 16.5 ± 30.2 | 10.3 ± 28.5 |
| 23-Nov | 11.8 ± 32.8 | 20.2 ± 37.0 | 18.5 ± 34.1 | 4.1 ± 29.8 | 12.2 ± 33.7 | (c) | -3.7 ± 23.0 |
| 1-Dec | 20.2 ± 28.9 | 43.7 ± 36.9 | 39.2 ± 36.5 | 26.1 ± 31.1 | 31.9 ± 33.2 | 25.3 ± 21.4 | 33.2 ± 34.5 |
| 8-Dec | 41.8 ± 38.8 | 35.1 ± 36.4 | 60.7 ± 44.0 | 15.9 ± 29.3 | 54.4 ± 42.6 | 75.8 ± 49.2 | 47.7 ± 40.7 |
| 15-Dec | 58.5 ± 45.9 | 79.2 ± 51.4 | 30.9 ± 36.9 | 79.2 ± 51.4 | 30.9 ± 36.9 | 3.3 ± 24.5 | 44.8 ± 41.4 |
| 21-Dec | 50.7 ± 45.9 | 35.2 ± 40.7 | 35.2 ± 40.7 | 42.9 ± 43.7 | 35.4 ± 41.1 | 42.9 ± 43.7 | 35.2 ± 40.7 |
| 28-Dec | 29.7 ± 34.5 | 23.9 ± 32.9 | 63.6 ± 45.9 | 17.2 ± 30.2 | -2.6 ± 20.1 | 10.6 ± 27.3 | 17.3 ± 30.2 |
| Detection frequency | 7 of 52 | 3 of 52 | 7 of 51 | 3 of 52 | 4 of 52 | 5 of 51 | 5 of 52 |
| Median | 16.8 | 9.64 | 13.9 | 16 | 16.4 | 10.1 | 16.4 |
| IQR[d] | 26.5 | 26 | 27.4 | 16.2 | 25.6 | 19.9 | 19.4 |
| Maximum | 73.6 | 79.2 | 63.6 | 79.2 | 56.2 | 75.8 | 47.7 |

| Date | Gross beta CAFE | Gross beta COW | Gross beta CRED | Gross beta MESQ | Gross beta MET | Gross beta SALV | Gross beta VIS |
|---|---|---|---|---|---|---|---|
| 6-Jan | 251 ± 111 | 385 ± 128 | 403 ± 129 | 392 ± 128 | 301 ± 117 | 411 ± 130 | 396 ± 128 |
| 13-Jan | 488 ± 156 | 574 ± 166 | 474 ± 152 | 492 ± 156 | 640 ± 173 | 444 ± 153 | 610 ± 168 |
| 20-Jan | 1350 ± 230 | 1110 ± 212 | 1380 ± 233 | 1300 ± 225 | 1170 ± 217 | 1170 ± 218 | 1390 ± 239 |
| 27-Jan | 503 ± 154 | 429 ± 148 | (b) | 640 ± 168 | 766 ± 183 | 736 ± 180 | 729 ± 181 |
| 3-Feb | 329 ± 134 | 525 ± 155 | 796 ± 186 | 625 ± 168 | 633 ± 167 | 729 ± 176 | 677 ± 175 |
| 10-Feb | 459 ± 152 | 444 ± 152 | 662 ± 172 | 522 ± 157 | 485 ± 157 | 544 ± 164 | 551 ± 161 |
| 17-Feb | 104 ± 102 | 20.8 ± 85.5 | 40.3 ± 89.9 | 20.7 ± 85.1 | 88.1 ± 98.0 | 30.4 ± 87.3 | 11.4 ± 84.7 |
| 24-Feb | 188 ± 114 | 131 ± 105 | 212 ± 118 | 210 ± 117 | 264 ± 125 | 195 ± 116 | 268 ± 131 |
| 3-Mar | 93.6 ± 99.9 | 131 ± 105 | 202 ± 116 | 153 ± 108 | 217 ± 118 | 136 ± 106 | 103 ± 101 |
| 10-Mar | 65.1 ± 95.5 | 55.1 ± 93.2 | 113 ± 104 | 44.8 ± 90.3 | 74.4 ± 96.6 | 94 ± 100 | 85.1 ± 99.9 |
| 17-Mar | 238 ± 122 | 176 ± 117 | 275 ± 127 | 135 ± 108 | 270 ± 127 | 187 ± 116 | 278 ± 128 |
| 24-Mar | 119 ± 102 | 82.5 ± 96.6 | 218 ± 121 | 88.4 ± 98.8 | 207 ± 117 | 52.5 ± 88.8 | 217 ± 121 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 31-Mar | 280 ± 133 | 228 ± 119 | 274 ± 124 | 236 ± 121 | 374 ± 139 | 239 ± 123 | 248 ± 122 |
| 7-Apr | 350 ± 138 | 330 ± 138 | 349 ± 141 | 295 ± 132 | 451 ± 149 | 20.9 ± 85.8 | 346 ± 139 |
| 14-Apr | 152 ± 113 | 91 ± 101 | 181 ± 110 | 185 ± 120 | 81 ± 163 | 97.3 ± 99.5 | 227 ± 117 |
| 21-Apr | 239 ± 123 | 190 ± 115 | 239 ± 127 | 246 ± 125 | 43.7 ± 14.8 | 175 ± 126 | 278 ± 133 |
| 28-Apr | 248 ± 121 | 237 ± 118 | 298 ± 129 | 235 ± 120 | 422 ± 142 | 195 ± 116 | 313 ± 131 |
| 4-May | 83 ± 114 | 130 ± 124 | 178 ± 129 | 143 ± 126 | 235 ± 140 | 112 ± 119 | 122 ± 120 |
| 12-May | 148.0 ± 97.7 | 121.0 ± 94.4 | 168 ± 102 | 219 ± 111 | 142.0 ± 98.0 | 144.0 ± 96.9 | 224 ± 111 |
| 19-May | 340 ± 139 | 281 ± 128 | 324 ± 134 | 313 ± 134 | 392 ± 142 | 295 ± 129 | 287 ± 130 |
| 26-May | 190 ± 115 | 228 ± 121 | 238 ± 122 | 260 ± 127 | 257 ± 125 | 199 ± 117 | 200 ± 117 |
| 2-Jun | 297 ± 130 | 282 ± 127 | 374 ± 139 | 291 ± 130 | 392 ± 141 | 296 ± 133 | 313 ± 132 |
| 9-Jun | 230 ± 118 | 138 ± 108 | 219 ± 118 | 146 ± 111 | 148 ± 110 | 174 ± 110 | 148 ± 107 |
| 16-Jun | 179 ± 118 | 181 ± 114 | 159 ± 110 | 132 ± 106 | 209 ± 118 | 123 ± 105 | 149 ± 108 |
| 23-Jun | 224 ± 117 | 196 ± 113 | 230 ± 124 | 205 ± 114 | 233 ± 118 | 205 ± 114 | 235 ± 124 |
| 29-Jun | 283 ± 148 | 228 ± 141 | 370 ± 157 | 317 ± 152 | 270 ± 148 | 253 ± 144 | 342 ± 152 |
| 7-Jul | 377 ± 129 | 197 ± 105 | 253 ± 113 | 264 ± 115 | 418 ± 133 | 258 ± 114 | 374 ± 128 |
| 14-Jul | 315 ± 133 | 209 ± 118 | 325 ± 134 | 296 ± 131 | 277 ± 128 | 185 ± 115 | 287 ± 129 |
| 21-Jul | 334 ± 135 | 276 ± 128 | 358 ± 138 | 305 ± 131 | 396 ± 143 | 223 ± 120 | 257 ± 125 |
| 28-Jul | 166 ± 112 | 132 ± 107 | 79.2 ± 97.3 | 156 ± 110 | 118 ± 104 | 149 ± 108 | 181 ± 114 |
| 4-Aug | 44.8 ± 90.3 | 54.4 ± 91.8 | 92.5 ± 98.8 | 54.4 ± 92.1 | 78.4 ± 96.2 | 60.3 ± 94.7 | 97.3 ± 99.5 |
| 11-Aug | 336 ± 136 | 229 ± 121 | 341 ± 137 | 253 ± 125 | 340 ± 137 | 231 ± 120 | 224 ± 121 |
| 19-Aug | 283 ± 117 | 220 ± 108 | 334 ± 124 | 271 ± 115 | 225 ± 109 | 196 ± 104 | 266 ± 115 |
| 25-Aug | 351 ± 153 | 270 ± 137 | 228 ± 131 | 311 ± 148 | 317 ± 148 | 266 ± 143 | 287 ± 140 |
| 1-Sep | 437 ± 146 | 330 ± 135 | 314 ± 132 | 403 ± 142 | 374 ± 139 | 313 ± 131 | 286 ± 129 |
| 8-Sep | 311 ± 134 | 252 ± 128 | 302 ± 135 | 238 ± 124 | 277 ± 130 | 278 ± 119 | 212 ± 122 |
| 15-Sep | 320 ± 130 | 302 ± 127 | 306 ± 128 | 316 ± 129 | 422 ± 168 | 283 ± 140 | 260 ± 122 |
| 22-Sep | 350 ± 138 | 250 ± 128 | 429 ± 152 | 336 ± 136 | 396 ± 144 | 319 ± 124 | 304 ± 136 |
| 29-Sep | 636 ± 170 | 485 ± 149 | 625 ± 165 | 577 ± 162 | 610 ± 167 | 614 ± 181 | 581 ± 160 |
| 6-Oct | 256 ± 128 | 122 ± 108 | 287 ± 132 | 194 ± 120 | 265 ± 129 | 246 ± 126 | 142 ± 111 |
| 12-Oct | 696 ± 196 | 548 ± 178 | 610 ± 185 | 640 ± 188 | 777 ± 205 | 488 ± 168 | 718 ± 196 |
| 20-Oct | 199 ± 106 | 136.0 ± 96.2 | 223 ± 107 | 111.0 ± 92.1 | 141.0 ± 96.9 | 159.0 ± 98.4 | 166.0 ± 98.8 |
| 27-Oct | 228 ± 119 | 233 ± 120 | 351 ± 137 | 299 ± 129 | 242 ± 121 | 312 ± 133 | 250 ± 124 |
| 3-Nov | 407 ± 144 | 218 ± 119 | 332 ± 137 | 219 ± 120 | 339 ± 136 | 358 ± 139 | 294 ± 131 |
| 10-Nov | 392 ± 141 | 317 ± 131 | 470 ± 149 | 374 ± 138 | 411 ± 143 | 310 ± 131 | 400 ± 142 |
| 17-Nov | 477 ± 155 | 466 ± 151 | 514 ± 161 | 474 ± 152 | 466 ± 151 | 485 ± 153 | 396 ± 147 |
| 23-Nov | 225 ± 137 | 67 ± 112 | 207 ± 128 | 197 ± 136 | 161 ± 130 | (c) | 164 ± 121 |
| 1-Dec | 548 ± 147 | 507 ± 144 | 610 ± 158 | 522 ± 145 | 625 ± 156 | 414.0 ± 95.5 | 422 ± 138 |
| 8-Dec | 925 ± 194 | 655 ± 168 | 829 ± 185 | 792 ± 181 | 814 ± 183 | 659 ± 172 | 722 ± 175 |
| 15-Dec | 662 ± 176 | 773 ± 188 | 692 ± 179 | 636 ± 174 | 788 ± 189 | 511 ± 157 | 551 ± 165 |
| 21-Dec | 651 ± 187 | 629 ± 184 | 585 ± 179 | 592 ± 180 | 622 ± 184 | 448 ± 164 | 648 ± 186 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28-Dec | 474 ± 149 | 511 ± 156 | 444 ± 148 | 536 ± 159 | 548 ± 160 | 477 ± 152 | 462 ± 151 |
| Detection frequency | 48 of 52 | 46 of 52 | 48 of 51 | 48 of 52 | 48 of 52 | 44 of 51 | 49 of 52 |
| Median | 304 | 231 | 314 | 281 | 328 | 253 | 282 |
| IQR[(d)] | 197 | 258 | 216 | 224 | 232 | 238 | 181 |
| Maximum | 1350 | 1110 | 1380 | 1300 | 1170 | 1170 | 1390 |

(a) See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) No sample due to power (GFI) malfunction
(c) Different sample dates occur when samples could not be collected on scheduled sampling date, or sampler ran longer than 1 week.
(d) IQR = Interquartile range

**A.2.2 Tritium concentrations (mBq/m$^3$) in air on the Livermore site, 2009[(a)]**

| Week | Month | ARAC | CAFE | COW | CRED | DWTF | MESQ | MET | B298[(b)] | B295[(c)] | POOL | SALV | SECO | VIS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Jan | 52.9 ± 15.8 | 17.8 ± 16.1 | 18.3 ± 15.3 | 21.1 ± 14.7 | 13.7 ± 15.8 | 25.5 ± 16.1 | 47.0 ± 16.3 | 98.0 ± 17.4 | - | 21.3 ± 15.7 | 23.6 ± 13.5 | 44.4 ± 14.7 | 43.3 ± 18.0 |
| 3 | Jan | 69.6 ± 12.2 | 39.6 ± 12.7 | 41.1 ± 11.5 | 27.7 ± 10.7 | 40.0 ± 11.9 | 52.9 ± 12.2 | 126.0 ± 14.3 | 179.0 ± 15.0 | - | 74.7 ± 13.0 | 32.0 ± 10.3 | 56.2 ± 11.0 | 51.8 ± 11.3 |
| 5 | Feb | 173.0 ± 18.2 | 116.0 ± 16.6 | 45.1 ± 16.1 | 57.4 ± 15.3 | 41.8 ± 15.9 | 176.0 ± 18.9 | 131.0 ± 17.7 | 156.0 ± 17.1 | - | 178.0 ± 18.9 | 62.9 ± 14.8 | 662.0 ± 24.6 | 45.9 ± 15.1 |
| 7 | Feb | 56.2 ± 15.7 | 44.4 ± 14.9 | 54.4 ± 15.8 | 31.5 ± 13.5 | 41.8 ± 15.4 | 47.4 ± 16.0 | 81.8 ± 17.2 | 3160.0 ± 61.0 | - | 55.9 ± 17.2 | 6.1 ± 12.2 | 37.4 ± 13.6 | 18.0 ± 13.2 |
| 9 | Mar | 51.4 ± 18.5 | 18.6 ± 16.6 | 30.8 ± 18.3 | 37.4 ± 18.4 | 22.9 ± 18.1 | 32.9 ± 16.9 | 28.2 ± 18.4 | 673.0 ± 34.8 | - | 50.7 ± 19.8 | 27.8 ± 16.5 | 38.1 ± 16.3 | 30.2 ± 16.8 |
| 11 | Mar | 24.8 ± 11.5 | 50.0 ± 12.4 | 36.3 ± 12.2 | 67.0 ± 12.5 | 89.5 ± 13.1 | 41.1 ± 11.5 | 29.5 ± 12.4 | 177.0 ± 15.8 | - | 67.7 ± 12.5 | 38.1 ± 11.3 | 34.0 ± 10.7 | 122.0 ± 14.2 |
| 13 | Apr | 57.0 ± 16.4 | 118.0 ± 17.2 | 33.4 ± 16.1 | 44.0 ± 14.9 | 23.0 ± 14.5 | 60.7 ± 15.4 | 1.6 ± 15.9 | 236.0 ± 18.7 | - | 264.0 ± 18.9 | 4.5 ± 14.8 | 17.9 ± 13.7 | 33.8 ± 14.6 |
| 15 | Apr | 20.5 ± 11.6 | 15.1 ± 10.9 | 21.9 ± 10.5 | 31.6 ± 11.2 | 37.0 ± 11.4 | 9.2 ± 10.1 | 12.10 ± 9.66 | 285.0 ± 18.3 | - | 42.6 ± 11.5 | 6.6 ± 10.7 | 14.90 ± 9.73 | 35.9 ± 11.3 |
| 17 | Apr | 36.9 ± 13.2 | 70.3 ± 14.1 | 50.7 ± 12.3 | 76.6 ± 13.7 | 68.4 ± 13.5 | 25.8 ± 12.4 | 25.1 ± 11.2 | 183.0 ± 17.4 | - | - | 48.8 ± 13.7 | 44.8 ± 12.1 | 75.8 ± 13.7 |
| 19 | May | 4.0 ± 17.1 | 88.8 ± 18.8 | 54.0 ± 15.9 | 123.0 ± 18.2 | 89.9 ± 18.6 | 29.0 ± 17.5 | 16.9 ± 15.4 | 223.0 ± 21.1 | - | 124.0 ± 18.4 | 32.2 ± 18.5 | 50.7 ± 16.0 | 145.0 ± 18.6 |
| 21 | May | 29.1 ± 15.7 | 65.1 ± 18.0 | 45.9 ± 15.4 | 78.8 ± 17.5 | 53.3 ± 18.5 | 17.8 ± 17.2 | 28.6 ± 15.0 | 403.0 ± 21.9 | - | 86.6 ± 17.7 | 44.8 ± 14.5 | 25.2 ± 14.6 | 53.3 ± 16.2 |
| 23 | Jun | 10.0 ± 15.8 | 14.1 ± 18.8 | -3.2 ± 15.6 | 38.5 ± 18.7 | 33.9 ± 21.0 | -2.9 ± 17.6 | 11.7 ± 16.4 | 237.0 ± 26.8 | - | 16.9 ± 17.3 | 4.4 ± 15.1 | -9.9 ± 15.2 | 33.4 ± 18.8 |
| 25 | Jun | 22.5 ± 14.1 | 59.2 ± 17.4 | 47.0 ± 15.5 | 41.8 ± 15.5 | 52.5 ± 15.0 | 57.4 ± 17.1 | 26.9 ± 14.5 | 123.0 ± 18.1 | - | 87.7 ± 16.9 | 41.4 ± 14.1 | 27.5 ± 13.4 | 67.3 ± 15.0 |
| 27 | Jul | 21.2 ± 14.4 | 43.7 ± 18.3 | 45.9 ± 16.5 | 60.3 ± 17.0 | 33.6 ± 15.7 | 6.0 ± 14.5 | 5.0 ± 14.5 | 155.0 ± 18.0 | - | 65.1 ± 17.9 | 24.3 ± 13.1 | 4.4 ± 14.0 | 56.2 ± 14.7 |
| 29 | Jul | 33.2 ± 14.7 | 53.6 ± 17.4 | 29.6 ± 12.0 | 67.7 ± 14.4 | 52.2 ± 15.0 | 32.7 ± 13.9 | 17.9 ± 11.4 | - | 21.9 ± 11.8 | 114.0 ± 17.7 | 41.1 ± 13.3 | 41.8 ± 14.1 | 85.1 ± 12.5 |
| 31 | Aug | 5.1 ± 15.3 | 9.5 ± 18.2 | 16.9 ± 16.1 | 66.6 ± 20.7 | 18.0 ± 15.9 | 0.8 ± 15.7 | 11.8 ± 15.7 | - | 3.2 ± 13.8 | 17.5 ± 16.4 | -1.9 ± 15.6 | 3.5 ± 14.6 | 40.7 ± 14.3 |
| 33 | Aug | 6.7 ± 13.5 | 29.7 ± 15.0 | 30.0 ± 15.5 | 42.2 ± 14.9 | 48.8 ± 16.4 | 10.9 ± 14.0 | 22.6 ± 15.5 | - | 22.8 ± 12.8 | 84.4 ± 17.5 | 26.2 ± 15.7 | 7.2 ± 12.5 | 46.2 ± 12.7 |
| 35 | Sep | 54.0 ± 17.4 | 60.3 ± 17.9 | 27.4 ± 13.2 | 37.4 ± 15.1 | 34.9 ± 13.8 | 27.6 ± 16.2 | 44.4 ± 17.7 | - | 64.0 ± 13.8 | 111.0 ± 17.5 | 20.6 ± 13.3 | 26.3 ± 12.5 | 44.8 ± 11.7 |
| 37 | Sep | 26.3 ± 15.2 | 42.9 ± 16.5 | 9.3 ± 14.2 | 21.5 ± 14.0 | 29.2 ± 15.7 | 16.9 ± 15.6 | 26.4 ± 16.5 | - | 26.9 ± 15.6 | 58.8 ± 17.7 | 12.9 ± 15.5 | 11.4 ± 13.7 | 25.7 ± 14.2 |
| 39 | Oct | 102.0 ± 16.7 | 248.0 ± 17.3 | 91.0 ± 15.0 | 74.4 ± 13.1 | 114.0 ± 17.1 | 66.6 ± 16.1 | 56.6 ± 16.5 | - | 145.0 ± 19.5 | 440.0 ± 23.9 | 62.9 ± 15.8 | 59.9 ± 15.6 | 88.8 ± 14.9 |
| 41 | Oct | 20.2 ± 12.1 | 34.6 ± 13.0 | 57.7 ± 14.5 | 62.2 ± 13.8 | 82.5 ± 14.1 | 24.7 ± 13.4 | 23.2 ± 12.5 | - | 55.9 ± 15.4 | 66.6 ± 15.4 | 2.3 ± 11.6 | 2.5 ± 11.6 | 55.5 ± 14.0 |
| 43 | Oct | 57.4 ± 17.5 | 120.0 ± 19.5 | 38.1 ± 19.1 | 30.3 ± 17.7 | 56.6 ± 17.6 | 45.9 ± 18.1 | 44.0 ± 18.0 | - | 80.3 ± 20.7 | 174.0 ± 22.2 | 24.2 ± 17.3 | 41.4 ± 17.6 | 52.2 ± 18.8 |
| 45 | Nov | 59.6 ± 13.0 | 75.8 ± 14.8 | 32.4 ± 13.6 | 39.6 ± 13.1 | 21.3 ± 11.8 | 43.7 ± 13.4 | 61.0 ± 13.5 | - | 115.0 ± 15.1 | 169.0 ± 18.5 | 35.0 ± 13.1 | 36.0 ± 12.6 | 20.8 ± 13.2 |
| 47 | Nov | 49.2 ± 11.6 | 86.2 ± 13.8 | 31.0 ± 12.8 | 38.8 ± 12.1 | 31.9 ± 11.7 | 61.8 ± 13.0 | 54.8 ± 12.5 | - | 86.6 ± 12.4 | 178.0 ± 15.8 | 25.2 ± 12.4 | 76.2 ± 12.4 | 34.6 ± 13.8 |
| 49 | Dec | 50.7 ± 10.3 | 204.0 ± 14.3 | 31.4 ± 10.8 | 47.7 ± 11.5 | 37.7 ± 11.2 | 83.6 ± 13.3 | 68.4 ± 11.5 | - | 71.4 ± 11.2 | - | 37.7 ± 12.6 | 87.0 ± 11.4 | 54.4 ± 15.5 |
| 51 | Dec | 296.0 ± 19.4 | 414.0 ± 28.0 | 350.0 ± 22.7 | 270.0 ± 23.5 | 345.0 ± 25.2 | 247.0 ± 18.1 | 228.0 ± 20.3 | - | 400.0 ± 24.2 | 1640.0 ± 40.7 | 215.0 ± 18.0 | 1490.0 ± 40.0 | 239.0 ± 18.2 |
| | Median | 43 | 56.4 | 34.8 | 43.1 | 40.9 | 32.8 | 28.4 | 203 | 67.7 | 85.5 | 27 | 36.7 | 49 |
| | IQR[(d)] | 35.3 | 52.3 | 17 | 29.5 | 23.5 | 36.8 | 37.1 | 112 | 67.8 | 112 | 25.5 | 33.6 | 29.6 |
| | Median Percent of DCG[(e)] | 0.0012 | 0.0015 | 0.00094 | 0.0012 | 0.0011 | 0.00089 | 0.00077 | 0.0055 | 0.0018 | 0.0023 | 0.00073 | 0.00099 | 0.0013 |
| | Mean Dose (nSv)[(f)] | 11.2 | 17.3 | 10.2 | 12.4 | 12.2 | 10 | 9.93 | 94 | 19.1 | 36.8 | 7.27 | 23.7 | 12.9 |

Note:  Radioactivities are reported as the measured concentration and an uncertainty (± 2σ) counting error.
(a)  See *Environmental Report 2009,* Figure 4-1 for map of sampling locations.
(b)  Removed from surveillance network.
(c)  Start of new sample collection.
(d)  IQR = Interquartile range
(e)   DCG = Derived Concentration Guide of 3.7E+06 mBq/m$^3$ for tritium in air. Percent of DCG is calculated from the median concentratic
(f)  This annual dose is calculated from the mean concentration and represents the effective dose equivalent from inhalation and skin absorption.  When the mean dose is based on a concentration less than the lower limit of detection (about 25 mBq/m$^3$), the dose is assumed to be less than that calculated from the lower limit of detection (i.e., 5 nSv/year).

AF-BE [pg/m3] 2009 data (created 2010-03-24 07:09:17, Oracle) (epprd02.llnl.gov)

**A.2.3 Beryllium concentration (pg/m$^3$) in air particulate samples at the Livermore site and Site 300 locations, 2009[a]**

| Month | Livermore Site Perimeter CAFE | Livermore Site Perimeter COW | Livermore Site Perimeter MESQ | Livermore Site Perimeter MET | Livermore Site Perimeter SALV | Livermore Site Perimeter VIS | Site 300 Perimeter TNK5 | Site 300 Perimeter EOBS | Site 300 Perimeter GOLF | Site 300 Off site TCDF |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 2.6 | 2.4 | 2.7 | 2.8 | 2.2 | 2.4 | 1.6 | 1.7 | 3.4 | 3.3 |
| Feb | 1.8 | 1.4 | 2.1 | 1.8 | 1.6 | 1.8 | 1.3 | 1.2 | 1.5 | 2.2 |
| Mar | 4.3 | 4.5 | 3.9 | 4.4 | 3.3 | 4 | 3.1 | 4.6 | 4.7 | 5.5 |
| Apr | 6.2 | 6.3 | 5.4 | 8.1 | 2.9 | 5.3 | 5.1 | 5.3 | 6.4 | 5.1 |
| May | 9.8 | 5 | 5.2 | 6.4 | 5 | 8.8 | 6.4 | 6.3 | 6.1 | 7.7 |
| Jun | 5.5 | 5 | 5.1 | 5.8 | 5.4 | 5 | 6 | 5.6 | 4.9 | 7.3 |
| Jul | 7.9 | 5.7 | 6.4 | 6.6 | 5.1 | 6.4 | 6.3 | 6.2 | 6.8 | 11 |
| Aug | 7.4 | 6.3 | 5.4 | 6.6 | 6.1 | 6.6 | 4.6 | 6.6 | 7 | 11 |
| Sep | 9.8 | 9.5 | 16 | 8.9 | 6 | 9.8 | 10 | 9.2 | 11 | 12 |
| Oct | 8.2 | 7.1 | 6.4 | 6 | 7.1 | 7.8 | 8.1 | 8.3 | 10 | 10 |
| Nov | 4.5 | 4.4 | 3.3 | 4.3 | 4.1 | 5 | 3.1 | 2.7 | 5.4 | 5.5 |
| Dec | 2.2 | 1.2 | 2.4 | 2.5 | 1.8 | 1.8 | 1.2 | 2.4 | 1.6 | 2.7 |
| Detection frequency | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 |
| Median | 5.8 | 5 | 5.2 | 5.9 | 4.6 | 5.2 | 4.8 | 5.4 | 5.8 | 6.4 |
| IQR[b] | 4.1 | 2.4 | 2.5 | 2.7 | 2.8 | 3.3 | 3.6 | 3.7 | 2.5 | 5.6 |
| Maximum | 9.8 | 9.5 | 16 | 8.9 | 7.1 | 9.8 | 10 | 9.2 | 11 | 12 |
| Median Percent of ACL[c] | 0.058 | 0.05 | 0.052 | 0.059 | 0.046 | 0.052 | 0.048 | 0.054 | 0.058 | 0.064 |
| ACL[c] | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 |

(a) See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) IQR = Interquartile range
(c) ACL=Ambient concentration limit of 10,000 pg/m$^3$ is established by the Bay Area Air Quality Management Air District. Median percent of ACL is calculated from the median value.

**A.2.4 Beryllium-7 concentrations (mBq/m$^3$) composites for the Livermore site and Site 300 air particulate samples, 2009[(a)]**

| Month | LLNL Composite | Site 300 Composite |
|---|---|---|
| Jan | 3.290 ± 0.241 | 3.850 ± 0.279 |
| Feb | 2.060 ± 0.193 | 1.760 ± 0.164 |
| Mar | 0.000 ± 0.343 | 4.590 ± 0.422 |
| Apr | 2.500 ± 0.236 | 4.440 ± 0.407 |
| May | 0.6140 ± 0.0212 | 4.770 ± 0.154 |
| Jun | 2.730 ± 0.107 | 4.700 ± 0.155 |
| Jul | 3.050 ± 0.102 | 5.400 ± 0.172 |
| Aug | 2.7300 ± 0.0895 | 5.110 ± 0.169 |
| Sep | 3.600 ± 0.119 | 4.660 ± 0.154 |
| Oct | 3.030 ± 0.109 | 0.3740 ± 0.0127 |
| Nov | 2.9200 ± 0.0966 | 3.360 ± 0.118 |
| Dec | 2.4900 ± 0.0899 | 3.04 ± 1.04 |
| Detection frequency | 11 of 12 | 12 of 12 |
| Median | 2.73 | 4.52 |
| IQR[(b)] | 0.652 | 1.44 |
| Maximum | 3.6 | 5.4 |

(a) See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) IQR = Interquartile range

AF-PULSS3 [nBq/m3] 2009 data (created 2010-03-24 07:09:25, Oracle) (epprd02.llnl.gov)

**A.2.5 Plutonium-239+240 concentrations (nBq/$m^3$) in air particulate samples from the Livermore site and Site 300 composite, 2009[(a)]**

| Month | Livermore Site Perimeter CAFE | Livermore Site Perimeter COW | Livermore Site Perimeter CRED | Livermore Site Perimeter MESQ | Livermore Site Perimeter MET | Livermore Site Perimeter SALV | Livermore Site Perimeter VIS | Site 300 Perimeter Perimeter Composite |
|---|---|---|---|---|---|---|---|---|
| Jan | 2.72 ± 6.84 | -1.66 ± 1.94 | -0.45 ± 3.96 | 0.00 ± 5.66 | 2.15 ± 5.14 | 3.59 ± 5.66 | 7.62 ± 7.84 | -0.97 ± 1.13 |
| Feb | 8.2 ± 10.1 | 3.05 ± 6.70 | -2.40 ± 2.80 | -1.6 ± 16.0 | 8.6 ± 12.4 | 7.3 ± 17.5 | 0.24 ± 5.66 | 2.37 ± 5.66 |
| Mar | 4.29 ± 9.14 | 4.1 ± 13.5 | 5.4 ± 10.5 | 17.3 ± 15.1 | 2.90 ± 6.96 | 3.77 ± 7.70 | -3.74 ± 6.88 | -0.22 ± 3.69 |
| Apr | 4.77 ± 8.62 | 1.70 ± 4.59 | -4.11 ± 5.36 | 0.00 ± 6.62 | 2.5 ± 10.9 | -2.90 ± 9.36 | 13.8 ± 16.2 | 0.292 ± 0.488 |
| May | 4.96 ± 7.07 | 4.8 ± 12.2 | 119.0 ± 50.0 | -7.0 ± 38.8 | -9.25 ± 9.25 | 0.51 ± 1.48 | 25.2 ± 37.4 | 2.16 ± 2.20 |
| Jun | 1.67 ± 3.36 | 0.00 ± 6.81 | 6.59 ± 8.07 | -1.97 ± 7.14 | 3.55 ± 9.18 | 8.9 ± 11.4 | 4.51 ± 7.73 | 6800 ± 64400 |
| Jul | 0 ± 180 | 24.9 ± 26.9 | 21.8 ± 31.1 | 16.8 ± 15.3 | 70.7 ± 29.0 | 6 ± 195 | 4.3 ± 19.1 | 7.7 ± 13.3 |
| Aug | -14.6 ± 10.6 | 0.00 ± 9.73 | 0.0 ± 11.7 | 0.00 ± 9.29 | 2.7 ± 12.1 | 0.0 ± 15.5 | 86.6 ± 96.6 | 2.97 ± 2.87 |
| Sep | 3.92 ± 5.55 | 14.1 ± 12.4 | 12.2 ± 12.6 | -6.73 ± 5.18 | 5.6 ± 13.4 | 2.2 ± 10.1 | 9.0 ± 14.0 | 4.8 ± 12.0 |
| Oct | 11.1 ± 13.6 | -0.8 ± 19.3 | 0.98 ± 4.37 | 7.4 ± 10.8 | 11.8 ± 11.2 | 0.25 ± 8.44 | 9.80 ± 8.10 | 3.49 ± 4.03 |
| Nov | 0.51 ± 9.55 | 1.70 ± 3.42 | 6.7 ± 11.6 | -1.49 ± 5.40 | 0.71 ± 6.70 | 0.94 ± 1.06 | 0.00 ± 7.73 | 3.03 ± 5.18 |
| Dec | 1.90 ± 8.77 | -8.0 ± 16.4 | -3.8 ± 18.9 | 7.5 ± 11.3 | -16.1 ± 10.0 | 5.25 ± 7.70 | 7.70 ± 7.77 | -0.55 ± 2.02 |
| Detection frequency | 0 of 12 | 1 of 12 | 1 of 12 | 2 of 12 | 2 of 12 | 0 of 12 | 1 of 12 | 1 of 12 |
| Median | 3.32 | 1.7 | 3.21 | 0 | 2.79 | 2.92 | 7.66 | 2.67 |
| IQR[(b)] | 3.44 | 4.49 | 8.98 | 9.14 | 4.55 | 4.95 | 7.49 | 3.65 |
| Maximum[(c)] | 11.1 | 24.9 | 119 | 17.3 | 70.7 | 8.95 | 86.6 | 6810 |
| Median Percent of DCG | 0.00045 | 0.00023 | 0.00043 | (d) | 0.00038 | 0.00039 | 0.001 | 0.00036 |
| DCG[(e)] | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 |

(a) See *Environmental Report 2009*, Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) IQR = Interquartile range
(c) Maximum values of analytical results are displayed whether or not the result is a detect.
(d) Median percent of DCG is calculated when medians are greater than zero
(e ) DCG is the Derived Air Concentration Guide established by the DOE and is the amount of plutonium-239+240 that can be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public.

**A.2.6 Uranium mass concentrations (pg/m$^3$) in air particulate samples from the Livermore site (composite) and Site 300 onsite and offsite locations, 2009[(a)]**

| Month | TNK5 Uranium-235 | TNK5 Uranium-238 | TNK5 U235/U238 ratio[(b)] | ECP Uranium-235 | ECP Uranium-238 | ECP U235/U238 ratio[(b)] | EOBS Uranium-235 |
|---|---|---|---|---|---|---|---|
| Jan | 0.0593 ± 0.0147 | 8.58 ± 2.08 | 0.006820 ± 0.000329 | 0.0626 ± 0.0278 | 8.94 ± 3.95 | 0.006910 ± 0.000314 | 0.0658 ± 0.0333 |
| Feb | 0.0394 ± 0.0148 | 5.47 ± 2.04 | 0.007120 ± 0.000264 | 0.0403 ± 0.0140 | 5.53 ± 1.91 | 0.007200 ± 0.000218 | 0.0376 ± 0.0176 |
| Mar | 0.0816 ± 0.0161 | 11.20 ± 2.20 | 0.007200 ± 0.000107 | 0.08750 ± 0.00893 | 11.90 ± 1.15 | 0.007260 ± 0.000238 | 0.08530 ± 0.00963 |
| Apr | 0.1820 ± 0.0223 | 25.30 ± 3.09 | 0.0071100 ± 0.0000410 | 0.2040 ± 0.0284 | 28.10 ± 3.88 | 0.007160 ± 0.000119 | 0.1860 ± 0.0202 |
| May | 0.1540 ± 0.0148 | 22.00 ± 2.08 | 0.006900 ± 0.000129 | 0.1700 ± 0.0107 | 23.70 ± 1.45 | 0.007090 ± 0.000103 | 0.1600 ± 0.0217 |
| Jun | 0.1170 ± 0.0120 | 17.80 ± 1.80 | 0.006480 ± 0.000118 | 0.1140 ± 0.0137 | 15.90 ± 1.90 | 0.007080 ± 0.000111 | 0.1200 ± 0.0150 |
| Jul | 0.1500 ± 0.0173 | 22.50 ± 2.55 | 0.006560 ± 0.000128 | 0.1280 ± 0.0108 | 17.80 ± 1.49 | 0.0071200 ± 0.0000880 | 0.1670 ± 0.0161 |
| Aug | 0.1700 ± 0.0133 | 24.50 ± 1.90 | 0.0068300 ± 0.0000690 | 0.1680 ± 0.0123 | 23.10 ± 1.68 | 0.0071900 ± 0.0000490 | 0.2010 ± 0.0173 |
| Sep | 0.2520 ± 0.0193 | 36.50 ± 2.74 | 0.006820 ± 0.000103 | 0.2320 ± 0.0184 | 32.00 ± 2.51 | 0.0071700 ± 0.0000890 | 0.27700 ± 0.00995 |
| Oct | 0.1910 ± 0.0180 | 27.60 ± 2.60 | 0.0068200 ± 0.0000410 | 0.1750 ± 0.0120 | 24.40 ± 1.64 | 0.007070 ± 0.000103 | 0.2060 ± 0.0102 |
| Nov | 0.1330 ± 0.0183 | 19.00 ± 2.61 | 0.0069100 ± 0.0000730 | 0.12300 ± 0.00870 | 16.90 ± 1.18 | 0.0071900 ± 0.0000800 | 0.07980 ± 0.00907 |
| Dec | 0.04380 ± 0.00496 | 6.280 ± 0.695 | 0.006890 ± 0.000165 | 0.04850 ± 0.00310 | 6.660 ± 0.411 | 0.007180 ± 0.000120 | 0.06340 ± 0.00546 |
| Detection frequency | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 |
| Median | 0.142 | 20.5 | 0.00686 | 0.126 | 17.4 | 0.00716 | 0.14 |
| IQR[(c)] | 0.097 | 14.2 | 0.00014 | 0.09 | 12.7 | 0.000103 | 0.113 |
| Maximum | 0.252 | 36.5 | 0.0072 | 0.232 | 32 | 0.00726 | 0.277 |
| Median Percent of DCG | 0.0003 | 0.0068 | (d) | 0.00027 | 0.0058 | (d) | 0.0003 |
| DCG[(d)] | 47000 | 300000 | (d) | 47000 | 300000 | (d) | 47000 |
| Maximum Percent of DCG | 0.00054 | 0.012 | (d) | 0.00049 | 0.011 | (d) | 0.00059 |

a  See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.  Livermore composite consists of samples from CAFE, COW, MESQ, MET, SALV, and VIS.
b  Naturally occurring uranium has a ratio of 0.0073; values less than that indicate the presence of depleted uranium, which has a ratio of 0.002.
c  IQR = Interquartile range
d  DCG is the Derived Air Concentration Guide established by the DOE and is the amount of uranium that can be inhaled continuously  365 days a year without exceeding the DOE primary ra

| EOBS Uranium-238 | EOBS U235/U238 ratio[b] | GOLF Uranium-235 | GOLF Uranium-238 | GOLF U235/U238 ratio[b] | NPS Uranium-235 | NPS Uranium-238 | NPS U235/U238 ratio[b] |
|---|---|---|---|---|---|---|---|
| 9.02 ± 4.55 | 0.007210 ± 0.000237 | 0.0728 ± 0.0274 | 10.00 ± 3.74 | 0.007190 ± 0.000294 | 0.0595 ± 0.0208 | 8.09 ± 2.81 | 0.007270 ± 0.000240 |
| 5.22 ± 2.43 | 0.007120 ± 0.000386 | 0.0437 ± 0.0149 | 5.98 ± 2.02 | 0.007220 ± 0.000352 | 0.0388 ± 0.0151 | 5.30 ± 2.06 | 0.007230 ± 0.000185 |
| 11.50 ± 1.29 | 0.0073300 ± 0.0000960 | 0.0947 ± 0.0177 | 12.90 ± 2.40 | 0.007250 ± 0.000146 | 0.0853 ± 0.0169 | 11.70 ± 2.31 | 0.007200 ± 0.000144 |
| 26.20 ± 2.81 | 0.007020 ± 0.000115 | 0.1940 ± 0.0204 | 26.60 ± 2.78 | 0.0072100 ± 0.0000690 | 0.1910 ± 0.0161 | 25.90 ± 2.17 | 0.0072800 ± 0.0000810 |
| 22.80 ± 3.05 | 0.006930 ± 0.000150 | 0.1540 ± 0.0154 | 21.00 ± 2.08 | 0.007240 ± 0.000111 | 0.1630 ± 0.0137 | 22.50 ± 1.89 | 0.0071500 ± 0.0000350 |
| 18.60 ± 2.28 | 0.006350 ± 0.000143 | 0.1280 ± 0.0167 | 17.50 ± 2.26 | 0.007190 ± 0.000136 | 0.1300 ± 0.0113 | 17.90 ± 1.55 | 0.0071400 ± 0.0000540 |
| 25.60 ± 2.44 | 0.0064300 ± 0.0000840 | 0.1620 ± 0.0151 | 22.20 ± 2.05 | 0.0071900 ± 0.0000740 | 0.1530 ± 0.0130 | 21.60 ± 1.83 | 0.0070000 ± 0.0000600 |
| 30.60 ± 2.60 | 0.0064800 ± 0.0000970 | 0.2270 ± 0.0183 | 31.00 ± 2.49 | 0.0072400 ± 0.0000500 | 0.1830 ± 0.0179 | 25.10 ± 2.44 | 0.0071800 ± 0.0000710 |
| 43.40 ± 1.45 | 0.0062900 ± 0.0000830 | 0.3040 ± 0.0199 | 41.50 ± 2.70 | 0.0072300 ± 0.0000550 | 0.2550 ± 0.0307 | 35.10 ± 4.21 | 0.0071600 ± 0.0000610 |
| 29.40 ± 1.41 | 0.0069300 ± 0.0000790 | 0.2180 ± 0.0238 | 29.90 ± 3.24 | 0.0072100 ± 0.0000970 | 0.1830 ± 0.0244 | 25.10 ± 3.33 | 0.0072200 ± 0.0000850 |
| 11.30 ± 1.27 | 0.006970 ± 0.000117 | 0.1760 ± 0.0202 | 24.20 ± 2.76 | 0.0071700 ± 0.0000900 | 0.12600 ± 0.00768 | 17.80 ± 1.07 | 0.0069900 ± 0.0000690 |
| 9.050 ± 0.758 | 0.006920 ± 0.000139 | 0.05280 ± 0.00829 | 7.34 ± 1.15 | 0.0071100 ± 0.0000650 | 0.06070 ± 0.00529 | 8.340 ± 0.694 | 0.007190 ± 0.000187 |
| 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 |
| 20.7 | 0.00693 | 0.158 | 21.6 | 0.00721 | 0.142 | 19.8 | 0.00718 |
| 16.3 | 0.000578 | 0.111 | 15.3 | 0.0000425 | 0.104 | 14.2 | 0.000075 |
| 43.4 | 0.00733 | 0.304 | 41.5 | 0.00725 | 0.255 | 35.1 | 0.00728 |
| 0.0069 | (d) | 0.00034 | 0.0072 | (d) | 0.0003 | 0.0066 | (d) |
| 300000 | (d) | 47000 | 300000 | (d) | 47000 | 300000 | (d) |
| 0.014 | (d) | 0.00065 | 0.014 | (d) | 0.00054 | 0.012 | (d) |

adiation protection standard for the public. DCG values are not used with isotopic ratios.

| PSTL Uranium-235 | PSTL Uranium-238 | PSTL U235/U238 ratio[(b)] | TCDF Uranium-235 | TCDF Uranium-238 | TCDF U235/U238 ratio[(b)] | WCP Uranium-235 | WCP Uranium-238 | WCP U235/U238 ratio[b] |
|---|---|---|---|---|---|---|---|---|
| 0.294 ± 0.192 | 40.5 ± 26.4 | 0.007160 ± 0.000317 | 0.1120 ± 0.0326 | 15.20 ± 4.37 | 0.007260 ± 0.000337 | 0.0621 ± 0.0249 | 9.40 ± 3.74 | 0.006530 ± 0.000323 |
| 0.0941 ± 0.0418 | 12.90 ± 5.71 | 0.007200 ± 0.000271 | 0.07240 ± 0.00701 | 9.780 ± 0.893 | 0.007310 ± 0.000234 | 0.0386 ± 0.0200 | 5.33 ± 2.76 | 0.007160 ± 0.000245 |
| 0.2950 ± 0.0279 | 40.30 ± 3.80 | 0.0072300 ± 0.0000450 | 0.1190 ± 0.0105 | 16.20 ± 1.40 | 0.007230 ± 0.000131 | 0.0829 ± 0.0153 | 11.90 ± 2.18 | 0.006880 ± 0.000153 |
| 0.9330 ± 0.0463 | 129.00 ± 6.24 | 0.0071400 ± 0.0000780 | 0.2130 ± 0.0196 | 29.10 ± 2.67 | 0.0072400 ± 0.0000600 | 0.1540 ± 0.0168 | 21.50 ± 2.32 | 0.007070 ± 0.000101 |
| 0.3180 ± 0.0295 | 44.00 ± 4.05 | 0.0071400 ± 0.0000820 | 0.2250 ± 0.0226 | 30.70 ± 3.07 | 0.0072300 ± 0.0000640 | 0.1580 ± 0.0202 | 22.20 ± 2.81 | 0.007020 ± 0.000108 |
| 0.3060 ± 0.0320 | 42.00 ± 4.39 | 0.0071900 ± 0.0000450 | 0.2070 ± 0.0166 | 28.20 ± 2.24 | 0.0072500 ± 0.0000870 | 0.1380 ± 0.0217 | 19.80 ± 3.08 | 0.006880 ± 0.000161 |
| 0.4890 ± 0.0309 | 67.10 ± 4.19 | 0.0072000 ± 0.0000670 | 0.3660 ± 0.0287 | 49.60 ± 3.87 | 0.0072800 ± 0.0000650 | 0.1310 ± 0.0140 | 18.50 ± 1.96 | 0.0070000 ± 0.0000950 |
| 0.5400 ± 0.0383 | 74.50 ± 5.26 | 0.0071600 ± 0.0000530 | 0.4380 ± 0.0233 | 59.60 ± 3.17 | 0.0072600 ± 0.0000240 | 0.16900 ± 0.00854 | 24.20 ± 1.18 | 0.0068800 ± 0.0000910 |
| 0.6140 ± 0.0341 | 85.20 ± 4.69 | 0.0071200 ± 0.0000500 | 0.4570 ± 0.0368 | 62.40 ± 5.02 | 0.0072300 ± 0.0000230 | 0.2460 ± 0.0239 | 35.10 ± 3.37 | 0.006930 ± 0.000102 |
| 0.6350 ± 0.0413 | 87.70 ± 5.67 | 0.0071400 ± 0.0000470 | 0.3240 ± 0.0234 | 44.40 ± 3.19 | 0.0072100 ± 0.0000430 | 0.1820 ± 0.0151 | 26.70 ± 2.19 | 0.0067200 ± 0.0000700 |
| 0.5440 ± 0.0359 | 74.80 ± 4.91 | 0.0071900 ± 0.0000480 | 0.2750 ± 0.0128 | 37.40 ± 1.70 | 0.0072500 ± 0.0000660 | 0.13100 ± 0.00994 | 19.90 ± 1.48 | 0.0065200 ± 0.0000980 |
| 0.2130 ± 0.0103 | 29.20 ± 1.32 | 0.007200 ± 0.000124 | 0.11400 ± 0.00751 | 15.400 ± 0.969 | 0.007280 ± 0.000141 | 0.07030 ± 0.00623 | 10.400 ± 0.878 | 0.006670 ± 0.000179 |
| 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 |
| 0.403 | 55.6 | 0.00718 | 0.219 | 29.9 | 0.00725 | 0.134 | 19.8 | 0.00688 |
| 0.267 | 36.9 | 0.00006 | 0.217 | 29.7 | 0.000035 | 0.081 | 11.2 | 0.000298 |
| 0.933 | 129 | 0.00723 | 0.457 | 62.4 | 0.00731 | 0.246 | 35.1 | 0.00716 |
| 0.00086 | 0.019 | (d) | 0.00047 | 0.01 | (d) | 0.00029 | 0.0066 | (d) |
| 47000 | 300000 | (d) | 47000 | 300000 | (d) | 47000 | 300000 | (d) |
| 0.002 | 0.043 | (d) | 0.00097 | 0.021 | (d) | 0.00052 | 0.012 | (d) |

| WOBS Uranium-235 | WOBS Uranium-238 | WOBS U235/U238 ratio[b] | Livermore composite Uranium-235 | Livermore composite Uranium-238 | Livermore composite U235/U238 ratio[b] |
|---|---|---|---|---|---|
| 0.0611 ± 0.0197 | 8.39 ± 2.67 | 0.007200 ± 0.000367 | 0.0629 ± 0.0339 | 8.63 ± 4.64 | 0.007190 ± 0.000198 |
| 0.0372 ± 0.0135 | 5.43 ± 1.97 | 0.006770 ± 0.000177 | 0.2960 ± 0.0156 | 40.60 ± 2.04 | 0.007200 ± 0.000111 |
| 0.08610 ± 0.00861 | 11.70 ± 1.15 | 0.007270 ± 0.000136 | 0.4980 ± 0.0123 | 67.90 ± 1.29 | 0.007250 ± 0.000114 |
| 0.17900 ± 0.00899 | 24.60 ± 1.13 | 0.007180 ± 0.000146 | 0.1640 ± 0.0138 | 22.20 ± 1.86 | 0.0072800 ± 0.0000650 |
| 0.1300 ± 0.0188 | 17.90 ± 2.59 | 0.0071700 ± 0.0000570 | 0.1330 ± 0.0151 | 18.20 ± 2.06 | 0.0071900 ± 0.0000860 |
| 0.10400 ± 0.00968 | 15.40 ± 1.40 | 0.006660 ± 0.000134 | 0.10900 ± 0.00795 | 14.90 ± 1.08 | 0.0072100 ± 0.0000590 |
| 0.11400 ± 0.00944 | 17.00 ± 1.38 | 0.006640 ± 0.000110 | 0.1250 ± 0.0151 | 16.60 ± 2.00 | 0.0074400 ± 0.0000830 |
| 0.1620 ± 0.0101 | 24.10 ± 1.48 | 0.0066300 ± 0.0000610 | 0.1190 ± 0.0101 | 16.10 ± 1.36 | 0.0072700 ± 0.0000730 |
| 0.1910 ± 0.0142 | 26.50 ± 1.94 | 0.0071300 ± 0.0000990 | 0.1810 ± 0.0138 | 24.70 ± 1.88 | 0.0072300 ± 0.0000430 |
| 0.1770 ± 0.0150 | 26.00 ± 2.17 | 0.0067300 ± 0.0000910 | 0.13200 ± 0.00794 | 18.10 ± 1.08 | 0.0072100 ± 0.0000540 |
| 0.1140 ± 0.0105 | 16.60 ± 1.50 | 0.006750 ± 0.000122 | 0.13000 ± 0.00655 | 17.700 ± 0.877 | 0.0072600 ± 0.0000670 |
| 0.05030 ± 0.00633 | 7.210 ± 0.879 | 0.006890 ± 0.000215 | 0.06420 ± 0.00712 | 8.810 ± 0.963 | 0.007200 ± 0.000134 |
| 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 | 12 of 12 |
| 0.114 | 16.8 | 0.00683 | 0.131 | 17.9 | 0.00722 |
| 0.0859 | 13.4 | 0.00046 | 0.0518 | 7.02 | 0.0000625 |
| 0.191 | 26.5 | 0.00727 | 0.498 | 67.9 | 0.00744 |
| 0.00024 | 0.0056 | (d) | 0.00028 | 0.006 | (d) |
| 47000 | 300000 | (d) | 47000 | 300000 | (d) |
| 0.00041 | 0.0088 | (d) | 0.0011 | 0.023 | (d) |

**A.2.7 Weekly gross alpha and gross beta concentrations (μBq/m$^3$) from air particulate samples from the Livermore Valley downwind locations, 2009[(a)]**

| Date | Gross alpha AMON | Gross alpha CPET | Gross alpha PATT | Gross alpha TANK | Gross alpha ZON7 |
|---|---|---|---|---|---|
| 6-Jan | 8.4 ± 23.3 | 30.2 ± 31.3 | 2.8 ± 20.7 | 11.4 ± 16.3 | 14.0 ± 25.8 |
| 13-Jan | 16.5 ± 30.4 | 16.2 ± 29.8 | 43.3 ± 40.0 | 3.3 ± 24.1 | 23.0 ± 32.8 |
| 20-Jan | 16.2 ± 29.8 | 9.7 ± 26.8 | 36.0 ± 37.4 | 16.3 ± 30.0 | 48.8 ± 41.4 |
| 27-Jan | 16.5 ± 30.4 | 30.2 ± 36.0 | 16.5 ± 30.3 | 10.3 ± 28.5 | 3.3 ± 24.0 |
| 3-Feb | 23.0 ± 32.8 | 3.2 ± 23.9 | 3.4 ± 25.2 | 9.9 ± 27.4 | 17.0 ± 31.3 |
| 10-Feb | 16.4 ± 30.0 | 36.7 ± 38.1 | 9.9 ± 27.5 | 62.9 ± 45.9 | 22.1 ± 31.6 |
| 17-Feb | 3.3 ± 24.0 | -3.3 ± 20.7 | 9.9 ± 27.3 | 3.2 ± 23.2 | 3.3 ± 23.9 |
| 24-Feb | 3.2 ± 23.7 | -3.3 ± 20.5 | 9.9 ± 27.4 | -3.3 ± 20.3 | 29.3 ± 35.0 |
| 3-Mar | -9.4 ± 15.1 | 3.3 ± 24.0 | 3.4 ± 25.1 | -8.9 ± 14.2 | -10.1 ± 16.2 |
| 10-Mar | -9.9 ± 15.9 | 3.4 ± 24.8 | 3.4 ± 24.6 | 3.9 ± 28.6 | -3.3 ± 20.6 |
| 17-Mar | -9.8 ± 15.7 | 9.9 ± 27.6 | -9.7 ± 15.5 | 9.6 ± 26.5 | 9.6 ± 26.7 |
| 24-Mar | -10.2 ± 16.4 | -3.4 ± 20.8 | -3.4 ± 21.3 | 44.0 ± 41.1 | 10.2 ± 28.2 |
| 31-Mar | 22.6 ± 32.3 | 3.2 ± 23.9 | -3.3 ± 20.2 | -9.6 ± 15.4 | 30.6 ± 36.6 |
| 7-Apr | 16.5 ± 30.4 | 3.2 ± 23.8 | 22.6 ± 32.2 | -3.3 ± 20.7 | 9.7 ± 26.8 |
| 14-Apr | 3.3 ± 24.0 | 16.5 ± 30.4 | 19.9 ± 36.5 | 3.3 ± 24.0 | 3.4 ± 25.2 |
| 21-Apr | 3.3 ± 24.1 | 17.3 ± 31.9 | 22.5 ± 32.2 | -10.0 ± 16.1 | 28.9 ± 34.5 |
| 28-Apr | 3.3 ± 24.2 | 29.2 ± 34.9 | -3.4 ± 20.9 | 3.3 ± 24.3 | 10.1 ± 28.0 |
| 4-May | 11.2 ± 30.9 | 3.9 ± 28.6 | -3.7 ± 23.2 | (b) | 3.8 ± 27.6 |
| 12-May | 21.1 ± 30.1 | 8.8 ± 24.4 | 33.2 ± 34.4 | 15.1 ± 17.9 | 15.0 ± 27.6 |
| 19-May | 23.2 ± 33.1 | 3.3 ± 24.3 | 62.9 ± 45.9 | 22.7 ± 32.4 | 9.9 ± 27.5 |
| 26-May | 42.9 ± 40.0 | 3.3 ± 24.3 | -9.9 ± 15.9 | 16.5 ± 30.3 | 9.9 ± 27.5 |
| 2-Jun | 28.6 ± 34.1 | 23.1 ± 32.9 | 3.2 ± 23.3 | 36.7 ± 38.1 | 15.9 ± 29.2 |
| 9-Jun | -3.4 ± 21.1 | 16.2 ± 29.8 | 17.0 ± 31.3 | -9.8 ± 15.7 | 10.2 ± 28.3 |
| 16-Jun | 16.8 ± 30.9 | 3.3 ± 24.0 | -9.8 ± 15.7 | 37.7 ± 39.2 | 22.9 ± 32.8 |
| 23-Jun | 43.3 ± 40.3 | 3.4 ± 25.0 | 23.0 ± 32.9 | 9.8 ± 27.3 | 9.9 ± 27.3 |
| 29-Jun | 27.6 ± 39.2 | -3.9 ± 24.2 | 20.5 ± 37.7 | 12.1 ± 33.5 | -12.4 ± 19.8 |
| 7-Jul | 14.2 ± 26.2 | 8.6 ± 23.9 | 14.4 ± 26.4 | 8.5 ± 23.5 | 8.6 ± 23.9 |
| 14-Jul | 3.3 ± 24.4 | 56.6 ± 44.0 | -9.9 ± 15.9 | -10.2 ± 16.3 | 16.6 ± 30.5 |
| 21-Jul | -3.2 ± 19.8 | 9.9 ± 27.5 | 13.6 ± 37.7 | 9.7 ± 26.8 | -3.2 ± 19.8 |
| 28-Jul | -10.4 ± 16.6 | 30.0 ± 35.7 | 10.4 ± 28.7 | 17.0 ± 31.3 | 17.2 ± 31.7 |
| 4-Aug | 29.0 ± 34.6 | -3.3 ± 20.4 | 23.1 ± 32.9 | 9.7 ± 26.9 | 9.9 ± 27.3 |
| 11-Aug | 78.1 ± 50.7 | 43.3 ± 40.3 | 23.3 ± 33.3 | -3.3 ± 20.6 | 49.9 ± 42.2 |
| 19-Aug | 37.7 ± 34.9 | 31.8 ± 33.1 | 26.0 ± 31.0 | 14.5 ± 26.6 | 8.7 ± 24.0 |
| 25-Aug | 26.8 ± 38.1 | 40.7 ± 42.6 | 33.4 ± 40.0 | 19.2 ± 35.3 | 18.8 ± 34.6 |
| 1-Sep | 22.5 ± 32.0 | 29.7 ± 35.4 | 42.9 ± 39.6 | 23.1 ± 32.9 | 16.5 ± 30.2 |
| 8-Sep | 9.9 ± 27.5 | 17.2 ± 31.7 | 36.2 ± 37.7 | -3.3 ± 20.5 | 62.5 ± 45.5 |
| 15-Sep | 30.0 ± 35.8 | 34.9 ± 36.3 | 36.4 ± 37.7 | -9.9 ± 15.9 | 3.3 ± 24.3 |
| 22-Sep | 17.1 ± 31.5 | (c) | 17.5 ± 32.2 | 21.1 ± 30.1 | 17.4 ± 32.0 |
| 29-Sep | 61.8 ± 45.1 | 26.5 ± 37.7 | 9.6 ± 26.4 | 63.6 ± 49.6 | 35.0 ± 36.3 |
| 6-Oct | 3.2 ± 23.7 | 31.0 ± 37.0 | 16.6 ± 30.5 | 9.9 ± 27.5 | 3.3 ± 24.3 |
| 12-Oct | 52.5 ± 48.8 | 43.3 ± 45.1 | 12.1 ± 33.7 | 19.8 ± 36.3 | 20.3 ± 37.4 |
| 20-Oct | 2.9 ± 21.3 | 8.7 ± 24.1 | -8.7 ± 13.9 | 2.9 ± 20.9 | 2.9 ± 21.3 |
| 27-Oct | 3.2 ± 23.4 | 22.3 ± 31.9 | 35.1 ± 36.4 | 9.8 ± 27.3 | 22.3 ± 31.9 |
| 3-Nov | 23.9 ± 34.2 | 10.1 ± 27.9 | 10.1 ± 27.9 | 3.3 ± 24.2 | 3.4 ± 24.6 |
| 10-Nov | 15.9 ± 29.3 | 16.3 ± 30.0 | 16.2 ± 29.7 | 8.7 ± 24.1 | 3.2 ± 23.8 |
| 17-Nov | 58.5 ± 45.5 | 17.0 ± 31.3 | 23.5 ± 33.6 | 19.5 ± 35.7 | -3.3 ± 20.7 |
| 23-Nov | 3.9 ± 28.4 | 11.7 ± 32.5 | 12.0 ± 33.3 | 11.5 ± 31.9 | -4.0 ± 24.8 |
| 1-Dec | 66.6 ± 43.3 | 37.7 ± 35.0 | 44.0 ± 37.0 | 20.5 ± 29.3 | 55.1 ± 40.0 |
| 8-Dec | 36.4 ± 37.7 | 85.8 ± 50.7 | 35.2 ± 36.5 | 75.1 ± 48.8 | 41.4 ± 38.5 |
| 15-Dec | 42.9 ± 40.0 | 51.8 ± 43.7 | 30.9 ± 36.9 | 44.4 ± 41.1 | 3.4 ± 25.2 |
| 21-Dec | 42.9 ± 43.3 | 35.2 ± 40.7 | 19.9 ± 34.8 | (b) | 12.2 ± 31.4 |
| 22-Dec | (b) | (b) | (b) | 3.9 ± 23.4 | (b) |
| 28-Dec | 50.7 ± 42.2 | 23.9 ± 32.9 | -2.7 ± 20.2 | (b) | 10.7 ± 27.3 |
| Detection frequency | 10 of 52 | 5 of 51 | 4 of 52 | 5 of 50 | 5 of 52 |
| Median | 16.5 | 16.3 | 16.4 | 9.86 | 10.2 |
| IQR[(d)] | 26 | 26.8 | 20.7 | 16.2 | 17.3 |
| Maximum | 78.1 | 85.8 | 62.9 | 75.1 | 62.5 |

| Date | Gross beta AMON | Gross beta CPET | Gross beta PATT | Gross beta TANK | Gross beta ZON7 |
|---|---|---|---|---|---|
| 6-Jan | 440 ± 134 | 388 ± 125 | 317 ± 120 | 293.0 ± 81.4 | 364 ± 125 |
| 13-Jan | 503 ± 155 | 477 ± 151 | 426 ± 147 | 474 ± 152 | 474 ± 152 |
| 20-Jan | 1380 ± 232 | 1400 ± 233 | 1420 ± 236 | 1380 ± 232 | 1470 ± 238 |
| 27-Jan | 555 ± 161 | 603 ± 168 | 525 ± 158 | 770 ± 187 | 603 ± 165 |
| 3-Feb | 666 ± 172 | 718 ± 176 | 625 ± 172 | 710 ± 177 | 699 ± 179 |
| 10-Feb | 500 ± 154 | 414 ± 146 | 385 ± 142 | 577 ± 164 | 655 ± 167 |
| 17-Feb | 92.1 ± 98.4 | 50.3 ± 92.1 | 92.5 ± 98.8 | 75.1 ± 92.5 | 58.5 ± 91.8 |
| 24-Feb | 181 ± 112 | 175 ± 113 | 131 ± 105 | 178 ± 112 | 153 ± 108 |
| 3-Mar | 111.0 ± 98.4 | 154 ± 109 | 156 ± 113 | 144.0 ± 98.8 | 174 ± 114 |
| 10-Mar | 142 ± 108 | 55.5 ± 94.4 | 40.7 ± 90.6 | 64 ± 109 | 175 ± 113 |
| 17-Mar | 177 ± 112 | 151 ± 109 | 185 ± 112 | 299 ± 127 | 282 ± 126 |
| 24-Mar | 170 ± 114 | 158 ± 111 | 92 ± 102 | 239 ± 125 | 159 ± 112 |
| 31-Mar | 185 ± 112 | 262 ± 124 | 120 ± 103 | 221 ± 117 | 294 ± 132 |
| 7-Apr | 247 ± 123 | 261 ± 124 | 370 ± 138 | 327 ± 135 | 320 ± 131 |
| 14-Apr | 107 ± 101 | 155 ± 110 | 175 ± 130 | 116 ± 102 | 117 ± 107 |
| 21-Apr | 217 ± 119 | 269 ± 131 | 268 ± 124 | 299 ± 132 | 287 ± 127 |
| 28-Apr | 265 ± 126 | 271 ± 125 | 237 ± 124 | 377 ± 141 | 301 ± 132 |
| 4-May | 175 ± 124 | 132 ± 121 | 111 ± 114 | (b) | 133 ± 118 |
| 12-May | 164 ± 103 | 147.0 ± 98.8 | 155 ± 102 | 193.0 ± 71.4 | 124.0 ± 96.9 |
| 19-May | 266 ± 126 | 281 ± 128 | 299 ± 131 | 275 ± 125 | 247 ± 124 |
| 26-May | 276 ± 128 | 218 ± 120 | 242 ± 123 | 204 ± 117 | 310 ± 132 |
| 2-Jun | 311 ± 129 | 289 ± 129 | 302 ± 128 | 269 ± 127 | 302 ± 128 |
| 9-Jun | 195 ± 118 | 209 ± 116 | 125 ± 107 | 154 ± 109 | 185 ± 117 |

| | | | | | |
|---|---|---|---|---|---|
| 16-Jun | 148 ± 110 | 154 ± 109 | 130 ± 105 | 167 ± 115 | 159 ± 110 |
| 23-Jun | 268 ± 127 | 190 ± 118 | 164 ± 111 | 207 ± 117 | 198 ± 116 |
| 29-Jun | 392 ± 160 | 377 ± 157 | 270 ± 148 | 295 ± 149 | 248 ± 145 |
| 7-Jul | 333 ± 122 | 353 ± 125 | 210 ± 107 | 277 ± 114 | 269 ± 115 |
| 14-Jul | 316 ± 134 | 374 ± 141 | 243 ± 123 | 343 ± 139 | 291 ± 130 |
| 21-Jul | 313 ± 130 | 448 ± 149 | 318 ± 166 | 236 ± 120 | 360 ± 135 |
| 28-Jul | 168 ± 115 | 128 ± 106 | 97 ± 104 | 195 ± 118 | 107 ± 105 |
| 4-Aug | 85.8 ± 95.8 | 126 ± 104 | 64.0 ± 93.6 | 81.4 ± 95.5 | 92.5 ± 98.8 |
| 11-Aug | 392 ± 145 | 253 ± 125 | 220 ± 120 | 400 ± 144 | 350 ± 138 |
| 19-Aug | 313 ± 121 | 250 ± 112 | 262 ± 114 | 326 ± 123 | 241 ± 111 |
| 25-Aug | 319 ± 148 | 381 ± 152 | 305 ± 142 | 388 ± 157 | 265 ± 138 |
| 1-Sep | 411 ± 142 | 481 ± 153 | 332 ± 134 | 470 ± 152 | 455 ± 149 |
| 8-Sep | 209 ± 118 | 312 ± 136 | 256 ± 124 | 343 ± 136 | 275 ± 127 |
| 15-Sep | 297 ± 131 | 283 ± 125 | 242 ± 123 | 353 ± 138 | 290 ± 130 |
| 22-Sep | 392 ± 146 | (c) | 359 ± 144 | 396 ± 134 | 295 ± 135 |
| 29-Sep | 670 ± 172 | 562 ± 176 | 629 ± 165 | 625 ± 182 | 574 ± 159 |
| 6-Oct | 241 ± 121 | 268 ± 130 | 233 ± 122 | 252 ± 124 | 276 ± 128 |
| 12-Oct | 662 ± 196 | 581 ± 183 | 722 ± 202 | 588 ± 185 | 729 ± 203 |
| 20-Oct | 187 ± 104 | 204 ± 107 | 208 ± 107 | 159.0 ± 98.4 | 141.0 ± 96.9 |
| 27-Oct | 252 ± 121 | 289 ± 126 | 224 ± 117 | 322 ± 133 | 280 ± 125 |
| 3-Nov | 335 ± 138 | 265 ± 127 | 339 ± 137 | 275 ± 127 | 407 ± 146 |
| 10-Nov | 496 ± 151 | 392 ± 141 | 355 ± 136 | 451 ± 138 | 385 ± 139 |
| 17-Nov | 688 ± 179 | 400 ± 146 | 368 ± 141 | 426 ± 163 | 448 ± 150 |
| 23-Nov | 194 ± 130 | 127 ± 120 | 153 ± 127 | 124 ± 118 | 107 ± 119 |
| 1-Dec | 784 ± 170 | 470 ± 139 | 599 ± 154 | 525 ± 147 | 574 ± 150 |
| 8-Dec | 888 ± 194 | 740 ± 176 | 744 ± 177 | 773 ± 182 | 866 ± 188 |
| 15-Dec | 777 ± 184 | 588 ± 169 | 581 ± 168 | 799 ± 189 | 651 ± 176 |
| 21-Dec | 899 ± 212 | 522 ± 172 | 507 ± 170 | (b) | 633 ± 185 |
| 22-Dec | (b) | (b) | (b) | 525 ± 155 | (b) |
| 28-Dec | 540 ± 159 | 411 ± 144 | 392 ± 142 | (b) | 610 ± 167 |
| Detection frequency | 50 of 52 | 49 of 51 | 46 of 52 | 47 of 50 | 49 of 52 |
| Median | 304 | 281 | 259 | 299 | 290 |
| IQR[(d)] | 310 | 230 | 206 | 240 | 267 |
| Maximum | 1380 | 1400 | 1420 | 1380 | 1470 |

(a) See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) Different sample dates occur when samples could not be collected on scheduled sampling date, or sampler ran longer than 1 week.
(c) No sample due to sampler malfunction.
(d) IQR =Interquartile range

AT-VAL [mBq/m3]   2009 data    (created 2010-03-08 15:07:32, Oracle) (epprd02.llnl.gov)

**A.2.8 Tritium concentrations (mBq/m3) in air, Livermore Valley, 2009[(a)]**

| Week | Month | AMON | CPET | FIRE | HOSP | PATT | VET | ZON7 |
|---|---|---|---|---|---|---|---|---|
| 1 | Jan | 22.9 ± 15.0 | 24.7 ± 15.7 | 3.6 ± 16.7 | -1.1 ± 15.1 | -1.2 ± 14.6 | -1.6 ± 15.1 | 18.3 ± 15.0 |
| 3 | Jan | 87.0 ± 12.7 | 37.4 ± 11.6 | 33.4 ± 14.8 | 13.40 ± 9.66 | 7.25 ± 9.80 | 25.0 ± 10.5 | 31.2 ± 10.3 |
| 5 | Feb | 15.9 ± 14.3 | 40.3 ± 15.9 | 26.8 ± 14.9 | 11.9 ± 14.5 | -0.2 ± 14.0 | 61.0 ± 15.5 | 26.4 ± 14.5 |
| 7 | Feb | 8.4 ± 13.2 | 24.1 ± 15.1 | 10.5 ± 13.4 | 14.0 ± 14.3 | -2.6 ± 13.4 | 16.3 ± 13.7 | 21.5 ± 12.9 |
| 9 | Mar | 12.9 ± 15.8 | 13.4 ± 17.3 | 7.5 ± 15.6 | 0.7 ± 15.9 | 6.0 ± 14.9 | 10.7 ± 16.1 | 19.6 ± 15.5 |
| 11 | Mar | 40.7 ± 11.7 | 154.0 ± 15.8 | 27.4 ± 11.0 | 22.3 ± 11.1 | 23.3 ± 10.8 | 23.9 ± 10.8 | 53.3 ± 11.3 |
| 13 | Apr | 5.1 ± 14.1 | 37.4 ± 15.7 | -8.1 ± 14.1 | 18.2 ± 15.1 | 17.9 ± 14.1 | 22.3 ± 14.6 | 20.4 ± 13.8 |
| 15 | Apr | 10.3 ± 10.1 | 48.8 ± 13.1 | 12.3 ± 10.7 | 5.1 ± 10.1 | 5.33 ± 9.73 | 23.5 ± 10.4 | 16.4 ± 10.1 |
| 17 | Apr | 19.3 ± 11.4 | 152.0 ± 18.1 | 18.3 ± 12.3 | 16.0 ± 12.0 | 14.9 ± 11.1 | 16.9 ± 11.5 | 40.7 ± 12.4 |
| 19 | May | 29.4 ± 16.1 | 179.0 ± 24.3 | 5.2 ± 17.4 | 1.6 ± 17.1 | 19.2 ± 14.9 | 40.3 ± 16.9 | 42.6 ± 15.5 |
| 21 | May | 19.6 ± 15.7 | 59.2 ± 15.7 | 29.3 ± 17.4 | 2.2 ± 17.3 | 10.2 ± 13.5 | 25.2 ± 16.3 | 31.8 ± 15.6 |
| 23 | Jun | -12.8 ± 15.3 | 59.9 ± 18.2 | -9.2 ± 18.7 | -1.5 ± 17.9 | -9.8 ± 15.3 | 0.5 ± 16.9 | 0.8 ± 15.9 |
| 25 | Jun | 19.8 ± 14.0 | 48.1 ± 14.6 | 43.7 ± 15.6 | 27.0 ± 14.1 | 18.7 ± 13.1 | 44.0 ± 15.1 | 32.4 ± 14.0 |
| 27 | Jul | 19.3 ± 15.4 | 59.9 ± 14.8 | 24.4 ± 15.8 | 15.6 ± 15.2 | 12.4 ± 12.5 | 1.5 ± 13.4 | 20.0 ± 15.2 |
| 29 | Jul | 7.1 ± 11.9 | 63.3 ± 13.9 | 18.3 ± 12.0 | 7.7 ± 13.2 | 11.30 ± 9.84 | 12.5 ± 11.0 | 42.2 ± 11.7 |
| 31 | Aug | 18.3 ± 16.2 | 39.2 ± 17.6 | (b) | 11.4 ± 15.8 | 13.2 ± 15.5 | 6.2 ± 16.8 | 26.8 ± 16.3 |
| 33 | Aug | 9.5 ± 13.4 | 77.7 ± 16.1 | -5.9 ± 15.1 | 4.9 ± 14.7 | -2.9 ± 11.5 | 8.3 ± 14.2 | 20.8 ± 13.6 |
| 35 | Sep | 8.5 ± 13.8 | 42.9 ± 16.4 | 31.4 ± 14.3 | -10.6 ± 14.3 | -0.7 ± 10.8 | 15.1 ± 13.0 | 19.8 ± 12.8 |
| 37 | Sep | 1.8 ± 14.4 | 28.7 ± 16.7 | -0.5 ± 15.0 | 8.8 ± 14.7 | 6.0 ± 11.7 | -5.3 ± 13.5 | 16.5 ± 15.3 |
| 39 | Oct | 16.9 ± 14.5 | 52.5 ± 13.9 | 22.0 ± 15.5 | 9.3 ± 13.0 | 8.73 ± 8.55 | 36.9 ± 15.0 | 40.3 ± 13.7 |
| 41 | Oct | 2.3 ± 12.8 | 43.7 ± 12.5 | 9.6 ± 12.6 | 5.4 ± 12.1 | 3.6 ± 11.3 | 18.9 ± 12.1 | 25.3 ± 13.7 |
| 43 | Oct | 14.0 ± 15.9 | 47.0 ± 16.7 | -7.3 ± 16.8 | -15.4 ± 16.4 | -3.6 ± 13.9 | 21.4 ± 16.6 | 23.3 ± 19.1 |
| 45 | Nov | 22.7 ± 11.9 | 10.0 ± 11.0 | 20.2 ± 12.5 | 6.6 ± 11.6 | 12.1 ± 12.1 | 20.9 ± 12.2 | 28.6 ± 14.1 |
| 47 | Nov | 25.2 ± 10.9 | 32.3 ± 10.7 | 25.4 ± 12.0 | 21.5 ± 11.8 | 6.6 ± 10.8 | 19.5 ± 10.8 | 16.6 ± 13.2 |
| 49 | Dec | 18.4 ± 10.2 | 38.5 ± 10.1 | 26.3 ± 10.8 | 2.8 ± 10.5 | -1.9 ± 10.4 | 20.40 ± 9.73 | 45.9 ± 13.3 |
| 51 | Dec | 41.8 ± 15.1 | 262.0 ± 18.8 | 133.0 ± 18.4 | 80.3 ± 15.5 | 28.6 ± 12.7 | 315.0 ± 20.6 | 112.0 ± 14.9 |
| | Median | 17.6 | 45.4 | 18.3 | 8.25 | 6.94 | 20 | 25.8 |
| | IQR[(c)] | 13.2 | 22.5 | 21.6 | 12.8 | 13.6 | 13.6 | 18.5 |
| | Median Percent of DCG[(d)] | 0.00048 | 0.0012 | 0.00049 | 0.00022 | 0.00019 | 0.00054 | 0.0007 |
| | Mean Dose (nSv)[(e)(f)] | <5 | 13.5 | <5 | <5 | <5 | 6.45 | 6.4 |

(a) See *Environmental Report 2009,* Figure 4-3 for map of sampling locations.

(b) Lost sample

(c) IQR = Interquartile range

(d) DCG = Derived Concentration Guide of 3.7E+06 mBq/$m^3$ for tritium in air. Percent of DCG is calculated from the median concentration.

(e) This annual dose is calculated from the mean concentration and represents the effective dose equivalent from inhalation and skin absorbtion.

(f) When the mean dose is based on a concentration less than the lower limit of detection (about 25 mBq/$m^3$), the dose is assumed to be less than that calculated from the lower limit of detection (i.e., 5 nSv/year).

**A.2.9 Weekly gross alpha and gross beta concentrations (μBq/m$^3$) from air particulate samples from the Livermore Valley upwind locations and the special interest location 2009 [(a)]**

| Date | Gross alpha CHUR | Gross alpha FCC | Gross alpha FIRE | Gross alpha HOSP | Gross alpha LWRP |
|---|---|---|---|---|---|
| 6-Jan | 48.1 ± 37.4 | 42.6 ± 36.0 | 14.4 ± 26.5 | 8.6 ± 23.8 | 25.7 ± 30.7 |
| 13-Jan | 23.2 ± 33.1 | 36.7 ± 38.1 | 16.4 ± 30.1 | 16.2 ± 29.7 | 22.8 ± 32.6 |
| 20-Jan | 49.9 ± 42.2 | 10.1 ± 27.9 | 36.0 ± 37.4 | 22.2 ± 31.7 | 60.7 ± 44.0 |
| 27-Jan | 28.6 ± 34.2 | 28.8 ± 34.4 | 22.9 ± 32.6 | 42.6 ± 39.6 | 23.4 ± 33.4 |
| 3-Feb | 22.9 ± 32.7 | -3.3 ± 20.4 | 23.0 ± 32.8 | -3.5 ± 21.8 | 55.5 ± 43.3 |
| 10-Feb | 36.0 ± 37.4 | 3.3 ± 24.2 | 16.5 ± 30.4 | 3.3 ± 24.4 | 16.4 ± 30.1 |
| 17-Feb | -3.3 ± 20.3 | (b) | 3.3 ± 24.0 | 16.5 ± 30.3 | -9.8 ± 15.7 |
| 18-Feb | (b) | -3.3 ± 20.3 | (b) | (b) | (b) |
| 24-Feb | 9.7 ± 27.0 | -3.2 ± 20.2 | -10.3 ± 16.5 | 3.2 ± 23.6 | 16.4 ± 30.1 |
| 3-Mar | 16.4 ± 30.2 | 29.7 ± 35.4 | -9.8 ± 15.7 | 16.7 ± 30.7 | 3.2 ± 23.5 |
| 10-Mar | 23.1 ± 32.9 | -9.9 ± 15.8 | -9.8 ± 15.8 | -3.3 ± 20.5 | -3.3 ± 20.3 |
| 17-Mar | 3.2 ± 23.8 | 10.0 ± 27.8 | -3.4 ± 21.3 | 3.4 ± 24.9 | 3.3 ± 24.5 |
| 24-Mar | -10.2 ± 16.3 | 10.0 ± 27.8 | 3.3 ± 24.2 | 23.2 ± 33.1 | -3.3 ± 20.5 |
| 31-Mar | 9.9 ± 27.6 | 29.4 ± 35.0 | 23.6 ± 33.7 | 10.0 ± 27.8 | -3.4 ± 21.3 |
| 7-Apr | 16.7 ± 30.7 | -3.3 ± 20.6 | 16.4 ± 30.0 | -3.3 ± 20.3 | 16.4 ± 30.1 |
| 14-Apr | 3.3 ± 24.3 | 3.3 ± 24.5 | 15.9 ± 29.3 | 16.6 ± 30.5 | -3.3 ± 20.6 |
| 21-Apr | 3.3 ± 24.3 | 3.3 ± 24.3 | 10.1 ± 27.9 | (c) | 3.4 ± 24.6 |
| 28-Apr | 36.4 ± 37.7 | 16.5 ± 30.4 | 16.9 ± 31.0 | 16.7 ± 30.7 | 3.3 ± 24.2 |
| 4-May | 33.1 ± 39.6 | 11.0 ± 30.6 | 18.8 ± 34.6 | 33.9 ± 40.3 | 26.7 ± 38.1 |
| 12-May | 3.0 ± 22.1 | 9.0 ± 25.0 | 31.9 ± 33.2 | 8.8 ± 24.3 | -8.7 ± 14.0 |
| 19-May | 16.5 ± 30.4 | 9.9 ± 27.5 | 29.6 ± 35.3 | 29.7 ± 35.4 | 3.4 ± 25.1 |
| 26-May | -3.3 ± 20.5 | 36.4 ± 37.7 | 3.2 ± 23.8 | 23.3 ± 33.2 | 23.2 ± 33.1 |
| 2-Jun | -3.2 ± 19.7 | 15.9 ± 29.2 | 16.6 ± 30.6 | 16.4 ± 30.0 | 9.7 ± 26.9 |
| 9-Jun | 3.5 ± 25.4 | 17.3 ± 31.8 | 10.1 ± 28.1 | -3.4 ± 21.3 | 3.4 ± 24.9 |
| 16-Jun | 29.5 ± 35.2 | -3.3 ± 20.3 | -3.4 ± 21.3 | 3.3 ± 24.4 | 3.3 ± 24.4 |
| 23-Jun | -3.3 ± 20.6 | 23.2 ± 33.2 | 3.2 ± 23.3 | 3.3 ± 23.9 | 16.7 ± 30.7 |
| 29-Jun | 4.0 ± 29.0 | 19.8 ± 36.3 | 20.5 ± 37.7 | 20.6 ± 37.7 | 53.6 ± 49.9 |
| 7-Jul | 14.2 ± 26.2 | 42.6 ± 36.2 | -2.9 ± 17.9 | 8.7 ± 24.0 | 31.8 ± 33.0 |
| 14-Jul | 16.6 ± 30.6 | 16.6 ± 30.6 | 9.8 ± 27.0 | 10.0 ± 27.6 | 16.6 ± 30.6 |
| 21-Jul | 22.9 ± 32.7 | 9.8 ± 27.3 | 16.7 ± 30.7 | 3.3 ± 24.3 | 9.9 ± 27.5 |
| 28-Jul | 3.4 ± 24.7 | -10.1 ± 16.1 | 3.3 ± 24.1 | 10.0 ± 27.7 | 3.3 ± 24.5 |
| 4-Aug | 41.8 ± 38.8 | 3.2 ± 23.6 | -3.2 ± 20.0 | 22.6 ± 32.2 | 29.0 ± 34.6 |
| 11-Aug | 23.8 ± 34.0 | 44.4 ± 41.1 | 23.9 ± 34.1 | 58.1 ± 45.1 | 23.9 ± 34.1 |
| 19-Aug | 20.2 ± 28.9 | 26.0 ± 31.0 | 8.6 ± 23.9 | 14.4 ± 26.4 | 8.7 ± 24.0 |
| 25-Aug | 42.2 ± 44.0 | 19.3 ± 35.5 | 59.2 ± 50.3 | 35.4 ± 42.2 | 11.9 ± 32.9 |
| 1-Sep | 9.9 ± 27.5 | 16.5 ± 30.5 | 36.4 ± 37.7 | 3.3 ± 24.3 | 36.4 ± 37.7 |
| 8-Sep | 29.5 ± 35.2 | 9.8 ± 27.3 | 9.9 ± 27.5 | 49.2 ± 41.8 | 23.1 ± 33.0 |
| 15-Sep | -3.2 ± 20.1 | -3.2 ± 20.1 | 22.6 ± 32.2 | 16.2 ± 29.8 | 22.8 ± 32.5 |
| 22-Sep | 10.2 ± 28.5 | 10.2 ± 28.4 | 3.4 ± 24.7 | 3.4 ± 24.7 | 37.0 ± 38.5 |
| 29-Sep | 42.6 ± 39.6 | 22.9 ± 32.7 | 22.6 ± 32.3 | 10.0 ± 27.7 | 23.3 ± 33.2 |
| 6-Oct | 30.0 ± 35.8 | 10.0 ± 27.6 | 10.2 ± 28.4 | 9.9 ± 27.3 | 42.9 ± 40.0 |
| 12-Oct | 35.0 ± 41.8 | 35.0 ± 41.8 | 19.1 ± 35.1 | 44.4 ± 46.2 | 4.0 ± 29.0 |
| 20-Oct | 8.7 ± 24.1 | -2.9 ± 17.9 | -2.9 ± 17.9 | -2.9 ± 18.1 | 20.2 ± 28.9 |
| 27-Oct | 16.5 ± 30.3 | 16.5 ± 30.3 | 30.0 ± 35.8 | 10.1 ± 27.9 | 23.4 ± 33.4 |
| 3-Nov | 9.9 ± 27.5 | -3.3 ± 20.5 | 9.6 ± 26.6 | 9.6 ± 26.5 | 47.7 ± 40.3 |
| 10-Nov | 28.7 ± 34.2 | 9.6 ± 26.5 | 3.3 ± 23.9 | 9.8 ± 27.3 | 42.6 ± 39.6 |
| 17-Nov | 17.4 ± 32.0 | 17.4 ± 32.0 | 24.1 ± 34.4 | 17.3 ± 31.8 | 45.5 ± 42.2 |
| 23-Nov | 34.4 ± 41.1 | 11.5 ± 31.7 | 11.1 ± 30.7 | 18.3 ± 33.7 | 65.5 ± 51.1 |
| 1-Dec | 31.8 ± 33.0 | 31.8 ± 33.0 | 20.6 ± 29.5 | 20.9 ± 29.9 | 60.3 ± 41.4 |
| 8-Dec | 69.9 ± 47.7 | 36.7 ± 38.1 | 90.6 ± 53.3 | 16.9 ± 31.0 | 91.0 ± 53.6 |
| 15-Dec | 9.9 ± 27.5 | 23.1 ± 32.9 | 43.3 ± 40.0 | 55.5 ± 43.3 | 82.1 ± 50.7 |
| 21-Dec | 35.2 ± 40.7 | 4.6 ± 27.6 | 19.3 ± 33.7 | 41.4 ± 42.2 | 11.9 ± 30.5 |
| 28-Dec | 30.6 ± 35.4 | 17.3 ± 30.3 | 17.8 ± 31.1 | -2.7 ± 20.8 | 4.1 ± 24.7 |
| Detection frequency | 5 of 52 | 3 of 52 | 3 of 52 | 4 of 51 | 11 of 52 |
| Median | 17 | 11.2 | 16.4 | 14.4 | 18.4 |
| IQR[(d)] | 23.4 | 19.8 | 19.4 | 18.2 | 29.5 |
| Maximum | 69.9 | 44.4 | 90.6 | 58.1 | 91 |

| Date | Gross beta CHUR | Gross beta FCC | Gross beta FIRE | Gross beta HOSP | Gross beta LWRP |
|---|---|---|---|---|---|
| 6-Jan | 470 ± 137 | 429 ± 133 | 396 ± 131 | 403 ± 131 | 525 ± 144 |
| 13-Jan | 685 ± 175 | 536 ± 160 | 640 ± 169 | 392 ± 141 | 659 ± 171 |
| 20-Jan | 1400 ± 237 | 1270 ± 228 | 1170 ± 217 | 1310 ± 224 | 1490 ± 238 |
| 27-Jan | 744 ± 176 | 659 ± 169 | 629 ± 168 | 729 ± 178 | 877 ± 194 |
| 3-Feb | 914 ± 195 | 884 ± 193 | 796 ± 185 | 670 ± 180 | 833 ± 187 |
| 10-Feb | 603 ± 165 | 477 ± 152 | 481 ± 153 | 331 ± 135 | 507 ± 155 |
| 17-Feb | 49.2 ± 90.3 | (b) | 102.0 ± 99.9 | 6.4 ± 82.5 | 20.6 ± 84.7 |
| 18-Feb | (b) | 44.8 ± 89.9 | (b) | (b) | (b) |
| 24-Feb | 190 ± 114 | 191 ± 114 | 162 ± 114 | 151 ± 107 | 273 ± 126 |
| 3-Mar | 183 ± 114 | 175 ± 112 | 192 ± 114 | 109 ± 103 | 137 ± 104 |
| 10-Mar | 112 ± 102 | 131 ± 105 | 82.9 ± 96.9 | 160 ± 110 | 111 ± 102 |
| 17-Mar | 248 ± 122 | 317 ± 134 | 176 ± 116 | 244 ± 125 | 303 ± 132 |
| 24-Mar | 159 ± 112 | 142 ± 108 | 179 ± 113 | 98 ± 100 | 185 ± 114 |
| 31-Mar | 296 ± 131 | 320 ± 132 | 188 ± 117 | 128 ± 106 | 257 ± 128 |
| 7-Apr | 143 ± 108 | 392 ± 143 | 320 ± 132 | 259 ± 124 | 321 ± 132 |
| 14-Apr | 137 ± 107 | 148 ± 110 | 178 ± 110 | 127 ± 105 | 137 ± 107 |
| 21-Apr | 324 ± 134 | 363 ± 139 | 304 ± 132 | (c) | 343 ± 138 |
| 28-Apr | 194 ± 116 | 357 ± 138 | 282 ± 130 | 250 ± 125 | 338 ± 136 |
| 4-May | 184 ± 124 | 93 ± 108 | 210 ± 130 | 84 ± 109 | 124 ± 117 |
| 12-May | 151 ± 101 | 185 ± 107 | 191 ± 105 | 73.6 ± 86.2 | 175 ± 102 |
| 19-May | 194 ± 116 | 300 ± 131 | 303 ± 131 | 276 ± 127 | 310 ± 135 |
| 26-May | 262 ± 125 | 170 ± 112 | 256 ± 123 | 122 ± 105 | 127 ± 105 |
| 2-Jun | 251 ± 121 | 312 ± 129 | 302 ± 131 | 196 ± 115 | 312 ± 130 |
| 9-Jun | 87 ± 102 | 178 ± 117 | 90 ± 101 | 226 ± 124 | 150 ± 111 |
| 16-Jun | 154 ± 109 | 96.9 ± 99.2 | 112 ± 106 | 64.4 ± 94.7 | 137 ± 107 |
| 23-Jun | 214 ± 119 | 175 ± 113 | 224 ± 117 | 206 ± 117 | 167 ± 112 |
| 29-Jun | 307 ± 149 | 266 ± 144 | 264 ± 147 | 344 ± 159 | 392 ± 165 |
| 7-Jul | 266 ± 114 | 308 ± 119 | 353 ± 125 | 228 ± 110 | 241 ± 111 |
| 14-Jul | 215 ± 119 | 248 ± 124 | 323 ± 132 | 258 ± 125 | 215 ± 119 |
| 21-Jul | 287 ± 128 | 297 ± 130 | 265 ± 127 | 295 ± 130 | 305 ± 131 |
| 28-Jul | 110 ± 104 | 104 ± 102 | 97.3 ± 99.5 | 137 ± 107 | 99 ± 101 |
| 4-Aug | 48.5 ± 89.2 | 71.8 ± 93.6 | 48.5 ± 89.2 | 62.5 ± 91.8 | 90.6 ± 96.6 |
| 11-Aug | 239 ± 125 | 303 ± 134 | 235 ± 124 | 269 ± 130 | 289 ± 132 |
| 19-Aug | 266 ± 115 | 216 ± 108 | 215 ± 107 | 215 ± 107 | 194 ± 105 |
| 25-Aug | 282 ± 143 | 210 ± 132 | 289 ± 147 | 208 ± 134 | 324 ± 152 |
| 1-Sep | 324 ± 134 | 213 ± 119 | 247 ± 124 | 348 ± 137 | 396 ± 143 |
| 8-Sep | 207 ± 117 | 149 ± 108 | 189 ± 115 | 217 ± 118 | 275 ± 127 |
| 15-Sep | 210 ± 117 | 257 ± 123 | 274 ± 125 | 266 ± 124 | 286 ± 127 |
| 22-Sep | 270 ± 130 | 275 ± 130 | 350 ± 139 | 296 ± 132 | 286 ± 131 |
| 29-Sep | 577 ± 162 | 562 ± 161 | 492 ± 152 | 518 ± 158 | 496 ± 155 |
| 6-Oct | 181 ± 114 | 200 ± 117 | 225 ± 123 | 179 ± 113 | 280 ± 128 |
| 12-Oct | 725 ± 197 | 470 ± 169 | 703 ± 192 | 437 ± 169 | 673 ± 194 |
| 20-Oct | 162 ± 100 | 111.0 ± 92.1 | 149.0 ± 98.0 | 73.3 ± 85.8 | 186 ± 104 |
| 27-Oct | 251 ± 124 | 155 ± 110 | 351 ± 138 | 289 ± 131 | 279 ± 129 |
| 3-Nov | 323 ± 134 | 323 ± 134 | 304 ± 128 | 289 ± 126 | 518 ± 154 |
| 10-Nov | 385 ± 138 | 285 ± 125 | 551 ± 159 | 265 ± 125 | 470 ± 151 |
| 17-Nov | 500 ± 160 | 422 ± 151 | 462 ± 155 | 385 ± 146 | 581 ± 169 |
| 23-Nov | 263 ± 139 | 146 ± 121 | 196 ± 126 | 119 ± 113 | 287 ± 144 |
| 1-Dec | 677 ± 161 | 474 ± 139 | 636 ± 158 | 459 ± 141 | 762 ± 168 |
| 8-Dec | 814 ± 188 | 747 ± 182 | 988 ± 204 | 525 ± 160 | 984 ± 205 |
| 15-Dec | 659 ± 172 | 581 ± 164 | 685 ± 175 | 607 ± 165 | 633 ± 168 |
| 21-Dec | 722 ± 194 | 551 ± 175 | 500 ± 166 | 581 ± 176 | 592 ± 177 |
| 28-Dec | 429 ± 147 | 477 ± 152 | 496 ± 157 | 377 ± 143 | 507 ± 158 |
| Detection frequency | 49 of 52 | 48 of 52 | 48 of 52 | 44 of 51 | 49 of 52 |
| Median | 262 | 280 | 278 | 258 | 296 |
| IQR[(d)] | 256 | 250 | 276 | 218 | 321 |
| Maximum | 1400 | 1270 | 1170 | 1310 | 1490 |

(a) See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) Nonconsecutive sample dates occur when samples could not be collected on scheduled sampling date, or when a sampler ran longer than 1 week.
(c) No sample for this period due to power (GFI) or sampler malfunction
(d) IQR = Interquartile range

**A.2.10 Plutonium-239+240 concentrations (nBq/m3) in air particulate samples from the Livermore Valley, 2009[(a)]**

| Month | Valley upwind CHUR | Valley upwind FCC | Valley upwind FIRE | Valley upwind HOSP | Valley downwind AMON | Valley downwind CPET | Valley downwind PATT | Valley downwind TANK | Valley downwind ZON7 | Special interest LWRP |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 1.15 ± 5.33 | 6.44 ± 7.51 | -3.54 ± 4.07 | 4.8 ± 12.4 | 10.4 ± 75.8 | 1.12 ± 5.03 | 4.18 ± 7.88 | 2.92 ± 6.40 | -0.18 ± 4.22 | 5.70 ± 8.03 |
| Feb | 7.99 ± 8.77 | 6.36 ± 9.95 | 2.04 ± 6.48 | 2.34 ± 4.40 | 4.62 ± 7.29 | -11.1 ± 37.7 | -5.44 ± 6.25 | -11.50 ± 8.40 | 1.99 ± 9.21 | 13.20 ± 9.88 |
| Mar | -4.62 ± 6.88 | 8.0 ± 13.7 | 6.1 ± 10.5 | 13.7 ± 13.4 | 6.4 ± 11.6 | 9.5 ± 11.1 | 5.14 ± 8.10 | 11.2 ± 13.1 | 13.7 ± 23.5 | 8.6 ± 10.5 |
| Apr | -0.24 ± 5.81 | 7.62 ± 8.40 | -2.77 ± 8.92 | -1.08 ± 6.70 | -8.18 ± 8.14 | -0.31 ± 7.40 | -0.93 ± 5.74 | -1.99 ± 4.85 | 1.13 ± 9.25 | 5.40 ± 7.22 |
| May | 9.9 ± 14.1 | 71.8 ± 79.9 | 61.4 ± 40.0 | 31.5 ± 44.8 | 45.5 ± 45.9 | -46.3 ± 33.5 | 18.2 ± 23.3 | 1.2 ± 14.8 | -3.0 ± 11.6 | 238 ± 118 |
| Jun | -0.23 ± 5.48 | -2.66 ± 4.92 | -0.24 ± 9.21 | 7.4 ± 11.5 | -0.51 ± 4.48 | 4.48 ± 8.07 | 2.55 ± 8.07 | 1.85 ± 3.70 | 5.11 ± 5.92 | 0.23 ± 7.81 |
| Jul | 8.0 ± 35.7 | 3.03 ± 9.58 | 7.8 ± 18.8 | 5.2 ± 13.1 | -6.6 ± 40.7 | 44.0 ± 57.0 | 8.8 ± 10.3 | -26.2 ± 55.9 | -1.3 ± 32.2 | -17 ± 117 |
| Aug | 2.3 ± 10.2 | -4.92 ± 9.14 | 11.7 ± 13.1 | 10.20 ± 9.51 | 7.88 ± 8.66 | 1.1 ± 10.8 | 0.20 ± 9.80 | -0.7 ± 11.9 | 11.5 ± 12.2 | -18.1 ± 76.6 |
| Sep | 8.40 ± 9.77 | 7.4 ± 12.7 | 10.4 ± 27.6 | 2.2 ± 10.1 | 11.8 ± 20.4 | -66.6 ± 67.3 | -1.6 ± 10.7 | 25.6 ± 40.3 | 5.1 ± 16.4 | 21.0 ± 15.1 |
| Oct | 3.46 ± 9.18 | 1.69 ± 5.11 | -2.87 ± 5.33 | -5.11 ± 7.77 | 5.99 ± 9.47 | 4.14 ± 7.07 | -0.6 ± 13.4 | 2.07 ± 6.55 | 1.1 ± 10.0 | 22.7 ± 15.0 |
| Nov | 2.7 ± 12.0 | 7.25 ± 9.95 | 7.1 ± 11.0 | 9.4 ± 10.3 | 8.77 ± 9.80 | 2.24 ± 6.73 | 6.25 ± 9.40 | -0.30 ± 7.29 | 1.43 ± 6.62 | 25.7 ± 15.1 |
| Dec | 11.6 ± 22.9 | 2.13 ± 9.55 | 1.6 ± 15.1 | 11.1 ± 17.4 | 1.97 ± 8.81 | 1.6 ± 15.5 | 13.4 ± 24.4 | -4.7 ± 17.0 | -19.4 ± 25.7 | 23.3 ± 23.1 |
| Detection frequency | 0 of 12 | 0 of 12 | 1 of 12 | 2 of 12 | 0 of 12 | 0 of 12 | 0 of 12 | 0 of 12 | 0 of 12 | 6 of 12 |
| Median | 3.09 | 6.4 | 4.09 | 6.29 | 6.22 | 1.39 | 3.36 | 0.468 | 1.28 | 10.9 |
| IQR[(b)] | 7.29 | 5.46 | 9.36 | 8.11 | 7.83 | 7.23 | 7.55 | 4.94 | 5.58 | 18.7 |
| Maximum | 11.6 | 71.8 | 61.4 | 31.5 | 45.5 | 44 | 18.2 | 25.6 | 13.7 | 238 |
| Median Percent of DCG | 0.00042 | 0.00086 | 0.00055 | 0.00085 | 0.00084 | 0.00019 | 0.00045 | 0.000063 | 0.00017 | 0.0015 |
| DCG[(c)] | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 | 740000 |

(a) See *Environmental Report 2009*, Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) IQR = Interquartile range
(c) DCG is the Derived Air Concentration Guide established by the DOE and is the amount of plutonium-239+240 that can be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public.

AT-S3 [mBq/m3]   2009 data    (created 2010-03-08 15:07:28, Oracle) (epprd02.llnl.gov)

**A.2.11 Tritium concentrations (mBq/m$^3$) in air, Site 300, 2009[a]**

| Week | Month | PSTL |
|---|---|---|
| 1 | Jan | -10.4 ± 13.7 |
| 3 | Jan | 7.18 ± 9.03 |
| 5 | Feb | 17.0 ± 13.7 |
| 7 | Feb | 4.4 ± 12.4 |
| 9 | Mar | 19.8 ± 15.8 |
| 11 | Mar | 12.6 ± 10.0 |
| 13 | Apr | -4.9 ± 13.1 |
| 17 | Apr | 12.2 ± 10.1 |
| 19 | May | 1.1 ± 14.0 |
| 21 | May | 20.8 ± 14.2 |
| 23 | Jun | -6.2 ± 15.9 |
| 25 | Jun | 32.7 ± 14.3 |
| 27 | Jul | 14.1 ± 12.9 |
| 29 | Jul | 11.30 ± 7.59 |
| 31 | Aug | -11.1 ± 12.0 |
| 33 | Aug | 5.1 ± 10.7 |
| 35 | Sep | 5.0 ± 10.7 |
| 37 | Sep | 10.0 ± 11.7 |
| 39 | Sep | -8.3 ± 10.7 |
| 41 | Oct | 4.00 ± 9.44 |
| 43 | Oct | -5.9 ± 15.4 |
| 45 | Nov | 4.77 ± 9.73 |
| 47 | Nov | 10.1 ± 10.1 |
| 49 | Dec | 5.11 ± 8.77 |
| 51 | Dec | 10.1 ± 11.3 |
| | Median | 5.11 |
| | IQR[b] | 11.1 |
| | Median Percent of DCG[c] | 0.00014 |
| | Mean Dose (nSv)[d][e] | <5 |

(a) See *Environmental Report 2009,* Figure 4-2 for map of sampling locations.
(b)  IQR = Interquartile range

(c)  DCG = Derived Concentration Guide of 3.7E+06 mBq/m$^3$ for tritium in air. Percent of DCG is calculated from the median concentration.

(d)  This annual dose is calculated from the mean concentration and represents the effective dose equivalent from inhalation and skin absorbtion.

(e)  When the mean dose is based on a concentration less than the lower limit of detection (about 25 mBq/m$^3$), the dose is assumed to be less than that calculated from the lower limit of detection (i.e., 5 nSv/year).

**A.2.12 Weekly gross alpha and gross beta concentrations ($\mu Bq/m^3$) from air particulate samples from Site 300 onsite and offsite locations, 2009[(a)]**

| Date | Gross alpha TNK5 | Gross alpha PSTL | Gross alpha ECP | Gross alpha EOBS | Gross alpha GOLF | Gross alpha NPS | Gross alpha WCP | Gross alpha WOBS | Gross alpha TCDF |
|---|---|---|---|---|---|---|---|---|---|
| 7-Jan | 8.6 ± 23.8 | 26.1 ± 20.4 | 20.8 ± 29.7 | -2.9 ± 17.8 | 25.9 ± 30.9 | 14.6 ± 26.8 | 14.5 ± 26.6 | 14.6 ± 26.8 | 8.7 ± 24.0 |
| 14-Jan | 16.2 ± 29.8 | 16.4 ± 30.2 | 50.7 ± 42.9 | 9.8 ± 27.1 | 22.9 ± 32.7 | 16.5 ± 30.4 | 16.4 ± 30.0 | -3.3 ± 20.5 | 23.8 ± 34.0 |
| 21-Jan | 34.9 ± 36.3 | 54.4 ± 42.6 | 36.4 ± 37.7 | 41.4 ± 38.5 | 67.3 ± 45.9 | 18.6 ± 34.3 | (b) | (b) | (b) |
| 22-Jan | (b) | (b) | (b) | (b) | (b) | (b) | 31.4 ± 32.6 | 37.4 ± 34.8 | 49.2 ± 38.5 |
| 28-Jan | 3.4 ± 24.6 | (c) | -10.5 ± 16.9 | 3.4 ± 24.6 | 10.1 ± 28.2 | 31.4 ± 37.4 | 3.9 ± 28.5 | 11.8 ± 32.6 | 4.0 ± 28.9 |
| 4-Feb | 16.3 ± 29.9 | 17.0 ± 31.3 | 10.3 ± 28.5 | 9.9 ± 27.4 | 3.3 ± 24.1 | -3.3 ± 20.6 | 23.0 ± 32.8 | 3.3 ± 24.3 | 23.2 ± 33.2 |
| 11-Feb | 16.2 ± 29.7 | 44.0 ± 41.1 | 23.8 ± 33.9 | 16.2 ± 29.8 | 3.3 ± 23.9 | 17.0 ± 31.3 | -3.2 ± 20.1 | 23.0 ± 32.9 | 3.3 ± 24.0 |
| 18-Feb | 3.3 ± 24.2 | -3.4 ± 20.8 | 10.3 ± 28.5 | 9.9 ± 27.6 | -3.3 ± 20.5 | -3.4 ± 21.0 | 3.3 ± 24.4 | -3.4 ± 20.9 | -3.4 ± 20.8 |
| 25-Feb | 16.8 ± 30.8 | -3.2 ± 20.1 | 9.9 ± 27.6 | 3.2 ± 23.3 | -3.2 ± 19.7 | -9.7 ± 15.6 | -3.2 ± 19.7 | -9.7 ± 15.5 | -3.4 ± 20.9 |
| 4-Mar | -10.2 ± 16.4 | (b) | 17.6 ± 32.3 | -3.4 ± 20.8 | -3.4 ± 20.9 | 3.4 ± 25.1 | -3.4 ± 20.8 | 10.2 ± 28.3 | -3.4 ± 21.3 |
| 11-Mar | -10.1 ± 16.1 | 11.9 ± 16.9 | 3.5 ± 25.4 | -9.9 ± 15.8 | -3.3 ± 20.4 | -10.1 ± 16.1 | -3.3 ± 20.5 | 3.3 ± 24.5 | 10.1 ± 28.0 |
| 18-Mar | 10.2 ± 28.3 | 36.3 ± 37.7 | -3.4 ± 21.2 | 9.7 ± 26.8 | 3.2 ± 23.8 | 16.4 ± 30.2 | 3.2 ± 23.7 | 9.8 ± 27.2 | -3.3 ± 20.4 |
| 25-Mar | -3.4 ± 21.2 | 44.4 ± 41.1 | 10.7 ± 29.5 | -10.2 ± 16.4 | 23.5 ± 33.5 | -3.4 ± 21.2 | 10.1 ± 27.9 | -10.2 ± 16.3 | 3.4 ± 25.2 |
| 1-Apr | -3.3 ± 20.6 | 16.7 ± 30.7 | 17.3 ± 31.8 | 9.9 ± 27.5 | -10.3 ± 16.5 | 3.3 ± 24.4 | 16.4 ± 30.0 | 9.9 ± 27.5 | 10.1 ± 27.9 |
| 8-Apr | 23.4 ± 33.4 | (c) | 23.3 ± 33.3 | 16.6 ± 30.6 | 3.3 ± 24.4 | 16.8 ± 30.8 | 9.9 ± 27.4 | -3.3 ± 20.7 | 10.1 ± 28.0 |
| 15-Apr | -9.9 ± 15.9 | (c) | -3.3 ± 20.4 | 3.3 ± 24.2 | 16.5 ± 30.3 | 3.3 ± 24.4 | (b) | (b) | 3.4 ± 24.6 |
| 16-Apr | (b) | (b) | (b) | (b) | (b) | (b) | -2.9 ± 18.0 | 43.7 ± 37.0 | (b) |
| 22-Apr | 16.7 ± 30.7 | (b) | 23.2 ± 33.0 | 23.1 ± 33.0 | 3.3 ± 24.2 | -3.3 ± 20.6 | 12.0 ± 33.2 | 36.0 ± 42.9 | 30.2 ± 36.0 |
| 23-Apr | (b) | 16.0 ± 44.4 | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| 29-Apr | 3.5 ± 25.4 | 35.8 ± 42.6 | 24.1 ± 34.4 | 31.0 ± 36.9 | -3.3 ± 20.4 | -10.4 ± 16.6 | 3.4 ± 25.2 | 3.3 ± 24.3 | 23.6 ± 33.7 |
| 5-May | 3.9 ± 28.4 | (b) | 19.3 ± 35.4 | 11.6 ± 32.0 | -3.9 ± 24.1 | 27.2 ± 38.8 | 27.0 ± 38.5 | 27.0 ± 38.5 | -3.9 ± 24.3 |
| 6-May | (b) | 9.9 ± 27.5 | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| 13-May | -2.8 ± 17.6 | 16.4 ± 30.0 | 2.8 ± 20.7 | 48.1 ± 37.7 | -8.5 ± 13.6 | 19.9 ± 28.5 | (b) | (b) | -2.9 ± 17.9 |
| 20-May | 43.3 ± 40.3 | 23.5 ± 33.5 | 29.9 ± 35.7 | 9.9 ± 27.6 | 36.6 ± 38.1 | 30.2 ± 36.0 | 29.0 ± 21.2 | 22.9 ± 19.4 | 30.3 ± 36.2 |
| 27-May | 17.2 ± 31.6 | 51.4 ± 43.7 | 17.1 ± 31.4 | 10.2 ± 28.4 | 17.1 ± 31.4 | 10.3 ± 28.7 | -3.4 ± 21.2 | 30.7 ± 36.7 | 38.1 ± 39.6 |
| 4-Jun | 23.3 ± 33.2 | 16.6 ± 30.6 | 29.7 ± 35.5 | 3.3 ± 24.2 | 16.5 ± 30.4 | 23.3 ± 33.3 | 36.4 ± 37.7 | 29.7 ± 35.5 | 16.8 ± 30.8 |
| 10-Jun | 9.9 ± 27.6 | 29.9 ± 35.7 | -3.3 ± 20.5 | 3.3 ± 24.2 | 3.3 ± 24.3 | 16.6 ± 30.6 | 9.9 ± 27.5 | 3.3 ± 24.2 | 16.5 ± 30.4 |
| 17-Jun | 3.3 ± 24.4 | (b) | -3.3 ± 20.6 | 9.9 ± 27.6 | 3.3 ± 24.3 | 16.6 ± 30.5 | 23.2 ± 33.2 | 9.9 ± 27.6 | 9.9 ± 27.6 |
| 18-Jun | (b) | 8.5 ± 23.5 | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| 24-Jun | -3.4 ± 20.9 | (b) | 3.3 ± 24.3 | 16.9 ± 31.0 | -3.3 ± 20.5 | 16.9 ± 31.0 | 3.3 ± 24.3 | -3.3 ± 20.5 | 9.9 ± 27.6 |
| 1-Jul | 16.6 ± 30.6 | 9.1 ± 16.8 | 30.0 ± 35.8 | 10.0 ± 27.7 | 23.3 ± 33.3 | 3.3 ± 24.4 | 36.6 ± 38.1 | 16.6 ± 30.6 | 3.3 ± 24.4 |
| 8-Jul | 16.4 ± 30.2 | 36.1 ± 37.4 | 9.8 ± 27.3 | 9.8 ± 27.3 | 23.0 ± 32.8 | -3.3 ± 20.3 | 9.8 ± 27.3 | 9.8 ± 27.3 | 16.4 ± 30.2 |
| 15-Jul | 36.7 ± 38.1 | 30.0 ± 35.8 | 10.0 ± 27.8 | 3.3 ± 24.5 | 49.9 ± 42.6 | -3.3 ± 20.6 | 36.7 ± 38.1 | 10.0 ± 27.7 | 10.0 ± 27.7 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 22-Jul | 23.2 ± 33.1 | 29.8 ± 35.6 | 3.3 ± 24.3 | 23.2 ± 33.1 | -3.3 ± 20.5 | 23.2 ± 33.1 | -3.3 ± 20.5 | 16.6 ± 30.5 | 23.2 ± 33.1 |
| 29-Jul | 3.3 ± 24.3 | 16.7 ± 30.7 | 16.6 ± 30.5 | 3.3 ± 24.3 | -3.3 ± 20.6 | -3.3 ± 20.5 | (b) | (b) | 3.3 ± 24.4 |
| 30-Jul | (b) | (b) | (b) | (b) | (b) | (b) | -8.7 ± 14.0 | 8.7 ± 24.2 | (b) |
| 5-Aug | 3.3 ± 24.0 | 68.8 ± 47.4 | 9.8 ± 27.3 | 9.8 ± 27.2 | 9.8 ± 27.3 | 9.8 ± 27.2 | -3.8 ± 23.4 | 19.0 ± 34.9 | 22.8 ± 32.6 |
| 12-Aug | 9.9 ± 27.6 | 110.0 ± 57.4 | 69.9 ± 47.7 | 36.6 ± 38.1 | 23.2 ± 33.2 | 10.0 ± 27.7 | 10.0 ± 27.8 | 30.0 ± 35.7 | 43.3 ± 40.3 |
| 19-Aug | (b) | 95.5 ± 54.0 | 49.2 ± 41.8 | 36.1 ± 37.4 | 42.9 ± 39.6 | 36.1 ± 37.4 | 29.6 ± 35.3 | 42.6 ± 39.6 | 55.9 ± 43.7 |
| 20-Aug | 48.8 ± 38.1 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| 26-Aug | 28.6 ± 34.2 | 89.9 ± 52.9 | (b) | 30.0 ± 35.7 | 29.9 ± 35.7 | 23.3 ± 33.3 | (b) | (b) | 3.3 ± 24.5 |
| 27-Aug | (b) | (b) | 23.3 ± 33.3 | (b) | (b) | (b) | 8.8 ± 24.3 | 8.8 ± 24.3 | (b) |
| 2-Sep | 36.6 ± 38.1 | 42.2 ± 39.2 | -3.9 ± 24.0 | 29.7 ± 35.5 | 9.9 ± 27.5 | 9.9 ± 27.5 | 3.9 ± 28.1 | 19.2 ± 35.3 | 23.1 ± 32.9 |
| 9-Sep | 23.5 ± 33.4 | 57.4 ± 44.8 | 36.6 ± 38.1 | 30.0 ± 35.7 | 10.0 ± 27.6 | 10.0 ± 27.7 | 10.0 ± 27.7 | 16.6 ± 30.6 | 36.6 ± 38.1 |
| 16-Sep | (c) | 69.2 ± 47.4 | 3.3 ± 24.3 | 10.0 ± 27.7 | 9.9 ± 27.5 | 23.3 ± 33.3 | 35.6 ± 50.7 | 23.4 ± 33.4 | 16.6 ± 30.6 |
| 21-Sep | (b) | (b) | (b) | 49.9 ± 51.8 | (b) | 13.6 ± 37.7 | 13.6 ± 37.7 | 31.7 ± 45.5 | (b) |
| 23-Sep | 24.1 ± 34.4 | 42.9 ± 40.0 | 3.3 ± 24.3 | (b) | 30.0 ± 35.7 | (b) | (b) | (b) | 29.8 ± 35.6 |
| 30-Sep | -3.3 ± 20.5 | 23.3 ± 33.3 | 16.5 ± 30.3 | (b) | 36.4 ± 37.7 | (b) | (b) | (b) | 16.5 ± 30.3 |
| 1-Oct | (b) | (b) | (b) | 18.2 ± 25.9 | (b) | 23.3 ± 27.8 | 21.1 ± 25.2 | (b) | (b) |
| 7-Oct | 43.3 ± 40.3 | 29.9 ± 35.7 | 69.9 ± 47.7 | 49.9 ± 42.2 | 16.6 ± 30.5 | -3.3 ± 20.6 | 11.5 ± 31.7 | 39.2 ± 23.2 | 43.3 ± 40.0 |
| 14-Oct | (b) | 36.4 ± 37.7 | 9.9 ± 27.5 | 36.4 ± 37.7 | 42.9 ± 40.0 | 9.9 ± 27.5 | (b) | 23.2 ± 33.1 | 16.7 ± 30.6 |
| 15-Oct | 20.4 ± 29.2 | (b) | (b) | (b) | (b) | (b) | 43.3 ± 45.1 | (b) | (b) |
| 21-Oct | 3.7 ± 27.5 | 16.5 ± 30.4 | -9.9 ± 15.9 | -9.9 ± 15.8 | 3.3 ± 24.2 | 3.3 ± 24.2 | -3.9 ± 23.8 | 3.3 ± 24.2 | 16.1 ± 29.6 |
| 28-Oct | 14.7 ± 27.0 | 9.9 ± 27.5 | -3.3 ± 20.5 | 9.9 ± 27.5 | -9.9 ± 15.9 | 9.9 ± 27.5 | 3.3 ± 24.3 | 36.4 ± 37.7 | 17.0 ± 31.2 |
| 4-Nov | 59.9 ± 50.7 | 3.2 ± 23.5 | 9.9 ± 27.5 | 23.1 ± 33.0 | 3.3 ± 24.3 | 29.7 ± 35.4 | 16.5 ± 30.3 | 3.3 ± 24.2 | 16.5 ± 30.3 |
| 11-Nov | 29.7 ± 35.4 | 50.3 ± 42.6 | 3.3 ± 24.2 | -3.3 ± 20.6 | 3.3 ± 24.2 | 36.3 ± 37.7 | 16.5 ± 30.3 | 9.9 ± 27.4 | 23.0 ± 32.9 |
| 18-Nov | 10.1 ± 27.9 | 44.0 ± 40.7 | 10.0 ± 27.7 | 16.6 ± 30.6 | 16.6 ± 30.6 | 30.0 ± 35.8 | 10.0 ± 27.8 | 23.3 ± 33.3 | 43.3 ± 40.3 |
| 23-Nov | 32.8 ± 46.6 | -4.7 ± 28.8 | 41.8 ± 49.9 | 4.7 ± 34.1 | -4.7 ± 28.8 | -13.9 ± 22.3 | 51.1 ± 53.3 | -13.9 ± 22.3 | 4.7 ± 34.2 |
| 2-Dec | 28.5 ± 29.6 | 103.0 ± 45.5 | 54.0 ± 37.0 | 33.3 ± 31.0 | 43.7 ± 34.2 | 43.7 ± 34.1 | 28.2 ± 29.3 | 48.8 ± 35.6 | 110.0 ± 49.6 |
| 9-Dec | 43.3 ± 40.3 | (c) | 42.9 ± 40.0 | 36.6 ± 38.1 | 29.8 ± 35.5 | 56.6 ± 44.4 | 23.2 ± 33.2 | 56.2 ± 44.0 | 36.7 ± 38.1 |
| 16-Dec | 49.9 ± 42.6 | 88.1 ± 36.9 | 16.6 ± 30.5 | 43.3 ± 40.0 | 3.3 ± 24.3 | 9.9 ± 27.6 | 43.3 ± 40.0 | 3.3 ± 24.3 | 56.6 ± 44.0 |
| 22-Dec | 4.7 ± 28.0 | 66.6 ± 51.1 | 27.9 ± 38.5 | 51.1 ± 46.6 | 35.6 ± 41.4 | 27.9 ± 38.5 | 27.9 ± 38.5 | 12.4 ± 31.9 | 27.9 ± 38.5 |
| 29-Dec | 77.7 ± 49.9 | 76.6 ± 49.2 | 17.2 ± 30.1 | 63.3 ± 45.5 | 17.2 ± 30.1 | 17.2 ± 30.1 | 10.5 ± 27.1 | 4.0 ± 23.9 | 37.0 ± 37.4 |
| Detection frequency | 7 of 51 | 19 of 46 | 6 of 52 | 7 of 52 | 5 of 52 | 2 of 52 | 2 of 51 | 7 of 50 | 7 of 52 |
| Median | 16.3 | 30 | 16.6 | 10.1 | 9.92 | 14.1 | 10.5 | 12.1 | 16.6 |
| IQR[d] | 25.1 | 34.7 | 21.7 | 25.9 | 21.7 | 20 | 21.8 | 22.8 | 25.4 |
| Maximum | 77.7 | 110 | 69.9 | 63.3 | 67.3 | 56.6 | 51.1 | 56.2 | 110 |

| Date | Gross beta TNK5 | Gross beta PSTL | Gross beta ECP | Gross beta EOBS | Gross beta GOLF | Gross beta NPS | Gross beta WCP | Gross beta WOBS | Gross beta TCDF |
|---|---|---|---|---|---|---|---|---|---|
| 7-Jan | 276 ± 115 | 320.0 ± 81.4 | 448 ± 139 | 298 ± 118 | 440 ± 136 | 370 ± 129 | 317 ± 121 | 374 ± 129 | 544 ± 147 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14-Jan | 581 ± 162 | 488 ± 153 | 548 ± 162 | 507 ± 155 | 566 ± 161 | 640 ± 170 | 349 ± 136 | 622 ± 168 | 718 ± 181 |
| 21-Jan | 1670 ± 249 | 1330 ± 226 | 1670 ± 255 | 2290 ± 288 | 1360 ± 228 | 1590 ± 267 | (b) | (b) | (b) |
| 22-Jan | (b) | (b) | (b) | (b) | (b) | (b) | 1520 ± 225 | 1490 ± 225 | 1830 ± 247 |
| 28-Jan | 353 ± 139 | (c) | 451 ± 156 | 544 ± 162 | 610 ± 170 | 205 ± 122 | 374 ± 156 | 333 ± 152 | 414 ± 163 |
| 4-Feb | 725 ± 177 | 995 ± 207 | 932 ± 202 | 1060 ± 208 | 810 ± 186 | 918 ± 197 | 858 ± 190 | 847 ± 191 | 829 ± 189 |
| 11-Feb | 222 ± 118 | 307 ± 134 | 268 ± 129 | 299 ± 129 | 244 ± 122 | 219 ± 122 | 271 ± 125 | 293 ± 130 | 321 ± 133 |
| 18-Feb | 11.2 ± 83.2 | 100 ± 102 | 46.6 ± 94.0 | 64.4 ± 94.4 | 74.0 ± 96.2 | 36.1 ± 90.6 | 98 ± 101 | 40.7 ± 91.0 | 95 ± 101 |
| 25-Feb | 241 ± 124 | 195 ± 114 | 151 ± 109 | 214 ± 115 | 224 ± 117 | 195 ± 114 | 219 ± 116 | 184 ± 112 | 272 ± 129 |
| 4-Mar | 176 ± 116 | (b) | 135 ± 112 | 109 ± 103 | 119 ± 105 | 191 ± 118 | 187 ± 116 | 160 ± 113 | 186 ± 118 |
| 11-Mar | 104 ± 102 | 191.0 ± 71.8 | 52.2 ± 95.5 | 126 ± 104 | 131 ± 105 | 114 ± 104 | 83.2 ± 97.7 | 21.1 ± 86.6 | 100 ± 102 |
| 18-Mar | 225 ± 123 | 362 ± 138 | 206 ± 120 | 203 ± 115 | 317 ± 131 | 155 ± 109 | 175 ± 111 | 240 ± 122 | 208 ± 117 |
| 25-Mar | 101 ± 104 | 175 ± 115 | 162 ± 117 | 201 ± 120 | 167 ± 113 | 195 ± 119 | 89.5 ± 99.9 | 204 ± 120 | 142 ± 111 |
| 1-Apr | 185 ± 115 | 312 ± 133 | 400 ± 148 | 247 ± 123 | 267 ± 130 | 287 ± 130 | 363 ± 138 | 290 ± 130 | 250 ± 125 |
| 8-Apr | 333 ± 136 | (c) | 485 ± 154 | 422 ± 147 | 364 ± 139 | 377 ± 142 | 323 ± 134 | 433 ± 148 | 286 ± 131 |
| 15-Apr | 97.7 ± 99.9 | (c) | 159 ± 110 | 141 ± 107 | 203 ± 117 | 98 ± 101 | (b) | (b) | 109 ± 103 |
| 16-Apr | (b) | (b) | (b) | (b) | (b) | (b) | 69.2 ± 85.1 | 128.0 ± 95.5 | (b) |
| 22-Apr | 336 ± 136 | (b) | 440 ± 148 | 333 ± 135 | 400 ± 144 | 341 ± 137 | 263 ± 144 | 357 ± 157 | 433 ± 149 |
| 23-Apr | (b) | 540 ± 218 | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| 29-Apr | 208 ± 122 | 361 ± 157 | 287 ± 132 | 272 ± 131 | 260 ± 125 | 204 ± 121 | 257 ± 128 | 219 ± 120 | 169 ± 114 |
| 5-May | 159 ± 125 | (b) | 221 ± 134 | 142 ± 121 | 178 ± 128 | 161 ± 125 | 131 ± 120 | 165 ± 125 | 134 ± 122 |
| 6-May | (b) | 151 ± 109 | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| 13-May | 237 ± 110 | 344 ± 135 | 326 ± 121 | 228 ± 108 | 195 ± 103 | 279 ± 115 | (b) | (b) | 207 ± 107 |
| 20-May | 327 ± 135 | 411 ± 146 | 354 ± 138 | 335 ± 136 | 297 ± 131 | 367 ± 141 | 296.0 ± 78.8 | 212.0 ± 69.6 | 257 ± 127 |
| 27-May | 347 ± 141 | 488 ± 158 | 440 ± 151 | 325 ± 137 | 403 ± 147 | 327 ± 138 | 370 ± 143 | 403 ± 147 | 385 ± 147 |
| 4-Jun | 234 ± 122 | 326 ± 135 | 462 ± 151 | 353 ± 138 | 339 ± 136 | 403 ± 145 | 324 ± 134 | 462 ± 151 | 241 ± 124 |
| 10-Jun | 181 ± 114 | 234 ± 122 | 165 ± 111 | 102 ± 101 | 151 ± 109 | 181 ± 114 | 131 ± 106 | 127 ± 105 | 107 ± 102 |
| 17-Jun | 219 ± 120 | (b) | 238 ± 122 | 195 ± 116 | 190 ± 115 | 209 ± 118 | 209 ± 118 | 103 ± 101 | 176 ± 113 |
| 18-Jun | (b) | 293 ± 116 | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| 24-Jun | 208 ± 120 | (b) | 300 ± 131 | 228 ± 122 | 281 ± 128 | 267 ± 128 | 199 ± 117 | 185 ± 114 | 281 ± 128 |
| 1-Jul | 507 ± 157 | 192.0 ± 75.5 | 422 ± 147 | 400 ± 144 | 881 ± 194 | 455 ± 151 | 459 ± 151 | 448 ± 150 | 448 ± 150 |
| 8-Jul | 422 ± 145 | 718 ± 177 | 369 ± 139 | 388 ± 141 | 396 ± 142 | 326 ± 134 | 303 ± 131 | 377 ± 140 | 293 ± 129 |
| 15-Jul | 403 ± 145 | 792 ± 186 | 418 ± 147 | 346 ± 138 | 400 ± 144 | 522 ± 158 | 326 ± 135 | 346 ± 137 | 370 ± 141 |
| 22-Jul | 414 ± 145 | 866 ± 192 | 488 ± 154 | 444 ± 149 | 485 ± 154 | 437 ± 148 | 392 ± 143 | 305 ± 132 | 374 ± 140 |
| 29-Jul | 248 ± 124 | 462 ± 152 | 316 ± 133 | 262 ± 126 | 306 ± 132 | 281 ± 128 | (b) | (b) | 239 ± 122 |
| 30-Jul | (b) | (b) | (b) | (b) | (b) | (b) | 269 ± 116 | 400 ± 132 | (b) |
| 5-Aug | 197 ± 115 | 288 ± 128 | 159 ± 110 | 183 ± 113 | 216 ± 118 | 211 ± 118 | 123 ± 117 | 140 ± 120 | 201 ± 115 |
| 12-Aug | 345 ± 137 | 610 ± 168 | 474 ± 153 | 330 ± 135 | 320 ± 134 | 365 ± 140 | 346 ± 138 | 205 ± 118 | 235 ± 122 |
| 19-Aug | (b) | 1270 ± 225 | 440 ± 148 | 474 ± 152 | 426 ± 146 | 466 ± 151 | 522 ± 157 | 507 ± 155 | 350 ± 137 |
| 20-Aug | 344 ± 124 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 26-Aug | 462 ± 147 | 892 ± 195 | (b) | 331 ± 135 | 388 ± 142 | 263 ± 126 | (b) | (b) | 312 ± 133 |
| 27-Aug | (b) | (b) | 361 ± 139 | (b) | (b) | (b) | 337 ± 125 | 324 ± 123 | (b) |
| 2-Sep | 518 ± 158 | 636 ± 168 | 381 ± 157 | 367 ± 139 | 440 ± 148 | 333 ± 135 | 411 ± 159 | 388 ± 157 | 304 ± 131 |
| 9-Sep | 304 ± 132 | 462 ± 153 | 282 ± 129 | 355 ± 138 | 331 ± 135 | 346 ± 137 | 268 ± 127 | 225 ± 121 | 297 ± 131 |
| 16-Sep | (c) | 718 ± 178 | 329 ± 135 | 312 ± 133 | 319 ± 133 | 374 ± 141 | 396 ± 192 | 279 ± 129 | 326 ± 135 |
| 21-Sep | (b) | (b) | (b) | 466 ± 186 | (b) | 392 ± 176 | 352 ± 171 | 326 ± 168 | (b) |
| 23-Sep | 437 ± 152 | 936 ± 198 | 448 ± 149 | (b) | 577 ± 164 | (b) | (b) | (b) | 574 ± 164 |
| 30-Sep | 614 ± 168 | 1070 ± 211 | 722 ± 178 | (b) | 969 ± 201 | (b) | (b) | (b) | 833 ± 189 |
| 1-Oct | (b) | (b) | (b) | 755 ± 157 | (b) | 692 ± 152 | 670 ± 141 | (b) | (b) |
| 7-Oct | 308 ± 133 | 755 ± 182 | 340 ± 137 | 411 ± 145 | 330 ± 135 | 374 ± 141 | 319 ± 147 | 518.0 ± 95.8 | 349 ± 137 |
| 14-Oct | (b) | 1490 ± 242 | 570 ± 163 | 574 ± 164 | 733 ± 179 | 603 ± 167 | (b) | 636 ± 170 | 607 ± 168 |
| 15-Oct | 551 ± 149 | (b) | (b) | (b) | (b) | (b) | 640 ± 190 | (b) | (b) |
| 21-Oct | 138 ± 118 | 511 ± 157 | 107 ± 102 | 179 ± 113 | 204 ± 117 | 194 ± 115 | 158 ± 124 | 97.7 ± 99.9 | 194 ± 114 |
| 28-Oct | 347 ± 126 | 310 ± 132 | 237 ± 122 | 319 ± 133 | 242 ± 123 | 296 ± 130 | 242 ± 123 | 305 ± 131 | 433 ± 150 |
| 4-Nov | 496 ± 174 | 422 ± 143 | 426 ± 147 | 481 ± 153 | 426 ± 147 | 429 ± 147 | 400 ± 143 | 323 ± 134 | 462 ± 151 |
| 11-Nov | 361 ± 138 | 492 ± 156 | 370 ± 140 | 340 ± 137 | 314 ± 132 | 304 ± 131 | 337 ± 135 | 232 ± 121 | 381 ± 140 |
| 18-Nov | 540 ± 161 | 636 ± 172 | 448 ± 149 | 360 ± 139 | 433 ± 148 | 297 ± 131 | 307 ± 132 | 317 ± 134 | 429 ± 148 |
| 23-Nov | 193 ± 151 | 239 ± 157 | 144 ± 142 | 151 ± 143 | 178 ± 148 | 178 ± 148 | 90 ± 132 | 124 ± 138 | 239 ± 158 |
| 2-Dec | 503 ± 133 | 847 ± 154 | 640 ± 146 | 681 ± 150 | 618 ± 144 | 607 ± 143 | 566 ± 139 | 496 ± 132 | 810 ± 161 |
| 9-Dec | 766 ± 184 | (b) | 696 ± 176 | 688 ± 176 | 833 ± 189 | 688 ± 176 | 736 ± 180 | 681 ± 175 | 1110 ± 215 |
| 16-Dec | 488 ± 155 | 1190 ± 157 | 433 ± 148 | 440 ± 149 | 722 ± 179 | 392 ± 143 | 437 ± 148 | 459 ± 151 | 947 ± 200 |
| 22-Dec | 622 ± 185 | 1010 ± 224 | 500 ± 171 | 485 ± 169 | 703 ± 194 | 466 ± 167 | 562 ± 178 | 355 ± 152 | 866 ± 210 |
| 29-Dec | 566 ± 163 | 914 ± 196 | 365 ± 138 | 518 ± 157 | 481 ± 152 | 466 ± 151 | 422 ± 145 | 470 ± 151 | 777 ± 183 |
| Detection frequency | 48 of 51 | 45 of 46 | 50 of 52 | 51 of 52 | 51 of 52 | 50 of 52 | 46 of 51 | 46 of 50 | 50 of 52 |
| Median | 336 | 488 | 370 | 334 | 335 | 330 | 323 | 320 | 316 |
| IQR[d] | 278 | 523 | 211 | 225 | 244 | 223 | 184 | 221 | 223 |
| Maximum | 1670 | 1490 | 1670 | 2290 | 1360 | 1590 | 1520 | 1490 | 1830 |

(a) See *Environmental Report 2009,* Figures 4-1, 4-2, and 4-3 for maps of sampling locations.
(b) Nonconsecutive sample dates occur when samples could not be collected on scheduled sampling date, or sampler ran longer than 1 week.
(c) Missed sample due to power (GFI) or air sampler malfunction.
(d) IQR = Interquartile range

SW-ABH3 [Bq/L] 2009 data (created 2010-07-15 08:19:45, Oracle) (epprd02.llnl.gov)

**A.3.1 Daily monitoring results for gross alpha, gross beta, and tritium in the Livermore site sanitary sewer effluent, 2009**

| Month Day | Gross alpha (Bq/L) | Gross beta (Bq/L) | Tritium (Bq/L) |
|---|---|---|---|
| Jan | | | |
| 1 | 0.1370 ± 0.0917 | 0.462 ± 0.143 | 1.90 (<9.40) |
| 2 | 0.0921 (<0.0951) | 0.206 ± 0.126 | -3.22 (<9.62) |
| 3 | 0.0825 (<0.0958) | 0.306 ± 0.132 | 0.226 (<9.36) |
| 4 | 0.0707 (<0.0940) | 0.385 ± 0.139 | -5.11 (<9.51) |
| 5 | 0.1750 ± 0.0943 | 0.338 ± 0.135 | 1.32 (<9.06) |
| 6 | 0.244 ± 0.132 | 0.866 ± 0.165 | -1.26 (<9.44) |
| 7 | 0.351 ± 0.165 | 0.936 ± 0.168 | -1.36 (<9.44) |
| 8 | 0.200 ± 0.128 | 0.699 ± 0.154 | -5.51 (<9.77) |
| 9 | 0.219 ± 0.134 | 0.799 ± 0.160 | 9.18 ± 5.60 |
| 10 | 0.167 (<0.172) | 0.684 ± 0.157 | 6.66 (<9.44) |
| 11 | 1.540 ± 0.353 | 0.507 ± 0.137 | 2.89 (<9.40) |
| 12 | 0.288 ± 0.176 | 0.829 ± 0.157 | 7.92 (<9.29) |
| 13 | 0.304 ± 0.176 | 0.796 ± 0.159 | -2.23 (<9.40) |
| 14 | 1.120 ± 0.314 | 0.655 ± 0.151 | 0.277 (<9.36) |
| 15 | 1.700 ± 0.374 | 1.040 ± 0.166 | 5.55 (<9.29) |
| 16 | 1.080 ± 0.312 | 0.910 ± 0.155 | -0.481 (<9.66) |
| 17 | 0.0847 (<0.198) | 0.566 ± 0.142 | -3.77 (<9.80) |
| 18 | 0.181 (<0.211) | 0.781 ± 0.156 | 0.907 (<9.51) |
| 19 | 0.105 (<0.196) | 0.533 ± 0.139 | 3.63 (<9.44) |
| 20 | 0.176 (<0.205) | 0.873 ± 0.157 | -4.74 (<9.88) |
| 21 | 0.0929 (<0.217) | 1.040 ± 0.167 | 4.44 (<9.62) |
| 22 | 0.148 (<0.196) | 0.955 ± 0.162 | 2.13 (<9.44) |
| 23 | 0.0221 (<0.210) | 0.947 ± 0.161 | -1.68 (<9.51) |
| 24 | 0.222 (<0.230) | 0.910 ± 0.164 | -0.840 (<9.55) |
| 25 | 0.144 (<0.223) | 0.707 ± 0.148 | -0.0858 (<9.40) |
| 26 | 0.0696 (<0.217) | 0.914 ± 0.165 | 9.55 ± 5.25 |
| 27 | 0.216 (<0.223) | 0.892 ± 0.161 | -0.655 (<9.32) |
| 28 | 0.278 ± 0.197 | 0.914 ± 0.165 | 0.588 (<9.40) |
| 29 | 0.0903 (<0.210) | 0.862 ± 0.164 | 0.977 (<9.51) |
| 30 | 0.0932 (<0.217) | 0.659 ± 0.151 | 6.40 (<9.14) |
| 31 | 0.0492 (<0.230) | 0.488 ± 0.142 | 1.67 (<9.29) |
| Feb | | | |
| 1 | 0.147 (<0.228) | 0.396 ± 0.139 | 1.78 (<9.29) |
| 2 | -0.0451 (<0.209) | 0.625 ± 0.150 | 4.11 (<9.25) |
| 3 | 0.0940 (<0.219) | 0.755 ± 0.159 | -2.62 (<9.40) |
| 4 | 0.0729 (<0.227) | 0.818 ± 0.164 | 12.50 ± 5.74 |
| 5 | 0.0947 (<0.221) | 0.610 ± 0.153 | 12.20 ± 5.74 |
| 6 | 0.0696 (<0.216) | 0.777 ± 0.163 | 15.20 ± 5.92 |
| 8 | 0.0918 (<0.171) | 0.459 ± 0.142 | -0.796 (<9.66) |
| 9 | 0.0162 (<0.151) | 0.455 ± 0.141 | 3.61 (<9.32) |
| 10 | -0.0322 (<0.149) | 0.755 ± 0.159 | 3.70 (<9.47) |
| 11 | 0.825 ± 0.231 | 0.618 ± 0.148 | 1.31 (<9.25) |
| 12 | -0.0271 (<0.124) | 0.903 ± 0.163 | 3.02 (<9.25) |
| 13 | 0.0255 (<0.120) | 0.603 ± 0.145 | -0.784 (<9.47) |
| 14 | -0.000196 (<0.111) | 0.481 ± 0.135 | -0.574 (<9.51) |
| 15 | 0.400 ± 0.144 | 0.418 ± 0.130 | 0.862 (<9.55) |
| 16 | -0.0115 (<0.105) | 0.533 ± 0.139 | 0.219 (<9.44) |
| 17 | -0.0212 (<0.0973) | 0.555 ± 0.139 | 3.04 (<9.18) |
| 18 | 0.0332 (<0.104) | 0.936 ± 0.159 | 1.87 (<9.40) |
| 19 | 0.0332 (<0.104) | 0.707 ± 0.148 | -3.81 (<9.58) |
| 20 | 0.0230 (<0.108) | 0.718 ± 0.151 | 0.462 (<9.55) |
| 21 | 0.0918 (<0.0947) | 0.474 ± 0.137 | 3.64 (<9.10) |
| 22 | 0.0385 (<0.0895) | 0.377 ± 0.128 | 4.51 (<8.99) |
| 23 | 0.1040 ± 0.0783 | 0.426 ± 0.132 | 2.26 (<9.25) |
| 24 | 0.0466 (<0.109) | 0.729 ± 0.153 | 0.336 (<9.32) |
| 25 | 0.381 ± 0.137 | 0.836 ± 0.159 | 0.353 (<9.21) |
| 26 | -0.0130 (<0.118) | 1.010 ± 0.162 | -4.18 (<9.77) |
| 27 | -0.0117 (<0.107) | 0.803 ± 0.153 | 2.53 (<9.44) |
| 28 | -0.000115 (<0.0962) | 0.566 ± 0.142 | 0.241 (<9.51) |
| Mar | | | |
| 1 | 0.0692 (<0.0918) | 0.455 ± 0.132 | -6.22 (<9.95) |
| 2 | 2.360 ± 0.330 | 0.699 ± 0.140 | 0.570 (<9.69) |
| 3 | 0.925 ± 0.213 | 0.851 ± 0.153 | 0.610 (<9.40) |
| 4 | 1.970 ± 0.296 | 0.725 ± 0.145 | -2.78 (<9.58) |
| 5 | -0.0236 (<0.109) | 0.955 ± 0.162 | -1.21 (<9.66) |

| | | | | |
|---|---|---|---|---|
| | 6 | 0.0362 (<0.113) | 0.881 ± 0.159 | 1.74 (<9.40) |
| | 7 | 1.260 ± 0.227 | 0.559 ± 0.134 | 3.48 (<9.06) |
| | 8 | 0.0199 (<0.0929) | 0.444 ± 0.133 | 1.89 (<9.44) |
| | 9 | -0.0105 (<0.0966) | 0.377 ± 0.132 | 0.792 (<9.40) |
| | 10 | 0.0599 (<0.112) | 0.673 ± 0.148 | -0.511 (<9.66) |
| | 11 | 0.0455 (<0.106) | 0.844 ± 0.160 | -2.10 (<9.62) |
| | 12 | 0.1310 ± 0.0927 | 1.350 ± 0.176 | 2.33 (<9.21) |
| | 13 | -0.0113 (<0.101) | 0.832 ± 0.158 | -5.77 (<9.77) |
| | 14 | 0.1100 ± 0.0778 | 0.603 ± 0.145 | 0.907 (<9.36) |
| | 15 | 0.496 ± 0.144 | 0.359 ± 0.126 | 2.53 (<9.69) |
| | 16 | 0.0451 (<0.105) | 0.555 ± 0.139 | 4.14 (<9.18) |
| | 17 | 0.0239 (<0.113) | 0.781 ± 0.156 | 0.403 (<9.51) |
| | 18 | 0.0684 (<0.107) | 0.807 ± 0.153 | -1.62 (<9.55) |
| | 19 | 0.0114 (<0.108) | 0.877 ± 0.158 | 3.96 (<9.25) |
| | 20 | 0.0444 (<0.104) | 0.829 ± 0.157 | 0.644 (<9.55) |
| | 21 | 0.0234 (<0.110) | 0.629 ± 0.145 | 5.44 (<9.36) |
| | 22 | -0.0102 (<0.0929) | 0.622 ± 0.143 | 4.40 (<9.51) |
| | 23 | 0.825 ± 0.182 | 0.703 ± 0.148 | 1.79 (<9.40) |
| | 24 | 0.0367 (<0.115) | 0.951 ± 0.162 | -1.49 (<9.69) |
| | 25 | -0.000299 (<0.111) | 0.858 ± 0.155 | 0.00918 (<9.32) |
| | 26 | 0.0736 (<0.115) | 1.160 ± 0.174 | -1.76 (<9.44) |
| | 27 | 0.0232 (<0.111) | 1.170 ± 0.175 | -4.92 (<9.66) |
| | 28 | 0.357 ± 0.139 | 0.929 ± 0.158 | 8.03 (<8.88) |
| | 29 | 0.388 ± 0.136 | 0.670 ± 0.147 | 6.10 (<9.36) |
| | 30 | 0.0448 (<0.105) | 0.755 ± 0.151 | 5.07 (<9.44) |
| | 31 | 0.0703 (<0.110) | 1.060 ± 0.170 | 1.39 (<9.44) |
| Apr | | | | |
| | 1 | 0.0377 (<0.118) | 0.870 ± 0.157 | 1.63 (<9.58) |
| | 2 | 2.230 ± 0.335 | 0.892 ± 0.152 | -3.59 (<9.69) |
| | 3 | 2.220 ± 0.310 | 0.662 ± 0.139 | 0.377 (<9.66) |
| | 4 | 0.0548 (<0.102) | 0.725 ± 0.152 | 2.73 (<9.25) |
| | 5 | 0.0592 (<0.0921) | 0.437 ± 0.135 | 4.55 (<9.44) |
| | 6 | 0.0403 (<0.0944) | 0.481 ± 0.135 | -1.40 (<9.69) |
| | 7 | -0.000581 ± -0.000105 | 1.010 ± 0.161 | -1.35 (<9.69) |
| | 8 | 1.210 ± 0.242 | 0.788 ± 0.150 | -2.08 (<9.14) |
| | 9 | 0.0111 (<0.108) | 0.803 ± 0.153 | 0.666 (<9.40) |
| | 10 | 0.0832 (<0.112) | 0.929 ± 0.167 | -1.91 (<9.44) |
| | 11 | 0.0101 (<0.101) | 0.696 ± 0.153 | -1.78 (<9.55) |
| | 12 | 0.0666 (<0.0892) | 0.548 ± 0.142 | 6.96 (<9.32) |
| | 13 | 0.1480 ± 0.0903 | 0.585 ± 0.140 | -3.85 (<9.73) |
| | 14 | 0.287 ± 0.118 | 0.792 ± 0.150 | 0.0725 (<9.44) |
| | 15 | 0.0581 (<0.110) | 0.951 ± 0.162 | -1.26 (<9.29) |
| | 16 | 0.0551 (<0.104) | 0.814 ± 0.155 | -0.264 (<9.51) |
| | 17 | 3.050 ± 0.366 | 0.940 ± 0.150 | -0.888 (<9.62) |
| | 18 | 0.0548 (<0.103) | 0.740 ± 0.155 | 0.128 (<8.99) |
| | 19 | 0.0433 (<0.102) | 0.596 ± 0.143 | 2.36 (<9.25) |
| | 20 | 0.0511 (<0.0962) | 0.766 ± 0.153 | -1.37 (<9.66) |
| | 21 | 0.0367 (<0.117) | 1.030 ± 0.165 | -2.37 (<9.66) |
| | 22 | 0.0858 (<0.115) | 1.050 ± 0.168 | 2.80 (<9.47) |
| | 23 | 0.0514 (<0.122) | 0.747 ± 0.149 | 0.0356 (<9.36) |
| | 24 | 0.0825 (<0.131) | 1.060 ± 0.169 | -0.633 (<9.58) |
| | 25 | 0.0570 (<0.108) | 0.629 ± 0.145 | 3.51 (<9.69) |
| | 26 | 3.510 ± 0.386 | 0.659 ± 0.132 | 1.27 (<9.40) |
| | 27 | 0.1320 ± 0.0885 | 0.688 ± 0.151 | 1.02 (<9.25) |
| | 28 | 0.0603 (<0.114) | 0.725 ± 0.152 | 35.10 ± 6.32 |
| | 29 | -0.0138 (<0.113) | 0.962 ± 0.164 | 71.80 ± 7.18 |
| | 30 | -0.0122 (<0.101) | 0.947 ± 0.161 | 0.123 (<9.58) |
| May | | | | |
| | 1 | 0.0585 (<0.111) | 0.918 ± 0.165 | 1.53 (<9.36) |
| | 2 | 0.0566 (<0.108) | 0.784 ± 0.157 | 2.06 (<9.55) |
| | 3 | 0.0607 (<0.0955) | 0.633 ± 0.146 | 1.08 (<9.58) |
| | 4 | 0.00981 (<0.0980) | 0.518 ± 0.140 | 2.43 (<9.40) |
| | 5 | 0.0481 (<0.116) | 0.999 ± 0.170 | -0.766 (<9.32) |
| | 6 | 0.577 ± 0.173 | 0.899 ± 0.162 | -7.84 (<9.84) |
| | 7 | 0.0240 (<0.117) | 1.300 ± 0.181 | -3.46 (<9.69) |
| | 8 | 0.992 ± 0.238 | 1.140 ± 0.171 | 4.74 (<9.47) |
| | 9 | 0.0359 (<0.114) | 0.818 ± 0.155 | 6.70 (<9.21) |
| | 10 | -0.0117 (<0.103) | 0.692 ± 0.152 | 0.474 (<9.44) |
| | 11 | 0.0230 (<0.110) | 0.814 ± 0.155 | -2.60 (<9.44) |
| | 12 | 0.0381 (<0.122) | 1.240 ± 0.173 | 4.22 (<9.32) |
| | 13 | 1.490 ± 0.269 | 0.921 ± 0.157 | 1.08 (<9.69) |
| | 14 | 0.0241 (<0.115) | 0.796 ± 0.151 | 2.48 (<9.55) |
| | 15 | 0.0221 (<0.106) | 0.918 ± 0.165 | -8.40 (<10.1) |

| | | | | |
|---|---|---|---|---|
| | 16 | -0.0422 (<0.0966) | 0.792 ± 0.158 | 3.96 (<9.14) |
| | 17 | 0.0100 (<0.0977) | 0.625 ± 0.144 | 0.0481 (<9.62) |
| | 18 | 2.350 ± 0.328 | 0.736 ± 0.140 | 2.82 (<9.32) |
| | 19 | 0.0640 (<0.121) | 1.040 ± 0.167 | -1.79 (<9.51) |
| | 20 | 0.0381 (<0.123) | 1.710 ± 0.206 | -4.18 (<9.58) |
| | 21 | 0.00903 (<0.107) | 1.390 ± 0.181 | -0.733 (<9.47) |
| | 22 | 0.0429 (<0.103) | 0.858 ± 0.163 | 1.79 (<9.55) |
| | 23 | 0.0944 (<0.0988) | 0.807 ± 0.153 | 4.07 (<9.40) |
| | 24 | 0.0770 (<0.0903) | 0.673 ± 0.148 | -2.06 (<9.62) |
| | 25 | 0.247 ± 0.106 | 0.744 ± 0.149 | 1.99 (<9.36) |
| | 26 | 0.1400 ± 0.0940 | 0.895 ± 0.161 | 3.24 (<9.40) |
| | 27 | 0.0522 (<0.100) | 0.980 ± 0.167 | 2.62 (<9.36) |
| | 28 | -0.00167 (<0.111) | 0.918 ± 0.165 | 0.977 (<9.58) |
| | 29 | 0.0105 (<0.117) | 1.070 ± 0.172 | -3.41 (<9.55) |
| | 30 | 0.00995 (<0.105) | 0.788 ± 0.158 | 4.51 (<9.40) |
| | 31 | 0.0536 (<0.102) | 0.770 ± 0.154 | -0.895 (<9.55) |
| Jun | | | | |
| | 1 | 0.0932 (<0.0973) | 0.488 ± 0.137 | 0.122 (<9.47) |
| | 2 | 1.550 ± 0.278 | 1.170 ± 0.175 | -6.51 (<9.80) |
| | 3 | 0.0221 (<0.110) | 0.881 ± 0.159 | -6.10 (<9.77) |
| | 4 | 0.0345 (<0.112) | 0.873 ± 0.157 | 1.35 (<9.77) |
| | 5 | 0.0459 (<0.111) | 0.881 ± 0.159 | -0.984 (<9.84) |
| | 6 | -0.0112 (<0.0940) | 0.648 ± 0.149 | -1.20 (<9.44) |
| | 7 | 0.0570 (<0.0895) | 0.507 ± 0.137 | 2.22 (<9.47) |
| | 8 | 0.0396 (<0.0947) | 0.655 ± 0.151 | -2.40 (<9.51) |
| | 9 | 0.0499 (<0.122) | 1.050 ± 0.168 | 4.70 (<9.06) |
| | 10 | -0.0363 (<0.108) | 0.773 ± 0.155 | 1.61 (<9.32) |
| | 11 | -0.0134 (<0.108) | 0.907 ± 0.163 | 0.636 (<9.51) |
| | 12 | 0.360 ± 0.141 | 0.958 ± 0.163 | -2.41 (<9.55) |
| | 13 | 0.0925 (<0.0969) | 0.799 ± 0.160 | -1.98 (<9.66) |
| | 14 | 0.0485 (<0.0921) | 0.651 ± 0.150 | -2.85 (<9.92) |
| | 15 | 0.0651 (<0.103) | 0.740 ± 0.155 | 1.51 (<9.44) |
| | 16 | -0.0129 (<0.106) | 0.792 ± 0.158 | -0.448 (<9.32) |
| | 17 | 0.0559 (<0.107) | 0.995 ± 0.169 | -2.84 (<9.58) |
| | 18 | 0.0216 (<0.111) | 1.050 ± 0.169 | 0.179 (<9.66) |
| | 19 | 0.0218 (<0.110) | 0.903 ± 0.163 | 2.48 (<9.36) |
| | 20 | 0.0292 (<0.0940) | 0.648 ± 0.149 | -0.581 (<9.51) |
| | 21 | -0.0303 (<0.0906) | 0.599 ± 0.144 | 1.25 (<9.51) |
| | 22 | 0.0429 (<0.103) | 0.736 ± 0.155 | -6.99 (<9.62) |
| | 23 | 0.00918 (<0.0988) | 0.799 ± 0.160 | 3.77 (<9.51) |
| | 24 | 0.165 ± 0.100 | 0.718 ± 0.151 | -3.60 (<9.92) |
| | 25 | -0.00159 (<0.108) | 0.799 ± 0.160 | -0.610 (<9.58) |
| | 26 | 0.0892 (<0.105) | 0.655 ± 0.151 | -0.459 (<9.66) |
| | 27 | 0.0414 (<0.0984) | 0.507 ± 0.137 | 3.77 (<9.69) |
| | 28 | 0.0407 (<0.0966) | 0.518 ± 0.140 | 1.21 (<9.47) |
| | 29 | -0.00118 (<0.104) | 0.618 ± 0.148 | 3.44 (<9.44) |
| | 30 | -0.0129 (<0.108) | 0.618 ± 0.148 | -1.71 (<9.55) |
| Jul | | | | |
| | 1 | 0.0607 (<0.117) | 0.980 ± 0.167 | -1.22 (<9.51) |
| | 2 | 0.0703 (<0.112) | 1.140 ± 0.171 | 8.10 (<9.25) |
| | 3 | 0.0551 (<0.105) | 0.703 ± 0.148 | 3.96 (<9.51) |
| | 4 | 0.0477 (<0.114) | 0.755 ± 0.151 | 3.13 (<9.40) |
| | 5 | 0.0291 (<0.0925) | 0.488 ± 0.137 | 2.20 (<9.25) |
| | 6 | 0.0202 (<0.0984) | 0.607 ± 0.146 | -5.51 (<9.77) |
| | 7 | 0.0995 (<0.118) | 0.995 ± 0.169 | -1.78 (<9.80) |
| | 8 | 0.0629 (<0.122) | 1.290 ± 0.180 | -5.44 (<9.62) |
| | 9 | -0.00166 (<0.112) | 0.877 ± 0.158 | 2.16 (<9.62) |
| | 10 | 0.0207 (<0.103) | 0.847 ± 0.161 | 0.426 (<9.44) |
| | 11 | 0.00910 (<0.0980) | 0.855 ± 0.162 | -0.500 (<9.51) |
| | 12 | 0.0302 (<0.0969) | 0.677 ± 0.149 | 1.32 (<9.44) |
| | 13 | 0.0555 (<0.105) | 0.766 ± 0.153 | -1.68 (<9.55) |
| | 14 | 0.0722 (<0.115) | 1.010 ± 0.172 | -3.16 (<9.88) |
| | 15 | 0.269 ± 0.126 | 1.040 ± 0.166 | 0.00636 (<9.66) |
| | 16 | 0.0651 (<0.123) | 2.070 ± 0.207 | 4.92 (<9.40) |
| | 17 | 0.0633 (<0.120) | 1.840 ± 0.202 | 1.92 (<9.66) |
| | 18 | -0.0266 (<0.120) | 1.320 ± 0.184 | -0.607 (<9.88) |
| | 19 | -0.0114 (<0.102) | 0.788 ± 0.158 | 3.16 (<9.32) |
| | 20 | 0.0803 (<0.107) | 0.907 ± 0.163 | -0.290 (<9.32) |
| | 21 | 0.0829 (<0.130) | 1.240 ± 0.173 | 4.33 (<9.10) |
| | 22 | 0.144 ± 0.102 | 1.320 ± 0.185 | -1.52 (<9.40) |
| | 23 | 0.0107 (<0.112) | 0.903 ± 0.163 | -1.70 (<9.58) |
| | 24 | 0.400 ± 0.148 | 0.969 ± 0.165 | -3.62 (<9.69) |
| | 25 | 0.0829 (<0.0969) | 0.629 ± 0.145 | 0.511 (<9.58) |

| | | | |
|---|---|---|---|
| 26 | 0.0710 (<0.0955) | 0.536 ± 0.139 | 0.334 (<9.25) |
| 27 | 0.0407 (<0.0962) | 0.592 ± 0.142 | 2.45 (<9.51) |
| 28 | 0.0357 (<0.115) | 1.000 ± 0.170 | 4.66 (<9.32) |
| 29 | 0.0213 (<0.105) | 0.888 ± 0.160 | -0.651 (<9.62) |
| 30 | 0.0847 (<0.113) | 0.536 ± 0.150 | -3.69 (<9.77) |
| 31 | 0.108 (<0.111) | 0.581 ± 0.151 | -0.759 (<9.36) |
| Aug | | | |
| 1 | 0.0243 (<0.114) | 0.496 ± 0.145 | 5.18 (<9.18) |
| 2 | 0.0625 (<0.116) | 0.274 ± 0.131 | -4.48 (<9.51) |
| 3 | -0.000153 (<0.0992) | 0.370 ± 0.138 | -1.75 (<9.55) |
| 4 | 0.0840 (<0.0977) | 0.618 ± 0.152 | -2.13 (<9.51) |
| 5 | 0.0374 (<0.0877) | 0.725 ± 0.157 | 4.07 (<9.32) |
| 6 | -0.0121 (<0.109) | 0.640 ± 0.154 | 1.27 (<9.40) |
| 7 | 0.0729 (<0.113) | 0.610 ± 0.152 | -2.02 (<9.66) |
| 8 | 0.0228 (<0.107) | 0.514 ± 0.146 | 1.58 (<9.44) |
| 9 | 0.0440 (<0.102) | 0.269 ± 0.131 | 2.63 (<9.32) |
| 10 | 0.0844 (<0.112) | 0.488 ± 0.145 | 2.57 (<9.36) |
| 11 | 0.0929 (<0.124) | 0.696 ± 0.156 | 3.42 (<9.44) |
| 12 | 0.0518 (<0.121) | 0.633 ± 0.153 | 5.70 (<9.06) |
| 13 | 0.0349 (<0.109) | 0.440 ± 0.142 | 2.46 (<9.77) |
| 14 | 0.0444 (<0.104) | 0.525 ± 0.148 | 2.09 (<9.58) |
| 15 | 0.0599 (<0.111) | 0.448 ± 0.143 | 2.23 (<9.69) |
| 16 | 0.0426 (<0.0995) | 0.306 ± 0.134 | 5.66 (<9.58) |
| 17 | 0.0596 (<0.111) | 0.481 ± 0.145 | -1.72 (<9.99) |
| 18 | 0.0258 (<0.121) | 0.666 ± 0.155 | 3.92 (<9.66) |
| 19 | 0.0740 (<0.115) | 0.555 ± 0.149 | 2.42 (<9.92) |
| 20 | -0.000112 (<0.0877) | 0.429 ± 0.142 | 0.328 (<10.1) |
| 21 | 0.0194 (<0.0906) | 0.514 ± 0.146 | 1.23 (<10.0) |
| 22 | -0.000102 (<0.0903) | 0.381 ± 0.139 | 2.02 (<10.2) |
| 23 | 0.0422 (<0.0980) | 0.300 ± 0.133 | 0.0148 (<10.6) |
| 24 | 0.00984 (<0.0925) | 0.437 ± 0.142 | 3.02 (<9.92) |
| 25 | -0.000199 (<0.0988) | 0.677 ± 0.156 | 3.03 (<10.1) |
| 26 | -0.000159 (<0.0932) | 0.574 ± 0.150 | 0.360 (<10.2) |
| 27 | -0.000332 (<0.107) | 0.477 ± 0.144 | -0.123 (<10.4) |
| 28 | 0.0347 (<0.0814) | 0.655 ± 0.153 | 6.51 (<9.95) |
| 29 | 0.0474 (<0.224) | 0.455 ± 0.142 | 1.39 (<10.0) |
| 30 | 0.00984 (<0.0932) | 0.328 ± 0.134 | 0.710 (<10.2) |
| 31 | 0.0551 (<0.103) | 0.361 ± 0.136 | 6.48 (<9.95) |
| Sep | | | |
| 1 | 0.129 (<0.134) | 0.618 ± 0.151 | 4.74 (<10.2) |
| 2 | 0.0581 (<0.109) | 0.625 ± 0.151 | -0.167 (<10.4) |
| 3 | 0.209 ± 0.127 | 0.881 ± 0.166 | -0.215 (<10.2) |
| 4 | 0.103 (<0.107) | 0.522 ± 0.147 | -0.999 (<10.6) |
| 5 | 0.1940 ± 0.0948 | 0.477 ± 0.143 | 0.903 (<10.4) |
| 6 | 0.1260 ± 0.0800 | 0.396 ± 0.138 | 7.47 (<10.2) |
| 7 | 0.0988 ± 0.0745 | 0.114 (<0.185) | 3.15 (<10.1) |
| 8 | 0.173 ± 0.101 | 0.522 ± 0.146 | 2.03 (<10.4) |
| 9 | 0.0784 (<0.122) | 0.636 ± 0.153 | 1.83 (<10.3) |
| 10 | -0.000906 (<0.128) | 0.792 ± 0.162 | 6.44 (<9.47) |
| 11 | 0.0536 (<0.101) | 0.932 ± 0.169 | 0.329 (<9.62) |
| 12 | 0.0810 (<0.0944) | 0.290 ± 0.132 | 1.34 (<9.77) |
| 13 | 0.0205 (<0.0966) | 0.336 ± 0.136 | 2.78 (<9.29) |
| 14 | 0.1220 ± 0.0867 | 0.648 ± 0.153 | -2.67 (<9.77) |
| 15 | 0.109 (<0.127) | 0.670 ± 0.155 | -3.14 (<9.77) |
| 16 | 0.188 ± 0.109 | 0.692 ± 0.156 | 6.18 (<9.44) |
| 17 | 0.633 ± 0.208 | 0.466 ± 0.139 | 4.29 (<9.18) |
| 18 | 0.0354 (<0.110) | 0.566 ± 0.148 | 9.10 (<9.32) |
| 19 | 0.1300 ± 0.0828 | 0.263 ± 0.128 | 11.30 ± 5.71 |
| 20 | 0.0799 (<0.0929) | 0.196 ± 0.124 | 3.03 (<9.47) |
| 21 | 0.0899 (<0.0929) | 0.337 ± 0.134 | 4.33 (<9.51) |
| 22 | 0.0940 (<0.109) | 0.462 ± 0.141 | 0.670 (<9.62) |
| 23 | 0.0426 (<0.0988) | 0.331 ± 0.134 | 5.11 (<9.69) |
| 24 | 0.108 (<0.112) | 0.433 ± 0.141 | 0.940 (<9.47) |
| 25 | -0.000121 (<0.0988) | 0.514 ± 0.146 | 1.92 (<9.47) |
| 26 | 0.0121 (<0.113) | 0.377 ± 0.138 | 7.51 (<8.99) |
| 27 | -0.0236 (<0.109) | 0.218 ± 0.128 | 8.88 (<9.06) |
| 28 | 0.1180 ± 0.0887 | 0.361 ± 0.136 | -1.92 (<9.40) |
| 29 | 0.0407 (<0.127) | 0.633 ± 0.152 | -3.65 (<9.36) |
| 30 | 0.0474 (<0.110) | 0.455 ± 0.142 | 0.150 (<9.10) |
| Oct | | | |
| 1 | 0.0570 (<0.106) | 0.518 ± 0.146 | 1.37 (<9.29) |
| 2 | 0.0377 (<0.118) | 0.610 ± 0.151 | 1.26 (<9.18) |
| 3 | 0.1020 ± 0.0773 | 0.161 (<0.184) | 3.19 (<9.03) |

| | | | | |
|---|---|---|---|---|
| | 4 | 0.0792 (<0.0921) | 0.210 ± 0.126 | 1.44 (<9.36) |
| | 5 | 0.0988 (<0.102) | 0.488 ± 0.144 | 1.59 (<9.10) |
| | 6 | 0.0825 (<0.128) | 0.877 ± 0.165 | 0.312 (<9.55) |
| | 7 | 0.134 ± 0.101 | 0.721 ± 0.157 | 0.151 (<9.25) |
| | 8 | 0.341 ± 0.146 | 0.855 ± 0.163 | 2.69 (<9.29) |
| | 9 | 0.162 ± 0.103 | 0.640 ± 0.152 | 2.81 (<9.32) |
| | 10 | 0.0944 (<0.0977) | 0.332 ± 0.134 | 3.70 (<9.14) |
| | 11 | 0.1480 ± 0.0862 | 0.369 ± 0.136 | -0.992 (<9.36) |
| | 12 | 0.182 ± 0.110 | 0.770 ± 0.159 | -1.24 (<9.40) |
| | 13 | 0.0962 (<0.0995) | 0.507 ± 0.145 | 3.31 (<9.14) |
| | 14 | 0.0429 (<0.101) | 0.640 ± 0.153 | -1.24 (<9.25) |
| | 15 | 0.0361 (<0.112) | 0.396 ± 0.139 | -5.88 (<9.69) |
| | 16 | -0.000186 (<0.0955) | 0.411 ± 0.140 | 0.936 (<9.21) |
| | 17 | 0.0773 (<0.103) | 0.350 ± 0.136 | 7.40 (<8.92) |
| | 18 | 0.0403 (<0.0940) | 0.251 ± 0.129 | 5.81 (<8.88) |
| | 19 | 0.1120 ± 0.0843 | 0.422 ± 0.140 | 7.25 (<8.95) |
| | 20 | 0.0873 (<0.117) | 0.714 ± 0.157 | -0.0662 (<9.25) |
| | 21 | 0.0514 (<0.0962) | 0.544 ± 0.148 | 2.43 (<9.14) |
| | 22 | 0.171 ± 0.102 | 0.618 ± 0.148 | 2.79 (<9.25) |
| | 23 | 0.0544 (<0.134) | 0.536 ± 0.144 | -3.85 (<9.77) |
| | 24 | 0.0984 (<0.132) | 0.326 ± 0.130 | 4.48 (<9.36) |
| | 25 | 0.118 (<0.119) | 0.243 ± 0.124 | 2.17 (<9.06) |
| | 26 | 0.0496 (<0.121) | 0.297 ± 0.128 | 2.19 (<9.18) |
| | 27 | 0.229 ± 0.126 | 0.555 ± 0.143 | 1.72 (<9.29) |
| | 28 | 0.0951 (<0.129) | 0.559 ± 0.144 | -0.799 (<9.36) |
| | 29 | 0.0796 (<0.138) | 0.374 ± 0.135 | -2.43 (<9.73) |
| | 30 | -0.00180 (<0.139) | 0.625 ± 0.150 | -0.640 (<9.44) |
| | 31 | 0.00936 (<0.122) | 0.310 ± 0.131 | -1.09 (<9.55) |
| Nov | | | | |
| | 1 | 0.0392 (<0.119) | 0.257 ± 0.127 | -0.951 (<9.66) |
| | 2 | 0.188 ± 0.112 | 0.500 ± 0.142 | 5.14 (<9.14) |
| | 3 | 0.0936 (<0.143) | 0.666 ± 0.152 | 6.18 (<8.99) |
| | 4 | 0.158 ± 0.113 | 0.803 ± 0.159 | -1.39 (<9.44) |
| | 5 | 0.0107 (<0.144) | 0.448 ± 0.140 | -0.275 (<9.73) |
| | 6 | 0.0101 (<0.137) | 0.462 ± 0.140 | -3.12 (<9.66) |
| | 7 | -0.000955 (<0.120) | 0.385 ± 0.136 | -0.895 (<9.55) |
| | 8 | 0.0194 (<0.118) | 0.131 (<0.179) | 5.59 (<9.18) |
| | 9 | 0.0216 (<0.136) | 0.385 ± 0.136 | -2.76 (<9.44) |
| | 10 | 0.0903 (<0.160) | 0.951 ± 0.167 | -1.11 (<9.44) |
| | 11 | -0.0342 (<0.132) | 0.448 ± 0.140 | 1.11 (<9.14) |
| | 12 | -0.0315 (<0.120) | 0.368 ± 0.135 | 4.51 (<9.18) |
| | 13 | 0.0955 (<0.117) | 0.369 ± 0.134 | 24.70 ± 5.98 |
| | 14 | -0.000707 (<0.115) | 0.171 (<0.179) | 11.10 ± 5.40 |
| | 15 | 0.1580 ± 0.0940 | 0.108 (<0.179) | 0.829 (<9.25) |
| | 16 | 0.0183 (<0.122) | 0.451 ± 0.140 | 6.36 (<9.14) |
| | 17 | 0.0414 (<0.130) | 0.392 ± 0.136 | 1.00 (<9.03) |
| | 18 | 0.0747 (<0.132) | 0.400 ± 0.136 | 1.38 (<9.21) |
| | 19 | -0.000744 (<0.115) | 0.179 (<0.179) | -0.699 (<9.21) |
| | 20 | -0.0101 (<0.110) | 0.236 ± 0.126 | 2.35 (<8.88) |
| | 21 | -0.0396 (<0.117) | 0.185 ± 0.123 | -1.25 (<9.10) |
| | 22 | -0.0102 (<0.114) | 0.184 ± 0.123 | 0.666 (<8.88) |
| | 23 | 0.1570 ± 0.0973 | 0.314 ± 0.130 | -2.79 (<9.03) |
| | 24 | 0.0318 (<0.139) | 0.599 ± 0.149 | 0.888 (<8.95) |
| | 25 | 0.0407 (<0.130) | 0.536 ± 0.145 | -2.87 (<9.14) |
| | 26 | -0.0385 (<0.114) | 0.192 ± 0.123 | 1.43 (<9.29) |
| | 27 | 0.00906 (<0.109) | 0.0127 (<0.178) | -5.85 (<9.66) |
| | 28 | -0.0271 (<0.108) | 0.0444 (<0.178) | 0.995 (<9.21) |
| | 29 | 0.00895 (<0.111) | 0.134 (<0.178) | -1.23 (<9.51) |
| | 30 | 0.208 ± 0.107 | 0.297 ± 0.127 | 2.32 (<9.29) |
| Dec | | | | |
| | 1 | 0.353 ± 0.135 | 0.536 ± 0.142 | -2.65 (<9.44) |
| | 2 | 0.00892 (<0.117) | 0.433 ± 0.138 | 5.51 (<8.70) |
| | 3 | 0.0324 (<0.134) | 0.448 ± 0.138 | 0.351 (<9.29) |
| | 4 | 0.0104 (<0.147) | 0.718 ± 0.153 | 1.26 (<9.29) |
| | 5 | -0.0414 (<0.122) | 0.311 ± 0.130 | 2.69 (<9.47) |
| | 6 | -0.00973 (<0.114) | 0.0992 (<0.177) | -1.20 (<9.62) |
| | 7 | 0.0914 (<0.123) | 0.422 ± 0.135 | 5.48 (<9.29) |
| | 8 | -0.0144 (<0.151) | 0.677 ± 0.151 | 4.00 (<9.06) |
| | 9 | 0.0703 (<0.144) | 0.636 ± 0.149 | -2.32 (<9.40) |
| | 10 | 0.0339 (<0.141) | 0.581 ± 0.146 | 3.06 (<9.10) |
| | 11 | 0.0339 (<0.142) | 0.644 ± 0.149 | -1.13 (<9.10) |
| | 12 | 0.00929 (<0.122) | 0.392 ± 0.135 | 1.44 (<9.29) |
| | 13 | -0.0286 (<0.114) | 0.130 (<0.177) | -3.29 (<9.44) |

| | | | |
|---|---|---|---|
| 14 | 0.0788 (<0.120) | 0.252 ± 0.125 | 0.279 (<9.47) |
| 15 | -0.0511 (<0.148) | 0.625 ± 0.148 | 1.99 (<9.40) |
| 16 | 0.0440 (<0.135) | 0.422 ± 0.136 | 2.58 (<9.29) |
| 17 | 0.0189 (<0.121) | 0.503 ± 0.142 | 0.492 (<8.81) |
| 18 | 0.0481 (<0.120) | 0.673 ± 0.151 | -6.55 (<9.44) |
| 19 | 0.0459 (<0.112) | 0.306 ± 0.129 | 0.888 (<9.36) |
| 20 | 0.1690 ± 0.0965 | 0.367 ± 0.132 | 3.52 (<9.18) |
| 21 | 0.0499 (<0.122) | 0.345 ± 0.132 | 1.19 (<9.73) |
| 22 | 0.0862 (<0.117) | 0.555 ± 0.144 | 7.07 (<8.88) |
| 23 | 0.1310 ± 0.0942 | 0.588 ± 0.146 | 9.10 ± 5.27 |
| 24 | 0.300 ± 0.186 | 0.629 ± 0.148 | 7.99 (<9.03) |
| 25 | 1.070 ± 0.362 | 0.536 ± 0.142 | 6.22 (<9.10) |
| 26 | 0.614 ± 0.283 | 0.633 ± 0.149 | 11.00 ± 5.45 |
| 27 | 0.361 ± 0.224 | 0.403 ± 0.135 | 2.26 (<9.29) |
| 28 | 0.183 (<0.278) | 0.481 ± 0.140 | 5.03 (<9.18) |
| 29 | 0.349 ± 0.238 | 0.648 ± 0.150 | 4.00 (<8.92) |
| 30 | 0.370 ± 0.252 | 0.636 ± 0.150 | -3.36 (<9.25) |
| 31 | 0.681 ± 0.332 | 0.666 ± 0.151 | 7.29 (<8.73) |

Note: The activities shown in this table are measured concentrations and their associated 2$\sigma$ counting errors. Mininum detectable concentration (MDC) is shown in parentheses when calculated concentration is less than the MDC.

SW-FLOW [ML] 2009 data (created 2010-03-12 16:30:06, Oracle) (epprd02.llnl.gov)

**A.3.2 Daily flow totals for Livermore site sanitary sewer effluent (ML), 2009**

| Day | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.41 | 1.135 | 0.57 | 0.951 | 0.905 | 1.059 | 1.054 | 0.485 | 1.002 | 1.108 | 0.581 | 0.952 |
| 2 | 0.393 | 1.649 | 1.116 | 0.948 | 0.468 | 0.916 | 0.829 | 0.522 | 0.979 | 0.869 | 1.152 | 1.158 |
| 3 | 0.406 | 1.589 | 1.422 | 0.818 | 0.486 | 0.879 | 0.501 | 1.005 | 0.941 | 0.572 | 1.029 | 0.989 |
| 4 | 0.411 | 1.675 | 1.153 | 0.393 | 1.029 | 0.956 | 0.451 | 0.959 | 0.957 | 0.584 | 1.032 | 0.839 |
| 5 | 0.888 | 1.65 | 0.936 | 0.433 | 1.081 | 0.96 | 0.493 | 1.041 | 0.52 | 1.112 | 1.099 | 0.566 |
| 6 | 0.971 | 1.33 | 0.865 | 0.89 | 1.051 | 0.452 | 1.04 | 1.106 | 0.537 | 0.97 | 0.928 | 0.555 |
| 7 | 0.987 | 0.592 | 0.477 | 0.967 | 1.01 | 0.452 | 0.884 | 0.751 | 0.619 | 1.041 | 0.644 | 1.055 |
| 8 | 1.01 | 0.593 | 0.467 | 1.042 | 0.825 | 0.962 | 0.918 | 0.403 | 1.001 | 1.057 | 0.647 | 1.03 |
| 9 | 1.122 | 1.238 | 0.943 | 0.938 | 0.473 | 1.029 | 0.831 | 0.457 | 0.958 | 0.853 | 1.066 | 1.008 |
| 10 | 0.721 | 1.146 | 1.007 | 0.835 | 0.545 | 0.943 | 0.821 | 0.96 | 1.097 | 0.544 | 1.056 | 1.004 |
| 11 | 0.827 | 1.085 | 0.924 | 0.466 | 1.029 | 0.902 | 0.339 | 1.003 | 0.998 | 0.574 | 1.035 | 1.005 |
| 12 | 1.557 | 1.029 | 1.066 | 0.459 | 0.899 | 0.851 | 0.358 | 1.217 | 0.604 | 1.137 | 1.183 | 0.535 |
| 13 | 1.63 | 0.995 | 0.919 | 0.558 | 0.991 | 0.438 | 0.863 | 1.02 | 0.532 | 1.521 | 1.075 | 0.559 |
| 14 | 1.733 | 0.568 | 0.493 | 0.921 | 1.087 | 0.346 | 0.895 | 0.99 | 1.036 | 1.212 | 0.512 | 1.016 |
| 15 | 1.494 | 0.537 | 0.515 | 1.003 | 0.955 | 0.947 | 0.947 | 0.517 | 1.146 | 1.382 | 0.561 | 1.162 |
| 16 | 1.468 | 0.58 | 0.947 | 0.948 | 0.447 | 0.903 | 0.967 | 0.418 | 1.211 | 1.093 | 1.121 | 1.03 |
| 17 | 0.863 | 1.277 | 0.942 | 0.862 | 0.399 | 0.932 | 0.778 | 0.933 | 1.31 | 0.663 | 1.065 | 0.996 |
| 18 | 0.952 | 1.024 | 0.994 | 0.487 | 0.862 | 0.991 | 0.427 | 0.983 | 0.989 | 0.682 | 1.041 | 0.907 |
| 19 | 0.987 | 0.975 | 0.953 | 0.615 | 0.951 | 0.849 | 0.436 | 1.051 | 0.706 | 1.27 | 2.472 | 0.526 |
| 20 | 1.642 | 1.03 | 0.965 | 1.126 | 1 | 0.507 | 0.95 | 1.03 | 0.723 | 1.137 | 2.032 | 0.505 |
| 21 | 1.692 | 0.56 | 0.563 | 1.022 | 1.061 | 0.561 | 0.989 | 0.907 | 1.201 | 1.231 | 0.563 | 1.059 |
| 22 | 2.026 | 0.556 | 0.54 | 1.041 | 0.819 | 1.018 | 0.966 | 0.427 | 1.272 | 1.135 | 0.565 | 0.96 |
| 23 | 1.663 | 1.097 | 1.002 | 1.02 | 0.435 | 0.921 | 0.944 | 0.522 | 1.235 | 0.98 | 1.1 | 0.953 |
| 24 | 1.086 | 1.151 | 1.004 | 0.958 | 0.509 | 0.943 | 0.874 | 0.939 | 1.242 | 0.625 | 0.985 | 0.855 |
| 25 | 0.967 | 1.029 | 0.955 | 0.618 | 0.659 | 0.871 | 0.489 | 0.95 | 0.902 | 0.617 | 0.846 | 1.129 |
| 26 | 1.498 | 1.07 | 0.911 | 0.407 | 1.095 | 0.667 | 0.518 | 1.01 | 0.627 | 1.124 | 0.521 | 1.006 |
| 27 | 1.593 | 0.923 | 0.806 | 1.01 | 1.041 | 0.385 | 1.04 | 1.1 | 0.628 | 1.064 | 0.499 | 0.965 |
| 28 | 1.51 | 0.556 | 0.438 | 1.017 | 0.949 | 0.473 | 0.957 | 0.923 | 1.149 | 1.14 | 0.501 | 1.603 |
| 29 | 1.491 | - | 0.418 | 0.924 | 0.97 | 0.895 | 1.04 | 0.601 | 1.166 | 1.08 | 0.531 | 1.71 |
| 30 | 1.498 | - | 0.967 | 1.098 | 0.737 | 0.979 | 1.111 | 0.615 | 1.172 | 0.956 | 1.061 | 1.625 |
| 31 | 0.92 | - | 0.932 | - | 0.79 | - | 0.895 | 1.096 | - | 0.569 | - | 1.154 |

Weekend and holiday daily flow totals are shown in the shaded areas. The daily sample flow volume is for the 24 hours of the sampling day.

SW-FLOWSUM [ML] 2009 data (created 2010-03-12 16:30:09, Oracle) (epprd02.llnl.gov)

**A.3.3 Monthly and annual flow summary statistics for Livermore site sanitary sewer effluent (ML), 2009**

| Period<br>Statistic | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weekends & Holidays | | | | | | | | | | | | | |
| Total | 10.14 | 6.554 | 5.526 | 5.437 | 7.034 | 5.109 | 5.575 | 6.004 | 6.303 | 7.724 | 6.754 | 6.513 | 78.673 |
| Minimum | 0.393 | 0.556 | 0.438 | 0.393 | 0.435 | 0.385 | 0.339 | 0.403 | 0.52 | 0.544 | 0.499 | 0.526 | 0.339 |
| Maximum | 1.663 | 1.33 | 0.965 | 0.958 | 0.97 | 0.96 | 0.895 | 0.99 | 0.998 | 1.093 | 2.032 | 1.129 | 2.032 |
| Mean | 1.014 | 0.819 | 0.691 | 0.68 | 0.703 | 0.639 | 0.619 | 0.667 | 0.788 | 0.772 | 0.844 | 0.814 | 0.756 |
| Weekdays | | | | | | | | | | | | | |
| Total | 26.276 | 22.085 | 20.684 | 19.338 | 18.524 | 18.878 | 19.03 | 19.937 | 22.157 | 22.178 | 21.749 | 23.903 | 254.739 |
| Minimum | 0.41 | 0.537 | 0.418 | 0.407 | 0.399 | 0.346 | 0.358 | 0.418 | 0.532 | 0.574 | 0.521 | 0.505 | 0.346 |
| Maximum | 2.026 | 1.675 | 1.422 | 1.126 | 1.095 | 1.059 | 1.111 | 1.217 | 1.31 | 1.521 | 2.472 | 1.71 | 2.472 |
| Mean | 1.251 | 1.104 | 0.899 | 0.879 | 0.882 | 0.858 | 0.865 | 0.906 | 1.007 | 1.056 | 0.989 | 1.039 | 0.976 |
| All days | | | | | | | | | | | | | |
| Total | 36.416 | 28.639 | 26.21 | 24.775 | 25.558 | 23.987 | 24.605 | 25.941 | 28.46 | 29.902 | 28.503 | 30.416 | 333.412 |
| Minimum | 0.393 | 0.537 | 0.418 | 0.393 | 0.399 | 0.346 | 0.339 | 0.403 | 0.52 | 0.544 | 0.499 | 0.505 | 0.339 |
| Maximum | 2.026 | 1.675 | 1.422 | 1.126 | 1.095 | 1.059 | 1.111 | 1.217 | 1.31 | 1.521 | 2.472 | 1.71 | 2.472 |
| Mean | 1.175 | 1.023 | 0.845 | 0.826 | 0.824 | 0.8 | 0.794 | 0.837 | 0.949 | 0.965 | 0.95 | 0.981 | 0.913 |

SW-MONMET [mg/L]   2009 data    (created 2010-04-14 09:40:41, Oracle) (epprd02.llnl.gov)

**A.3.4 Monthly 24-hour composite results for metals in Livermore site sanitary sewer effluent, 2009**

| Composite dates | Ag | Al | As | Be | Cd | Cr | Cu | Fe | Hg | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-Jan | <0.01 | 0.1 | 0.004 | <0.001 | <0.005 | <0.01 | 0.051 | 0.47 | <0.0002 | <0.005 | <0.002 | 0.091 |
| 4-Feb | <0.01 | 0.074 | 0.0024 | <0.01 | <0.005 | <0.01 | 0.027 | 0.32 | <0.0002 | <0.005 | <0.002 | 0.073 |
| 4-Mar | <0.01 | 0.38 | 0.0035 | <0.01 | <0.005 | <0.01 | 0.037 | 0.87 | <0.0002 | <0.005 | <0.002 | 0.12 |
| 8-Apr | <0.01 | 0.091 | <0.002 | <0.01 | <0.005 | <0.01 | 0.028 | 0.49 | <0.0002 | <0.005 | <0.002 | 0.086 |
| 6-May | <0.01 | 0.18 | 0.004 | <0.01 | <0.005 | <0.01 | 0.11 | 0.48 | <0.0002 | <0.005 | 0.022 | 0.12 |
| 3-Jun | <0.01 | 0.17 | 0.0087 | <0.01 | <0.005 | <0.01 | 0.056 | 0.67 | <0.0002 | <0.005 | 0.0022 | 0.12 |
| 8-Jul | <0.01 | 0.11 | 0.0036 | <0.01 | <0.005 | <0.01 | 0.052 | 0.47 | <0.0002 | <0.005 | 0.0025 | 0.082 |
| 11-Aug | <0.01 | 0.11 | 0.0032 | <0.01 | <0.005 | <0.01 | 0.047 | 0.51 | <0.0002 | <0.005 | 0.0024 | 0.07 |
| 9-Sep | <0.01 | 0.17 | 0.0046 | <0.01 | <0.005 | <0.01 | 0.056 | 0.69 | <0.0002 | <0.005 | 0.013 | 0.074 |
| 7-Oct | <0.01 | 0.19 | 0.0024 | <0.01 | <0.005 | <0.01 | 0.029 | 1.1 | <0.0002 | <0.005 | 0.0034 | 0.12 |
| 10-Nov | <0.01 | 0.13 | 0.0023 | <0.01 | <0.005 | <0.01 | 0.043 | 0.53 | <0.0002 | <0.005 | 0.0022 | 0.091 |
| 9-Dec | <0.01 | 0.15 | 0.0022 | <0.01 | <0.005 | <0.01 | 0.028 | 0.58 | <0.0002 | <0.005 | <0.002 | 0.086 |
| Detection frequency | 0 of 12 | 12 of 12 | 11 of 12 | 0 of 12 | 0 of 12 | 0 of 12 | 12 of 12 | 12 of 12 | 0 of 12 | 0 of 12 | 7 of 12 | 12 of 12 |
| Minimum | <0.01 | 0.074 | <0.002 | <0.001 | <0.005 | <0.01 | 0.027 | 0.32 | <0.0002 | <0.005 | <0.002 | 0.07 |
| Maximum | <0.01 | 0.38 | 0.0087 | <0.01 | <0.005 | <0.01 | 0.11 | 1.1 | <0.0002 | <0.005 | 0.022 | 0.12 |
| Median | (a) | 0.14 | 0.0034 | (a) | (a) | (a) | 0.045 | 0.52 | (a) | (a) | <0.0022 | 0.088 |
| IQR[(b)] | (a) | 0.065 | 0.0016 | (a) | (a) | (a) | 0.024 | 0.2 | (a) | (a) | (c) | 0.04 |
| EPL[(d)] | 0.2 | (e) | 0.06 | (e) | 0.14 | 0.62 | 1 | (e) | 0.01 | 0.61 | 0.2 | 3 |
| Maximum Percent of EPL | <5.0 | (e) | 14 | (e) | <3.6 | <1.6 | 11 | (e) | <2.0 | <0.82 | 11 | 4 |

(a)  Not applicable because there are no detections. See *Environmental Report 2009*, Chapter 9.
(b)  IQR = interquartile range
(c)  Not applicable because of the large number of nondetections. See *Environmental Report 2009*, Chapter 9.
(d)  EPL = Effluent pollutant limit
(e)  There is no EPL for this parameter; therefore, no comparison can be calculated.

SW-PHYSCHEM [mg/L; ug/L] 2009 data (created 2010-04-14 09:41:33, Oracle) (epprd02.llnl.gov)

**A.3.5 Monthly monitoring results for physical and chemical characteristics of the Livermore site sanitary sewer effluent, 2009**

| Sample type<br>Analyte type | Analyte | EPA Method | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24-hour composite sample | | | | | | | | | | | | | | |
| Alkalinity (mg/L) | Bicarbonate Alk (as CaCO3) | 310.1 | 310 | 290 | 180 | 250 | 240 | 250 | 240 | 220 | 230 | 230 | 200 | 230 |
| | Carbonate Alk (as CaCO3) | 310.1 | <4.1 | <8.2 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 |
| | Hydroxide Alk (as CaCO3) | 310.1 | <4.1 | <8.2 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 | <4.1 |
| | Total Alkalinity (as CaCO3) | Calc | 310 | 290 | 180 | 250 | 240 | 250 | 240 | 220 | 230 | 230 | 200 | 230 |
| Anions (mg/L) | Bromide | 300 | 0.51 | 0.64 | 0.18 | <0.1 | 0.56 | <0.1 | 0.52 | 1.3 | 0.59 | 0.31 | 0.96 | 0.31 |
| | Chloride | 300 | 90 | 340 | 41 | 65 | 61 | 61 | 59 | 61 | 68 | 51 | 49 | 52 |
| | Fluoride | 300 | 0.078 | 0.37 | <0.05 | <0.05 | 0.096 | 0.059 | 0.58 | 0.11 | 0.66 | <0.05 | 0.079 | 0.93 |
| | Nitrate (as N) | 300 | <0.1 | <0.2 | <0.1 | <0.1 | <0.1 | 0.11 | 0.17 | <0.1 | <0.1 | <0.1 | <0.5 | <0.1 |
| | Nitrate (as NO3) | Calc | <0.5 | 0.63 | <0.44 | <0.5 | <0.5 | <0.5 | 0.74 | <0.5 | <0.44 | <0.5 | <0.5 | <0.5 |
| | Nitrite (as N) | 353.2 | <0.5 | <0.05 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.05 | <0.05 | <0.5 | <0.5 | <0.5 |
| | Nitrite (as NO2) | Calc | <0.5 | <0.17 | 0.64 | <0.5 | <0.5 | <0.5 | <0.17 | <0.5 | <0.17 | <0.5 | <0.5 | <0.5 |
| | Ortho-Phosphate | 365.1 | 15 | 9.1 | 3.8 | 16 | 15 | 16 | 16 | 15 | 16 | 15 | 13 | 15 |
| | Sulfate | 300 | 26 | 90 | 12 | 12 | 10 | 14 | 8.9 | 8.8 | 11 | 9.8 | 7.6 | 8.7 |
| Nutrients (mg/L) | Ammonia Nitrogen (as N) | 350.1 | 61 | 35 | 37 | 57 | 56 | 60 | 58 | 49 | 51 | 53 | 47 | 55 |
| | Total Kjeldahl Nitrogen | 351.2 | 64 | 38 | 40 | 61 | 60 | 65 | 60 | 57 | 59 | 61 | 57 | 58 |
| | Total Organic Carbon (TOC) | 415.1 | 29 | 21 | 16 | 34 | 28 | 32 | 27 | 31 | 12 | 32 | 29 | 30 |
| | Total Phosphorus (as P) | 365.4 | 7.7 | 4.3 | 4.8 | 8 | 6.7 | 7.3 | 7.1 | 6.8 | 7.1 | 7.4 | 6.2 | 7.5 |
| Oxygen demand (mg/L) | Biochemical Oxygen Demand | SM17-5210B | 95 | 59 | 66 | 77 | 92 | 90 | 82 | 74 | 88 | 140 | 85 | 80 |
| | Chemical Oxygen Demand | 410.4 | 200 | 140 | 160 | 200 | 190 | 250 | 200 | 190 | 220 | 270 | 200 | 200 |
| Solids (mg/L) | Settleable Solids | 160.5 | <0.1 | <0.1 | <0.1 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.1 |
| | Total dissolved solids (TDS) | 160.1 | 280 | 890 | 190 | 250 | 210 | 580 | 260 | 270 | 300 | 210 | 230 | 200 |
| | Total suspended solids (TSS) | 160.2 | 72 | 38 | 64 | 63 | 73 | 72 | 66 | 56 | 84 | 84 | 61 | 73 |
| | Volatile Solids | 160.4 | 180 | 200 | 90 | 170 | 200 | 280 | 170 | 120 | 97 | 310 | 190 | 220 |
| Total metals (mg/L) | Aluminum | 200.7 | 0.1 | 0.074 | 0.38 | 0.091 | 0.18 | 0.17 | 0.11 | 0.11 | 0.17 | 0.19 | 0.13 | 0.15 |
| | Arsenic | 200.8 | 0.004 | 0.0024 | 0.0035 | <0.002 | 0.004 | 0.0087 | 0.0036 | 0.0032 | 0.0046 | 0.0024 | 0.0023 | 0.0022 |
| | Beryllium | 200.8 | <0.001 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | Cadmium | 200.8 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| | Calcium | 200.7 | 29 | 57 | 11 | 14 | 11 | 13 | 12 | 14 | 16 | 13 | 12 | 12 |
| | Chromium | 200.7 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | Copper | 200.8 | 0.051 | 0.027 | 0.037 | 0.028 | 0.11 | 0.056 | 0.052 | 0.047 | 0.056 | 0.029 | 0.043 | 0.028 |
| | Iron | 200.7 | 0.47 | 0.32 | 0.87 | 0.49 | 0.48 | 0.67 | 0.47 | 0.51 | 0.69 | 1.1 | 0.53 | 0.58 |
| | Lead | 200.8 | <0.002 | <0.002 | <0.002 | <0.002 | 0.022 | 0.0022 | 0.0025 | 0.0024 | 0.013 | 0.0034 | 0.0022 | <0.002 |
| | Magnesium | 200.7 | 8.1 | 34 | 3.2 | 3.7 | 2.8 | 2.9 | 2.5 | 2.4 | 2.7 | 2.2 | 2.1 | 2.4 |
| | Mercury | 245.1 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| | Nickel | 200.8 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| | Potassium | 200.7 | 26 | 23 | 16 | 26 | 22 | 25 | 23 | 20 | 22 | 22 | 18 | 22 |
| | Selenium | 200.8 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0032 | <0.002 | <0.002 | 0.0024 | <0.002 |
| | Silver | 200.7 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | Sodium | 200.7 | 70 | 220 | 34 | 55 | 44 | 49 | 44 | 47 | 51 | 42 | 33 | 38 |
| | Zinc | 200.7 | 0.091 | 0.073 | 0.12 | 0.086 | 0.12 | 0.12 | 0.082 | 0.07 | 0.074 | 0.12 | 0.091 | 0.086 |
| Grab sample | | | | | | | | | | | | | | |
| Total oil and grease (mg/L) | Oil and Grease - 07:01 AM | 1664HEM | 13 | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) |
| | Oil and Grease - 07:07 AM | 1664HEM | (a) | (a) | (a) | (a) | (a) | (a) | 23 | (a) | (a) | (a) | (a) | (a) |
| | Oil and Grease - 09:01 AM | 1664HEM | <5 | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) |
| | Oil and Grease - 10:07 AM | 1664HEM | (a) | (a) | (a) | (a) | (a) | (a) | 25 | (a) | (a) | (a) | (a) | (a) |
| | Oil and Grease - 01:01 PM | 1664HEM | 26 | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) |
| | Oil and Grease - 02:07 PM | 1664HEM | (a) | (a) | (a) | (a) | (a) | (a) | 38 | (a) | (a) | (a) | (a) | (a) |
| | Oil and Grease - 03:01 PM | 1664HEM | 8.5 | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) |
| | Oil and Grease - 03:07 PM | 1664HEM | (a) | (a) | (a) | (a) | (a) | (a) | 19 | (a) | (a) | (a) | (a) | (a) |
| Volatile organic compounds (µg/L) | 1,1,1-Trichloroethane | 624 | <1 | <1 | <1 | <1 | < 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1,1,2,2-Tetrachloroethane | 624 | <1 | <1 | <1 | <1 | < 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | 1,1,2-Trichloroethane | 624 | <1 | <1 | <1 | <1 | < 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,1-Dichloroethane | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 1,1-Dichloroethene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 1,2-Dichlorobenzene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 1,2-Dichloroethane | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 1,2-Dichloroethene (total) | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 1,2-Dichloropropane | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 1,3-Dichlorobenzene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 1,4-Dichlorobenzene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| 2-Butanone | 624 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 |
| 2-Chloroethylvinylether | 624 | <20 | <20 | <20 | <20 | <20 | (b) | <20 | <20 | <20 | <20 | <20 | <20 |
| 2-Hexanone | 624 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 |
| 4-Methyl-2-pentanone | 624 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 |
| Acetone | 624 | 380 | 400 | 390 | 340 | 340 | 190 | 140 | 83 | 82 | 47 | 540 | 110 |
| Benzene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Bromodichloromethane | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Bromoform | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Bromomethane | 624 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Carbon disulfide | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbon tetrachloride | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Chlorobenzene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Chloroethane | 624 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Chloroform | 624 | 1.9 | <1 | 6.7 | 2.5 | 1.2 | 2.4 | 6.9 | 2 | 5.7 | 4.6 | 5.9 | 3.4 |
| Chloromethane | 624 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Dibromochloromethane | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Dibromomethane | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Dichlorodifluoromethane | 624 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Ethylbenzene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Freon 113 | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Methylene chloride | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Styrene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Tetrachloroethene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Toluene | 624 | <1 | <1 | <1 | <1 | 1.9 | <1 | <1 | <1 | <1 | 9.1 | 3.9 | <1 |
| Total xylene isomers | 624 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Trichloroethene | 624 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Trichlorofluoromethane | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Vinyl acetate | 624 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 |
| Vinyl chloride | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| cis-1,2-Dichloroethene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| cis-1,3-Dichloropropene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| trans-1,2-Dichloroethene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| trans-1,3-Dichloropropene | 624 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |

(a) The requirement to sample for oil & grease has been suspended until further notice based on the LWRP letter of April 1, 1999. LLNL collects these samples semiannually as part of the source control program.
(b) Reported value was <20 µg/L. Data rejected due to low recovery on QA sample.

SW-MONH3 [Bq/L]   2009 data    (created 2010-03-23 07:14:29, Oracle) (epprd02.llnl.gov)

**A.3.6 Monthly composite results for tritium for the Livermore site and LWRP effulent, 2009**

| Month | Tritium (Bq/L) B196 | Tritium (Bq/L) LWRP |
|---|---|---|
| Jan | 2.29 ± 1.57 | 1.89 ± 1.54 |
| Feb | 2.67 ± 1.69 | 0.87 ± 1.63 |
| Mar | 1.15 ± 2.24 | 1.12 ± 2.23 |
| Apr | 5.36 ± 2.02 | 0.14 ± 1.78 |
| May | 2.53 ± 1.53 | 2.16 ± 1.51 |
| Jun | 1.61 ± 1.49 | 0.21 ± 1.44 |
| Jul | 0.7210 ± 0.0136 | -0.57 ± 1.30 |
| Aug | 4.22 ± 1.53 | -0.15 ± 1.32 |
| Sep | 3.03 ± 2.21 | 0.48 ± 2.16 |
| Oct | 3.92 ± 1.49 | 0.63 ± 1.36 |
| Nov | 4.29 ± 2.04 | 3.48 ± 2.01 |
| Dec | 4.22 ± 2.06 | 0.32 ± 1.96 |

Note: The activities shown in this table are measured concentrations and their associated 2σ counting errors.

**A.3.7 Weekly composite metals in Livermore site sanitary sewer effluent, 2009**

| Composite dates[a] | Ag | As | Cd | Cr | Cu | Hg | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|
| 7-Jan | <0.01 | 0.0028 | <0.005 | <0.01 | 0.033 | <0.0002 | <0.005 | <0.002 | 0.077 |
| 14-Jan | <0.01 | 0.015 | <0.005 | <0.01 | 0.028 | <0.0002 | <0.005 | <0.002 | <0.05 |
| 21-Jan | <0.01 | 0.0049 | <0.005 | <0.01 | 0.018 | <0.0002 | <0.005 | <0.002 | <0.05 |
| 28-Jan | <0.01 | 0.0076 | <0.005 | <0.01 | 0.021 | <0.0002 | <0.005 | <0.002 | <0.05 |
| 4-Feb | <0.01 | 0.0041 | <0.005 | <0.01 | 0.023 | <0.0002 | <0.005 | <0.002 | <0.05 |
| 11-Feb | <0.01 | 0.0042 | <0.005 | <0.01 | 0.019 | <0.0002 | <0.005 | <0.002 | 0.058 |
| 18-Feb | <0.01 | 0.0023 | <0.005 | <0.01 | 0.022 | <0.0002 | <0.005 | <0.002 | 0.057 |
| 25-Feb | <0.01 | 0.0027 | <0.005 | <0.01 | 0.027 | <0.0002 | <0.005 | <0.002 | 0.068 |
| 4-Mar | <0.01 | 0.0027 | <0.005 | <0.01 | 0.028 | <0.0002 | <0.005 | <0.002 | 0.074 |
| 11-Mar | <0.01 | <0.002 | <0.005 | <0.01 | 0.021 | <0.0002 | <0.005 | <0.002 | 0.058 |
| 18-Mar | <0.01 | <0.002 | <0.005 | <0.01 | 0.023 | <0.0002 | <0.005 | <0.002 | 0.059 |
| 25-Mar | <0.01 | 0.003 | <0.005 | <0.01 | 0.029 | <0.0002 | <0.005 | <0.002 | 0.062 |
| 1-Apr | <0.01 | <0.002 | <0.005 | <0.01 | 0.024 | <0.0002 | <0.005 | <0.002 | <0.05 |
| 8-Apr | <0.01 | 0.0023 | <0.005 | <0.01 | 0.026 | <0.0002 | <0.005 | <0.002 | 0.063 |
| 15-Apr | <0.01 | <0.002 | <0.005 | <0.01 | 0.026 | <0.0002 | <0.005 | <0.002 | 0.068 |
| 22-Apr | <0.01 | 0.0023 | <0.005 | <0.01 | 0.027 | <0.0002 | <0.005 | <0.002 | 0.076 |
| 29-Apr | <0.01 | 0.0035 | <0.005 | <0.01 | 0.026 | <0.0002 | <0.005 | <0.002 | 0.064 |
| 6-May | <0.01 | 0.0026 | <0.005 | <0.01 | 0.069 | <0.0002 | <0.005 | 0.012 | 0.097 |
| 13-May | <0.01 | 0.0032 | <0.005 | <0.01 | 0.029 | <0.0002 | <0.005 | 0.0027 | 0.075 |
| 20-May | <0.01 | 0.0032 | <0.005 | <0.01 | 0.035 | <0.0002 | 0.0054 | 0.0052 | 0.13 |
| 27-May | <0.01 | 0.0023 | <0.005 | <0.01 | 0.029 | <0.0002 | <0.005 | <0.002 | 0.052 |
| 3-Jun | <0.01 | 0.0035 | <0.005 | <0.01 | 0.039 | <0.0002 | <0.005 | 0.002 | 0.073 |
| 10-Jun | <0.01 | 0.003 | <0.005 | <0.01 | 0.027 | <0.0002 | <0.005 | <0.002 | 0.058 |
| 17-Jun | <0.01 | 0.04 | <0.005 | <0.01 | <0.01 | <0.0002 | 0.01 | 0.0035 | 0.078 |
| 24-Jun | <0.01 | 0.0032 | <0.005 | <0.01 | 0.047 | <0.0002 | <0.005 | 0.0049 | 0.062 |
| 1-Jul | <0.01 | 0.0029 | <0.005 | <0.01 | 0.074 | <0.0002 | <0.005 | 0.004 | 0.08 |
| 8-Jul | <0.01 | 0.0027 | <0.005 | <0.01 | 0.039 | <0.0002 | <0.005 | 0.0024 | <0.05 |
| 15-Jul | <0.01 | 0.0032 | <0.005 | <0.01 | 0.03 | <0.0002 | <0.005 | <0.002 | 0.052 |
| 22-Jul | <0.01 | 0.0082 | <0.005 | <0.01 | 0.04 | <0.0002 | <0.005 | <0.002 | <0.05 |
| 29-Jul | <0.01 | 0.0034 | <0.005 | <0.01 | 0.068 | <0.0002 | <0.005 | 0.0049 | 0.084 |
| 5-Aug | <0.01 | 0.0029 | <0.005 | <0.01 | 0.053 | <0.0002 | <0.005 | 0.0058 | 0.068 |
| 12-Aug | <0.01 | 0.0024 | <0.005 | <0.01 | 0.046 | <0.0002 | <0.005 | 0.0043 | 0.055 |
| 19-Aug | <0.01 | 0.002 | <0.005 | <0.01 | 0.038 | <0.0002 | <0.005 | 0.0031 | 0.054 |
| 26-Aug | <0.01 | 0.0045 | <0.005 | <0.01 | 0.048 | <0.0002 | <0.005 | 0.0037 | 0.066 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2-Sep | <0.01 | 0.0033 | <0.005 | <0.01 | 0.04 | <0.0002 | <0.005 | 0.0024 | 0.061 |
| 9-Sep | <0.01 | 0.0031 | <0.005 | <0.01 | 0.048 | <0.0002 | <0.005 | 0.0085 | 0.051 |
| 16-Sep | <0.01 | 0.0046 | <0.005 | <0.01 | 0.099 | <0.0002 | <0.005 | 0.016 | 0.15 |
| 23-Sep | <0.01 | 0.004 | <0.005 | 0.013 | 0.11 | 0.00022 | 0.0064 | 0.031 | 0.25 |
| 30-Sep | <0.01 | 0.0037 | <0.005 | <0.01 | 0.038 | <0.0002 | <0.005 | 0.0031 | 0.054 |
| 7-Oct | <0.01 | 0.0027 | <0.005 | <0.01 | 0.046 | 0.0002 | <0.005 | 0.0042 | 0.11 |
| 14-Oct | <0.01 | 0.0043 | <0.005 | <0.01 | 0.082 | <0.0002 | 0.0058 | 0.0083 | 0.13 |
| 21-Oct | <0.01 | 0.0023 | <0.005 | <0.01 | 0.065 | <0.0002 | <0.005 | 0.016 | 0.082 |
| 28-Oct | <0.01 | <0.002 | <0.005 | <0.01 | 0.043 | <0.0002 | <0.005 | 0.0046 | 0.064 |
| 4-Nov | <0.01 | 0.0028 | <0.005 | <0.01 | 0.057 | <0.0002 | <0.005 | 0.0076 | 0.12 |
| 11-Nov | <0.01 | <0.002 | <0.005 | <0.01 | 0.031 | <0.0002 | <0.005 | 0.0022 | 0.071 |
| 18-Nov | <0.01 | 0.0022 | <0.005 | <0.01 | 0.066 | <0.0002 | <0.005 | 0.0061 | 0.096 |
| 25-Nov | <0.01 | <0.002 | <0.005 | <0.01 | 0.017 | <0.0002 | <0.005 | <0.002 | <0.05 |
| 2-Dec | <0.01 | 0.0021 | <0.005 | <0.01 | 0.029 | <0.0002 | <0.005 | 0.0046 | 0.093 |
| 9-Dec | <0.01 | 0.0021 | <0.005 | <0.01 | 0.026 | <0.0002 | <0.005 | <0.002 | 0.052 |
| 16-Dec | <0.01 | 0.0025 | <0.005 | <0.01 | 0.029 | <0.0002 | <0.005 | <0.002 | 0.054 |
| 23-Dec | <0.01 | <0.002 | <0.005 | <0.01 | 0.024 | <0.0002 | <0.005 | <0.002 | 0.064 |
| 30-Dec | <0.01 | 0.015 | <0.005 | <0.01 | 0.029 | <0.0002 | <0.005 | <0.002 | <0.05 |
| Detection frequency | 0 of 52 | 44 of 52 | 0 of 52 | 1 of 52 | 51 of 52 | 2 of 52 | 4 of 52 | 26 of 52 | 43 of 52 |
| Minimum | <0.01 | <0.002 | <0.005 | <0.01 | <0.01 | <0.0002 | <0.005 | <0.002 | <0.05 |
| Maximum | <0.01 | 0.04 | <0.005 | 0.013 | 0.11 | 0.00022 | 0.01 | 0.031 | 0.25 |
| Median | (b) | 0.0028 | (b) | <0.01 | 0.03 | <0.0002 | <0.005 | <0.002 | 0.064 |
| IQR[(c)] | (b) | 0.0013 | (b) | (d) | 0.02 | (d) | (d) | (d) | 0.024 |
| EPL[(e)] | 0.2 | 0.06 | 0.14 | 0.62 | 1 | 0.01 | 0.61 | 0.2 | 3 |
| Maximum Percent of EPL | <5.0 | 67 | <3.6 | 2.1 | 11 | 2.2 | 1.6 | 16 | 8.3 |

(a) Ending date of composite period
(b) Not applicable because there are no detections. See *Environmental Report 2009,* Chapter 9.
(c) IQR = Interquartile range
(d) Not applicable because of the large number of nondetections. See *Environmental Report 2009,* Chapter 9.
(e) EPL = Effluent pollutant limit

**A.4.1 Metals detected in storm water runoff (μg/L), Livermore site, 2009**

| Analyte[(a)] | Date | Type | Arroyo Seco Site influent ASS2 | Arroyo Seco Site effluent ASW | Arroyo Las Positas Site influent ALPE | Arroyo Las Positas Site influent ALPO | Arroyo Las Positas Site influent GRNE | Arroyo Las Positas Site effluent WPDC | Drainage Retention Basin DRB effluent CDBX |
|---|---|---|---|---|---|---|---|---|---|
| Beryllium | 22-Jan | Total | <2 | <2 | <2 | <2 | <2 | <0.2 | <0.2 |
| Beryllium | 17-Feb | Total | <0.2 | <0.2 | 0.3 | 0.5 | 0.3 | <0.2 | <0.2 |
| Beryllium | 13-Oct | Total | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Cadmium | 22-Jan | Total | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <1 | <1 |
| Cadmium | 17-Feb | Total | <0.2 | <0.2 | 0.2 | <0.2 | <0.2 | 0.2 | <0.2 |
| Cadmium | 13-Oct | Total | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.5 | <0.5 |
| Chromium(VI) | 22-Jan | Total | 0 | 0 | <0.2 | 2 | 0 | 1 | 0 |
| Chromium(VI) | 17-Feb | Total | <0.2 | 0 | 0 | 1 | 0 | 1 | 0 |
| Chromium(VI) | 13-Oct | Total | 0 | 4 | 0 | 1 | 1 | <0.2 | 4 |
| Copper | 22-Jan | Total | 5 | 5 | 10 | 14 | 5 | 5 | 4 |
| Copper | 17-Feb | Total | 7 | 17 | 31 | 23 | 16 | 21 | 23 |
| Copper | 13-Oct | Total | 9 | 11 | 15 | 30 | 17 | 22 | <1 |
| Lead | 22-Jan | Total | <5 | <5 | <5 | 6 | <5 | 1 | 1 |
| Lead | 17-Feb | Total | <5 | 6 | 18 | 12 | 5 | 6 | <5 |
| Lead | 13-Oct | Total | <5 | <5 | 7 | 17 | 6 | 7 | <5 |
| Mercury | 22-Jan | Total | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Mercury | 17-Feb | Total | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Mercury | 13-Oct | Total | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Zinc | 22-Jan | Total | 58 | 56 | 27 | 48 | 67 | 150 | 53 |
| Zinc | 17-Feb | Total | 67 | 99 | 150 | 70 | 120 | 170 | 34 |
| Zinc | 13-Oct | Total | 93 | 96 | 56 | 92 | 37 | 230 | 27 |

(a)  Constituent nondetections are shown as less than (<) the reporting limit for that analysis.

RO-LSNR [mg O/L; mg/L; pH units; ug/L]   2009 data    (created 2010-07-14 10:08:55, Oracle) (epprd02.llnl.gov)

**A.4.2 Nonradioactive constituents (other than metals) detected in storm water runoff, Livermore site, 2009**

| Group<br>Analyte | Date | Arroyo Seco<br>Site influent<br>ASS2 | Arroyo Seco<br>Site effluent<br>ASW | Arroyo Las Positas<br>Site influent<br>ALPE | Arroyo Las Positas<br>Site influent<br>ALPO | Arroyo Las Positas<br>Site influent<br>GRNE | Arroyo Las Positas<br>Site effluent<br>WPDC | Drainage Retention Basin<br>DRB influent<br>CDB | Drainage Retention Basin<br>DRB influent<br>CDB2 | Drainage Retention Basin<br>DRB effluent<br>CDBX |
|---|---|---|---|---|---|---|---|---|---|---|
| Physical (mg/L)[a] | | | | | | | | | | |
| Chemical oxygen demand (mg O/L) | 22-Jan | <25 | <25 | 120 | 65 | <25 | <25 | (b) | (b) | <25 |
| Chemical oxygen demand (mg O/L) | 17-Feb | <25 | 51 | 96 | 60 | <25 | 58 | (b) | (b) | <25 |
| Chemical oxygen demand (mg O/L) | 13-Oct | 45 | 54 | 94 | 120 | 47 | 120 | (b) | (b) | <25 |
| Dissolved oxygen (mg O/L) | 22-Jan | 11 | 11 | 11 | 11 | 12 | 11 | 11 | 10 | 11 |
| Dissolved oxygen (mg O/L) | 17-Feb | 12 | 11 | 11 | 11 | 12 | 12 | 11 | 11 | 11 |
| Dissolved oxygen (mg O/L) | 13-Oct | 11 | 11 | 10 | 8 | 11 | 11 | 12 | 10 | 10 |
| Total suspended solids | 22-Jan | 10 | 38 | 59 | 130 | 27 | 25 | 21 | 27 | 19 |
| Total suspended solids | 17-Feb | 58 | 130 | 400 | 310 | 170 | 130 | 120 | 30 | 19 |
| Total suspended solids | 13-Oct | 18 | 34 | 64 | 580 | 140 | 140 | 42 | 76 | <1.1 |
| Total dissolved solids | 22-Jan | 44 | 44 | 1300 | 390 | 92 | 180 | 110 | 290 | 410 |
| Total dissolved solids | 17-Feb | 28 | 30 | 150 | 300 | 59 | 71 | 43 | 120 | 460 |
| Total dissolved solids | 13-Oct | 49 | 220 | 120 | 270 | 73 | 190 | 83 | 110 | 750 |
| pH (pH units) | 22-Jan | 7.06 | 7.11 | 8.03 | 7.81 | 7.15 | 7.61 | 7.61 | 7.32 | 7.96 |
| pH (pH units) | 17-Feb | 7.3 | 7.3 | 8.24 | 8.02 | 7.64 | 7.62 | 7.39 | 7.5 | 8.22 |
| pH (pH units) | 13-Oct | 6.65 | 7.88 | 7 | 7.18 | 6.85 | 7.23 | 7.15 | 6.44 | 8.76 |
| Anions/General Minerals (mg/L) | | | | | | | | | | |
| Nitrate (as NO3) | 22-Jan | 3.5 | 2.7 | 6.5 | 12 | 17 | 3.7 | 4.8 | 4 | 3.7 |
| Nitrate (as NO3) | 17-Feb | 1.1 | 1.1 | 3 | 9 | 6.7 | 1.4 | 1.1 | 0.89 | 6.7 |
| Nitrate (as NO3) | 13-Oct | 2.9 | 15 | 17 | 12 | 8.4 | 7.6 | 3.4 | 6.3 | 13 |
| Ortho-Phosphate | 22-Jan | 0.55 | 0.44 | 2.1 | 0.58 | 0.52 | 0.3 | 0.21 | 0.7 | 0.37 |
| Ortho-Phosphate | 17-Feb | 0.29 | 0.18 | 0.67 | 0.4 | 0.43 | 0.17 | 0.14 | 0.21 | 0.073 |
| Ortho-Phosphate | 13-Oct | 0.67 | 0.83 | 0.69 | 2.1 | 0.62 | 1 | 0.48 | 1.2 | 0.074 |
| Total hardness (as CaCO3) | 13-Oct | (b) | 120 | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| Alkalinity (mg/L)[a] | | | | | | | | | | |
| Bicarbonate Alk (as CaCO3) | 13-Oct | (b) | 110 | (b) | (b) | (b) | 42 | (b) | (b) | (b) |
| Carbonate Alk (as CaCO3) | 13-Oct | (b) | <4.1 | (b) | (b) | (b) | <4.1 | (b) | (b) | (b) |
| Total Alkalinity (as CaCO3) | 13-Oct | (b) | 110 | (b) | (b) | (b) | 42 | (b) | (b) | (b) |
| Herbicides (µg/L)[a] | | | | | | | | | | |
| Bromacil | 22-Jan | <0.5 | <0.5 | 1.2 | 20 | <0.5 | 3.7 | 0.56 | 0.52 | <0.5 |
| Bromacil | 17-Feb | <0.5 | <0.5 | 1.5 | 15 | 45 | 1.1 | <0.5 | <0.5 | <0.5 |
| Bromacil | 13-Oct | <0.5 | <0.5 | <0.5 | <0.57 | 7.4 | <0.5 | <0.5 | <0.5 | <0.5 |
| Diazinon | 22-Jan | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Diazinon | 17-Feb | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Diazinon | 13-Oct | <0.2 | <0.2 | <0.2 | <0.23 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Diuron | 22-Jan | <1 | <1 | 12 | 2.1 | 5 | 1.7 | <1 | 3.6 | 1.7 |
| Diuron | 17-Feb | 1.2 | <1 | 7.1 | <1 | 1.8 | <1 | <1 | <1 | <1 |
| Diuron | 13-Oct | <1 | <1 | 100 | <1 | 130 | <1 | <1 | <1 | <1 |
| Glyphosate | 22-Jan | 37 | 17 | <5 | 9.5 | <5 | 6.7 | 50 | 16 | 14 |
| Glyphosate | 17-Feb | <5 | 8.6 | 7 | <5 | <5 | <5 | <5 | <5 | <5 |
| Glyphosate | 13-Oct | 14 | 9.2 | 45 | 210 | 45 | <5 | 14 | 28 | <5 |
| Miscellaneous organics (mg/L)[a] | | | | | | | | | | |
| Oil and grease | 22-Jan | <5 | <5 | <5 | <5 | <5.7 | <5 | <5 | <5 | <5 |
| Oil and grease | 17-Feb | <5 | <5 | <5 | <5 | <5.6 | <5.6 | <5.7 | <5 | <5.6 |
| Oil and grease | 13-Oct | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Total organic carbon | 22-Jan | 7.5 | 6.9 | 32 | 9.8 | 3.2 | 8.4 | (b) | (b) | 9 |
| Total organic carbon | 17-Feb | 3.8 | 3.1 | 5 | 6.5 | 2.2 | 4.5 | (b) | (b) | 5.2 |
| Total organic carbon | 13-Oct | 15 | 18 | 19 | 22 | 7.9 | 31 | (b) | (b) | 4.1 |

(a)  Constituent nondetections are shown as less than (<) the reporting limit for that analysis.
(b)  Analysis was not conducted for that sampling event.

**A.4.3 Routine gross alpha, gross beta, and tritium sampling in storm water runoff, Livermore site, 2009**

| Parameter<br>Date | Arroyo Seco[(a)]<br><br>Site influent<br>ASS2 | Arroyo Seco[(a)]<br><br>Site effluent<br>ASW |
|---|---|---|
| Gross alpha (Bq/L) | | |
| 22-Jan | 0.004 ± 0.014 | 0.015 ± 0.015 |
| 17-Feb | 0.017 ± 0.013 | 0.059 ± 0.024 |
| 13-Oct | 0.002 ± 0.026 | 0.091 ± 0.057 |
| Gross beta (Bq/L) | | |
| 22-Jan | 0.110 ± 0.041 | 0.120 ± 0.041 |
| 17-Feb | 0.061 ± 0.024 | 0.160 ± 0.033 |
| 13-Oct | 0.015 ± 0.058 | 0.120 ± 0.046 |
| Tritium (Bq/L) | | |
| 22-Jan | 2.1 ± 2.0 | 3.8 ± 2.0 |
| 17-Feb | -0.7 ± 2.0 | -0.5 ± 2.1 |
| 13-Oct | 0.1 ± 1.4 | 1.3 ± 1.4 |

| Parameter<br>Date | Arroyo Las Positas[(a)]<br><br>Site influent<br>ALPE | Arroyo Las Positas[(a)]<br><br>Site influent<br>ALPO | Arroyo Las Positas[(a)]<br><br>Site influent<br>GRNE | Arroyo Las Positas<br><br>Site effluent<br>WPDC |
|---|---|---|---|---|
| Gross alpha (Bq/L) | | | | |
| 22-Jan | 0.74 ± 0.27 | 0.140 ± 0.074 | 0.013 ± 0.016 | 0.025 ± 0.059 |
| 17-Feb | 0.160 ± 0.063 | 0.160 ± 0.067 | 0.050 ± 0.026 | 0.047 ± 0.024 |
| 13-Oct | 0.074 ± 0.056 | 0.44 ± 0.24 | 0.38 ± 0.15 | 0.150 ± 0.068 |
| Gross beta (Bq/L) | | | | |
| 22-Jan | 0.420 ± 0.078 | 0.270 ± 0.052 | 0.110 ± 0.036 | 0.130 ± 0.052 |
| 17-Feb | 0.410 ± 0.059 | 0.320 ± 0.048 | 0.190 ± 0.037 | 0.140 ± 0.044 |
| 13-Oct | 0.190 ± 0.067 | 1.00 ± 0.24 | 0.53 ± 0.13 | 0.210 ± 0.067 |
| Tritium (Bq/L) | | | | |
| 22-Jan | 2.0 ± 2.0 | 1.5 ± 2.0 | 1.3 ± 2.0 | 5.3 ± 2.1 |
| 17-Feb | -2.9 ± 2.0 | -1.9 ± 2.0 | -1.8 ± 2.0 | 1.8 ± 2.1 |
| 13-Oct | 0.4 ± 1.4 | 0.1 ± 1.3 | 1.0 ± 1.4 | 4.7 ± 1.8 |

| Parameter<br>Date | Drainage Retention Basin<br><br>DRB influent<br>CDB | Drainage Retention Basin<br><br>DRB influent<br>CDB2 | Drainage Retention Basin<br><br>DRB effluent<br>CDBX |
|---|---|---|---|
| Gross alpha (Bq/L) | | | |
| 22-Jan | 0.019 ± 0.018 | 0.071 ± 0.055 | 0.072 ± 0.059 |
| 17-Feb | 0.030 ± 0.022 | 0.016 ± 0.015 | 0.130 ± 0.063 |
| 13-Oct | 0.130 ± 0.071 | 0.024 ± 0.036 | 0.33 ± 0.20 |
| Gross beta (Bq/L) | | | |
| 22-Jan | 0.095 ± 0.028 | 0.190 ± 0.044 | 0.150 ± 0.035 |
| 17-Feb | 0.160 ± 0.033 | 0.120 ± 0.035 | 0.110 ± 0.036 |
| 13-Oct | 0.200 ± 0.067 | 0.240 ± 0.063 | 0.21 ± 0.12 |
| Tritium (Bq/L) | | | |
| 22-Jan | 2.2 ± 2.0 | 2.3 ± 2.0 | 2.9 ± 2.0 |
| 17-Feb | 0.4 ± 2.1 | 1.3 ± 2.1 | 2.2 ± 2.1 |
| 13-Oct | 2.3 ± 1.6 | 4.2 ± 1.8 | 6.0 ± 2.0 |

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

**A.4.4 Dioxins and furans in storm water (pg/L), Site 300, 2009**

| Analyte[(a)] | Date | Upstream location Influent CARW2 | Effluent locations Effluent NLIN2 | Downstream location Downstream GEOCRK |
|---|---|---|---|---|
| 2,3,7,8-TCDD | 22-Jan | (b) | <0.508 | <0.463 |
| 2,3,7,8-TCDD | 17-Feb | <0.447 | <0.395 | <0.468 |
| 2,3,7,8-TCDD | 13-Oct | 1.4 | <0.534 | <0.568 |
| 1,2,3,7,8-PeCDD | 22-Jan | (b) | <0.874 | <0.964 |
| 1,2,3,7,8-PeCDD | 17-Feb | 1.2 | 4.8 | <0.958 |
| 1,2,3,7,8-PeCDD | 13-Oct | 6.6 | 2.3 | <0.572 |
| 1,2,3,4,7,8-HxCDD | 22-Jan | (b) | <2.91 | <2.48 |
| 1,2,3,4,7,8-HxCDD | 17-Feb | <0.917 | 11 | <0.832 |
| 1,2,3,4,7,8-HxCDD | 13-Oct | 7.2 | 4.2 | <0.729 |
| 1,2,3,6,7,8-HxCDD | 22-Jan | (b) | <2.85 | <2.4 |
| 1,2,3,6,7,8-HxCDD | 17-Feb | 3.7 | 26 | 2 |
| 1,2,3,6,7,8-HxCDD | 13-Oct | 17 | 8.4 | <0.751 |
| 1,2,3,7,8,9-HxCDD | 22-Jan | (b) | <2.77 | <2.35 |
| 1,2,3,7,8,9-HxCDD | 17-Feb | 4.8 | 22 | 2.8 |
| 1,2,3,7,8,9-HxCDD | 13-Oct | 15 | 6.9 | <0.717 |
| 1,2,3,4,6,7,8-HpCDD | 22-Jan | (b) | 41 | <3.75 |
| 1,2,3,4,6,7,8-HpCDD | 17-Feb | 29 | 860 | 29 |
| 1,2,3,4,6,7,8-HpCDD | 13-Oct | 200 | 130 | <0.79 |
| Octachlorinated dibenzo-p-dioxin | 22-Jan | (b) | 330 | 6.2 |
| Octachlorinated dibenzo-p-dioxin | 17-Feb | 150 | 7400 | 200 |
| Octachlorinated dibenzo-p-dioxin | 13-Oct | 1300 | 1700 | 3.5 |
| 2,3,7,8-TCDF | 22-Jan | (b) | <0.444 | <0.464 |
| 2,3,7,8-TCDF | 17-Feb | <0.5 | <1.05 | <0.525 |
| 2,3,7,8-TCDF | 13-Oct | <100 | <0.518 | <0.466 |
| 1,2,3,7,8-PeCDF | 22-Jan | (b) | <0.624 | <0.579 |
| 1,2,3,7,8-PeCDF | 17-Feb | <0.372 | 0.81 | <0.431 |
| 1,2,3,7,8-PeCDF | 13-Oct | <100 | <0.799 | <0.495 |
| 2,3,4,7,8-PeCDF | 22-Jan | (b) | <0.589 | <0.584 |
| 2,3,4,7,8-PeCDF | 17-Feb | <0.368 | 2.1 | <0.411 |
| 2,3,4,7,8-PeCDF | 13-Oct | <0.615 | <0.803 | <0.474 |
| 1,2,3,4,7,8-HxCDF | 22-Jan | (b) | <1.39 | <1.14 |
| 1,2,3,4,7,8-HxCDF | 17-Feb | 1.5 | 14 | <0.477 |
| 1,2,3,4,7,8-HxCDF | 13-Oct | 4.1 | 4.6 | <0.285 |
| 1,2,3,6,7,8-HxCDF | 22-Jan | (b) | <1.35 | <1.2 |
| 1,2,3,6,7,8-HxCDF | 17-Feb | 0.94 | 6.4 | <0.502 |
| 1,2,3,6,7,8-HxCDF | 13-Oct | 4.1 | 2.3 | <0.32 |
| 2,3,4,6,7,8-HxCDF | 22-Jan | (b) | <1.55 | <1.39 |
| 2,3,4,6,7,8-HxCDF | 17-Feb | 1.2 | 9.7 | <0.547 |
| 2,3,4,6,7,8-HxCDF | 13-Oct | 4.1 | 2.7 | <0.394 |
| 1,2,3,7,8,9-HxCDF | 22-Jan | (b) | <2.13 | <1.95 |
| 1,2,3,7,8,9-HxCDF | 17-Feb | 3.7 | 3 | 1.4 |
| 1,2,3,7,8,9-HxCDF | 13-Oct | 2.3 | <250 | <0.502 |
| 1,2,3,4,6,7,8-HpCDF | 22-Jan | (b) | 13 | <2.14 |
| 1,2,3,4,6,7,8-HpCDF | 17-Feb | 13 | 220 | 6.2 |
| 1,2,3,4,6,7,8-HpCDF | 13-Oct | 57 | 570 | <0.792 |
| 1,2,3,4,7,8,9-HpCDF | 22-Jan | (b) | <3.43 | <2.55 |
| 1,2,3,4,7,8,9-HpCDF | 17-Feb | <0.69 | 21 | <0.761 |
| 1,2,3,4,7,8,9-HpCDF | 13-Oct | 3.6 | 4.5 | <0.754 |
| Octachlorinated dibenzo-furan | 22-Jan | (b) | 42 | <1.61 |
| Octachlorinated dibenzo-furan | 17-Feb | 22 | 1100 | 20 |
| Octachlorinated dibenzo-furan | 13-Oct | 120 | 190 | <500 |

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.
(b) Analysis was not conducted for that sampling event.

RO-S3PCB [ug/L]   2009 data    (created 2010-03-17 08:30:18, Oracle) (epprd02.llnl.gov)

**A.4.5 Polychlorinated biphenyls (PCBs) in storm water runoff (µg/L), Site 300, 2009**

| Locations | PCB 1016 | PCB 1016 | PCB 1016 | PCB 1221 | PCB 1221 | PCB 1221 |
|---|---|---|---|---|---|---|
| | 22-Jan | 17-Feb | 13-Oct | 22-Jan | 17-Feb | 13-Oct |
| Upstream CARW2 | (a) | <0.5 | <0.1 | (a) | <0.5 | <0.1 |
| Effluent NLIN2 | <0.1 | <0.5 | <0.1 | <0.1 | <0.5 | <0.1 |
| Downstream GEOCRK | <0.1 | <0.5 | <0.1 | <0.1 | <0.5 | <0.1 |

| Locations | PCB 1232 | PCB 1232 | PCB 1232 | PCB 1242 | PCB 1242 | PCB 1242 |
|---|---|---|---|---|---|---|
| | 22-Jan | 17-Feb | 13-Oct | 22-Jan | 17-Feb | 13-Oct |
| Upstream CARW2 | (a) | <0.5 | <0.1 | (a) | <0.5 | <0.1 |
| Effluent NLIN2 | <0.1 | <0.5 | <0.1 | <0.1 | <0.5 | <0.1 |
| Downstream GEOCRK | <0.1 | <0.5 | <0.1 | <0.1 | <0.5 | <0.1 |

| Locations | PCB 1248 | PCB 1248 | PCB 1248 | PCB 1254 | PCB 1254 | PCB 1254 |
|---|---|---|---|---|---|---|
| | 22-Jan | 17-Feb | 13-Oct | 22-Jan | 17-Feb | 13-Oct |
| Upstream CARW2 | (a) | <0.5 | <0.1 | (a) | <0.5 | <0.1 |
| Effluent NLIN2 | <0.1 | <0.5 | <0.1 | <0.1 | <0.5 | <0.1 |
| Downstream GEOCRK | <0.1 | <0.5 | <0.1 | <0.1 | <0.5 | <0.1 |

| Locations | PCB 1260 | PCB 1260 | PCB 1260 |
|---|---|---|---|
| | 22-Jan | 17-Feb | 13-Oct |
| Upstream CARW2 | (a) | <0.5 | <0.1 |
| Effluent NLIN2 | <0.1 | <0.5 | <0.1 |
| Downstream GEOCRK | <0.1 | <0.5 | <0.1 |

Note:  PCB nondetections are shown as less than (<) the reporting limit for each analyte.

(a)  Analysis was not conducted for that sampling event.

RO-S3MET [ug/L] 2009 data (created 2010-03-17 08:30:13, Oracle) (epprd02.llnl.gov)

**A.4.6 Metals in storm water runoff (μg/L), Site 300, 2009**

| Analyte[a] | Date | Type | Upstream location Influent CARW2 | Effluent locations Effluent N883 | Effluent locations Effluent NPT7 | Effluent locations Effluent NLIN2 | Downstream location Downstream GEOCRK |
|---|---|---|---|---|---|---|---|
| Arsenic | 22-Jan | Total | (b) | <2 | <2 | 19 | 3 |
| Arsenic | 17-Feb | Total | 72 | <2 | 3 | 15 | 34 |
| Arsenic | 13-Oct | Total | 28 | 5 | <2 | 35 | 7 |
| Beryllium | 22-Jan | Total | (b) | <2 | <2 | <2 | <2 |
| Beryllium | 17-Feb | Total | 8 | <0.2 | 0.6 | 2.9 | 4 |
| Beryllium | 13-Oct | Total | <4 | <2 | <2 | <4 | <4 |
| Cadmium | 22-Jan | Total | (b) | 0.5 | <0.5 | <0.5 | <0.5 |
| Cadmium | 17-Feb | Total | 1.7 | <0.5 | 0.5 | 1.3 | 0.8 |
| Cadmium | 13-Oct | Total | 0.6 | 5.2 | <0.5 | <0.5 | <0.5 |
| Iron | 22-Jan | Total | (b) | 1100 | 2800 | 510 | 960 |
| Iron | 17-Feb | Total | 200000 | 270 | 18000 | 50000 | 110000 |
| Iron | 13-Oct | Total | 71000 | 14000 | 6100 | 16000 | 840 |
| Lead | 22-Jan | Total | (b) | 6 | <5 | <5 | <5 |
| Lead | 17-Feb | Total | 83 | <5 | 5 | 17 | 43 |
| Lead | 13-Oct | Total | 28 | 290 | <5 | 6 | <5 |
| Mercury | 22-Jan | Total | (b) | <0.2 | <0.2 | <0.2 | <0.2 |
| Mercury | 17-Feb | Total | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Mercury | 13-Oct | Total | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Selenium | 22-Jan | Total | (b) | <2 | <2 | 3 | 2 |
| Selenium | 17-Feb | Total | 6 | <2 | <2 | <2 | 3 |
| Selenium | 13-Oct | Total | 3 | 7 | <2 | 14 | 6 |
| Silver | 22-Jan | Total | (b) | <1 | <1 | <1 | <1 |
| Silver | 17-Feb | Total | <1 | <1 | <1 | <1 | <1 |
| Silver | 13-Oct | Total | <1 | <1 | <1 | <1 | <1 |

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.
(b) Analysis was not conducted for that sampling event.

RO-S3NR [mg O/L; mg/L; pH units; uS/cm]   2009 data   (created 2010-03-23 07:01:56, Oracle) (epprd02.llnl.gov)

**A.4.7 Nonradioactive constituents detected in storm water runoff, Site 300, 2009**

| Group<br>Analyte | Date | Upstream location | Effluent locations | Effluent locations | Effluent locations | Downstream location |
|---|---|---|---|---|---|---|
| | | CARW2 | N883 | NPT7 | NLIN2 | GEOCRK |
| Physical (mg/L)[(a)] | | | | | | |
| Chemical oxygen demand (mg O/L) | 22-Jan | (b) | 150 | 25 | 30 | 93 |
| Chemical oxygen demand (mg O/L) | 17-Feb | 370 | <25 | <25 | 75 | 120 |
| Chemical oxygen demand (mg O/L) | 13-Oct | 98 | 440 | 35 | 430 | 110 |
| Total suspended solids | 22-Jan | (b) | 22 | 53 | 14 | 16 |
| Total suspended solids | 17-Feb | 3500 | 14 | 320 | 1100 | 2100 |
| Total suspended solids | 13-Oct | 1200 | 140 | 130 | 390 | 12 |
| pH (pH units) | 22-Jan | (b) | 6.61 | 8 | 7.96 | 8.31 |
| pH (pH units) | 17-Feb | 7.99 | 6.9 | 8.29 | 8.06 | 8.12 |
| pH (pH units) | 13-Oct | 7.48 | 6.14 | 7.22 | 7.05 | 7.99 |
| Conductivity (µS/cm) | 22-Jan | (b) | 25 | 154 | 952 | 2500 |
| Conductivity (µS/cm) | 17-Feb | 225 | 16 | 136 | 332 | 745 |
| Conductivity (µS/cm) | 13-Oct | 280 | 144 | 68 | 1230 | 3900 |
| Anions/General Minerals (mg/L)[(a)] | | | | | | |
| Ammonia (as Nitrogen) | 22-Jan | (b) | 0.46 | 0.11 | 0.071 | 0.083 |
| Ammonia (as Nitrogen) | 17-Feb | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Ammonia (as Nitrogen) | 13-Oct | 0.33 | 3 | 0.28 | 1.6 | 0.5 |
| Total hardness (as CaCO3) | 13-Oct | 200 | (b) | (b) | 430 | 940 |
| Cyanide | 22-Jan | (b) | <0.005 | <0.005 | <0.005 | <0.005 |
| Cyanide | 17-Feb | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Cyanide | 13-Oct | <0.005 | 0.0066 | <0.005 | 0.014 | <0.005 |
| Alkalinity (mg/L)[(a)] | | | | | | |
| Bicarbonate Alk (as CaCO3) | 13-Oct | 32 | (b) | (b) | 160 | 510 |
| Carbonate Alk (as CaCO3) | 13-Oct | <4.1 | (b) | (b) | <8.2 | <8.2 |
| Total Alkalinity (as CaCO3) | 13-Oct | 32 | (b) | (b) | 160 | 510 |
| Miscellaneous organics (mg/L)[(a)] | | | | | | |
| Oil and grease | 13-Oct | <5 | <5 | <5 | <5 | <5 |
| Total organic carbon | 22-Jan | (b) | 9.2 | 7.4 | 12 | 34 |
| Total organic carbon | 17-Feb | 5.6 | 2.8 | 3.7 | 5.4 | 8.4 |

(a) Constituent nondetections are shown as less than (<) the reporting limit for that analysis.
(b) Analysis was not conducted for that sampling event.

**A.4.8 Radioactivity in storm water runoff, Site 300, 2009**

| Parameter<br>Date | Method | Upstream location | Effluent locations | Effluent locations | Effluent locations | Downstream location |
|---|---|---|---|---|---|---|
| | | CARW2 | N883[(a)] | NPT7[(a)] | NLIN2[(a)] | GEOCRK[(a)] |
| Gross alpha (Bq/L) | | | | | | |
| 22-Jan | E900 | (b) | 0.160 ± 0.052 | 0.055 ± 0.037 | 0.130 ± 0.092 | -0.44 ± 0.37 |
| 17-Feb | E900 | 0.310 ± 0.085 | -0.0006 ± 0.0092 | 0.022 ± 0.018 | 0.064 ± 0.037 | 0.26 ± 0.10 |
| 13-Oct | E900 | 1.50 ± 0.54 | 0.130 ± 0.080 | 0.210 ± 0.097 | 0.51 ± 0.27 | 0.04 ± 0.18 |
| Gross beta (Bq/L) | | | | | | |
| 22-Jan | E900 | (b) | 0.240 ± 0.044 | 0.200 ± 0.041 | 0.450 ± 0.063 | 0.55 ± 0.24 |
| 17-Feb | E900 | 0.430 ± 0.059 | 0.025 ± 0.021 | 0.100 ± 0.037 | 0.310 ± 0.048 | 0.420 ± 0.059 |
| 13-Oct | E900 | 1.60 ± 0.43 | 0.380 ± 0.097 | 0.250 ± 0.085 | 1.40 ± 0.33 | 0.97 ± 0.31 |
| Tritium (Bq/L) | | | | | | |
| 22-Jan | E906 | (b) | -0.4 ± 1.8 | -0.2 ± 1.8 | -0.1 ± 1.8 | -0.4 ± 1.8 |
| 17-Feb | E906 | 0.7 ± 1.8 | 0.3 ± 1.8 | -0.2 ± 1.8 | 0.9 ± 1.8 | -1.0 ± 1.8 |
| 13-Oct | E906 | 0.9 ± 1.4 | 0.8 ± 1.5 | 0.3 ± 1.4 | 0.3 ± 1.4 | 2.1 ± 1.5 |
| U235/U238 mass ratio[(c)] | | | | | | |
| 22-Jan | AS | (b) | (b) | 0.017 ± 0.017 | 0.0062 ± 0.0025 | 0.0118 ± 0.0044 |
| 17-Feb | AS | 0.0055 ± 0.0042 | (b) | (b) | 0.0055 ± 0.0041 | 0.0109 ± 0.0073 |
| 13-Oct | AS | (b) | (b) | (b) | 0.0106 ± 0.0059 | 0.0123 ± 0.0055 |
| Uranium-234+233 (mBq/L) | | | | | | |
| 22-Jan | AS | (b) | 5.0 ± 2.3 | 8.2 ± 2.5 | 140 ± 15 | 77.0 ± 8.9 |
| 17-Feb | AS | 58.0 ± 7.8 | -0.67 ± 0.81 | 10.0 ± 3.0 | 41.0 ± 6.3 | 32.0 ± 5.6 |
| 13-Oct | AS | 26.0 ± 6.8 | 6.3 ± 2.9 | 3.3 ± 2.0 | 90 ± 16 | 140 ± 24 |
| Uranium-235+236 (mBq/L) | | | | | | |
| 22-Jan | AS | (b) | -0.27 ± 0.56 | 1.1 ± 1.1 | 4.8 ± 1.8 | 5.1 ± 1.8 |
| 17-Feb | AS | 2.0 ± 1.5 | 0.33 ± 0.67 | 0.64 ± 0.85 | 1.9 ± 1.4 | 2.3 ± 1.5 |
| 13-Oct | AS | 1.0 ± 1.4 | 0.35 ± 0.69 | -0.30 ± 0.73 | 5.1 ± 2.7 | 9.5 ± 3.9 |
| Uranium-238 (mBq/L) | | | | | | |
| 22-Jan | AS | (b) | 7.4 ± 2.8 | 10.0 ± 2.6 | 120 ± 13 | 67.0 ± 8.1 |
| 17-Feb | AS | 57.0 ± 7.8 | -0.13 ± 0.56 | 16.0 ± 3.7 | 54.0 ± 7.4 | 33.0 ± 5.6 |
| 13-Oct | AS | 23.0 ± 6.3 | 5.7 ± 2.7 | 2.9 ± 1.9 | 75 ± 14 | 120 ± 21 |

(a) A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus.
(b) Analysis was not conducted for that sampling event.
(c) Represents the mass ratio, not the activity ratio, of uranium-235 to uranium-238 with the propagated 2$\sigma$ error.

**A.5.1 Livermore site metals surveillance wells, 2009**

| Type<br>Constituents of concern | W-307 | W-307 | W-226 | W-226 | W-306 |
|---|---|---|---|---|---|
| | 22-Apr | 23-Apr | 22-Apr | 23-Apr | 27-Apr |
| Inorganic | | | | | |
| Field pH (pH units) | 7.37 | (a) | 7.31 | (a) | 7.51 |
| Field Conductivity (µS/cm) | 982 | (a) | 881 | (a) | 878 |
| Water temperature (Degrees C) | 21.2 | (a) | 22.1 | (a) | 19.9 |
| Metals (µg/L)[(b)] | | | | | |
| Aluminum | (a) | <50 | (a) | <50 | <50 |
| Antimony | (a) | <2 | (a) | <2 | <2 |
| Arsenic | (a) | <2 | (a) | <2 | <2 |
| Barium | (a) | 260 | (a) | 190 | 97 |
| Beryllium | (a) | <0.2 | (a) | <0.2 | <0.2 |
| Boron | (a) | 620 | (a) | 550 | 1100 |
| Cadmium | (a) | <1 | (a) | <1 | <1 |
| Chromium | (a) | 10 | (a) | 21 | 30 |
| Chromium(VI) | (a) | 10 | (a) | 24 | 29 |
| Cobalt | (a) | <50 | (a) | <50 | <50 |
| Copper | (a) | <2 | (a) | <2 | <2 |
| Iron | (a) | <50 | (a) | <50 | <50 |
| Lead | (a) | <1 | (a) | <1 | <1 |
| Manganese | (a) | <10 | (a) | <10 | <10 |
| Mercury | (a) | <0.2 | (a) | <0.2 | <0.2 |
| Molybdenum | (a) | <1 | (a) | <1 | 1 |
| Nickel | (a) | <2 | (a) | <2 | <2 |
| Selenium | (a) | <2 | (a) | <2 | <2 |
| Silver | (a) | <1 | (a) | <1 | <1 |
| Thallium | (a) | <1 | (a) | <1 | <1 |
| Vanadium | (a) | <10 | (a) | <10 | <10 |
| Zinc | (a) | <10 | (a) | <10 | 10 |

(a)  Analysis was not conducted for that sampling event.
(b)  Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

**A.5.2 Livermore site Buildings 514 and 612 area surveillance wells, 2009**

| Type<br>Constituents of concern | W-270 | W-270 | W-359 | W-359 | GSW-011 | GSW-011 |
|---|---|---|---|---|---|---|
| | 6-Apr | 7-Oct | 7-Apr | 7-Oct | 1-Apr | 5-Oct |
| Inorganic | | | | | | |
| Field pH (pH units) | 7.57 | 7.51 | 7.39 | 7.35 | 7.31 | 7.07 |
| Field Conductivity (µS/cm) | 766 | 826 | 638 | 654 | 844 | 874 |
| Water temperature (Degrees C) | 20.3 | 23.6 | 19.8 | 20.9 | 19.9 | 20.5 |
| Radioactive (Bq/L)[(a)] | | | | | | |
| Gross alpha | (b) | 0.058 ± 0.052 | (b) | 0.038 ± 0.050 | (b) | 0.120 ± 0.068 |
| Gross beta | (b) | 0.017 ± 0.047 | (b) | -0.088 ± 0.050 | (b) | 0.190 ± 0.073 |
| Americium 241 | 0.0011 ± 0.0016 | (b) | 0.0004 ± 0.0023 | (b) | 0.0006 ± 0.0016 | (b) |
| Plutonium 238 (mBq/L) | -0.10 ± 0.78 | (b) | -0.26 ± 0.85 | (b) | -0.4 ± 1.3 | (b) |
| Plutonium 239+240 (mBq/L) | 0.10 ± 0.37 | (b) | 0.17 ± 0.34 | (b) | -0.38 ± 0.74 | (b) |
| Tritium | -0.6 ± 1.9 | -0.8 ± 1.7 | -1.5 ± 1.8 | 1.4 ± 1.8 | 2.8 ± 1.9 | 0.3 ± 2.1 |

(a) Nondetections of radioactive constituents are equal to or are less than the 2$\sigma$ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

(b) Analysis was not conducted for that sampling event.

**A.5.3 Livermore site near Decontamination and Waste Treatment Facility (DWTF) surveillance wells, 2009**

| Type<br>Constituents of concern | W-007 | W-593 | W-594 |
|---|---|---|---|
| | 6-Apr | 6-Apr | 6-Apr |
| Inorganic | | | |
| Field pH (pH units) | 7.26 | 7.22 | 7.39 |
| Field Conductivity (µS/cm) | 1810 | 2320 | 1470 |
| Water temperature (Degrees C) | 19.3 | 19.4 | 19.8 |
| Radioactive (Bq/L)[(a)] | | | |
| Tritium | 0.2 ± 1.8 | 0.9 ± 1.9 | 1.8 ± 1.8 |

(a)  Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-EASTTCLFA [pH units; uS/cm; Degrees C; ug/L; mBq/L; Bq/L]   2009 data    (created 2010-03-08 15:08:14, Oracle) (epprd02.llnl.gov)

**A.5.4 Livermore site East Traffic Circle Landfill surveillance wells 1308 and 1303, 2009**

| Type<br>Constituents of concern | W-1308 | W-1303 |
|---|---|---|
| | 14-Jan | 14-Jan |
| Inorganic | | |
| Field pH (pH units) | 7.19 | 7.36 |
| Field Conductivity (µS/cm) | 1020 | 1780 |
| Water temperature (Degrees C) | 17.8 | 20.9 |
| Metals (µg/L)[(a)] | | |
| Copper | <10 | <10 |
| Lead | <50 | <50 |
| Zinc | <10 | <10 |
| Radioactive (Bq/L)[(b)] | | |
| Plutonium 238 (mBq/L) | 0.6 ± 1.1 | 2.0 ± 1.6 |
| Plutonium 239+240 (mBq/L) | 0.91 ± 0.67 | 7.8 ± 2.2 |
| Radium 226 (mBq/L) | 4.0 ± 4.8 | 4.1 ± 4.8 |
| Radium 228 (mBq/L) | 18 ± 13 | 22 ± 13 |
| Tritium | 13.0 ± 1.9 | 5.8 ± 1.8 |

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.
(b) Nondetections of radioactive constituents are equal to or are less than the 2$\sigma$ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-EASTTCLFB [pH units; uS/cm; Degrees C; ug/L; mBq/L; Bq/L] 2009 data (created 2010-03-08 15:08:18, Oracle) (epprd02.llnl.gov)

**A.5.5 Livermore site East Traffic Circle Landfill surveillance wells 119 and 1306, 2009**

| Type<br>Constituents of concern | W-119<br><br>13-Jan | W-1306<br><br>14-Jan |
|---|---|---|
| Inorganic | | |
| Field pH (pH units) | 6.91 | 7.09 |
| Field Conductivity (µS/cm) | 624 | 1940 |
| Water temperature (Degrees C) | 17.5 | 23.4 |
| Metals (µg/L)[(a)] | | |
| Copper | <10 | <10 |
| Lead | <50 | <50 |
| Zinc | <10 | <10 |
| Radioactive (Bq/L)[(b)] | | |
| Plutonium 238 (mBq/L) | -0.1 ± 1.1 | 0.8 ± 1.1 |
| Plutonium 239+240 (mBq/L) | 0.27 ± 0.74 | -0.09 ± 0.37 |
| Radium 226 (mBq/L) | 3.3 ± 4.8 | 3.2 ± 4.8 |
| Radium 228 (mBq/L) | -4 ± 11 | 13 ± 15 |
| Tritium | 5.6 ± 2.0 | 6.4 ± 1.8 |

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

(b) Nondetections of radioactive constituents are equal to or are less than the 2$\sigma$ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-EASTTCLFC [pH units; uS/cm; Degrees C; ug/L; mBq/L; Bq/L]   2009 data
(created 2010-03-08 15:08:22, Oracle) (epprd02.llnl.gov)

**A.5.6 Livermore site East Traffic Circle Landfill surveillance well 906, 2009**

| Type<br>Constituents of concern | W-906<br><br>3-Jun |
|---|---|
| Inorganic | |
| Field pH (pH units) | 7.63 |
| Field Conductivity (µS/cm) | 2160 |
| Water temperature (Degrees C) | 19.9 |
| Metals (µg/L)[(a)] | |
| Copper | <10 |
| Lead | <50 |
| Zinc | <10 |
| Radioactive (Bq/L)[(b)] | |
| Plutonium 238 (mBq/L) | 0.9 ± 2.6 |
| Plutonium 239+240 (mBq/L) | 1.3 ± 1.3 |
| Radium 226 (mBq/L) | 1.0 ± 3.1 |
| Radium 228 (mBq/L) | 6 ± 21 |
| Tritium | 3.2 ± 1.8 |

(a)  Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.
(b)  Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-LSNITRATE [mg/L]   2009 data   (created 2010-03-08 15:08:46, Oracle) (epprd02.llnl.gov)

**A.5.7 Nitrate concentrations in selected Livermore site surveillance wells, 2009**

| Area<br>Location | Screened in HSU | Sampling date | Nitrate as NO3 (mg/L) |
|---|---|---|---|
| Nitrate wells | | | |
| W-1012 | 2 | 20-Jan | 32 |
| W-1012 | 2 | 6-Jul | 29 |
| W-571 | 1B | 20-Jan | 35 |

GW-B331 [Bq/L] 2009 data (created 2010-03-08 15:07:45, Oracle) (epprd02.llnl.gov)

**A.5.8 Livermore site Tritium Facility surveillance wells, 2009**

| Area<br>Location | Screened in HSU | Sampling date | Tritium (Bq/L) |
|---|---|---|---|
| Upgradient of Tritium Facility | | | |
| W-305 | 2 | 6-Apr | 5.5 ± 2.0 |
| Downgradient of Tritium Facility | | | |
| W-101 | 1B | 6-Apr | 9.7 ± 2.2 |
| W-147 | 1B | 23-Apr | 5.8 ± 2.0 |
| W-148 | 1B | 23-Apr | 36.0 ± 4.4 |
| W-148 | 1B | 14-Dec | 45.0 ± 9.6 |

**A.5.9 Livermore site perimeter off-site surveillance wells, 2009**

| Type<br>Constituents of concern | 14B1 | 14B1 | W-121 | W-121 | W-151 | W-151 | W-571 | W-571 |
|---|---|---|---|---|---|---|---|---|
| | 12-Jan | 1-Jul | 12-Jan | 1-Jul | 12-Jan | 1-Jul | 20-Jan | 6-Jul |
| Inorganic | | | | | | | | |
| Field pH (pH units) | 7.01 | 6.88 | 7.82 | 7.76 | 7.6 | 7.48 | 7.38 | 7.23 |
| Field Conductivity (μS/cm) | 914 | 898 | 760 | 748 | 947 | 931 | 848 | 868 |
| Water temperature (Degrees C) | 18.1 | 20.2 | 19.1 | 19.6 | 18.7 | 19.8 | 19.1 | 18.8 |
| General minerals (mg/L) | | | | | | | | |
| Bromide | 0.5 | (a) | 0.5 | (a) | 0.6 | (a) | 0.7 | (a) |
| Chloride | 100 | (a) | 86 | (a) | 100 | (a) | 89 | (a) |
| Fluoride | 0.2 | (a) | 0.3 | (a) | 0.3 | (a) | 0.4 | (a) |
| Nitrate | 38 | (a) | 31 | (a) | 41 | (a) | 35 | (a) |
| Ortho-Phosphate | 0.2 | (a) | 0.2 | (a) | 0.2 | (a) | 0.2 | (a) |
| Sulfate | 40 | (a) | 40 | (a) | 43 | (a) | 35 | (a) |
| Radioactive (Bq/L)(b) | | | | | | | | |
| Gross alpha | 0.021 ± 0.059 | (a) | -0.029 ± 0.092 | (a) | 0.016 ± 0.048 | (a) | 0.066 ± 0.059 | (a) |
| Gross beta | 0.071 ± 0.033 | (a) | 0.061 ± 0.029 | (a) | 0.075 ± 0.030 | (a) | 0.090 ± 0.041 | (a) |
| Radium 226 (mBq/L) | 4.6 ± 5.2 | (a) | 0.1 ± 4.1 | (a) | 2.7 ± 4.4 | (a) | 2.3 ± 4.8 | (a) |
| Tritium | 3.3 ± 1.8 | 2.4 ± 1.8 | 2.2 ± 1.7 | -0.2 ± 1.7 | 2.3 ± 1.7 | 1.2 ± 1.8 | 3.4 ± 1.9 | 5.5 ± 1.9 |

(a) Analysis was not conducted for that sampling event.
(b) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

**A.5.10 Livermore site perimeter on-site surveillance wells, 2009**

| Type<br>Constituents of concern | W-1012 | W-1012 | W-556 | W-556 | W-373 | W-373 |
|---|---|---|---|---|---|---|
| | 20-Jan | 6-Jul | 12-Jan | 6-Jul | 12-Jan | 7-Jul |
| Inorganic | | | | | | |
| Field pH (pH units) | 7.23 | 7.12 | 7.34 | 7.24 | 7.42 | 7.26 |
| Field Conductivity (µS/cm) | 934 | 920 | 1130 | 1140 | 969 | 965 |
| Water temperature (Degrees C) | 18.8 | 19.4 | 19.5 | 19.4 | 19.2 | 18.8 |
| Metals (µg/L) | | | | | | |
| Chromium(VI) | 17 | (a) | 17 | (a) | 5 | (a) |
| General minerals (mg/L)[(b)] | | | | | | |
| Bromide | 0.5 | (a) | 1 | (a) | (a) | (a) |
| Chloride | 82 | (a) | 170 | (a) | (a) | (a) |
| Fluoride | 0.3 | (a) | 0.3 | (a) | (a) | (a) |
| Nitrate | 32 | 29 | 34 | (a) | (a) | (a) |
| Ortho-Phosphate | 0.1 | (a) | 0.1 | (a) | (a) | (a) |
| Sulfate | 38 | (a) | 41 | (a) | (a) | (a) |
| Radioactive (Bq/L)[(b)] | | | | | | |
| Gross alpha | 0.21 ± 0.11 | (a) | 0.18 ± 0.10 | (a) | 0.074 ± 0.096 | (a) |
| Gross beta | 0.087 ± 0.031 | (a) | 0.077 ± 0.048 | (a) | 0.110 ± 0.044 | (a) |
| Tritium | 6.3 ± 2.1 | 5.7 ± 1.9 | 3.4 ± 1.7 | 3.7 ± 1.8 | 8.9 ± 2.0 | (a) |

(a) Analysis was not conducted for that sampling event.
(b) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-NIF [pH units; uS/cm; Degrees C; Bq/L]   2009 data    (created 2010-03-08 15:09:00, Oracle) (epprd02.llnl.gov)

**A.5.11 Livermore site near the National Ignition Facility (NIF) surveillance wells, 2009**

| Type<br>Constituents of concern | W-653 | W-1207 |
|---|---|---|
| | 28-Apr | 28-Apr |
| Inorganic | | |
| Field pH (pH units) | 6.59 | 7.18 |
| Field Conductivity (µS/cm) | 1390 | 2060 |
| Water temperature (Degrees C) | 9.7 | 18.4 |
| Radioactive (Bq/L)[a] | | |
| Tritium | -2.4 ± 1.8 | -1.9 ± 1.8 |

(a) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-LSPU [pH units; uS/cm; Degrees C; mBq/L]   2009 data    (created 2010-07-14 10:56:54, Oracle) (epprd02.llnl.gov)

**A.5.12 Livermore site Plutonium Facility surveillance wells, 2009**

| Type<br>Constituents of concern | W-305 | W-101 | W-148 | W-147 |
|---|---|---|---|---|
| | 6-Apr | 6-Apr | 23-Apr | 23-Apr |
| Inorganic | | | | |
| Field pH (pH units) | 7.42 | 7.1 | 7.73 | 7.25 |
| Field Conductivity (µS/cm) | 756 | 1030 | 979 | 1080 |
| Water temperature (Degrees C) | 21 | 19.8 | 20.2 | 20.3 |
| Radioactive (mBq/L)[(a)] | | | | |
| Plutonium 238 | 0.2 ± 1.2 | 0.4 ± 1.2 | 0.31 ± 0.78 | 0.75 ± 0.81 |
| Plutonium 239+240 | 0.24 ± 0.48 | -0.14 ± 0.59 | 0.16 ± 0.31 | 0.08 ± 0.48 |

(a) Nondetections of radioactive constituents are equal to or are less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-TAXI [pH units; uS/cm; Degrees C; ug/L; mBq/L; Bq/L]   2009 data    (created 2010-03-08 15:09:15, Oracle) (epprd02.llnl.gov)

**A.5.13  Livermore site Taxi Strip surveillance wells, 2009**

| Type<br>Constituents of concern | W-204 | W-363 | W-363 |
|---|---|---|---|
| | 14-Jan | 13-Jan | 8-Apr |
| Inorganic | | | |
| Field pH (pH units) | 7.64 | 7.75 | (a) |
| Field Conductivity (µS/cm) | 517 | 509 | (a) |
| Water temperature (Degrees C) | 20.9 | 18.4 | (a) |
| Metals (µg/L)[b] | | | |
| Copper | <10 | <10 | (a) |
| Lead | <50 | <50 | (a) |
| Zinc | <10 | <10 | (a) |
| Radioactive (Bq/L)[c] | | | |
| Plutonium 238 (mBq/L) | -0.2 ± 1.1 | 0.6 ± 1.2 | (a) |
| Plutonium 239+240 (mBq/L) | 0.00 ± 0.31 | 0.34 ± 0.67 | (a) |
| Tritium | 15.0 ± 1.9 | 19.0 ± 2.3 | 41.0 ± 4.8 |

(a)  Analysis was not conducted for that sampling event.

(b)  Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.

(c)  Nondetections of radioactive constituents are equal to or are less than the 2s uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

**A.5.14 Livermore site background surveillance wells, 2009**

| Type<br>Constituents of concern | W-008 | W-008 | W-221 | W-221 | W-017 | W-017 |
|---|---|---|---|---|---|---|
| | 7-Jan | 1-Jul | 14-Jan | 1-Jul | 7-Jan | 1-Jul |
| Inorganic | | | | | | |
| Field pH (pH units) | 7.4 | 7.27 | 6.63 | 6.79 | 6.7 | 6.98 |
| Field Conductivity (µS/cm) | 2550 | 2540 | 1630 | 1660 | 992 | 974 |
| Water temperature (Degrees C) | 17.9 | 20.1 | 17.6 | 20.2 | 16 | 19.3 |
| General minerals (mg/L)[(a)] | | | | | | |
| Bromide | 3.9 | (b) | 1 | (b) | 1.4 | (b) |
| Chloride | 510 | (b) | 250 | (b) | 200 | (b) |
| Fluoride | 1.5 | (b) | 0.7 | (b) | 0.5 | (b) |
| Nitrate | 29 | (b) | 31 | (b) | 5 | (b) |
| Ortho-Phosphate | <0.05 | (b) | <0.05 | (b) | 0.1 | (b) |
| Sulfate | 340 | (b) | 110 | (b) | 33 | (b) |
| Radioactive (Bq/L)[(c)] | | | | | | |
| Gross alpha | 0.14 ± 0.21 | (b) | 0.38 ± 0.24 | 0.36 ± 0.15 | -0.03 ± 0.14 | 0.110 ± 0.059 |
| Gross beta | 0.140 ± 0.081 | (b) | 0.05 ± 0.18 | 0.032 ± 0.052 | -0.03 ± 0.14 | 0.039 ± 0.081 |
| Radium 226 (mBq/L) | 2.5 ± 5.2 | (b) | 2.8 ± 4.8 | (b) | 30.0 ± 9.2 | (b) |
| Tritium | 3.1 ± 1.7 | (b) | 20.0 ± 2.0 | 15.0 ± 2.5 | 1.9 ± 1.7 | 0.9 ± 1.8 |

(a) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis.
(b) Analysis was not conducted for that sampling event.
(c) Nondetections of radioactive constituents are equal to or are less than the 2$\sigma$ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-H3VAL [Bq/L]   2009 data   (created 2010-03-13 13:35:06, Oracle) (epprd02.llnl.gov)

**A.5.15  Tritium activity in Livermore Valley wells, 2009**

| Location | Date | Tritium (Bq/L)[a] |
|---|---|---|
| 7C2 | 10-Aug | 1.5 ± 1.8 |
| 8F1 | 4-Jun | 1.5 ± 1.8 |
| 9Q1 | 4-Jun | 1.1 ± 1.8 |
| 11B1 | 10-Aug | 0.9 ± 2.0 |
| 16B1 | 4-Jun | 0.1 ± 1.7 |
| 7P3 | 4-Jun | -0.2 ± 1.7 |
| 2R1 | 10-Aug | -0.7 ± 2.0 |
| 12G1 | 10-Aug | -0.9 ± 2.0 |
| 12A2 | 10-Aug | -1.2 ± 1.9 |
| 1H3 | 10-Aug | -1.2 ± 1.9 |
| 8H18 | 30-Jun | -1.6 ± 2.0 |
| 9M3 | 23-Jun | -1.6 ± 2.0 |
| 16A2 | 9-Jun | -1.7 ± 2.0 |
| 12D2 | 10-Aug | -1.8 ± 1.9 |
| 9B1 | 8-Jun | -2.4 ± 1.9 |
| 1R2 | 10-Aug | -2.7 ± 2.0 |
| 16L5 | 9-Jun | -2.7 ± 1.9 |

(a)  Nondetections of tritium are equal to or less than the $2\sigma$ uncertainty shown.  A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus. The result is zero when the measured sample radioactivity is equal to the measured background radioactivity.

GW-S3ANNL [ug/L; mg/L; Bq/L]   2009 data    (created 2010-03-12 14:53:57, Oracle) (epprd02.llnl.gov)

**A.6.1  Site 300 annually monitored off-site surveillance wells, 2009**

| Type<br>Constituents of concern[a] | MUL1 | MUL2 | STONEHAM1 | VIE1 | VIE2 | W-35A-04 | W-35A-04 | W-35A-04 |
|---|---|---|---|---|---|---|---|---|
| | 27-Aug | 27-Aug | 3-Aug | 23-Jul | 23-Jul | 9-Feb | 13-May | 16-Dec |
| Inorganic (µg/L) | | | | | | | | |
| Arsenic | (b) | <2 | <2 | 12 | <2 | 2 | (b) | 3.6 |
| Barium | (b) | <25 | 30 | 41 | 27 | 49 | (b) | 50 |
| Beryllium | (b) | <5 | <2.5 | <0.5 | <0.5 | (b) | (b) | <2.5 |
| Cadmium | (b) | <0.5 | <0.5 | <0.5 | <0.5 | <50 | (b) | <0.5 |
| Chromium | (b) | <1 | <1 | <1 | <1 | <1 | (b) | <1 |
| Cobalt | (b) | <25 | <25 | <25 | <25 | (b) | (b) | <25 |
| Copper | (b) | <10 | <10 | <10 | <10 | 1.7 | <10 | <10 |
| Lead | (b) | <2 | <2 | <2 | <2 | <5 | (b) | <2 |
| Mercury | (b) | <0.2 | <0.2 | <0.2 | <0.2 | (b) | (b) | <0.2 |
| Molybdenum | (b) | <25 | <25 | <25 | <25 | <50 | (b) | <25 |
| Nickel | (b) | <5 | 8.5 | <5 | <5 | <2 | (b) | <5 |
| Nitrate (mg/L) | (b) | 10 | 3.8 | (b) | 22 | 13 | 12 | 11 |
| Perchlorate (mg/L) | (b) | <0.004 | <0.004 | <0.004 | <0.004 | (b) | (b) | <0.004 |
| Potassium (mg/L) | (b) | 11 | (b) | 6.1 | (b) | 5.4 | (b) | 6 |
| Selenium | (b) | 3 | 2.5 | 3 | <2 | 3 | (b) | 4 |
| Silver | (b) | <0.5 | <0.5 | <0.5 | <0.5 | (b) | (b) | <0.5 |
| Thallium | (b) | <1 | <1 | <1 | <1 | (b) | (b) | <1 |
| Vanadium | (b) | <25 | <25 | 28 | <25 | <20 | (b) | <25 |
| Zinc | (b) | <20 | <20 | <20 | 76 | <5 | (b) | <20 |
| Organic (µg/L)[c] | | | | | | | | |
| EPA 502.2 | (b) | 0 of 60 | 0 of 60 | 0 of 60 | (b) | (b) | (b) | 0 of 60 |
| EPA 625 | (b) | 0 of 61 | 0 of 62 | 0 of 61 | 0 of 61 | (b) | (b) | 0 of 62 |
| Explosive (µg/L) | | | | | | | | |
| HMX[d] | (b) | <1 | <1 | <1 | <1 | (b) | (b) | <1 |
| RDX[e] | (b) | <1 | <1 | <1 | <1 | (b) | (b) | <1 |
| Radioactive (Bq/L)[f] | | | | | | | | |
| Gross alpha | 0.020 ± 0.036 | 0.035 ± 0.078 | 0.69 ± 0.26 | 0.14 ± 0.10 | 0.11 ± 0.10 | (b) | (b) | 0.052 ± 0.048 |
| Gross beta | 0.180 ± 0.067 | 0.330 ± 0.063 | 0.490 ± 0.096 | 0.190 ± 0.037 | 0.110 ± 0.041 | (b) | (b) | 0.140 ± 0.050 |
| Tritium | -1.9 ± 1.8 | -0.8 ± 1.9 | -0.6 ± 1.8 | 0.1 ± 1.8 | 2.4 ± 1.8 | (b) | (b) | -0.1 ± 2.2 |
| Uranium (calculated total) | (b) | 0.0260 ± 0.0051 | 0.970 ± 0.071 | 0.1000 ± 0.0090 | 0.190 ± 0.015 | (b) | (b) | 0.170 ± 0.027 |

(a)  Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.
(b)  An analysis was not conducted for that sampling event.
(c)  See *Environmental Report 2009,* Appendix B for EPA methods 502.2 and 625 constituents and their RLs.
(d)  HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
(e)  RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.
(f)  Nondetections of radioactive constituents are equal to or less than their 2σ uncertainty shown.  A negative number means the sample radioactivity  was less than the background radioactivity.

**A.6.2 Site 300 off-site surveillance well CARNRW1, 2009**

| Type<br>Constituents of concern | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 | CARNRW1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7-Jan | 2-Feb | 2-Mar | 1-Apr | 4-May | 1-Jun | 7-Jul | 3-Aug | 1-Sep | 5-Oct | 3-Nov | 1-Dec |
| Inorganic (µg/L)[(a)] | | | | | | | | | | | | |
| Perchlorate | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 | <4 |
| Organic (µg/L)[(b)] | | | | | | | | | | | | |
| EPA 601 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 |
| Radioactive (Bq/L)[(c)] | | | | | | | | | | | | |
| Tritium | -2.1 ± 1.9 | -1.1 ± 2.0 | 1.3 ± 1.8 | 1.6 ± 1.8 | -1.1 ± 1.8 | -1.0 ± 1.8 | 0.6 ± 1.8 | -2.6 ± 1.8 | -0.7 ± 1.9 | -2.2 ± 1.9 | 0.1 ± 1.8 | 0.6 ± 2.0 |

(a) Constituent nondetections are shown as less than (<) the reporting limit (RL) for that analysis.
(b) See *Environmental Report 2009,* Appendix B, for EPA Method 601 constituents and RLS.
(c) Nondetections of radioactive constituents are equal to or less than their 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

**A.6.3 Site 300 off-site surveillance well CARNRW2, 2009**

| Type<br>Constituents of concern[(a)] | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 | CARNRW2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7-Jan | 2-Feb | 2-Mar | 1-Apr | 4-May | 1-Jun | 7-Jul | 3-Aug | 1-Sep | 5-Oct | 3-Nov | 1-Dec |
| Inorganic (µg/L) | | | | | | | | | | | | |
| Arsenic | 4.6 | (b) | (b) | 3.3 | (b) | (b) | 2.3 | (b) | (b) | 2.6 | (b) | (b) |
| Barium | 16 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Beryllium | <2.5 | (b) | (b) | <0.5 | (b) | (b) | <2.5 | (b) | (b) | <0.5 | (b) | (b) |
| Cadmium | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) |
| Chromium | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) |
| Cobalt | <50 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Copper | <10 | (b) | (b) | <10 | (b) | (b) | <10 | (b) | (b) | <10 | (b) | (b) |
| Lead | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) |
| Mercury | <0.2 | (b) | (b) | <0.2 | (b) | (b) | <0.2 | (b) | (b) | <0.2 | (b) | (b) |
| Molybdenum | 27 | (b) | (b) | 25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Nickel | <5 | (b) | (b) | <5 | (b) | (b) | <5 | (b) | (b) | <5 | (b) | (b) |
| Nitrate (mg/L) | 0.75 | <0.5 | 1.4 | 0.61 | <0.5 | <0.5 | 0.68 | 1.9 | 0.5 | <0.5 | <0.5 | <0.5 |
| Perchlorate (mg/L) | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| Selenium | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) |
| Silver | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) |
| Thallium | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) |
| Vanadium | <10 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Zinc | <10 | (b) | (b) | 48 | (b) | (b) | <20 | (b) | (b) | <20 | (b) | (b) |
| Organic (µg/L)[(c)] | | | | | | | | | | | | |
| EPA 502.2 | 0 of 60 | (b) | (b) | 0 of 60 | (b) | (b) | 0 of 60 | (b) | (b) | 0 of 59 | (b) | (b) |
| EPA 625 | 0 of 62 | (b) | (b) | (b) | (b) | (b) | 0 of 62 | (b) | (b) | (b) | (b) | (b) |
| Explosive (µg/L) | | | | | | | | | | | | |
| HMX[(d)] | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) |
| RDX[(e)] | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) |
| Radioactive (Bq/L)[(f)] | | | | | | | | | | | | |
| Gross alpha | -0.14 ± 0.27 | (b) | (b) | -0.046 ± 0.059 | (b) | (b) | -0.012 ± 0.041 | (b) | (b) | 0.026 ± 0.042 | (b) | (b) |
| Gross beta | 0.31 ± 0.11 | (b) | (b) | 0.35 ± 0.14 | (b) | (b) | 0.270 ± 0.052 | (b) | (b) | 0.190 ± 0.079 | (b) | (b) |
| Tritium | -1.4 ± 1.9 | -0.4 ± 2.0 | 1.6 ± 1.8 | 2.9 ± 1.9 | -0.9 ± 1.8 | -1.3 ± 1.8 | 0.3 ± 1.8 | 0.3 ± 1.9 | -1.2 ± 1.9 | -0.1 ± 1.8 | 1.7 ± 1.9 | 1.5 ± 2.0 |
| Uranium (calculated total) | 0.0003 ± 0.0012 | (b) | (b) | 0.0017 ± 0.0012 | (b) | (b) | 0.00068 ± 0.00088 | (b) | (b) | 0.00130 ± 0.00074 | (b) | (b) |

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.
(b) An analysis was not conducted for that sampling event.
(c) See *Environmental Report 2009,* Appendix B for EPA methods 502.2 and 625 constituents and RLs.
(d) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
(e) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.
(f) Nondetections of radioactive constituents are equal to or less than their 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

GW-CDF1 [ug/L; Bq/L] 2009 data (created 2010-03-12 16:34:57, Oracle) (epprd02.llnl.gov)

**A.6.4 Site 300 off-site surveillance well CDF1, 2009**

| Type<br>Constituents of concern[a] | CDF1 |
|---|---|
| | 13-Jan |
| Inorganic (µg/L) | |
| Arsenic | 5 |
| Barium | 27 |
| Beryllium | <0.5 |
| Cadmium | <0.5 |
| Cobalt | <25 |
| Copper | <10 |
| Lead | <2 |
| Nickel | <5 |
| Vanadium | <25 |
| Zinc | <20 |
| Organic (µg/L)[b] | |
| EPA 502.2 | 0 of 60 |
| Explosive (µg/L) | |
| HMX[c] | <1 |
| RDX[d] | <1 |
| Radioactive (Bq/L)[e] | |
| Gross alpha | -0.091 ± 0.096 |
| Gross beta | 0.270 ± 0.052 |
| Tritium | 1.6 ± 2.0 |

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) See *Environmental Report 2009,* Appendix B, for EPA Method 502.2 constituents and RLS.

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

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

(e) Nondetections of radioactive constituents are equal to or less than their 2$\sigma$ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

GW-CON1 [ug/L; Bq/L] 2009 data (created 2010-03-12 16:35:07, Oracle) (epprd02.llnl.gov)

**A.6.5 Site 300 off-site surveillance well CON1, 2009**

| Type<br>Constituents of concern[a] | CON1 |
|---|---|
| | 13-Jan |
| Inorganic (µg/L) | |
| Arsenic | <2 |
| Barium | 25 |
| Beryllium | <0.5 |
| Cadmium | <0.5 |
| Cobalt | <25 |
| Copper | <10 |
| Lead | <2 |
| Nickel | <5 |
| Vanadium | <25 |
| Zinc | <20 |
| Organic (µg/L)[b] | |
| EPA 502.2 | 0 of 60 |
| Explosive (µg/L) | |
| HMX[c] | <1 |
| RDX[d] | <1 |
| Radioactive (Bq/L)[e] | |
| Gross alpha | -0.04 ± 0.13 |
| Gross beta | 0.350 ± 0.092 |
| Tritium | 0.8 ± 2.0 |

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.

(b) See *Environmental Report 2009,* Appendix B, for EPA Method 502.2 constituents and RLS.

(c) HMX is octahydro-1,3,5,6-tetranitro-1,3,5,7-tetrazocine.

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

(e) Nondetections of radioactive constituents are equal to or less than their 2σ uncertainty shown.
A negative number means the sample radioactivity was less than the background radioactivity.

**A.6.6 Site 300 off-site surveillance well CON2, 2009**

| Type<br>Constituents of concern | CON2 | CON2 | CON2 | CON2 | CON2 | CON2 | CON2 | CON2 | CON2 | CON2 | CON2 | CON2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13-Jan | 18-Feb | 12-Mar | 22-Apr | 20-May | 9-Jun | 20-Jul | 17-Aug | 10-Sep | 19-Oct | 16-Nov | 9-Dec |
| Organic (μg/L)[a] | | | | | | | | | | | | |
| EPA 601 | 0 of 32 | 0 of 32 | 0 of 29 | 0 of 32 | 0 of 31 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 | 0 of 32 |

(a)  See *Environmental Report 2009,* Appendix B, for EPA Method 601 constituents and reporting limits.

**A.6.7 Elk Ravine surveillance wells, Site 300, 2009**

| Type<br>Constituents of concern[a] | NC7-61 | NC7-61 | NC7-61 | NC7-61 | NC7-69 | NC7-69 | K2-04D | K2-04S | K2-01C | K2-01C | NC2-12D | NC2-11D | 812CRK (Spring 6) | 812CRK (Spring 6) | NC2-07 | NC2-07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21-Jan | 6-Apr | 6-Aug | 12-Nov | 2-Apr | 18-Nov | 9-Apr | 9-Apr | 13-Jan | 6-May | 15-Apr | 15-Apr | 20-Apr | 4-Aug | 29-Apr | 12-Nov |
| Inorganic (μg/L) | | | | | | | | | | | | | | | | |
| Arsenic | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | 37 | 40 |
| Barium | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | 39 | 40 |
| Beryllium | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <0.5 | <0.5 |
| Cadmium | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <0.5 | <0.5 |
| Chromium | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <1 | <1 |
| Cobalt | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <50 | <25 |
| Copper | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <10 | <10 |
| Lead | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <2 | <2 |
| Mercury | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <0.2 | <0.2 |
| Molybdenum | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <25 | <25 |
| Nickel | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <5 | <5 |
| Nitrate (mg/L) | 66 | (b) | 65 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) |
| Selenium | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | 3 | 3.8 |
| Silver | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <0.5 | <0.5 |
| Thallium | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <1 | <1 |
| Vanadium | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | 46 | 54 |
| Zinc | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | 40 | <20 |
| Organic (μg/L)[c] | | | | | | | | | | | | | | | | |
| EPA 601 | (b) | (b) | (b) | (b) | 0 of 32 | 0 of 32 | (b) | (b) | (b) | 0 of 32 | (b) | (b) | (b) | 0 of 32 | (b) | (b) |
| Explosive (μg/L) | | | | | | | | | | | | | | | | |
| HMX[d] | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <1 | <1 |
| RDX[e] | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | <1 | <1 |
| Radioactive (Bq/L)[f] | | | | | | | | | | | | | | | | |
| Gross alpha | (b) | 0.089 ± 0.085 | (b) | (b) | 0.016 ± 0.037 | (b) | 0.036 ± 0.041 | 0.100 ± 0.055 | 0.130 ± 0.067 | (b) | 0.041 ± 0.041 | 0.100 ± 0.055 | 0.200 ± 0.085 | (b) | 0.100 ± 0.078 | 0.23 ± 0.11 |
| Gross beta | (b) | 0.150 ± 0.035 | (b) | (b) | 0.220 ± 0.048 | (b) | 0.096 ± 0.041 | 0.073 ± 0.028 | 0.170 ± 0.044 | (b) | 0.096 ± 0.030 | 0.160 ± 0.044 | 0.180 ± 0.037 | (b) | 0.240 ± 0.041 | 0.310 ± 0.094 |
| Tritium | (b) | 980 ± 100 | (b) | 1100 ± 210 | (b) | (b) | (b) | (b) | (b) | (b) | (b) | (b) | -0.2 ± 1.7 | (b) | -1.1 ± 1.9 | 0.2 ± 1.8 |

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.
(b) An analysis was not conducted for that sampling event.
(c) See *Environmental Report 2009,* Appendix B for EPA method 601 constituents and RLs.
(d) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
(e) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.
(f) Nondetections of radioactive constituents are equal to or less than their 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

GW-GALLO1 [ug/L; mg/L; Bq/L] 2009 data (created 2010-03-08 15:08:32, Oracle) (epprd02.llnl.gov)

**A.6.8 Site 300 off-site surveillance well GALLO1, 2009**

| Type<br>Constituents of concern[a] | GALLO1<br>13-Jan | GALLO1<br>22-Apr | GALLO1<br>20-May | GALLO1<br>23-Jul | GALLO1<br>17-Aug | GALLO1<br>14-Oct |
|---|---|---|---|---|---|---|
| Inorganic (µg/L) | | | | | | |
| Arsenic | 4.4 | 4.8 | (b) | 2.1 | (b) | 4.5 |
| Barium | <25 | <25 | (b) | <25 | (b) | <25 |
| Beryllium | <0.5 | <0.5 | (b) | <0.5 | (b) | <0.5 |
| Cadmium | <0.5 | <0.5 | (b) | <0.5 | (b) | <0.5 |
| Cobalt | <25 | <25 | (b) | <25 | (b) | <25 |
| Copper | <10 | <10 | (b) | <10 | (b) | <10 |
| Lead | <2 | <2 | (b) | <2 | (b) | <2 |
| Nickel | <5 | <5 | (b) | <5 | (b) | <5 |
| Nitrate (mg/L) | <0.5 | (b) | <0.44 | (b) | <0.44 | <0.5 |
| Perchlorate (mg/L) | <0.004 | (b) | <0.004 | (b) | <0.004 | <0.004 |
| Vanadium | <25 | <25 | (b) | <25 | (b) | <25 |
| Zinc | <20 | 48 | (b) | <20 | (b) | <20 |
| Organic (µg/L)[c] | | | | | | |
| EPA 502.2 | 0 of 60 | 0 of 60 | (b) | 0 of 60 | (b) | 0 of 60 |
| Radioactive (Bq/L)[d] | | | | | | |
| Gross alpha | -0.051 ± 0.089 | -0.014 ± 0.067 | (b) | 0.026 ± 0.063 | (b) | 0.010 ± 0.039 |
| Gross beta | 0.160 ± 0.067 | 0.140 ± 0.055 | (b) | 0.120 ± 0.036 | (b) | 0.051 ± 0.036 |
| Tritium | 0.3 ± 1.9 | 0.1 ± 1.9 | (b) | 2.5 ± 1.8 | (b) | -0.2 ± 1.4 |

(a) Constituent nondetections other than radioactive are shown as less than (<) reporting limit (RL) for that analysis.
(b) An analysis was not conducted for that sampling event.
(c) See *Environmental Report 2009,* Appendix B, for EPA Method 502.2 constituents and RLs.
(d) Nondetections of radioactive constituents are equal to or less than the 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

**A.6.9 Site 300 potable supply well 18, 2009**

| Type<br>Constituents of concern[a] | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 | WELL18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21-Jan | 11-Feb | 12-Mar | 21-Apr | 21-May | 10-Jun | 15-Jul | 12-Aug | 17-Sep | 14-Oct | 11-Nov | 10-Dec |
| Inorganic (µg/L) | | | | | | | | | | | | |
| Nitrate (mg/L) | <0.5 | <0.5 | <0.5 | <0.5 | 0.7 | <0.5 | <0.5 | 0.53 | <0.5 | <0.5 | <0.5 | <0.5 |
| Explosive (µg/L) | | | | | | | | | | | | |
| HMX[b] | <1 | <1 | <1.3 | <0.74 | <1 | <1 | <0.69 | <0.72 | <0.67 | <1.4 | <1.2 | <1.1 |
| RDX[c] | <1 | <1 | <1.3 | <0.74 | <1 | <1 | <0.69 | <0.72 | <0.67 | <1.4 | <1.2 | <1.1 |

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.
(b) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
(c) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.

**A.6.10 Site 300 potable supply well 20, 2009**

| Type Constituents of concern[a] | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 | WELL20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21-Jan | 11-Feb | 12-Mar | 21-Apr | 21-May | 10-Jun | 15-Jul | 12-Aug | 17-Sep | 14-Oct | 11-Nov | 10-Dec |
| Inorganic (µg/L) | | | | | | | | | | | | |
| Arsenic | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) |
| Barium | 15 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Beryllium | <2.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) |
| Cadmium | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) |
| Chromium | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) |
| Cobalt | <50 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Copper | <10 | (b) | (b) | <10 | (b) | (b) | <10 | (b) | (b) | <10 | (b) | (b) |
| Lead | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) |
| Mercury | <0.2 | (b) | (b) | <0.2 | (b) | (b) | <0.2 | (b) | (b) | <0.2 | (b) | (b) |
| Molybdenum | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Nickel | <5 | (b) | (b) | <5 | (b) | (b) | <5 | (b) | (b) | <5 | (b) | (b) |
| Nitrate (mg/L) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.44 | <0.5 | <0.5 | <0.5 | <0.5 |
| Selenium | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) | <2 | (b) | (b) |
| Silver | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) | <0.5 | (b) | (b) |
| Thallium | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) | <1 | (b) | (b) |
| Vanadium | <10 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) | <25 | (b) | (b) |
| Zinc | <20 | (b) | (b) | 42 | (b) | (b) | <20 | (b) | (b) | <20 | (b) | (b) |
| Organic (µg/L)[c] | | | | | | | | | | | | |
| EPA 502.2 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 | 0 of 60 |
| Explosive (µg/L) | | | | | | | | | | | | |
| HMX[d] | <1 | <1 | <1.3 | <0.69 | <1 | <1.5 | <0.67 | <0.69 | <0.9 | <1 | <0.67 | <0.82 |
| RDX[e] | <1 | <1 | <1.3 | <0.69 | <1 | <1.5 | <0.67 | <0.69 | <0.9 | <1 | <0.67 | <0.82 |
| Radioactive (Bq/L)[f] | | | | | | | | | | | | |
| Gross alpha | -0.140 ± 0.078 | (b) | (b) | -0.023 ± 0.041 | (b) | (b) | -0.009 ± 0.044 | (b) | (b) | 0.008 ± 0.037 | (b) | (b) |
| Gross beta | 0.240 ± 0.044 | (b) | (b) | 0.300 ± 0.048 | (b) | (b) | 0.280 ± 0.048 | (b) | (b) | 0.120 ± 0.046 | (b) | (b) |
| Tritium | 2.9 ± 1.9 | (b) | (b) | -0.8 ± 1.8 | (b) | (b) | -1.1 ± 1.9 | (b) | (b) | 0.3 ± 1.4 | (b) | (b) |

(a) Constituent nondetections other than radioactive are shown as less than (<) the reporting limit (RL) for that analysis.
(b) An analysis was not conducted for that sampling event.
(c) See *Environmental Report 2009,* Appendix B for EPA method 502.2 constituents and its RLs.
(d) HMX is octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
(e) RDX is hexahydro-1,3,5-trinitro-1,3,5-triazine.
(f) Nondetections of radioactive constituents are equal to or less than their 2σ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity.

OW-DRBREL [mg/L; ug/L; mg O/L; -; Bq/L]   2009 data    (created 2010-06-09 17:08:32, Oracle) (epprd02.llnl.gov)

**A.7.1 Dry season (June 1 to September 30, 2009) monitoring data for releases from Lake Haussmann**

| Analyte type<br>Analyte | CDBX | CDBX | CDBX | CDBX | WPDC | WPDC | WPDC | WPDC |
|---|---|---|---|---|---|---|---|---|
| | 25-Jun | 5-Aug | 26-Aug | 29-Sep | 25-Jun | 5-Aug | 26-Aug | 29-Sep |
| **Biological aquatic bioassay** | | | | | | | | |
| Pimephales promelas survival (percent survival) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| General minerals (mg/L) | | | | | | | | |
| pH | 9.8 | 9.5 | 9.3 | 9.6 | 8.3 | 8.3 | 8.2 | 8.4 |
| **Total metals (mg/L)** | | | | | | | | |
| Aluminum | <0.05 | <0.05 | <0.05 | <0.05 | 0.34 | 0.25 | 0.2 | 0.19 |
| Antimony | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Arsenic | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Barium | 0.067 | 0.093 | 0.094 | 0.093 | 0.11 | 0.12 | 0.12 | 0.12 |
| Beryllium | <0.0002 | <0.002 | <0.002 | <0.002 | <0.0002 | <0.002 | <0.002 | <0.002 |
| Boron | 1.6 | 1.8 | 2 | 1.9 | 1.3 | 1.2 | 1.3 | 1.3 |
| Cadmium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Chromium | <0.003 | <0.003 | <0.003 | <0.003 | 0.011 | 0.011 | 0.007 | 0.0098 |
| Cobalt | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Copper | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Hexavalent Chromium | 0.0011 | 0.0015 | 0.0024 | 0.0014 | 0.0069 | 0.0072 | 0.0053 | 0.0074 |
| Iron | <0.05 | <0.05 | <0.05 | <0.05 | 0.45 | 0.36 | 0.28 | 0.25 |
| Lead | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Manganese | 0.0051 | 0.0016 | 0.0012 | 0.0014 | 0.014 | 0.011 | 0.006 | 0.0057 |
| Mercury | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Molybdenum | 0.0024 | 0.0029 | 0.0028 | 0.003 | 0.0022 | 0.0023 | 0.0023 | 0.0024 |
| Nickel | <0.002 | <0.002 | <0.002 | <0.002 | 0.0027 | 0.0025 | 0.0025 | <0.002 |
| Selenium | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Silver | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Thallium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Vanadium | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| **Polychlorinated biphenyls (µg/L)** | | | | | | | | |
| PCB 1016 | <0.5 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) | (a) |
| PCB 1221 | <0.5 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) | (a) |
| PCB 1232 | <0.5 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) | (a) |
| PCB 1242 | <0.5 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) | (a) |
| PCB 1248 | <0.5 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) | (a) |
| PCB 1254 | <0.5 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) | (a) |
| PCB 1260 | <0.5 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) | (a) |
| **Miscellaneous organics (mg/L)** | | | | | | | | |
| Total suspended solids (TSS) | 1.7 | 2.4 | 1.2 | <1.2 | 79 | 28 | 6.8 | 7.2 |

(a) no sample required

**A.7.2 Wet season (October 1 to May 31, 2009) monitoring data for releases from Lake Haussmann**

| Analyte type<br>Analyte | CDBX<br>22-Jan | CDBX<br>12-Oct | CDBX<br>13-Oct | WPDC<br>22-Jan | WPDC<br>12-Oct | WPDC<br>13-Oct |
|---|---|---|---|---|---|---|
| **Biological aquatic bioassay** | | | | | | |
| Pimephales promelas survival (percent survival) | (a) | 90 | (a) | 95 | 100 | 95 |
| Pimephales promelas growth LOEC | (a) | 100 | (a) | 100 | (a) | (a) |
| Pimephales promelas growth NOEC | (a) | 100 | (a) | 100 | (a) | (a) |
| Selanastrum capricomutum growth LOEC | (a) | 100 | (a) | (a) | (a) | (a) |
| Selanastrum capricomutum growth NOEC | (a) | 100 | (a) | (a) | (a) | (a) |
| Ceriodaphnia dubia reproduction NOEC | (a) | 100 | (a) | (a) | (a) | (a) |
| Ceriodaphnia dubia reproduction LOEC | (a) | 100 | (a) | (a) | (a) | (a) |
| **General minerals (mg/L)** | | | | | | |
| pH | 8 | 9 | 8.8 | 7.6 | 6.2 | 7.2 |
| Total dissolved solids (TDS) | 410 | 840 | 750 | 180 | 590 | 190 |
| Specific Conductance | (a) | 1300 | (a) | (a) | 960 | (a) |
| **Total metals (mg/L)** | | | | | | |
| Aluminum | 1.3 | <0.05 | <0.05 | 1.3 | 0.17 | 2.5 |
| Antimony | <0.002 | <0.005 | <0.005 | <0.002 | <0.005 | <0.005 |
| Arsenic | 0.003 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Barium | 0.12 | 0.13 | 0.11 | 0.066 | 0.12 | 0.087 |
| Beryllium | <0.0002 | <0.004 | <0.002 | <0.0002 | <0.002 | <0.002 |
| Boron | 1.3 | 2.6 | 2.1 | 0.46 | 1.5 | 0.28 |
| Cadmium | <0.001 | <0.0005 | <0.0005 | <0.001 | <0.0005 | <0.0005 |
| Chromium | <0.003 | 0.0046 | 0.0048 | <0.003 | 0.007 | 0.021 |
| Cobalt | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Copper | 0.0042 | <0.001 | <0.001 | 0.0054 | 0.0014 | 0.022 |
| Hexavalent Chromium | 0.00037 | 0.0047 | 0.0043 | 0.00069 | 0.007 | <0.0002 |
| Iron | 1.5 | <0.1 | <0.1 | 1.7 | 0.25 | 3.6 |
| Lead | 0.001 | <0.005 | <0.005 | 0.0012 | <0.005 | 0.0072 |
| Manganese | 0.035 | <0.03 | <0.03 | 0.033 | <0.03 | 0.19 |
| Mercury | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.0002 |
| Molybdenum | 0.003 | <0.025 | <0.025 | 0.0015 | <0.025 | <0.025 |
| Nickel | 0.006 | <0.002 | 0.0022 | 0.0046 | <0.002 | 0.017 |
| Selenium | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Silver | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Thallium | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Vanadium | <0.01 | <0.02 | <0.02 | <0.01 | <0.02 | <0.02 |
| Zinc | 0.053 | <0.02 | 0.027 | 0.15 | <0.02 | 0.23 |
| **Volatile organic compounds (µg/L)** | | | | | | |
| cis-1,2-Dichloroethene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Bromodichloromethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,2-Dichloroethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Vinyl chloride | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Total Trihalomethanes | <2 | (a) | (a) | (a) | (a) | (a) |
| Trichlorofluoromethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Trichloroethene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,1,2-Trichloroethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,1,1-Trichloroethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Tetrachloroethene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,1,2,2-Tetrachloroethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Methylene chloride | <1 | <1 | <1 | (a) | (a) | (a) |
| Methyl t-Butyl Ether | <0.5 | (a) | (a) | (a) | (a) | (a) |
| Freon 113 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| trans-1,3-Dichloropropene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| cis-1,3-Dichloropropene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,2-Dichloropropane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,2-Dichloroethene (total) | <1 | <1 | <1 | (a) | (a) | (a) |
| trans-1,2-Dichloroethene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,1-Dichloroethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 2-Chloroethylvinylether | <10 | <10 | <10 | (a) | (a) | (a) |
| 1,3-Dichlorobenzene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,2-Dichlorobenzene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,4-Dichlorobenzene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Chloroethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Dichlorodifluoromethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Dibromochloromethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Chloromethane | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Chloroform | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Chlorobenzene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Carbon tetrachloride | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| Bromomethane | <1 | <1 | <0.57 | (a) | (a) | (a) |
| Bromoform | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| 1,1-Dichloroethene | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| **Polychlorinated biphenyls (µg/L)** | | | | | | |
| PCB 1016 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| PCB 1221 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| PCB 1232 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| PCB 1242 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| PCB 1248 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| PCB 1254 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| PCB 1260 | <0.5 | <0.5 | <0.5 | (a) | (a) | (a) |
| **Herbicides (µg/L)** | | | | | | |
| Glyphosate | 14 | (a) | <5 | 6.7 | (a) | <5 |
| **Miscellaneous organics (mg/L)** | | | | | | |
| Chemical Oxygen Demand (mg O/L) | <25 | <25 | <25 | <25 | (a) | 120 |
| Oil and Grease | <5 | (a) | <5 | <5 | (a) | <5 |
| Total Organic Carbon (TOC) | 9 | 3 | 4.1 | 8.4 | (a) | 31 |
| Total suspended solids (TSS) | 19 | 2 | <1.1 | 25 | 5.1 | 140 |
| **Radioactive (Bq/L)[(b)]** | | | | | | |
| Gross alpha | 0.072 ± 0.059 | 0.120 ± 0.085 | (a) | 0.025 ± 0.059 | (a) | (a) |
| Gross beta | 0.150 ± 0.035 | 0.086 ± 0.096 | (a) | 0.130 ± 0.052 | (a) | (a) |
| Tritium | 2.9 ± 2.0 | 4.9 ± 3.4 | (a) | 5.3 ± 2.1 | (a) | (a) |

(a) No sample required

(b) Radioactivities are reported as the measured concentration and an uncertainty (±2σ counting error). If the concentration is less than or equal to the uncertainty, the result is considered to be a nondetection.

RA-H3 [Bq/L] 2009 data (created 2010-04-16 08:26:21, Oracle) (epprd02.llnl.gov)

**A.7.3 Tritium activities in rain water samples collected in the vicinity of the Livermore site, 2009**

| Site Location | 22-Jan[(a)] | 17-Feb[(a)] | 13-Oct[(a)] | 14-Oct[(a)] |
|---|---|---|---|---|
| Livermore site | | | | |
| SALV | 1.1 ± 1.9 | 4.3 ± 2.0 | 3.1 ± 1.7 | (b) |
| MET | 2.8 ± 2.0 | 3.8 ± 2.0 | 3.8 ± 1.7 | (b) |
| DWTF | 0.8 ± 1.9 | 4.3 ± 2.0 | 1.3 ± 1.7 | (b) |
| SECO | 3.0 ± 2.0 | 5.1 ± 2.0 | 3.4 ± 1.7 | (b) |
| Site 300 | | | | |
| ECP | 1.4 ± 2.0 | 3.1 ± 2.0 | (b) | 1.9 ± 1.7 |
| PSTL | -0.1 ± 1.9 | 2.5 ± 1.9 | 1.3 ± 1.7 | (b) |

(a) Nondetections of radioactive constituents are equal to or are less than the 2$\sigma$ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus.

(b) Sample location ECP was not accessible on October 13 so was sampled on October 14.

DW-RAD [Bq/L] 2009 data (created 2010-03-08 15:07:39, Oracle) (epprd02.llnl.gov)

**A.7.4 Radioactivity (Bq/L) in surface and drinking water in Livermore Valley, 2009**

| Site Location | Date | Tritium[a] | Gross alpha[a] | Gross beta[a] |
|---|---|---|---|---|
| Drinking waters | | | | |
| GAS | 18-Mar | 1.85 ± 1.78 | 0.0721 ± 0.0555 | 0.0969 ± 0.0311 |
| GAS | 13-Aug | -0.08 ± 1.85 | 0.0325 ± 0.0444 | 0.0858 ± 0.0366 |
| TAP | 18-Mar | 1.41 ± 1.78 | -0.0102 ± 0.0111 | 0.0282 ± 0.0355 |
| TAP | 13-Aug | 0.61 ± 1.89 | -0.00123 ± 0.00666 | 0.0030 ± 0.0204 |
| Surface waters | | | | |
| CAL | 13-Aug | -0.61 ± 1.85 | 0.0092 ± 0.0159 | 0.0503 ± 0.0407 |
| DEL | 13-Aug | 0.23 ± 1.85 | 0.0036 ± 0.0185 | 0.0803 ± 0.0252 |
| DUCK | 13-Aug | -0.15 ± 1.85 | 0.233 ± 0.166 | 0.3850 ± 0.0925 |
| ALAG | 13-Aug | -0.31 ± 1.85 | 0.0781 ± 0.0555 | 0.1540 ± 0.0444 |
| SHAD | 13-Aug | -0.77 ± 1.85 | 0.0229 ± 0.0629 | 0.0907 ± 0.0329 |
| ZON7 | 13-Aug | 0.08 ± 1.85 | 0.0103 ± 0.0189 | 0.0992 ± 0.0289 |

(a) Nondetections of radioactive constituents are equal to or are less than the 2$\sigma$ uncertainty shown. A negative number means the sample radioactivity was less than the background radioactivity inside the measurement apparatus.

SO-VAL [Bq/dry g; ug/dry g; mBq/dry g; Bq/L; ratio]   2009 data    (created 2010-05-04 17:41:28, Oracle) (epprd02.llnl.gov)

**A.8.1 Radionuclides in soils in the Livermore Valley, 2009**

| Area<br>Location | Cesium-137 (Bq/dry g) | Potassium-40 (Bq/dry g) | Thorium-232 (µg/dry g)[(a)] | Uranium-235 (µg/dry g)[(b)] | Uranium-238 (µg/dry g)[(c)] | U235/U238 activity ratio | Gross alpha (Bq/dry g) | Gross beta (Bq/dry g) | Plutonium-238 (mBq/dry g) | Plutonium-239+240 (mBq/dry g) | Americium-241 (mBq/dry g) | Tritium (Bq/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Livermore Valley soil | | | | | | | | | | | | |
| L-AMON-SO | 0.00170 ± 0.00023 | 0.5220 ± 0.0146 | 8.50 ± 0.22 | 0.022 ± 0.010 | 2.00 ± 0.99 | 0.0110 ± 0.0074 | (d) | (d) | 0.0008 ± 0.0011 | 0.0190 ± 0.0046 | <0.57 | (d) |
| L-CHUR-SO | 0.00270 ± 0.00025 | 0.4850 ± 0.0135 | 7.50 ± 0.19 | 0.0210 ± 0.0083 | 2.3 ± 2.0 | 0.0091 ± 0.0087 | (d) | (d) | 0.0008 ± 0.0020 | 0.110 ± 0.022 | <0.81 | (d) |
| L-COW-SO | 0.00036 ± 0.00024 | 0.5180 ± 0.0176 | 7.00 ± 0.18 | 0.0180 ± 0.0089 | 2.0 ± 1.3 | 0.0090 ± 0.0074 | (d) | (d) | 0.0015 ± 0.0014 | 0.064 ± 0.012 | <0.93 | (d) |
| L-ESB-SO | 0.00099 ± 0.00025 | 0.4110 ± 0.0148 | 8.20 ± 0.21 | 0.027 ± 0.010 | 2.7 ± 1.1 | 0.0100 ± 0.0055 | 0.130 ± 0.061 | 0.16 ± 0.11 | 0.170 ± 0.029 | 2.00 ± 0.29 | <0.97 | 5.0 ± 1.7 |
| L-FCC-SO | 0.00190 ± 0.00017 | 0.4180 ± 0.0118 | 6.00 ± 0.16 | 0.0170 ± 0.0097 | 2.3 ± 1.1 | 0.0074 ± 0.0055 | (d) | (d) | 0.0034 ± 0.0018 | 0.072 ± 0.013 | <0.63 | (d) |
| L-HOSP-SO | 0.00160 ± 0.00019 | 0.3850 ± 0.0116 | 5.70 ± 0.16 | 0.0170 ± 0.0093 | 1.9 ± 1.0 | 0.0089 ± 0.0068 | (d) | (d) | 0.0019 ± 0.0012 | 0.0490 ± 0.0094 | <0.92 | (d) |
| L-MESQ-SO | 0.00067 ± 0.00019 | 0.4550 ± 0.0127 | 7.00 ± 0.18 | 0.0210 ± 0.0088 | 2.2 ± 1.6 | 0.0095 ± 0.0080 | (d) | (d) | 0.0016 ± 0.0015 | 0.0360 ± 0.0075 | <0.8 | (d) |
| L-MET-SO | 0.00120 ± 0.00021 | 0.5250 ± 0.0168 | 6.90 ± 0.19 | 0.0180 ± 0.0089 | 2.1 ± 1.3 | 0.0086 ± 0.0068 | (d) | (d) | 0.0018 ± 0.0012 | 0.0480 ± 0.0091 | <0.57 | (d) |
| L-NEP-SO | 0.00210 ± 0.00021 | 0.4920 ± 0.0128 | 6.20 ± 0.15 | 0.0170 ± 0.0063 | 1.7 ± 1.4 | 0.0100 ± 0.0090 | 0.097 ± 0.054 | 0.22 ± 0.12 | 0.0039 ± 0.0016 | 0.076 ± 0.013 | <0.66 | 1.7 ± 1.5 |
| L-PATT-SO | 0.00110 ± 0.00027 | 0.5510 ± 0.0121 | 7.50 ± 0.15 | 0.0190 ± 0.0071 | 1.5 ± 1.0 | 0.0130 ± 0.0097 | (d) | (d) | 0.0016 ± 0.0012 | 0.0420 ± 0.0081 | <0.75 | (d) |
| L-SALV-SO | 0.00150 ± 0.00022 | 0.4290 ± 0.0112 | 6.40 ± 0.15 | 0.0160 ± 0.0073 | 1.7 ± 1.2 | 0.0094 ± 0.0079 | 0.150 ± 0.065 | 0.22 ± 0.12 | 0.0073 ± 0.0025 | 0.120 ± 0.020 | <0.7 | 1.9 ± 1.5 |
| L-TANK-SO | 0.00200 ± 0.00023 | 0.32700 ± 0.00980 | 6.40 ± 0.17 | 0.0150 ± 0.0081 | 1.6 ± 1.6 | 0.009 ± 0.011 | (d) | (d) | 0.0046 ± 0.0020 | 0.090 ± 0.015 | <0.72 | (d) |
| L-VIS-SO | 0.00084 ± 0.00020 | 0.3740 ± 0.0134 | 6.60 ± 0.20 | 0.0170 ± 0.0087 | 1.50 ± 0.92 | 0.0110 ± 0.0091 | 0.073 ± 0.051 | 0.27 ± 0.13 | 0.0180 ± 0.0041 | 0.330 ± 0.050 | <0.52 | 2.0 ± 1.5 |
| L-ZON7-SO | 0.00034 ± 0.00018 | 0.3920 ± 0.0110 | 7.60 ± 0.20 | 0.0450 ± 0.0090 | 4.8 ± 1.1 | 0.0094 ± 0.0029 | (d) | (d) | 0.0021 ± 0.0014 | 0.0300 ± 0.0064 | <0.84 | (d) |
| Median | 0.0014 | 0.442 | 7 | 0.018 | 2 | 0.0094 | 0.11 | 0.22 | 0.002 | 0.068 | (e) | 2 |
| IQR | 0.00097 | 0.115 | 1.1 | 0.004 | 0.57 | 0.00098 | (f) | (f) | 0.0028 | 0.062 | (f) | (f) |
| Maximum | 0.0027 | 0.551 | 8.5 | 0.045 | 4.8 | 0.013 | 0.15 | 0.27 | 0.17 | 2 | <0.97 | 5 |
| LWRP soil | | | | | | | | | | | | |
| L-WRP1-SO | 0.00380 ± 0.00026 | 0.40700 ± 0.00814 | 6.60 ± 0.15 | 0.0160 ± 0.0076 | 2.00 ± 0.72 | 0.0080 ± 0.0048 | (d) | (d) | 0.440 ± 0.065 | 7.8 ± 1.1 | 4.3 ± 1.3 | (d) |
| L-WRP3-SO | 0.00024 ± 0.00016 | 0.3880 ± 0.0101 | 7.30 ± 0.16 | 0.0160 ± 0.0074 | 2.1 ± 1.6 | 0.0076 ± 0.0068 | (d) | (d) | 0.0420 ± 0.0084 | 0.81 ± 0.12 | <0.71 | (d) |
| L-WRP6-SO | 0.00021 ± 0.00014 | 0.42200 ± 0.00840 | 6.60 ± 0.13 | 0.0140 ± 0.0079 | 1.80 ± 0.75 | 0.0078 ± 0.0055 | (d) | (d) | 0.0210 ± 0.0047 | 0.370 ± 0.056 | <0.55 | (d) |
| Median | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (e) | (e) |
| IQR | (f) | (f) | (f) | (f) | (f) | (f) | (f) | (f) | (f) | (f) | (f) | (f) |
| Maximum | 0.0038 | 0.422 | 7.3 | 0.016 | 2.1 | 0.008 | (d) | (d) | 0.44 | 7.8 | 4.3 | (d) |

Note:  Radioactivities are reported as the measured concentration and an uncertainty (± 2σ counting error), or as being less than or equal to the detection limit. If the concentration is less than or equal to the
(a)  Thorium-232 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of thorium-232, i.e., 0.004044 Bq/µg or 0.1093 pCi/µg.
(b)  Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of uranium-235, i.e., 0.080 Bq/µg or 2.16 pCi/µg.
(c)  Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of uranium-238, i.e., 0.01245 Bq/µg or 0.3367 pCi/µg.
(d)  Analysis not required.
(e)  Median not calculated because of small number of samples.
(f)   Interquartile range not calculated because of small number of samples.

SO-S3 [Bq/dry g; ug/dry g; mg/kg; ratio]   2009 data    (created 2010-04-20 15:59:08, Oracle) (epprd02.llnl.gov)

**A.8.2  Radionuclides and beryllium in soil at Site 300, 2009**

| Location | Cesium-137 (Bq/dry g) | Potassium-40 (Bq/dry g) | Thorium-232 (µg/dry g)[a] | Uranium-235 (µg/dry g)[b] | Uranium-238 (µg/dry g)[c] | U235/U238 mass ratio | Beryllium (mg/kg) |
|---|---|---|---|---|---|---|---|
| 3-801N-SO | 0.00190 ± 0.00031 | 0.4740 ± 0.0179 | 13.00 ± 0.30 | 0.029 ± 0.014 | 5.6 ± 1.6 | 0.0052 ± 0.0029 | <0.6 |
| 3-801W-SO | 0.00280 ± 0.00021 | 0.5400 ± 0.0141 | 10.00 ± 0.23 | 0.0390 ± 0.0095 | 9.5 ± 2.9 | 0.0041 ± 0.0016 | <1.5 |
| 3-812N-SO | 0.00150 ± 0.00022 | 0.3920 ± 0.0134 | 17.00 ± 0.40 | 0.230 ± 0.023 | 110.0 ± 8.1 | 0.00210 ± 0.00026 | 3.1 |
| 3-834W-SO | 0.00290 ± 0.00022 | 0.4550 ± 0.0118 | 11.00 ± 0.24 | 0.014 ± 0.011 | 1.4 ± 1.0 | 0.010 ± 0.011 | <0.2 |
| 3-851N-SO | 0.00230 ± 0.00030 | 0.4480 ± 0.0161 | 14.00 ± 0.30 | 0.027 ± 0.011 | 3.5 ± 1.6 | 0.0077 ± 0.0047 | <0.2 |
| 3-856N-SO | 0.00130 ± 0.00019 | 0.3960 ± 0.0111 | 10.00 ± 0.23 | 0.0240 ± 0.0090 | 2.40 ± 0.90 | 0.0100 ± 0.0053 | <1.5 |
| 3-DSW-SO | 0.00390 ± 0.00025 | 0.4400 ± 0.0114 | 9.10 ± 0.20 | 0.030 ± 0.012 | 3.3 ± 1.9 | 0.0091 ± 0.0064 | <2.5 |
| 3-EOBS-SO | 0.00110 ± 0.00017 | 0.4740 ± 0.0179 | 8.80 ± 0.32 | 0.022 ± 0.010 | 2.1 ± 1.7 | 0.0100 ± 0.0097 | <1 |
| 3-EVAP-SO | 0.00120 ± 0.00020 | 0.3810 ± 0.0107 | 13.00 ± 0.23 | 0.027 ± 0.013 | 4.7 ± 1.2 | 0.0057 ± 0.0031 | <0.79 |
| 3-NPS-SO | 0.00250 ± 0.00020 | 0.5810 ± 0.0104 | 7.70 ± 0.15 | 0.0140 ± 0.0083 | 1.60 ± 0.96 | 0.0088 ± 0.0074 | <0.2 |
| 3-TNK5-SO | 0.00230 ± 0.00024 | 0.5000 ± 0.0130 | 9.00 ± 0.18 | 0.0170 ± 0.0087 | 1.90 ± 0.97 | 0.0089 ± 0.0065 | <1.5 |
| 3-WOBS-SO | 0.00320 ± 0.00024 | 0.4110 ± 0.0107 | 7.60 ± 0.15 | 0.0180 ± 0.0071 | 2.8 ± 2.3 | 0.0064 ± 0.0059 | <2.5 |
| Median | 0.0023 | 0.452 | 10 | 0.026 | 3 | 0.0082 | <1.2 |
| IQR | 0.0014 | 0.0732 | 4.1 | 0.012 | 2.9 | 0.0038 | (d) |
| Maximum | 0.0039 | 0.581 | 17 | 0.23 | 110 | 0.01 | 3.1 |

Note:  Radioactivities are reported as the measured concentration and an uncertainty (± 2σ counting error), or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection.  See the *Environmental Report 2009*, Chapter 9.

(a)  Thorium-232 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of thorium-232, i.e., 0.004044 Bq/µg or 0.1093 pCi/µg.

(b)  Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of uranium-235, i.e., 0.080 Bq/µg or 2.16 pCi/µg.

(c)  Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by the specific activity of uranium-238, i.e., 0.01245 Bq/µg or 0.3367 pCi/µg.

(d)  Interquartile range not calculated because of small number of samples.

TLD-LS [mSv]   2009 data   (created 2010-04-13 14:15:43, Oracle) (epprd02.llnl.gov)

**A.9.1 Calculated dose from TLD environmental radiation measurements, Livermore site perimeter, 2009**

| Location[a] | Jan-Mar[b] | Apr-Jun[b] | Jul-Sep[b] | Oct-Dec[b] | Annual Dose[c] |
|---|---|---|---|---|---|
| L-001-TD | 0.145 ± 0.004 | 0.139 ± 0.006 | 0.149 ± 0.005 | 0.154 ± 0.017 | 0.587 ± 0.019 |
| L-004-TD | 0.151 ± 0.006 | 0.176 ± 0.098 | 0.158 ± 0.009 | 0.151 ± 0.019 | 0.636 ± 0.100 |
| L-005-TD | 0.153 ± 0.004 | 0.162 ± 0.008 | 0.167 ± 0.007 | 0.161 ± 0.016 | 0.643 ± 0.020 |
| L-006-TD | 0.156 ± 0.016 | 0.159 ± 0.008 | 0.156 ± 0.006 | 0.153 ± 0.000 | 0.624 ± 0.019 |
| L-011-TD | 0.128 ± 0.012 | (d) | 0.141 ± 0.012 | 0.139 ± 0.009 | 0.544 ± 0.025 |
| L-014-TD | 0.143 ± 0.003 | 0.148 ± 0.007 | 0.144 ± 0.006 | 0.141 ± 0.005 | 0.576 ± 0.011 |
| L-016-TD | 0.152 ± 0.011 | 0.137 ± 0.003 | 0.152 ± 0.021 | 0.151 ± 0.004 | 0.592 ± 0.024 |
| L-042-TD | 0.147 ± 0.002 | 0.148 ± 0.002 | 0.145 ± 0.010 | 0.152 ± 0.018 | 0.592 ± 0.021 |
| L-043-TD | 0.136 ± 0.004 | 0.132 ± 0.005 | 0.139 ± 0.010 | 0.139 ± 0.014 | 0.546 ± 0.018 |
| L-047-TD | 0.137 ± 0.017 | 0.130 ± 0.007 | 0.144 ± 0.001 | 0.138 ± 0.002 | 0.549 ± 0.019 |
| L-052-TD | 0.142 ± 0.006 | 0.146 ± 0.011 | 0.143 ± 0.005 | 0.148 ± 0.008 | 0.579 ± 0.016 |
| L-056-TD | 0.147 ± 0.005 | 0.144 ± 0.008 | 0.148 ± 0.012 | 0.152 ± 0.007 | 0.591 ± 0.017 |
| L-068-TD | 0.148 ± 0.012 | 0.154 ± 0.002 | 0.156 ± 0.009 | 0.146 ± 0.008 | 0.604 ± 0.017 |
| L-069-TD | 0.144 ± 0.005 | 0.145 ± 0.007 | 0.146 ± 0.009 | 0.145 ± 0.012 | 0.580 ± 0.017 |
| Mean[e] | 0.145 ± 0.004 | 0.148 ± 0.007 | 0.149 ± 0.004 | 0.148 ± 0.004 | 0.589 ± 0.017 |

(a) See *Environmental Report 2009,* Figure 6-1 for location reference.
(b) The quarterly sample error represents 2 standard deviations of the measured elements.
(c) The associated annual error is calculated as twice the rms location error.
(d) Data not available due to missing or damaged TLD.
(e) The uncertainty associated with quarterly mean dose is represented by 2 Standard Error of the site-wide location averages.

TLD-VAL [mSv] 2009 data (created 2010-04-13 14:16:49, Oracle) (epprd02.llnl.gov)

**A.9.2 Calculated dose from TLD environmental radiation measurements, Livermore Valley, 2009**

| Location[a] | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec | Annual Dose[b] |
|---|---|---|---|---|---|
| V-018-TD | 0.121 ± 0.011 | 0.117 ± 0.007 | 0.121 ± 0.007 | 0.115 ± 0.019 | 0.474 ± 0.024 |
| V-019-TD | 0.130 ± 0.005 | 0.132 ± 0.012 | 0.135 ± 0.011 | 0.140 ± 0.003 | 0.537 ± 0.017 |
| V-022-TD | 0.154 ± 0.003 | 0.156 ± 0.009 | 0.153 ± 0.011 | 0.154 ± 0.020 | 0.617 ± 0.025 |
| V-024-TD | 0.150 ± 0.008 | 0.158 ± 0.014 | 0.157 ± 0.007 | 0.154 ± 0.006 | 0.619 ± 0.019 |
| V-027-TD | 0.143 ± 0.004 | 0.144 ± 0.014 | 0.141 ± 0.005 | 0.140 ± 0.011 | 0.568 ± 0.019 |
| V-028-TD | 0.137 ± 0.006 | 0.131 ± 0.018 | 0.133 ± 0.004 | 0.130 ± 0.011 | 0.531 ± 0.022 |
| V-030-TD | 0.145 ± 0.008 | 0.146 ± 0.008 | 0.146 ± 0.009 | 0.138 ± 0.012 | 0.575 ± 0.019 |
| V-032-TD | 0.138 ± 0.011 | 0.144 ± 0.007 | 0.144 ± 0.012 | 0.145 ± 0.007 | 0.571 ± 0.019 |
| V-033-TD | 0.148 ± 0.010 | 0.148 ± 0.007 | 0.156 ± 0.010 | 0.156 ± 0.008 | 0.608 ± 0.018 |
| V-035-TD | 0.139 ± 0.012 | 0.143 ± 0.006 | 0.144 ± 0.009 | 0.135 ± 0.003 | 0.561 ± 0.016 |
| V-037-TD | (c) | 0.144 ± 0.007 | 0.155 ± 0.003 | 0.145 ± 0.009 | 0.592 ± 0.016[d] |
| V-045-TD | 0.144 ± 0.002 | 0.150 ± 0.010 | 0.149 ± 0.010 | 0.149 ± 0.009 | 0.592 ± 0.017 |
| V-057-TD | 0.152 ± 0.007 | 0.159 ± 0.011 | 0.160 ± 0.008 | 0.164 ± 0.011 | 0.635 ± 0.019 |
| V-060-TD | (c) | 0.152 ± 0.008 | 0.146 ± 0.004 | 0.157 ± 0.015 | 0.607 ± 0.023[d] |
| V-066-TD | 0.153 ± 0.008 | 0.149 ± 0.009 | 0.160 ± 0.015 | 0.154 ± 0.004 | 0.616 ± 0.020 |
| V-070-TD | 0.141 ± 0.004 | 0.150 ± 0.003 | 0.148 ± 0.005 | 0.145 ± 0.002 | 0.584 ± 0.007 |
| V-072-TD | 0.163 ± 0.012 | 0.164 ± 0.012 | 0.169 ± 0.007 | 0.161 ± 0.001 | 0.657 ± 0.018 |
| V-074-TD | 0.131 ± 0.007 | 0.133 ± 0.005 | 0.140 ± 0.011 | 0.142 ± 0.003 | 0.546 ± 0.014 |
| V-075-TD | 0.118 ± 0.003 | 0.119 ± 0.003 | 0.118 ± 0.007 | 0.123 ± 0.006 | 0.478 ± 0.010 |
| V-076-TD | 0.141 ± 0.010 | 0.145 ± 0.013 | 0.144 ± 0.017 | 0.140 ± 0.004 | 0.570 ± 0.024 |
| V-077-TD | 0.130 ± 0.008 | 0.137 ± 0.007 | 0.146 ± 0.004 | 0.144 ± 0.006 | 0.557 ± 0.013 |
| V-122-TD | 0.188 ± 0.109 | 0.162 ± 0.005 | 0.170 ± 0.001 | 0.167 ± 0.003 | 0.687 ± 0.109 |
| Mean[e] | 0.143 ± 0.007 | 0.145 ± 0.005 | 0.147 ± 0.006 | 0.145 ± 0.005 | 0.581 ± 0.022 |

(a) See *Environmental Report 2009,* Figure 6-2 for location reference.
(b) The associated annual error is calculated as twice the rms location error.
(c) Data not available due to missing or damaged TLD.
(d) When TLD data is missing, the annual dose is calculated as four times the average of available quarterly data.
(e) The uncertainty associated with quarterly mean dose is represented by 2 Standard Error of the site-wide location averages.

TLD-3OFF [mSv]   2009 data   (created 2010-04-13 14:15:15, Oracle) (epprd02.llnl.gov)

**A.9.3  Calculated dose from TLD environmental radiation measurements, Site 300 vicinity, 2009**

| Area Location[(a)] | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec | Annual Dose[(b)] |
|---|---|---|---|---|---|
| Tracy | | | | | |
| 3-092-TD | 0.151 ± 0.002 | 0.158 ± 0.009 | 0.155 ± 0.014 | 0.161 ± 0.008 | 0.625 ± 0.019 |
| 3-093-TD | 0.161 ± 0.007 | 0.172 ± 0.020 | 0.167 ± 0.013 | 0.160 ± 0.013 | 0.660 ± 0.028 |
| Mean[(c)] | 0.156 ± 0.010 | 0.165 ± 0.014 | 0.161 ± 0.012 | 0.160 ± 0.001 | 0.643 ± 0.035 |
| Other off-site | | | | | |
| 3-090-TD | 0.170 ± 0.009 | 0.174 ± 0.006 | 0.183 ± 0.014 | 0.195 ± 0.013 | 0.722 ± 0.022 |
| 3-099-TD | 0.157 ± 0.016 | 0.152 ± 0.010 | 0.151 ± 0.011 | 0.157 ± 0.003 | 0.617 ± 0.022 |
| Mean[(c)] | 0.164 ± 0.013 | 0.163 ± 0.022 | 0.167 ± 0.032 | 0.176 ± 0.038 | 0.670 ± 0.105 |

(a)  See *Environmental Report 2009,* Figure 6-3 for location reference.
(b)  The associated annual error is calculated as twice the rms location error.

(c)  The uncertainty associated with quarterly mean dose is represented by 2 Standard Error of the site-wide location average.

TLD-S3 [mSv]   2009 data   (created 2010-04-13 14:16:11, Oracle) (epprd02.llnl.gov)

**A.9.4 Calculated dose from TLD environmental radiation measurements, Site 300 perimeter, 2009**

| Location[a] | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec | Annual Dose[b] |
|---|---|---|---|---|---|
| 3-078-TD | 0.151 ± 0.016 | 0.149 ± 0.013 | 0.155 ± 0.016 | 0.154 ± 0.012 | 0.609 ± 0.029 |
| 3-081-TD | 0.174 ± 0.004 | 0.172 ± 0.013 | 0.184 ± 0.016 | 0.170 ± 0.004 | 0.700 ± 0.021 |
| 3-082-TD | 0.173 ± 0.014 | 0.172 ± 0.010 | 0.169 ± 0.004 | 0.177 ± 0.019 | 0.691 ± 0.026 |
| 3-085-TD | 0.158 ± 0.008 | 0.164 ± 0.017 | 0.166 ± 0.011 | 0.164 ± 0.013 | 0.652 ± 0.025 |
| 3-086-TD | 0.158 ± 0.009 | 0.169 ± 0.007 | 0.179 ± 0.022 | 0.171 ± 0.017 | 0.677 ± 0.030 |
| 3-088-TD | 0.161 ± 0.002 | 0.171 ± 0.003 | 0.172 ± 0.015 | 0.162 ± 0.004 | 0.666 ± 0.016 |
| 3-089-TD | 0.187 ± 0.023 | 0.182 ± 0.002 | 0.194 ± 0.023 | 0.189 ± 0.015 | 0.752 ± 0.036 |
| 3-091-TD | 0.167 ± 0.008 | 0.183 ± 0.005 | 0.193 ± 0.017 | 0.175 ± 0.010 | 0.718 ± 0.022 |
| 3-121-TD | 0.183 ± 0.010 | 0.190 ± 0.008 | 0.194 ± 0.006 | 0.185 ± 0.005 | 0.752 ± 0.015 |
| Mean[c] | 0.168 ± 0.008 | 0.172 ± 0.008 | 0.178 ± 0.009 | 0.172 ± 0.007 | 0.691 ± 0.031 |

(a) See *Environmental Report 2009,* Figure 6-3 for location reference.

(b) The associated annual error is calculated as twice the rms location error.

(c) The uncertainty associated with quarterly mean dose is represented by 2 Standard Error of the site-wide location average.

VG-ALL [Bq/L] 2009 data (created 2010-03-19 07:50:32, Oracle) (epprd02.llnl.gov)

**Table A.9.5 Quarterly concentrations of tritium in plant water (Bq/L) for the Livermore site, Livermore Valley, and Site 300, 2009[(a)]**

| Area<br>Location[(b)] | Q1 | Q2 | Q3 | Q4 | Median | Mean |
|---|---|---|---|---|---|---|
| within 1 km | | | | | | |
| AQUE | 3.0 ± 2.2 | 1.1 ± 1.7 | 6.0 ± 2.1 | 6.7 ± 1.9 | 4.5 | 4.2 |
| GARD | 2.7 ± 2.1 | 2.3 ± 1.8 | 0.6 ± 2.0 | 4.4 ± 1.8 | 2.5 | 2.5 |
| MESQ | 2.7 ± 2.1 | 2.4 ± 1.8 | 8.4 ± 2.2 | 40.0 ± 2.9 | 5.6 | 13 |
| MET | 1.7 ± 2.1 | 1.2 ± 1.7 | 5.8 ± 2.1 | 6.7 ± 1.9 | 3.8 | 3.8 |
| NPER | 7.9 ± 2.3 | 3.0 ± 1.8 | 4.7 ± 2.1 | 4.1 ± 1.8 | 4.4 | 4.9 |
| VIS | 9.4 ± 2.3 | 3.2 ± 1.8 | 7.2 ± 2.2 | 3.4 ± 1.7 | 5.3 | 5.8 |
| 1 - <5 km | | | | | | |
| I580 | 6.6 ± 2.2 | 2.7 ± 1.8 | 2.0 ± 2.0 | 6.5 ± 1.8 | 4.6 | 4.4 |
| PATT | 1.5 ± 2.1 | 1.0 ± 1.7 | 0.1 ± 2.0 | 0.3 ± 1.6 | 0.66 | 0.73 |
| TESW | 2.3 ± 2.1 | 0.0 ± 1.7 | 0.9 ± 2.0 | 4.2 ± 1.7 | 1.6 | 1.8 |
| ZON7 | 3.3 ± 2.2 | -0.1 ± 1.7 | 5.6 ± 2.1 | 0.0 ± 1.6 | 1.7 | 2.2 |
| more than 5 km | | | | | | |
| CAL | 0.2 ± 2.1 | 0.9 ± 1.7 | -0.0 ± 2.0 | 0.8 ± 1.6 | 0.5 | 0.46 |
| FCC | 1.6 ± 2.1 | -0.5 ± 1.7 | 0.1 ± 2.0 | 1.6 ± 1.6 | 0.86 | 0.72 |
| Site 300 | | | | | | |
| DSW | 0.3 ± 2.1 | 1.7 ± 1.7 | 0.2 ± 2.0 | 1.0 ± 1.6 | 0.64 | 0.8 |
| EVAP | 2.2 ± 2.1 | 5.6 ± 1.8 | 350.0 ± 6.3 | 3.6 ± 1.7 | 4.6 | 90 |
| PSTL | 1.1 ± 2.1 | 0.8 ± 1.7 | 0.1 ± 2.0 | 0.0 ± 1.5 | 0.46 | 0.51 |
| TNK5 | 0.2 ± 2.1 | 0.9 ± 1.7 | 0.5 ± 2.0 | 0.7 ± 1.6 | 0.57 | 0.58 |

(a) Radioactivities are reported as the measured concentration and an uncertainty ($\pm 2\sigma$ counting error). If the concentration is less than or equal to the uncertainty, the result is considered to be a nondetection. See *Environmental Report 2009,* Chapter 9.
(b) See *Environmental Report 2009,* Figures 6-1, 6-2, and 6-3 for location reference.