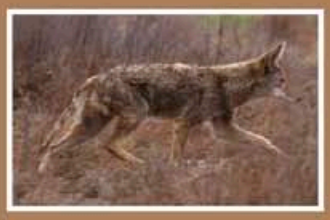
Environmental Report

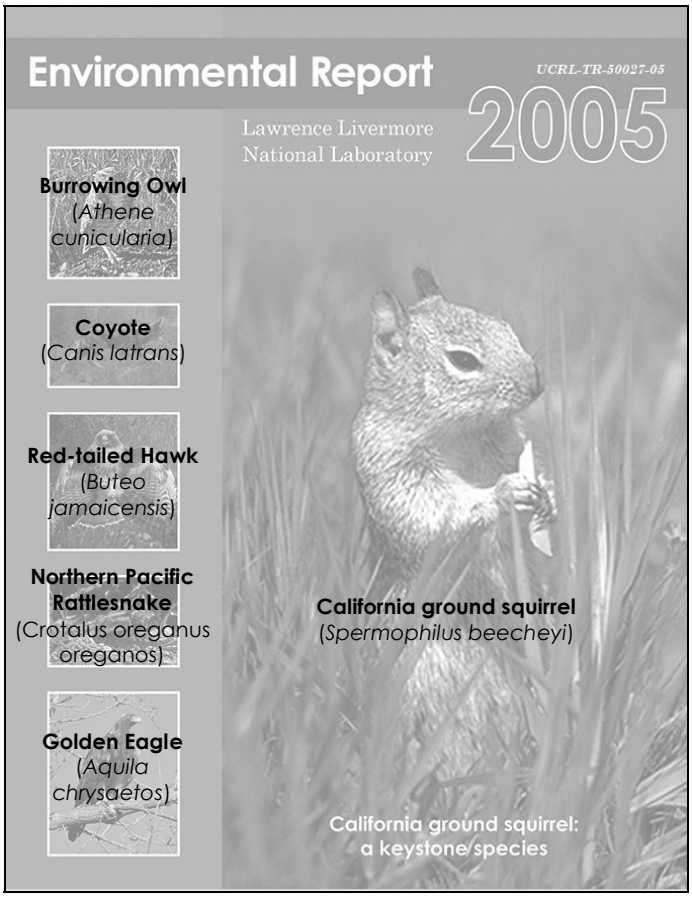
UCRL-TR-50027-05

Lawrence Livermore National Laboratory

2005



California ground squirrel: a keystone species



Cover photos

Ground squirrel: Gerald and Buff Crosi @ California Academy of Sciences

Burrowing owl: Jim Woollett, LLNL Wildlife Biologist

Coyote: U.S. Fish and Wildlife Service

Red-tailed Hawk and northern Pacific rattlesnake: Michael van Hattem, LLNL Wildlife Biologist

Golden Eagle: George W. Hartwell © 2004

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This report can be accessed on the Internet at http://www.llnl.gov/saer. It is also available to DOE employees and DOE contractors from:
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831
and to the public from:
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California ground squirrels (*Spermophilus beecheyi*), which are common at both the Livermore site and Site 300, are being investigated as a "keystone species" for the California prairie ecosystem. (A "keystone species" is one whose presence or absence, or significant increase or decrease in population size, profoundly affects other species' survivability in that habitat.) Recognition of this ecological standing is usually derived from the results of studies in which the species is added to or removed from the community.

Why are ground squirrels of heightened interest to ecologists? More than 200 other wildlife species have been sighted using ground squirrel colonies. Some species prey upon ground squirrels while others use their burrows for shelter. In Central California, common wildlife visitors to areas of ground squirrel occupation include red-tailed hawks, coyotes, golden eagles, northern Pacific rattlesnakes, and burrowing owls. Also, a long list of insects and plant species are associated with the colony's construction area.

Additionally, squirrel feeding activities result in a tilling or churning of the soil, enhancing its ability to support plants. A greater vegetative diversity—with nitrogen-rich mixtures of grasses and forbs—offers sustenance to other animals. This enriched habitat attracts a wide array of grazers and browsers that wish to utilize these food resources. Ecologically heralded as the food web hierarchy, this diverse association of plants and wildlife is dependent on the ground squirrel's presence for life.

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

Environmental Report 2005

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September 29, 2006

Lawrence Livermore National Laboratory
UCRL-TR-500270-05
Distribution Category UC-702

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SEP 1 4 2006

5484.5.7
ES-06-133

To: Distribution

Subject: 2005 Annual Site Environmental Report for the Lawrence Livermore National Laboratory

The Annual Site Environmental Report (ASER) was prepared by Lawrence Livermore National Laboratory (LLNL) for the Department of Energy National Nuclear Security Administration (NNSA) Livermore Site Office, and provides a comprehensive summary of the environmental program activities at LLNL for calendar year 2005. This report is prepared annually and is distributed 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.

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

LLNL continues to commit to achieving continuous improvement in environmental performance through pollution prevention, energy efficiency, and other measures. An ISO 14001 Environmental Management System has been implemented at LLNL.

A reader survey form is provided with the ASER to provide comments or suggestions for future versions of the report. Your response is appreciated.

Sincerely,

Phillip E. Hill
Technical Deputy
for Safety and Environmental Programs

cc:
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Preface

The *Environmental Report 2005* is prepared for the U.S. Department of Energy (DOE) by the Environmental Protection Department at Lawrence Livermore National Laboratory (LLNL). The submittal of the *Environmental Report 2005* 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 purpose of the *Environmental Report 2005* is to present summary environmental data, confirm compliance with environmental standards and requirements, and highlight facility programs and efforts.

The *Environmental Report 2005* will by distributed in electronic form on compact disc (CD), and will also be accessible on the Internet at the LLNL Site Annual Environmental Report homepage: http://www.llnl.gov/saer/. Both the report and data tables can be viewed in their most up-to-date form on the website. Environmental reports covering calendar years 1994 through 2004, and corrections to them, are also found at http://www.llnl.gov/saer/.

The report contains an executive summary, an introduction with an overview of the meteorology and hydrogeology of the two LLNL sites (Chapter 1), a summary of LLNL's compliance with environmental regulations (Chapter 2), and a description of LLNL's environmental programs, with emphasis on the Environmental Management System including pollution prevention (Chapter 3). The majority of the report features LLNL's environmental monitoring programs: effluent and ambient air (Chapter 4); waters, including wastewater, storm water runoff, surface water, rain, and groundwater (Chapter 5); and terrestrial, including soil and sediment, vegetation and foodstuff, ambient radiation, and special status wildlife and plants (Chapter 6). All environmental monitoring data summarized in this report are provided in files on the CD. The radiological impact on the public is discussed in Chapter 7, and Chapter 8 provides an overview of LLNL's groundwater remediation program. Information on both the Livermore site and Site 300 is included in each chapter. The report concludes with a discussion of quality assurance activities associated with these monitoring programs (Chapter 9).

The *Environmental Report 2005* continues the practice of using Système International units. This is consistent with federal law stated in the Metric Conversion Action of 1975 and Presidential Order 12770, Metric Usage in Federal Government Programs (July 25, 1991). For ease of comparison to environmental reports issued prior to 1991, dose values and many radiological measurements are presented in both metric and U.S. customary units.

A conversion table for all units used in this report (**Table GL-1**) is also provided in the Glossary under the heading of "metric units."

The document is the responsibility of LLNL's Operations and Regulatory Affairs Division of the Environmental Protection Department. Monitoring data were obtained through the combined efforts of the Operations and Regulatory Affairs Division, Environmental Restoration Division, Chemistry and Materials Science Environmental Services' Environmental Monitoring Radiation Laboratory, and the Hazards Control Department. Special recognition is deserved for the dedication and professionalism of the technologists who gathered the data—Gary A. Bear, Karl Brunckhorst, David J. Castro, Crystal Foster, Steven Hall, Renee Needens, Terrance W. Poole, Donald G. Ramsey, and Robert Williams—of the data management personnel—Hildy Kiefer, Kimberley A. Swanson, Beth Schad, Suzanne Chamberlain, Della Burruss, and Susan Lambaren—and of the secretarial staff who prepared and distributed the drafts—Annette Freschi and Loni Hoellwarth. Special thanks go to Gretchen Gallegos and Richard Blake for their strong support of the project and reviews of the drafts.

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Executive Summary

EX

Purpose of this Report

The Lawrence Livermore National Laboratory (LLNL) annual *Environmental Report,* prepared for the Department of Energy (DOE) and made available to the public, presents information that demonstrates compliance with environmental standards and requirements, both radiological and nonradiological; discusses the status of the Environmental Management System (EMS); describes significant accomplishments of pollution prevention activities; reports data for effluent and ambient air and water monitoring; reports radiological doses; summarizes LLNL's activities involving special status wildlife and plants; and describes the progress made in remediating groundwater contamination. The report demonstrates LLNL's continuing commitment to the protection of the public and the environment. The report is available on the Internet at http://www.llnl.gov/saer/.

Major LLNL Programs

The University of California manages LLNL for the National Nuclear Security Administration (NNSA) within DOE. LLNL was established in 1952 in Livermore to ensure national security through the design, development, and stewardship of nuclear weapons; operations at Site 300, LLNL's experimental test site, began in 1955.

LLNL plays a prominent role in NNSA's Stockpile Stewardship Program, in which laboratory scientists and engineers ensure the safety and reliability of the nation's nuclear weapons and certify weapon performance without nuclear testing. At LLNL, nuclear weapons expertise and extensive capabilities in physical and life sciences are applied to meet the challenge of the proliferation of weapons of mass destruction and to protect the nation from terrorism. Analytical support and advanced technologies are provided by LLNL to the Department of Defense, the intelligence community, and other agencies.

Reinforcing the national security mission, LLNL pursues research and development in other areas of importance. Using LLNL's physical science, computing, and engineering capabilities, bioscience research is directed at understanding causes and mechanisms of ill health, developing biodefense capabilities, improving disease prevention, and helping lower health costs. Long-term research is carried out to provide the nation with abundant, reliable energy and a clean environment. LLNL scientists and engineers also pursue projects in fundamental science and applied technology that take advantage of the unique research capabilities and facilities at LLNL.

Other Key Initiatives

Safe, secure, and efficient operations that provide a safe, clean environment for employees and neighboring communities are a necessary part of the Laboratory's research and development programs and underpin their success. Experts in environment, safety and health (ES&H) within the Safety and Environmental Protection Directorate support all Laboratory activities. A high-quality radiological control program at LLNL ensures that radiological exposures and releases are reduced to as low as reasonably achievable to protect the health and safety of all its employees, contractors, the general public, and the environment.

Over the last two decades, LLNL has made great strides in improving its environmental performance and has actively taken steps to reduce any potential impacts the Laboratory's operations might have on the environment and the community.

The Laboratory encourages participation by the public on matters related to its environmental impact on the community by initiating communications and providing opportunities for citizens to give input to the decision-making process on matters of significant public interest. It also provides access to information on its ES&H activities.

All environmental monitoring and analysis of samples and data, including the preparation of this report, are conducted under the Environmental

Protection Department's Quality Assurance Management Plan. This plan is included under LLNL's Quality Assurance Policy, with its commitment to effectiveness, excellence, innovation, and continuous quality improvement.

LLNL's Environmental Management System

In 1998, LLNL began the process of developing and implementing an Integrated Safety Management System (ISMS) in accordance with the University of California's Prime Contract W-7405-ENG-48, Clause 6.7. The ISMS ensures the systematic integration of ES&H considerations into management and work practices so that missions are accomplished safely. Work Smart Standards (WSS), based on applicable laws, regulations, and DOE orders, establish workplace ES&H controls and are an integral part of LLNL's ISMS. The University of California and the Department of Energy require LLNL to have an Environmental Management Program (EMP) as part of the WSS.

In June 2004, LLNL enhanced its EMP by adopting the rigorous requirements of the globally recognized International Organization for Standardization (ISO) 14001 Environmental Management System (EMS) as a WSS; on July 22, 2004, the LLNL Director issued an Administrative Memo defining LLNL's Environmental Policy. An internal EMS audit was held November 9 and 10, 2005. Subsequently, the Livermore Site Office (LSO) of the DOE conducted an independent evaluation of LLNL's EMS. On December 20, 2005, LSO/DOE issued a draft Corrective Action Plan to address the minor nonconformances identified in the LSO audit. On December 22, 2005, LLNL, per agreement with LSO/DOE, self-declared its conformance with ISO 14001:1996.

In December 2005, nine EMP documents were completed that describe different environmental aspects[1]. These include Ecological Resource Disturbance, Electrical Energy Use, Fossil Fuel Consumption and Renewable Energy, Hazardous Materials Use Study and Evaluation, Mixed Waste, Municipal Waste Generation, Nonhazardous Materials Use, Radioactive Materials Use, and Transuranic Use Generation. Each document lists the objectives and targets and the responsible individuals for each category

During 2006, LLNL is implementing the corrective actions that address the deficiencies identified in the DOE/LSO audit and is starting to update the present EMS to meet the requirements of ISO 14001:2004.

1 Environmental aspects are elements of an organization's activities, products or services that can interact with the environment.

The EMS commits LLNL—and each employee—to responsible stewardship of all the environmental resources in our care. To educate all LLNL employees, the Environmental Protection Department distributed a brochure (UCRL-BR-216486) describing EMS. An LLNL website that describes the LLNL EMS can be accessed at http://www-epd.llnl.gov/ems/ems_logo.htm.

Pollution Prevention

A strong Pollution Prevention (P2) Program is an essential element of LLNL's EMS. The P2 team is responsible for P2 program stewardship and maintenance, waste stream analysis, reporting of waste generation, and coordination of institutional P2 programs and activities.

In December 2005, DOE NNSA selected two projects at LLNL to receive DOE Best-in-Class awards. The first of the awards was for the Space Action Team's initiative that provides a contractual mechanism for converting the value of equipment or building materials into an offset against payment for demolition work. The second award was for the replacement of the greenhouse/asphyxiant gas sulfur hexafluoride with ultra-zero compressed air for use as a dielectric in a portable flash x-ray system used at the Experimental Explosive Facility at Site 300. Both projects reduce LLNL's impact on the environment and save money. Another project, the Joint Actinide Shock Physics Experiment Research (JASPER), managed by LLNL at the Nevada Test Site, also received a Best-in-Class award for the incorporation of waste minimization and pollution prevention into the design, execution and maintenance of the project.

A DOE Environmental Stewardship award was issued to the Contained Firing Facility at Site 300 for the development and implementation of an inexpensive low-tech method of particulate capture combined with an extensive water recycling and polishing system that clean the facility after each experiment while reducing wastewater, saving worker time, and increasing safety.

LLNL also conducted activities to promote employee awareness of P2. These included the annual Earth Expo held in April, articles in the LLNL newspaper, and training for purchasing staff. A P2 resource is the website http://www-p2.llnl.gov/.

Regulatory Permitting and Compliance

LLNL undertakes substantial activities to comply with the 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 and the California Environmental Quality Act; the Endangered Species Act; the National Historic Preservation Act; the Antiquities Act; and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

In 2005, LLNL held many permits for many activities and hosted numerous inspections and tours by outside agencies. Overall, LLNL has an excellent record with very few notices of violations and permit nonconformances during 2005. A high pH excursion in LLNL's sanitary sewer discharge resulted in the only environmental occurrence report for 2005.

Air Monitoring

Releases of radioactivity to the environment from LLNL operations occur through stacks and from diffuse area sources. In 2005, radioactivity released to the atmosphere was monitored at 71 sampling locations at six facilities on the Livermore site and one at Site 300. There were no releases from the HEPA-filtered monitored stacks at the Livermore site. Stack releases of tritium from the Tritium Facility and the Decontamination and Waste Treatment Facility contributed 85% of the estimated of 1.5 TBq (40.5 Ci) of tritium released from the Livermore site in 2005. The 2005 tritium release rate is essentially equal to the release rate in 2004, but, in 2005, the fraction of total tritium contributed by diffuse area sources was greater than in 2004. At Site 300, only very small quantities of gross alpha and gross beta radiation associated with particles (fewer than 6×10^{4} Bq [1.6×10^{-6} Ci] each) were estimated very conservatively to have been released from the Contained Firing Facility during 2005.

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 2005 for the Livermore site were within about 10% of those in 2004; estimated releases at Site 300 were consistently lower than in 2004. Nonradiological releases from

LLNL continue to be a very small fraction of releases from the Bay Area or San Joaquin County

In addition to 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 sites, monitor natural background. In 2005, 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.

The wildfire that burned 2100 acres of Site 300 in July 2005 released approximately 21 tons of particulate matter (PM) and 0.4 tons of nitrogen oxides (NOx). Because Site 300 is regularly burned under permit to prevent wildfires that may result from operations, the fire did not spread. As a result, the quantities of PM and NOx released by the fire were estimated at less than 20% of what they might have been had the fire spread. Concentrations of gross alpha, gross beta, and uranium after the fire were similar to those seen after prescribed burns and were due to increased mass loading of the filters due to resuspension of particles during the fire.

Water Monitoring

Monitoring of various categories of water is carried out to determine if any radioactive or nonradioactive hazardous contaminants released by LLNL might have a negative impact on public health and the environment.

Permits, including one for discharging treated groundwater from the Ground Water Project, regulate discharges to the City of Livermore sanitary sewer system. There was one Notice of Violation (NOV) in 2005 from the Livermore Water Reclamation Plant (LWRP) for exceeding the maximum pH limit of 10. Approximately 300–600 gallons of effluent with a pH of 11.6 were discharged to the LWRP; the remainder of the effluent was captured and contained on site by the Sewer Diversion Facility. This incident was reportable under DOE Order 232.1A. No discharges exceeded any discharge limits for release of radioactive materials to the sewer, and only one other pH excursion occurred during 2005. All discharges from the Site 300 sewage evaporation pond to the percolation pond, as well as discharges to the surface impoundments, were in compliance with discharge limits.

Storm water is sampled for contaminants such as radioactivity, metals, oxygen, dioxins, polychlorinated biphenyls (PCBs), and nitrate both upstream and downstream from both sites to determine the impact of each site. Data show that storm water downstream of Livermore site has not been impacted

by LLNL activities; at Site 300, concentrations of monitored constituents—including lead, uranium, and dioxins—in the downstream waters of Corral Hollow Creek are similar to those upstream of Site 300.

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 pesticides, herbicides, radioactivity, nitrates and hexavalent chromium. To detect any offsite contamination quickly, the well water is sampled in the uppermost water-bearing layers. As in other years, all contaminants in groundwater away from the Livermore site were well below allowable limits for drinking water. Near Site 300, monitored constituents for offsite groundwater include explosives residue, nitrate, perchlorate, metals, volatile and semivolatile organic compounds, tritium, uranium, and other (gross alpha and beta) radioactivity. One groundwater sample collected from an offsite private well about six kilometers to the west of Site 300 had nitrate concentrations slightly above the drinking water limit (45 mg/L). This result appears to be unrelated to LLNL activities. No other constituent reached any drinking water limit in offsite wells near Site 300.

Rainwater is analyzed for tritium. Concentrations in rain samples may be highly variable depending upon operations taking place during the rain. In 2005, the maximum concentration of tritium in rain collected on the Livermore site was 1.6% of the drinking water standard of 740 Bq/L (20,000 pCi/L), and no offsite concentrations were above the lower limit of detection (0.5% of the drinking water standard). At Site 300, all rain samples were below detection limits.

Surface waters and drinking water are analyzed for tritium, gross alpha, and gross beta radioactivity. In the Livermore Valley, there were no tritium measurements above the detection limit, median gross alpha measurements were below detection limits, and the median gross beta concentration was less than 6% of the drinking water standard of 1.85 Bq/L (50 pCi/L). The onsite surface water in the Drainage Retention Basin (DRB) exhibited levels of gross alpha, gross beta, tritium, metals, organics, pesticides and PCBs that were well below discharge limits; aquatic bioassays for acute and chronic toxicity showed no toxicity effects in DRB discharge water. At Site 300, maintenance on the drinking and cooling water systems resulted in permitted discharges to ground without adverse impact on surrounding waters.

Groundwater Remediation

Groundwater at both the Livermore site and Site 300 is contaminated from historical operations; both are undergoing CERCLA cleanup. 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. Cleanup began in 1989. Site 300 cleanup began in 1991. VOCs are the main contaminant found at the eight Site 300 Operable Units (OUs). In addition, nitrate, perchlorate, tritium, high explosives, depleted uranium, organosilicate oil and metals are found at one or more of the OUs.

The present contamination, for the most part, is confined to each site. In 2005, concentrations continued to decrease in most of the Livermore site VOC plumes due to active remediation and the removal of over 267 kg of VOCs from both groundwater and soil vapor. VOC concentrations on the western margin of the site continued their gradual decline, indicating effective hydraulic control of the boundary plumes. Within the interior of the site, remediation activities, including soil vapor extraction, dual extraction, and groundwater extraction, have resulted in declines of VOC concentrations in numerous source areas. Of special interest is the significant five-fold increase in the mass of VOCs removed from soil vapor during the past four years.

In 2005 at Site 300**,** perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 90 kg of VOCs. Each OU has a different profile of contaminants, but, overall, groundwater and soil vapor extraction and natural attenuation at Site 300 continue to reduce the mass of contaminants in the subsurface. The cleanup of volatile organic compounds was completed at the Site 300 General Services Area. An additional four areas are under investigation and have not yet reached a final CERCLA remedy to address environmental contamination.

Terrestrial Radiological Monitoring

The impact of LLNL operations on surface soil, sediment, and vadose zone soils in 2005 was insignificant. Soils and sediments are analyzed for plutonium, gamma-emitting radionuclides, tritium, total and soluble metals, and PCBs as appropriate. Plutonium concentrations at the Livermore Water Reclamation Plant continued to be high relative to any other sampled location, but even this concentration was only 2% 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 2005, uranium-238 concentrations in soils at Site 300 were below NCRP recommended screening levels.

Vegetation and Livermore Valley wine were sampled for tritium. In 2005, the median concentrations of all offsite vegetation samples were below the lower limit of detection of the analytical method. The mean concentration in Livermore Valley wines, at about 0.2% of the drinking water standard, was a

factor of three times lower than concentrations in wines from the Rhone Valley in France.

LLNL's extensive network of thermoluminescent dosimeters (TLDs) measures the natural terrestrial and cosmogenic background; in 2005, as in recent years, no impact of LLNL operations was detected.

Multimedia Comparison

In **Figure EX-1**, annual median concentrations of tritium in air moisture[1] at location VIS (see **Figure 6-1**), in water in the Drainage Retention Basin (DRB; see **Figure 5-9**), and in wine from the Livermore Valley over the last ten years are compared with background levels of tritium in rain (measured at Portland, Oregon, and Anchorage, Alaska) and California wine (excluding the Livermore Valley), and with total tritium releases to the atmosphere from the Livermore site. Concentrations of tritium in air moisture at VIS and water from the DRB in 2005 were less than 0.7% of the Environmental Protection Agency's drinking water standard of 740 Bq/L (20,000 pCi/L).

Generally, the correlation between concentrations in environmental media and annual releases of tritium to the atmosphere from LLNL is weak. Differences are due to distance from the tritium sources to the location of the sampled medium, whether the released tritium was from a stack or from an area source, the fraction of time the wind blew towards the location, and how well the sample medium integrated tritium concentrations throughout the year. Nevertheless, a reasonable correlation may be seen between the concentrations in air moisture and those in the DRB. Concentrations in Livermore Valley wine can vary independently of release rates because of random sampling of wines made from grapes grown at various distances from the sources of tritium at the Livermore site.

Background tritium levels seen in rain from Portland and Anchorage include cosmogenic tritium and residual tritium from bomb tests. These background tritium levels show large variability because of latitude-effects and distance from large bodies of water. California wines and rain in Portland exhibit similar tritium concentrations.

1 Air moisture is collected by the sampling medium. Concentrations of tritium in air (see Chapter 4) are calculated by dividing the total tritium collected by the volume of air passed through the sampler.

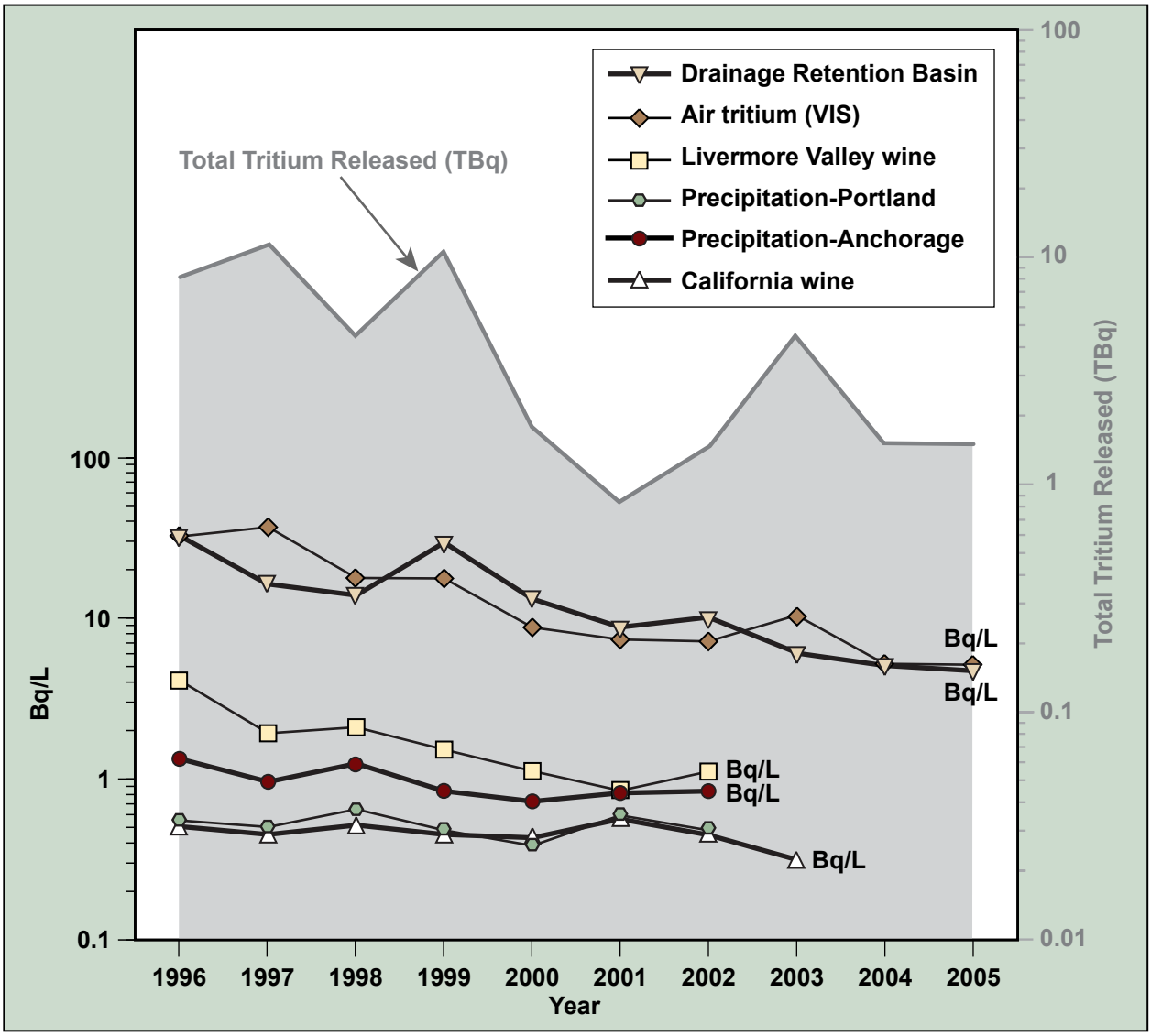


Figure EX-1. Annual median concentrations of tritium in three LLNL media compared with natural background (e.g., precipitation) and total annual releases of tritium from LLNL.

Biota

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, California red-legged frog, Alameda whipsnake, valley elderberry longhorn beetle, and the large-flowered fiddleneck) as well as rare species or those of special interest otherwise. At Site 300, LLNL also monitors populations of birds and rare species of plants. The red-legged frog is also protected on the Livermore site.

At Site 300, red-legged frogs were translocated to two new pools that were created to replace wetlands maintained artificially by discharge from several buildings, and a new seasonal pool was created for the tiger salamander after the removal of Class II impoundments. At the DRB, adult bullfrogs and egg masses were removed. LLNL employees are being educated about the illegality of releasing any non-native animal to the DRB or of fishing in the DRB, what animals are not native (e.g., bullfrogs and large-mouth bass, both current residents of the DRB), the threat these introduced predators pose to the red-legged frog, and the cost of eliminating them from the DRB. In early 2006, a brochure (UCRL-BR-217784) discussing these issues was distributed to all employees; also in early 2006, there was an article in NewsOnLine and an "LLNL Lessons Learned" was distributed. In addition, a series of eight posters (UCRL-POST-213624) were placed around the DRB to educate LLNL employees and visitors about the history and ecology of the "Laboratory's Basin." Algal blooms are explained, and dragonflies, frogs, toads, and muskrat are profiled colorfully and informatively.

The 2005 radiological doses calculated for biota at the Livermore site or at Site 300 were far below screening limits set by DOE, even though extremely unlikely assumptions maximized the potential effect of LLNL operations on biota.

Radiological Dose

Dose calculated to the site-wide maximally exposed individual (SW-MEI) for 2005 was 0.065 μSv (0.0065 mrem) for the Livermore Site and 0.18 μSv (0.018 mrem) at Site 300. Four sources of tritium at LLNL contributed nearly 100% of the dose received by the SW-MEI. The dose for 2005 was about 80% of the 2004 dose for the Livermore site. At Site 300, the shots at the Building 851 firing table contributed 48% of the dose; resuspended uranium-contaminated soil contributed the remainder of the dose. The dose to the SW-MEI at Site 300 was about 70% of the 2004 dose because doses are more or less proportional to the number of shots in a year. There were no unplanned releases to the atmosphere from either site.

In **Figure EX-2**, calculated radiological doses to the SW-MEI from operations at each site in 2005 are compared with regulatory limits and doses potentially received from the environment or from common activities (e.g., medical x-rays). The contribution of LLNL operations to unavoidable dose was inconsequential.

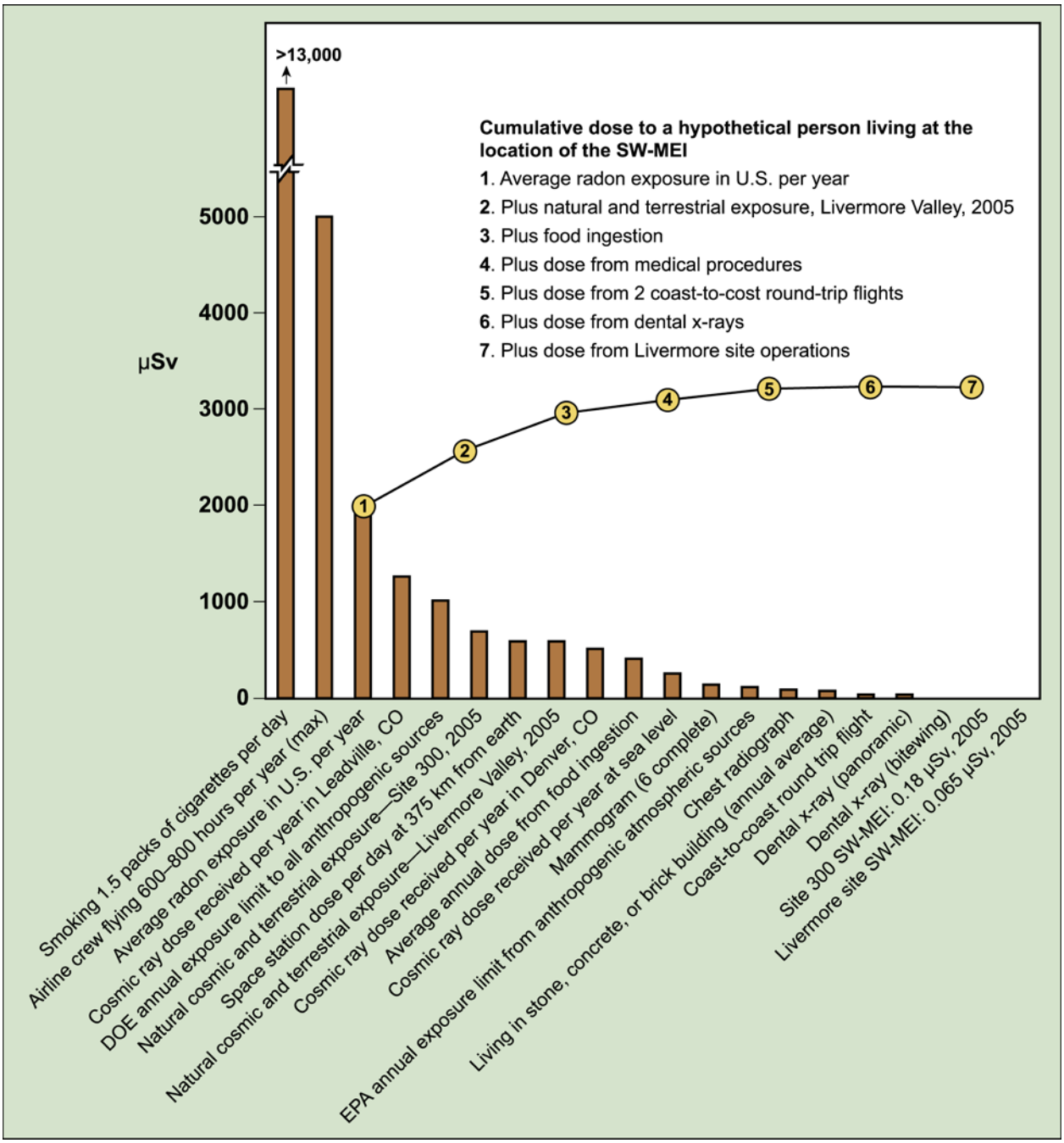


Figure EX-2. Doses from the Livermore site and Site 300 operations compared with doses potentially received by an average individual. Dose to a hypothetical member of the public living at the perimeter of the Livermore site is also demonstrated.

Conclusion

The combination of surveillance and effluent monitoring, source characterization, and dose assessment showed that the radiological dose to the most-exposed member of the public caused by LLNL operations in 2005 was less than 0.2% of regulatory standards and more than 16,000 times smaller than 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 generally showed a minimal contribution 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.

The Agency for Toxic Substances and Disease Registry released their final Public Health Assessment (PHA) for LLNL in 2005. This PHA was specific to Site 300, but the conclusion of "No Public Health Hazard" was similar to the conclusion of ATSDR's 2004 PHA for the Livermore site. Clearly, LLNL's environmental program demonstrates a commitment to protecting the environment by controlling pollutants.

Introduction

CHAPTER 1

Founded in 1952, Lawrence Livermore National Laboratory (LLNL) is a premier research and development institution for science and technology applied to national security. The Laboratory is managed and operated by the University of California for the U.S. Department of Energy. LLNL's primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory's special capabilities are also applied to the prevention of the spread and use of weapons of mass destruction and to strengthen homeland security. With broadly based capabilities and leadership in mission-focused areas of science and technology, the Laboratory meets other national needs with major advances in research programs in energy and environment, bioscience and biotechnology, and basic science and applied technology. The Laboratory and its more than 8000 employees serve as a resource to the U.S. government and partner with industry and academia.

LLNL operations release a variety of contaminants to the environment via atmospheric and surface water or groundwater pathways. Some of these contaminants are common at many facilities (e.g., particles from diesel engines), while others are unique to facilities like LLNL (e.g., radionuclides). All releases are carefully monitored and regulated. The dispersion of the contaminants is highly dependent upon local meteorology, topography and hydrogeology; any health impact of these dispersed contaminants will depend on where people and biota are situated with respect to LLNL.

Location

LLNL consists of two sites—the urban Livermore site located in Livermore, California in Alameda County, and the rural Experimental Test Site (Site 300) located near Tracy, California, in San Joaquin and Alameda counties (**Figure 1-1**).

The Livermore site lies just east of Livermore, a city with a population of about 80,000. The Livermore site occupies an area of 3.3 km^2 (1.3 mi^2), including the land that serves as a buffer zone around most of the site. Adjoining the site border to the south is Sandia National Laboratories/ California (Sandia/California), operated by Lockheed-Martin under U.S. Department of Energy (DOE) contract.

To the south of the LLNL and Sandia/California sites are mostly low-density residential areas and agricultural areas devoted to grazing, orchards, and vineyards. Farther south, property is primarily open space and ranchettes with some agricultural use. Residential developments, including houses and apartments, abut the property immediately to the west of the Livermore site. A small business park lies to the southwest. A small amount of very low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills that define the eastern margin of the Livermore Valley. An extensive business park is located to the north, and a 200 hectare (500 acre) parcel of open space to the northeast has been rezoned to allow development of light industry. Within an 80-km (50-mi) radius of the Livermore site lie nearby communities, such as Tracy and Pleasanton, and the distant population centers of Oakland, San Jose, and San Francisco. Although over seven million people reside within 80 km of the Laboratory, just 10% of them live within 32 km (20 miles).

Site 300, LLNL's Experimental Test Site, which dates from 1955, is located 20 km (12 mi) east of the Livermore site in San Joaquin and Alameda counties in the Altamont Hills of the Diablo Range; it occupies an area of 28.3 km^2 (10.9 mi^2). SRI International operates a testing site located approximately 1 km (0.62 mi) south of Site 300. Property immediately to the east of Site 300 is owned by Fireworks America, which uses it for packaging and storing fireworks displays. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills to the northwest. Forty hectares (99 acres) of riparian woodland and annual grassland, formerly the southeastern corner of Site 300 transferred in 1974 to the California Department of Fish and Game because of its unique assemblage of rare amphibian and reptile species, comprise a protected refuge area for wildlife called the "Corral Hollow Ecological Reserve". The remainder of the surrounding area is in agricultural use, primarily as grazing land for cattle and sheep. The city of Tracy, with a

population of over 80,000, is located 10 km[1] (6 mi) to the northeast. About 6.2 million people live within 80 km (50 mi) of Site 300. 95% live more than 32 km (20 mi) from Site 300 in such distant metropolitan areas as Oakland, San Jose, and Stockton.

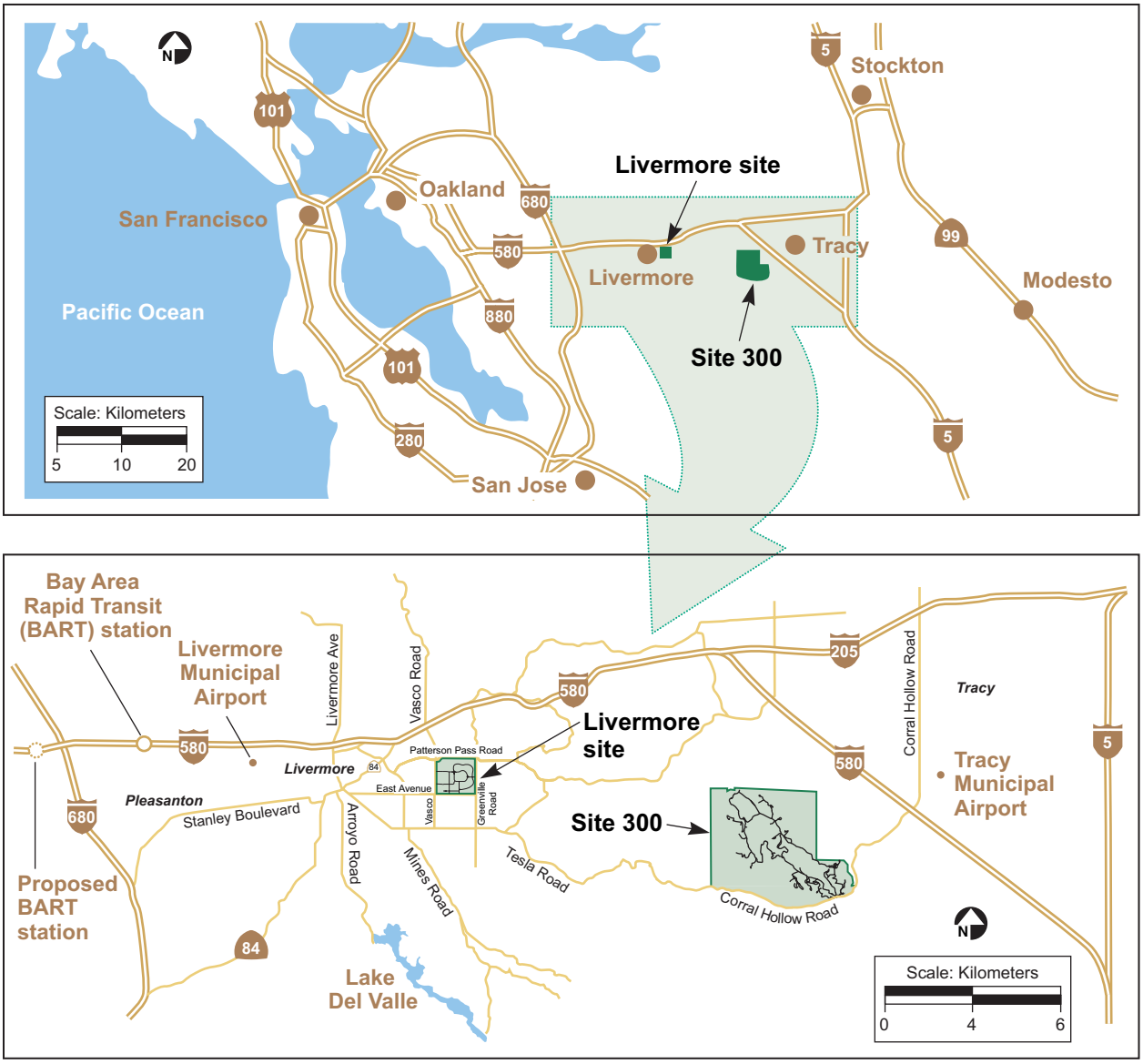


Figure 1-1. Locations of LLNL Livermore site and Site 300

1 This distance is from the northeast border of Site 300 to Sutter Tracy Community Hospital.

Meteorology

A new 52-m meteorological tower was installed at the Livermore site in late September 2005 to replace the 35-m tower that was installed in 1979. The new tower is located within 20 meters of the old tower, in the northwestern buffer zone. The new tower has an electrical instrument elevator that will allow safer and quicker maintenance than the older tower that had a hand-crank elevator. The new tower also has three measurement levels, one more than the previous tower. A fast-response hygrometer has been installed at the tower in order to estimate evaporation from the ground.

Meteorological data (including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature) are continuously gathered at both the Livermore site and Site 300. Mild, rainy winters and mild-to-hot, dry summers characterize the climate. A detailed review of the climatology for LLNL can be found in *Climatology of Lawrence Livermore National Laboratory* (Gouveia and Chapman 1989). The mean daily maximum, minimum, and average temperatures for the Livermore site in 2005 were 22.0 °C (71.6 °F), 8.0 °C (46.3 °F), and 15.0 °C (59.0 °F), respectively. The mean daily maximum, minimum, and average temperatures for Site 300 in 2005 were 21.1 °C (70.0 °F), 12.6 °C (54.7 °F), and 16.9 °C (62.4 °F), respectively. Nighttime temperatures are typically higher (and diurnal temperature range smaller) at Site 300 compared to the Livermore site; stronger winds at the higher elevation prevent formation of strong nighttime inversions near the ground. Temperatures typically range from –4 °C (25 °F) during the coldest winter mornings to 40 °C (104 °F) during the warmest summer afternoons at the Livermore site. The typical temperature range at Site 300 is somewhat smaller, ranging from –1 °C (30 °F) during the coldest winter mornings to 38 °C (100 °F) during the warmest afternoons.

While the mean annual temperature was near normal during 2005, several individual months experienced large departures from normal. Rainfall in the first part of January followed by persistent fog caused this month to be the coldest January since 1992. The lowest daytime high temperature reached only 5.6 °C (42 °F) on January 13. A strong high-pressure system persisted over the western U.S. during July and August causing offshore winds with widespread dry conditions and record heat. It was the warmest July for both the Livermore site and Site 300 since at least 1989 and 1991, respectively.[1] High temperatures reached or exceeded 37.8 °C (100 °F) at the Livermore site on six days in the month including four consecutive days in the middle of the month. The high temperature of 40.0 °C (104 °F) at Site 300 on July 17 matched the record of August 4, 1998. Slightly cooler but still hot weather,

[1] Daily temperature statistics have been analyzed since 1990 and 1992 for the Livermore site and Site 300, respectively.

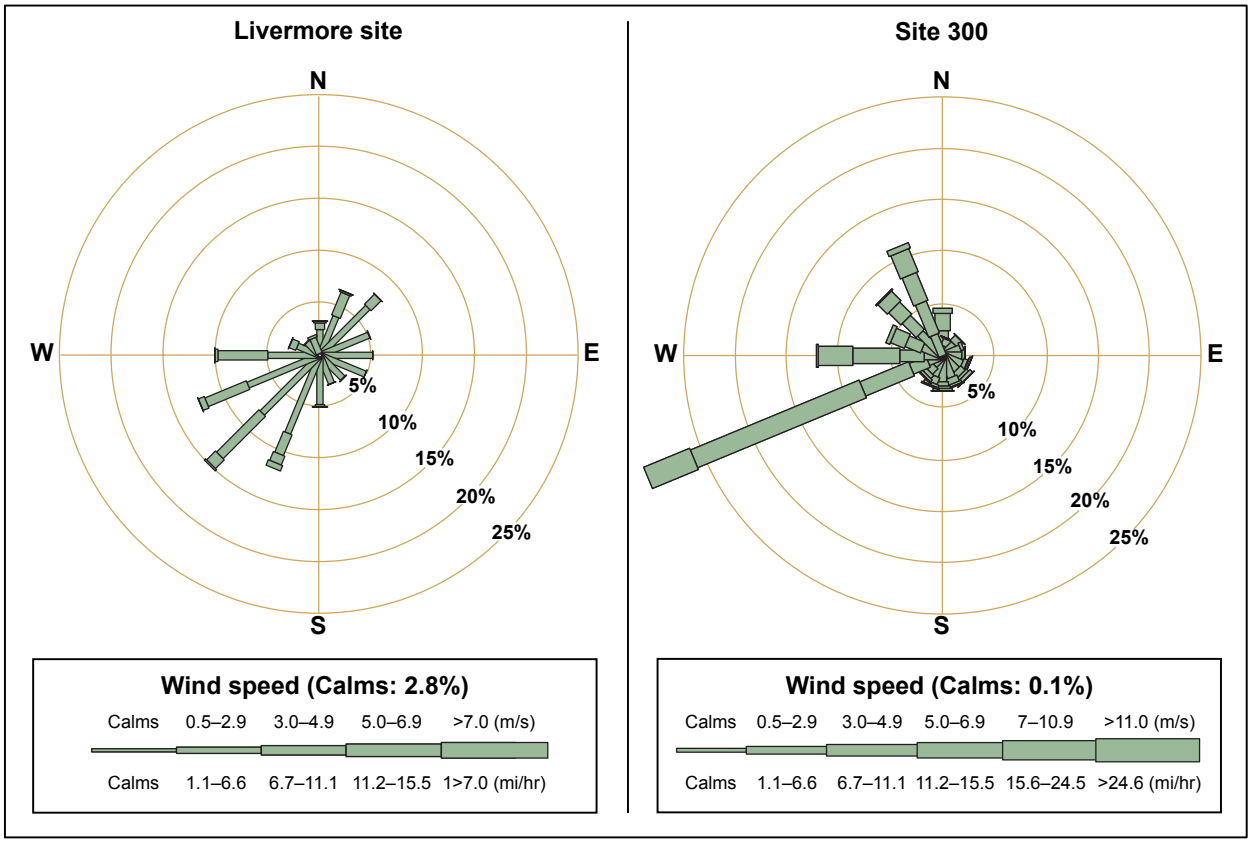
strong west-southwesterly winds with average wind speeds of 22–30 mph, and an extremely dry atmosphere mixing down to the surface contributed to a 6200 acre fire that burned primarily west of Site 300 in the late afternoon and evening of July 19. The relative humidity hovered near 10% during the fire. After some welcome clouds, and a few sprinkles, but no measurable rain on July 21 from remnants of a Gulf of Mexico hurricane, the heat quickly returned, with temperatures reaching 39.6 °C (103 °F) and 37.7 °C (100 °F) at the Livermore site on the 23rd and 24th. Temperatures on the final seven days of the month reached or exceeded 90 °F. While the dry atmosphere allowed the Livermore site to cool off at night, temperatures stayed high during the night at Site 300 for much of the month. The temperature remained above 26.7 °C (80 °F) at Site 300 for nearly nine consecutive days, from 7 a.m. on July 12 until 4 a.m. on the 21st. The heat persisted into August with Site 300 having its warmest August since at least 1991 and the Livermore site just missed having its warmest August on record.

The pattern changed dramatically the next month as persistent sea breezes caused it to be the coldest September on record at both the Livermore site and Site 300. Overnight temperatures were especially cool at the Livermore site, with low temperatures dipping below 10.0 °C (50 °F) on 10 mornings, including 6.7 °C (44 °F) on September 11. Record warmth returned in December as a series of storms brought rains and tropical air to the area in the second half of the month. High temperatures at the Livermore site reached 15.6 °C (60 °F) or higher on 11 of the final 14 days of the month including a peak of 19.4 °C (67 °F) on the 20th and 21st. The Site 300 temperature reached 21.3 °C (70 °F) for a few minutes on the 20th as warmer air aloft was apparently transported downward locally. It was the highest temperature recorded since 1991 at Site 300 during December. Both the Livermore site and Site 300 recorded their highest average daily maximum temperatures for December on record.

The highest temperature recorded at the Livermore site during 2005 was 39.5 °C (103 °F) on July 16 and 23; the peak temperature at Site 300 of 40.0 °C (104 °F) occurred on July 17. The lowest temperatures during the year were –2.4 °C (28 °F) at the Livermore site on November 27 and –1.6 °C (29 °F) at Site 300 on December 16.

Both rainfall and wind exhibit strong seasonal patterns. These wind patterns 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. Most precipitation occurs between October and April, with very little rainfall during the warmer months.

Annual wind data for the Livermore site are included in **Figure 1-2**. These data show that winds blow from the south-southwest through west about 49% of the time. This prevailing pattern occurs primarily during the summer.



Note: 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. The average wind speed in 2005 at the Livermore site was 2.3 m/s (5.2 mph); at Site 300 it was 5.5 m/s (12.3 mph).

Figure 1-2. Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2005

During the winter, winds from the northeast are more common. The peak wind gust at the Livermore site of 20 m/s (44 mph) from the southwest occurred on April 8 as a cold front swept through the area. Based on a 48-year record, the highest and lowest annual rainfalls were 85.2 and 16.7 cm (33.57 and 6.57 in.), and the normal (mean for 1971–2000) annual rainfall is 34.6 cm (13.62 in.). In 2005, the Livermore site received 45.5 cm (17.91 in.) of rain, or 131% of normal. The 2005 rainfall was the most since 1998 when 52.3 cm (20.58 in.) fell. Thunderstorms with intense and frequent lightning dropped 1.3 cm (0.52 in.) of rain on September 19. December was the rainiest month of the year with 11.2 cm (5.02 in.) falling or about 275% of normal. The maximum daily rainfall of 3.6 cm (1.42 in.) fell on December 31.

The meteorological conditions at Site 300, while generally similar to those at the Livermore site, are modified by higher elevation and more pronounced topological relief. The complex topography of the site strongly influences local wind and temperature patterns. Annual wind data are presented in **Figure 1-2**. The data show that winds are stronger and show less directional distribution than at the Livermore site. Winds from the west-southwest through west occurred 43% of the time during 2005. The peak wind gust at Site 300 reached 27 m/s (60 mph) from the west-southwest on January 7 and October 8. As is the case for the Livermore site, precipitation at Site 300 is seasonal, with most rainfall occurring between October and April. Because Site 300 is situated downwind of more extensive elevated terrain located to the south and southwest (i.e., upper winds are typically southerly and southwesterly during storms) than at the Livermore site, rainfall amounts are typically 20 to 25% lower. Based on a 46-year record, the highest and lowest annual rainfalls were 59.9 and 14.2 cm (23.58 and 5.61 in.), and the normal annual rainfall is 27.0 cm (10.64 in.). In 2005, Site 300 received 32.5 cm (12.81 in.) of rain, or 120% of normal. As was the case for the Livermore site, the 2005 rainfall at Site 300 was the most since 1998 when 47.5 cm (18.69 in.) fell. An early storm dropped 0.9 cm (0.34 in.) of rain on September 19. The rainiest month at Site 300 was also December with accumulation of 7.8 cm (3.09 in.) or about 218% of normal. The maximum daily rainfall of 2.8 cm (1.12 in.) fell on December 30.

Topography

The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east-west within the Diablo Range. The Livermore Valley, the most prominent valley in the Diablo Range, is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley floor is covered by alluvial, lake, and wetland deposits, consisting of gravels, sands, silts, and clays, at an average thickness of about 100 m (325 ft). The valley is approximately 22.6 km (14 mi) long and generally varies in width between 4 and 11.3 km (2.5 and 7 miles). The valley floor is at its highest elevation of 220 m (720 ft) above sea level along the eastern margin and gradually dips to 92 m (300 ft) at the southwest corner. The major streams passing through the Livermore Valley are the Arroyo del Valle and the Arroyo Mocho, which drain the southern highlands and flow intermittently. Surface waterways in the vicinity of the Livermore site are the Arroyo Seco (along the southwest corner of the site), the Arroyo Las Positas (along the northern perimeter of the site), and the Arroyo Mocho (southwest of the site). These arroyos are shown in **Figure 5-8**. Lake Del Valle, located about 10 km (6 mi) south of LLNL, is the closest large body of water.

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 530 m (1740 ft) above sea level at the northwestern corner of the site to approximately 150 m (490 ft) in the southeast portion.

Hydrogeology

Livermore Site

The hydrogeology and movement of groundwater in the vicinity of the Livermore site have been the subjects of several investigations (Stone and Ruggieri 1983; Carpenter et al. 1984; Webster-Scholten and Hall 1988; Thorpe et al. 1990; Blake et al. 1995). This section summarizes the reports of these investigations and the data supplied by Alameda County Flood Control and Water Conservation District Zone 7, the agency responsible for groundwater management in the Livermore Valley basin (SFBRWQCB 1982a,b).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley groundwater basin and is considered an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Groundwater flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Groundwater flow in the basin is primarily horizontal, although a significant vertical component probably exists in fringe areas, under localized sources of recharge, and in the vicinity of heavily used extraction (production) wells.

Beneath the Livermore site, the depth to the water table varies from about 10 to 40 m (30 to 130 ft) below the ground surface. **Figure 1-3** shows a groundwater elevation contour map of the Livermore site's shallowest, laterally extensive water-bearing unit (hydrostratigraphic unit or HSU), HSU-2. Hydrostratigraphic units are further described in Chapter 8 and illustrated in a cross section (**Figure 8-1**). Although groundwater elevations vary due to seasonal and year-to-year differences in both recharge and groundwater withdrawal from the basin, the qualitative patterns shown in **Figure 1-3** are generally maintained. At the eastern edge of the Livermore site, groundwater gradients (change in vertical elevation per unit of horizontal distance) are relatively steep, but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003.

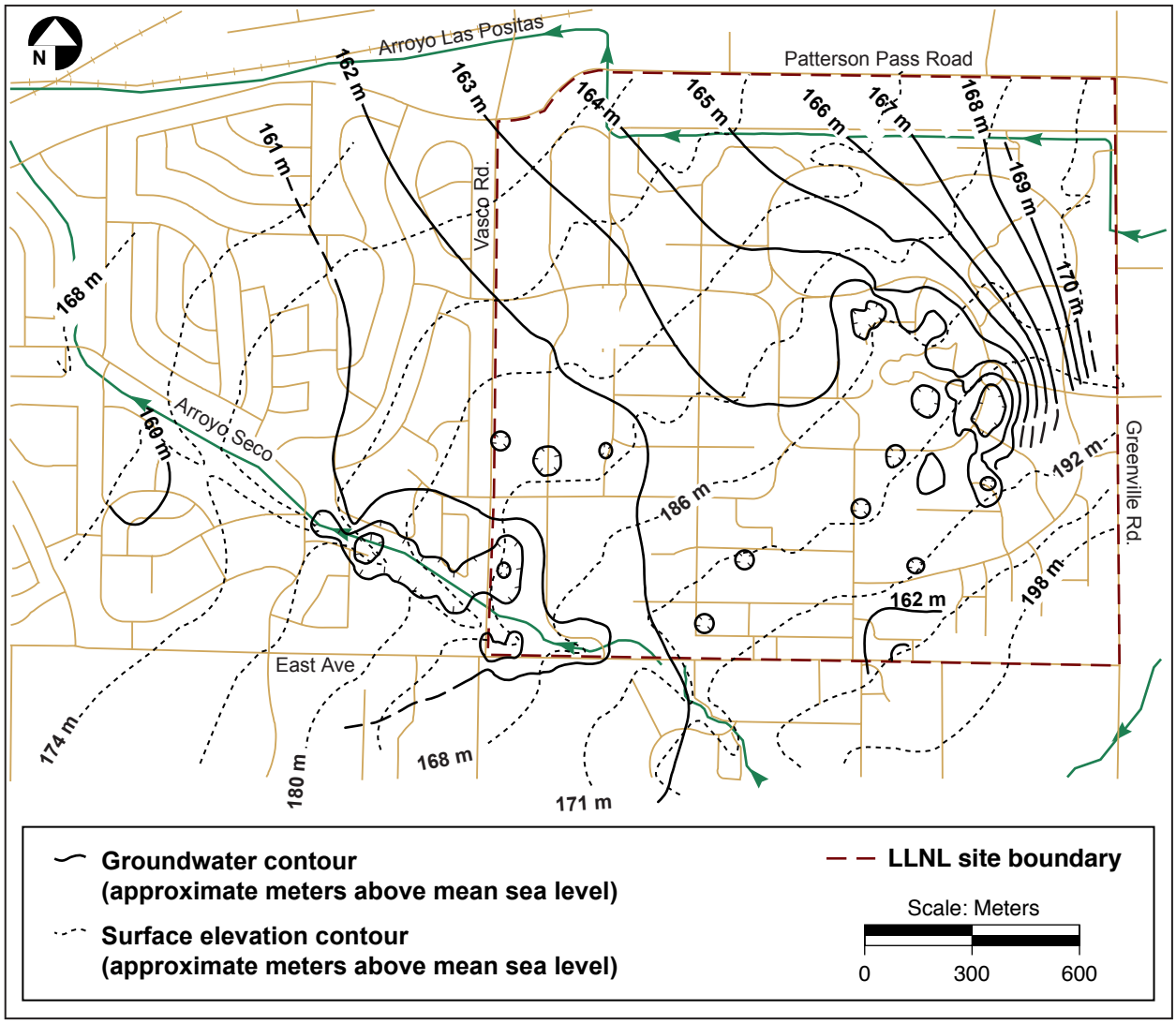


Figure 1-3 Groundwater elevation contours of hydrostratigraphic unit 2 (HSU-2), the shallowest laterally extensive water-bearing unit beneath the Livermore site, October 2005

While groundwater flow beneath the site is generally westward, similar to the regional flow direction, in places it becomes southwesterly, and even easterly, due to extensive groundwater extraction associated with the remedial activities at the site. Groundwater recharge and agricultural pumping have also affected the direction of groundwater flow at the site. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity (a measure of the ability of geologic media to transmit water) of the permeable sediments ranges from 1 to about 16 m/day (3.3 to 52 ft/day) (Isherwood et al. 1991). The range in these values reflects the heterogeneity typical of the more permeable alluvial sediments that underlie the area. This range, in combination with the observed water table

gradients, yields an estimated average groundwater velocity of about 20 m/y (66 ft/y) (Thorpe et al. 1990).

Site 300

Gently dipping sedimentary bedrock dissected by steep ravines generally underlies Site 300. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Groundwater primarily occurs in the Neroly Formation upper and lower blue sandstone units and in the underlying Cierbo Formation. **Figure 8-5** depicts the stratigraphic units that occur beneath Site 300**. Figure 1-4** is a map of the potentiometric surface for the first continuous water-bearing zone at Site 300, which principally occurs in sandstones within the base of the Neroly formation. Significant groundwater is also locally present in permeable Quaternary alluvium valley fill and underlying decomposed bedrock, especially during wet winters. Much less groundwater is 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. Because water quality generally is poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies.

Fine-grained siltstone and claystone interbeds in the lower Neroly sandstone unit and the Cierbo Formation may act as aquitards, confining layers, or perching horizons. Groundwater is present under confined conditions in parts of the deeper bedrock aquifers but is generally unconfined elsewhere. Portions of the bedrock section at Site 300 are abundantly fractured, and thus much of the groundwater flow occurs in fractures as well as in pores.

The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock generally dips east-northeast. South of the anticline, bedrock dips south-southeast. Groundwater flow in most water-bearing strata follows the attitude (dip) of the bedrock. In the northwest part of Site 300, groundwater in bedrock generally flows northeast except where it is locally influenced by the geometry of alluvium-filled ravines. In the southern half of Site 300 and in the central-east portion, groundwater in bedrock flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

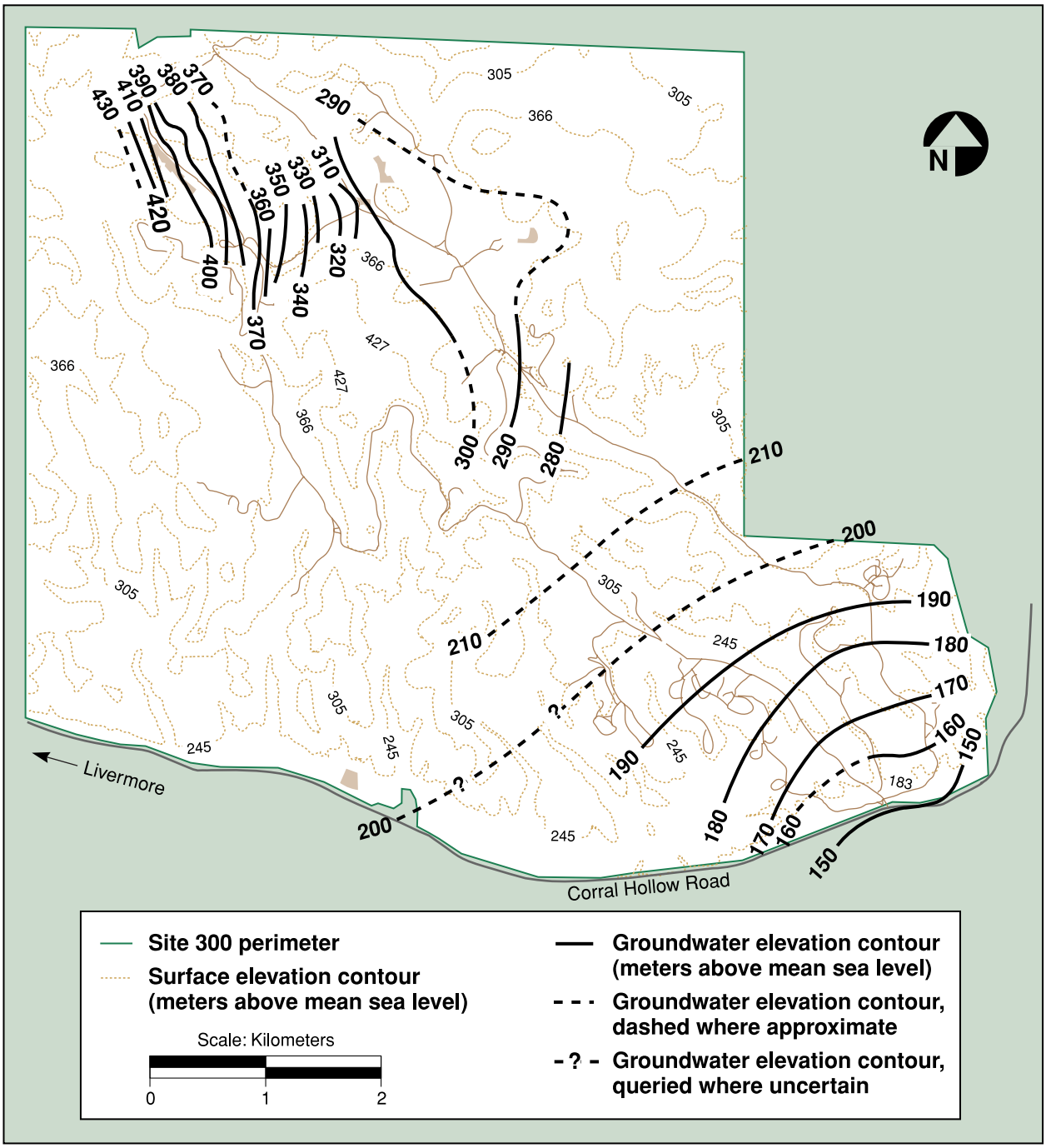


Figure 1-4. Approximate groundwater elevations for the principal continuous water-bearing zone at Site 300

The thick Neroly Formation lower blue sandstone, stratigraphically near the base of the formation, generally contains confined groundwater. Wells located in the western part of the General Services Area pump water from this aquifer and are used for drinking and process supply.

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. Local recharge also occurs on hilltops, creating some perched water-bearing zones. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the deeper bedrock aquifers.

Summary

Meteorology, topography, and geology affect the dispersal of contaminants in the vicinity of the Livermore site and Site 300 and their impact on the public and biota Each year, LLNL strives to add to what is known about the movement of contaminants in groundwater (see Chapter 8) and to improve the quality of meteorological data needed to model dose impacts (see Chapter 7) , LLNL also takes into account the unique features of the Livermore site and Site 300 to tailor sampling and analysis programs for each potentially important environmental pathway.

Contributing Authors

We acknowledge the work of Brent Bowen, John Karachewski, Donald MacQueen, Ring Peterson, and Michael Taffet in preparing this chapter.

Compliance Summary

CHAPTER 2

Lawrence Livermore National Laboratory participates in numerous activities to comply with federal, state, and local environmental regulations as well as internal requirements and applicable U.S. Department of Energy (DOE) orders. The following describes regulations and guidance applicable to LLNL during 2005, including a summary of permits active in 2005, and inspections of the Livermore site and Site 300 by external agencies. The following summaries also provide references for more information where available.

Environmental Restoration and Waste Management

Comprehensive Environmental Response, Compensation and Liability Act

Ongoing groundwater investigations and remedial activities at the Livermore site and Site 300 are called the Livermore Site Ground Water Project (GWP) and the Site 300 CERCLA Project, respectively. These activities fall under the jurisdiction of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Title I of the Superfund Amendments and Reauthorization Act (SARA). As part of work on these projects, DOE and LLNL also continued to conduct community relations activities. CERCLA compliance activities are summarized in the following sections; program activities and findings are further described in Chapter 8.

Livermore Site Ground Water Project

The Livermore site became a CERCLA site in 1987 when it was placed on the National Priorities List. The GWP at the Livermore site 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 project addresses compliance issues by investigating potential contamination source areas (such as suspected old release sites, solvent-handling areas, and leaking underground tank systems) through continuous monitoring and by the remediation of soil and groundwater. The primary soil and groundwater contaminants (constituents of concern) are volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE).

Significant 2005 Livermore site GWP restoration activities include installing one dual (groundwater and soil vapor) extraction well, three groundwater monitoring wells, eight soil vapor wells, and three anode wells; decommissioning three anode wells; conducting four hydraulic tests; and conducting 13 soil vapor extraction tests. LLNL met all regulatory milestones on schedule by activating a groundwater treatment facility (TF) at TFE Hotspot (TFE-HS) and soil vapor treatment facilities (VTFs) at VTFD East Traffic Circle South (VTFD-ETCS), VTFD Hotspot (VTFD-HS), VTFE Hotspot (VTFE-HS), and VTF406 Hotspot (VTF406-HS).

Treatment Facilities: In 2005, LLNL operated 27 groundwater treatment facilities in the TFA, TFB, TFC, TFD, TFE, TFG, and TFH (TF406, TF518, and TF5475) areas (**Figure 8-1**). The 77 groundwater extraction wells and 22 dual extraction wells produced more than 1.1 billion liters of groundwater at an average flow rate of about 2150 liters per minute, removing more than 71 kilograms of VOCs. For comparison, in 2004 the groundwater treatment facilities removed approximately 86 kilograms of VOCs. The smaller quantity of mass removed in 2005 is partially due to decreasing concentrations in the TFD and TFE source areas and declining extraction well flow rates due to remediation-induced dewatering at the site. Since remediation began in 1989, approximately 10.8 billion liters of groundwater have been treated, resulting in removal of more than 1168 kilograms of VOCs. See Chapter 8 for further information.

In 2005, LLNL also operated eight soil VTFs: VTFD East Traffic Circle South, VTFD Helipad, VTFD Hotspot, VTFE Eastern Landing Mat, VTFE Hotspot, VTF406 Hotspot, VTF518 Perched Zone, and VTF5475. The 20 soil vapor extraction wells and 22 dual extraction wells produced over 2.3 million cubic meters of soil vapor, and the treatment facilities removed more than 196 kilograms of VOCs. For comparison, in 2004 the soil vapor treatment facilities removed approximately 133 kilograms of VOCs. The

significantly higher rate of mass removal in 2005 (a 47% increase) is due to activation of four new vapor treatment facilities: VTFD-ETCS, VTFD-HS, VTFE-HS, and VTF406-HS. Since initial operation, approximately 5 million cubic meters of soil vapor have been extracted and treated, removing over 911 kilograms of VOCs from the subsurface. See Chapter 8 for further information.

Community Relations: Livermore site community relations activities in 2005 included communicating and meeting with neighbors and local, regional, and national interest groups and other community organizations; making public presentations; producing and distributing the Environmental Community Letter; maintaining the information repositories and the administrative record; conducting tours of site environmental activities; and responding to public and news media inquiries. In addition, DOE and LLNL met with members of Tri-Valley Communities Against a Radioactive Environment (Tri-Valley CAREs) and their 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 at www-envirinfo.llnl.gov.

Documentation: In 2005, DOE/LLNL submitted the *LLNL Ground Water Project 2004 Annual Report* (Karachewski et al. 2005) and quarterly self-monitoring reports on schedule. In addition, DOE/LLNL completed all 2005 Remedial Action Implementation Plan (Dresen et al. 1993) milestones on schedule.

Site Evaluations Prior to Construction: LLNL was placed on the National Priorities List in 1987 based on historical contamination of soil and groundwater. The *CERCLA Record of Decision for the Lawrence Livermore National Laboratory Livermore Site* (LLNL 1992) identifies selected remedial actions agreed upon by the EPA, SFBRWQCB, and DTSC. The Record of Decision requires that before any construction begins, the project site must be evaluated to determine if soil or rubble (concrete and asphalt) is contaminated. Soil is sampled and analyzed for potential radioactive and/or hazardous contamination. Depending on the potential for radioactive contamination, rubble may be either surveyed or analyzed for radioactivity. During 2005, soil and/or rubble were evaluated at 99 construction sites. Based on the evaluations, the soil and/or rubble were either reused on site or disposed of according to established procedures.

Site 300 CERCLA Project

Investigations and remedial activities are ongoing at Site 300, which became a CERCLA site in 1990, when it was placed on the National Priorities List. Investigations and remedial activities are conducted under the joint oversight

of the EPA, the Central Valley Regional Water Quality Control Board (CVRWQCB), DTSC, and the authority of an FFA for the site. (There are separate FFAs for Site 300 and the Livermore site.) The groundwater contaminants (constituents of concern) for Site 300 vary within the different environmental restoration operable units at the site. Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994) and *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1999).

Treatment Facilities and Field Investigations: VOCs (primarily TCE) are the main contaminants at Site 300. Explosives, tritium, depleted uranium, organosilicate oil, nitrate, and perchlorate are also found in the groundwater. Sixteen treatment facilities operated during 2005. Twenty-five wells that extract groundwater only, 7 wells that extract soil vapor only, and 24 wells that extract both groundwater and soil vapor operated during 2005, treating more than 100.3 million liters of groundwater. The 24 wells that extract both vapor and groundwater and the 7 wells that extract only vapor together removed 111,151 m^3 of vapor. In 2005, the Site 300 treatment facilities removed approximately 89.7 kilograms of VOCs, 0.089 kilograms of perchlorate, 739.7 kilograms of nitrate, 0.09 kilograms of RDX high explosive compound, and 0.41 kilograms of organic silicate oil. Since remediation efforts began in 1990, more than 1176 million liters of groundwater and approximately 528,196 million m^3 of vapor have been treated, to yield about 379.9 kilograms of removed VOCs, 0.397 kilograms of perchlorate, 3391 kilograms of nitrate, 0.57 kilograms of RDX high explosive compound, and 9.41 kilograms of organic silicate oil. See Chapter 8 for further information.

Community Relations: The Site 300 CERCLA project maintains continuing communications with the community of Tracy and nearby neighbors. Community relations activities in 2005 included maintenance of information repositories and administrative records; participation in community meetings; off-site, private well-sampling activities; mailings to stakeholders; and interviews with the news media. LLNL hosted TAG meetings with Tri-Valley CAREs. TAG meetings provided a forum for focused discussions on CERCLA activities at the various operable units at Site 300. Tri-Valley CARES receives the annual TAG grant from EPA to support an environmental consultant to review and comment on Site 300 CERCLA activities.

Documentation: In 2005, LLNL submitted all required documentation to oversight agencies by agreed upon regulatory submission dates. The *Final Remedial Investigation/Feasibility Study (RI/FS) for the Pit 7 Complex Operable Unit* (Taffet et al. 2005), *Draft Final Remedial Design for the Building 832 Operable Unit* (Madrid et al. 2005), *Annual 2004 Compliance*

Report for Lawrence Livermore National Laboratory Site 300 (Dibley et al. 2005a), *First Semester 2005 Compliance Report for Lawrence Livermore National Laboratory Site 300* (Dibley et al. 2005b), *Characterization Summary for the Building 812 Firing Table Area at Lawrence Livermore National Laboratory* (Ferry and Holtzapple 2005a), *Characterization Summary for the Sandia Test Site at Lawrence Livermore National Laboratory* (Ferry and Holtzapple 2005b), quarterly reports, and work plans were among the documents submitted.

Agency for Toxic Substances and Disease Registry Assessment

The Agency for Toxic Substances and Disease Registry (ATSDR) is an agency of the U.S. Public Health Service. Congress established ATSDR in 1980 as part of CERCLA, also known as the Superfund law.

Since 1986, amendments to the Superfund law have required ATSDR to conduct a public health assessment (PHA) at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out whether people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. In 2005, after more than ten years of investigating the public health impacts of various contaminants in and around the Livermore site and Site 300, the ATSDR completed its PHA for Site 300.[1] This PHA (ATSDR 2005) concluded that

> "... the environmental contamination related to Site 300 presents No Public Health Hazard based on the fact that exposure to contaminants from Site 300 is not occurring now, has not occurred in the past and is not expected to occur in the future...."

The ATSDR held a public meeting in Tracy on February 24, 2005, to discuss its findings and answer questions. The LLNL health consultations and assessments completed by ATSDR can be found at http://www.atsdr.cdc.gov/HAC/PHA/region_9.html#california.

[1] The PHA for the Livermore site was completed in 2004 and found "No Apparent Public Health Hazard."

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

Title III of SARA is known as the Emergency Planning and Community Right-to-Know Act (EPCRA). It requires owners or operators of facilities that 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 13148 directs all federal agencies to comply with the requirements of the EPCRA, including SARA Section 313, "Toxics Release Inventory (TRI) Program."

On June 22, 2005, LLNL submitted to the National Nuclear Security Administration (NNSA)/DOE the TRI Form R for lead detailing environmental release estimates for Site 300. (Form R is used for reporting TRI chemical releases including waste management and waste minimization activities.) With greater than 85% reduction in lead releases since TRI reporting year 2001, there continues to be a significant decline in the lead released at Site 300. This is directly attributable to the increased use of nonlead (frangible) and reduced-lead-containing ammunition.

EPCRA requirements and LLNL compliance are summarized in **Table 2-1**.

Table 2-1. Compliance with EPCRA

EPCRA requirement[a]	Brief description of requirement[a]	LLNL action
302 Planning Notification	Notify SERC of presence of extremely hazardous substances.	Originally submitted May 1987.
303 Planning Notification	Designate a facility representative to serve as emergency response coordinator.	Update submitted May 24, 2005.
304 Release Notification	Report releases of certain hazardous substances to SERC and LEPC.	No EPCRA-listed extremely hazardous substances were released above reportable quantities in 2005.
311 MSDS/Chemical Inventory	Submit MSDSs or chemical list to SERC, LEPC, and Fire Department.	Update submitted May 24, 2005.
312 MSDS/Chemical Inventory	Submit hazardous chemical inventory to local administering agency (county).	Business plans and chemical inventory submitted to San Joaquin County (January 17, 2005) and Alameda County (March 1, 2005).
313 Toxics Release Inventory	Submit Form R to U.S. EPA and California EPA for toxic chemicals released above threshold levels.	Form R for lead (Site 300 only) was submitted to DOE June 22, 2005; DOE forwarded it to U.S. EPA and California EPA June 28, 2005.

a See Acronyms and Abbreviations for list of acronyms.

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 the generation, storage, treatment, and management of solid wastes, including wastes designated as hazardous. The California Hazardous Waste Control Act (HWCA) and the California Code of Regulations (CCR) Title 22 set requirements for managing hazardous wastes and implement RCRA in California. RCRA and HWCA also regulate hazardous waste treatment, storage, and disposal facilities, including permit requirements. Because RCRA program authorization was delegated to the State of California in 1992, LLNL works with DTSC to comply with federal and state issues and obtain hazardous waste permits.

Hazardous Waste Permits

Livermore Site: The hazardous waste management facilities at the Livermore site consist of permitted units located in Area 612 and Buildings 693, 695 and 696 (except for Room 1001) of the Decontamination and Waste Treatment Facility (DWTF). The units that were operated under interim status (Area 514 Facility and the Building 233 Container Storage Facility) have been relocated to permitted facilities. Building 233 and Area 514 are currently undergoing RCRA closure. Permitted waste management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction). During 2004/2005, LLNL also submitted several Class 1 and Class 2 permit modification requests to DTSC; all Class 2 permit modifications were approved on December 9, 2005, and all except one of the requested Class 1 permit modifications were approved and implemented. The one Class 1 permit modification that was not approved was submitted to DTSC on August 5, 2005 as a modification to treat regulated wastes in up to 85-gallon containers within the Small Scale Treatment Laboratory (SSTL). Many of these modification requests are related to as-built changes and consolidation of storage and treatment of hazardous waste at the DWTF complex. On December 9, 2005, DTSC updated LLNL's Hazardous Waste Facility Permit (HWFP).

A final closure plan for the Building 419 Interim Status Facility was submitted to DTSC in February 2001. DTSC is continuing its review of this closure plan. LLNL has provided additional information requested by DTSC, including responding to Building 419 Notices of Deficiency (NODs) that DTSC issued in November 2004.

See **Table 2-2** for a summary of permits active in 2005. LLNL received no violations as a result of any of the three inspections DTSC conducted during 2005.

Table 2-2. Permits Active in 2005

Type of permit	Livermore site[a][b]	Site 300[a][b]
Hazardous waste	EPA ID No. CA2890012584. Hazardous Waste Facility Permit Number 99-NC-006 (RCRA Part B permit)—to operate hazardous waste management facilities including Buildings 693, 695, and 696, and Area 612. Activities authorized in these areas include treatment and storage of hazardous and mixed wastes subject to the conditions specified in the Part B permit. LLNL is also a Registered Hazardous Waste Hauler and is authorized to transport wastes from Site 300 to the Livermore site. Conditionally Exempt Specified Wastestream permit to mix resin in Unit CE231-1. Conditional Authorization Permit to operate sludge dewatering unit in Building 322A.	EPA ID No. CA2890090002. Part B Permit—Container Storage Area (Building 883) and Explosives Waste Storage Facility. Part B Permit—Explosives Waste Treatment Facility. Part B Permit—RCRA-Closed Building 829 Explosives Open Burn Facility, Post-Closure Permit.
Medical waste	Two permits for large quantity medical waste generation and treatment: one covering the Biosciences Directorate; Safety and Environmental Protection Directorate (Health Services Department); Nonproliferation, Homeland and International Security Directorate (Forensic Science Center, Medical Photonics Lab, Culture Growth Lab); Energy and Environment Directorate (Tissue Culture Lab); and Chemistry and Materials Science Directorate; the second covering medical waste generation and treatment activities planned for the Biosafety Level 3 (BSL-3) laboratory.	Limited Quantity Hauling Exemption for small quantity medical waste generator.
Air	BAAQMD issued 181 permits for operation of various types of equipment, including boilers, emergency diesel generators, cold cleaners, degreasers, printing press operations, manual wipe-cleaning operations, metal machining and finishing operations, silk-screening operations, silk-screen washers, paint spray booths, adhesives operations, optic coating operations, drum crusher, semiconductor operations, diesel air-compressor engines, groundwater air strippers, soil vapor extraction units, material-handling equipment, sewer diversion system, oil and water separator, fire-test cells, gasoline-dispensing operation, paper-pulverizer system, and firing tanks.	SJVAPCD issued 43 permits for operation of various types of equipment, including emergency diesel generators, paint spray booth, groundwater air strippers, soil vapor extraction units, woodworking cyclone, gasoline-dispensing operation, explosive waste treatment units, drying ovens, and the Contained Firing Facility.
Storage tanks	Seven operating permits covering 10 underground petroleum product and hazardous waste storage tanks: 111-D1U2 Permit No. 6480; 113-D1U2 Permit No. 6482; 152-D1U2 Permit No. 6496; 271-D2U1 Permit No. 6501; 321-D1U2 Permit No. 6491; 365-D1U2 Permit No. 6492; and 611-D1U1, 611-G1U1, 611-G2U1, and 611-O1U1 Permit No. 6505.	One operating permit covering three underground petroleum product tanks assigned individual permit numbers: 879-D1U1 Permit No. 006785; 879-G3U1 Permit No. 007967; and 882-D1U1 Permit No. 006530.

Table 2-2 Permits Active in 2005 (continued)

Type of permit	Livermore site[a][b]	Site 300[a][b]
Sanitary sewer	Discharge Permit 1250[c] (2004/2005 and 2005/2006[d]) for discharges of wastewater to the sanitary sewer. Permit 1510G (2004/2006[e]) for discharges of groundwater from CERCLA restoration activities to the sanitary sewer.	
Water	WDR Order No. 88-075 for discharges of treated groundwater from Treatment Facility A to recharge basin.[f] WDR Order No. 95-174, NPDES Permit No. CA0030023 for discharges of storm water associated with industrial activities and low-threat nonstorm water discharges to surface waters. WDR Order No. 99-08-DWQ, NPDES California General Construction Activity Permit No. CAS000002; Terascale Simulation Facility, Site ID No. 201C317827; Soil Reuse Project, Site ID No. 201C305529; National Ignition Facility, Site ID No. 201C306762; Building 583 Project, Site ID No. 201C332958; Arroyo Seco Water Management Plan, Site ID No. 201C335224; and A-4 Parking Lot, Site ID No. 201C333137; for discharges of storm water associated with construction activities affecting 0.4 hectares (1 acre) or more. FFA for groundwater investigation/remediation. NWPs 27, 13, and 7 for the implementation of the Arroyo Seco Management Plan.	WDR Order No. 93-100 for post-closure monitoring requirements for two Class I landfills. WDR Order No. 96-248 for operation of two Class II surface impoundments, a domestic sewage lagoon, and percolation pits. WDR Order No. 97-03-DWQ, NPDES California General Industrial Activity General Permit No. CAS000001 for discharge of storm water associated with industrial activities. WDR Order No. 99-08-DWQ, NPDES California General Construction Activity Permit No. CAS000002: Surface Impoundments Closure and Tanks Installation Project, Site ID No. 5S39C334065; Mid-Elk Ravine CRLF Project, Site ID No. 5S39C335461; WDR Order No. 97-242, NPDES Permit No. CA0082651 for discharges of treated groundwater from the eastern General Services Area treatment facility.[g] WDR Order No. 5-00-175, NPDES Permit No. CAG995001 for large volume discharges from the drinking water system that reach surface waters. NWP 27 for enhancing mid-Elk Ravine red-legged frog breeding ponds. Water Quality Certification for mid-Elk Ravine red-legged frog breeding ponds, WDID # 5B39CR00047. NWP 14 for installing lower Elk Ravine culvert. Water Quality Certification for installing lower Elk Ravine culvert, WDID # 5B39CR00089. FFA for groundwater investigation/remediation. 34 registered Class V injection wells.[h]

a Numbers of permits are based on actual permitted units or activities maintained and renewed by LLNL during 2005.
b See Acronyms and Abbreviations for list of acronyms.
c Permit 1250 includes wastewater generated at Site 300 and discharged at the Livermore site.
d The Discharge Permit 1250 period is from May 15 to May 14; therefore, two permits were active during the 2005 calendar year.
e Permit 1510G is a two-year (January to December) permit.
f Recharge basins referenced in WDR Order No. 88-075 are located south of East Avenue within Sandia National Laboratories/California boundaries.
g This permit was rescinded on August 8, 2005 by the Central Valley RWQCB after the substantive requirements of the permit were incorporated into the CERCLA Record of Decision.
h One injection well was closed on August 5, 2005, reducing the total to 33.

Site 300: The hazardous waste management facilities at Site 300 consist of three operational RCRA-permitted facilities. The Explosives Waste Storage Facility and Explosives Waste Treatment Facility are permitted to store and treat explosives waste only. The Building 883 Container Storage Area is permitted to store routine facility-generated waste such as spent acids, bases, contaminated oil, and spent solvents. See **Tables 2-2** and **2-3** for a summary of active permits and inspections, respectively, at Site 300 in 2005.

DTSC conducted the 2005 inspection of Site 300 on June 16 and 21, 2005. No violations were issued in the summary of observations at the conclusion of the inspection.

Hazardous Waste Reports

LLNL completed two annual hazardous waste reports, one for the Livermore site and the other for Site 300, that addressed the 2005 transportation, storage, disposal, and recycling of hazardous wastes at the respective sites. The 2005 Hazardous Waste Report-Main Site and 2005 Hazardous Waste Report-Site 300 were submitted to the DTSC by April 1, 2006.

Hazardous Waste Transport Registration

Transportation of hazardous waste over public roads (e.g., from one LLNL site to another) requires DTSC registration (22 CCR 66263.10). DTSC renewed LLNL's registration in November 2005.

Waste Accumulation Areas

LLNL Programs maintain waste accumulation areas (WAAs) in compliance with waste generator requirements specified in 40 Code of Federal Regulations (CFR) Part 262, and Title 22 California Code of Regulations (CCR) Part 66262.34, for the temporary storage (less than 90 days) of hazardous waste prior to transfer to a treatment, storage, and disposal facility. In January 2005, there were 23 WAAs at the Livermore site. During 2005, twelve temporary WAAs were put into service, while seven temporary WAAs and one permanent WAA were taken out of service. Program representatives conducted inspections at least weekly at all WAAs to ensure that they were operated in compliance with regulatory requirements. At the Livermore site, 1368 prescribed WAA inspections were conducted.

At Site 300 during 2005, two WAAs were in operation; three temporary WAAs were put into service, while four temporary WAAs were taken out of service. Program representatives conducted 131 prescribed WAA inspections at Site 300.

Table 2-3. Inspections and tours of Livermore site and Site 300 by external agencies in 2005

Medium	Description[a]	Agency[a]	Date	Finding[a]
Livermore Site				
Waste	Hazardous waste facilities CEI	DTSC	4/25, 4/26, 4/27, 5/5	Received the initial inspection report and SOOs 5/5. There were no violations of hazardous waste laws, regulations or requirements. LLNL is waiting for DTSC's final report.
	Hazardous waste facilities ESI	DTSC	1/26, 1/27, 1/31 10/31, 11/1	Received two initial inspection reports on 1/31 and 11/1 detailing SOOs. There were no violations of hazardous waste laws, regulations or requirements. DTSC sent a final report on 6/9/06 and issued a Class II violation, which LLNL requested to be reduced to a minor violation.
	Medical waste	ACDEH	9/29	No violations
	Waste tire management	ACDEH	6/23	No violations
Air	97 emission sources	BAAQMD	4/6, 5/12, 6/29, 9/22	No violations
Sanitary sewer	Annual compliance sampling	LWRP	10/4–10/5	No violations
	Categorical sampling			
	Bldg. 153		10/4	No violations
	Bldg. 321C		10/12	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits	ACDEH	3/14, 4/18, 9/20, 9/27	No violations
Site 300				
Waste	Permitted hazardous waste operational facilities (EWTF, EWSF, Building 883 CSA), RCRA-closed, post-closure permitted facility Building 829 Open Burn Facility, Building 883 WAA, and a review of hazardous waste-related documentation	DTSC	6/16, 6/21	Received no violations in initial inspection report and SOOs.
	Biennial inspection of terminal (transportation)	CHP	1/12	Received one violation for an air leak at a break relay valve. It was repaired.
Air	35 emission sources	SJVAPCD	11/16, 12/12	No violations
	Asbestos removal		3/21	No violations
Water	Permitted operations	CVRWQCB	4/14 10/27	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits	SJCEHD	3/22, 9/28, 11/10	No violations

a See Acronyms and Abbreviations for list of acronyms.

California Medical Waste Management Act

All LLNL medical waste management operations comply with the California Medical Waste Management Act, which establishes a comprehensive program for regulating the management, transport, and treatment of medical wastes that contain substances that may potentially infect humans. The program is administered by California Department of Health Services and is enforced by the Alameda County Department of Environmental Health (ACDEH).

LLNL is registered with the ACDEH as a generator of medical waste and has a treatment permit. No violations were issued as a result of the September 2005 ACDEH inspection of buildings at LLNL Health Services and the Biosciences Directorate. (See **Tables 2-2** and **2-3**.)

Radioactive Waste and Mixed Waste Management

LLNL manages radioactive waste and mixed waste in compliance with applicable sections of DOE Order 435.1, as described in LLNL's ES&H Manual, Document 36.1, "Hazardous, Radioactive, and Biological Waste Management Requirements." LLNL has also developed and maintains the Radioactive Waste Management Basis (LLNL 2006), which summarizes radioactive waste management controls relating to waste generators and treatment and storage facilities.

Federal Facility Compliance Act

LLNL is continuing to work with DOE to maintain compliance with the Federal Facilities Compliance Act Site Treatment Plan (STP) for LLNL that was signed in February 1997. LLNL completed 65 milestones during 2005; of the 65 milestones completed, 46 of the milestones had dates beyond 2005 (ranging from 2006 to 2011). In addition to completing the 19 milestones from 2005, LLNL requested extensions for six milestones that were due in 2005. The six milestones were associated with 3.4 cubic meters of waste.

There was a major effort to reduce the volume of waste stored at LLNL. Through this effort LLNL was able to reduce the volume of waste protected by the STP by more than 456 cubic meters. DTSC granted the milestone extensions because of the progress LLNL made toward completion of the milestones and the overall progress made in reducing the amount of mixed waste stored at LLNL.

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

Toxic Substances Control Act

The Federal Toxic Substances Control Act (TSCA) and implementing regulations found in 40 CFR Part 700-789 govern the uses of newly developed chemical substances and TSCA-governed waste by establishing the following partial list of requirements: record keeping, reporting, disposal standards, employee protection, compliance and enforcement, and cleanup standards.

In 2005, LLNL generated TSCA-regulated polychlorinated biphenyl (PCB) waste from electrical equipment contaminated with PCBs, liquid PCBs used to calibrate analytical equipment, and asbestos from building demolition or renovation projects.

All TSCA-regulated waste was disposed in accordance with TSCA, state, and local disposal requirements except for radioactively contaminated PCB waste. Radioactive PCB waste is currently stored at one of LLNL's hazardous waste storage facilities until an approved facility accepts this waste for final disposal.

Air Quality and Protection

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 Air Districts are overseen by the California Air Resources Board (CARB).

In 2005, LLNL operated 181 permitted air emission sources at the Livermore site and 43 permitted air emission sources at Site 300 (see **Table 2-2**). During the year, the BAAQMD performed four Livermore site inspections of 97 emission sources, and the SJVAPCD performed two Site 300 inspections of 35 emission sources. Both the BAAQMD and the SJVAPCD found all inspected sources to be in compliance with the applicable air emission regulations and permit conditions. As a result, no violations were issued. The dates and findings of the inspections are identified in **Table 2-3**.

In addition, the Livermore site continues to maintain a Synthetic Minor Operating Permit (SMOP), which was issued by the BAAQMD in 2002. The Livermore site initially had the potential to emit regulated air pollutants from permitted and permit-exempt sources in quantities exceeding federal Title V limits. In lieu of obtaining a Title V permit, LLNL opted to obtain and maintain a SMOP for the Livermore site. A SMOP places enforceable limits on the facility's operations to ensure the emission from the facility's permitted and permit-exempt sources stay well below the Title V limits for regulated air pollutants. The Livermore site is restricted by the SMOP to 31.8 MT (35 tons) per year for nitrogen oxides (NOx), 31.8 MT (35 tons) per year of precursor organic compounds, 20.9 MT (23 tons) per year for any combination of hazardous air pollutants (HAP), and 8.2 MT (9 tons) per year for any single HAP. The actual air pollutant emissions from the Livermore site are identified in Chapter 4.

In 2005, two significant air emission regulations were enacted. The first was CARB's "Airborne Toxic Control Measure for Stationary Compression Ignition Engines" (ATCM), and the second was BAAQMD's revision to its list of Toxic Air Contaminants (TACs) and associated "trigger levels" (i.e., emission limits).

The CARB ATCM established reduced particulate matter (PM) emission standards for diesel-fueled compression ignition generators and air compressors, and required, in certain instances, replacement of such generators and air compressors that cannot meet the new PM emission standards. LLNL has 89 permitted generators and 3 permitted air compressors at the Livermore site that are affected by the ATCM. Initially, 61 of the generators required replacement pursuant to the ATCM. However, LLNL was able to reclassify 47 of the initial 61 generators, by limiting their usage and modifying their permits, to an equipment status that would not require replacement of the generators under the ATCM. As a result, LLNL saved an estimated $5,500,000 in generator replacement costs through the permit modification process. LLNL has 16 permitted diesel generators at Site 300 that are affected by ATCM. None of these generators require replacement under the ATCM.

In July 2005, an uncontrolled wildland fire was ignited west of Site 300 by an arsonist. Approximately 4100 acres of public and private land adjacent to Site 300 were consumed by the fire; about 2100 acres burned at Site 300. Suppression of the wildland fire at Site 300 was attributed by Fire Department and the California Department of Forestry (CDF) personnel to the fire line perimeters established by LLNL's annual prescribed burn. If it had not been for the prescribed burn, the wildland fire would have consumed the process areas within Site 300 and an estimated additional 10,000 acres of public and private lands. The potential public exposure to PM and NOx emissions from the additional burning of 10,000 acres would have been, at a

minimum, 100 tons of PM and 40 tons of NOx. SJVAPCD representatives acknowledged and commended LLNL Fire Department personnel for their role in preventing the spread of the fire.

National Emission Standards for Hazardous Air Pollutants, Radionuclides

To demonstrate compliance with Title 40 of the Code of Federal Regulations Part 61, Subpart H (the National Emission Standards for Hazardous Air Pollutants [NESHAPs] for radiological emissions from DOE facilities), LLNL is required to monitor certain air release points and evaluate the maximum possible dose to the public. These evaluations include modeling dose (using EPA-sanctioned computer codes) based on air effluent (source emission) and air surveillance monitoring and assessing dose from small sources based on air surveillance monitoring. The *LLNL NESHAPs 2005 Annual Report* (Larson et al. 2006), submitted to EPA, reported that the estimated maximum radiological doses that could have been received by a member of the public were 0.065 μSv (0.0065 mrem) for the Livermore site and 0.18 μSv (0.018 mrem) for Site 300 in 2005. The reported doses include contributions from both point and diffuse sources. The totals were well below the 100 μSv/y (10 mrem/y) dose limits defined by the NESHAPs regulations. Additional information on the data is described in Chapter 7.

In 2005, LLNL continuously monitored radionuclide emissions from Building 331 (the Tritium Facility), Building 332 (the Plutonium Building), and portions of five other facilities (see Chapter 4). There were no unplanned atmospheric releases at the Livermore site or at Site 300 in 2005. Monitoring activities and results related to air are described further in Chapter 4.

Water Quality and Protection

Clean Water Act and Related State Programs

Preserving clean water is an objective of local, state, and federal regulations. The National Pollutant Discharge Elimination System (NPDES) under the federal Clean Water Act (CWA) establishes permit requirements for discharges into waters of the United States. In addition, the State of California, under the Porter-Cologne Water Quality Control Act, requires permits, known as Waste Discharge Requirements (WDRs), for any waste discharges affecting the beneficial uses of waters of the state. These permits, as well as water quality certification for discharges authorized under Section 401 of the CWA, are issued by local Regional Water Quality Control Boards

(RWQCBs) and the State Water Resources Control Board. RWQCBs enforce both the regional and state issued permits. Section 401 state certifications are required when the Army Corps of Engineers issues permits under Section 404 of the CWA. Several other agencies issue other water-related permits. The Livermore Water Reclamation Plant (LWRP) requires permits for discharges to the city's sanitary sewer system. The Safe Drinking Water Act requires registration with the EPA and management of injection wells to protect underground sources of drinking water.

Water-related permits and inspections from outside agencies are summarized in **Tables 2-2** and **2-3**, respectively. LLNL received one Notice of Violation (NOV) from the LWRP in April 2005 for exceeding the maximum pH limit of 10. No other enforcement actions were taken against LLNL by other water-related regulatory agencies in 2005. See **Table 2-4** for a summary of nonconformance with water-related permits identified by LLNL.

Table 2-4. Water-related permit nonconformance

Permit No[a]	Nonconformance[a]	Date(s) of nonconformance	Description–solution[a]
1250, LWRP sanitary sewer permit	Excursion above pH permit limit of 10; approximately 300-600 gallons of effluent discharged to the LWRP with a pH of 11.6.	4/6/05-4/7/05	Remainder of effluent captured and contained on site by Sewer Diversion Facility. LLNL received an NOV from the LWRP.
CAS000002, WDID No. 201C305529 ALP	Soil Reuse Project—Failure to conduct required predicted rain event inspections.	9/04 through 4/05[b]	Incidents were identified to project management and noted in the annual compliance certification dated 6/30/05.
CAS000002, WDID No. 201C306762 ALP	National Ignition Facility—Failure to document 2 required storm water inspections.	12/17/05 and 12/30/05	Incidents were identified to project management and noted in the annual compliance certification dated 6/28/05.

a See Acronyms and Abbreviations for list of acronyms.
b These dates reflect the construction reporting period of June 2004 through May 2005.

In 2005, LLNL completed three projects authorized by the Army Corps of Engineers (ACOE) under Nationwide Permits (NWPs). At the Livermore site, LLNL implemented a long-term management plan for Arroyo Seco that incorporates biotechnical bank and channel restoration techniques. The goals of the long-term plan are to ensure flood capacity conveyance while protecting water quality and habitat values in Arroyo Seco. The project included repairing existing bank erosion; constructing better transitions downstream of areas where the stream bank was previously stabilized by gabions and steel sheet-piling; constructing a berm system to redirect overland flow; and widening and lengthening the lower two-thirds of the project reach. This project was authorized under three NWPs: NWP 27 for Stream and Wetland Restoration Activities, NWP 13 for Bank Stabilization, and NWP 7 for Outfall Structures

and Maintenance. The SFBRWQCB waived certification and permitting requirements for this project.

At Site 300, LLNL completed the construction of mitigation habitat for the California red-legged frog. Two breeding pools were constructed in mid-Elk Ravine to compensate for the loss of habitat as a result of turning off artificial flow in the upper reaches of Elk Ravine. This project was authorized under NWP 27 and certified by the Central Valley RWQCB. Also at Site 300, LLNL installed a culvert in lower Elk Ravine to maintain year-round access of a fire trail. This project was authorized under NWP 14 for Linear Transportation Projects and certified by the Central Valley RWQCB.

Monitoring activities and results related to water permits are described in Chapter 4.

Tank Management

The CWA and California Aboveground Petroleum Storage Act require facilities meeting specific storage requirements to have and implement Spill Prevention Control and Countermeasure (SPCC) plans for aboveground, oil-containing containers, including equipment and tanks. ACDEH and San Joaquin County Environmental Health Department (SJCEHD) also issue permits for operating underground storage tanks containing hazardous materials or hazardous waste as required under the California Health and Safety Code.

LLNL manages its underground and aboveground storage tanks through the use of underground tank permits, monitoring programs, operational plans, closure plans and reports, leak reports and follow-up activities, and inspections. At LLNL, permitted underground storage tanks contain diesel fuel, gasoline, and used oil; aboveground storage tanks contain fuel, insulating oil, and process wastewater. Some nonpermitted wastewater tank systems are a combination of underground storage tanks and aboveground storage tanks. All permitted underground storage tanks were inspected by the regulating agencies in 2005. No violations were noted during the inspections. See **Table 2-3** for summary of inspections.

In 2005, LLNL conducted extensive, site-wide surveys of outdoor areas at both the Livermore site and Site 300 for aboveground oil containers of 55 gallons or greater. These activities were conducted in compliance with SPCC regulation updates promulgated in 2002. Updates to the SPCC plans for both the Livermore site and Site 300 will be completed in 2006.

Other Environmental Statutes

National Environmental Policy Act

The National Environmental Policy Act (NEPA) is our country's basic environmental charter. NEPA requires the federal government to do two things when they consider a proposed project or action: 1) consider how the action will affect the human environment, and 2) inform the public and involve them in the decision making process. LLNL activities must comply with the requirements of NEPA because they are generally funded by the federal government.

Federal agencies meet the first NEPA requirement by studying the impact a project would have on the human environment. The agency studies the components of the human environment that may be affected by the project, which may or may not include air, water, soil, biological resources, socio-economics, aesthetics, noise, or cultural resources. The results of their studies are written in a "NEPA document." Federal agencies meet the second requirement (inform the public) by distributing the NEPA documents. NEPA documents are made available in public reading rooms and on the internet, and are sometimes directly mailed to interested parties. Federal agencies often involve the public in their decisions about proposed projects by holding public meetings and asking for comments on their NEPA documents.

There are two types of NEPA documents: environmental impact statements (EISs) and environmental assessments (EAs). Environmental impact statements are prepared for major federal actions that significantly affect the quality of the human environment. In contrast, EAs are prepared for federal actions that will not have a significant impact on the environment. The federal agency decides which type of document to prepare after studying the impact to the environment.

Some projects do not require the preparation of either an environmental impact statement or an environmental assessment. These projects fit into categories of activities that are well understood and known to have no impact on the human environment. After an agency studies the environmental impacts of a project and determines that the project fits into one of these categories, no further documentation is required. Nonetheless, some federal agencies, including DOE at LLNL, choose to write a memorandum that describes the project and explains why it meets the criteria for being categorically excluded. These memoranda are referred to as CXs, Cat Xs, and Categorical Exclusions—technically, they are not actual NEPA documents.

The paragraphs that follow provide details about the NEPA documents and Categorical Exclusions that have been prepared for LLNL projects this year.

There were no LLNL projects in 2005 that required DOE EAs. Twelve categorical exclusion recommendations were approved by DOE. There were no proposed actions at LLNL that required separate DOE floodplain or wetlands assessments under DOE regulations in 10 CFR 1022.

In 2004, DOE published the draft *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory (DOE/EIS-0348)* and *Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement (DOE/EIS-0236-53) (LLNL SW/SPEIS)*. The draft *LLNL SW/SPEIS* was issued for a 90-day public comment period (February 27 to May 27, 2004). Three public hearings were held in 2004: April 27 in Livermore, April 28 in Tracy, and April 30 in Washington, D.C. The final LLNL SW/SPEIS (DOE 2005) was published in March 2005, and a Record of Decision filed on November 29, 2005.

Since November 1992, the University of California (UC) and LLNL have implemented mitigation measures identified by the *1992 EIS/EIR*. An addendum to the *1992 EIS/EIR* was prepared in 1997. The measures are being implemented in accordance with the approved 1992 Mitigation Monitoring and Reporting Program associated with the *1992 EIS/EIR*. The 2000 mitigation monitoring report was published in 2003. Publication of the 2001 through 2004 mitigation monitoring reports is pending.

National Historic Preservation Act

The National Historic Preservation Act (NHPA) applies to historically important places and to the preservation of prehistoric and historic resources of the United States. LLNL resources subject to NHPA consideration range from prehistoric archeological sites to remnants of LLNL's own history of scientific and technological endeavor. The responsibility to comply with the provisions of NHPA rests solely with DOE as a federal agency. LLNL and UC as its contractor operator support DOE NHPA responsibilities. LLNL does so with direction from DOE.

The two primary NHPA sections that apply to LLNL are Sections 106 and 110. Section 106 requires federal agencies to take into account the effects their undertakings may have on historic properties. The agencies must allow and consider comments of the federal Advisory Council on Historic Preservation. The Section 106 regulations outline a five-step review process that is conducted for individual federal actions. Section 110 sets forth broad affirmative responsibilities to balance agency missions with cultural values. Its purpose is to ensure full integration of historic preservation into federal agency programs.

LLNL has taken two approaches to streamline historic preservation efforts and focus on important historic properties under its management. First, DOE, UC, and the State Historic Preservation Officer (SHPO) reached an agreement in July 2003 that governed historic preservation program activities until resource inventory and assessment activities specified in the agreement were complete. The goal was to reduce the amount of paperwork necessary to ensure protection of important historic properties by reaching a consensus on where and how to effectively focus LLNL's efforts. The second goal, as is specified in the agreement, was to complete within a reasonable timeframe an inventory of places (prehistoric and historic, archeological, and architectural) that meets a statutory threshold of historic importance. The inventory of places specified in the agreement was completed in 2004. In 2005, LLNL prepared a document describing the inventory of prehistoric and historic archaeological resources and recommending those that appear to meet the statutory threshold of historic importance. DOE, in consultation with the SHPO, used the information contained in the document to formally determine that five of LLNL's archaeological resources qualify for listing in the National Register of Historic Places. DOE, in consultation with the SHPO, also formally determined that six buildings, two historic districts, and one object at LLNL are eligible for listing in the National Register of Historic Places. Until a new agreement is in place, LLNL and NNSA continue to consult with the SHPO for individual actions in accordance with the July 2003 agreement.

With the inventory and assessment completed, DOE, UC, the SHPO, and the Advisory Council on Historic Preservation (ACHP) initiated discussions toward the development of a new agreement that would govern how these National Register-eligible properties will be managed. To assist in these discussions, LLNL prepared a draft archaeological resources treatment plan in July 2005 and a draft historic buildings treatment plan in September 2005 that describe specific resource management and treatment strategies that could be implemented by DOE, in cooperation with LLNL, to ensure that these properties are managed in a manner that considers their historic values. At the end of 2005, these documents were under consideration by DOE.

Antiquities Act

Provisions of the Antiquities Act provide for recovery of paleontological remains. After the discovery of mammoth remains in conjunction with the National Ignition Facility construction in 1997, LLNL has remained vigilant for other fossil finds. No remains subject to the provisions of the Antiquities Act were identified in 2005.

Endangered Species Act and Sensitive Natural Resources

Requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and the California Native Plant Protection Act are met 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. For example, DOE consults with the U.S. Fish and Wildlife Service (USFWS) when activities have the potential to result in impacts to federally endangered or threatened species. The following list describes the highlights of recent consultations and analyses conducted in reference to the federal Endangered Species Act.

- Routine maintenance, including vegetation trimming and culvert replacement, of Arroyo Las Positas at the Livermore site was conducted under the 1998 Biological Opinion from the USFWS.
- A biological assessment (BA) for the implementation of the Arroyo Seco Management Plan was prepared and submitted to USFWS on August 14, 2003. The USFWS issued a biological opinion for this project on June 10, 2005. Work was completed under this biological opinion during the summer of 2005. Monitoring of the restoration at the Arroyo Seco site is required for five years after the completion of this project.
- On December 13, 2004, a BA was submitted to the USFWS for closure of two Site 300 Class II Surface Impoundments, which were built to contain and evaporate explosives formulation and process operations nonhazardous wastewater and nonhazardous photo process rinse water. The USFWS completed the biological opinion for this project on March 21, 2005. Work under this biological opinion was completed during the summer and fall of 2005. As required mitigation for impacts to California tiger salamander *(Ambystoma californiense)* habitat during the removal of the surface impoundments, a seasonal pool was created in the northwest portion of Site 300. Monitoring for California tiger salamanders was also conducted at the surface impoundment site after construction (winter 2005/2006) as required by the biological opinion for this project.
- A BA for the *LLNL SW/SPEIS* was prepared and submitted to the USFWS on April 9, 2004. It is currently being reviewed by the USFWS and being revised by LLNL to include more detailed environmental information.
- On June 6, 2005, the USFWS concurred with DOE that the creation of the Mid-Elk Ravine Wetland Enhancement Project (Site 300 Mid-Elk Ravine Mitigation Ponds) and the Upper Round Valley Culvert Replacement Project are not likely to adversely affect the California

tiger salamander. These projects are both included in the May 17, 2002, Biological Opinion for Routine Maintenance and Operations of Site 300, which was completed before the California tiger salamander was proposed for listing as threatened by the USFWS.

- In the summer and fall of 2005, the Mid-Elk Ravine Wetland Enhancement Project was completed. This project is included in the May 17, 2002, Biological Opinion for Routine Maintenance and Operations of Site 300 as mitigation for the termination of water discharge to artificial wetlands created initially from cooling tower blowdown near Buildings 865, 801, 827, and 851 that provided suitable habitat for California red-legged frogs.
- The proposed construction and operation of evidence receiving and temporary storage facilities, in support of the Forensic Science Center analyses programs, was reviewed in 2005 to determine the potential for this project to impact endangered species. Construction of the new facility is proposed to occur at the existing Building 858 complex which lies within the *Amsinckia grandiflora* preserve at Site 300. This project is not likely to result in any impacts to the endangered plant *Amsinckia grandiflora* or other listed species because all construction will occur within the developed area. Construction is scheduled to begin in 2006.

In 2005 and early 2006, the USFWS published three critical habitat final or proposed rules that are pertinent to LLNL. The final rule designating critical habitat for the California tiger salamander was issued on August 23, 2005 (USFWS 2005a). This designation did not include any critical habitat for California tiger salamanders at the Livermore site or Site 300.

On April 13, 2006, the USFWS published a final rule designating critical habitat for the California red-legged frog *(Rana aurora draytonii)* (USFWS 2006). This new critical habitat designation does not include any portion of the Livermore site or Site 300.

A proposed critical habitat designation was also issued for the Alameda whipsnake *(Masticophis lateralis euryxanthus)* on October 18, 2005, (USFWS 2005b). This proposal includes the southwestern portion of Site 300 (**Figure 6-16**). No portion of the Livermore site is included in the Alameda whipsnake critical habitat proposal.

Biological surveys for special-status species and monitoring results are described in Chapter 6.

Environmental Occurrences

In 2005, notification of environmental occurrences was required under a number of environmental laws and regulations as well as DOE Order 231.1A and DOE Manual 231.1-2. The orders and manual provide guidelines to contractor facilities regarding categorization and reporting of environmental occurrences to DOE and divides occurrences into categories.

LLNL's response to environmental occurrences is part of the larger on-site emergency response organization that includes representatives from Hazards Control (including the LLNL Fire Department), Health Services, Plant Engineering, Public Affairs, Safeguards and Security, and Environmental Protection. In 2005, one environmental incident, summarized in **Table 2-5**, was reportable under DOE Order 232.1A and was categorized as a Significance Category 4 reportable occurrence under Group 9, Noncompliance Notifications according to DOE Order 232.1A. DOE was notified of this incident. No occurrences were reportable under Group 5, Environmental.

Table 2-5 Environmental Occurrence reported under the Occurrence Reporting System in 2005

Date[a]	Occurrence category/group	Description[b]
April 20	Significance Category SC4 Occurrence under Group 9(2)	LLNL received an NOV from the City of Livermore Water Reclamation Plant for briefly exceeding the pH limit for high-pH bearing materials into the sanitary sewer. On April 6 and 7, the LLNL sewer monitoring complex experienced a high pH alarm. The pH of the captured effluent was 11.6; the maximum pH permit limit is 10. OR 2005-0032

a The date indicated is the date when the occurrence was categorized, not the date of its discovery.
b See Acronyms and Abbreviations for list of acronyms.

Contributing Authors

Many authors contributed to this large and diverse chapter. We acknowledge here the work of Shari Brigdon, Karl Brunckhorst, Joseph G. Byrne, Steven Cerruti, Allen Grayson, Rod Hollister, John Karachewski, Carol Kielusiak, Sandra Mathews, Jennifer Nelson-Childs, Lisa Paterson, Brian Perkins, Ring Peterson, Vicki Salvo, Lily Sanchez, William Schwartz, Michael Taffet, Stan Terusaki, Earl Thomas, Jim Woollett, Joseph Woods, and Peter Yimbo.

Environmental Program Information CHAPTER 3

Lawrence Livermore National Laboratory is committed to enhancing its environmental stewardship and the steps it takes to reduce any potential impacts its operations may have on the environment. The Environmental Protection Department (EPD) is the lead organization at LLNL that provides environmental expertise and guidance for LLNL operations. This chapter provides a description of EPD's departments and activities. One of the most important activities in 2005 was the integration of the International Organization for Standardization (ISO) 14001:1996 Environmental Management System (EMS) requirements into the Integrated Safety Management System (ISMS). This process of developing LLNL's EMS is described in detail. Pollution Prevention (P2), a significant component of EMS, plays an important role at LLNL. The progress made by P2 in meeting DOE pollution protection goals, diverting waste, and tackling projects that reduce the quantity of waste being generated is itemized. Award winning projects, Energy Management Program Projects, and Training and Awareness Programs are also described.

Environmental Protection Department

EPD is responsible for environmental monitoring, environmental regulatory interpretation and implementation guidance, environmental restoration, environmental community relations, and waste management in support of LLNL's programs. EPD prepares and maintains environmental plans, reports, and permits; maintains the environmental portions of the 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; and assesses the effectiveness of

pollution control programs. EPD has also taken the leadership role in the decommissioning and decontamination (D&D) of facilities at LLNL to adapt to changes in programs resulting from the end of the Cold War. EPD's Space Action Team tactically implements LLNL's institutional D&D activities. Since 1994, 168 real property facilities encompassing 481,686 gross square feet have been removed from LLNL.

EPD monitors air, sewerable water, groundwater, surface water, rain, soil, sediment, vegetation, and foodstuff, as well as direct radiation; evaluates possible contaminant sources; and models the impact of LLNL operations on humans and the environment. These monitoring activities in 2005 are presented in the remaining chapters of this report.

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 impacts and is in compliance with regulatory requirements. EPD helps LLNL programs manage and minimize hazardous, radioactive, and mixed wastes, as well as identify opportunities for pollution prevention, including minimization of nonhazardous waste; determines the concentrations of environmental contaminants remaining from past activities; cleans up environmental contamination to acceptable standards; responds to emergencies in order to minimize and assess any impact on the environment and the public; and provides training programs to improve the ability of LLNL employees to comply with environmental regulations. These functions are organized into three divisions within the department: Operations and Regulatory Affairs (ORAD), Radioactive and Hazardous Waste Management (RHWM), and Environmental Restoration (ERD).

Operations and Regulatory Affairs Division

The Operations and Regulatory Affairs Division (ORAD) consists of six groups that specialize in environmental compliance and monitoring and provide LLNL programs with a wide range of information, data, and guidance to make more informed environmental decisions. ORAD prepares the environmental permit applications and related documents for submittal to federal, state, and local agencies; provides the liaison between LLNL and regulatory agencies conducting environmental inspections; tracks chemical inventories; prepares NEPA documents and conducts related field studies; oversees wetland protection and floodplain management requirements; coordinates cultural and wildlife resource protection and management; facilitates and provides support for the pollution prevention and recycling programs; teaches environmental training courses; coordinates the tank environmental compliance program; coordinates Spill Prevention Control and Countermeasure and Storm Water compliance programs; coordinates wastewater discharge compliance programs; provides guidance to LLNL

operations on regulatory requirements and compliance strategies; conducts compliance and surveillance monitoring; provides environmental impact modeling and analysis, risk assessment, and reporting; and develops new methods and innovative applications of existing technologies to improve environmental practices and assist LLNL in achieving its mission. ORAD interacts with the community on these issues through Environmental Community Relations. ORAD also actively assists in responding to environmental emergencies such as spills. During normal working hours, an environmental analyst from the ORAD Environmental Operations Group (EOG) responds to environmental emergencies and notifies a specially trained Environmental Duty Officer (EDO). EDOs are on duty 24 hours a day, 7 days a week, and coordinate emergency response with other first responders and environmental specialists.

Radioactive and Hazardous Waste Management Division

The Radioactive and Hazardous Waste Management (RHWM) Division 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, 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 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, including the annual and biennial hazardous waste reports required by the California and U.S. Environmental Protection Agencies. RHWM also prepares waste acceptance criteria documents, safety analysis reports, and various waste guidance and management plans.

RHWM meets regulations for the treatment of LLNL's mixed waste in accordance with the requirements of the Federal Facilities Compliance Act. The schedule for this treatment is negotiated with the State of California and involves developing new on-site treatment options as well as finding off-site alternatives. RHWM is also responsible for implementing a program directed at eliminating the backlog of legacy waste (waste that is not at present certified for disposal). This effort includes a large characterization program to identify all components of the waste and a certification effort that provides appropriate documentation for the disposal site.

Environmental Restoration Division

The Environmental Restoration Division (ERD) was established to evaluate and remediate 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, both prior to and during LLNL operations. ERD conducts field investigations at both the Livermore site and Site 300 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 assisting in closing inactive facilities in a manner designed to prevent environmental contamination. 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. ERD interacts with the community on these issues through Environmental Community Relations. Public workshops are held regularly, and information is provided to the public as required in the ERD CERCLA Community Relations Plans. These CERCLA activities in 2005 are summarized in the "Environmental Restoration and Waste Management" section in Chapter 2. ERD's groundwater remediation activities in 2005 are further described in Chapter 8.

Response to Spills and Other Environmental Emergencies

All spills and leaks (releases) at LLNL that are potentially hazardous to the environment are investigated and evaluated. The release response process includes identifying the release, shutting off the source (if it is safe to do so), eliminating ignition sources, contacting appropriate emergency personnel, cordoning off the area containing the released material, absorbing and neutralizing the released material, assisting in cleanup, determining if a release must be reported to regulatory agencies, and verifying that cleanup (including decontaminating and replenishing spill equipment) is complete. ORAD staff also provide guidance to the programs on preventing spill recurrence.

As previously described, the EDO is available 24 hours a day, 7 days a week to maximize efficient and effective emergency environmental response. Specialized EDO training includes simulated incidents to provide the response personnel with the experience of working together to mitigate an environmental emergency, determine any reporting requirements to regulatory agencies and DOE, and resolve environmental and regulatory

issues within the LLNL emergency response organization. The on-duty EDO can be reached by pager or cellular phone at any time.

During normal work hours, LLNL employees report any environmental incidents to an EOG environmental analyst assigned to support their program area. The EOG environmental analyst then notifies the on-duty EDO of the incident, and together with other ORAD staff, the team determines applicable reporting requirements to local, state, and federal regulatory agencies and to DOE. The EDO and the EOG environmental analyst also notify and consult with program management and have 7-day-a-week, 24-hour-a-day access to the office of Laboratory Counsel for questions concerning regulatory reporting requirements.

During off hours, LLNL employees report all environmental incidents to the Fire Dispatcher, who, in turn, notifies the EDO and the Fire Department, if required. The EDO then calls out additional EPD support to the incident scene as necessary, and follows the same procedures as outlined above for normal work hours.

Integrated Safety Management System

LLNL implements an Integrated Safety Management System (ISMS) designed to ensure the systematic integration of environment, safety, and health (ES&H) considerations into management and work practices so that missions are accomplished safely. “Safety,” used in this context, is synonymous with environment, safety, and health to encompass protection of the public, workers, and the environment, including pollution prevention and waste minimization. LLNL regards protection of the environment as an essential component in its overall safety management system.

The core requirements of ISMS are based on DOE’s Seven Guiding Principles summarized as: (1) line management responsibility for safety; (2) clear roles and responsibilities; (3) competence commensurate with responsibilities; (4) balanced priorities; (5) identification of safety standards and requirements; (6) hazard/environmental aspect controls tailored to work being performed; (7) operations authorization. How LLNL manages and performs work can be described by the Five Core Functions: (1) define the scope of work; (2) analyze the hazards/environmental aspects; (3) develop and implement hazard/environmental aspect controls; (4) perform work within controls; and (5) provide feedback and continuous improvement.

In 2005 LLNL enhanced the environmental emphasis of the ISMS based on the International Organization for Standardization (ISO) standard 14001:1996, Environmental Management Systems. ISO 14001 defines an EMS as "that part of the overall management system that includes

organizational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy." The EMS is based on requirements relating to the following five EMS principles: 1) define an environmental policy and ensure commitment to its EMS; 2) formulate a plan to fulfill the environmental policy; 3) develop the capabilities and support mechanisms necessary to achieve the environmental policy, objectives, and targets; 4) measure, monitor, and evaluate environmental performance; and 5) review and continually improve the environmental management system with the objective of improving overall environmental performance.

The implementation of a management system based on all these principles and functions results in accountability at all levels of the organization, project planning with environmental protection in mind, and excellence in program execution. The ISMS Program at LLNL employs a process of assessing hazards and the environmental implications of work; designing and implementing standards-based methods intended to control risks and reduce the negative impacts of work activities to meet established targets and objectives; and complying with applicable ES&H requirements. The ISMS effective at LLNL in 2005 was *Integrated Safety Management System Description, Version 8* (LLNL 2005) which can be found at http://www.llnl.gov/es_and_h/ism/ism-descriptionv8.pdf.

Work Smart Standards

Work Smart Standards (WSS) establish workplace ES&H controls and are an integral part of the LLNL ISMS. This comprehensive set of standards (applicable laws, regulations, DOE orders, etc.) defines the ES&H requirements for LLNL and is used by ES&H professionals to identify hazards and environmental aspects[1], and establish standards of operation appropriate for a particular work environment. The original WSS were selected using the necessary and sufficient process, which involves review and recommendation by LLNL subject matter experts (SMEs) and their DOE counterparts. The WSS are continually reviewed and revised through a formal change control process when applicable DOE orders or regulations are issued or adopted. The Change Control Board (CCB), which consists of representatives from DOE, UC, and LLNL, manages the change control process. In addition, LLNL SMEs perform periodic review of all the requirements to ensure that the WSS set is current and complete.

[1] *Environmental aspects* are elements of an organization's activities, products, or services that can interact with the environment.

The WSS set currently identified to satisfy the ES&H needs of the LLNL work environment is in Appendix G of the UC contract, and can be viewed at http://labs.ucop.edu/internet/comix/contract/LLNL/wss_llnl.pdf.

Environmental Management System

The LLNL EMS was designed to meet the requirements of ISO 14001:1996, which was adopted by LLNL as a WSS in June 2004. In 2005, LLNL began the process of integrating ISO 14001:1996 requirements into its ISMS with the intention of self-declaring conformance. The LLNL EMS is defined in the LLNL ISMS Description, and its requirements are in the LLNL *ES&H Manual*. The integration of ISO 14001:1996 requirements into the LLNL ISMS fulfills requirements in the University of California–Department of Energy contract for LLNL to maintain an environmental management program consistent with DOE-approved parameters. LLNL self-declared its conformance with ISO 14001:1996 in December 2005.

The LLNL EMS promotes responsible environmental stewardship practices that are protective of the air, water, land, and other natural and cultural resources; complies with applicable environmental regulations in a cost-effective manner; and focuses on continuous improvement of LLNL's environmental system. LLNL's senior management has committed to achieve continuous improvement in operational and environmental performance through P2 and other sustainable business tools.

Overview and General Requirements

The LLNL EMS is applicable to LLNL facilities and operations located at the Livermore Site and Site 300, and offsite activities, products and services that it can control and over which it can be expected to have an influence. LLNL Nevada Test Operations are subject to the requirements of the Nevada Test Site, and are not addressed in the LLNL EMS. The LLNL EMS centers on management of environmental aspects. Environmental aspects at LLNL are managed in accordance with ISMS requirements. Each LLNL directorate is responsible for supporting institutional environmental objectives and targets where appropriate, as well as managing and reducing the negative impacts of significant environmental aspects that are specific to the directorate and its work activities, products, and services.

P2 is a critical part of the LLNL EMS. **Table 3-1** shows the applicability of P2 to each of the elements of the EMS.

Table 3-1. Pollution Prevention in the LLNL EMS

EMS Element	Pollution Prevention Connection
Environmental Commitment and Policy	P2 included in LLNL environmental policy by senior management
Planning	P2 principles assimilated into environmental planning and decision-making at the institutional as well as at the directorate level. P2 Opportunity Assessment (PPOA) methods used to identify significant aspects. PPOA methods employed to evaluate EMS objectives, targets, and mitigation approaches in terms of environmental benefit and technical and economic feasibility.
Implementation and Operation	P2 Team support to EMS Team: Project expertise, database interface, financial support identification, document preparation, assistance performing Self-Assessments, interface with community, performance testing.
Checking and Corrective Action	Corrective measures are accomplished through Return-On-Investment (ROI) projects, process changes funded by programs, and informal cooperation between LLNL programs, P2 Team staff, and EPD environmental analysts leading to improved environmental performances.
Periodic Management Review and Continuous Improvement	P2 Team support of self-assessment process and use of self-assessment reports in generating P2 documents.

All LLNL environmental aspects and regulatory or other identified requirements are managed according to the *ES&H Manual*. Environmental Management Programs (EMPs) are prepared for projects and studies that are not specifically addressed in the *ES&H Manual*, Integration Work Sheets (IWSs), or National Environmental Policy Act (NEPA) mitigation measures, and for aspects that have not been traditionally managed under ISMS (electrical energy use, water use, etc.).

Environmental Policy

On July 22, 2004, the Laboratory Director issued LLNL's Environmental Policy, which was distributed to all LLNL employees. This policy, described below, is the basis on which the EMS was developed:

> LLNL is committed to providing responsible stewardship of the environmental resources in our care. Environmental stewardship is integrated into our strategic planning and decision-making processes and into the management of our work activities through the Integrated Safety Management System.

In support of this policy, LLNL commits to

- Work to continuously improve the efficient and effective performance of our environmental management system;
- Comply with applicable environmental laws and regulations;
- Incorporate pollution prevention, waste minimization, and resource conservation into our planning and decision making processes;
- Ensure that interactions with our regulators, DOE, and our community are based upon integrity, openness, and adherence to national security requirements;
- Establish appropriate environmental objectives and performance indicators to guide these efforts and measure our progress.

The Environmental Policy is found in the *ES&H Manual,* Section 3.0 of Document 1.2, ES&H Policies of LLNL.

Identification of Significant Environmental Aspects and Their Impacts

The ISO 14001:1996 standard requires the identification, determination-of-significance, and mitigation of environmental aspects to drive and measure environmental protection improvements within work activities, facilities, and the institution. Significant environmental aspects are those that have or can have a significant environmental impact (that is, any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products, or services). The management of environmental aspects, with emphasis on those that are significant, is key to the success of an EMS. In 2005, LLNL developed its initial set of significant environmental aspects through the process described below.

Identification of LLNL Activities, Products, and Services

A comprehensive list of LLNL activities, products, and services was developed using several existing resources, starting with the Work and Associated Hazard database used to develop the original LLNL WSS set in 1998 and 1999. This database provided descriptions of buildings or work areas broken into work categories, work elements, work activities, and hazard categories.

A shortened activity list was generated from the database by compiling activities into categories. For example, the Laser Operations category includes installation, maintenance, repair, and operation of lasers throughout LLNL. The shortened activity list was augmented with activities, products and services from current IWSs, the 2005 *Final Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement (LLNL SW/SPEIS)*, other ISMS environmental and safety documents, and LLNL personnel knowledge. The initial list of the activities, products, and services was reviewed and updated by LLNL program and facility personnel, as well as environmental analysts supporting those programs and facilities.

Identification of LLNL Environmental Aspects

The EMS requires that LLNL identify its environmental aspects and associated environmental impacts based on its activities, products and services. LLNL developed an initial list of environmental aspects by evaluating each activity, product, or service from the list described in the previous paragraph. This initial list of environmental aspects was augmented using other existing resources, such as IWSs, ISMS environmental and safety documents, and LLNL personnel knowledge. The list of environmental aspects (**Table 3-2**) was reviewed and updated by LLNL program and facility personnel, as well as environmental analysts supporting those programs and facilities.

Table 3-2. LLNL's Environmental Aspects

Radioactive material use	Radioactive air emissions
Electrical energy use	Discharges to ground
Renewable energy use	Greenhouse gas emissions
Mixed waste (MW) generation	Low-level radioactive waste(LLW) generation
Nonhazardous materials use	Environmental noise
Municipal waste generation	Hazardous air pollutant emissions
Fossil fuel consumption	Energy emissions
Hazardous materials use	Medical/biological waste generation
Transuranic (TRU) waste generation	Biological material use
Ecological resource disturbance	Water use
Criteria pollutant emissions	Land use/land management
Discharges to arroyo/surface waters	Cultural resources disturbance
Discharges to sanitary sewer system	Industrial waste generation
Hazardous waste (HW) generation	Other air emissions (odors, etc.)
Discharges to storm drain system	

Note: LLNL's Significant Environmental Aspects for calendar year 2005 are in bold.

Determination of Environmental Impacts

As environmental aspects were identified, associated environmental impacts were also determined. LLNL utilized existing resources, such as the LLNL *SW/SPEIS*, ISMS documents, and environmental personnel knowledge to determine the environmental impacts associated with each aspect.

Identification of Significant Environmental Aspects

LLNL developed a Significance Criteria matrix or table that identified its significant environmental aspects. The development of the significant environmental aspects included consideration of both environmental and business factors, as is recommended by ISO 14004:1996[1] (**Table 3-3**).

Table 3-3. Environmental and business factors used for evaluating environmental aspects

Environmental Factor	Business Factor
Scale of the impact	Potential regulatory and legal exposure
Severity of the impact	Difficulty of changing the impact
Probability of occurrence	Cost of changing the impact
Duration of impact	Effect of change on other activities and processes Concerns of interested parties

Source: ISO 14004:1996, EMS–General guidelines on principles, systems and supporting techniques

LLNL's business and environmental factors and description of low, moderate, and high impacts are described in a Significance Criteria table (**Table 3-4**).

The environmental aspects were then scored based on the Significance Criteria table. The scoring of environmental aspects considered the following assumptions that were globally applied to all aspects:

- Application of both environmental and human health impacts
- Impacts that occur both within a facility, exterior to the facility, and beyond the LLNL fence line
- Impacts from both normal operations and upset conditions, including the assumptions behind a worst-case scenario

[1] ISO 14004:1996 provides guidance on the establishment, implementation, maintenance, and improvement of an environmental management system and its coordination with other management systems.

Table 3-4. LLNL environmental aspects significance criteria

Factors	Impacts		
	Low	**Moderate**	**High**
Laws, Regulations, Standards (LRS)	There are no established LRSs to address impact; or there are established LRSs to address impact, and impact is within compliance requirements.	There are established LRSs to address impact, and impact approaches compliance requirements; or impact does not result in a regulatory violation/fine.	There are established LRSs to address impact, and impact has exceeded the LRSs reporting thresholds, or fails to meet compliance requirements.
Perceptions	Interested parties do not express an opinion; or no negative or positive opinions of impact.	Interested parties identified impact that warrants monitoring; or an interested party expresses a strong view (either positive or negative) concerning the impact; or an interested party's view does not negatively influence other Interested parties' perceptions.	Strong views (either positive or negative) concerning the impact are expressed by multiple interested parties; or expressed views result in increased media attention and/or interested parties oversight and/or public controversy.
Controls	No controls needed to mitigate impact. Impact identified, but is self-remediating with little or no resources needed.	Identified impact eliminated through the use of controls, engineered or administrative.	Identified impact mitigated to moderate impact level through the use of administrative and engineered controls.
Scale	Impacts are localized to the work area or are limited to personnel involved in the work area; or an accident could result in "Alert" emergency status on-site.	Impact is contained within LLNL site boundaries; impacts Lab population only; or an accident could result in "Site Area Emergency" on-site.	Impacts are not limited to LLNL sites; impacts surrounding community or region; or an accident could result in "General Emergency" in surrounding communities.
Severity & Duration	No long-term impact; impact is self-remediating with little or no resources needed.	Impact is recoverable over a long period of time, with the expenditure of resources.	Impact is not recoverable or is permanent.
Frequency & Probability	Frequency of occurrence is low (i.e., is less than 5% of the number of LLNL related activities).	Moderate frequency of occurrence (i.e., the number of LLNL related activities is equal to or greater than 5% and less than or equal to 95%).	High to very high frequency of occurrence (i.e., greater than 95% of the number of LLNL related activities).
Reuse and Recycling Opportunities	Minimal or no resource depletion is expected; re-use, recycling or waste minimization opportunities are not available or needed.	Resource depletion is moderate; reuse, recycling, or waste minimization opportunities may be available with some cost avoidance.	Resource depletion is high; reuse, recycling, and waste minimization could significantly reduce impacts to programs, schedules, and/or costs.

Table 3-4. LLNL environmental aspects significance criteria (continued)

Factors	Impacts		
	Low	Moderate	High
Operational & Technical Limitation	Impacts to programs, schedules, and costs are small; or administrative and engineering controls are not needed; or technology to manage the impact does not exist or is in the experimental stage.	Moderate impacts to programs, schedules, and/or costs; some administrative and engineering control opportunities are available. Technologies are limited or requires significant modifications.	High impacts to programs, schedules, and costs; engineering and administrative controls could reduce impacts. Technology is readily available and proven. Operations can be implemented with existing staff and equipment.
Ability and Cost of Change	Do not have ability to change; or no significant results are expected if changes were made; or cost of change is prohibitive.	Will have some ability to change, but moderate results are expected; cost of change is moderate.	Will have ability to effect change; significant results are achievable if change is implemented; cost of change is minimal.

The specific assumptions used to score each LLNL environmental aspect were documented.

LLNL's significant environmental aspects are listed in **Table 3-2**.

As a part of the process for annual review and revision of LLNL's environmental aspects, the LLNL EMS Coordinator and the LLNL EMS Team reevaluate the significance criteria and determine whether any newly identified aspects are significant using a process similar to the one described here. The LLNL EMS Team briefs programmatic and facility organizations on an as needed basis to advise them of the changes and solicit input to the process of identifying significant environmental aspects.

Identifying and Managing Environmental Targets and Objectives

ISO 14001:1996 requires the establishment and maintenance of documented environmental targets and objectives for each relevant function and level within the organization. When establishing and reviewing its targets and objectives, LLNL considers legal and other requirements; significant environmental aspects; technological options; financial, operational, and business requirements; and the views of interested parties. The objectives and targets are consistent with the environmental policy, including the commitment to prevent pollution.

LLNL has identified targets and objectives for its significant environmental aspects, the measurements (or metrics) that will be used to track each target, as well as the projected cost of implementation. Where appropriate, LLNL utilizes activities and programs that are already in place to achieve targets and objectives. When targets for measuring management of significant environmental aspects cannot easily be identified, studies are performed to establish baselines and determine a path forward. The established set of environmental objectives and targets are reviewed annually (or more frequently if needed) and revised as necessitated by changes to regulatory or program requirements, or other influencing factors. The need to develop and implement new objectives is evaluated whenever new significant environmental aspects are identified. See **Table 3-5** for a summary of the objectives for LLNL's significant environmental aspects.

Establishing and Maintaining Environmental Management Programs (EMPs)

The targets and objectives for each significant environmental aspect are managed through an Environmental Management Program (EMP), which assigns responsibilities for achieving the goals for that aspect. The EMP Lead assigned to each EMP is responsible for collecting information and working with the appropriate Program representative(s) to negotiate actions to be incorporated in the EMP. Each EMP includes schedules, resources, operational controls, records generated, and responsibilities for achieving the environmental objectives and targets applicable to it. Where appropriate, documents that define operational controls applicable to the EMP (e.g., IWSs, studies, and mitigations required by NEPA) are referenced. The EMP Lead works with the Program representative(s) and the EMS Team when preparing the EMP. The EMS Coordinator must approve the completed EMP before it is implemented.

The EMS Coordinator and the LLNL EMS Team review progress on each EMP annually (or more frequently if needed) and work with EMP Program Leads to revise EMPs as necessary. The EMS Coordinator and EMS Team ensure that new EMPs are developed and implemented as needed.

Senior Management Review

LLNL senior management reviews the EMS at least annually (and more frequently if needed) as required by ISO 14001:1996. Each review must be comprehensive; however, not all elements of the EMS are required to be included.

Table 3-5. Objectives for significant environmental aspects

Significant Environmental Aspect	Objective
Radioactive Material Use	Identify and reduce radioactive materials impacts at LLNL by an amount to be determined by this study
Electrical Energy Use	• Meet the objectives provided in DOE Order 430.2A, "Departmental Energy and Utilities Management" • President's Initiative for Hurricane Relief (September 2005)
Mixed Waste (MW) Generation	Reduce the amount of mixed and California combined solid waste generated from routine LLNL Programmatic operations when economically and technologically feasible
Nonhazardous Materials Use	• Incorporate affirmative procurement site-wide • Increase site-wide use of products with recycled content • Continue EPD's participation in the Federal Electronics Challenge (FEC)
Municipal Waste Generation	• Maintain compliance with applicable regulatory requirements • Prevent/reduce waste generation and increase reuse/recycling of routine and nonroutine waste that would otherwise be disposed of at a municipal landfill
Fossil Fuel Consumption/Renewable Energy Use	Meet the DOE Vehicle Fleet Efficiency goal, in I.106 DEAR 970.5223-5
Hazardous Materials Use	Conduct a study to identify the databases or other information sources that provide a comprehensive list of hazardous materials
Transuranic (TRU) Waste Generation	Conduct a study to review the characterization of transuranic waste to ensure generation of nonconforming waste is minimized and characterization is accurate to maximize the ability to disposition the waste.
Ecological Resources Disturbance	• Establish Laboratory policy prohibiting the introduction of exotic species within the borders of LLNL • Control exotic species to benefit native threatened species as need is determined

The EMS Coordinator prepares the necessary input to be considered in the management review. The following topics are typically included:

- Review of environmental objectives and targets and the extent to which they have been met
- Findings of EMS audits and results of Directorate self-assessments

- Regulatory compliance status
- Follow-up actions from previous audits
- Changing circumstances, including developments in legal and other requirements related to significant environmental aspects

Recommendations for Improvement

Upon review of the above information, senior management determines the continuing effectiveness of the EMS implementation, specifically the ability of LLNL to achieve its documented objectives and targets. Senior management also determines whether the system continues to be adequate and suitable for its intended purpose.

Having made these determinations, senior management provides a response to the EMS Coordinator that includes any changes that must be made to the EMS to ensure its continual improvement. Senior management directives may include changes to the environmental policy, targets and objectives, and other elements of the EMS.

LLNL's Self Declaration Process

To conform with the requirements of Executive Order 13148 (Greening the Government Through Leadership in Environmental Management), LLNL initiated an internal review process to facilitate self-declaration of conformance with ISO 14001:1996. An internal EMS audit was conducted November 9 and 10, 2005.

Subsequent to the internal audit, the Livermore Site Office (LSO) of the Department of Energy (DOE) also conducted an independent evaluation of LLNL's existing EMS against the requirements specified in ISO14001:1996. The purpose of this evaluation was to fulfill the LSO requirement to conduct an independent review and determine whether the LLNL EMS met the intent of ISO 14001:1996, was being implemented, and was effective. More than 145 documents and websites were reviewed, and approximately 48 interviews were conducted. The audit team could not fully assess implementation or measure the effectiveness of the LLNL EMS because the EMS documents were completed and the system was implemented just prior to the audit.

The LSO audit resulted in no major nonconformances (a major nonconformance is a missing system element, or evidence that a system element is not implemented or not effective); 13 minor nonconformances (a minor nonconformance is a single observed discrepancy in the system, with evidence that the overall system is defined, implemented, and effective);

8 observations (an observation is not a nonconformance, but something that could lead to a nonconformance if allowed to continue uncorrected, or an existing condition without adequate supporting evidence to verify that it constitutes a nonconformance); 20 opportunities for improvement (OFI) (an OFI is a suggested or recommended means of accomplishing an activity, fulfilling the intent of a procedural requirement, or improving the efficiency or effectiveness of the EMS); and 22 noteworthy practices (a noteworthy practice is performance that exceeds expectations in terms of efficiency and/or effectiveness and provides a model for others to follow).

Corrective Action Plan (CAP) and Self-Declaration

DOE/LSO agreed to validate the self-declaration of LLNL's EMS upon submittal of a draft Corrective Action Plan (CAP) that contained corrective actions specific to the minor nonconformances identified in the LSO audit. LLNL prepared the draft CAP and submitted it to LSO on December 20, 2005. LLNL and LSO agreed that observations and OFIs would not be addressed in the CAP but they would be entered and tracked to closure in the LLNL Issues Tracking System (ITS).

On December 22, 2005, LLNL provided DOE with a self-declaration of LLNL's EMS based on the audit performed by DOE/LSO and the draft CAP that was submitted.

Path Forward

During 2006, LLNL will implement the corrective actions that will address the deficiencies identified in the DOE/LSO audit. In addition LLNL will submit the ISO 14001:2004 Standard to the Change Control Board so that it can be added as a WSS and begin the process of updating the existing EMS to meet the requirements of the 2004 standard. LLNL will continue to work towards meeting its EMS targets and objectives and will perform reviews and measurement to ensure they are appropriate and that progress is being made.

Pollution Prevention

The LLNL P2 team facilitates LLNL's P2 program within the framework of the ISMS and EMS and in accordance with applicable laws, regulations and DOE orders as required within the UC Contract. P2 team responsibilities include P2 program 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 team

supports institutional and directorate P2 activities via environmental teams, including implementation of source reduction and/or reclamation, recycling, and reuse programs for hazardous and nonhazardous waste, facilitation of the environmentally preferable procurement (EPP) program, preparation of P2 opportunity assessments, and development and management of high return-on-investment projects. LLNL's P2 program is described in Document 30.1 in LLNL's *ES&H Manual*.

DOE Pollution Prevention Goals

In 1999, DOE developed pollution prevention and energy efficiency leadership goals for DOE facilities in response to presidential executive orders for the Greening of the Federal Government. The pollution prevention goals are compared in **Table 3-6** with LLNL's quantities of routine waste generated in 1993 (i.e., LLNL's baseline), its 2005 target, the actual amount of waste generated in 2005, and the percent reduction in 2005 compared with the baseline. Routine waste described in **Table 3-6** includes waste from ongoing operations produced by any type of production, analysis, and/or research and development taking place at the Laboratory. Periodic laboratory or facility clean-outs and spill cleanups that occur as a result of these processes are also considered normal operations. Residues, resulting from the treatment of routine waste in the RHWM facilities on site are not included to avoid double counting.

The following five energy efficiency goals were included in the leadership goals. **Table 3-7** lists the goals, baseline quantities, the 2005 targets when applicable and provides the status for each goal.

- Reduce energy consumption per gross square foot in the Laboratory & Industrial Facilities category by 20% by 2005 and 25% by 2010 relative to 1990.
- Increase the use of clean energy sources (renewable and low greenhouse gas energy).
- Retrofit or replace 100% of chillers with capacity greater than 150 tons that use Class I refrigerants by 2005.
- Eliminate the use of Class I ozone-depleting substances.
- Reduce greenhouse gas emissions attributed to facility energy use through life-cycle cost-effective measures by 25% by 2005 and 30% by 2010, using 1990 as a baseline.[1]

[1] DOE Order 430.2A, Section 1, Objectives, lists the 2005 target as a DOE goal. The Contractor Requirements Document, Attachment 1 to the Order, only mentions the 2010 goal.

Table 3-6. Pollution prevention leadership goals at LLNL

Goal	Item	1993 baseline quantity	2005 target based on DOE leadership goal	2005 LLNL target commitment	2005 actuals	Percent reduction since 1993	Percent of 2005 target
1	Routine Hazardous Wastes Generated (90% reduction of 1993 baseline)	1054 MT[a]	105.4 MT	105.4 MT	127 MT	88	98
1	Routine Mixed Waste Generated (80% reduction of 1993 Baseline)	26 m^3	5.2 m^3	5.2 m^3	16 m^3	38	48
1	Routine Low-level Waste Generated (80% reduction of 1993 baseline)	346 m^3	69.2 m^3	69.2 m^3	54 m^3	84	105
1	Routine TRU/Mixed TRU Waste Generated (80 % reduction of 1993 baseline)	12.0 m^3	2.4 m^3	2.4 m^3	1 m^3	92	115
3	Routine Sanitary Waste Generated (75% reduction of 1993 baseline)	5873 MT	1468 MT	1468 MT	5116.5 MT	13	17
4	Routine Sanitary Wastes Recycled (45% of waste generated)	N/A	45% of 2005 sanitary waste	45% of 2005 sanitary waste	3386.4 MT	66% of 2005 sanitary waste	N/A
6	Purchases of EPA-designated items with Recycled Content (100% by cost of recycled versus nonrecycled)	N/A	100%	—[b]	$3.768M/ $6.382M	59%	59%
2	TRI Chemical Releases (90% of 1993 Baseline)	3983.3 lb[c]	398.3 lb	398.3 lb	471.9 lb (Site 300) 0 lb (Livermore site)[d]		
10	Eliminate use of Class 1 ozone-depleting substances by 2010	NA	0	The current schedule based on life-cycle cost-effective use of existing chillers and one halon fire-suppression unit shows five chillers and up to three fire-suppression units being replaced after 2010.			

a MT = metric ton

b LLNL was not able to meet this goal by 2005.

c In 2005, lead was the only toxic chemical that had exceeded the TRI reporting threshold at LLNL. In just four years, from 2001 to 2005, Site 300 reduced the amount of TRI-reportable lead from 3983 lbs to 471.9 lbs, a reduction of 88%.

d In 2005, the requirement to carry out TRI reporting for lead at the Livermore site was triggered by exceeding the threshold for on-site use of lead. Reporting "0 pounds" for on-site releases indicates that the total quantity of lead released on site was less than 0.05 pounds for the calendar year.

Table 3-7. Energy efficiency leadership goals at LLNL

Goal	Item	1990 baseline quantity	2005 target based on DOE leadership goal	Status
7	Reduce Unit Energy Consumption 20% by 2005 and 25% by 2010 for lab and industrial facilities	289,600 BTU/gross ft^2	231,700 BTU/gross ft^2	As of FY 2005, LLNL has met the goal, with consumption of 229,100 BTU/gross ft^2.
8	Request for bid packages for energy supply with clean energy provisions (100% of requests with provisions versus those without)	N/A	100%	Because NNSA purchases LLNL's electricity, LLNL cannot commit to meeting this goal.
8	Purchase of electricity from sources with low greenhouse gas emissions (% of electricity from less greenhouse gas intensive sources to total consumption)	N/A	100% of all future DOE competitive solicitations for electricity	Because NNSA purchases LLNL's electricity, LLNL cannot commit to meeting this goal. However, during FY 2005, LLNL worked through the Western Area Power Administration to purchase Renewable Energy Credits (RECs) with other DOE facilities in the San Francisco Bay Area.
9	Replacement of chillers (100% of total 150 ton [or larger] pre-1984 units with Class I refrigerants replaced)	7 (number of units in use in 1999)	0	The current schedule based on life-cycle cost-effective use of existing equipment shows three chillers being replaced by 2007.
11	Reduce greenhouse gas emission from facility energy use (30% of greenhouse gas emission reduced relative to 1990 baseline by 2010)	(1990 baseline) 143,059.4 MT[a]	(2010 target) 100,141.6 MT	Because NNSA purchases LLNL's electricity, LLNL cannot commit to meeting this goal. In 2005 LLNL emitted 121,127.3 metric tons. Note: While DOE has a goal of 25% reduction by 2005 (DOE O 430.2A, Attachment 1), it is not included in LLNL contract requirements.

a MT = metric ton

This will be the last year that LLNL reports on the 1999 Pollution Prevention/Energy Efficiency Goals. DOE/NNSA have developed new performance-based goals (approved in 2005) for 2006 and beyond. These goals are described in Attachment 3 to DOE O 450.1.

In 2001, LLNL revised the method by which it calculates waste to better identify future P2 opportunities and to eliminate categories of wastes that would otherwise be counted twice under the RHWM Division's Total Waste Management System (TWMS) database, which was replaced in FY 2004 with a new database called HazTrack. The quantities for hazardous waste, low-level radioactive waste, and mixed low-level waste reported in HazTrack now include all wastes generated under requisition.

Pollution Prevention Program

The P2 Program at LLNL strives to systematically reduce solid, hazardous, radioactive, and mixed-waste generation, and eliminate or minimize pollutant releases to all environmental media from all aspects of the site's operations. 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 potential 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) applied, where feasible, to all types of waste. The P2 team tracks waste generation using the HazTrack database. By reviewing the information in this database, program managers and P2 staff can monitor and analyze waste streams to determine cost effective improvements to LLNL operations.

Diverted Waste

Together, the Livermore site and Site 300 generated 5116.5 metric tons of routine nonhazardous solid waste in 2005. This volume includes diverted waste (for example, material diverted through recycling and reuse programs) and landfill wastes. LLNL generated 6492.5 metric tons of nonroutine nonhazardous solid waste in FY 2005. This includes waste that is reused as cover soil at Class II landfills or is recycled through the nonroutine metals recycling programs. Nonroutine nonhazardous solid wastes include wastes from construction, and decontamination and demolition activities. In FY 2005, the portion of nonhazardous waste (routine and nonroutine) sent to landfill was 2905.4 metric tons. The routine portion was 1730.1 metric tons and the nonroutine portion was 1175.3 metric tons. The breakdown for routine and nonroutine nonhazardous waste that was sent to landfills in FY 2005 is shown in **Table 3-8**.

Table 3-8. Total nonhazardous waste sent to landfills in FY 2005

Nonhazardous waste	2005 total (metric tons)
Routine	
Compacted (landfill)	1730.1
Nonroutine	
Construction demolition (noncompacted landfill)	1083.3
Industrial (TWMS and HazTrack[a])	92.0
Nonroutine subtotal	1175.3
LLNL total	**2905.4**

a RHWM Waste Data Management Systems

Together the Livermore Site and Site 300 diverted 3386.4 metric tons of routine nonhazardous waste in 2005. This represents a diversion rate of 66%. This diversion rate includes waste recycled by RHWM and waste diverted through the surplus sales program. The total routine and nonroutine waste diverted from landfills through LLNL's comprehensive waste diversion program was 8703.6 metric tons in FY 2005 (**Table 3-9**).

Table 3-9. Diverted waste in FY 2005

Waste description	Cumulative 2005 total (metric tons)
Routine	
Batteries (small)	5.4
Batteries (lead-acid)	27.6
Beverage containers	6.6
Cardboard	140.2
Compost	414.2
Cooking grease	2.4
Magazines, newspapers, and phone books	31.4
Metals	1857.2
Paper	300.4
Street sweepings	77.5
Tires and scrap	25.3
Toner cartridges	9.1
Wood pallets	489.6
Total routine waste diverted	**3386.4**
Nonroutine	
Asphalt/concrete	3547.2
Class II Cover	1027.3
Miscellaneous	5.6
Nonroutine metals	637.2
Offsite daily cover/onsite reuse	99.7
SAT Freon	0.2
Total nonroutine waste diverted	**5317.2**
LLNL diversion total	**8703.6**

Pollution Prevention Activities

During the summer of 2005, EPD's Water Guidance & Monitoring Group and the Energy Management Program collaborated to audit LLNL Livermore site restroom facilities. The audit findings are being used to develop several water conservation retrofit projects. The first project submitted for

consideration in LLNL's FY07–FY09 Institutional Investments Facility and Infrastructure (F&I) call for proposals consists of replacing existing flushometers serving women's toilets with dual-volume flushometers. Significant cost savings are anticipated from reduced water, sewage, and pumping requirements.

During FY 2005, LLNL arranged, with other San Francisco Bay Area DOE facilities, to purchase Renewable Energy Credits (RECs) through the Western Area Power Administration. LLNL's portion of the purchase totals 13,220.1 megawatt-hours per year annually for 5 years. This represents about 3.7% of annual LLNL electric power consumption and is a source emissions reduction of about 3,657 metric tons per year (carbon dioxide equivalent).

Since October 2003, EPD has been participating in the Federal Electronics Challenge (FEC), a voluntary partnership program that encourages federal facilities and agencies to purchase greener electronic products, reduce impacts of electronic products during use, and manage obsolete electronics in an environmentally safe way. During 2005, objectives and targets related to the FEC and development of a lab-wide electronics management strategy were incorporated into LLNL's Environmental Management System via the Environmental Management Program (EMP) for nonhazardous materials use. LLNL also began recordkeeping for the Electronics Recycling and Reuse Challenge (ERRC). The ERRC is an FEC initiative that poses a friendly "competition" between federal facilities to see which can reuse and recycle the most surplus computers and other electronics between America Recycles Day (November 15, 2005) and Earth Day (April 22, 2006).

In December 2005, DOE NNSA selected four projects at the Livermore site, Site 300, and the Nevada Test Site to receive pollution prevention awards: three DOE Best-in-Class awards and one DOE Environmental Stewardship award.

The first Best-in-Class award was for LLNL's Space Action Team (SAT) implementation of Assets for Value strategies as a core element of its facility management and D&D processes. This innovative strategy provides a contractual mechanism for converting the value of equipment or building materials into an offset against payment for contracted demolition work. Assets for Value lowers facility operating costs, reduces D&D contracting costs, eliminates waste streams, increases reuse of materials, and increases material recycling.

The second Best-in-Class award was for a pollution prevention/health and safety measure implemented at Site 300's Experimental Explosive Facility—the replacement of sulfur-hexafluoride with an ultra-zero compressed air for use as a dielectric in a portable flash x-ray system. This replacement has the substantial pollution prevention benefit of eliminating the use of a potent greenhouse gas that also, as an asphyxiant, poses a serious health and safety

concern. Of additional benefit is the cost savings associated with use of the Ultra-Zero air, and the concern that SF-6 availability may be limited in the future.

The third Best-in-Class award went to the Joint Actinide Shock Physics Experiment Research (JASPER) gas gun project at the Nevada Test Site, for the incorporation of waste minimization and pollution prevention into the design, execution, and maintenance of the project. JASPER, managed by LLNL, provides data for the dynamic properties of nuclear materials of interest to the stockpile stewardship program. At onset, rather than building a new facility the JASPER project was constructed within an existing facility. The gas gun was manufactured from metal that was recovered from a canceled project. Double containment design features prevent both the escape of contamination and generation of low-level waste. During operations many of JASPER's surrogate shot parts are reusable. Collection cables, originally taken from stock left over from nuclear testing operations, are used outside primary containment, permitting reuse for multiple shots. Additionally, at JASPER recycled chemicals are used as a first choice.

LLNL's Contained Firing Facility (CFF) at Site 300 received a DOE Environmental Stewardship award for their integration of pollution prevention and water conservation during the development of operations practices. The containment of explosives and nondestructive testing within the CFF provides greater environmental protection than provided in the controlled, outdoor firing areas because there are no hazardous emissions to the environment. However, following an experiment, the CFF chamber requires cleaning to remove hazardous and radioactive contamination. The CFF staff have developed and implemented both an inexpensive low-tech method of particulate capture, and an extensive water recycling and polishing system. These practices and system facilitate the cleaning process, reduce the quantity of waste generated as a result of cleaning, save worker time, improve worker safety, and increase the availability of the chamber.

All four award nominations were forwarded to the Office of the Federal Environmental Executive for the 2006 White House Closing-the-Circle (CTC) Awards. The CTC program recognizes outstanding efforts and achievements of Federal employees and their facilities in promoting environmental stewardship.

Energy Management Program Projects

The primary responsibility of the LLNL Energy Management Program is to track and report LLNL's compliance with DOE Order 430.2A and to promote energy efficiency and water conservation onsite. The Energy Management Program completed three energy efficiency projects during FY 2005 and

began a fourth project supported by Federal Energy Management Program (FEMP) funds with LLNL cost sharing.

- **Energy & Water Conservation Audit of Trailer, Modular, and Prefabricated Buildings**

  During FY 2005, LLNL completed energy efficiency and water conservation audits contracted during FY 2003. All LLNL trailer, modular and prefabricated buildings were inspected to identify energy and water conservation measures. These audits were supported jointly by funds awarded from the DOE–FEMP Model Program study and by the LLNL–Energy Management Program (LLNL–EMP). These audits represent about 12.9% of the LLNL baseline floor area and total more than 917,000 square feet. Energy Conservation Measures recommended for implementation are addressed below.

- **Site 300 Heating, Ventilating and Air Conditioning (HVAC) Direct Digital Controls (DDC) Retrofit**

  This retrofit was cost-shared between DOE–FEMP and the LLNL–EMP. The project involved replacing pneumatic controls with direct digital controls at several Site 300 buildings.

- **Building 451 Retrofit of Variable Frequency Drives (VFDs) and DDC Controls of Air Conditioning Units ACU–12 & ACU–13**

  This retrofit is also a cost sharing effort between DOE–FEMP and the LLNL–Computations Directorate. The retrofit implemented an energy efficiency project recommended in 2001 by a DOE energy savings audit team sent to help during the California electrical emergency. This corrected a long-standing cause of energy waste.

- **Computerized Building Automation System, Version II (CBAS-II) Trailer / Modular Building HVAC System DDC Controls Pilot Project**

  Jointly supported by DOE–FEMP Model Program and LLNL–EMP funding, this project was begun in FY 2005. The effort consists of installing a prototype, cost-effective DDC control system in a typical office trailer. The system provides space temperature control and scheduling, building power metering, and remote access via LLNL's Lab-net. The system also provides the capability of "shelter-in-place" operations, improving employee safety in the event of a toxics release, by preventing air flow into and from the building.

During FY 2005, LLNL received two awards from the DOE–FEMP. One award was for a small group of National Ignition Facility (NIF) personnel who worked together to optimize HVAC systems, saving over $758K per year of energy costs. The other award recognizes the individual contributions by LLNL's Energy Manager, who was selected as an FY 2005 DOE–FEMP

Energy Champion for effective implementation of energy and water savings projects during his tenure.

Return-on-Investment Projects

Implementation of three P2 projects, funded by DOE in late 2004 with DOE High-Return-on-Investment (ROI) funds, was completed this year.

- **Biodiesel Project for Medium Service Vehicles**

  This pilot project brought B20, a blend of 20% biodiesel[1] and 80% petroleum diesel, onsite for trial in a selected group (LLNL's medium duty fleet) to evaluate use and maintenance issues, and to build user and management confidence in this alternative fuel. Use of B20 significantly reduces vehicle emissions of carbon monoxide (–13%), unburned hydrocarbons (–11%), particulates (–18%), and the greenhouse gas, carbon dioxide (–16%) as compared to petroleum diesel (World Energy; Howell 2003). Under the Energy Policy Act of 1992, use of biodiesel is an option for applicable federal fleets to meet a portion of their annual alternative fuel vehicle (AFV) acquisition requirements.

  The pilot project, completed in late summer 2005, was deemed a success. Scheduled preventative maintenance for the vehicles did not reveal any problems associated with use of the fuel. At the end of the pilot, use of B20 continued at a low level as LLNL Fleet Management continues to develop their strategy to make use of this and other alternative (non-petroleum based) fuels.

- **Accelerated Solvent Extraction System for Preparation of Semivolatile Organic Compound/Polychlorinated Biphenyl Samples**

  LLNL's Chemistry and Materials Science Environmental Services (CES) routinely analyzes radioactive waste samples for semivolatile organic compounds (SVOCs) and polychlorinated biphenyl (PCB) compounds; in the process, mixed, radioactive and hazardous solvent wastes are generated. This ROI project involved the purchase and application of an accelerated solvent extraction (ASE) system that uses high temperature and pressures to allow the extraction of SVOCs and PCBs from solid samples in less time and with less volume of solvent. Implemented in 2005, the project is expected to have a payback period of 1.6 years and will result in the diversion of 230 kg of mixed low-level waste and 1 kg of TRU waste each year.

[1] Biodiesel is a renewable, domestically produced, and nontoxic diesel fuel substitute. It is a methyl ester most commonly derived from either soy or rapeseed oil.

- **Purchase and Application of a Flow-through Radionuclide Detector**

  This project funded the Chemical Biology and Nuclear Science Division's Environmental Radiochemistry Group's purchase of a flow-through radionuclide detector system and accessories. Implemented in 2005, this detector system is used to detect multiple radionuclide contaminants in a waste stream. This project is expected to reduce the generation of mixed waste by 200 kg each year and will have a payback period of a little less than one year. The flow-through radionuclide detector also minimizes personnel exposure to hazardous and radioactive materials.

Review of New Processes, Programs, or Experiments

During 2005 the Pollution Prevention Team actively participated in the planning and implementation of LLNL's EMS. (See the section "Environmental Management System" in this chapter.)

Pollution Prevention Employee Training and Awareness Programs

In 2005, LLNL conducted a number of activities to promote employee awareness of Pollution Prevention. A key event, the annual Earth Expo, was held in April to coincide with Earth Day. It featured representatives from EPD, businesses with environmentally friendly products, environmental conservation organizations, utilities, environmental agencies, and other organizations with environmental charters and interests. During the course of the year, Pollution Prevention articles appeared in the LLNL newspaper, *Newsline*, and electronic newsletter, *NewsOnLine*. The P2 team conducted training for purchasing staff on EPA requirements for affirmative procurement. The P2 team also placed banners at entry gates for America Recycles Day and National Pollution Prevention Week.

The P2 team maintains a P2 web site (http://www-p2.llnl.gov/) for LLNL employees. The web site is a resource for employees regarding pollution prevention, energy efficiency, the 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 team also operates the Earth Hotline for employees to call with questions, suggestions, or ideas regarding LLNL's pollution prevention and waste diversion endeavors. During 2005 the P2 team brought an EMS web page online to facilitate communication about LLNL's EMS efforts.

Contributing Authors

Many authors contributed to this diverse chapter. We acknowledge here the work of Bruce Campbell, Lucinda M. Clark, Katharine Gabor, Blair Horst, C. Susi Jackson, Hank Khan, Lily Sanchez, and Judy Steenhoven.

Air Monitoring Programs

CHAPTER 4

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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. Department of Energy (DOE) regulations include Title 40 of the Code of Federal Regulations (CFR) Part 61 (the National Emissions Standards for Hazardous Air Pollutants [NESHAPs] section of the Clean Air Act), applicable portions of DOE Order 5400.5 "Radiation Protection of the Public and the Environment", and American National Standards Institute (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 U.S. Environmental Protection Agency (EPA) Region IX has enforcement authority for LLNL compliance with radiological air emissions regulations. Enforcement authority for the Clean Air Act regulations pertaining to nonradiological air emissions belongs to two local air districts, the Bay Area Air Quality Management District (BAAQMD) and the San Joaquin Valley Air Pollution Control District (SJVAPCD).

Air effluent monitoring of atmospheric discharge points is conducted to measure the quantities of radionuclides released from individual facilities during routine and nonroutine operations; ambient air monitoring at LLNL-site and off-site locations determines if airborne radionuclides or beryllium are being released in measurable quantities to the environs 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. (See *LLNL NESHAPs 2005 Annual Report* [Larson et al. 2006].)

Air Effluent Monitoring

For research purposes, LLNL uses a variety of radioisotopes including uranium, transuranic radionuclides, biomedical tracers, tritium, and mixed-fission products. The principal radionuclide released to the atmosphere from the Livermore site is tritium. In addition to effluent sampling for tritium, a number of facilities at the Livermore site have air effluent samplers to detect the release of uranium and transuranic aerosols. The air effluent sampling systems described in this section apply to stationary point source discharges.

Air effluent monitoring of atmospheric discharge points is used to determine the actual radionuclide releases from individual facilities during routine and non-routine operations and to confirm the operation of facility emission control systems. Air effluent and ambient air monitoring measurements can be compared to confirm the expected relationship between them and to help resolve unexpected differences. Air effluent monitoring involves the extraction of a measured volume of air from the exhaust of a facility and subsequent collection of particles by filters or of vapors by a collection medium. After collection, the various radionuclides in the sample are measured by appropriate analytical methods. Currently, the air effluent sampling program measures only radiological emissions. LLNL has operations with nonradiological discharges. When applicable, LLNL obtains permits for the operations from local air districts (i.e., BAAQMD or SJVAPCD). 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" legislation, BAAQMD and SJVAPCD have ranked LLNL as a low-risk facility for nonradiological air emissions.

Methods

LLNL evaluates all discharge points with the potential to release radionuclides to the air according to 40 CFR 61, Subpart H, of the NESHAPs regulations. Subpart H regulations require that facility radiological air effluents must be continuously monitored if the potential off-site dose equivalent is greater than 1 μSv/y (0.1 mrem/y), as calculated using the EPA-mandated air dispersion dose model and assuming that there are no emission control devices. The results from monitoring the air discharge points provide the actual emission source information for modeling, which is used to ensure

that the NESHAPs standard, 100 μSv/y (10 mrem/y) total site effective dose equivalent, is not exceeded. Monitoring of radionuclide air effluents at LLNL has been implemented according to the DOE as low as reasonably achievable (ALARA) policy. This policy is meant to ensure that DOE facilities are capable of monitoring routine and nonroutine radiological releases so that the dose to members of the public can be assessed, and so that doses are ALARA.

In 2005, LLNL operated 71 sampling systems that measured releases of radioactivity from air exhausts at 6 facilities at the Livermore site and 1 sampling system at Site 300. These systems are listed in **Table 4-1** along with the analytes of interest, the type of sampler, and the number of samplers (see **Figures 4-1** and **4-2** for Livermore site and Site 300 air monitoring locations). LLNL periodically reassesses the need for continuous monitoring and assesses new operations or changes in operations.

Table 4-1. Air effluent sampling locations and sampling systems

Facility	Analytes	Sampler type	Number of samplers
Chemistry and Materials Science	Gross α, β on particles	Filter	1
Heavy Element	Gross α, β on particles Gross α, β on particles	Stack CAM[a,b] Filter	2 28
Tritium	Tritium Gaseous tritium and tritiated water vapor	Stack ionization chamber[a] Molecular sieves	4 4
Plutonium	Gross α, β on particles Gross α, β on particles	Stack CAM[a,b] Filter	12 15
Laser isotope separation[c]	Gross α, β on particles	Filter	1
Decontamination and Waste Treatment Facility TRU Mover	Gross α, β on particles Gaseous tritium and tritiated water vapor Gross α, β on particles	Filter Glycol bubbler Filter	1 1 1
Contained Firing Facility	Gross α, β on particles	Filter	1

a Alarmed systems (real-time)
b CAM = Eberline continuous air monitors (real-time)
c Isotopic separation operations were discontinued; area now used for storage of contaminated parts

Sampling for radioactive particles was conducted in all facilities except for the Tritium Facility, where only tritium is measured. Both radioactive particulates and tritium are sampled at the Decontamination and Waste Treatment Facility. All sampling systems operated continuously. Samples were collected weekly or biweekly, depending on the facility. Most air samples for particulate emissions were extracted downstream of high-efficiency particulate air (HEPA) filters and before the emissions were

discharged to the atmosphere. Particles in the extracted air were collected on sample filters and analyzed for gross alpha and beta activity. Tritium was collected using molecular sieves and glycol bubblers.

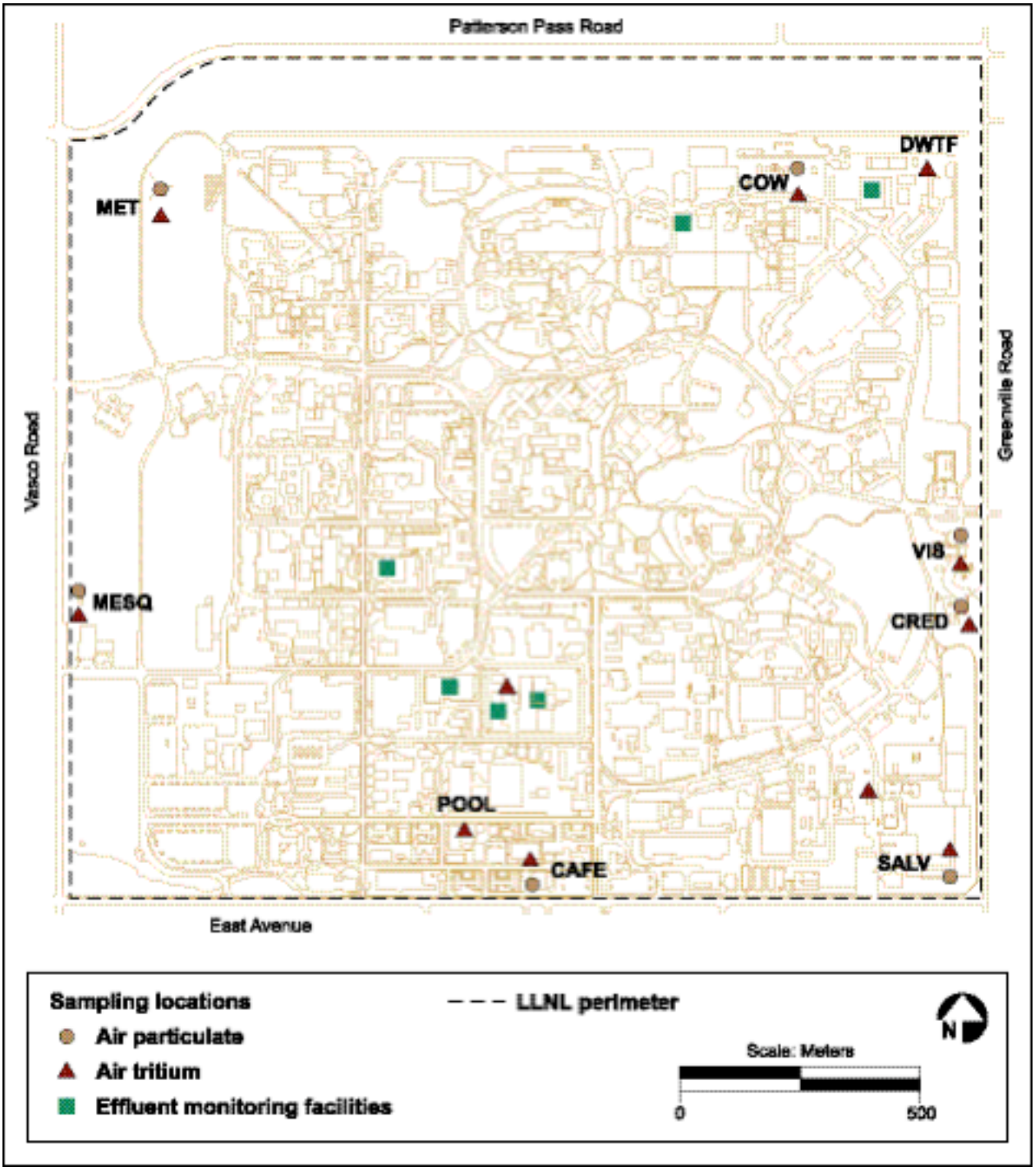


Figure 4-1. Livermore site air monitoring locations, 2005

In addition to sample collection for environmental reporting, some facilities used real-time alarm monitors (listed in **Table 4-1**) at discharge points to provide faster notification in the event of a release of radioactivity. Analytical results from the continuous samplers are reported as a measured concentration per volume of air or as less than the minimum detectable concentration (MDC) when no activity is detected. In all cases, the MDC is more than adequate for demonstrating compliance with the pertinent regulatory requirements for radionuclides that are present or may be present in the sampled air. Air effluent samples were obtained in accordance with written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005).

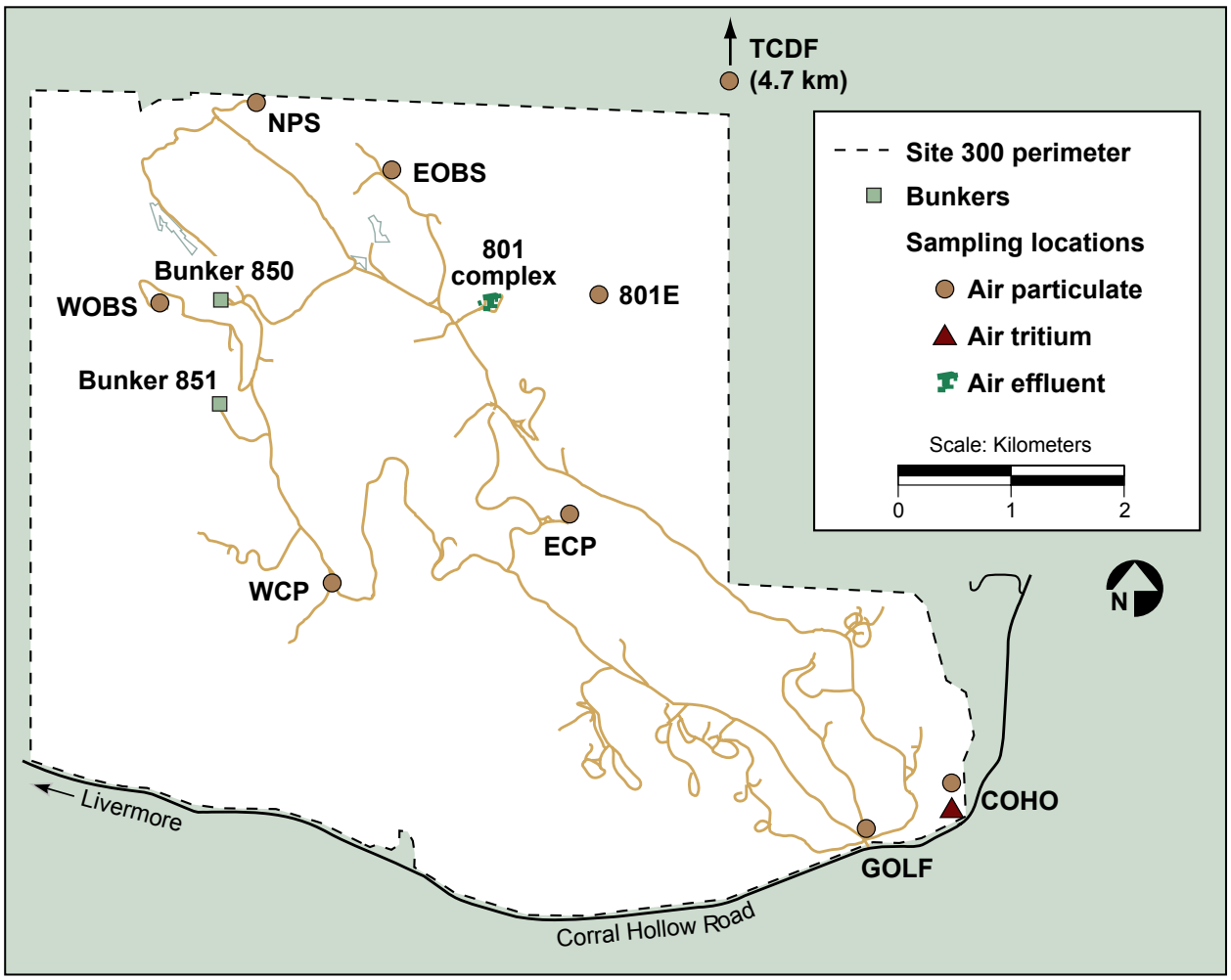


Figure 4-2. Site 300 air monitoring locations, 2005

To establish the background levels of gross alpha and beta activity that are used to determine if a particulate release has occurred from monitored stacks, LLNL operates three low-volume radiological air particulate samplers at locations HOSP and FCC in the Livermore Valley (see **Figure 4-3**) and NPS at Site 300 (see **Figure 4-2**). These samplers collect particulate on membrane filters at a continuous rate of 0.03 m^3/min. The low-volume samplers are not part of the ambient air network.

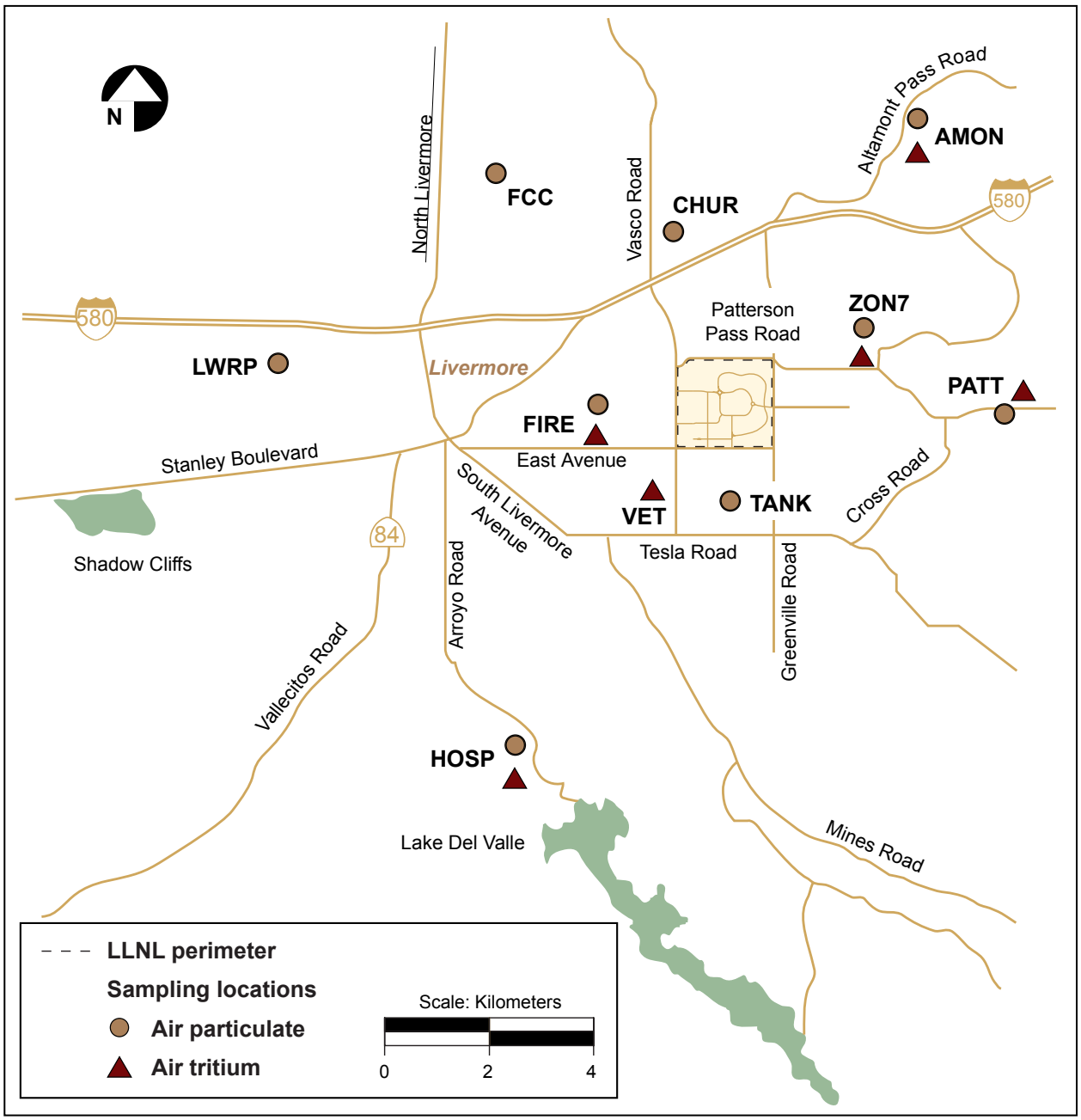
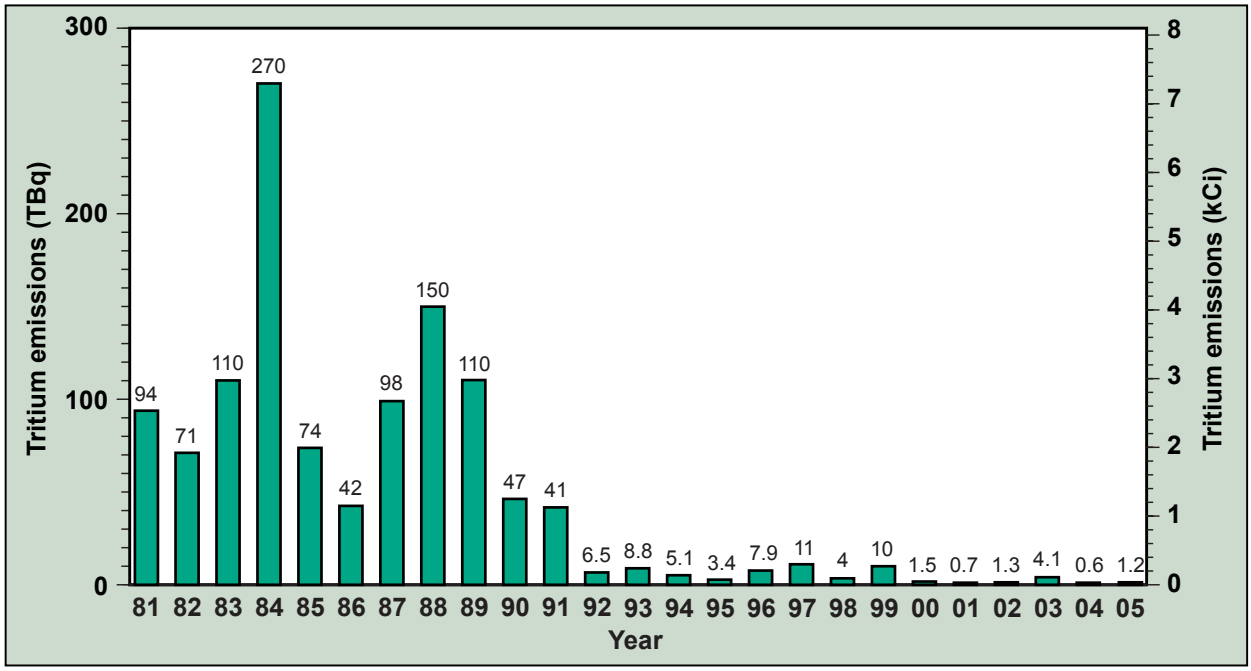


Figure 4-3. Air particulate and tritium sampling locations in the Livermore Valley, 2005

The following sections discuss the radiological air emissions from facilities that have continuously monitored discharge points. All effluent air analytical results are summarized in the file "Ch4 Air Effluent" included on the report CD.

Air Effluent Radiological Monitoring Results

In 2005, a total of 1.2 TBq (32 Ci) of tritium was released from the Tritium Facility (Building 331). Of this, approximately 1.1 TBq (30 Ci) were released as tritiated water vapor (HTO). The remaining tritium released, 0.074 TBq (2.0 Ci), was tritiated hydrogen gas (HT). The median emissions from the facility were 2000 Bq/m^3 (5.4 × 10^{-8} Ci/m^3) for HTO, and 110 Bq/m^3 (3.1 × 10^{-9} Ci/m^3) for HT. The highest single weekly stack emission from the facility was 0.18 TBq (4.9 Ci), of which more than 99% was HTO. Emissions from Building 331 for 2005 continued to remain considerably lower than those during the 1980s. **Figure 4-4** illustrates the combined HTO and HT emissions from the facility since 1981.



Note: Emissions from accidental releases in 1984, 1985, 1990, and 1991 contribute to total tritium released.

Figure 4-4. Tritium Facility combined HTO and HT emissions from 1981 through 2005

Monitoring for tritium emissions at the Decontamination and Waste Treatment Facility (Building 695) began in February 2005. A total of 0.085 TBq (2.3 Ci) of measured tritium was released with 0.081 TBq (2.2 Ci) as HTO and 3.3×10^{-3} TBq (0.088 Ci) as HT. Because monitoring did not begin at the first of the year, an additional emission of 0.017 TBq (0.47 Ci) was estimated by taking an average of measured emissions and applying it to the time period when monitoring was not in place. The total emission for 2005 (measured and estimated emissions combined) was 0.10 TBq (2.7Ci), of which 4.0×10^{-3} TBq (0.11 Ci) was HT. The tritium emissions from Building 695 are far below the level of regulatory concern, and monitoring is in place as part of a best management practice.

Most sample results from the continuously sampled discharge points that have the potential for releasing particulate radionuclides were below the MDC of the analysis. Some sampling systems may exhibit as few as one to four values (out of 26 to 52 samples per year) greater than the MDC. Generally, these samples are only marginally above the MDC. In addition, due to the way some of the exhaust systems are configured, the monitoring systems sometimes sample air from the atmosphere in addition to HEPA-filtered air from facility operations, thereby collecting background atmospheric radioactivity. LLNL uses zero values for these results based on knowledge of the facility, the use of HEPA filters in all significant release pathways, and alpha-spectroscopy-based isotopic analyses of selected air sampling filters. These analyses demonstrate the presence of naturally occurring radionuclides, such as radon daughters like polonium. Even if LLNL used the MDC values to calculate the emission estimates for these facilities (which would be an extremely conservative approach), the total dose to a member of the public attributable to LLNL activities would not be significantly affected.

In 2005, a significant number of samples (7) collected throughout the year from one release emission point at Building 801A yielded gross alpha results greater than the MDC. Gross alpha is used as the primary indicator of potential emissions for operations, such as those at Building 801A, that involve the use of uranium and/or transuranic materials. The gross alpha and gross beta activity emissions for Building 801A were 1.6×10^{4} Bq/y (4.2×10^{-7} Ci/y) and 5.9×10^{4} Bq/y (1.6×10^{-6} Ci/y). Because of the number of samples with values above the MDC, gross alpha and gross beta measurements are being reported as actual emissions. **Table 4-2** provides a summary of all 2005 radiological emissions as determined from continuous sampling of facility exhausts.

Table 4-2. Measured radiological air effluent emissions above the detection limit for Livermore site and Site 300, 2005

Building (Facility)	HT (Bq)	HTO (Bq)	Gross alpha (Bq)	Gross beta (Bq)
331 (Tritium Facility)	5.8×10^{10}	1.1×10^{12}	—	—
695 (Decontamination and Waste Treatment Facility)	4.1×10^{9}	9.6×10^{10}	—	—
801A (Contained Firing Facility)	—	—	1.6×10^{4}	5.9×10^{4}

Nonradiological Results

The Livermore site currently emits approximately 151 kg/day of regulated air pollutants as defined by the Clean Air Act, including nitrogen oxides, sulfur oxides, particulate matter (PM-10), carbon monoxide, and reactive organic gases/precursor organic compounds (ROGs/POCs) (see **Table 4-3**). The stationary emission sources that release the greatest amount of regulated pollutants at the Livermore site are natural gas fired boilers, internal combustion engines (such as diesel generators), solvent cleaning, and surface coating operations (such as painting). The ROGs/POCs emissions appear higher in 2005 than in 2004 because, in 2005, the ROGs/POCs emissions from permit-exempt adhesive and architectural paint sources were added to the "Estimated releases" for the Livermore site for consistency with the source tracking requirements of the site-wide Synthetic Minor Operating Permit (SMOP). Such permit-exempt sources represent an additional 9.5 kg/day of total ROGs/POCs in 2005, while the permit sources contributed 15.4 kg/day (as compared to 16.0 kg/day in 2004). Overall, the ROGs/POCs, nitrogen oxides, carbon monoxide, and PM-10 emissions decreased in 2005, and the sulfur oxide emissions increased slightly.

Table 4-3. Nonradioactive air emissions, Livermore site and Site 300, 2005

Pollutant	Estimated releases (kg/day)	
	Livermore site	Site 300
ROGs/POCs	24.9	0.41
Nitrogen oxides	68.6	0.52
Carbon monoxide	49.9	0.11
Particulates (PM-10)	5.6	0.28
Sulfur oxides	1.7	0.03

Note: In previous Environmental Reports, the ROGs/POCs pollutant category was titled "Organics/volatile organics."

LLNL air pollutant emissions are very low compared with daily releases of air pollutants from all sources in the entire Bay Area. For example, the total emissions of nitrogen oxides released in the Bay Area for 2005 were approximately 4.89×10^5 kg/day, compared with the estimated release from the Livermore site of 68.6 kg/day, which is 0.014% of total Bay Area source emissions for nitrogen oxides. The 2005 BAAQMD estimate for ROGs/POCs emissions was 3.63×10^5 kg/day, while the estimated releases for 2005 from the Livermore site were 24.9 kg/day, or 0.007% of the total Bay Area source emissions for ROGs/POCs.

The total estimated air pollutant emissions during 2005 from operations (permitted and exempt stationary sources) at Site 300 are presented in **Table 4-3**. The stationary emission sources that release the greatest amounts of regulated air pollutants at Site 300 include internal combustion engines (such as diesel generators), a gasoline-dispensing facility, paint spray booths, drying ovens, and soil vapor extraction equipment. Overall, the emissions for all pollutant categories at Site 300 decreased in 2005.

Impact of Air Effluent on the Environment

The dose to the hypothetical maximally exposed member of the public caused by the measured air emissions from the Tritium Facility (modeling HT emissions as HTO as required by EPA) was 2.9×10^{-2} µSv/y (2.9×10^{-3} mrem/y) and the dose from Building 695 (modeling HT emissions as HTO) was 8.7×10^{-3} µSv/y (8.7×10^{-4} mrem/y). The dose from Building 801A was 1.1×10^{-4} µSv/y (1.1×10^{-5} mrem/y). Thus, the estimated radiological dose caused by measured air emissions from LLNL operations is minimal. See Chapter 7 for a discussion of doses.

Estimated nonradioactive air emissions are small compared with local air district emission criteria for the surrounding areas, and as such, have little impact on the environment or public health.

Ambient Air Monitoring

LLNL monitors ambient air to determine if radionuclides or beryllium are being released by Laboratory operations, what the concentrations are, and what the trends are in the environs. Beryllium is the only nonradiological emission from LLNL that is monitored in air. Normally for nonradiological emissions, LLNL obtains permits from local air districts (i.e., BAAQMD or SJVAPCD) that require monitoring of equipment usage, material usage, and record keeping during operations. The BAAQMD has exempted LLNL from the permitting process because LLNL can demonstrate that monthly average

beryllium concentrations in air are well below regulatory limits of 10,000 pg/m^3 at perimeter locations.

In 2003, the EPA approved use of air surveillance monitoring data from the location of the site-wide maximally exposed individual (SW-MEI) to demonstrate compliance with NESHAPs for minor emission point sources (Harrach et al. 2004). In addition, the Derived Concentration Guides (DCGs) found in DOE Order 5400.5 specify the concentrations of radionuclides 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. Data tables referred to in this chapter present the DCG and the percent of the DCG for the given isotope.

Sampling Locations

Sampling locations for each monitoring network are listed in **Table 4-4** and shown in **Figures 4-1**, **4-2** and **4-3**. Monitoring networks are established for air surveillance of radioactive particulates, tritiated water vapor, and beryllium metal. There are 7 air particulate samplers on the Livermore site, 9 in the Livermore Valley, 8 at Site 300, and 1 just west of the outskirts of Tracy There are 11 air tritium samplers at the Livermore site, 6 in the Livermore Valley, and 1 at Site 300. Beryllium is monitored at 6 Livermore site perimeter locations as required by the BAAQMD. Although there is no requirement to monitor beryllium at Site 300, as a best management practice, it is monitored at 3 locations onsite and at the location north of Site 300. All monitoring networks use continuously operating samplers.

Air sampling locations are grouped in the following categories: site perimeter, upwind, downwind, diffuse sources or areas of known contamination on site, and special interest locations. At the Livermore site, the mean air monitoring results for values greater than zero at locations CRED and VIS are used to calculate dose from minor sources to the SW-MEI for NESHAPs compliance; at Site 300, because resuspension of soil is the minor source of greatest interest, the mean concentrations of all on-site air samplers are used to calculate dose to the SW-MEI (see Chapter 7). Based on 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 are expected. Before startup of a new operation, the need for a new sampling location is assessed.

Table 4-4. Sampling locations with type and frequency of analyses for ambient air

Livermore site						
	Target location	**Weekly gross alpha & beta (high volume)**	**Monthly $^{239+240}Pu$**	**Monthly Gamma & $^{235, 238}U$[a]**	**Monthly beryllium**	**Biweekly tritium**
Network	**Air particulate**					**Air vapor**
Collection Media	**Cellulose**					**Silica gel**
SALV, MET, MESQ, COW, CAFE, VIS[b]	Onsite	X	X	X	X	X
DWTF, POOL	Onsite					X
B331, B624	Diffuse/onsite					X
CRED[b]	SW-MEI[c]	X	X			X
ZON7, PATT, AMON	Downwind	X	X			X
CHUR, FCC[d], TANK	Upwind	X	X			
FIRE, HOSP[d]	Upwind	X	X			X
VET	Upwind					X
LWRP	Historic Interest	X	X			
Site 300						
		Weekly gross alpha & beta (high volume)	**Monthly Gamma & $^{239+240}Pu$[a]**	**Monthly $^{235, 238}U$**	**Monthly beryllium**	**Biweekly tritium**
Network		**Air particulate**				**Air vapor**
Collection Media		**Cellulose**				**Silica gel**
EOBS, GOLF, WOBS	Onsite[b]	X	X	X	X	
ECP, WCP, NPS[d], 801E	Onsite[b]	X	X	X		
COHO	Onsite[b]	X		X		X
TCDF	Offsite	X		X	X	

a Perimeter composite samples include portions of weekly filters from the specified locations.
b On the Livermore site, samplers VIS and CRED represent the location of the site-wide maximally exposed individual (SW-MEI), and concentrations obtained from them are averaged for compliance with minor sources; at Site 300, the average of all locations is applied.
c SW-MEI for NESHAPs compliance based on air dispersion modeling.
d Low-volume sampler also operated at this location; particles are collected on millipore filters. These samplers are operated to provide background values for the air effluent monitoring program.

Sample Collection and Analysis

The air particulate networks use high-volume air sampling units, which collect airborne particulate on Whatman 41 cellulose filters. Air flows through the filters at a continuous rate of 0.42 m^3/min, and samples are collected weekly.

Tritium samplers, operating at a flow rate of 500 cm^3/min, draw air through sampling flasks containing silica gel that absorbs the air moisture. These flasks are changed every two weeks.

Throughout the year at varied locations, additional samplers are placed next to permanent samplers. Duplicate samples thus obtained provide quality control of the data. Trip blanks are also taken on the air particulate sampling routes to help identify any contaminant introduced during the sampling process. Ambient air samples were obtained in accordance with written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005).

An LLNL state-certified analytical laboratory performed all sample analyses. Gross alpha and gross beta activities are determined by gas flow proportional counting; plutonium isotopes by alpha spectrometry; uranium isotopes by inductively coupled plasma-mass spectrometry; gamma emitters by gamma spectroscopy; and tritium by freeze-dried vacuum distillation followed by liquid scintillation counting. Details about the analyses and the associated quality control are summarized in the *Environmental Monitoring Plan* (Woods 2005). Beryllium metal concentration is determined by inductively coupled plasma-mass spectrometry. See **Table 4-4** for the frequency of analysis at each location.

Because plutonium research occurs at the Livermore site, plutonium analyses are performed individually for all Livermore locations. However, because plutonium is not used at Site 300, a composite from all locations is analyzed.

Emissions from uranium use at the Livermore site are very minimal so a composite from all the Livermore site perimeter locations is created and analyzed for uranium activity. However, at Site 300, where depleted uranium is used in explosives testing, all sampling locations are analyzed for uranium activity.

Results

As outlined in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991), gross alpha, gross beta, and gamma emitters on air filters are used as indicators; nuclides known to be released from a facility, such as plutonium, uranium, and tritium at LLNL, must be analyzed for specifically. Radiological analytical results are reported as a measured activity per volume of air. Regardless of whether any activity is considered to have been detected, the result of the analysis is reported. The activities are shown in the tables located in the file "Ch4 Ambient Air" included on the report CD.

Particle size distribution of air samples is not determined because the estimated effective dose equivalent to the maximally exposed individual (from the total particulate) is well below the 0.01 mSv (1 mrem) environmental regulatory guide allowable limit (U.S. DOE 1991) using total particles collected.

Gross Alpha and Gross Beta Concentrations

The primary sources of alpha and beta activities are naturally occurring radioisotopes. **Figure 4-5** shows the three-year history of median monthly gross alpha and gross beta activities for the Livermore site perimeter, Livermore Valley, and Site 300 sampling locations. These data are slightly lower than last year for gross alpha but follow a pattern similar to previous years with a seasonal increase in the fall and early winter months. As soils dry out during the summer months, the resuspended particulate can build up and increase until the winter rains begin. In many cases there is an inverse relationship between rainfall and particulate activity indicating that the increases in activity may be from particulate mass from resuspended soils rather than LLNL airborne sources. Routine isotopic gamma results of site composite samples indicate that higher activities are the result of naturally occurring isotopes (uranium, thorium, potassium, and lead) which are also routinely found in local soils.

In 2005, the gross alpha activity (annual median value) for the Livermore site perimeter was 20 $\mu Bq/m^3$ (0.54 fCi/m^3); for the upwind and downwind Livermore Valley stations, the value was 16 $\mu Bq/m^3$ (0.43 fCi/m^3); and for Site 300, the value was 16 $\mu Bq/m^3$ (0.43 fCi/m^3). The annual gross beta median for all upwind and downwind locations was 271 $\mu Bq/m^3$ (7.3 fCi/m^3); for the Livermore site perimeter it was 287 $\mu Bq/m^3$ (7.7 fCi/m^3); and for Site 300 it was 323 $\mu Bq/m^3$ (8.7 fCi/m^3). These values are all typical annual average values. All ambient air analytical results are summarized in the file "Ch4 Ambient Air" included on the report CD.

Site 300 is less developed and has more barren soil compared to the Livermore site. As a result, Site 300 air samples tend to collect more particulate from resuspended soils. The pattern of activity as seen in **Figure 4-5** is very similar to the Livermore site.

On July 19, 2005, a grass fire burned more than 6200 acres including approximately 2100 acres at Site 300 on the west side of the site. During the fire, EPD/TAMM air sampling units were collecting particulate at eight locations on site. The filters were collected as soon as access to the sampling units was allowed. After being held for 4 days to allow for radon decay, the filters were screened for gross alpha and gross beta (GAB) activities. Concentrations of GAB were elevated compared with the weekly sampling data from the weeks leading up to the fire. The samples were also analyzed by

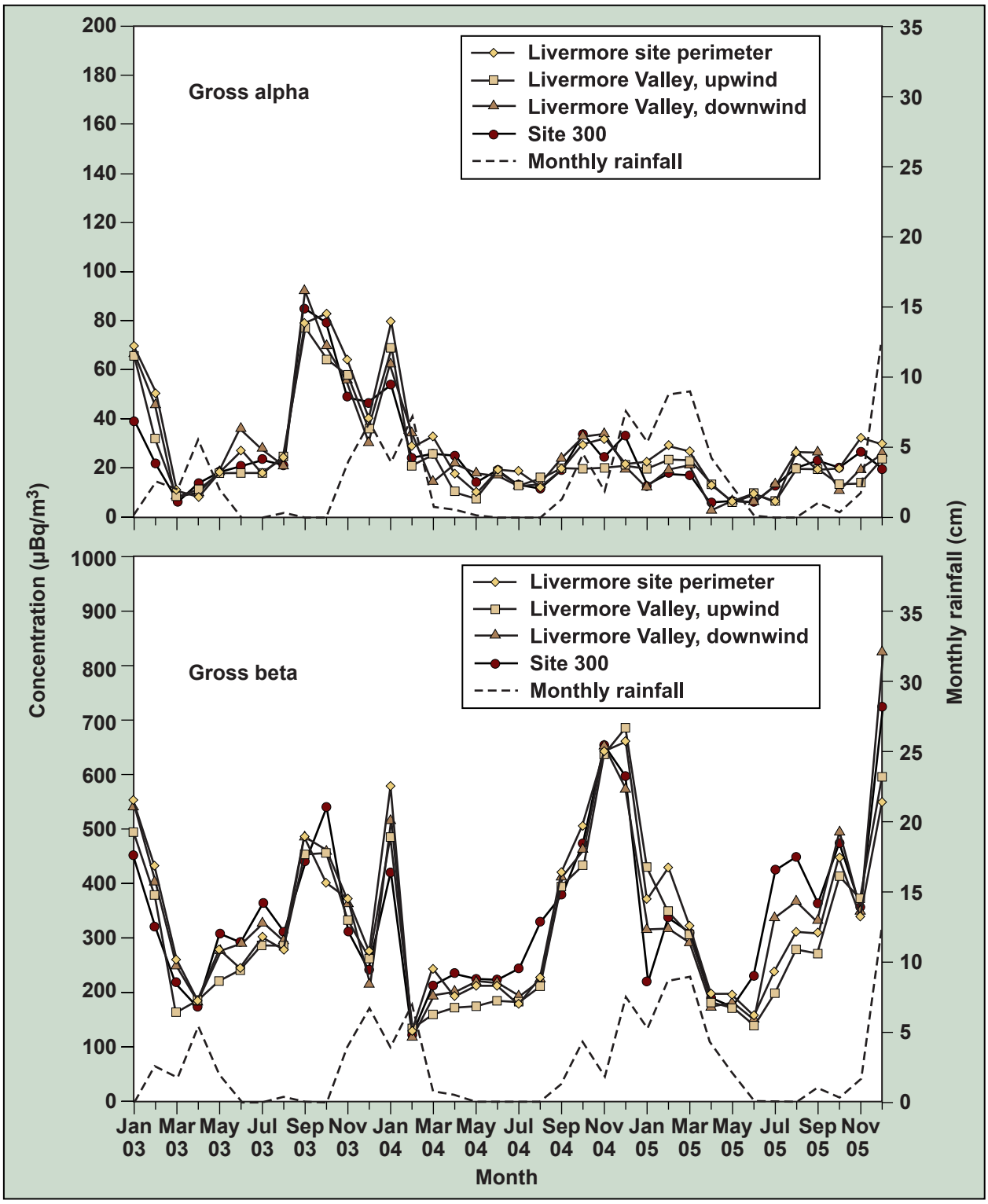


Figure 4-5. Three-year history of monthly median gross alpha and gross beta activities for all particulate samples grouped by area, along with corresponding monthly rainfall totals, 2003–2005

mass spectrometry for uranium isotopes; concentrations were slightly elevated over the monthly composite samples. Similar elevated concentrations of GAB and uranium are observed after controlled burns at Site 300.

Gamma-Emitting Radionuclides

By analyzing air samples for gamma-emitting radionuclides, LLNL verifies that there is no evidence of release of the small inventories of mixed fission products and radiochemical tracers used by LLNL. This analysis can also reveal emissions from global fallout sources such as aboveground tests and the Chernobyl accident (Holland et al. 1987). Composite samples for the Livermore site and Site 300 are analyzed for an environmental suite of gamma-emitting radionuclide concentrations in air. Site composite samples are scanned for 47 isotopes, which contain over 350 different gamma ray energies. These include fission products, activation products, actinides, and naturally occurring products. Of these isotopes, beryllium-7 (cosmogenic), lead-210, and potassium-40, all of which are naturally occurring in the environment, were consistently detected at both sites. The results are within known background levels.

Plutonium Concentrations

Historical environmental plutonium-239+240 activity for the past 20 years is shown in **Figure 4-6**. Locations HOSP and VIS represent typical upwind and onsite sampling locations, respectively. Plutonium concentrations at both of these sites have been decreasing as fallout diminishes and on-site surface areas of potential resuspension have been covered with pavement or buildings.

Plutonium-239+240 was detected in 14 of the 204 samples tested from Livermore area air samples. Six of those positive samples came from on-site samplers. The highest recorded on-site plutonium-239+240 detection of 33 nBq/m^3 (0.89 aCi/m^3) was at the COW location and was 0.004% of the DCG, while the highest off-site plutonium value of 88 nBq/m^3 (2.4 aCi/m^3) was recorded at the LWRP location and was 0.012% of the DCG. Plutonium was detected in 3 of the 12 composite samples collected from Site 300 with the highest detection of 25 nBq/m^3 (0.68 aCi/m^3), which was 0.003% of the DCG, occurring in July.

Uranium Concentrations

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.

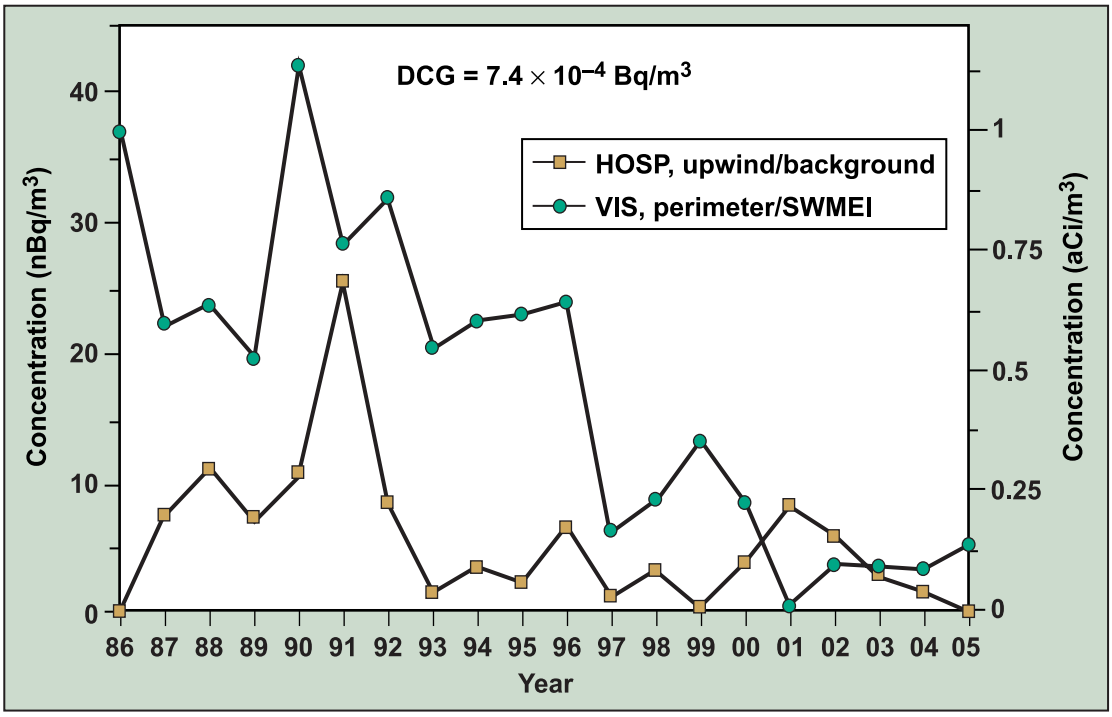


Figure 4-6. Calculated annual median concentrations of plutonium-239+240 for HOSP and VIS for the last 20 years

Uranium isotopes are naturally occurring. All but two of the uranium-235 analyses had positive detections, and all but one of the uranium-238 samples had a positive detection. The Livermore site monthly composites had a uranium-235 median concentration of 0.11 pg/m^3 and a uranium-238 median concentration of 15 pg/m^3. This results in a uranium-235/uranium-238 median ratio of 0.0073, which is considered natural uranium and typical of what has been recorded in the past.

The annual median uranium-235 concentration for all Site 300 locations was 0.17 pg/m^3 (or less than 0.0004% of the DCG) and the uranium-238 median concentration was 26 pg/m^3 (or less than 0.009% of the DCG). The annual median for the Site 300 uranium-235/uranium-238 ratio was 0.0063, which is indicative of the presence of some depleted uranium.

In 2005, a total of six depleted uranium shot experiments were conducted at Bunker 851. The two closest sample locations to the bunker were WOBS and WCP with annual median isotopic ratios of 0.0056 and 0.0042, respectively. The other sample locations at Site 300 had annual median isotopic ratios ranging from 0.0068 to 0.00729, which are more in line with natural uranium ratios.

Concentrations for both uranium-235 and uranium-238 were elevated at locations WCP and NPS after the grass fire in July (see Section "Gross Alpha and Gross Gamma Concentrations" earlier in this chapter for more information on the grass fire). The highest measured uranium-235 value for 2005 was 3.4 pg/m^3 (0.007% of the DCG) at WCP in July. The highest measured uranium-238 value was 952 pg/m^3 (0.3% of the DCG) at WCP also in July. Both WCP and NPS were downwind from the fire and near the fire's edge. The uranium-235/uranium-238 ratio for all locations at Site 300 for July ranged from 0.0035 to 0.0074, which is consistent with depleted and natural uranium ratios (0.002 and 0.0072, respectively). The elevated concentrations are attributed to increased mass loading of the filter due to resuspension of particulates from the fire.

Tritium Concentrations

Tritium data presented in **Table 4-5** summarize the biweekly tritium in air data provided in data tables (see file "Ch4 Ambient Air" on the report CD). Locations (see **Figures 4-1**, **4-2** and **4-3**) are grouped by expected concentrations of tritium. The highest concentrations of tritium are found near area (diffuse) sources monitored by the B331 and B624 samplers on the Livermore site. Area sources include stored containers of tritium waste or tritium-contaminated equipment from which HTO diffuses into the atmosphere. The annual mean and median concentrations for 2005 for the B331 and B624 air tritium samplers combined were essentially no different than the 2004 values. However, this was due to 2005 concentrations being higher at the B331 sampler and lower at the B624 sampler than in 2004. Because of operations at the Tritium Facility, the concentration of the B331 sample for December 1–15 was extremely high (23,700 mBq/m^3; see file "Ch4 Ambient Air" on the report CD). Concentrations this high were last observed in 1998. Samples from seven other locations exhibited their maximum concentrations for the year for the same sampling period. Because some of the samples (e.g., HOSP and COHO) were from locations that monitor background concentrations of tritium and some of the samples (e.g., VET,

Table 4-5. Tritium in air samples (mBq/m^3), 2005

Sampling locations	Detection frequency[a]	Mean	Median	IQR	Maximum	Median Percent of DCG[b]
Diffuse on-site sources	51 of 51	1590	444	740	23700	0.012
Livermore site perimeter[c]	182 of 222	67.3	45.1	60.5	1350	0.0012
Livermore Valley	51 of 147	8.27	8.18	18.9	126	0.00022
Site 300	8 of 25	6.33	7.29	22.2	40.0	0.002

a Rejected samples are not included in the statistics.
b DCG = Derived Concentration Guide of 3.7 x 10^6 mBq/m^3 for tritium in air.
c Locations COW, DWTF, MET, and POOL are not strictly on the perimeter of the site.

AMON, PATT) were from locations where detections are not expected, contamination of the analytical laboratory by the B331 sample was considered the likely cause of the unexpectedly high concentrations observed. As a result, all samples except for B331 were rejected for the sampling period as not being representative.

Air concentrations measured at samplers near the perimeter of the Livermore site are the next highest after those measured near diffuse sources, but the concentrations near the perimeter are, on average, less than 10% of those near the diffuse sources. Location DWTF, which is a sampler located downwind of the Decontamination and Waste Treatment Facility, exhibited the highest median annual concentration of the perimeter locations at just 0.0039% of the DCG. Median concentrations for 2005 for perimeter locations were on average about 60% higher for 2005 than for 2004. In 2005, releases from the Tritium Facility were about double those in 2004. The effect of this may be seen when the mean of all maximum concentrations for all perimeter locations for 2005 (331 mBq/m^3 [8.94 pCi/m^3]) is compared with that for 2004 (161 mBq/m^3 [4.35 pCi/m^3]).

Three samples (CAFE, VET, and POOL) exhibited maximum concentrations for the March 10–24 sampling period (see file "Ch4 Ambient Air" on the report CD). The highest value for all perimeter locations was 1350 mBq/m^3 (36.5 pCi/m^3) at POOL during this time. These high values are probably due to the much higher than average release from the Tritium Facility during the week of March 17–25.

In 2005, median concentrations at perimeter locations COW, MET, and MESQ were about 2.6 times greater than the concentrations observed in 2004. This increase is greater than expected from known release rates and is correlated with the presence of a transportainer that was located in the northwest area of the laboratory and contained tritiated waste from a building undergoing renovation.

All of the median concentrations in the Livermore Valley and at Site 300 (**Table 4-5**; see also file "Ch4 Ambient Air" on report CD for biweekly data) were below the detection limit in 2005. Given the low tritium concentrations observed at the Livermore site perimeter, all samples from locations distant from the Livermore site are expected to exhibit tritium background concentrations that are below the detection limit. Similarly, because no operations at Site 300 released tritium to the environment in 2005, concentrations at COHO are expected to be below the detection limit. Detections occurring at these sampling locations are artifacts of scintillation counting with a high counter background.

Beryllium Metal Concentrations

LLNL measures the monthly concentrations of airborne beryllium for the Livermore site, Site 300, and the off-site sampler located north of Site 300. (See file "Ch4 Ambient Air" on report CD for data.) The highest value at the Livermore site was 19 pg/m^3, which was recorded at location CAFE in October. This value is only 0.19% of the BAAQMD ambient concentration limit (ACL) for beryllium (10,000 pg/m^3). These data are similar to data collected from previous years.

Figure 4-7 is a plot of the median beryllium concentration at the Livermore site perimeter from 1975 through 2005. The decrease in median concentration in 1993 and the slight increase in 1999 were likely the result of a change in the analytical laboratory used to perform this analysis.

There is no regulatory requirement to monitor beryllium in San Joaquin County; however, LLNL analyzes samples from several Site 300 locations as a best management practice. The monthly median beryllium concentration for all Site 300 locations was 7 pg/m^3. The highest value for the Site 300 area sampling occurred at the offsite location TCDF in November with a value of 83 pg/m^3, which was just 0.83% of the ambient concentration limit.

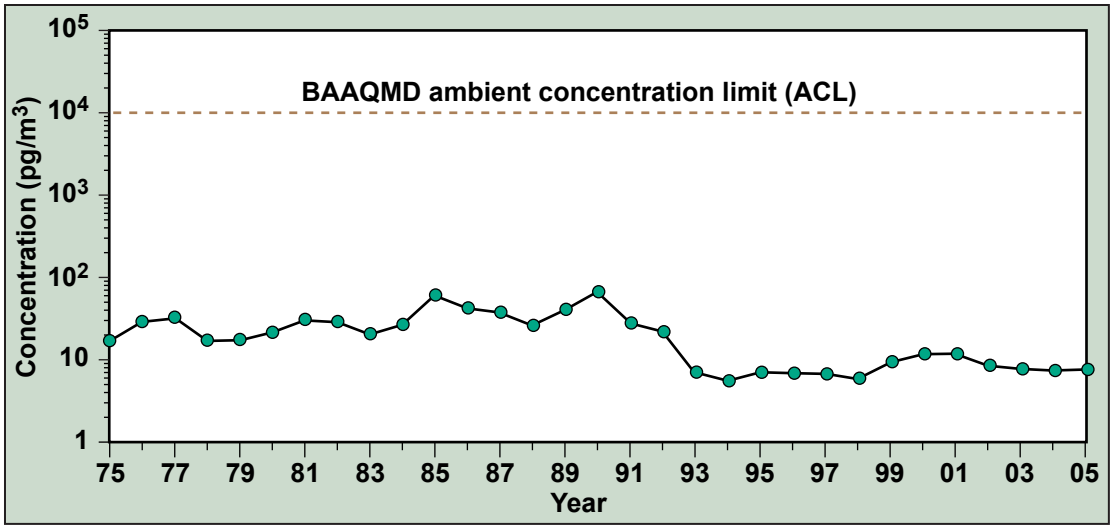


Figure 4-7. Median concentration of beryllium in air particulate samples taken at the Livermore site perimeter, 1975–2005

Environmental Impact of Ambient Air

LLNL operations involving radioactive materials had minimal impact on ambient air during 2005. Radionuclide particulate 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.

The diffuse tritium sources at Building 331 and the Building 612 Yard had a small, localized effect with minimal impact on the public. Any potential dose received by a member of the public from the diffuse sources is accounted for when doses are calculated based on tritium concentrations at the Livermore site perimeter. The median and mean tritium concentrations for all Livermore site perimeter air tritium sampling locations in 2005 were about 60% and 30% higher, respectively, than in 2004 due to higher release rates from the Tritium Facility and its area source. Both mean and median concentrations of tritium in the Livermore Valley or at Site 300 were all well below detection limits. For a location at which the mean concentration is at or below the detection limit, inhalation dose from tritium is assumed to be less than 5 nSv/y (0.5µrem/y) (i.e., the annual dose from inhaling air with a concentration at the detection limit of about 25 mBq/m^3 [0.675 pCi/m^3]).

There are two Livermore site locations (CRED and VIS) with public access, at least during working hours. If it were assumed that a member of the public inhaled air continuously for a year at the maximum biweekly concentration at CRED (145 mBq/m^3) or VIS (107 mBq/m^3), the resulting doses would still be tiny (30.5 nSv/y [3.05 µrem/y] and 22.5 nSv/y [2.25 µrem/y], respectively). Put another way, the maximum concentration at CRED is just 0.3% of concentration limits for minor sources set by the U.S. EPA in Table 2, Appendix E to 40 CFR 61 (Harrach et al. 2005).

The concentrations of beryllium at both the Livermore site and Site 300 can be attributed to resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and the air of the Livermore area and the Central Valley typically contains 10 to 100 µg/m^3 of particulates. Using a value of 50 µg/m^3 for an average dust load and 1 ppm for beryllium content of dust, a conservative airborne beryllium concentration of 50 pg/m^3 can be predicted. The overall median for the Livermore site and Site 300 (excluding the off-site location, TCDF) are both 7 pg/m^3. These data are lower than estimated for natural background, well below standards, and do not indicate the presence of a threat to the environment or public health from LLNL operations.

Water Monitoring Programs

CHAPTER 5

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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 operate differently between the Livermore site and Site 300. For example, Site 300 is not serviced by a publicly owned treatment works as is the Livermore site, so different methods of treating and disposing of sanitary wastewater are used at the two LLNL sites. As described below, many different drivers determine the appropriate methods and locations among the various water monitoring programs.

In general, water samples are collected according to written standardized procedures appropriate for the medium (see Woods 2005). Sampling plans are prepared in advance by each network analyst, who is the LLNL staff person responsible for developing and implementing the specific monitoring programs or networks. The network analyst decides what analytes are to be sampled (see Appendix A) and at what frequency, incorporating any permit-specified analyses. Except for certain sanitary sewer and retention tank analytes, the analyses were usually performed by off-site California-certified contract analytical laboratories.

Sanitary Sewer Effluent Monitoring

In 2005, the Livermore site discharged an average of 1.08 million liters (ML) per day of wastewater to the City of Livermore sewer system, 4% of the total flow into the city's system. This volume includes wastewater generated by Sandia National Laboratories/ California (Sandia/California) and very small quantities (26,420 gallons in 2005) of Site 300 wastewater, which is discharged to the LLNL collection system and combines with LLNL sewage before it is released at a single point to the municipal collection system

(**Figure 5-1**). Most of the process wastewater generated at the Livermore site is collected in various retention tanks and discharged to LLNL's collection system under prior approval from LLNL's Water Guidance and Monitoring Group (WGMG) Waste Discharge Authorization Record (WDAR) approval process. In 2005, Sandia/California generated approximately 10% of the total effluent discharged from the Livermore site. 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.

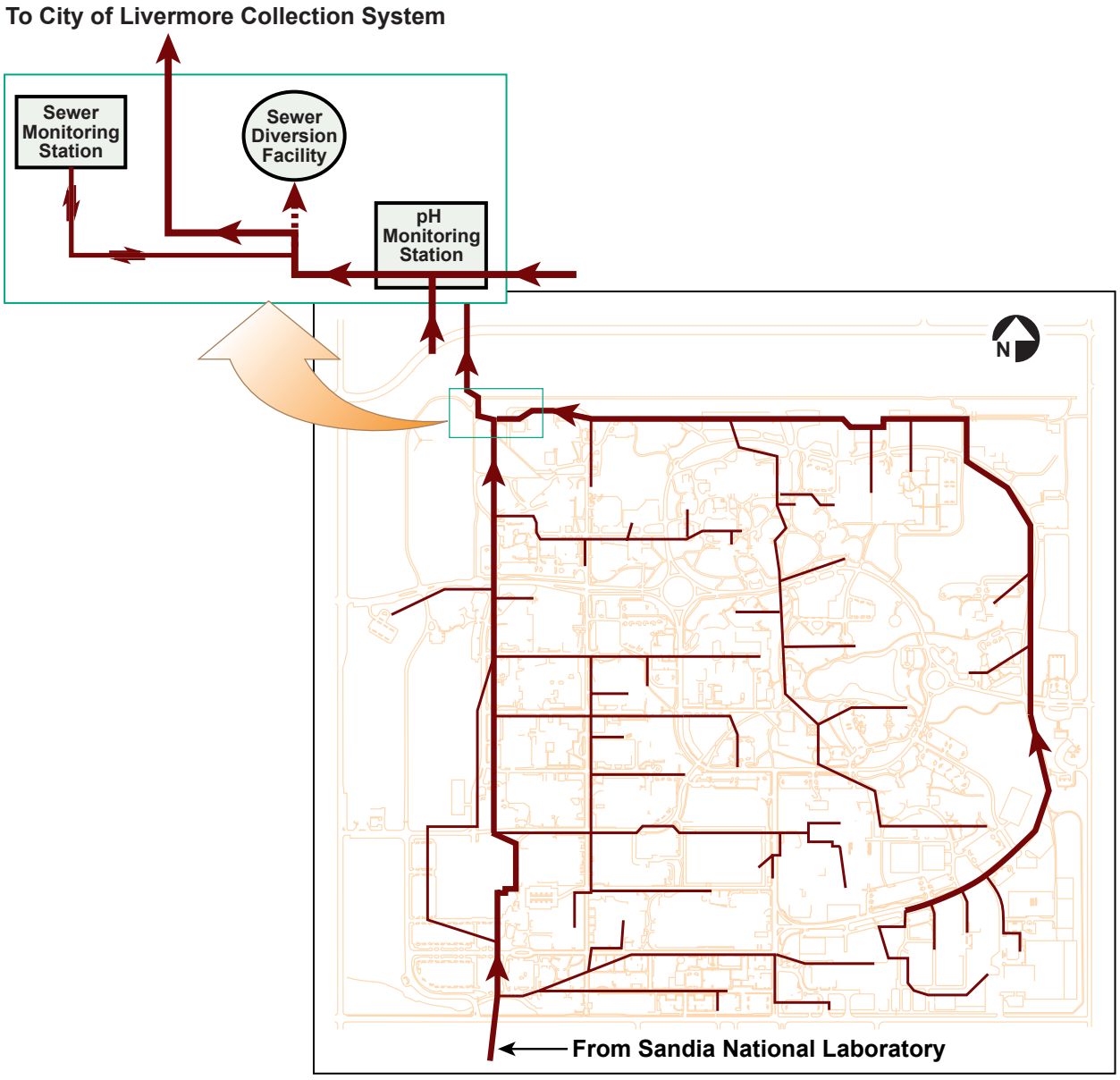


Figure 5-1. LLNL sanitary sewer system, monitoring stations, and diversion facility

Livermore Site Sanitary Sewer Monitoring Complex

LLNL's sanitary sewer discharge permit (Permit 1250, 2004/2005 and 2005/2006) 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, toxic chemicals, and water-quality parameters. In addition, as a best management practice, the outflow to the municipal collection system is sampled continuously and analyzed in real time for conditions that might cause upset or pass through to the Livermore Water Reclamation Plant (LWRP) treatment process or otherwise impact the public welfare. The effluent is continuously analyzed for flow, pH, regulated metals, and gamma radioactivity. If concentrations above warning levels are detected the site effluent is automatically diverted to the Sewer Diversion Facility (SDF), and an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day. The monitoring system provides a continuous check on sewage control, and the LWRP is notified of contaminant alarms. Trained LLNL staff respond to all alarms to evaluate the cause and take appropriate action.

In years prior to 2005, LLNL collected monthly grab samples, monthly 24-hour composites, and weekly composites from a subsurface vault location immediately adjacent to, but outside, the SMS. Experience demonstrated a number of limitations associated with this sampling location that impacted the homogeneity of effluent samples. On December 15, 2004, the LWRP approved an LLNL request to relocate the sewer monitoring sampling location to within the SMS facility. This new sampling location was activated on December 30, 2004 (for the December 30, 2004 to January 5, 2005 weekly composite sample), and all effluent samples collected since that date have been acquired using this upgraded sampling system within the SMS.

In addition to the continuous monitoring at the SMS, LLNL monitors pH at the upstream pH Monitoring Station (pHMS) (see **Figure 5-1**). The pHMS continuously monitors pH during peak flow hours between 7 a.m. and 7 p.m. during the workweek and diverts pH discharges outside the permit range of 5 to 10 to the SDF. The pHMS duplicates the pH monitoring and diversion capabilities of the SMS but is able to initiate diversion earlier because it is located upstream of the SDF.

LLNL maintains and operates a diversion system that activates automatically when either the SMS continuous monitoring system or the pHMS detects an anomalous condition. For SMS-activated alarms, the SDF ensures that all but the first few minutes of the potentially affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any potential cleanup. When the SDF is activated by the upstream pHMS for pH excursions, even the first few minutes of affected wastewater flow are

retained. Up to 775,000 L of potentially contaminated sewage can be held, pending analysis to determine the appropriate handling method. The diverted effluent may be returned to the sanitary sewer (if it meets LLNL's wastewater discharge permit limits), shipped for off-site disposal, or treated at LLNL's Radioactive and Hazardous Waste Management (RHWM) facilities and then released to the sanitary sewer. All diverted sewage in 2005 was returned to the sanitary sewer.

Radiological Monitoring Results

Work Smart Standards (WSS) establish the standards of operation at LLNL (see Chapter 2), and include the standards for sanitary sewer discharges. For radioactive material releases, complementary (rather than overlapping) sections from Department of Energy (DOE) Order 5400.5 and 10 CFR Part 20 are both part of the standards. From DOE Order 5400.5, the WSS for sanitary sewer discharges include the criteria DOE established for the application of best available technology to protect public health and minimize degradation of the environment. These criteria (the Derived Concentration Guides, or DCGs) limit the concentration of each radionuclide discharged to publicly owned treatment works. If a measurement of the monthly average concentration of a radioisotope exceeds its specific concentration limit, LLNL is required to improve discharge control measures until concentrations are again below the DOE limits. From 10 CFR Part 20, the numerical discharge limits for sanitary sewer discharges in the WSS include the annual discharge limits for radioactivity: 185 GBq (5 Ci) of tritium, 37 GBq (1 Ci) of carbon-14, and 37 GBq (1 Ci) of all other radionuclides combined. The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq [5 Ci]) is primary over the DOE Order 5400.5 concentration-based limit for tritium for facilities such as LLNL that generate wastewater in large volumes. In addition to the DOE average concentration discharge limit for tritium and the 10 CFR Part 20 annual total discharge limit for tritium, the LWRP established in 1999 an effluent concentration discharge limit for LLNL governing daily releases of tritium. This limit is more stringent than the DOE discharge limit: it is a factor of 30 smaller and applies to a daily rather than an annualized concentration. The following discussion includes the specific radioisotopes with potential to be found in the sanitary sewer effluent at LLNL with respect to the appropriate discharge limit. (All analytical results are included in the file "Ch5 LV Wastewater" provided on the report CD.)

LLNL determines the total radioactivity contributed by tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. The 2005 combined release of alpha and beta sources was 0.22 GBq (0.01 Ci), which is 0.59% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The combined total is the sum of the alpha

and beta results shown in Table 5-1. The tritium total was 3.1 GBq (0.08 Ci), which is 0.04% of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

Table 5-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2005

Radioactive emitter	Estimate based on effluent activity (GBq)[a]	Limit of sensitivity (GBq)
Tritium	3.12	1.00
Gross alpha sources	0.01	0.04
Gross beta sources	0.21	0.10

a 37 GBq = 3.7×10^{10} Bq = 1 Ci

Summary results and statistics for tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in Table 5-2. The total monthly activity is calculated by multiplying each monthly concentration by the total flow volume over which the sample was collected. (Per DOE guidance, all total annual results presented in this chapter for radionuclides are calculated by using all analytical results regardless of whether or not they are above the detection limit). The maximum daily concentration for tritium at 0.279 Bq/mL was far below the permit discharge limit (12 Bq/mL [333 pCi/mL]).

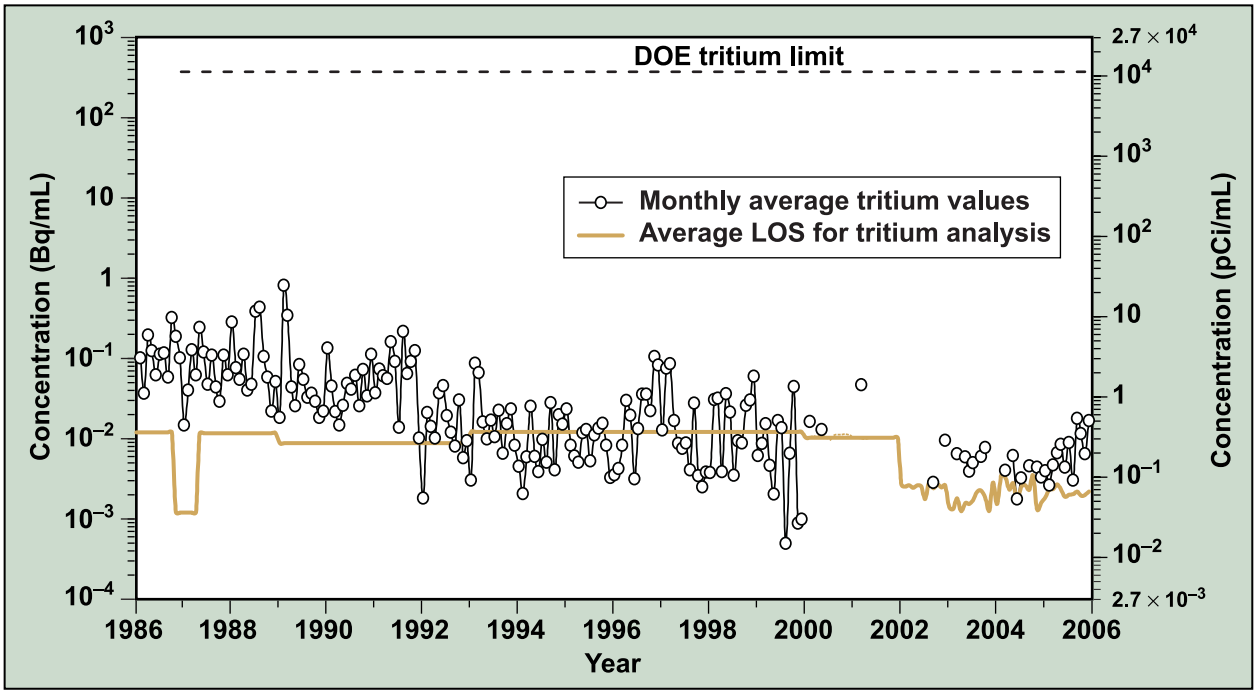
Table 5-2. Summary statistics of tritium in sanitary sewer effluents, LLNL and LWRP, 2005

Monitoring results			
	LLNL		LWRP
	Daily	Monthly	Monthly
Maximum (Bq/mL)	0.279[a]	0.018[b]	0.006[c]
Median (Bq/mL)	0.002	0.007	0.002
LLNL annual total (GBq)	3.12		

Discharge limits for LLNL effluent			
	Discharge limit	Monitoring results as percentage of limit	
		Maximum	Median
LWRP permit daily (Bq/mL)	12	2.33%	0.02%
DOE annualized discharge limit for application of BAT[d] (Bq/mL)	370	0.005%[e]	0.0005%[e]
10 CFR 20 annual total (GBq)	185	1.7%	

a This daily result is for a December sample.
b This is the monthly value for September. All monthly values above limit of sensitivity are plotted in Figure 5-2.
c This is the monthly result for April.
d The DOE annualized discharge limit for application of best available technology (BAT) is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.
e Monitoring results as a percentage of limit are calculated using the LLNL monthly sample concentration and the DOE annualized discharge limit.

The historical trend in the monthly concentration of tritium is shown in **Figure 5-2** (before 2002, the figure shows the monthly averages calculated from weekly data). Also included in the figure are the limit of sensitivity (LOS) values for the tritium analysis and the DOE tritium limit (370 Bq/mL [0.01 µCi/mL]).



Notes:
- Only values above the limit of sensitivity (LOS) of the analytical method used are plotted.
- The DOE annualized discharge limit for application of best available technology (BAT) is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

Figure 5-2. Historical tritium concentrations in the Livermore site sanitary sewer effluent

The concentrations of plutonium-239 and cesium-137 measured in the sanitary sewer effluent from LLNL and LWRP and in LWRP sludge are presented in **Tables 5-3** and **5-4**, respectively. The plutonium and cesium results are from monthly composite samples of LLNL and LWRP effluent, and quarterly composites of LWRP sludge. For 2005, 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 median plutonium concentration observed in 2005 sludge (**Table 5-4**), is many times lower than the EPA preliminary remediation goal for residential soil (93 mBq/dry g [2.5 pCi/dry g]) and is 2200 times lower than the remediation goal for industrial or commercial soil (370 mBq/dry g [10 pCi/dry g]).

Table 5-3. Cesium and plutonium in LLNL and LWRP sanitary sewer effluents, 2005

Month	Cesium-137 (µBq/mL)				Plutonium-239 (nBq/mL)			
	LLNL		LWRP		LLNL		LWRP	
	Radioactivity	MDC[a]	Radioactivity	MDC[a]	Radioactivity	MDC[a]	Radioactivity	MDC[a]
Jan	–8.21 ± 7.4	6.1	1.11 ± 6.0	5.4	11.6 ± 8.0	8.6	0.97 ± 2.2	3.6
Feb	–1.22 ± 6.9	6.0	0.33 ±5.9)	5.3	9.62 ± 6.8	6.8	–2.22 ± 1.7	5.9
Mar	3.60 ± 7.0	6.2	3.33 ± 5.8	5.3	16.4 ± 7.8	5.0	2.84 ± 3.6	4.9
Apr	–0.76 ± 5.9	5.3	–0.43 ± 7.0	6.1	6.18 ± 5.1	5.5	–0.99 ± 1.0	3.9
May	–0.07 ± 6.7	5.9	–0.14 ± 5.9	5.3	8.21 ± 5.6	5.4	1.26 ± 3.0	4.9
Jun	–3.35 ± 6.6	5.6	1.40 ± 5.7	5.2	0.27 ± 1.0	2.4	38.5 ± 11	3.2
Jul	–2.86 ±6.8	5.8	–2.04 ± 6.0	5.3	95.5 ± 21	3.5	1.22 ± 2.1	3.3
Aug	3.46 ± 6.6	5.9	–1.08 ± 5.6	5.0	50.3 ±16	7.6	7.51 ± 5.1	4.7
Sep	–0.41 ± 5.6	5.0	–1.28 ± 6.5	5.7	26.0 ± 10.6	6.1	3.04 ± 4.1	5.6
Oct	2.07 ± 5.4	4.9	0.95 ± 6.3	5.6	11.1 ± 16	21.6	0.62 ± 1.7	3.2
Nov	0.56 ± 6.3	5.5	–0.13 ± 5.4	4.9	15.7 ± 7.4	5.2	–0.82 ± 2.2	4.8
Dec	1.43 ± 6.1	5.4	–2.47 ± 5.4	4.8	35.5 ± 17	12	–2.57 ± 2.7	7.0
Median	–0.24		–0.13		13.7		1.10	
	Annual LLNL total discharge by radioisotope							
	Cesium-137				Plutonium-239			
Bq/y[b]	NA[c]				9.64×10^{3}			
Ci/y[b]	NA[c]				2.60×10^{-7}			
	Fraction of limit [d]							
DOE 5400.5 DCG[e]	NA[c]				3.69×10^{-8}			

Note: Results in this table are reported as radioactivity (the measured concentration and a ± 2σ counting uncertainty) along with the detection limit or minimum detectable concentration (MDC). A measured concentration exhibiting a 2σ counting uncertainty greater than or equal to the measured concentration is considered a nondetection (see Chapter 9).

a MDC = minimum detectable concentration

b 1 Ci = 3.7×10^{10} Bq

c Because the median value for Cs-137 is negative it cannot be compared to a positive limit. On average no measurable quantity of Cs-137 was released in 2005.

d Fraction of limit calculations are based on the annual total discharge for a given isotope and the corresponding concentration-based limit (0.56 and 0.37 Bq/mL for cesium-137 and plutonium-239, respectively) multiplied by the annual volume of Livermore site effluent.

e DCG = Derived Concentration Guide

Table 5-4. Radioactivity of cesium and plutonium in LWRP sludge, 2005

Month	Cesium-137 (mBq/dry g)[a]	Plutonium-239 (mBq/dry g)
Mar	<0.85	0.144 ± 0.038
Jun	<0.90	0.083 ± 0.021
Sep	<1.06	0.203 ± 0.051
Dec	<0.63	0.194 ± 0.050
Median	0.88	0.169

Note: Sludge from LWRP digesters is dried before analysis. The resulting data indicate the cesium and plutonium concentration of the sludge prepared by LWRP for disposal at the Vasco Road Landfill in Alameda County.

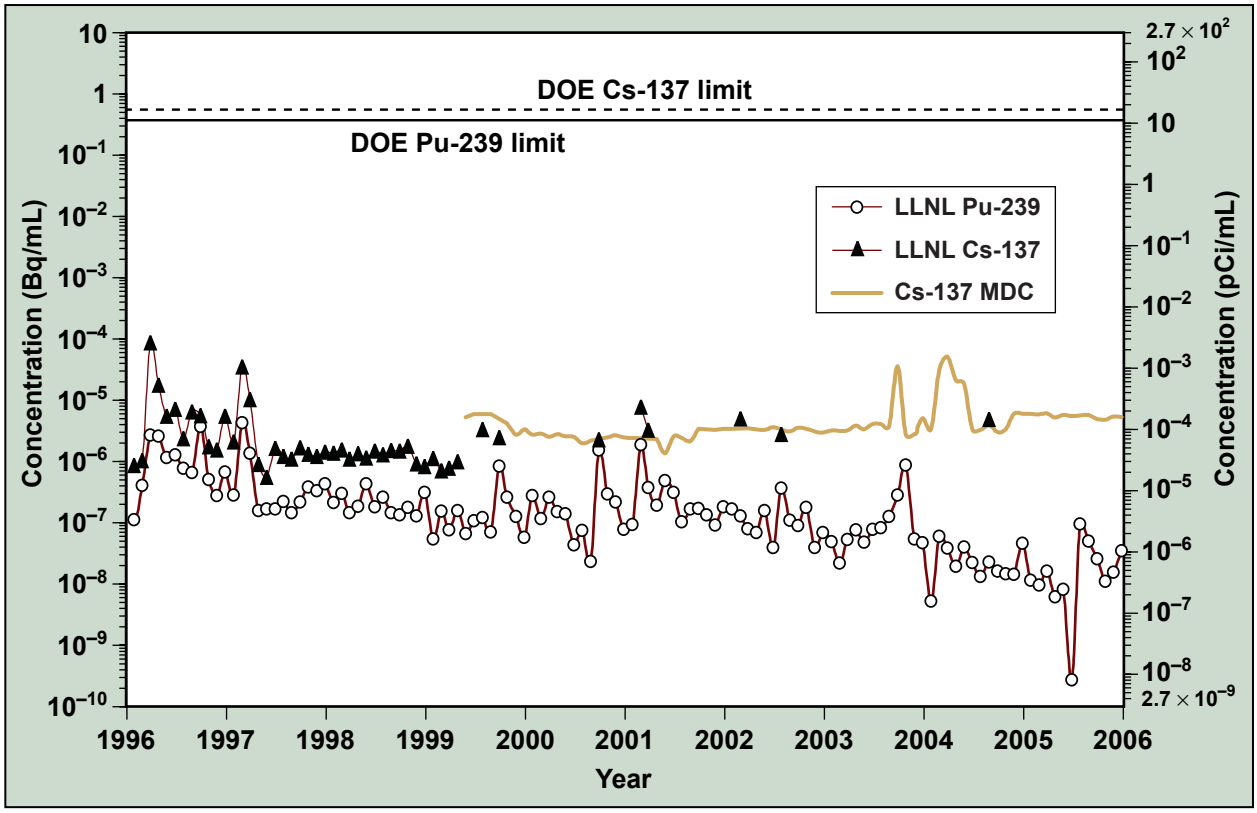
a Results are reported as radioactivity (the measured concentration ± 2σ counting uncertainty). A measured concentration exhibiting a 2σ counting uncertainty greater than or equal to 100% is considered to be a nondetection and is reported with a less than (<) symbol. See Chapter 9.

Figure 5-3 summarizes the cesium-137 and plutonium-239 monitoring data over the past 10 years. The historical levels for plutonium-239 observed since 1996 averaged approximately 1 μBq/mL (3×10^{-5} pCi/mL). These historical levels generally are 0.0003% of the DOE DCG for plutonium-239. The cyclic nature of the data in **Figure 5-3** suggests a potential frequency relationship in LLNL sewer lines for radionuclide buildup and subsequent liberation by line cleaning. Regardless, the higher plutonium and cesium concentrations are all well below applicable DOE DCGs.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-5** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2005, a total of 3.12 GBq (0.08 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 10 years.

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



Notes: The DOE annualized discharge limit for application of best available technology (BAT) is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

Figure 5-3. Average monthly plutonium and cesium concentrations in LLNL sanitary sewer effluent

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 daily samples, collected during the corresponding period, analyzed to determine if any of their concentrations are above the EPL.

To better understand the characteristics of the Livermore site sanitary sewer effluent, LLNL also tracks flow-weighted monthly concentrations for all regulated metals in LLNL's sanitary sewer effluent; **Table 5-6** presents the flow-weighted monthly concentrations for 2005. To obtain these concentrations, each weekly composite is weighted by the total flow volume for the period during which the sample was collected. (Daily flow volumes and sample results for the 2005 weekly composites are included in the file "Ch5 LV Wastewater" provided on the report CD.) This flow-weighted monthly

Table 5-5. Historical radioactive liquid effluent releases from the Livermore site, 1995–2005

Year	Tritium (GBq)	Plutonium-239 (GBq)
1995	6.0	1.2×10^{-4}
1996	12[a]	4.2×10^{-4}
1997	9.1	2.1×10^{-4}
1998	10	0.77×10^{-4}
1999	7.1	0.68×10^{-4}
2000	5.0	0.96×10^{-4}
2001	4.9	1.1×10^{-4}
2002[b]	0.74	0.42×10^{-4}
2003[b]	1.11	0.51×10^{-4}
2004[b]	1.34	1.16×10^{-5}
2005[b]	3.12	9.64×10^{-6}

a In 1995, Sandia/California ceased all tritium facility operations; therefore, the annual tritium totals beginning with the 1996 value do not include contributions from Sandia/California.

b Starting in 2002, following DOE guidance, actual analytical values instead of LOS values were used to calculate total.

concentration represents the characteristic concentration for that month. During 2005, the month-to-month characteristic concentrations for each metal show generally lower values and less variation than the trends observed in past years. These results follow from the improved homogeneity of composite effluent samples, made possible by the upgraded sampling system within the SMS. In **Table 5-6**, the 2005 median flow-weighted concentration for each metal is shown and compared with the EPL. These median flow-weighted monthly concentrations remained well below (less than 5%) their respective EPLs for all nine regulated metals.

Figure 5-4 presents historical trends for the monthly 24-hour composite sample results from 2000 through 2005 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 2000 through 2005 monthly sampling events. Typical PQLs for the regulated metals in LLNL sanitary effluent are shown in **Table 5-6**. (Sample results for the 2005 monthly 24-hour composites are included in the file "Ch5 LV Wastewater" provided on the report CD.) All of the monthly 24-hour composite samples were in compliance with LLNL's wastewater discharge permit limits. The 2005

results show concentrations of copper, and to a lesser degree both lead and zinc, at levels routinely above their respective PQLs; silver, arsenic, chromium, mercury, and nickel are rarely detected. (The elevated values reported for arsenic and nickel in June 2005 are analytical artifacts, resulting from matrix interference.) While these observations are generally consistent with the data trends from 2000 through 2004, the concentrations of those metals detected in 2005 have shown a downward trend. For example, the monthly 24-hour composite concentrations of copper and zinc, which peaked in 2004 at 28% and 16% of their respective EPLs, did not exceed 11% and 6%, respectively, of those same EPLs in 2005. As noted in the discussion of **Table 5-6** results, these trends are consistent with the improved homogeneity of composite effluent samples, made possible by the upgraded sampling system within the SMS.

Table 5-6. Flow-weighted monthly concentrations for regulated metals in LLNL sanitary sewer effluent (mg/L), 2005

Month	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Jan	<0.010	<0.0020	<0.0050	<0.010	0.034	<0.00020	<0.0050	<0.0020	0.10
Feb	<0.012	0.0023	<0.0050	<0.012	0.032	<0.00020	<0.0050	<0.0020	0.088
Mar	<0.019	0.0021	<0.0050	<0.019	0.032	<0.00020	<0.0050	0.0023	0.083
Apr	<0.010	0.0022	<0.0050	<0.010	0.036	<0.00020	<0.0050	0.0022	0.10
May	<0.010	0.0024	<0.0050	<0.010	0.052	<0.00020	<0.0050	0.0053	0.085
Jun	<0.010	0.0033	<0.0050	<0.010	0.061	<0.00020	0.0051	0.0030	0.078
Jul	<0.010	0.0021	<0.0050	<0.010	0.068	<0.00020	0.0053	0.0059	0.081
Aug	<0.010	0.0021	<0.0050	<0.010	0.050	<0.00020	<0.0050	0.0030	0.088
Sep	<0.010	0.0021	<0.0050	<0.010	0.052	<0.00020	0.0050	0.0032	0.10
Oct	<0.010	0.0021	<0.0050	<0.010	0.047	<0.00020	0.0051	0.0022	0.079
Nov	<0.010	0.0021	<0.0050	<0.010	0.040	<0.00020	0.0063	<0.0020	0.078
Dec	<0.010	0.0023	<0.0050	<0.010	0.043	<0.00020	<0.0050	0.0036	0.070
Median	<0.010	0.0021	<0.0050	<0.010	0.045	<0.00020	<0.0050	0.0026	0.084
IQR[a]	—[b]	0.00019	—[b]	—[b]	0.016	—[b]	—[b]	0.0011	0.012
EPL[c]	0.20	0.06	0.14	0.62	1.0	0.01	0.61	0.20	3.00
Median fraction of EPL	<0.05	0.04	<0.04	<0.02	0.04	<0.02	<0.01	0.01	0.03
PQL[d]	0.010	0.0020	0.0050	0.010	0.010	0.00020	0.0050	0.0020	0.050

Note: Monthly values are presented with less-than signs when all weekly composite sample results for the month are below the detectable concentration.

a IQR = Interquartile range

b Because of the large number of nondetects, the interquartile range cannot be calculated. See Chapter 9.

c EPL = Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2004/2005, and 2005/2006)

d PQL = practical quantitation limit (These limits are typical values for sanitary sewer effluent samples.)

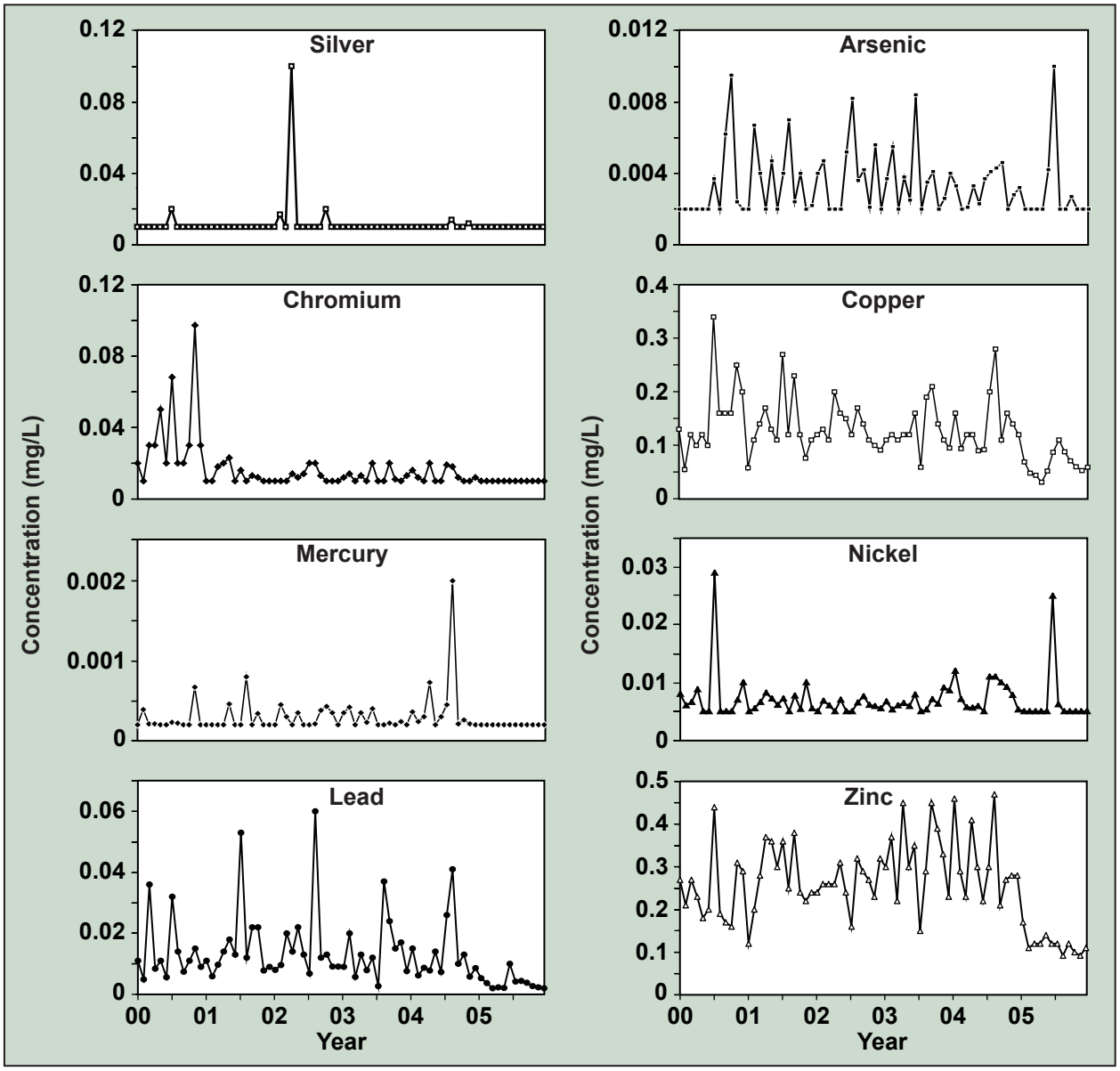


Figure 5-4. Monthly 24-hour composite sample concentrations for eight of the nine regulated metals in LLNL sanitary sewer effluent showing historical trends

The monthly 24-hour composite and weekly composite concentrations for 2005 are presented in **Figure 5-5** for eight of nine regulated metals as a percentage of the corresponding EPL. As in past years, cadmium results are not presented because the metal was not detected above the PQL in any of the weekly or monthly samples. In 2005, an additional three (silver, chromium, and mercury) of the nine regulated metals were not detected above PQLs in any of the weekly or monthly samples; these results are presented however, to facilitate comparisons with previous Environmental Reports. As discussed above, all of the regulated metal concentrations in the

monthly 24-hour composite samples are well below their respective EPLs. Similarly, none of the weekly composite samples showed metal concentrations above 50% of their respective EPLs, the permit-specified action limit that would require additional analyses of daily samples. The highest percentage of EPL reported during 2005 was for silver (at 25% of EPL) in the March 3–9 weekly composite. The corresponding silver concentration (<0.050 mg/L), however, was based on an elevated PQL. All other reported metal concentrations were <20% of the respective EPLs, with most being <10%.

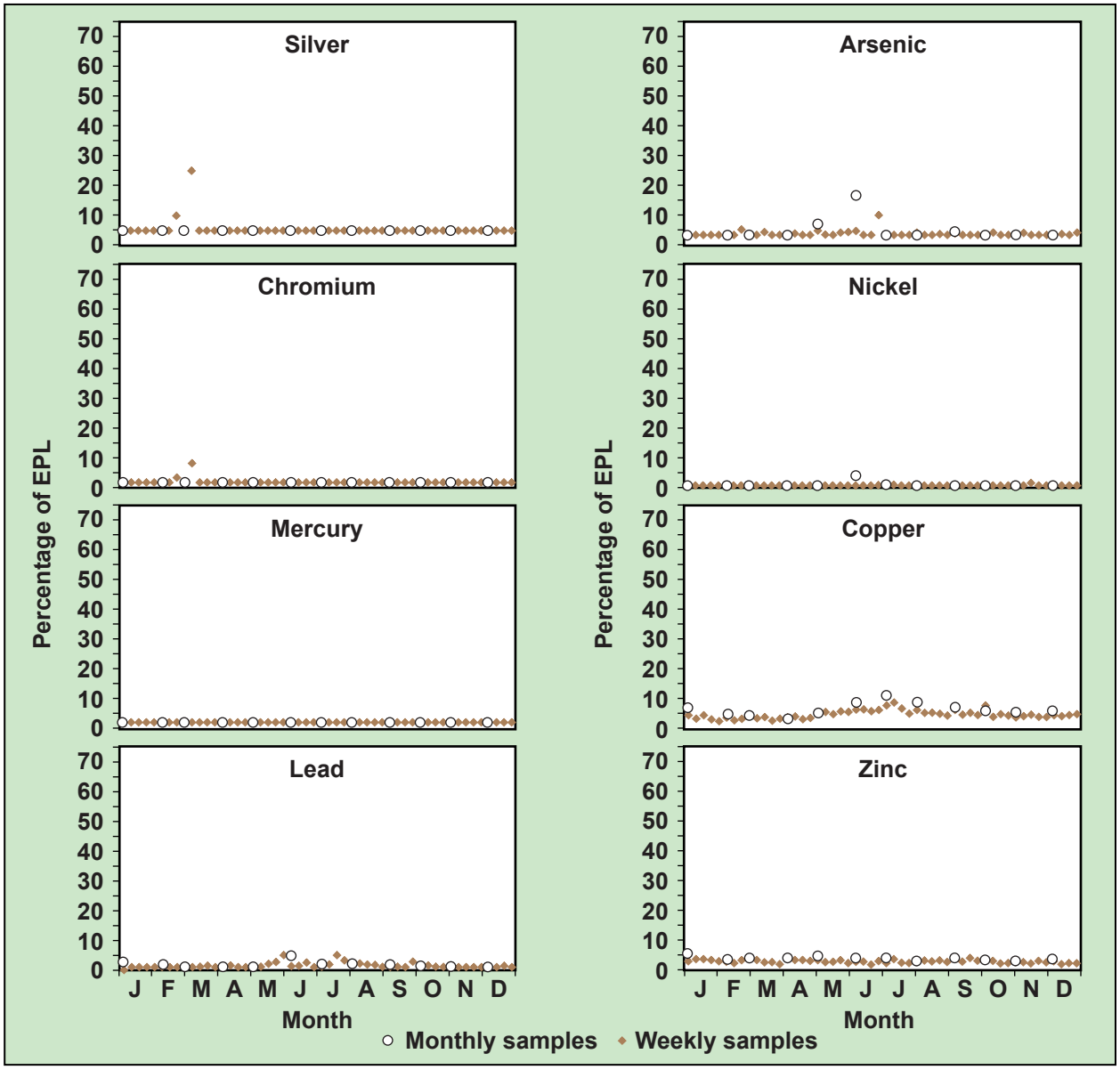


Figure 5-5. Results as percentages of effluent pollutant limits (EPLs) for eight of the nine regulated metals in LLNL sanitary sewer effluent, 2005

Detections of anions, metals, and organic compounds and summary data concerning other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 5-7**. (**Table 5-7** does not include the monthly metals results, which are plotted in **Figure 5-5**, or monthly monitoring results for analytes not detected in any of the 24-hour composite or grab samples. All analytical results are included in the file "Ch5 LV Wastewater" provided on the report CD.) The 2005 results are similar to typical values seen in previous years for the two regulated parameters, cyanide and total toxic organics (TTO; see chemicals with a "(e)" superscript in **Table 5-7**), and all other nonregulated parameters. Cyanide (permit limit 0.04 mg/L, sampled semiannually) was below analytical detection limits (0.02 mg/L) in the April sample and the October result (0.028 mg/L) was below the permit limit. The monthly TTO values ranged from 0.018 mg/L to 0.058 mg/L (with a TTO median value of 0.042 mg/L), well below the TTO permit limit of 1.0 mg/L. In addition to the organic compounds regulated under the TTO standard, five nonregulated organics were also detected in LLNL's sanitary sewer effluent: two volatile organic compounds (acetone and Freon 113) and three semi-volatile organic compounds (benzoic acid, benzyl alcohol, and 3- and 4-methylphenol [m- and p-Cresol]).

In 2005, the SMS continuous monitoring system detected a total of four inadvertent discharges outside the permitted pH range of 5 to 10. Two of these events, one with a pH below 5 and one with a pH above 10, were completely captured by the SDF. The other two events occurred off-hours when the upstream pH Monitoring Station (pHMS) was off-line. As a result, two front-end volumes (small quantity), of sanitary effluent outside the permitted pH range, were released to the LWRP system before a diversion to the SDF could be initiated. The first off-hours event (Saturday, March 5, 2005, at 0539) discharged approximately 200 gallons of pH 4.7 effluent to the LWRP, and another 1400 gallons were captured. The lowest pH recorded during the diversion was 4.4. The second off-hours event (Thursday, April 7, 2005, at 0503) discharged 300–600 gallons of pH 12 effluent to the LWRP, and another 1500 gallons were captured. The highest pH recorded during the diversion was 12.2. The LWRP was immediately notified of both these discharges; however, neither incident represented a threat to the integrity of the operations of the LWRP. The first event was not considered an enforceable exceedance of permit conditions. LLNL did receive a Notice of Violation (NOV) from the LWRP for exceeding the maximum pH limit of 10 in the April 7 release. (See Chapter 2.)

Table 5-7. Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2005[a]

Parameter	Detection frequency[b]	Minimum	Maximum	Median	IQR[c]
24-hour composite sample parameter (mg/L)					
Alkalinity					
Bicarbonate alkalinity (as $CaCO_3$)	12 of 12	190	280	240	30.0
Carbonate alkalinity (as $CaCO_3$)	1 of 12	<5	14	<5	—[d]
Total alkalinity (as $CaCO_3$)	11 of 12	<2.5	280	235	32.5
Anions					
Bromide	11 of 12	<0.1	0.66	0.21	0.15
Chloride	12 of 12	41	66	52	11
Fluoride	11 of 12	<0.05	0.19	0.14	0.025
Orthophosphate	12 of 12	13	73	17	4.5
Sulfate	12 of 12	8	19	12	3.3
Nutrients					
Ammonia nitrogen (as N)	12 of 12	35	56	50	9.5
Total Kjeldahl nitrogen	12 of 12	49	100	59	7.0
Total phosphorus (as P)	12 of 12	6.5	29	7.7	0.95
Oxygen demand					
Biochemical oxygen demand	12 of 12	78	140	110	23.3
Chemical oxygen demand	12 of 12	190	280	225	40.0
Solids					
Settleable solids	1 of 12	<0.1	50	<0.1	—[d]
Total dissolved solids (TDS)	12 of 12	200	500	230	76.5
Total suspended solids (TSS)	12 of 12	55	480	67	31.0
Volatile solids	12 of 12	82	500	155	35.0
Total metals					
Aluminum	9 of 12	<0.2	<1	<0.18	—[d]
Calcium	12 of 12	9.4	17	12	1.3
Iron	12 of 12	0.46	1.1	0.55	0.10
Magnesium	12 of 12	2	3.9	2.2	0.65
Potassium	12 of 12	15	40	19	3.3
Sodium	12 of 12	33	56	40	9.0
Total organic carbon (TOC)	12 of 12	24	320	37	8.8
Grab sample parameter					
Semivolatile organic compounds (µg/L)					
1,2,4-Trichlorobenzene[e]	1 of 12	<2	<50	<5	—[d]
Benzoic acid	1 of 12	<10	<250	<25	—[d]
Benzyl alcohol	4 of 12	<10	<50	<10	—[d]
Bis(2-ethylhexyl)phthalate[e]	8 of 12	<5	<120	<13	—[d]
Butylbenzylphthalate[e]	1 of 12	<5	<50	<5	—[d]
Diethylphthalate[e]	10 of 12	<5	<50	<19	—[d]
Phenol[e]	5 of 12	<5	<50	<7.5	—[d]
m- and p-Cresol	4 of 12	<5	<50	<5	—[d]
Total cyanide (mg/L)[f]	1 of 2	<0.02	0.028	—[g]	—[d]
Total oil and grease (mg/L)[h]	7 of 8	<6.2	28	19.5	18.9

Table 5-7. Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2005[a] (continued)

Parameter	Detection frequency[b]	Minimum	Maximum	Median	IQR[c]
Volatile organic compounds (µg/L)					
1,4-Dichlorobenzene[e]	4 of 12	<1	<1	<1	—[d]
Acetone	12 of 12	190	1800	410	260
Bromodichloromethane[e]	2 of 12	<0.5	<1	<0.5	—[d]
Chloroform[e]	12 of 12	7.7	17	12	4.3
Freon 113	1 of 12	<0.5	<1	<1	—[d]
Methylene chloride[e]	2 of 12	<1	8.3	<1	—[d]
Toluene[e]	6 of 12	<1	2.3	<1	—[d]

a The monthly sample results plotted in **Figure 5-5** and nondetected analytes are not included in this table.
b The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).
c IQR = Interquartile range
d When the detection frequency is less than or equal to 50%, or there is no range, or there are fewer than six results for a sample parameter, the interquartile range is omitted.
e Priority toxic pollutant parameter used in assessing compliance with the total toxic organic (TTO) permit limit of 1 mg/L (1000 µg/L), LLNL Wastewater Discharge Permit 1250, 2004/2005, and 2005/2006.
f Sampling for this parameter is required on a semiannual (April and October) rather than a monthly basis.
g When there are fewer than four results for a sample parameter, the median is not calculated.
h The requirement to sample for oil and grease has been suspended until further notice per LWRP letter of April 1, 1999; nevertheless, LLNL collects these samples (four per day) semiannually as part of the source control program.

Categorical Processes

The U.S. Environmental Protection Agency (EPA) publishes Categorical standards for broad categories of specific industrial processes determined to be the most significant contributors to point-source water pollution. These standards contain specific numerical limits for the discharge of industry-specific pollutants from individual processes. At LLNL, the federal Categorical requirements are incorporated into the wastewater discharge permit (Permit 1250, 2004/2005 and 2005/2006), which is administered by the LWRP. The number of processes at LLNL under these standards is subject to periodic change as programmatic requirements dictate. During 2005, the LWRP identified 15 specific LLNL wastewater-generating processes that fall under the definition of two categorical standards: Electrical and Electronic Components (40 CFR 469), and Metal Finishing (40 CFR 433). Only those processes that discharge to the sanitary sewer require sampling, inspection, and reporting. Three of the 15 processes meet these criteria. In 2005, LLNL analyzed compliance samples for all regulated parameters from these three processes and demonstrated compliance with all federal Categorical discharge limits. Other processes that do not discharge to the sanitary sewer but would otherwise be regulated under the Metal-Finishing Point Source Category include printed circuit board manufacturing, electrolysis plating, chemical

etching, electroplating, anodizing, coating, electrical discharge machining, and abrasive jet machining. These 12 nondischarging processes are evaluated semiannually. Wastewater from these nondischarging processes is either recycled or contained for eventual removal and appropriate disposal by LLNL's RHWM Division. Because these 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 *Lawrence Livermore National Laboratory, Livermore Site Semiannual Wastewater Point-Source Monitoring Reports for (December 2004–May 2005) and June 1–November 30, 2005)* (Grayson 2005a,b).

As required in LLNL's Wastewater Discharge Permit, compliance with Permit requirements is demonstrated by semiannual sampling and reporting. LWRP Source Control staff performed the required annual inspection and sampling of the three discharging categorical processes in 2005. The three processes sampled are 1) the Building 153 retention tank (for wastewater from various semiconductor processes [wafer cleaning/etching and photolithography]), 2) gallium arsenide saw cutting in Building 153, and 3) the Building 321C abrasive jet machining. LLNL Environmental staff sample the same processes semiannually. These compliance samples were analyzed for all regulated parameters and the resulting data collected demonstrate compliance with all federal and local pretreatment limits. Of the three discharging categorical processes, the Building 153 microfabrication facility released the largest volume of water to the sanitary sewer. As a further environmental safeguard, LLNL sampled each volume retained at Building 153 prior to discharge to the sanitary sewer. These monitoring data were reported to the LWRP in July 2005 and January 2006 semiannual wastewater reports (Grayson 2005, 2006).

Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2004-2006) allows treated groundwater from the Livermore site Ground Water Project (GWP) to be discharged in the City of Livermore sanitary sewer system. (See Chapter 8 for more information on the GWP.) During 2005, there were two discharges to the sanitary sewer from the GWP. The total volume of treated groundwater discharged to the sanitary sewer was 2560 liters. In each of these discharge events, the groundwater released to the sanitary sewer originated from the lower zone, beneath the LLNL site. These volumes of groundwater were acquired at one of the on-site treatment facilities and used to condition new ion exchange resin columns. These two events were separately sampled and discharged to the sanitary sewer during 2005, all in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in the *Ground Water Discharge Annual Self-Monitoring Report for 2005* (Revelli 2006a).

Environmental Impact of Sanitary Sewer Effluent

During 2005, no discharges exceeded any discharge limits for release of radioactive materials to the sanitary sewer. The data are comparable to the lowest historical values. All the values reported for radiological releases are a fraction of their corresponding limits. For nonradiological releases, LLNL achieved near perfect compliance with the provisions of its wastewater discharge permit; there were only two releases of pH outside permissible limits.

The data demonstrate that LLNL continues to have good control of radiological and nonradiological discharges to the sanitary sewer. Monitoring results for 2005 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.

Site 300 Sewage Ponds and Surface Impoundments

Wastewater samples collected from the influent to the sewage evaporation pond, within the sewage evaporation pond, and flow to the sewage percolation pond; and wastewater samples collected from discharges to the Class II surface impoundments from photographic processes, Chemistry Area processes, and Explosives processes were obtained in accordance with the written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005).

Sewage Evaporation and Percolation Ponds

Sewage generated at buildings in the General Services Area at Site 300 is discharged into a lined evaporation pond. The nonhazardous wastewater is disposed of through evaporation from the pond. However, during winter rains, treated wastewater may overflow into an unlined percolation pond, where it enters the ground and the shallow groundwater.

The environmental monitoring requirements for the sewage evaporation and percolation ponds (hereafter collectively referred to as sewage ponds) are specified in the Monitoring and Reporting Program (MRP) for Waste Discharge Requirements Order No. 96-248 (WDR 96-248). The monitoring requirements include both wastewater monitoring and groundwater monitoring to detect potential impacts of the sewage on groundwater quality. Wastewater is sampled quarterly at a sampling point (ISWP) in the line running into the sewage pond and within the sewage evaporation pond (ESWP). Overflows into the adjacent percolation pond are also permitted

under WDR 96-248 and are sampled as needed in the discharge line (DSWP) from the sewage pond to the percolation pond. Nine groundwater monitoring wells are sampled semiannually to provide information on the groundwater quality in the vicinity of the sewage ponds. All sampling locations are shown in **Figure 5-6**. The wells are screened in three different geological formations: Qal, $Tnbs_1$, and $Tnsc_1$ (see Chapter 8). $Tnbs_1$ (Neroly Formation lower blue sandstone unit) is the regional aquifer.

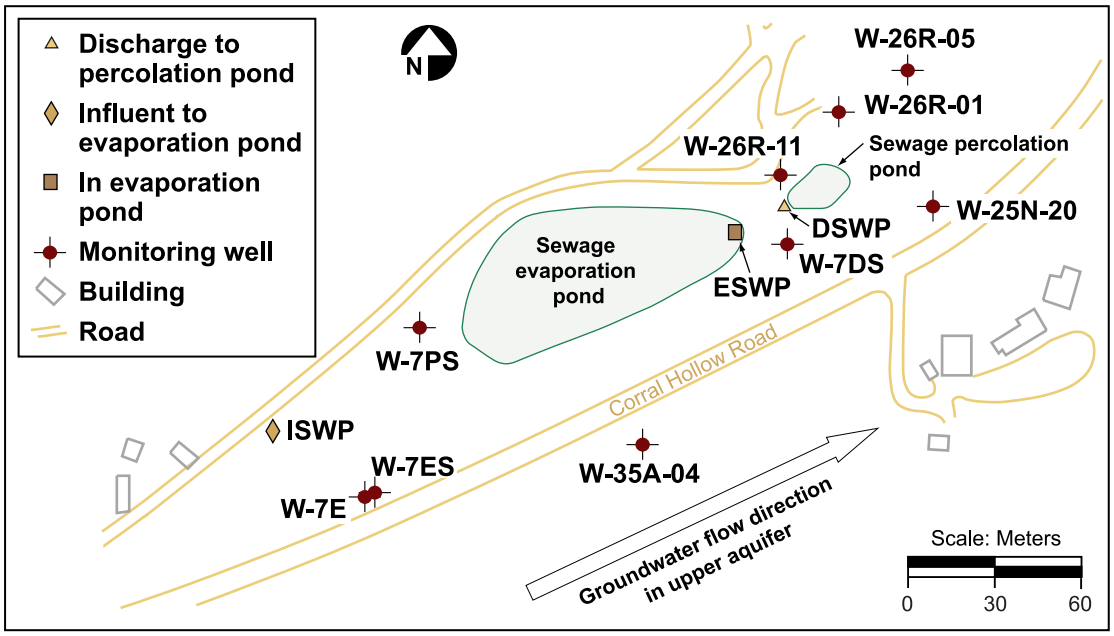


Figure 5-6. Sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations, 2005

All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2005. There was one continuous overflow from the sewage evaporation pond to the percolation pond that began in January 2005 and continued through the first quarter of 2005. This permitted discharge was sampled twice and reported to the Central Valley Regional Water Quality Control Board (CVRWQCB). In two instances during the first quarter, in samples collected from wells W-35A-04 and W-26R-11, the concentrations of the monitored groundwater constituent fecal coliform bacteria exceeded the permit limit. Those concentrations, however, were not confirmed by subsequent sample results and fecal coliform bacteria have not been detected in any subsequent groundwater samples. For details, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2005* (Brown 2006).

Surface Impoundments

WDR 96-248 also establishes the basis for compliance monitoring of two connected surface impoundments at Site 300 that receive nonhazardous wastewater and rinsewater discharges from the Explosives Process Area, chemistry buildings, and photographic processes. This includes monitoring of various influent waste streams to the surface impoundments. Influent monitoring complements administrative control of chemicals that could degrade the polyethylene liners of the impoundments. A two-tiered monitoring program comprising weekly visual inspections of the leachate collection and removal systems, and quarterly sampling of monitoring wells was in place to detect any release of chemicals from the surface impoundments.

LLNL completed clean closure of the two Class II surface impoundments in November 2005. In anticipation of the closure and demolition, wastewater discharges to the impoundments were discontinued by June 2005. Monitoring of wastewater continued until discharges ceased, and monitoring of the leachate collection system continued until the impoundments were demolished. The nonhazardous wastewater is now managed in retention tanks where it is allowed to evaporate or, if necessary, it is transported to the Livermore site for disposal to the sanitary sewer. Groundwater monitoring continued through the end of 2005 and was discontinued when the CVRWQCB modified the monitoring and reporting program associated with WDR 96-248.

Wastewater discharges from each of these three processes (explosives, chemistry, and photography) to the surface impoundments were analyzed for constituents of concern (COCs) that have been found, or were likely to be found, in the process water from each specified process area. The monitoring program contained in WDR 96-248 established limits for discharges of COCs into the surface impoundments. In addition, no hazardous or radioactive waste was allowed in the surface impoundments.

Influent waste streams were monitored at a prescribed frequency for area-specific COCs. Annual monitoring was performed on discharges from the Explosives Process Area: Buildings 806/807 and 817. (Building 809 is also included in this area but was inactive in 2005.) Discharges from this area flowed automatically into the surface impoundments. Wastewater from the Chemistry Area (Buildings 825 and 826, and the Building 827 Complex) was held in retention tanks until analytical results indicated that all COCs were within discharge limits. No discharges occurred from the retention tanks at Buildings 825, 826, or 827A; two discharges from Buildings 827C, 827D, and 827E to the surface impoundments occurred in the second quarter of 2005. Rinsewater from photographic processes at Building 823 was discharged automatically to the surface impoundments through the second quarter of

2005. Samples from Building 823 discharges were collected in the first and second quarters and analyzed to satisfy the requirements of WDR 96-248.

No release of water to ground from the surface impoundments occurred during 2005. For a detailed account of compliance monitoring of the Site 300 surface impoundments, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2005 (Brown 2006)*.

The two leachate collection and removal systems were monitored weekly for the presence of liquids to identify potential leaks. None were observed during 2005. No water has been observed in the leachate collection and removal system since liner repairs were made in 1997.

In the Explosives Process Area, LLNL is required to obtain groundwater samples quarterly from four monitoring wells (see **Figure 5-7**) and has established statistical concentration limits for COCs in groundwater beneath the surface impoundments. These requirements are part of the MRP for the surface impoundments detailed in WDR 96-248. Sporadic detections of ammonia and of the plasticizer compound bis(2-ethylhexyl)phthalate (DEHP) have occurred since 2000. However, because these chemicals have also been detected in method blank samples, LLNL has determined that these COCs were not present in the groundwater samples but were due to laboratory contamination of the samples.

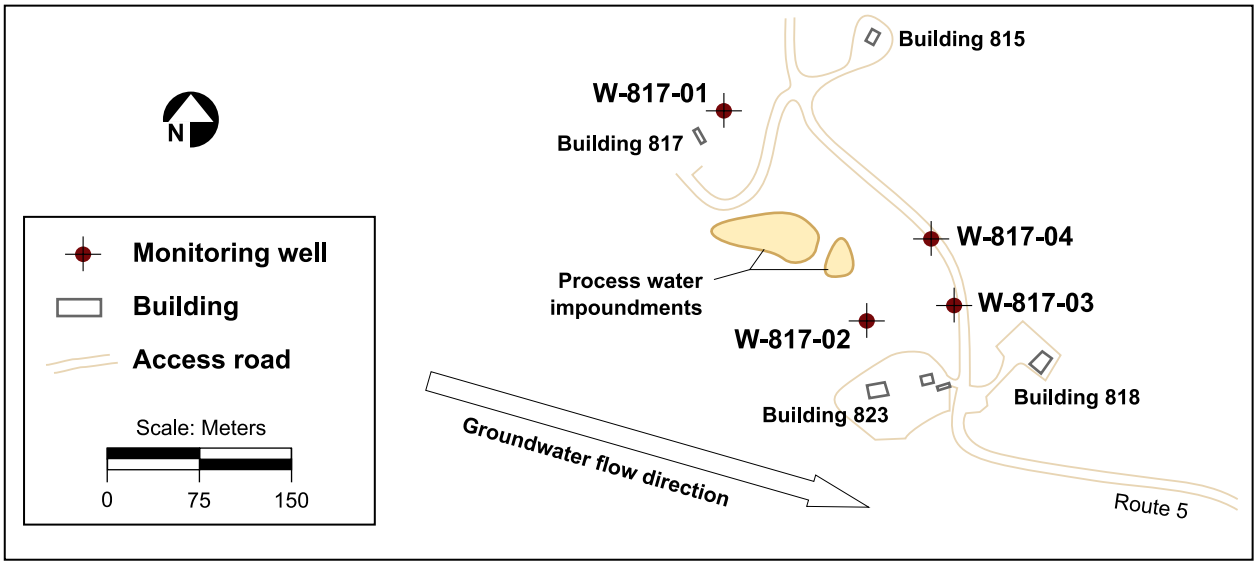


Figure 5-7. Locations of compliance groundwater monitoring wells in the Explosives Process Area, 2005

Explosive compounds (HMX, RDX, and breakdown products) and perchlorate are the compounds most indicative of discharges to groundwater from the Explosives Process Area surface impoundments. However, prior to 1985, explosives wastewater was discharged into unlined ponds in the vicinity of the present surface impoundments where it infiltrated the soil; some of the explosives wastewater reached groundwater. Because of this past practice, it is necessary under regulations to discriminate between new releases from the surface impoundments and past releases from the unlined ponds. Background concentrations were statistically calculated for each COC based on historical data from all four monitoring wells. Any sample concentration exceeding background concentrations, and confirmed by either of two retest sample concentrations exceeding background concentrations, is assumed to come from a new release of that COC. (See also Chapter 8.) A few concentrations of the energetic compounds PETN, RDX, and 4-amino-2,6-dinitrotoluene that exceeded statistical limits in downgradient monitor wells during the second, third, and fourth quarters were determined to be statistical outliers. As statistical outliers, it was not necessary to report them to the CVRWQCB as exceeding statistical limits. No concentrations exceeding the statistical limits were confirmed by two retest samples collected and analyzed one week apart from each of those wells. LLNL continues to monitor and to track these concentrations. For details, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2005* (Brown 2006).

Percolation Pits

Percolation pits designed to accept discharges from mechanical equipment are located at Site 300 Buildings 806A, 827A, 827C, 827D, and 827E. These discharges are permitted by WDR 96-248, which specifies monthly observations and monitoring requirements for overflows of the percolation pits. In other Site 300 facilities, these types of waste streams are discharged to septic systems. If an overflow should occur, it is sampled and analyzed to determine concentrations of any metals present. During 2005, all of the percolation pits operated normally with no overflows. Percolation pits at Buildings 827C and 827D contained standing water throughout the fourth quarter (Brown 2006).

Environmental Impact of Sewage Ponds and Surface Impoundments

All discharges from the Site 300 sewage evaporation pond to the percolation pond, as well as discharges to the surface impoundments from the Explosives Process Area, chemistry buildings, and photographic processes were in

compliance with discharge limits. Groundwater monitoring related to these areas indicates that there were no measurable impacts to the groundwater from the surface impoundment operations. There were sporadic detections of coliform bacteria in groundwater samples collected from two wells surrounding the sewage ponds early in 2005, but those detections were not validated by subsequent sampling and analysis. (Brown 2006)

Storm Water Compliance and Surveillance Monitoring

To assess compliance with permit requirements, LLNL monitors storm water at the Livermore site in accordance with WDR 95-174, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0030023, issued in 1995 by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB 1995a). LLNL monitors storm water discharges at Site 300 in accordance with the California NPDES General Permit for Storm Water Discharges Associated with Industrial Activity (WDR 97-03-DWQ), NPDES Permit No. CAS000001, State Water Resources Control Board (SWRCB 1997). For construction projects that disturb 0.4 hectares (1 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, NPDES Permit No. CAS000002) (SWRCB 1999) and subsequent modifications.

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). In addition to the storm water quality constituents required by the closure plan, LLNL monitors other constituents to provide a more complete water quality profile. Appendix A includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

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, Radiation Protection of the Public and the Environment.

At all monitoring locations at both the Livermore site and Site 300, grab samples are collected from the storm water runoff flowing in the storm drains and stream channels. Grab samples are collected by partially submerging sample bottles directly into the water and allowing them to fill with the sample water. If the water to be sampled is not directly accessible, an automatic water sampler is used to pump water into the appropriate containers. Sampling is conducted away from the edge of the arroyo to

prevent the collection of sediment into the water samples. Sample vials for volatile organics are filled before sample bottles for all other constituents and parameters.

For the purpose of evaluating the overall impact of the Livermore site and Site 300 operations on storm water quality, storm water flows are sampled at upstream and downstream locations. Because of flow patterns at the Livermore site, storm water at sampling locations includes runoff from other sources, such as neighboring agricultural land, parking lots, and landscaped areas. In contrast, storm water at Site 300 is sampled at locations that target specific on-site activities with no run-on from off-site sources. These samples provide the information necessary to maintain compliance with the SWRCB.

NPDES permits for storm water require that LLNL sample effluent two times per year. 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 of one year through April [Livermore site] or May [Site 300] of the following year) to observe runoff quality and twice during the dry season to identify any dry weather flows. Influent sampling is also required at the Livermore site. In addition, annual facility inspections are required to ensure that the best management practices (BMPs) to control storm water pollution are implemented and adequate.

Constituent Criteria

There are no numeric criteria that limit concentrations of specific constituents in LLNL's storm water effluent. The U.S. Environmental Protection Agency (EPA) established parameter benchmark values, but stressed that these concentrations are not intended to be interpreted as effluent limits (U.S. EPA 2000). Rather, the values are levels that the EPA has used to determine if storm water discharged from any given facility merits further monitoring. Although these criteria are not directly applicable, they are used as comparison criteria to help LLNL evaluate its storm water management program. To further evaluate the storm water management program, LLNL established or calculated site-specific threshold comparison criteria for a select group of parameters. A value exceeds the threshold if it is greater than the 95% confidence limit computed for the historical mean value for a specific parameter (**Table 5-8**). The threshold comparison criteria are used to identify out-of-the-ordinary data that merit further investigation to determine if concentrations of that parameter are increasing in the storm water runoff. For a better understanding of how LLNL storm water data relate to other target values, LLNL also compares water samples with criteria listed in the *Water Quality Control Plan, San Francisco Bay Basin* (SFBRWQCB 1995b), *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, Sacramento and San Joaquin*

River Basins (CVRWQCB 1998b), state and federal maximum contaminant levels (MCLs), and U.S. EPA ambient water quality criteria (AWQC). The greatest importance is placed on the site-specific comparison criteria calculated from historical concentrations in storm runoff.

Table 5-8. Threshold comparison criteria for selected water quality parameters

Parameter	Livermore site	Site 300
Total suspended solids (TSS)	750 mg/L[a]	1,700 mg/L[a]
Chemical oxygen demand (COD)	200 mg/L[a]	200 mg/L[a]
pH	<6.0, >8.5[a]	<6.0, >9.0[b]
Nitrate (as NO_3)	10 mg/L[a]	not monitored
Orthophosphate	2.5 mg/L[a]	not monitored
Beryllium	1.6 µg/L[a]	1.6 µg/L[a]
Chromium(VI)	15 µg/L[a]	not monitored
Copper	13 µg/L[c]	not monitored
Lead	15 µg/L[d]	30 µg/L[a]
Zinc	350 µg/L[a]	not monitored
Mercury	above RL[e]	1 µg/L[a]
Diuron	14 µg/L[a]	not monitored
Oil and grease	9 mg/L[a]	9 mg/L[a]
Tritium	36 Bq/L[a]	3.17 Bq/L[a]
Gross alpha radioactivity	0.34 Bq/L[a]	0.90 Bq/L[a]
Gross beta radioactivity	0.48 Bq/L[a]	1.73 Bq/L[a]

Note: If data exceed the threshold comparison criteria, an investigation is initiated to assess if those data are indicative of a water quality problem.

a Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for zinc, TSS, and COD.
b EPA benchmark
c Ambient water quality criteria (AWQC)
d California and EPA drinking water action level
e RL = reporting limit = 0.0002 mg/L for mercury

Storm Water Inspections

Each 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 associate directors certified in 2005 that their facilities complied with the provisions of LLNL's storm water pollution prevention plans. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Brown 2005b) and to the CVRWQCB (Brown 2005a) 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 BMPs. Annual compliance certifications summarize these inspections. Annual compliance certifications for 2005 covered the period of June 2004 through May 2005. When requested by the respective regional water quality control board (RWQCB), LLNL completes annual compliance status reports that cover the same reporting period. During the 2004/2005 reporting period, LLNL had active permits for six projects located at the Livermore site and two at Site 300 (see **Table 2-3**). Three of the projects that commenced in 2005 were completed during the reporting period: Arroyo Seco Management Plan, Surface Impoundment Closure and Tanks Installation, and the Mid Elk Ravine California red-legged Frog Project. LLNL terminated the permits for these three projects and for one multi-year project (the Terascale Simulation Project) that was completed during 2005

Livermore Site

As is commonly the case in urbanized areas, surface water bodies and runoff pathways at LLNL do not represent natural conditions. The drainage at the Livermore site was altered by construction activities several times up to 1966 (Thorpe et al. 1990) so that the current northwest flow of Arroyo Seco and the westward flow of Arroyo Las Positas do not represent historical flow paths. About 1.6 km to the west of the Livermore site, Arroyo Seco merges with Arroyo Las Positas, which continues to the west to eventually merge with Arroyo Mocho (see **Figure 5-8**).

The Drainage Retention Basin (DRB) was excavated and lined in 1992 to prevent infiltration of storm water that was dispersing groundwater contaminants. It also serves storm water diversion and flood control purposes. The DRB collects less than one-fourth of the surface water runoff from the site and a portion of the Arroyo Las Positas drainage (**Figure 5-9**). When full, the DRB discharges north to a culvert that leads to Arroyo Las Positas. The remainder of the site drains either directly or indirectly into the two arroyos by way of storm drains and swales. Arroyo Seco cuts across the southwestern corner of the site. Arroyo Las Positas follows the north-eastern and northern boundaries of the site and exits the site near the northwest corner.

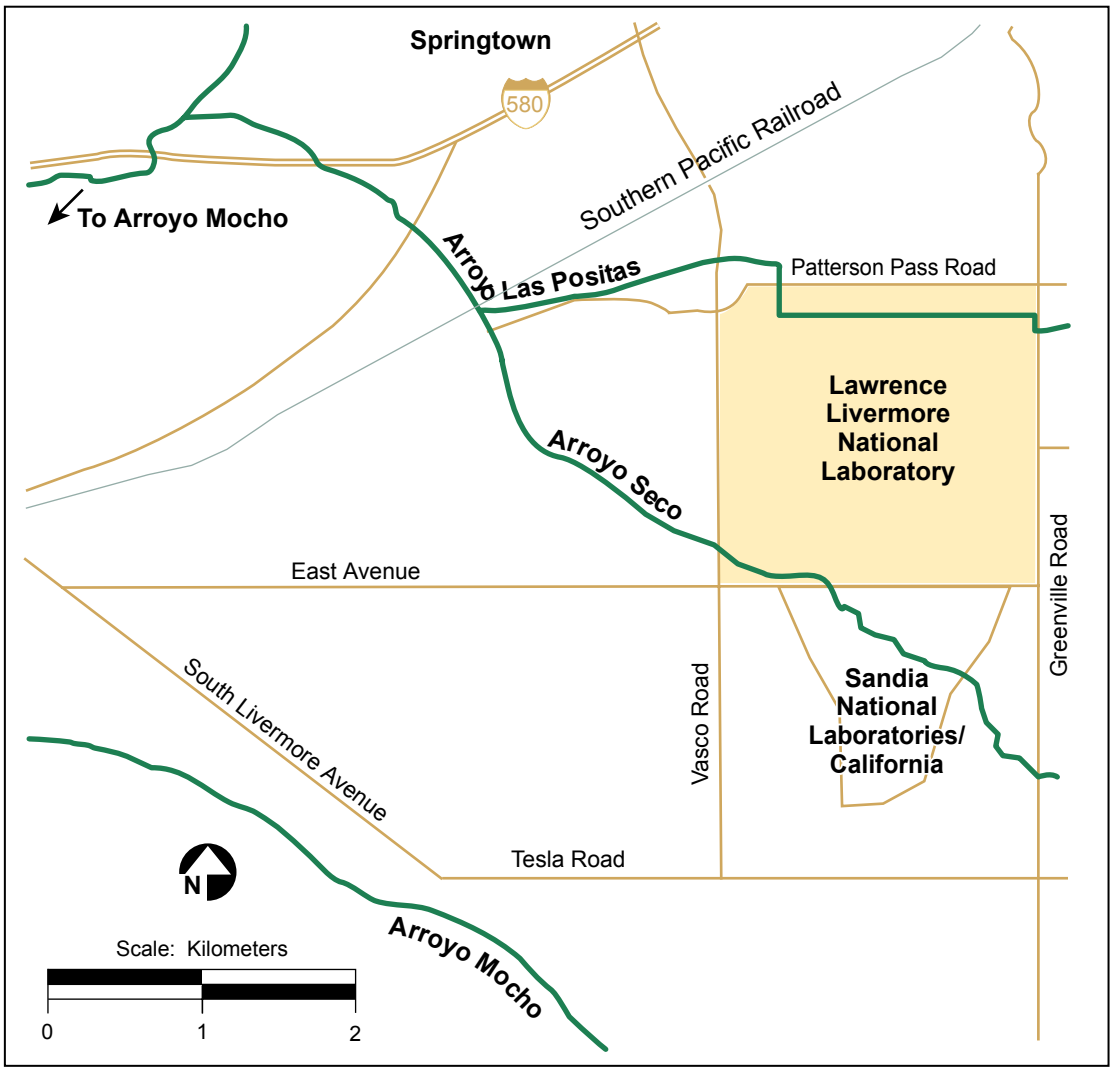


Figure 5-8. Surface waterways in the vicinity of the Livermore site

The routine Livermore site storm water runoff monitoring network consists of nine sampling locations (**Figure 5-9**). Six locations characterize storm water either entering (influent: ALPE, ALPO, ASS2, and GRNE) or exiting (effluent: ASW and WPDC) the Livermore site. Sampling locations CDB and CDBW are internal sites used by LLNL staff, outside the requirements of the storm water permit, to characterize storm water runoff quality entering the DRB; location CDBX characterizes water leaving the DRB. LLNL collected samples at all nine locations on January 11 and February 16, 2005.

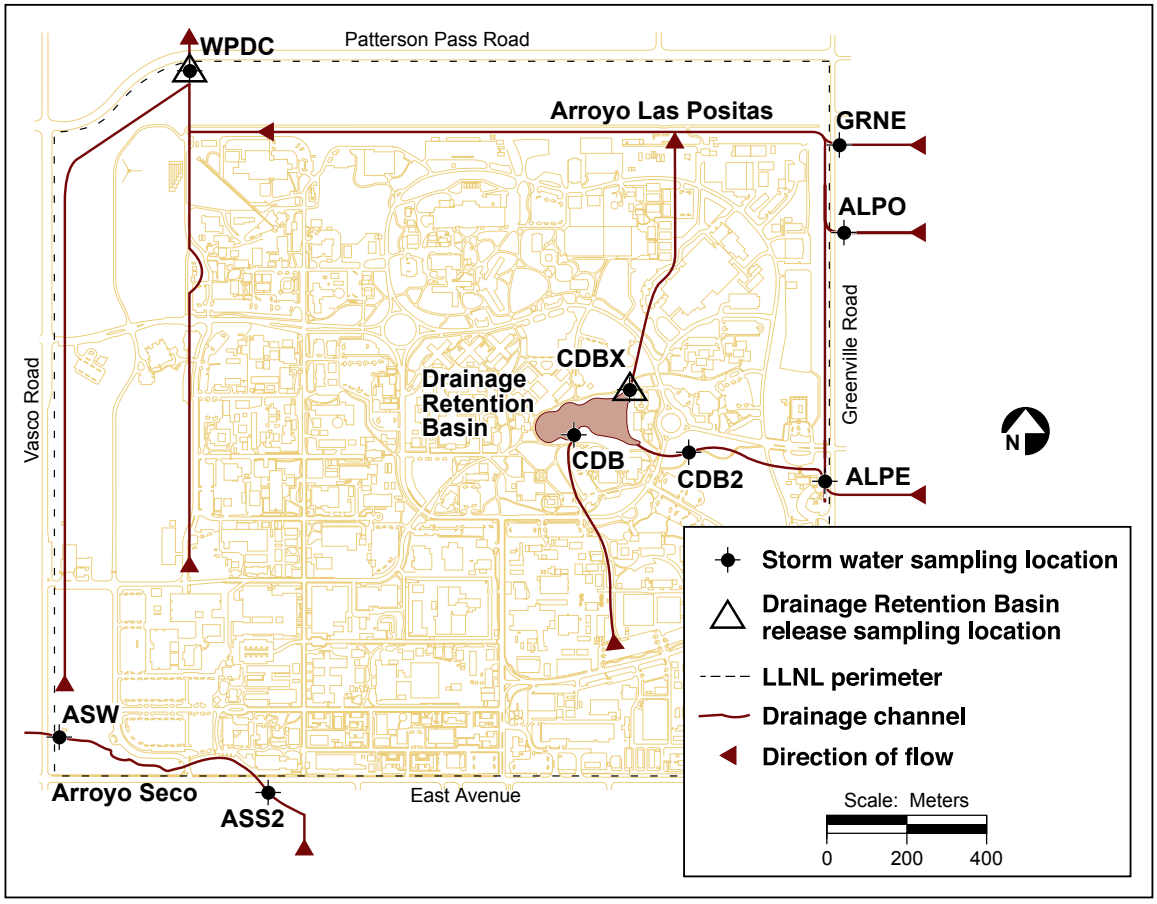


Figure 5-9. Storm water runoff and Drainage Retention Basin sampling locations, Livermore site, 2005

Acute and chronic toxicity testing using fathead minnows (*Pimephales promelas*) was not performed during the 2005 calendar year for WDR 95-174. Toxicity tests for WDR 95-174 are performed using water sampled from the first major runoff event occurring during normal work hours (8:00 am–5:00 pm). This runoff event did not take place in 2005, but in January 2006. However, toxicity testing was performed during 2005 for DRB releases (see the section "Drainage Retention Basin Release" in this chapter).

Radiological Monitoring Results

Storm water sampling and analysis were performed for gross alpha, gross beta, plutonium, and tritium. Storm water gross alpha, gross beta, and tritium results are summarized in **Table 5-9**. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.) Tritium activities at site effluent sampling locations were less than 1% of the MCL. Gross alpha and gross beta radioactivity in the storm water samples collected during 2005 were generally low, with medians around background

levels. Gross beta activities exceeded LLNL-specific comparison criteria on February 16, 2005, in water samples collected at effluent location ASW along the Arroyo Seco. However, gross beta activities in samples collected from the influent location ASS2 (where runoff flows onto the Livermore site) were also above the comparison criteria (**Table 5-10**). The difference between the influent and effluent locations is statistically insignificant. Therefore, this result was unlikely to be related to LLNL activities.

Table 5-9. Statistics on radioactivity in storm water from the Livermore site, 2005[a]

Parameters	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Median	1.26	0.022	0.169
Minimum	–0.41	–0.004	0.062
Maximum	6.0	0.146	0.622
Effluent			
Median	1.1	0.022	0.096
Minimum	0.2	0.013	0.084
Maximum	4.3	0.219	0.685

a See Chapter 9 for an explanation of calculated values.

Table 5-10. Water quality parameters in storm water runoff above LLNL-specific threshold comparison criteria, Livermore site in 2005

Parameter	Date	Location	Influent or Effluent	Result (mg/L)	LLNL threshold criteria (mg/L)
Nonradioactive (mg/L)					
Copper	1/11	ALPE	Influent	0.015	0.013
	1/11	ALPO	Influent	0.019	0.013
	2/16	ASW	Effluent	0.020	0.013
	2/16	ASS2	Influent	0.019	0.013
	2/16	ALPO	Influent	0.015	0.013
		Radioactive (Bq/L)			
Gross beta	2/16	ASW	Effluent	0.68 ± 0.11	0.48
	2/16	ASS2	Influent	0.62 ± 0.10	0.48

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). In 2005, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.10 pCi/L).

Nonradiological Monitoring Results

In addition to radioactivity, storm water was analyzed for other water quality parameters. Sample results were compared with the comparison criteria in **Table 5-8**. Of interest are the constituents that exceed comparison criteria at effluent points and whose concentrations are lower in influent than in effluent. 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 included in the file "Ch5 Storm Water" provided on the report CD.) Constituents that exceeded comparison criteria for effluent and/or influent locations are listed in **Table 5-10**. All of the values above threshold comparison criteria for the Livermore site during 2005 were found at influent tributaries at similar concentrations. Copper concentrations in samples collected from runoff exceeded LLNL's threshold comparison criteria on both sampling dates at influent locations and at one effluent location (ASW) on February 16, 2005. In this latter instance, the concentration of copper in samples collected from influent location ASS2 were similarly elevated, so it is concluded that these results are unrelated to LLNL discharges.

Site 300

Surface water at Site 300 consists of seasonal runoff, springs, and natural and man-made ponds. The primary waterway in the Site 300 area is Corral Hollow Creek, an ephemeral stream that borders the site to the south and southeast. No natural continuously flowing streams are present in the Site 300 area. Elk Ravine is the major drainage for most of Site 300; it extends from the northwest portion of the site to the east–central area. Elk Ravine drains the center of the site into Corral Hollow Creek, which drains eastward toward the San Joaquin River Basin. Some smaller canyons in the northeast portion of the site drain to the north and east toward Tracy.

There are at least 23 springs at Site 300. Nineteen are perennial, and four are intermittent. Most of the springs have very low flow rates and are recognized only by small marshy areas, pools of water, or vegetation. Several artificial surface water bodies at Site 300 are in fact wastewater treatment units discussed above. Three wetlands created by now-discontinued flows from cooling towers located at Buildings 827, 851, and 865 were maintained in 2005 by discharges of potable water.

In 2005, storm water runoff was characterized at five sampling locations that could be affected by specific Site 300 activities. In addition, off-site location CARW2 is used to characterize Corral Hollow Creek upstream and, therefore, is unaffected by Site 300 industrial storm water discharges. Off-site location

GEOCRK is used to characterize Corral Hollow Creek downstream of Site 300. These locations are shown in **Figure 5-10**.

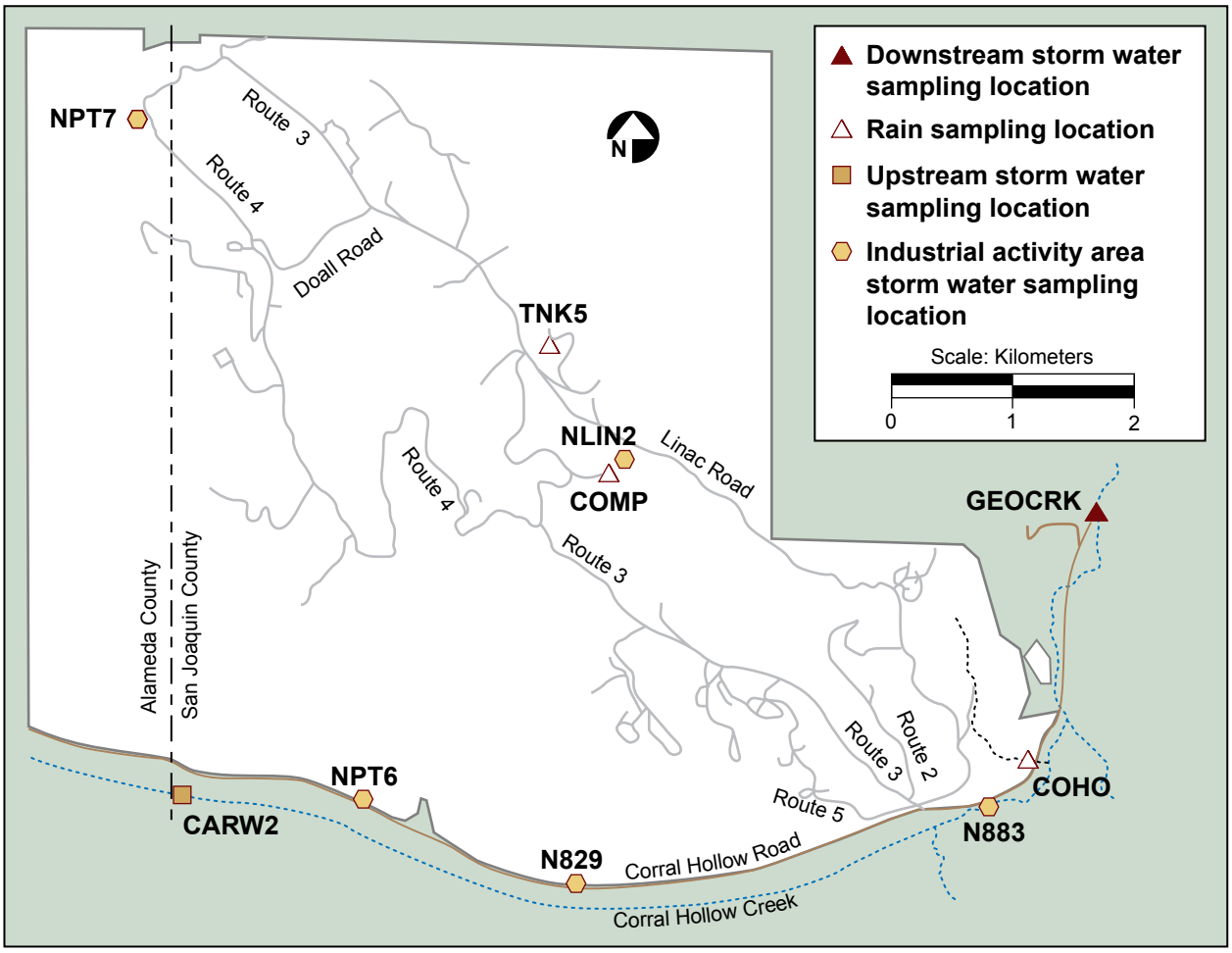


Figure 5-10. Storm water and rainwater sampling locations at Site 300, 2005

The Site 300 storm water permit specifies sampling a minimum of two storms per rainy season. Typically, a single storm does not produce runoff at all Site 300 locations because Site 300 receives relatively little rainfall and is largely undeveloped with few paved areas. Therefore, at many locations, a series of large storms is required to saturate the ground before runoff can occur. At some of the sampling locations in some years, there is not enough rain to generate runoff over an entire rainy season. On January 26 and February 15, storm water samples were collected and analyzed from all locations that normally have storm water flow.

Radiological Monitoring Results

Storm water sampling and analysis was performed for gross alpha and gross beta radioactivity, uranium isotopes, and tritium, and results were compared

with the comparison criteria in **Table 5-8**. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.) Concentrations of gross alpha or beta radioactivity exceeding Site 300's threshold concentrations are reported in **Table 5-11**. Tritium concentrations at all sampled locations were less than 1% of the MCL and less than Site 300's threshold concentration. Gross alpha and gross beta radioactivity in the storm water samples collected from upstream location CARW2 and from downstream location GEOCRK on February 15 exceeded LLNL's site-specific criteria. Those samples were associated with higher than normal TSS and lead concentrations. Previous environmental sampling has shown that suspended sediments from this area contain significant quantities of naturally occurring uranium and its daughter decay products, and sometimes other metals, that account for the elevated gross alpha and beta radioactivity.

Table 5-11. Water quality parameters in storm water runoff above LLNL-specific threshold comparison criteria, Site 300, 2005

Parameter	Date	Location	Upstream or Downstream	Result	Threshold criteria
Radioactive (Bq/L)					
Gross alpha[b]	2/15	CARW2	Upstream	2.4 ± 0.7	0.90
	2/15	GEOCRK	Downstream	2.2 ± 0.7	0.90
Gross beta[b]	2/15	CARW2	Upstream	3.5 ± 0.7	1.73
	2/15	GEOCRK	Downstream	4.5 ± 0.7	1.73
Nonradioactive (mg/L)					
Total suspended solids	2/15	CARW2	Upstream	3400	1700
	2/15	GEOCRK	Downstream	3800	1700
Lead[a]	2/15	CARW2	Upstream	0.050	0.030
	2/15	GEOCRK	Downstream	0.079	0.030
Chemical oxygen demand	2/15	GEOCRK	Downstream	288	200

a Total metals including particulates
b Total radiation including particulates

Nonradiological Monitoring Results

Site 300 storm water samples were analyzed for nonradiological water quality parameters, and sample results were compared with the comparison criteria in **Table 5-8**. Constituents that exceeded comparison criteria for upstream and downstream locations are listed in **Table 5-11**. During 2005 constituent concentrations of TSS (3800 mg/L), lead (0.079 mg/L), and chemical oxygen demand (288 mg/L) exceeded comparison criteria at GEOCRK. High TSS concentrations are not unusual in large storms generating runoff in Elk Ravine. Concentrations of TSS (3400 mg/L) and lead (0.050 mg/L) in storm water samples collected from upstream location CARW2 on February 15 also exceeded their site-specific criteria for those

parameters. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.)

Because of a Comprehensive Environmental Response Compensation Liability Act (CERCLA) remedial investigation finding of past releases of dioxins and polychlorinated biphenyls (PCBs) related to activities in the vicinity of Building 850, analysis for these compounds was conducted on runoff samples collected on January 26 from both locations NLIN2, the sampling location downstream from Building 850, and GEOCRK and on February 15 from location GEOCRK only. The intent of the sampling was to determine whether these constituents are being released down Elk Ravine and, eventually, off site in storm water runoff. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.) No PCBs were detected in those samples. All dioxins detected were below the equivalent federal MCL of 30 pg/L.

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-TCDD). The other dioxin and furan congeners reported have varying degrees of toxicity. EPA has assigned toxicity equivalency factors (TEFs) to specific dioxin and furan congeners. 2,3,7,8-TCDD is assigned a TEF of 1; the other dioxin and furan congeners have TEFs less than 1. The toxicity equivalency (TEQ) is determined by multiplying the concentration of a dioxin and furan congener by its TEF. **Table 5-12** shows the concentrations of dioxin and furan compounds that were detected in at least one sample at concentrations exceeding the analytical reporting limits at locations NLIN2 and GEOCRK along with their TEFs and calculated TEQs. If one uses the conservative approach of adding those congeners that were not detected at concentrations equal to one-half the analytical reporting limits, total TEQs for locations NLIN2 and GEOCRK add up to 15 and 17 pg/L, respectively; total TEQs for location GEOCRK for the February 15 sampling event add up to 16 pg/L. Although the congener 2,3,7,8-TCDD has not been detected in this network, its contribution to the total TEQ is still a major factor when added at half the analytical reporting limit. These values are below the federal MCL of 30 pg/L for 2,3,7,8-TCDD and are well below the concentrations of similar dioxins and furans measured at locations NLIN (located slightly downstream from location NLIN2) and GEOCRK in 2002 (see *LLNL Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ Annual Report 2002–2003* [Sanchez 2003]). LLNL will continue to monitor storm water concentrations to determine if any trends are developing.

Environmental Impact of Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impacts in 2005. Tritium activities in storm water runoff

effluent were less than 1% of the drinking water MCL. Gross alpha and gross beta activities in effluent samples at the Livermore site were both far less than their respective MCLs. Site 300 storm water monitoring continues to show that most contaminants (including dioxins and furans, naturally occurring lead and uranium) are transported sorbed to suspended sediments in the water; however, these concentrations pose no threat to the environment.

Table 5-12. Total toxicity equivalents of dioxin and furan congeners in storm water runoff (pg/L) at Site 300, January 26 and February 15, 2005

		January 26				February 15	
Dioxin congener[a]	TEF[b]	NLIN2 concentration	TEQ[c]	GEOCRK concentration	TEQ[c]	GEOCRK concentration	TEQ[c]
2,3,7,8-TCDD	1.00	<9.7	4.85	<6.9	3.45	<2.1	1.05
Total-HxCDD	0.00	<10	0.0	<10	0.0	12	0.0
1,2,3,4,6,7,8-HpCDD	0.01	35	0.35	11	0.11	24	0.24
Total-HpCDD	0.00	88	0.00	35	0.00	48	0.00
Total-OCDD	0.0001	250	0.025	100	0.010	95	0.0095
2,3,7,8-TCDF	0.1	<5.2	0.26	<2.9	0.145	2.5	0.25
Total-TCDF	0.00	<2.1	0.00	<2.1	0.00	5.0	0.00
1,2,3,4,7,8-HxCDF	0.1	<10	0.5	<10	0.5	14	1.4
2,3,4,6,7,8-HxCDF	0.1	<10	0.5	<10	0.5	12	1.2
Total-HxCDF	0.0	<10	0.0	<10	0.0	67	0.0
1,2,3,4,6,7,8-HpCDF	0.01	<10	0.05	<10	0.05	64	0.64
Total-HpCDF	0.00	<10	0.0	<10	0.0	79	0.0
Total-OCDF	0.0001	43	0.0043	<21	0.001	63	0.0063

a TCDD = tetrachloro-dibenzo-*p*-dioxin
HxCDD = hexachloro-dibenzo-*p*-dioxin
HpCDD = heptachloro-dibenzo-*p*-dioxin
OCDD = octachloro-dibenzo-*p*-dioxin
TCDF = tetrachlorodibenzofuran
HxCDF = hexachlorodibenzofuran
HpCDF = heptachlorodibenzofuran
OCDF = octachlorodibenzofuran
b Toxicity Equivalency Factor compared to 2,3,7,8-TCDD
c Toxicity Equivalents compared to 2,3,7,8-TCDD

Groundwater

LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and at Site 300 through networks of wells and springs that include private wells off site and DOE CERCLA wells on site.

The groundwaters monitored at the two LLNL facilities are not connected; they are separated by a major drainage divide and numerous faults. The Livermore site in the Livermore Valley drains to the San Francisco Bay via

Alameda Creek. Most of Site 300 drains to the San Joaquin River Basin via Corral Hollow Creek, with a small undeveloped portion in the north draining to the north and east onto grazing land.

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 surveillance monitoring plan.

Historically, the surveillance and compliance monitoring programs have detected higher than natural background concentrations of various metals, nitrate, perchlorate, and depleted uranium in groundwater at Site 300. Subsequent CERCLA studies have linked several of these contaminants, including depleted uranium, to past operations, while the sources of other contaminants, such as nitrate and perchlorate, are the objects of continuing study.

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; 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 surface impoundments, sewage ponds, and percolation pits; the latter were discussed previously in this chapter. Compliance monitoring is specified in WDRs issued by the CVRWQCB and in landfill closure and post-closure monitoring plans. (See **Table 2-2** for a summary of LLNL permits.)

The WDRs and post-closure plans specify wells and effluents to be monitored, COCs and parameters to be measured, frequency of measurement, inspections to be conducted, and the frequency and form of required reports. These monitoring programs include quarterly and semiannual 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.

Typically, because they are both accurate and sensitive, analytical methods approved by EPA are used to measure dissolved constituents in water.

Appendix A lists the analytical methods and reporting limits that are used to detect organic and inorganic constituents in groundwater (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods). The listed methods are not all used for samples from each groundwater monitoring location. Rather, for cost effectiveness, only those contaminants that have been detected historically or that might result from continuing LLNL operations are monitored at each groundwater sampling location. However, present-day administrative, engineering, and maintenance controls at both LLNL sites are specifically tailored to prevent releases of potential contaminants to the environment.

During 2005, 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 (SOPs) (Goodrich and Depue 2003). These protocols cover sampling techniques and specific 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 are compared with drinking water limits (MCLs); however, the MCLs do not apply as regulatory limits to any of these groundwaters.

Livermore Site and Environs

Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. Tritiated water (HTO) is potentially the most mobile groundwater contaminant from LLNL. Rain and storm water runoff in the Livermore Valley, which recharge local aquifers, contain small amounts of HTO from natural sources, past worldwide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL. (See Chapters 4 and 7 for further discussion of air emissions, and other parts of this chapter for further discussion of rain and storm water runoff.)

Groundwater is recharged at the Livermore site, primarily from arroyos, by rainfall. Groundwater flow beneath the Livermore site is generally southwestward. An overview of groundwater flow is provided in Chapter 1 and is discussed in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and in the LLNL Ground Water Project 2005 Annual Report (Karachewski et al. 2006).

Groundwater samples were obtained during 2005 from 23 of 25 water wells in the Livermore Valley (see **Figure 5-11**) and measured for tritium activity. Two wells were either dry or could not be sampled during 2005.

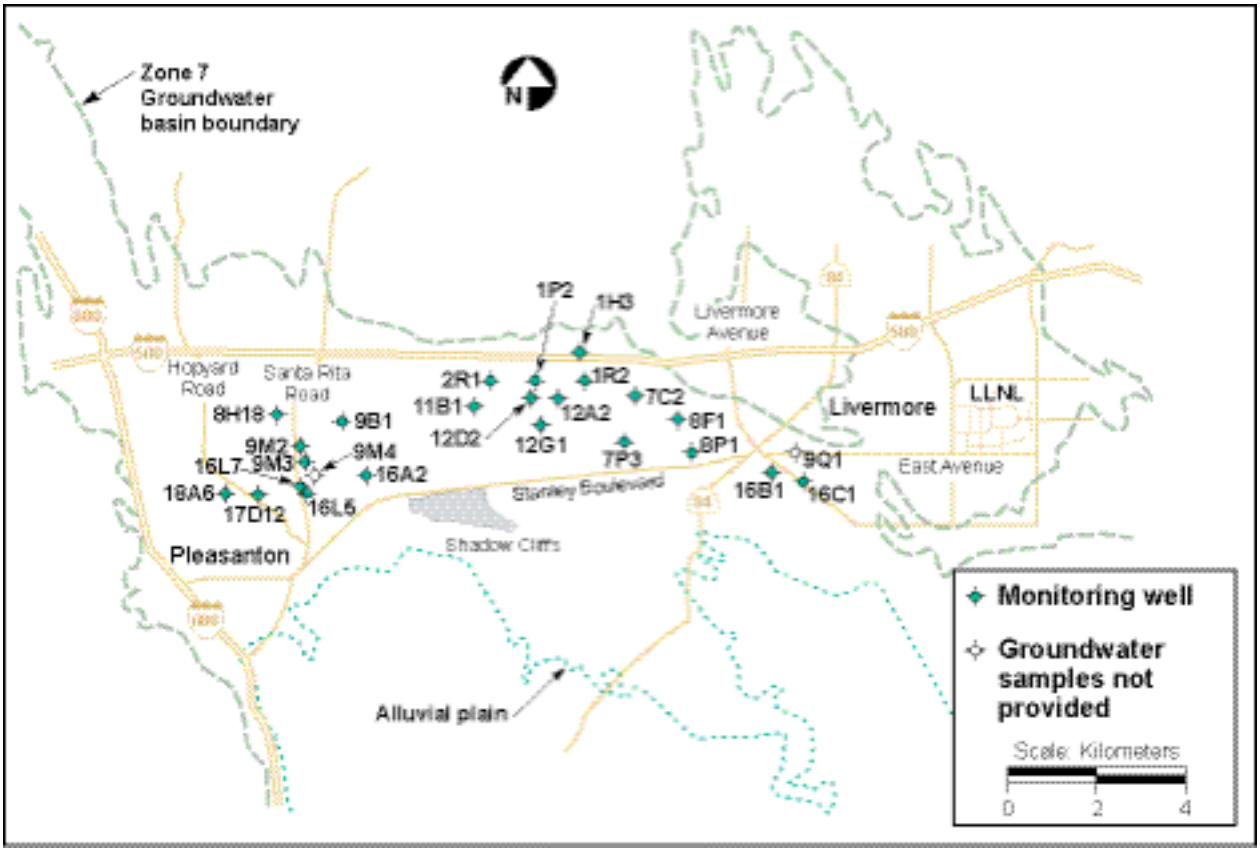


Figure 5-11. Locations of off-site tritium monitoring wells in the Livermore Valley, 2005

Tritium measurements of Livermore Valley groundwaters are contained in the file "Ch5 LV Groundwater" provided on the report CD. They 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 12A2, located about 9 km west of LLNL (see **Figure 5-11**). The measured activity there was 4.3 Bq/L (116 pCi/L) in 2005, less than 1% of the MCL.

Livermore Site Perimeter

LLNL designed a surveillance monitoring program to complement the Livermore Site GWP (discussed in Chapter 8). The intent of the surveillance monitoring network is to monitor for potential groundwater contamination from continuing LLNL operations. The perimeter portion of this surveillance groundwater monitoring network makes use of 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 5-12**). These seven wells, located in the regions of groundwater Treatment Facilities (TF) A, B, and C (see **Figure 8-1**) are located at or beyond the hydrologically downgradient boundary of the Livermore site. The western perimeter wells are screened (depth range from which groundwater is drawn) in the uppermost aquifers near the areas where groundwater is being remediated. As discussed in Chapter 8, the alluvial sediments have been divided into nine hydrostratigraphic units (HSUs) dipping gently westward, which are shown in **Figure 8-1**. Screened intervals for these monitoring wells range from the shallow HSU 1B, in which some of the western monitoring wells are screened, to the deeper HSU 5, in which background well W-017 and some wells around Buildings 514 and 612 are screened.

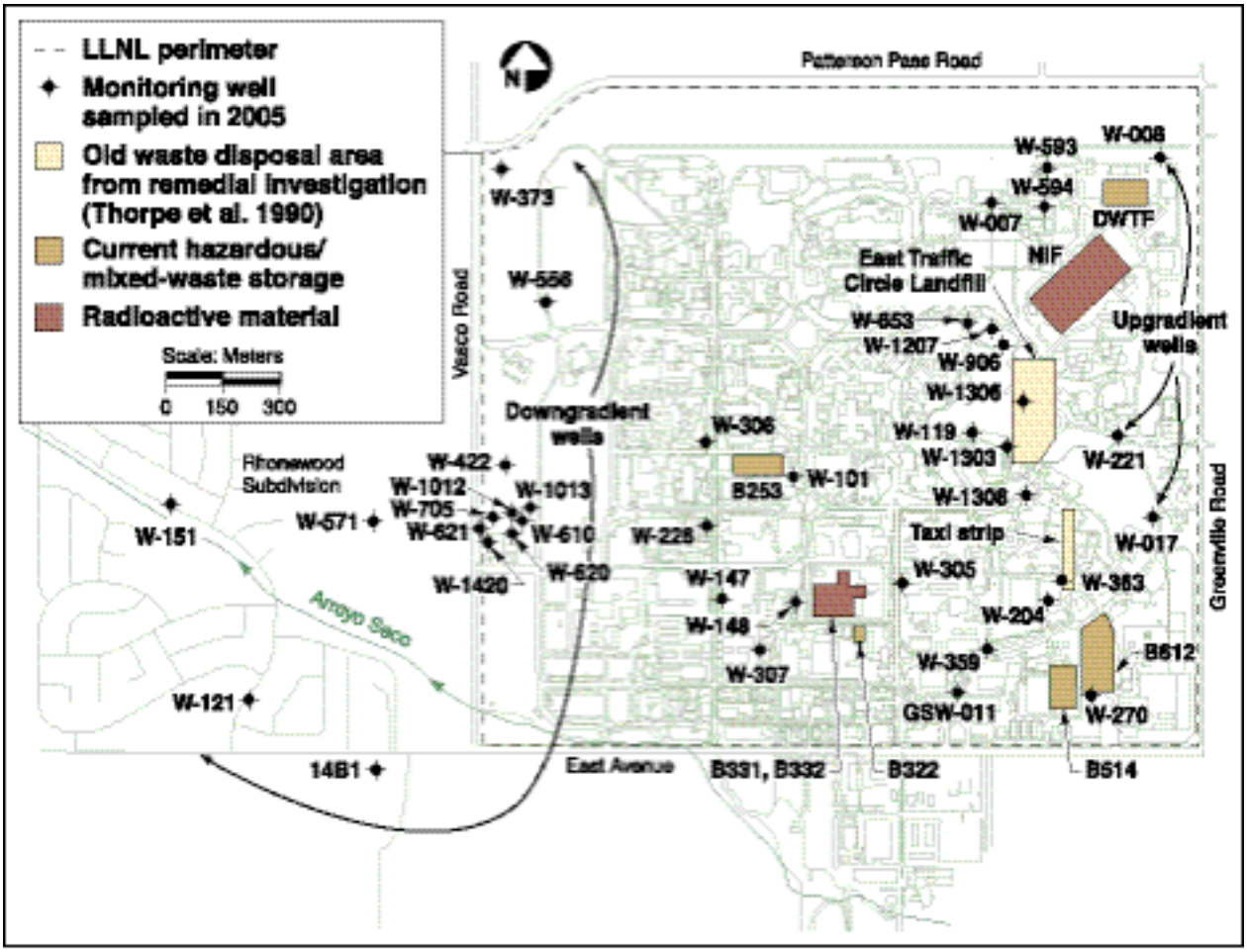


Figure 5-12. Locations of routine surveillance groundwater monitoring wells at the Livermore site, 2005

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. These background wells were sampled and analyzed in 2005 for pesticide and herbicide compounds that are used on site and off site, for nitrate, for hexavalent chromium (chromium(VI)), and for certain radioactive constituents including plutonium.

To detect contaminants as soon as possible, the seven western downgradient wells (except for well 14B1) are screened in shallower HSUs 1B and 2, the uppermost water-bearing HSUs at the western perimeter. (Because it was originally a production well, well 14B1 is screened over a depth range that includes HSUs 2, 3A, and 3B.) These wells were sampled and analyzed at least once during this reporting period for pesticides, herbicides, radioactive constituents, nitrate, and chromium(VI).

Analytical results for the Livermore site background wells and perimeter wells are contained in the file "Ch5 LV Groundwater" provided on the report CD. One sample from the background well W-017 was reported to contain the herbicide merphos (1.8 µg/L); however, this result is suspect due to analytical (QC) complications reported by the laboratory. An independent retest of this well in January 2006 failed to confirm this detection. No pesticide or herbicide organic compounds were detected above analytical reporting limits in groundwater samples from the other background or perimeter wells during 2005. The inorganic compounds detected include dissolved trace metals and minerals, which occur naturally in the groundwater. Although there have been variations in these concentrations since regular surveillance monitoring began in 1996, the concentrations detected in the 2005 groundwater samples from the upgradient wells represent current background values. Plutonium-238 and plutonium-239+240 were reported above minimum detectable activities in one perimeter well sample, collected from well W-1012 in March 2005. Failure to filter this sample prior to analysis, however, invalidated these results; nevertheless, two retests were initiated. Analytical results from samples collected at well W-1012 in both May 2005 and December 2005 failed to confirm the initial detection.

Since 1996, and continuing through 2004, concentrations of nitrate detected in groundwater samples from downgradient well W-1012 had been greater than the MCL of 45 mg/L. The nitrate concentrations detected in samples from this well during 2005 were reported at 43 and 41 mg/L; these values are less than the values of 61 and 45 mg/L observed in 2004, and are now below the MCL. Because of the hydrologic influence of TFB that pumps and treats groundwater from HSUs 1B and 2, groundwater with high nitrate concentrations is restrained from moving off site to the west. The highest concentrations measured in the downgradient off-site wells (screened in these HSUs) remained below the MCL: 41 mg/L in monitoring well W-151 and 37 mg/L in monitoring well W-571. During 2005, concentrations of nitrate in

on-site shallow background wells W-008 and W-221 ranged from 24 mg/L to 29 mg/L. Detected concentrations of nitrate in western perimeter wells, with the exception of well W-1012, ranged from 13 mg/L (in well W-373) to 42 mg/L (in well W-556).

Nitrate concentrations were also analyzed in groundwater samples collected from seven additional monitoring wells located nearby well W-1012 (**Figure 5-12**), similarly screened in HSUs 1B and 2. Again, no groundwater sample had a nitrate concentration greater than the MCL. Fluctuations in nitrate concentrations have occurred since regular surveillance monitoring began in 1996, but nitrate concentrations have not increased overall in groundwater from the western perimeter monitoring wells since 1996. The nitrate may originate as an agricultural residue (Thorpe et al. 1990).

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 situated down-gradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 5-12**. All analytical results are included in the file "Ch5 LV Groundwater" provided on the report CD.

The Taxi Strip and the East Traffic Circle Landfill areas within the Livermore site are two historic potential sources of groundwater contamination. Samples from monitoring wells screened in HSUs 2 (W-204) and 3A (W-363) downgradient from the Taxi Strip Area were analyzed in 2005 for copper, lead, zinc, americium-241, plutonium-238, plutonium-239, radium-226, radium-228, 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 in the Taxi Strip Area. No concentrations of plutonium or americium radioisotopes were detected above the radiological laboratory's minimum detectable activities. Concentrations of tritium and radium isotopes remain well below drinking water MCLs. Of the trace metals (copper, lead, and zinc), only zinc was detected in any of these monitoring wells during 2005. Zinc concentrations were reported as 26 µg/L in well W-119, 11 µg/L in well W-204, and <10 µg/L in four of these wells (W-363, W-1303, W-1306, and W-1308). The maximum zinc concentration reported in 2005 (500 µg/L in well W-906) is still an order of magnitude below the secondary MCL for zinc in drinking water (5000 µg/L).

Although the National Ignition Facility (NIF) has not yet begun full operations, LLNL obtains a baseline (pH, conductivity, and tritium concentration) of groundwater quality prior to start of operations. During 2005, tritium analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSUs 3A and 2, respectively) downgradient of NIF. Another new facility where groundwater baseline information is being acquired is the Decontamination and Waste Treatment Facility (DWTF) in the northeastern portion of LLNL. Samples were obtained downgradient from this facility from wells W-007, W-593, and W-594 (screened in HSUs 2/3A, 3A, and 2, respectively) during 2005 and were analyzed for tritium.

Monitoring results from the wells near NIF and DWTF show no detectable concentrations of tritium present, above the limit of sensitivity of the analytical method, in the groundwater samples collected during 2005. Monitoring will continue near these facilities to determine baseline conditions.

Area 514 and the hazardous waste/mixed waste storage facilities around Building 612 are also a potential source of contamination. They are monitored by wells W-270 and W-359 (both screened in HSU 5), and well GSW-011 (screened in HSU 3A). Groundwater from these wells was sampled and analyzed for general minerals, americium-241, plutonium-238, plutonium-239, radium-226, and tritium in 2005. No significant contamination was detected in the groundwater samples collected from wells W-270, W-359, or GSW-011 downgradient from those areas in 2005.

Groundwater samples were obtained from monitoring well W-307 (screened in HSU 1B). This location, downgradient from a fume hood vent on the roof of Building 322 (a metal plating shop), is an area where releases of metals to the ground have occurred. Soil samples previously obtained from the area showed elevated concentrations (in comparison with Livermore site's background levels) of 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 will migrate from the site. In 2005, the monitoring results for well W-307 show 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. The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). In 2005, the samples obtained from monitoring wells W-226 and W-306 (screened in HSUs 1B and 2, respectively) contained dissolved chromium at elevated concentrations, but concentrations

were essentially unchanged from last year. Concentrations of chromium(VI) were measured as 26 µg/L at well W-226 and 35 µg/L at well W-306. No concentration of either dissolved chromium or chromium(VI) was greater than the MCL of 50 µg/L for total chromium in drinking water.

Additional surveillance groundwater sampling locations, established in 1999, surround the area of the Plutonium Facility (Building 332) and the Tritium Facility (Building 331) (see **Figure 5-12**). Possible contaminants include plutonium and tritium from these respective facilities. Plutonium is much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, could migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU 2; down-gradient wells W-101, W-147, and W-148 are screened in HSU 1B. Groundwater samples collected from these wells during 2005 showed no detectable concentration, above the limit of sensitivity for the analytical method, of either plutonium-238 or plutonium-239+240.

In August 2000, relatively elevated tritium activity was measured in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L [3100 ± 135 pCi/L]). It was concluded that the activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater of this area have generally remained at this level since that time. LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that tritium and plutonium contents remain below environmental levels of concern.

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 surface or sub-surface operations at Site 300.

Twelve groundwater monitoring locations are off site (**Figure 5-13**). Two are springs, identified as MUL2 and VIE1, which are located near the northern boundary of Site 300. Off-site surveillance well VIE2 is located 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. Eight off-site surveillance locations are wells located near the southern boundary of Site 300 in or adjacent to the Corral Hollow Creek floodplain.

On-site wells are used to monitor closed landfills, a former open-air explosives burn pit, two connected surface water impoundments, and two connected sewer ponds (**Figure 5-13**). The closed landfills—identified as Pit 1, Pit 2, Pit 7 Complex, Pit 8, and Pit 9—are located in the northern portion of Site 300 in the Elk Ravine drainage area, while Pit 6, the former burn pit (Building 829), the two surface impoundments, and the sewage ponds are located in the southern portion of Site 300 in the Corral Hollow Creek drainage area. Two on-site water supply wells, identified as wells 18 and 20, are also used for surveillance monitoring purposes. Well 20 provides potable water to the site. Well 18 is maintained as a standby potable supply well.

Brief descriptions of the Site 300 groundwater monitoring networks that are reported in this chapter are given below. Networks of wells within the Elk Ravine drainage area are described first, followed by the well networks in the Corral Hollow Creek drainage area. Subsets of CERCLA wells, installed mainly for site characterization, have been selected for compliance and surveillance monitoring use based on their locations and LLNL's general understanding of local geologic and hydrogeologic conditions at Site 300. (Chapters 1 and 8 include summaries of Site 300 hydrology and stratigraphy, respectively. All analytical data from 2005 are included in the file "Ch5 S300 Groundwater" provided on the report CD.)

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 5-13**). 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 because of the system of surface and 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 the closed landfills has a liner, which is consistent with disposal practices in the past 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 contamination in this drainage area as determined from numerous CERCLA remedial investigations.)

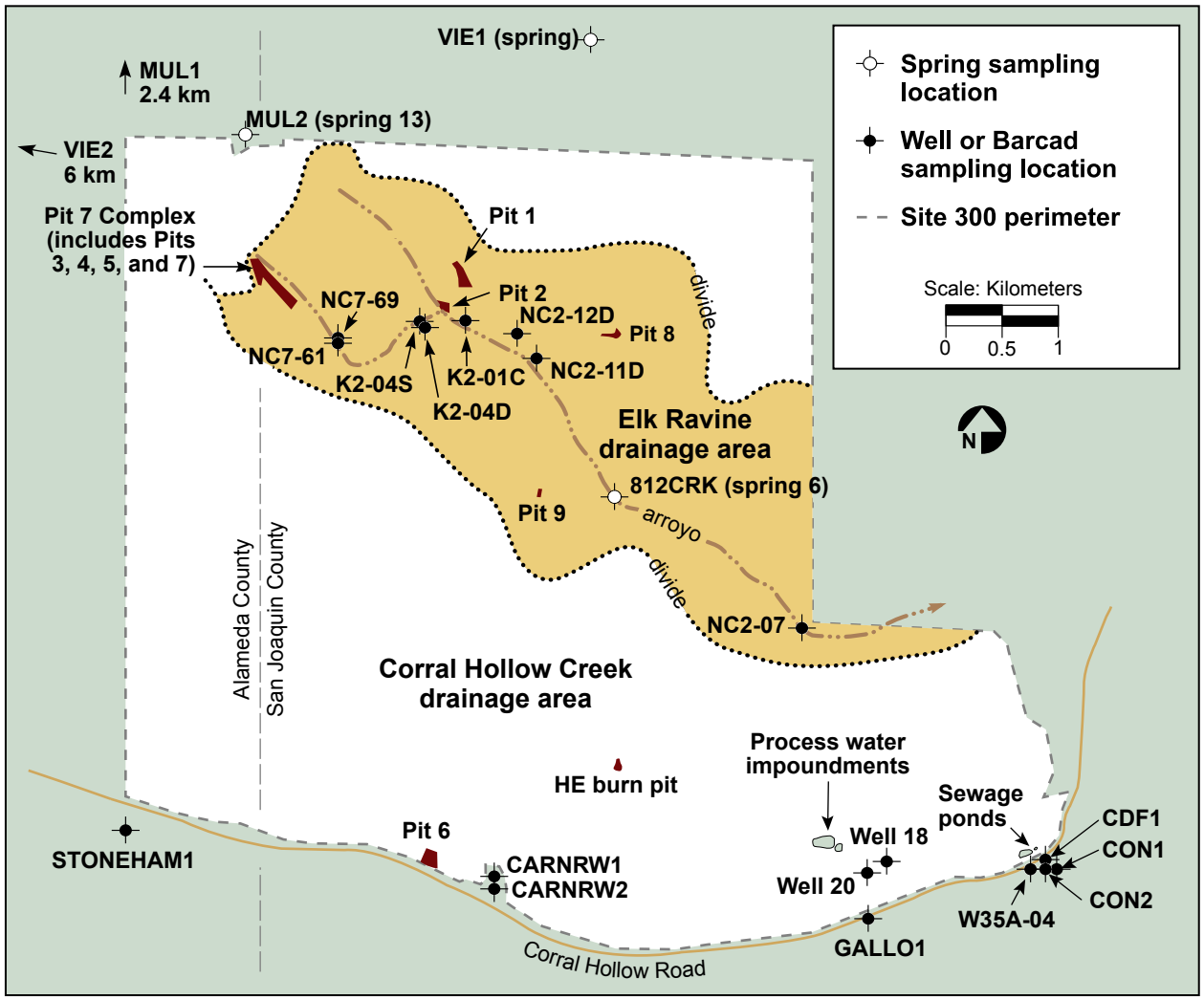


Figure 5-13. Locations of surveillance groundwater wells and springs at Site 300, 2005

Pit 7 Complex

Monitoring requirements for the Pit 7 landfill, which was closed under the Resource Conservation and Recovery Act (RCRA) in 1993, are specified in WDR 93-100 administered by the CVRWQCB (1993, 1998a) 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.

The Pit 7 Complex area is located at an elevation of about 400 m above sea level in the most elevated portion of the Elk Ravine drainage area. The complex consists of four adjacent landfills identified as Pits 3, 4, 5, and 7 (see **Figure 5-14**). From 1963 to 1988, the landfills received waste gravels and debris from hydrodynamic tests of explosive devices conducted on firing tables at Site 300. The gravels contained concrete, cable, plastic, wood,

tritium, uranium, beryllium, lead, and other metals in trace amounts. In 1988, 9440 m^3 of gravel were removed from six firing tables at Site 300 and placed in Pit 7 (Lamarre and Taffet 1989). These were the last solid wastes to be placed in any landfill at Site 300.

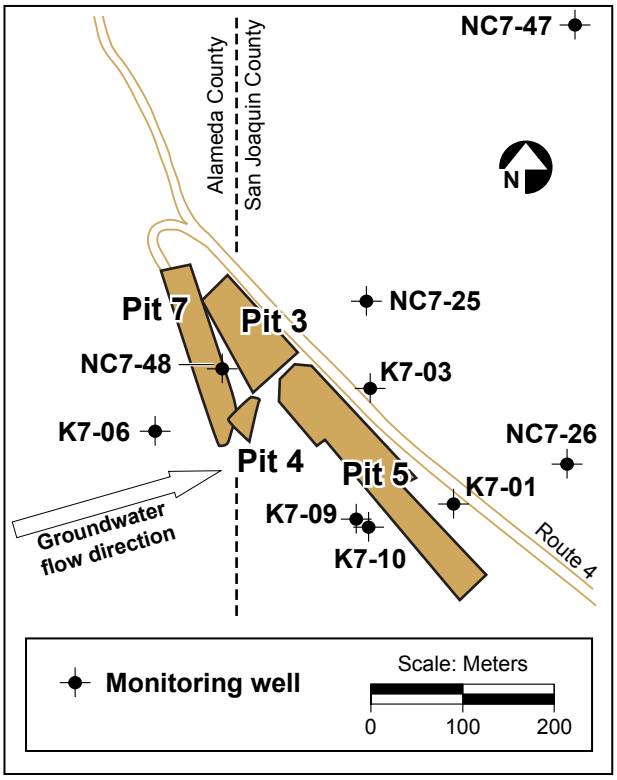


Figure 5-14. Locations of Pit 7 compliance groundwater monitoring wells, 2005

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2005 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 volatile organic compounds (VOCs). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

No new release of COCs to groundwater from Pit 7 is evident in the chemical data obtained during 2005. The COCs detected in groundwater include several metals, depleted uranium, tritium, and several VOCs. These are associated with releases that occurred prior to 2005. The primary sources of COCs detected by the network of Pit 7 monitoring wells are the closed landfills known as Pits 3 and 5, which are adjacent to Pit 7 (**Figure 5-14**). Natural sources in the rocks and sediments surrounding Pit 7 also have

contributed arsenic, barium, uranium, and, possibly nitrate to the groundwater. In the past, especially during the El Niño winters of 1982/1983 and 1997/1998, excessive seasonal rainfall caused groundwater levels to rise into Pit 3 and Pit 5 from beneath, leading to the release of COCs, mainly tritium in the form of HTO. Because of reduced rainfall since 1998, groundwater elevations have fallen generally at Site 300, thus reducing the potential for releases to occur by this mechanism. CERCLA modeling studies indicate that tritium and other COCs released in the past will not reach off-site aquifers at concentrations above MCLs. See Chapter 8 for a review of CERCLA activities regarding groundwater contamination in the upper reaches of the Elk Ravine drainage area. For a detailed account of Pit 7 compliance monitoring during 2005, including tables and graphs of groundwater COC analytical data, see *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2005* (Campbell and MacQueen 2006).

Elk Ravine

Groundwater samples were obtained on various dates in 2005 from the widespread Elk Ravine surveillance monitoring network (see **Figure 5-13**). Samples were analyzed for inorganic constituents (mostly metallic elements), VOCs, general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX).

No new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2005. 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 A.

Concentrations of arsenic range up to 43 µg/L (well NC2-07) in Elk Ravine monitoring wells. Earlier CERCLA characterization studies determined that the arsenic is from natural sources, particularly from the dissolution of the mineral arsenopyrite, which is a component of the underlying volcanogenic sediments and sedimentary rocks (Raber and Carpenter 1983). It should be noted that there are no wells in this area that are used for potable domestic, livestock, or industrial water supply. However, a perennial spring in Elk Ravine (location 812CRK on **Figure 5-13**), which is used by the indigenous wildlife there, contains concentrations of naturally occurring arsenic (28 µg/L arsenic in 2005).

An elevated tritium activity was detected in one of five shallow groundwater surveillance samples collected from wells in Elk Ravine during 2005. Tritium, as HTO, has been released in the past in the vicinity of Building 850. The largest HTO plume, which extends eastward more than a kilometer from a

source beneath the Building 850 firing table area to the vicinity of Pits 1 and 2, is confined to shallow depths in the Neroly lower blue sandstone unit and overlying alluvium.

The majority of the Elk Ravine surveillance network tritium measurements made during 2005 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). For example, tritium activity in groundwater at well NC7-61 has decreased from 6500 Bq/L (1.8×10^5 pCi/L) in 1996 to 1150 Bq/L (3.1×10^4 pCi/L) in 2005. CERCLA modeling studies indicate that the tritium will decay to background levels before it can reach a site boundary. Note that the tritium plume has not yet reached the surveillance monitoring perennial spring location 812CRK, which is approximately one mile upstream from where the Site 300 boundary crosses Elk Ravine.

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

Monitoring requirements for the Pit 1 landfill, which was closed under RCRA in 1993, are also specified in WDR 93-100 administered by the CVRWQCB (1993 and 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.

Pit 1 lies in the Elk Ravine drainage area about 330 m above sea level. The Pit 1 landfill and the positions of the eight groundwater wells used to monitor it are shown in **Figure 5-15**. The eight wells are K1-01C, K1-02B, K1-03, K1-04, K1-05, K1-07, K1-08, and K1-09.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2005 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 method 601). Every other quarter, analyses were conducted for an additional seven elements. Additional annual analyses were conducted on fourth-quarter samples for extractable organics (EPA method 625), pesticides and PCBs (EPA method 608), and herbicides (EPA method 615). Field

measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of quarterly sample collection.

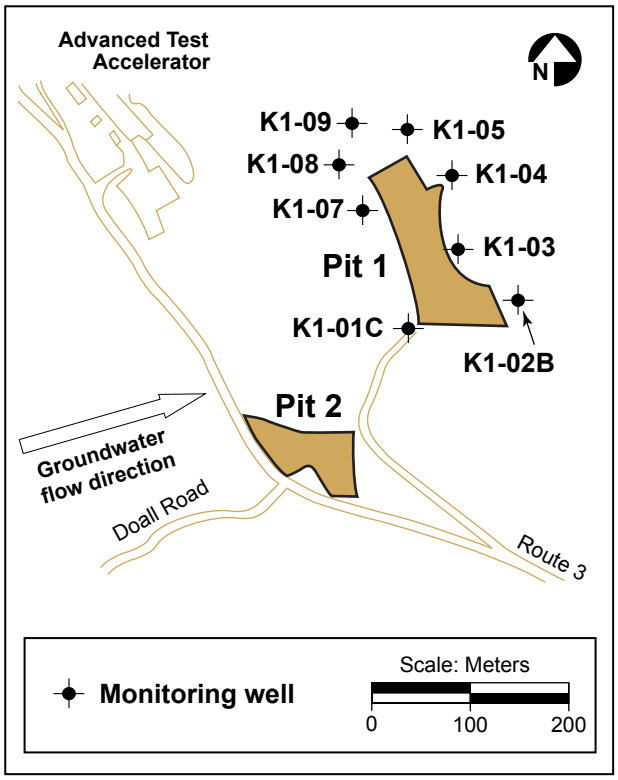


Figure 5-15. Locations of Pit 1 compliance groundwater monitoring wells, 2005

No release of COCs to groundwater from Pit 1 is evident in the monitoring data collected during 2005. A detailed account of Pit 1 compliance monitoring during 2005, including tables and graphs of groundwater COC analytical data, is in *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2005* (Campbell and MacQueen 2006).

During 2005, average tritium activities above analytical background levels (about 4 Bq/L [100 pCi/L]) were measued in the groundwater at Pit 1 monitoring wells K1-01C (24 Bq/L [641 pCi/L]), K1-02B (145 Bq/L [3908 pCi/L]), K1-03 (31 Bq/L [832 pCi/L]), K1-04 (6 Bq/L [165 pCi/L]), K1-08 (6 Bq/L [165 pCi/L]), and K1-09 (6 Bq/L [165 pCi/L]). The tritium activity in the groundwater sampled at these wells represents a distal lobe of the Building 850 tritium plume. Measurements of radium, thorium, and uranium made during 2005 in groundwater samples from Pit 1 compliance monitoring wells showed low activities indistinguishable from background levels.

The VOC 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) decreased from a maximum concentration of 140 µg/L measured in 1999 to 42 µg/L in 2005 in groundwater samples at Pit 1 monitoring well K1-09. Freon-113 concentrations were also found at other groundwater monitoring wells K1-05 (15 µg/L) and K1-08 (26 µg/L). The drinking water MCL for this VOC is 1200 µg/L. Previous CERCLA investigations have linked the Freon 113 detected in Pit 1 monitoring wells to past spills of Freon in the Advanced Test Accelerator area, about 200 m northwest of the affected wells (Webster-Scholten 1994; Taffet et al. 1996).

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 the *Post-Closure Plan for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1998) and in the *Compliance Monitoring Plan/ Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2002). The closed Pit 6 landfill covers an area of about 1 hectare (2.5 acres), at an elevation of approximately 215 m above sea level. From 1964 to 1973, approximately 1500 m^3 of solid wastes were buried there in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 m^3 of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 m^3 of biomedical waste, including animal carcasses and animal waste. During 1997, a multilayered cap was constructed over all the trenches, and a storm water drainage control system was installed around the cap. The cap and the drainage control system are engineered to keep rainwater from contacting the buried waste (Ferry et al. 1998).

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt) north of the Corral Hollow Creek flood plain. Surface runoff from the pit area flows southward to Corral Hollow Creek. The Carnegie-Corral Hollow Fault zone extends beneath the southern third of Pit 6. The northern limit of the fault zone is shown in **Figure 5-16**. Beneath the northern two-thirds of Pit 6, groundwater flows south-southeast, following the inclination of the underlying sedimentary rocks. Groundwater seepage velocities are less than 10 m/y. Depths to the water table range from 10 to 20 m. Beneath the southern third of Pit 6, a trough containing terrace gravel within the fault zone provides a channel for groundwater to flow southeast, parallel to the Site 300 boundary fence (Webster-Scholten 1994).

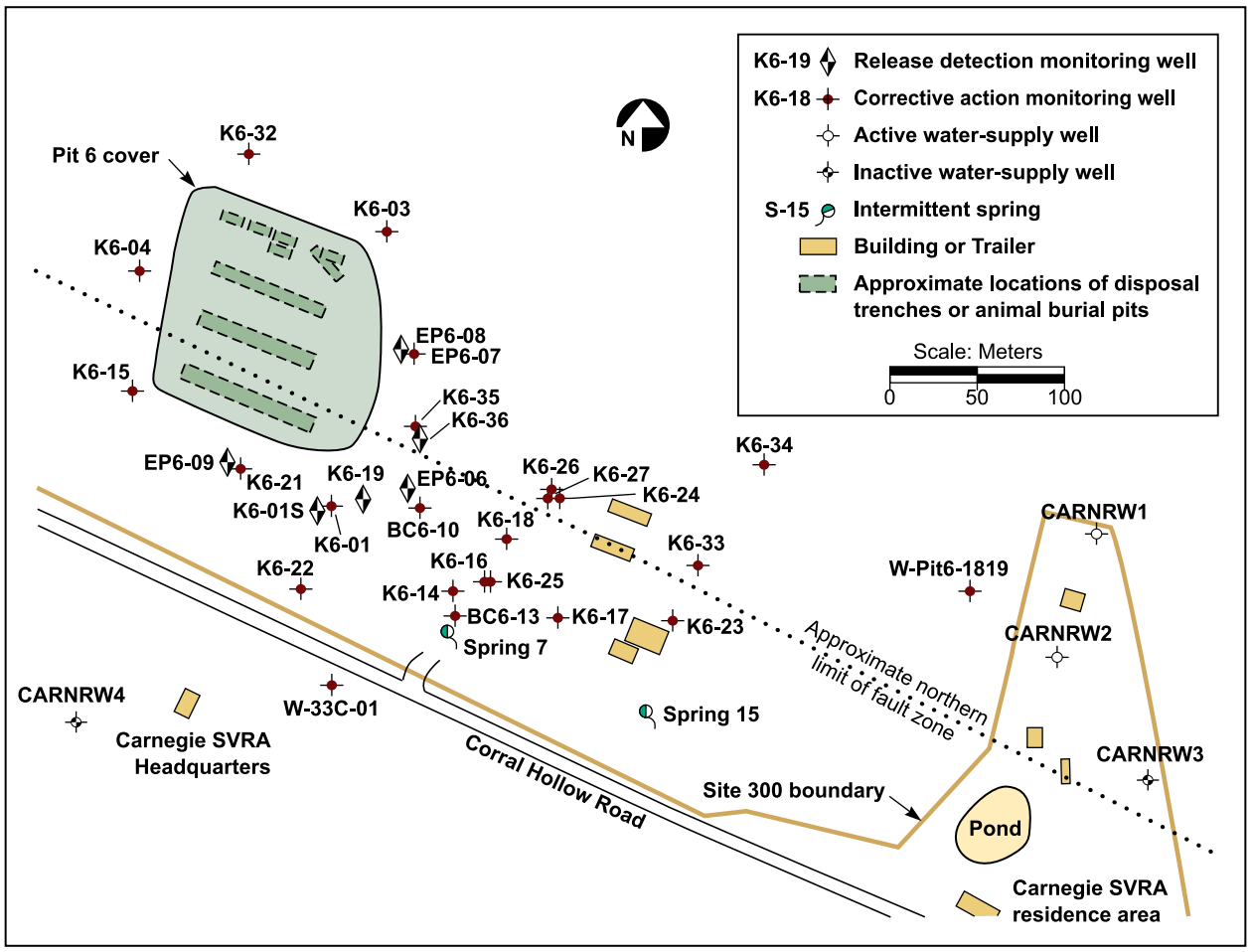


Figure 5-16. Locations of Pit 6 compliance groundwater monitoring wells and springs, 2005

Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Program (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 Program (CAMP), which monitors the movement and fate of historical releases. **Figure 5-16** shows the locations of Pit 6 and the wells used to monitor the groundwater there. To comply with monitoring requirements, LLNL obtained groundwater samples monthly, quarterly, semiannually, and annually during 2005 from specified Pit 6 monitoring wells. DMP samples were obtained quarterly and were analyzed for beryllium and mercury, general radioactivity (gross alpha and beta), tritium and uranium activity, specified VOCs, nitrate and perchlorate. CAMP samples were measured for VOCs, tritium activity, nitrate and perchlorate. Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

No new release of COCs from Pit 6 is indicated by the chemical analyses of groundwater samples obtained from Pit 6 monitoring wells during 2005. COCs that were released prior to constructing an impermeable cap over the closed landfill in 1997 continued to be detected in the groundwater at low concentrations during 2005. These COCs include tritium, perchlorate, trichloroethylene (TCE), perchloroethylene (PCE), and cis-1,2-dichloroethene (cis-1,2-DCE). All contaminant plumes associated with Pit 6 are confined to shallow depths. None has been detected beyond the Site 300 boundary. For a detailed account of Pit 6 compliance monitoring during 2005, including tables of groundwater analytical data and map figures showing the distribution of COC plumes, see *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report for 2005* (Campbell and Taffet 2006).

Building 829 Closed HE Burn Facility

Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in the *Final Closure Plan for the High-Explosives Open Burn Treatment Facility at Lawrence Livermore National Laboratory Experimental Test Site 300* (Mathews and Taffet 1997), and in the *Revisions to the Post-Closure Permit Application for the Building 829 HE Open Burn Facility – Volume 1* (LLNL 2001b) as modified by the *Hazardous Waste Facility Post-Closure Permit for the Building 829 HE Open Burn Facility* (DTSC 2003).

The former Burn Facility, part of the Building 829 Complex, is located on a ridge within the southeast portion of Site 300 at an elevation of about 320 m above sea level. The facility included three shallow, unlined pits constructed in unconsolidated sediments that cap the ridge (Tps formation). The facility was used to thermally treat explosives process waste generated by operations at Site 300 and similar waste from explosives research operations at the Livermore site. The facility was covered with an impervious cap in 1998 following RCRA guidance.

Surface water drains southward from the facility toward Corral Hollow Creek. The nearest site boundary lies about 1.6 km to the south at Corral Hollow Road. Stratified rocks of the Neroly (Tn) formation underlie the facility and dip southeasterly. Two water-bearing zones exist at different depths beneath the facility. The shallower zone, at a depth of about 30 m, is perched within the Neroly upper siltstone/claystone aquitard ($Tnsc_2$). The deeper zone, at a depth of about 120 m, represents a regional aquifer within the Neroly upper sandstone member ($Tnbs_2$). (See **Figure 8-5** for Site 300 stratigraphy.)

Based on groundwater samples recovered from boreholes, previous CERCLA remedial investigations determined that the perched groundwater near the Burn Facility was contaminated with VOCs, primarily TCE, but that the

deeper regional aquifer was free of any contamination stemming from operation of the facility (Webster-Scholten 1994). Subsequent assays of soil samples obtained from shallow boreholes prior to closure revealed that low concentrations of explosives compounds, VOCs, and metals exist beneath the burn pits (Mathews and Taffet 1997). Conservative transport modeling indicates that the shallow contamination will not adversely impact the regional aquifer primarily because its downward movement is blocked by more than 100 m of unsaturated Neroly Formation sediments that include interbeds of claystone and siltstone.

Beginning in 1999, LLNL implemented the intensive groundwater monitoring program for this area described in the post-closure plan (Mathews and Taffet 1997) to track the fate of contaminants in the soil and the perched water-bearing zone, and to monitor the deep regional aquifer for the appearance of any potential contaminants from the Burn Facility. This monitoring program remained in effect through the first quarter of 2003, at which time LLNL began implementation of the provisions specified in the *Hazardous Waste Facility Post-Closure Permit for the B829 Facility* (DTSC 2003). Following the guidance outlined in the DTSC Technical Completeness assessment (DTSC 2002), LLNL installed one additional groundwater monitoring well at the point of compliance within three meters of the edge of the capped High Explosive Open Burn Treatment Facility. This well (W-829-1938) was screened in the regional aquifer, the uppermost aquifer beneath the Building 829 facility. Since the first quarter of 2004, and continuing through 2005, well W-829-1938 has been used for quarterly collection of groundwater samples from the regional aquifer, as part of the permit-specified monitoring network (**Figure 5-17**). Also shown in **Figure 5-17** are two previously existing wells (W-829-15 and W-829-22), which were sampled in both the first and second quarters of 2005, prior to the DTSC-approved change (from quarterly to annual) in sampling frequency for wells W-829-15 and W-829-22 (DTSC 2005).

As planned for compliance purposes, LLNL obtained groundwater samples during 2005 from the Building 829 monitoring well network. Groundwater samples from the wells screened in the deep regional aquifer were analyzed for inorganic COCs (mostly metals), general minerals, turbidity, explosive compounds (HMX, RDX, and TNT), VOCs (EPA method 624), extractable organics (EPA method 625), pesticides (EPA method 608), herbicides (EPA method 615), general radioactivity (gross alpha and beta), radium activity, total organic carbon (TOC), total organic halides (TOX), and coliform bacteria.

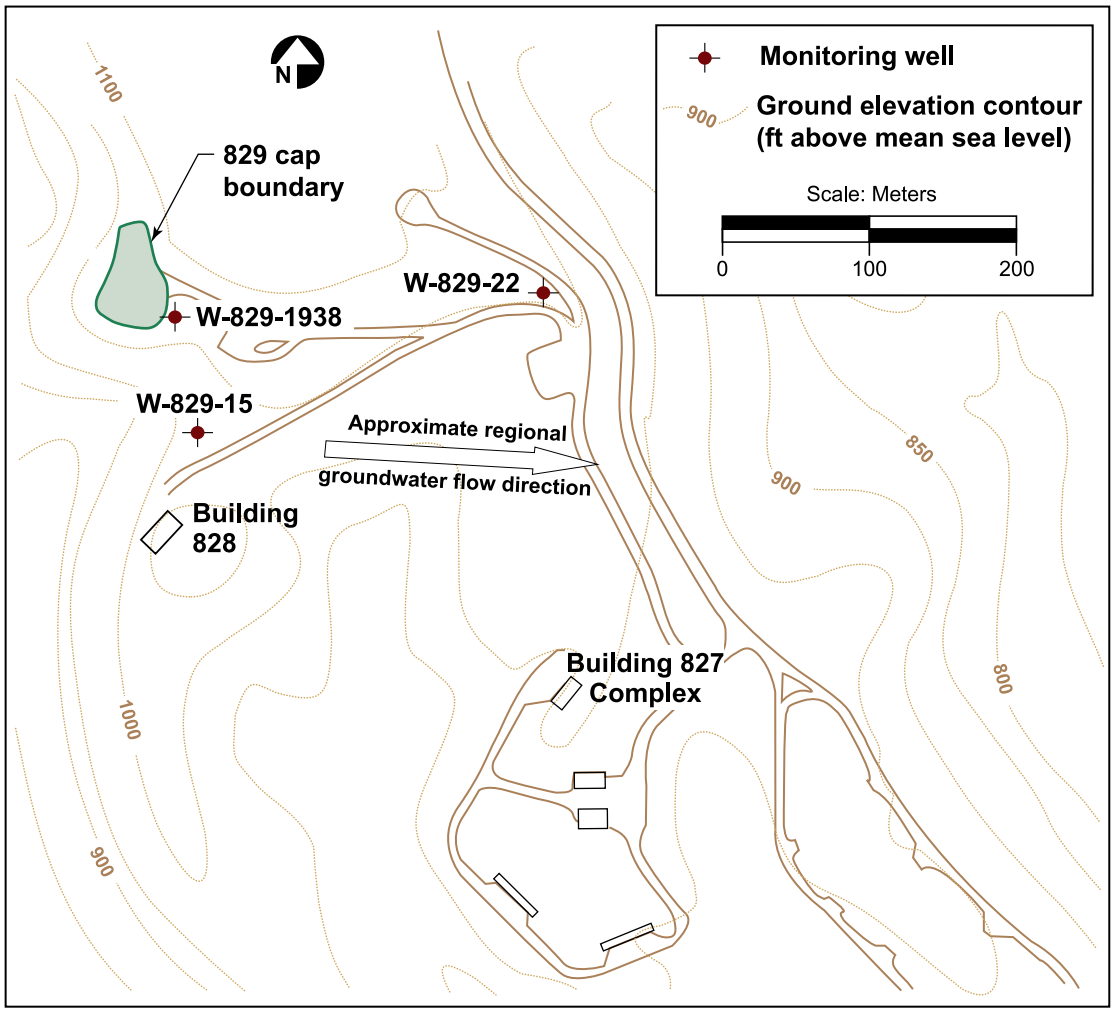


Figure 5-17. Locations of Building 829 closed burn pit compliance groundwater monitoring wells

No new release of COCs to groundwater from the closed Burn Facility is indicated by the monitoring data obtained during 2005. For a detailed account of compliance monitoring of the closed burn pit during 2005, including tables and graphs of groundwater COC analytical data, see *LLNL Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2005* (Revelli 2006b).

During 2005, no explosive COCs were detected above their respective reporting limits (RLs) in groundwater samples from any of the three monitoring wells. Among the organic COCs, only DEHP was reported to be above its RL in samples from one of the three wells (W-829-22); however, these DEHP results were eventually traced to laboratory contamination. The inorganic constituents that were detected in samples from the two established wells (W-829-15 and W-829-22) show concentrations that do not

differ significantly from background concentrations for the deep aquifer beneath the Explosives Process Area (Webster-Scholten 1994).

With one exception, the concentrations of inorganic COCs detected in the new well (W-829-1938) were consistent with background concentrations reported for the other wells that were also sampled for this network. Only nickel (detected at 14 µg/L, 5.1 µg/L, and 8.6 µg/L in the second and third quarter 2004 samples and in the first quarter 2005 sample, respectively) had not previously been detected in groundwater samples from this monitoring network. Nickel, however, is typically found in Site 300 groundwater at background concentrations of 21 µg/L (Webster-Scholten 1994). Based on the eight quarters of data currently available, LLNL has proposed statistical limits for nickel, and the other COCs detected above their respective RLs, at well W-829-1938 (Revelli 2006b). Continued quarterly sampling at well W-829-1938 will provide additional data to better establish background concentrations and statistically determined limits of concentrations in accordance with state regulations.

Water Supply Well

Water supply well 20, located in the southeastern part of Site 300 (**Figure 5-13**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer ($Tnbs_1$) and can produce up to 1500 L/min of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2005 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.

Off-site Surveillance Wells and Springs

As planned for surveillance purposes, LLNL obtained groundwater samples from two off-site springs and ten off-site wells during 2005. 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. One stock watering well, MUL1, and two stock watering springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04, are adjacent to the site on the south (**Figure 5-13**). Well W-35A-04 is a DOE CERCLA well that was installed off site for monitoring purposes only. The remaining seven wells south of Site 300 are privately owned and were

constructed to supply water either for human consumption, stock watering, or fire suppression. They are monitored to determine the concentrations of dissolved constituents in the groundwater beneath the Corral Hollow Creek flood plain.

Groundwater samples were obtained quarterly during 2005 at six of the off-site surveillance well locations south of Site 300. As planned, CARNRW1 and CON2 samples were analyzed for VOCs; samples from well CARNRW1 were also sampled for perchlorate and tritium. Samples from CARNRW2, CDF1, CON1, and GALLO1 were analyzed quarterly for inorganic COCs (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 on third-quarter samples for uranium activity and extractable organic compounds (EPA method 625).

Groundwater samples were obtained once (annually) during 2005 from the remaining off-site surveillance monitoring locations—MUL1, MUL2, and VIE1 (north of Site 300); VIE2 (west of Site 300); and STONEHAM1 and W-35A-04 (south of Site 300). Samples were analyzed for inorganic COCs (mostly metals), 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 COC attributable to LLNL operations at Site 300 was detected in the off-site groundwater samples. Arsenic and barium were widely detected at the off-site locations, but their concentrations were below MCLs and their occurrence is consistent with natural sources in the rocks. Scattered detections of metals are probably related to metals used in pumps and supply piping. As in past years, TCE was detected at concentrations of less than 1 µg/L in the groundwater samples obtained from well GALLO1. Previous CERCLA remedial investigations concluded that the TCE in the GALLO1 well water was likely caused by a localized surface spill on the property, possibly solvents used to service the private well (Webster-Scholten 1994). Radioactivity measurements of off-site groundwater are generally indistinguishable from background activities.

Environmental Impact on Groundwater

Groundwater monitoring at the Livermore site and Site 300 and their environs indicates that LLNL operations have minimal impact on groundwater beyond the site boundaries. During 2005, neither radioactivity nor concentrations of elements or compounds detected in groundwater were confirmed to be above potable water MCLs.

Other Monitoring Programs

Rainwater

Rainwater is sampled and analyzed for tritium activity in support of DOE Order 5400.5, Radiation Protection of the Public and the Environment. LLNL collects rainwater samples according to written standardized procedures which are summarized in the *Environmental Monitoring Plan* (Woods 2005). Rainwater is collected in stainless-steel buckets at fixed locations. The buckets are in open areas and are mounted about 1 m above the ground to prevent collection of splashback water. Rainwater samples are decanted into 250 mL amber glass bottles with Teflon-lined lids. The tritium activity of each sample is measured at a contracted laboratory by a scintillation counting method equivalent to EPA Method 906 that has a low reporting limit of about 3.7 Bq/L (100 pCi/L). All analytical results are included in the file "Ch5 Other Waters" provided on the report CD.

Livermore Site and Environs

Historically, the tritium activity measured in rainwater in the Livermore Valley was caused by atmospheric emissions of HTO from stacks at LLNL's Tritium Facility (Building 331), and prior to 1995, from the former Tritium Research Laboratory at Sandia/California. During 2005, tritium activity in air-moisture and, thence, in rainwater at the Livermore site and in the Livermore Valley, resulted primarily from atmospheric emissions of HTO from stacks at Building 331. Atmospheric emissions of HTO from Building 331 are shown in **Figure 4-4**. Other sources include the Waste Management Area (WMA) at Building 612 and the DWTF (see Chapter 4).

Rain sampling locations are shown in **Figure 5-18**. The fixed locations are used to determine the areal extent of detectable tritium activity in rainwater. During 2005, LLNL collected sets of rainwater samples following two rain events in the Livermore Valley and two rain events at Site 300. All of the rainwater sampling dates correspond to storm water runoff sampling.

Although the Livermore site rainwater has exhibited elevated tritium activities in the past (Gallegos et al. 1994), during 2005, 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. As in past years, the on-site rainwater sampling location B343 showed the highest tritium activity for the year, 12 Bq/L (324 pCi/L), for the rain event that was sampled on January 11. The maximum tritium activity measured in an off-site rainwater sample during 2005 was an estimated value below the minimum

reporting limit of 3.7 Bq/L (100pCi/L) in the rainwater sample obtained on January 11 from location VET (**Figure 5-18**).

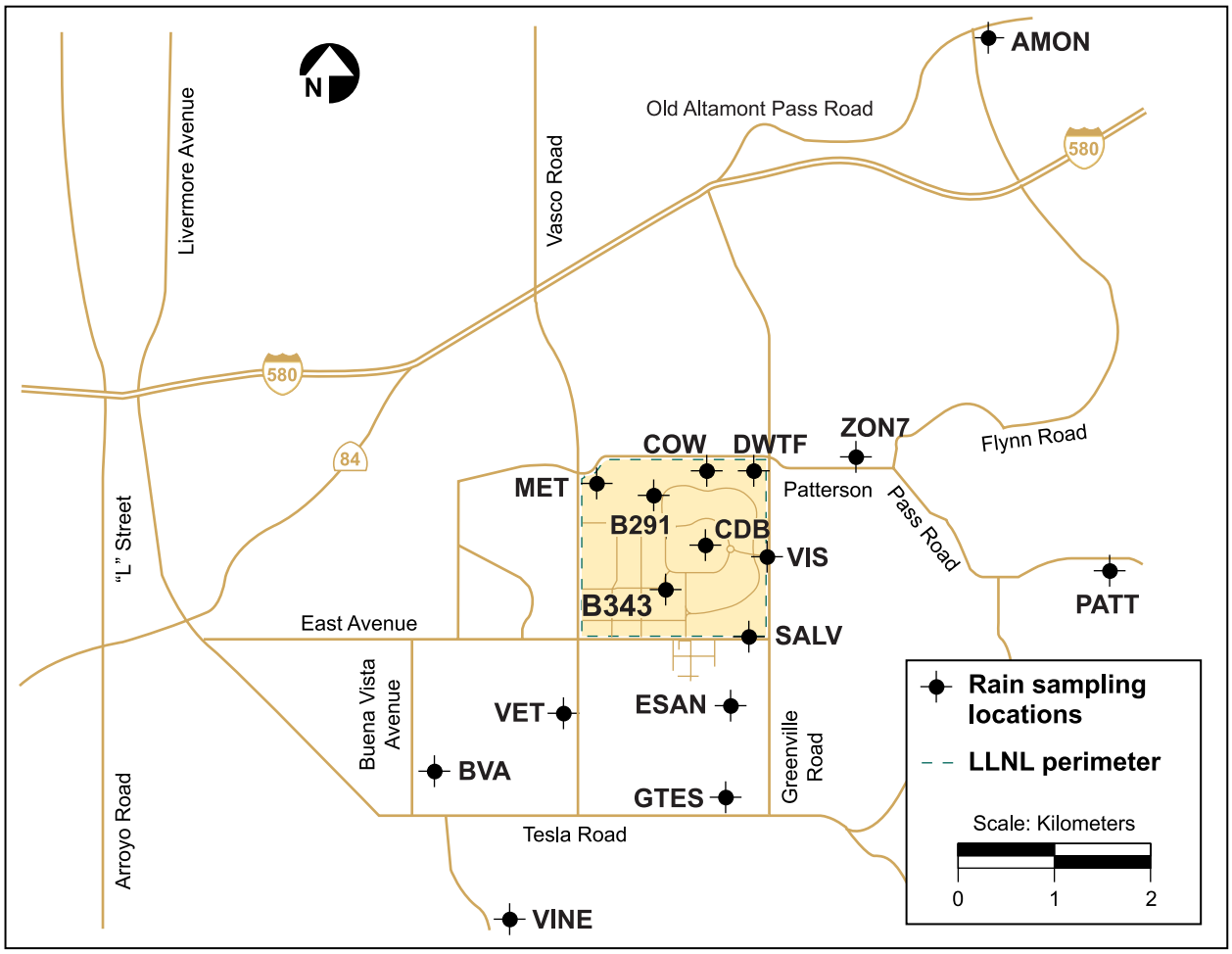


Figure 5-18. Rain sampling locations, Livermore site and Livermore Valley, 2005

Site 300 and Environs

Three on-site locations (COHO, COMP, and TNK5) were positioned to collect rainfall for tritium activity measurements at Site 300 during 2005 (**Figure 5-10**). During 2005, two rain events were sampled. As in past years, none of the rainwater samples from monitoring locations at Site 300 during 2005 had tritium activities above the analytical laboratory reporting limit of 3.7 Bq/L.

Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5, Radiation Protection of the Public and the Environment. Surface and drinking water near the Livermore site and in the Livermore Valley are sampled at the locations shown in **Figure 5-19**. Off-site sampling locations DEL, ZON7, DUCK, ALAG, SHAD, and CAL are surface water bodies; of these, DEL, ZON7, and CAL are also drinking water sources, GAS, ORCH, and TAP are drinking water outlets. Radioactivity data from drinking water sources are used to calculate drinking water statistics (see **Table 5-13**).

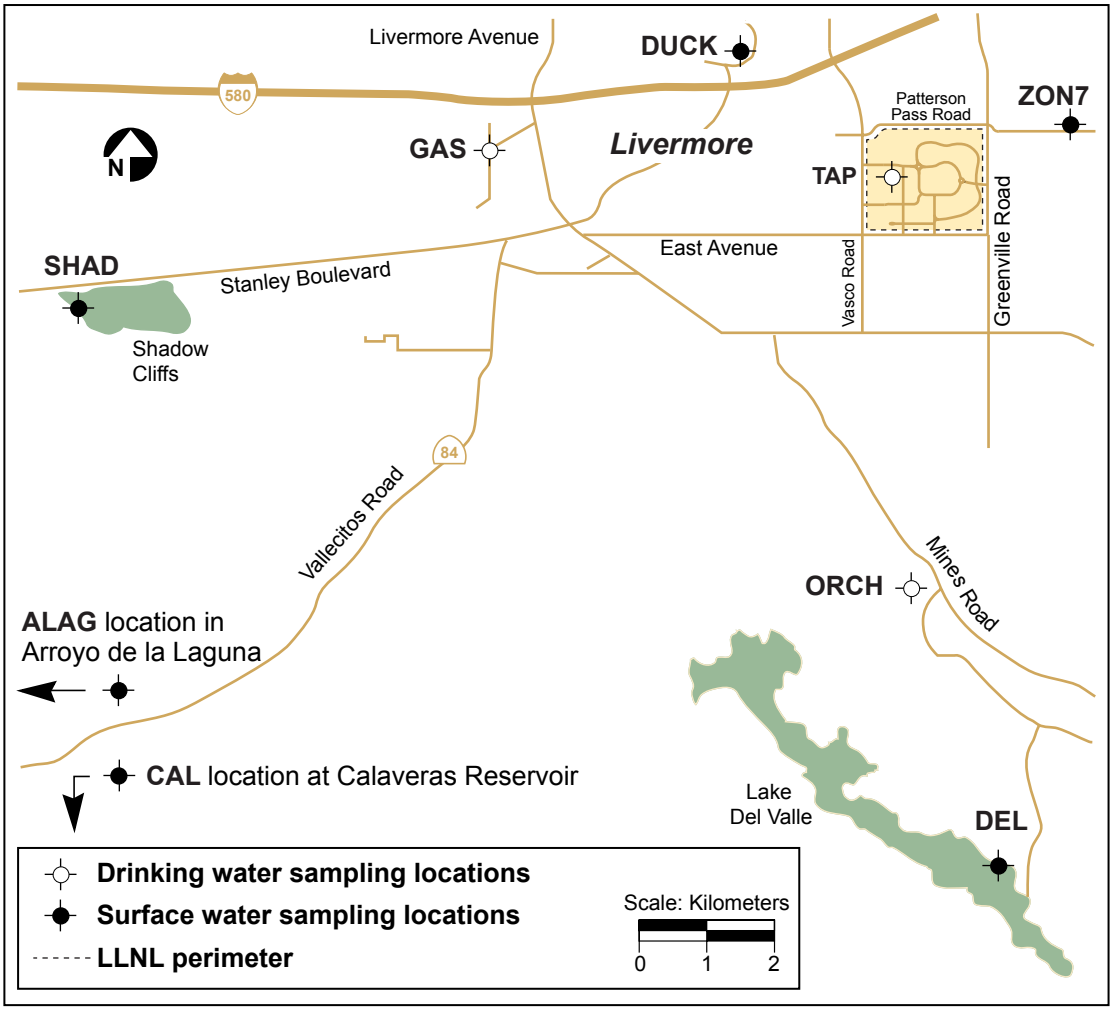


Figure 5-19. Livermore Valley surface and drinking water sampling locations, 2005

Samples are analyzed according to written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005). LLNL sampled these locations semiannually, in January and July 2005, for gross alpha, gross beta, and tritium. All analytical results are included in the file "Ch5 Other Waters" provided on the report CD.

The median activity for tritium in surface and drinking waters was estimated from calculated values to be below the analytical laboratory's minimum detectable activities, or minimum quantifiable activities. In fact, no tritium above the analytical laboratory's minimum detectable activities was detected in any sample. Median activities for gross alpha and gross beta radiation in surface and drinking water samples were both less than 5% of their respective MCLs. Maximum activities detected for gross alpha and gross beta, respectively, were 0.054 Bq/L (1.5 pCi/L) and 0.381 Bq/L (10.3 pCi/L); both were less than 25% of their respective MCLs (see **Table 5-13**). Historically, concentrations of gross alpha and gross beta radiation have fluctuated around the laboratory 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.

Since 1988, when measurements began, water in the LLNL swimming pool had the highest tritium activities because it was close to tritium sources within LLNL. After the first quarter of 2004 and the draining of the swimming pool in July 2004, the Drainage Retention Basin became the closest routinely monitored surface water to the Tritium Facility (Building 331).

Table 5-13. Radioactivity in surface and drinking waters in the Livermore Valley, 2005

Locations	Tritium (Bq/L)	Gross alpha (Bq/L)	Gross beta (Bq/L)
All locations			
Median	–2.06	0.010	0.080
Minimum	–5.07	–0.028	0.011
Maximum	0.45	0.054	0.381
Interquartile range	1.09	0.019	0.069
Drinking water locations			
Median	–2.29	0.010	0.057
Minimum	–5.07	–0.028	0.011
Maximum	–1.26	0.025	0.381
Interquartile range	0.46	0.013	0.140
Drinking water MCL	740	0.555	1.85

Note: A negative number means the sample radioactivity was less than the background radioactivity.

Drainage Retention Basin Release

The DRB was constructed and lined in 1992 after remedial action studies indicated that infiltration of storm water from the existing basin increased dispersal of groundwater contaminants. Located in the center of the Livermore site, the DRB can hold approximately 45.6 ML (37 acre-feet) of water. Previous *Environmental Reports* detail the history of the construction and management of the DRB (see Harrach et al. 1995, 1996, 1997). Beginning in 1997, LLNL discharges to the DRB included routine treated groundwater from TFD and TFE, and from related portable treatment units. These discharges contribute a year-round source of water entering and exiting the DRB. The discharge rate is approximately 380 L/min (100 gal/min). Storm water runoff still dominates wet weather flows through the DRB, but discharges from the treatment facilities now constitute a substantial portion of the total water passing through the DRB.

The SFBRWQCB regulates discharges from the DRB. The document *Drainage Retention Basin Monitoring Plan Change* (Jackson 2002) lists constituents of interest, sample frequencies, and discharge limits based on the Livermore site CERCLA Record of Decision (ROD) (U.S. DOE 1993), as modified by the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory Livermore Site* (Berg et al. 1997). The ROD established discharge limits for all remedial activities at the Livermore site to meet applicable, relevant, and appropriate requirements derived from laws and regulations identified in the ROD, including federal Clean Water Act, federal and state Safe Drinking Water Acts, and the California Porter-Cologne Water Quality Control Act. See Appendix B for the limits used.

The DRB sampling program implements requirements established by the SFBRWQCB. The program consists of monitoring wet and dry weather releases for compliance with discharge limits and performing routine reporting. For purposes of determining discharge monitoring requirements and frequency, the wet season is defined as October 1 through May 31, the period when rain-related discharges usually occur (Galles 1997). Discharge limits are applied to the wet and dry seasons as defined in the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory Livermore Site* (Berg et al. 1997) (wet season December 1 through March 31, dry season April 1 through November 30).

Discharge from the DRB is typically continuous because the evaporation rate is less than the flow into the DRB from storm water runoff and treated groundwater discharges. To characterize wet-season discharges, LLNL samples DRB discharges at location CDBX and the Livermore site outfall at location WPDC during the first release of the rainy season, and from a minimum of one additional release (chosen in conjunction with storm water

runoff sampling). During the dry season (June, July, August, September), samples are collected at the beginning of each discrete discharge event or monthly while discharge is continuous. Discharge sampling locations CDBX and WPDC are shown in **Figure 5-9**. LLNL collects samples at CDBX to determine compliance with discharge limits. Sampling at WPDC is performed to identify any change in water quality as the DRB discharges travel through the LLNL storm water drainage system and leave the site.

Written standardized sample collection procedures are summarized in the *Environmental Monitoring Plan* (Woods 2005). State-certified laboratories analyze the collected samples for chemical and physical parameters. All analytical results are included in the file "Ch5 Other Waters" provided on the report CD.

Water releases typically occurred continuously to maintain relatively low nutrient levels in the DRB and because treatment facility discharge to the DRB exceeded the evaporation rate. Samples collected at CDBX and WPDC exceeded only the pH discharge limits. The higher pH readings seen in the DRB discharge samples during the summer correspond to the peak of the summer algal bloom within the DRB. During 2005, total dissolved solids and specific conductance continued to reflect the levels found in groundwater discharged to the DRB. While some metals were detected, none were above discharge limits. All organics, pesticides, and PCBs were below analytical discharge limits. Gross alpha, gross beta, and tritium levels were well below discharge limits.

LLNL collects and analyzes samples for acute fish toxicity using fathead minnow (*Pimphales promelas*) and for chronic toxicity using three species (fathead minnow, water flea daphnid [*Ceriodaphnia dubia*], and green algae [*Selanastrum capricomutum*]). LLNL collects acute toxicity samples at the first wet-season release and from the four dry season sampling events from location CDBX. Samples for chronic fish toxicity were collected at location CDBX at the first wet-season release. Aquatic bioassays for toxicity showed no effects in DRB discharge water.

Site 300 Drinking Water System

LLNL samples large-volume discharges from the Site 300 drinking water distribution system that reach surface water drainage courses in accordance with the requirements of WDR 5-00-175, NPDES General Permit No. CAG995001. The monitoring and reporting program that LLNL developed for these discharges was approved by the CVRWQCB.

Discharges that are subject to sampling under WDR 5-00-175 and their monitoring requirements are:

- Drinking water storage tanks: Discharges that have the potential to reach surface waters are monitored.
- System flushes: One flush per pressure zone per year is monitored for flushes that have the potential to reach surface waters.
- Dead-end flushes: All flushes that have the potential to reach surface waters and any discharge that continues for more than four months are monitored.

Discharges must comply with the effluent limits for residual chlorine and pH established by the permit; that is, residual chlorine must not be greater than 0.02 mg/L, and the pH must be between 6.5 and 8.5. Discharges are also visually monitored to ensure that no erosion results and no other pollutants are washed into surface waters. To meet the chlorine limit, drinking water system discharges with the potential to reach surface waters are dechlorinated.

Sample collection procedures are discussed in the *Lawrence Livermore National Laboratory Site 300 Water Suppliers' Pollution Prevention and Monitoring and Reporting Program* (Mathews 2000). Grab samples are collected in accordance with written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005). Residual chlorine and pH are immediately analyzed in the field using a spectrophotometer and calibrated pH meter, respectively.

Samples are collected at the point of discharge and at the point where the discharge flows into a surface water. If the discharge reaches Corral Hollow Creek, samples are collected at the upstream sampling location, CARW2, and the downstream sampling location, GEOCRK.

During March 2005, the replacement of a fire hydrant flow valve necessitated the discharge of approximately 6000 gallons of water. This water was dechlorinated and released through a diffuser; sampling measurements, completed at the discharge location, showed the pH and residual chlorine to be in compliance with WDR 5-00-175 discharge requirements. Additionally, small volumes of water (less than 2000 gallons) were discharged in the first quarter of 2005, as a result of routine pressure tests conducted by the Site 300 fire department. Because of the nature of fire department activities, these small-volume discharges were not monitored. The annual pressure zone testing, required by the CVRWQCB, was completed during the third quarter, when LLNL conducted flushing of the drinking water system for water quality purposes. These system flush releases were monitored and met the effluent limits. All 2005 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 (Raber 2004). Monitoring results are detailed in the quarterly self-monitoring reports to the CVRWQCB.

Site 300 Cooling Towers

On August 4, 2000, the CVRWQCB rescinded WDR 94-131, NPDES Permit No. CA0081396, which previously governed discharges from the two primary cooling towers at Site 300. The CVRWQCB determined that these cooling towers discharge to the ground rather than to surface water drainage courses. Therefore, the CVRWQCB is issuing a new permit to incorporate these cooling tower discharges, and other low-threat discharges, going to ground. Pending the issuance of the new permit, LLNL continues to monitor the cooling tower wastewater discharges following the WDR 94-131 monitoring requirements at the direction of CVRWQCB staff.

Two primary cooling towers, located at Buildings 801 and 836A, regularly discharged to the ground during the first quarter of 2005. As in past years, blowdown flow from the cooling towers located at these two buildings was monitored biweekly and total dissolved solids (TDS) and pH were monitored quarterly. On April 13, 2005, the cooling tower at Building 836A was replaced with an air cooled system; discharges and monitoring were discontinued at that time. Biweekly flow and quarterly TDS and pH monitoring at cooling tower 801 continued throughout the year. The 13 secondary cooling towers routinely discharge to percolation pits under a waiver of Waste Discharge Requirements from the CVRWQCB. Cooling tower locations are shown in **Figure 5-20**.

Written standardized sample collection procedures are summarized in the *Environmental Monitoring Plan* (Woods 2005). To determine the effects of the cooling tower blowdown on Corral Hollow Creek, LLNL quarterly monitors pH, both upstream (background) and downstream of the cooling tower discharges, whenever the creek is flowing. CARW2 is the upstream sampling location, and GEOCRK is the downstream sampling location (**Figure 5-20**).

The GEOCRK sampling location is fed by sources from Site 300 and neighboring lands. Therefore, even when the upstream location is dry, there may be flow at GEOCRK. Field pH measurements, taken by LLNL using calibrated meters, are used to monitor Corral Hollow Creek. LLNL also performs the required visual observations that are recorded on field tracking forms along with the field pH measurements.

If the blowdown flow from any of the 13 secondary cooling towers is diverted to a surface water drainage course, the discharge is sampled for pH and TDS immediately. If the discharge continues, that location is monitored for the same constituents and on the same schedule as the primary cooling towers.

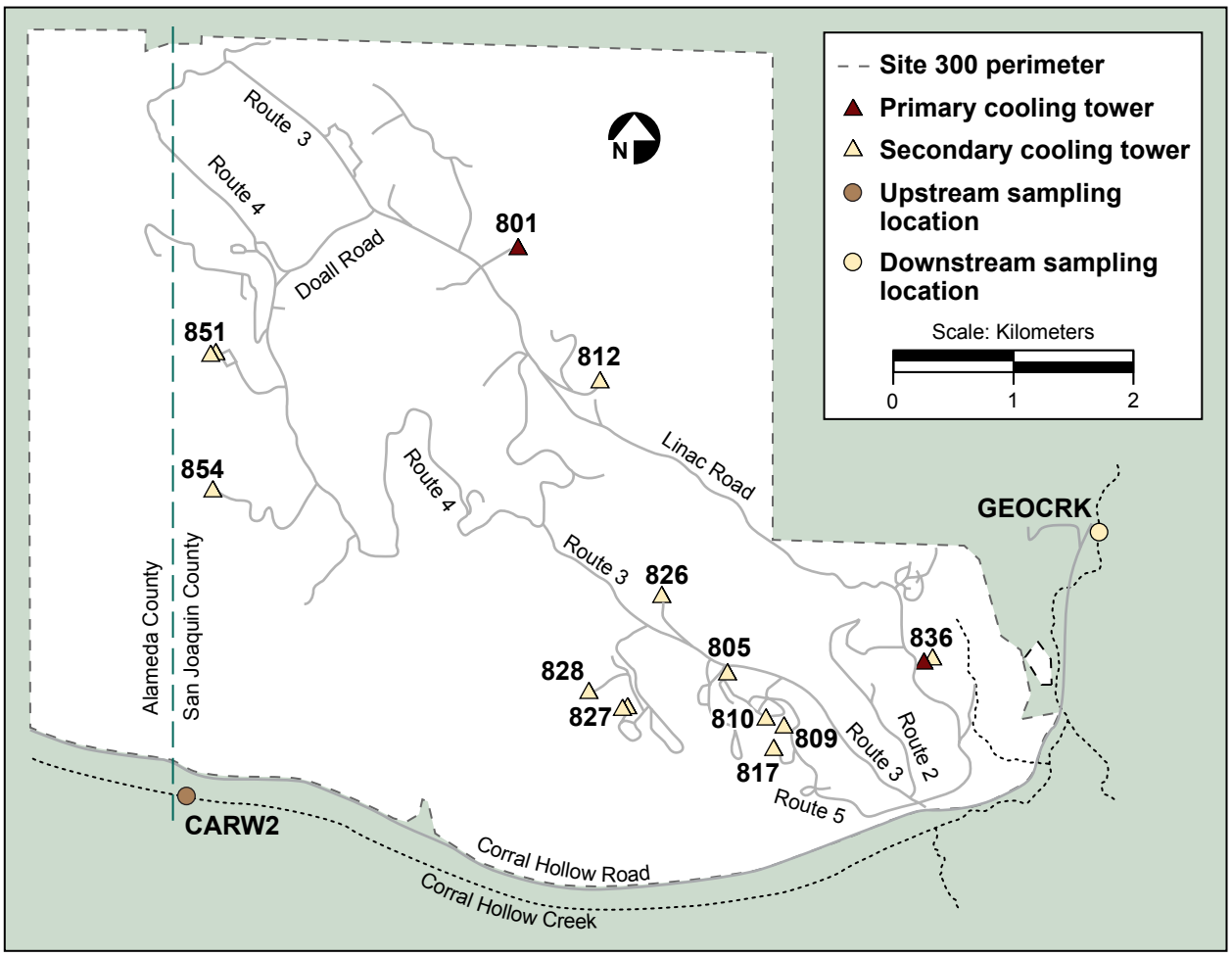


Figure 5-20. Cooling tower locations and receiving water monitoring locations, Site 300, 2005

Monitoring results in 2005 indicate that all discharges from the Building 801 and Building 836A cooling towers were below the maximum TDS (2400 mg/L) and pH (10) values that were previously imposed for discharges to surface water drainage courses under WDR 94-131. The blowdown flow rates from these towers were typical of volumes reported in recent years, except for two slightly elevated values (approximately twice the median value) that were recorded at the Building 801 tower. On July 14 and November 1, the blowdown flow rates were reported as 16,012 L/day and 16,588 L/day, respectively. In both cases, the flow readings for the preceding and following observation periods reported typical volumes, indicating that these high flows were transient events. No flow was observed at either the CARW2 or GEOCRK locations during the periods in question. **Table 5-14** summarizes the data from the quarterly TDS and pH monitoring, as well as the biweekly measurements of blowdown flow rate.

Table 5-14. Summary data from monitoring of primary cooling towers, Site 300, 2005

Test	Tower no.	Minimum	Maximum	Median	Interquartile range	Number of samples
Total dissolved solids (TDS) (mg/L)	801	1,000	2,200	1,300	—[a]	4
	836A	980	980	—[b]	—[a]	1[b]
Blowdown (L/day)	801	0	16,588	8,146	1,173	25[c]
	836A	1,393	2,514	2,241	589	7[b]
pH (pH units)	801	8.7	9.1	8.9	—[a]	4
	836A	8.8	8.8	—[b]	—[a]	1[b]

a Too few data points to determine

b Only one quarterly sample and seven biweekly blowdown measurements were collected. The monitoring program at cooling tower 836A was discontinued April 13, 2005, after that cooling tower was replaced with an air-cooled system.

c One biweekly blowdown measurement could not be collected because the area around Tower 801 was closed.

The biweekly observations at CARW2 and GEOCRK reported flowing conditions for both sampling locations during the first four months (January through April) of 2005. The resulting field pH measurements were between 7.56 and 8.96 at the CARW2 location, and between 7.97 and 8.99 at GEOCRK. These results indicate essentially no change in pH between the upstream and downstream locations. Dry or no flow conditions were reported for the remaining eight months of 2005. Visual observations of Corral Hollow Creek were performed each quarter, and no visible oil, grease, scum, foam, or floating suspended materials were noted in the creek during 2005.

No drinking water or cooling tower water releases from Site 300 reached Corral Hollow Creek. There is no evidence of any adverse environmental impact on surrounding waters resulting from these LLNL activities during 2005.

Terrestrial Monitoring

CHAPTER 6

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Introduction

Lawrence Livermore National Laboratory monitors several aspects of the terrestrial environment. LLNL measures the radioactivity present in soil, sediment, vegetation, and wine, and the absorbed gamma radiation dose at ground level receptors from terrestrial and atmospheric sources. In addition, LLNL monitors the abundance, distribution, and ecological requirements of plant and wildlife species as part of compliance activities and research programs.

The LLNL terrestrial radioactivity monitoring program is designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. All monitoring activity follows U.S. Department of Energy (DOE) guidance. Monitoring on site or in the vicinity of the Livermore site or Site 300 detects radioactivity released from LLNL that may contribute to radiological dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation.

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

Surface soil samples are analyzed for plutonium and gamma-emitting radionuclides. Gamma-emitting radionuclides in surface soils include uranium isotopes, which are used to provide data about the natural occurrence of uranium as well as data about the effects of explosive tests at Site 300, some of which contain depleted uranium. Other gamma-emitting, naturally occurring nuclides (potassium-40 and thorium-232) provide additional data about local background conditions, and the long-lived fission product cesium-137 provides information on global fallout from historical nuclear weapons testing. In addition, soils at Site 300 are analyzed for beryllium, a potentially toxic metal used there. With the addition of tritium, a similar suite of nuclides is analyzed in the sediments. Concentrations in soil to be taken from the vadose zone (the region below the land surface where the soil pores are only partially filled with water) are compared with de minimis concentrations for tritium and background concentrations for metals. Vegetation and wine samples are measured for tritium alone because tritium is the only nuclide released from LLNL that can be measured in these products. Cosmic radiation accounts for about half the absorbed gamma dose measured by the TLDs; naturally occurring isotopes of the uranium-thorium-actinium decay series provide the dose from natural background radiation found in the earth's crust. By characterizing the background radiation, LLNL can determine what, if any, excess dose can be attributed to laboratory operations.

Surface soils near the Livermore site and Site 300 have been sampled since 1971. Around the Livermore site, sediments (from selected arroyos and other drainage areas) and vadose zone soils have been sampled since 1988 and 1996, respectively; sampling of sediments or vadose zone soils is not warranted at Site 300. LLNL has been monitoring tritium in vegetation since 1966 and has performed routine vegetation sampling on and around the Livermore site and Site 300 since 1971. External radiation has been monitored around the Livermore site since 1973 and around Site 300 since 1988.

Sampling for all media is conducted according to written, standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005).

LLNL also monitors wildlife and plants at the Livermore site and Site 300, and carries out research relevant to the protection of rare plants and animals. Some monitoring and research programs are required by existing permits, while additional monitoring programs are designed to track the distribution and abundance of rare species. In addition, baseline surveys are conducted to determine distribution of special status species on LLNL property. 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 the California Native Plant Protection Act as they pertain to endangered or threatened species and other special status species, their habitats, and designated critical habitats that exist at the LLNL sites.

Soil and Sediment Monitoring

There are 6 soil and 4 sediment sampling locations on LLNL's Livermore site (**Figure 6-1**); 13 soil sampling locations in the Livermore Valley, including 6 at the Livermore Water Reclamation Plant (LWRP) (**Figure 6-2**); and 14 soil sampling locations at Site 300 (**Figure 6-3**). The locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas where there is the potential to be affected by LLNL operations. Areas with known contaminants, such as the LWRP and areas around explosives tests areas at Site 300, are also sampled.

Surface sediment and vadose zone soils are collected from selected arroyos and other drainage areas at and around the Livermore site; these locations (**Figure 6-1**) largely coincide with selected storm water sampling locations (see Chapter 5). Soils in the vadose zone are collected in arroyo channels at the Livermore site as part of the Ground Water Protection Management Program. Infiltration of natural runoff through arroyo channels is a significant source of groundwater recharge, accounting for an estimated 42% of resupply for the entire Livermore Valley groundwater basin (Thorpe et al. 1990). The collocation of sampling for sediment and storm water runoff facilitates comparison of analytical results.

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 the center of each square with an 8.25 cm diameter stainless steel core sampler. Surface sediment samples are collected in a similar manner. Ten subsamples, 5-cm deep, are collected at 1-m intervals along a transect of the arroyo or drainage channel. At one of the subsample locations, a 15-cm deep sample is acquired 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. A hand auger is used to collect a 30- to 45-cm deep sample for metals analysis, and an electric drive coring device is used to collect a sample 45- to 65-cm deep for analysis for polychlorinated biphenyls (PCBs).

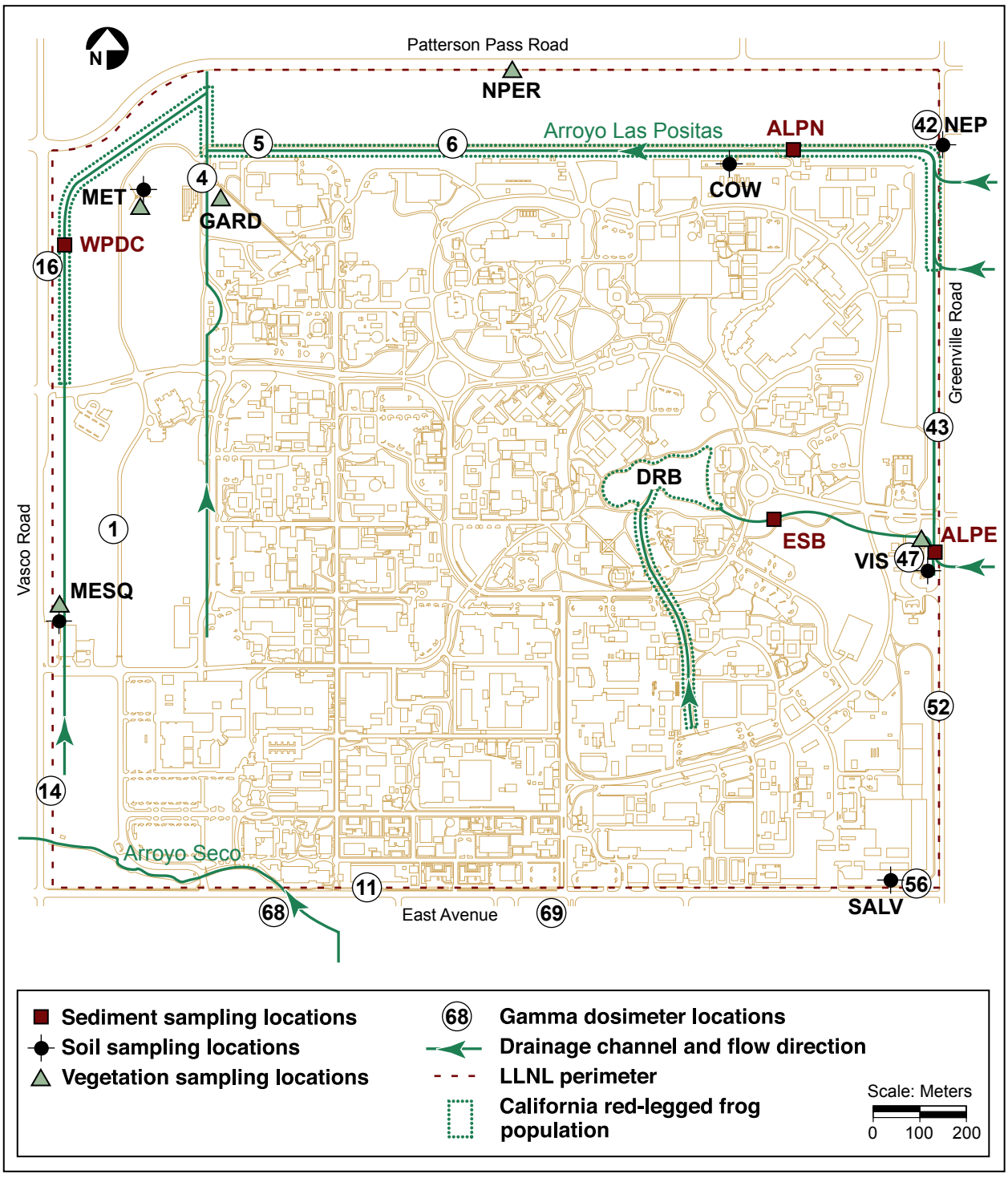


Figure 6-1. Sampling locations and California red-legged frog populations, Livermore site, 2005

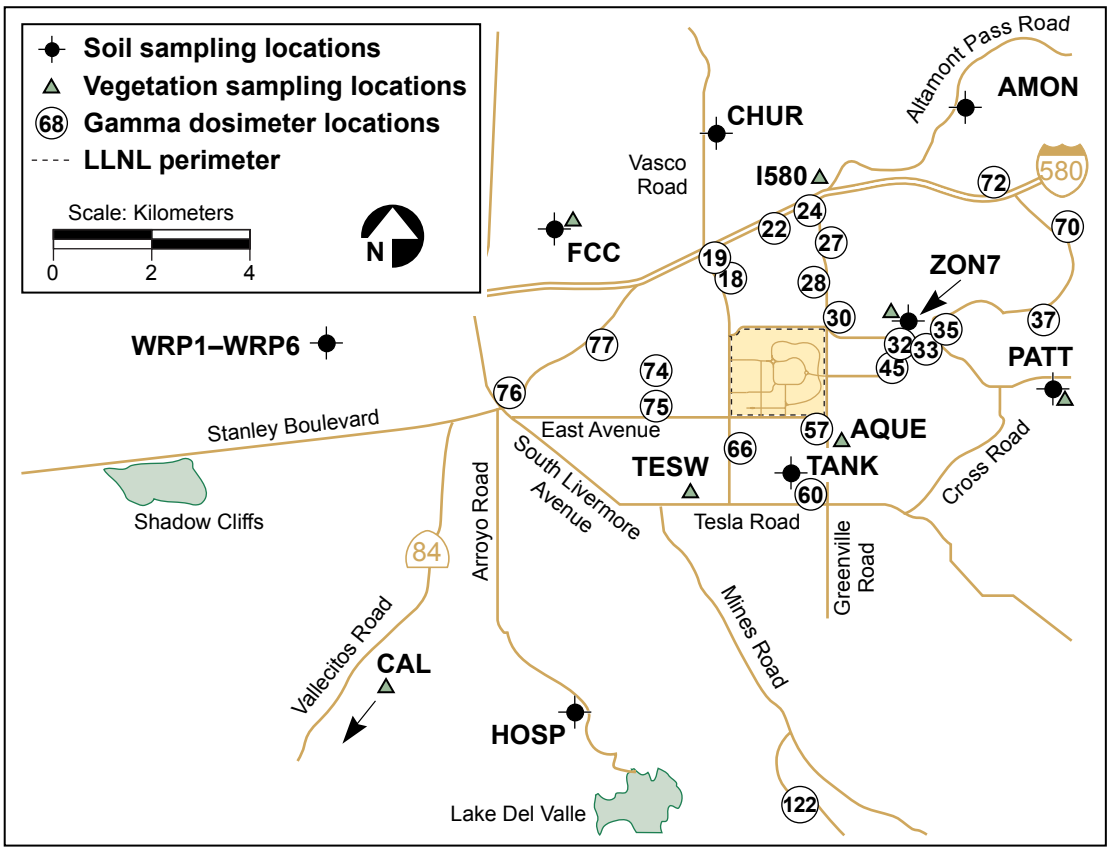


Figure 6-2. Sampling locations, Livermore Valley, 2005

In 2005, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Annual sediment samples collected at the Livermore site were analyzed for plutonium, gamma-emitting radionuclides, and tritium. Vadose zone samples were analyzed for total and soluble metals; one vadose zone location was analyzed for PCBs.

Prior to radiochemical analysis, surface soil and sediment samples are 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. The 10-g subsamples for beryllium analyses are analyzed by atomic emission spectrometry.

Vadose zone soil samples are analyzed by standard EPA methods. In 2005, as in the previous five years, a vadose zone soil sample from location ESB (**Figure 6-1**) was also analyzed for PCBs.

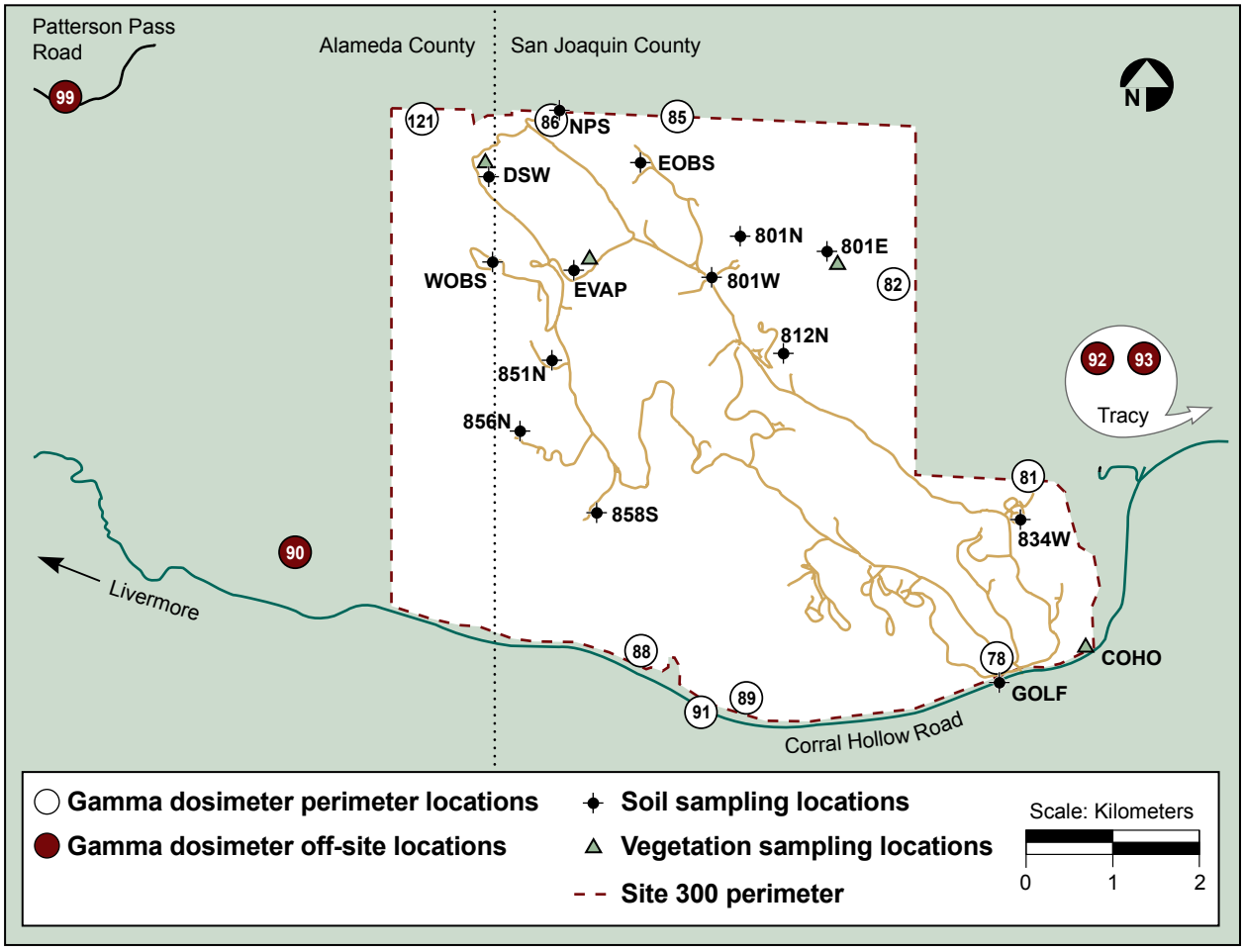


Figure 6-3. Sampling locations at Site 300 and off-site, 2005

Radiological Monitoring Results

Tables 6-1 through **6-3** present data on the concentrations of plutonium-238 and plutonium-239+240 in the Livermore Valley surface soils and sediments; data for americium-241, which is only detected at LWRP; and data for tritium, which is only measured in surface sediments. Data for cesium-137, potassium-40, thorium-232, uranium-235, and uranium-238 in surface soils from the Livermore Valley sampling locations are included in the file "Ch6 Soil" provided on the report CD.

Table 6-1. Plutonium activity concentrations in Livermore Valley soil, 2005

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)
L-AMON-SO	0.0077 ± 0.0024	0.054 ± 0.010
L-CHUR-SO	0.0085 ± 0.0030	0.12 ± 0.021
L-COW-SO	0.0065 ± 0.0034	0.023 ± 0.0065
L-FCC-SO	0.0032 ± 0.0015	0.069 ± 0.013
L-HOSP-SO	0.0060 ± 0.0022	0.028 ± 0.0060
L-MESQ-SO	0.0018 ± 0.0013	0.028 ± 0.0060
L-MET-SO	0.0020 ± 0.0013	0.040 ± 0.0078
L-NEP-SO	0.0031 ± 0.0020	0.055 ± 0.011
L-PATT-SO	0.0028 ± 0.0016	0.036 ± 0.0077
L-SALV-SO	0.0079± 0.0027	0.094 ± 0.017
L-TANK-SO	0.0057± 0.0023	0.11 ± 0.020
L-VIS-SO	0.023 ± 0.0052	0.39 ± 0.063
L-ZON7-SO	0.0078 ± 0.0026	0.020 ± 0.0048
Median	**0.0060**	**0.054**
IQR[a]	**0.0047**	**0.066**
Maximum	**0.023**	**0.39**

Note: Radioactivities are reported as the measured concentration and either 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 Chapter 9.

a IQR = Interquartile range

Table 6-2. Plutonium and americium activity concentrations in LWRP soil, 2005

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Americium-241 (mBq/dry g)
L-WRP1-SO	0.44 ± 0.071	8.2 ± 1.3	5.6 ± 1.4
L-WRP2-SO	0.26 ± 0.043	4.9 ± 0.77	<1.2
L-WRP3-SO	0.026 ± 0.0055	0.47 ± 0.075	<0.53
L-WRP4-SO	0.044 ± 0.0088	0.64 ± 0.10	<0.67
L-WRP5-SO	0.11 ± 0.019	2.0 ± 0.32	<2.1
L-WRP6-SO	0.12 ± 0.021	2.3 ± 0.36	<1.1
Median	**0.12**	**2.2**	**<1.2**
IQR[a]	**0.16**	**3.3**	**—[b]**
Maximum	**0.44**	**8.2**	**5.6**

Note: Radioactivities are reported as the measured concentration and either 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 Chapter 9.

a IQR = Interquartile range

b Interquartile range not calculated because of high incidence of nondetections.

Table 6-3. Plutonium and tritium activity concentrations in surface sediment, 2005

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Tritium (Bq/L)
L-ALPE-SD	0.0028 ± 0.0013	0.032 ± 0.0064	0.74 ± 2.1
L-ALPN-SD	0.0031 ± 0.0014	0.013 ± 0.0033	5.6 ± 2.2
L-ESB-SD	0.22 ± 0.036	1.8 ± 0.29	15 ± 2.4
L-WPDC-SD	0.0013 ± 0.0015	0.0066 ± 0.0029	1.4 ± 2.1
Median	**0.0030**	**0.023**	**3.5**
IQR[a]	**—[b]**	**—[b]**	**—[b]**
Maximum	**0.22**	**1.8**	**15**

Note: Radioactivities are reported as the measured concentration and either 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 Chapter 9.

a IQR = Interquartile range

b Interquartile range not calculated because of high incidence of nondetections

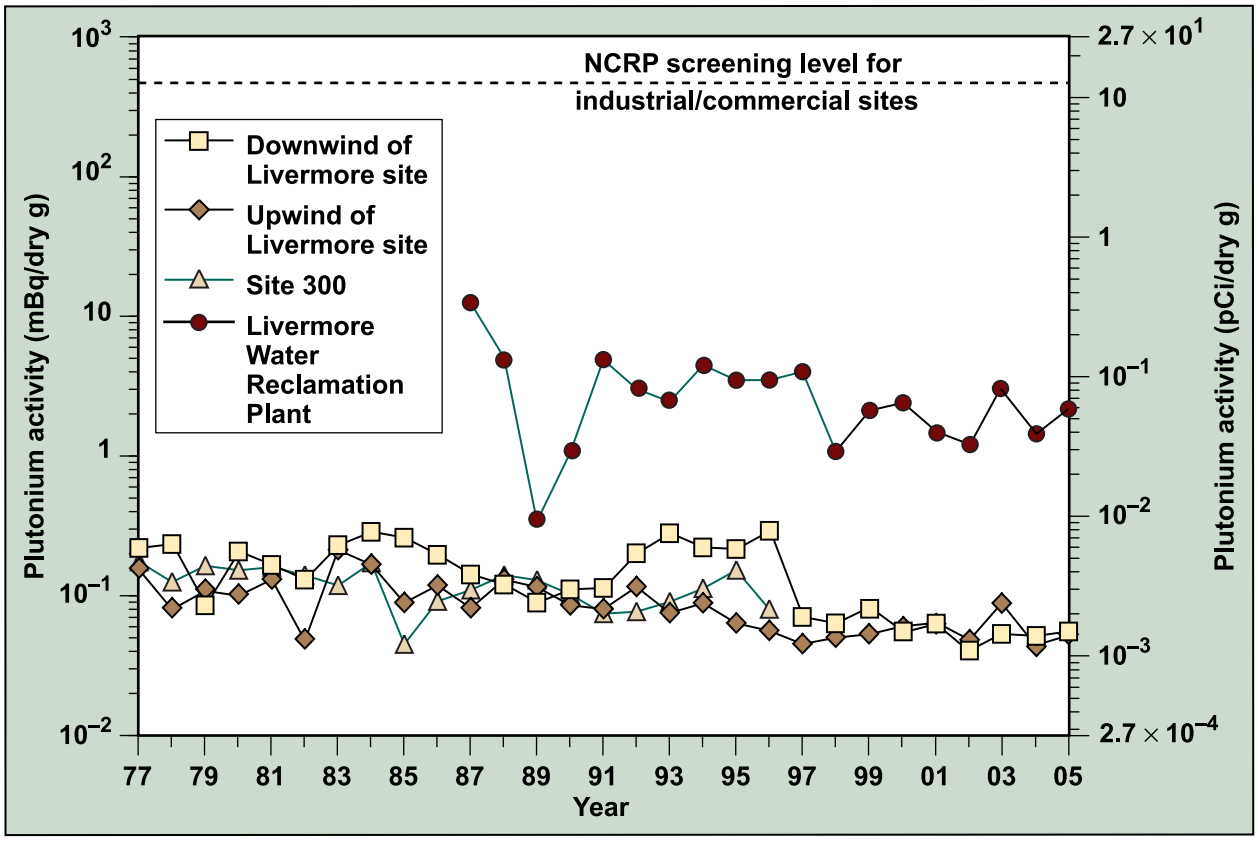
The concentrations and distributions of all observed radionuclides in soil for 2005 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Plutonium has, in the past, been detected at levels above background at VIS, a perimeter sampling location near the east boundary of the Livermore site. In 2005, the measured plutonium-239+240 value for VIS was 0.39 mBq/dry g (1.05×10^{-2} pCi/dry g), a value that is less than the 95% upper confidence level for the 95th percentile calculated for background data (i.e., 0.48 mBq/dry g [1.3×10^{-2} pCi/dry g]) (LLNL 1998, Appendix D). The slightly higher values at and near the Livermore site have been attributed to historic operations (Silver et al. 1974), including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant. LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste.

A sediment sampling location, ESB, also shows the effects of historic operation of the solar evaporators; it is in the drainage area for the southeast quadrant at LLNL. The measured value for plutonium-239+240 at this location for 2005 was 1.8 mBq/dry g (4.9×10^{-2} pCi/dry g). The highest detected value for tritium, 15 Bq/L (407 pCi/L), was at location ESB, which is located downwind of the Tritium Facility. There was a slight increase in tritium emissions from the Tritium Facility in 2005, as described in Chapter 4. However, all tritium concentrations were within the range of previous data. LLNL will continue to evaluate tritium in sediment.

Elevated levels of plutonium-239+240 (resulting from an estimated 1.2×10^{9} Bq [32 mCi] plutonium release to the sanitary sewer in 1967 and earlier releases) were again detected at LWRP sampling locations. In

addition, americium-241 was detected in one LWRP sample; it was most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in the releases to the sewer.

Historical median plutonium-239+240 concentrations in soil in the Livermore Valley upwind and downwind of the center of the LLNL Livermore site and at LWRP are shown in **Figure 6-4**. Livermore Valley upwind concentrations have remained relatively constant since monitoring began and generally are indicative of worldwide fallout. Greater variation can be noted over time in the downwind concentration data compared with the upwind concentration data. In 2005 the downwind location sites included VIS, PATT, NEP, COW, AMON, SALV, and ZON7. Notable variability in plutonium-239+240 is also seen in samples from LWRP. Because the plutonium-239+240 is likely to be present in discrete particles, the random presence or absence of the particles dominates the measured plutonium-239+240 in any given sample.



Note: Upwind and downwind designations are relative to the center of the Livermore site.
NCRP = National Council on Radiation Protection and Measurements

Figure 6-4. Median plutonium-239+240 activities in surface soils, 1977–2005

Table 6-4 presents data on the concentrations of uranium-235, uranium-238, and beryllium in soil from the Site 300 sampling locations; 2005 soils data for Site 300 for cesium-137, potassium-40, and thorium-232 are included in the file "Ch6 Soil" provided on the report CD. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2005 lie within the ranges reported in all years since monitoring began. At 10 of the 14 sampling locations, the ratio of uranium-235 to uranium-238 reflects the natural ratio of 0.7%. 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 and the lowest ratio of uranium-235 to uranium-238 for 2005 occurred at 812N. The uranium-235 to uranium-238 ratio in this sample equals the ratio for depleted uranium (i.e., 0.002). Such values at Site 300 result from the use of depleted uranium in explosive experiments.

Nonradiological Monitoring Results

Analytical results for metals are compared with site-specific natural background concentrations for metals. (See the file "Ch6 Soil" provided on the report CD for the background concentrations for both the Livermore site and Site 300 and analytical results for metals.)

All metals concentrations at the Livermore site were within site background, with the exception of total and soluble zinc at location ESB. Livermore site groundwater surveillance monitoring (see Chapter 5) will determine the impacts, if any, on site groundwater. Since 2000 when surveillance for PCBs at this location began, Aroclor 1260 (a PCB) has been detected at location ESB. In 2005, it was again detected at location ESB at a concentration of 1.7 mg/kg. The presence of PCBs suggests that this sample represents residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see Chapter 5). The detected concentrations are below the federal and state hazardous waste limits.

Beryllium results for soils at Site 300 (**Table 6-4**) were within the ranges reported since sampling began in 1991. The highest value, 5.6 mg/kg, was found at B812, which is an area that has been used for explosives testing. This value is much less than the 110 mg/kg detected at B812 in 2003. These differing results reflect the particulate nature of the contamination.

Table 6-4. Uranium and beryllium concentrations in Site 300 soil, 2005

Location	Uranium-235[a] (µg/dry g)	Uranium-238[b] (µg/dry g)	U235/U238 ratio[c]	Beryllium (mg/kg)
3-801E-SO	0.019 ± 0.0083	1.7 ± 0.81	0.011 ± 0.0072	<0.5
3-801N-SO	0.041 ± 0.011	9.7 ± 2.1	0.0042 ± 0.0015	0.51
3-801W-SO	0.024 ± 0.0083	5.4 ± 2.6	0.0044 ± 0.0026	<0.5
3-812N-SO	0.23 ± 0.017	130 ± 9.1	0.0018 ± 0.00018	5.6
3-834W-SO	0.023 ± 0.015	1.7 ± 1.9	—[d]	<0.5
3-851N-SO	0.026 ± 0.013	2.7 ± 1.5	0.0096 ± 0.0072	0.57
3-856N-SO	0.020 ± 0.0084	2.4 ± 3.0	—[d]	<0.5
3-858S-SO	0.026 ± 0.013	2.6 ± 1.6	0.010 ± 0.0079	<0.5
3-DSW-SO	0.022 ± 0.0091	3.1 ± 0.94	0.0071 ± 0.0036	<0.5
3-EOBS-SO	0.020 ± 0.0089	1.6 ± 1.9	—[d]	<0.5
3-EVAP-SO	0.038 ± 0.012	5.9 ± 2.1	0.0064 ± 0.0031	<0.5
3-GOLF-SO	0.020 ± 0.0091	1.1 ± 1.6	—[d]	<0.5
3-NPS-SO	0.020 ± 0.011	3.2 ± 2.0	0.0063 ± 0.0052	<0.5
3-WOBS-SO	0.052 ± 0.010	19 ± 2.6	0.0027 ± 0.00065	<2.5
Median	**0.024**	**2.9**	**0.0064**	**<0.5**
IQR[e]	**0.015**	**3.9**	**0.0047**	**—[f]**
Maximum	**0.23**	**130**	**0.011**	**5.6**

Note: Radioactivities are reported as the measured concentration and either 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 Chapter 9.

a Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by specific activity of uranium-235 (i.e., 0.080 Bq/µg or 2.15 pCi/µg).

b Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by specific activity of uranium-238 (i.e., 0.01245 Bq/µg or 0.3367 pCi/µg).

c Ratio of uranium-235 to uranium-238 is 0.00725 for naturally occurring uranium and 0.002 for depleted uranium.

d Not calculated because of uranium-235 or uranium-238 nondetections.

e IQR = Interquartile range

f Interquartile range not calculated because of high incidence of nondetections.

Environmental Impact on Soil and Sediment

Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2005 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 of 8.2 mBq/dry g (0.22 pCi/dry g) for plutonium-239+240 measured at LWRP is 2% of the National Council on Radiation Protection and Measurements (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999). Regression analysis of the annual medians of the upwind and downwind data groups shows a slight decrease in plutonium-239+240 values with time.

Over the years, LLNL has frequently investigated the presence of radionuclides in local soils. Several of the studies are listed in **Table 6-5**. These studies have consistently shown that the concentrations of radionuclides in local soils are below levels of health concern.

Table 6-5. Special soil and sediment studies

Year	Subject[a]	Reference
1971–1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972; Gudiksen et al. 1973
1973	Radionuclides in San Joaquin Valley soil	Silver et al. 1974
1974	Soil study of southeast quadrant of Livermore site	Silver et al. 1975
1976	Evaluation of the Use of Sludge Containing Plutonium as a Soil Conditioner for Food Crops	Myers et al. 1976
1977	Sediments from LLNL to the San Francisco Bay	Silver et al. 1978
1980	Plutonium in soils downwind of the Livermore site	Toy et al. 1981
1990	195 samples taken in southeast quadrant for study	Gallegos et al. 1992
1991	Drainage channels and storm drains studied	Gallegos 1991
1993	EPA studies southeast quadrant	Gallegos et al. 1994
1993	Historic data reviewed	Gallegos 1993
1995	LLNL, EPA, and DHS sample soils at Big Trees Park	MacQueen 1995
1999	Summary of results of 1998 sampling at Big Trees Park	Gallegos et al. 1999
2000	Health Consultation, Lawrence Livermore National Laboratory, Big Trees Park 1998 Sampling	ATSDR 2000
2002	Livermore Big Trees Park:1998 Results	MacQueen et al. 2002
2003	ATSDR Public Health Assessment Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community	ATSDR 2003

a See Acronyms and Abbreviations for list of acronyms.

Site 300

The concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 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 occur near firing tables at Buildings 801 and 812. They result from the fraction of the firing table operations that disperse depleted uranium. The uranium-238 concentrations are below the NCRP recommended screening level for commercial sites of 313 µg/g (3.9 Bq/g or 105 pCi/g). Historically, some measured concentrations of uranium-238 near Building 812 have been greater than the screening level. A Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial investigation is underway at the Building 812 firing table area to define the nature and extent of contamination.

Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore site (**Figure 6-1**) and in the Livermore Valley (**Figure 6-2**) are divided into three groups (Near, Intermediate, and Far) for comparison. Tritium from LLNL operations may be detected at the Near and Intermediate locations depending upon wind direction and the magnitude of the releases. Near locations (AQUE, GARD, MESQ, NPER, MET, and VIS) are onsite or within 1 km of the LLNL site perimeter; Intermediate locations in the Livermore Valley (I580, PATT, TESW, and ZON7) are greater than 1 and less than 5 km from the LLNL perimeter. Far locations are highly unlikely to be affected by LLNL operations; one background location (CAL) is more than 25 km distant, and the other (FCC) is about 5 km from the Livermore site but generally upwind.

There are four monitoring locations for vegetation at Site 300 (**Figure 6-3**). Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to uptake of contaminated groundwater by roots. At the two other locations, 801E and COHO, the only potential source of tritium uptake is the atmosphere.

Wines for sampling in 2005 were purchased from a supermarket in Livermore. Wines represent the Livermore Valley, two regions of California, and the Rhone Valley in France.

Water is extracted from vegetation by freeze-drying and counted for tritiated water (HTO) using liquid scintillation techniques. Both HTO and organically bound tritium (OBT) are detected in wine using helium-3 mass spectrometry, but the relative fractions of each are not determined.

Vegetation Monitoring Results

All concentrations of tritium in Livermore vegetation for 2005 are shown in **Table 6-6.** The highest mean tritium concentration in vegetation for 2005 was at the Near location MET, although concentrations at MESQ and NPER were quite similar. High concentrations of 12 Bq (320 pCi)/L at MET in the third quarter and 13 Bq (350 pCi)/L at MESQ in the fourth quarter may have been due to the presence of a transportainer containing tritiated equipment (see air tritium discussion in Chapter 4).

Median values for each set of sampling locations are graphed in **Figure 6-5** to show the trend in tritium concentrations in vegetation since 1972. Median concentrations at the Far and Intermediate locations have been below the detection limits for several years. Since 2003, the median concentrations for Near locations have also been below detection limits. The lower limit of detection (LLD) of scintillation counting has varied over the years, and a comparison of results based on the recent mean value of the LLD of about 2.0 Bq/L (54 pCi/L) eliminates some variability arising from uncertain counting statistics at these low levels. Detectable concentrations were higher in 2005 than in 2004 primarily due to higher releases from the Tritium Facility. The highest concentration in plant water in 2005 was just 1.8% of the drinking water standard (740 Bq or 20,000 pCi/L). Median concentrations in vegetation have decreased noticeably since 1989 (**Figure 6-5**); at MET, the only onsite location that was sampled in 1989, the annual median concentration of tritium in plant water in 2005 was sixteen times lower than it was in 1989.

Between 1996 and 2004, concentrations in needles from a pine tree growing near Building 292 were reported in the Environmental Report. Because the tree was rooted in groundwater having elevated concentrations of tritium, its annual median concentrations were on average more than 20 times higher than those of Near vegetation. Sampling was not carried out on this tree in 2005 because it was no longer necessary to treat it as a minor source of tritium for compliance dose calculations (Harrach et al. 2005) and because it was infested with red turpentine bark beetles. In August 2005, a large limb broke off the tree, and in January 2006 the tree was removed. Analysis of a representative core of the tree revealed concentrations of HTO and OBT of 0.0807 Bq/g (2.18 pCi/g) and 0.455 Bq/g (12.3 pCi/g) respectively. Because the concentration in the tree was greater than the 0.185 Bq/g (5 pCi/g) that can

be taken to the local landfill for disposal, the tree was treated as radioactive waste and moved to the Nevada Test Site.

Table 6-6. Quarterly concentrations of tritium in plant water (Bq/L) and mean annual ingestion doses, 2005

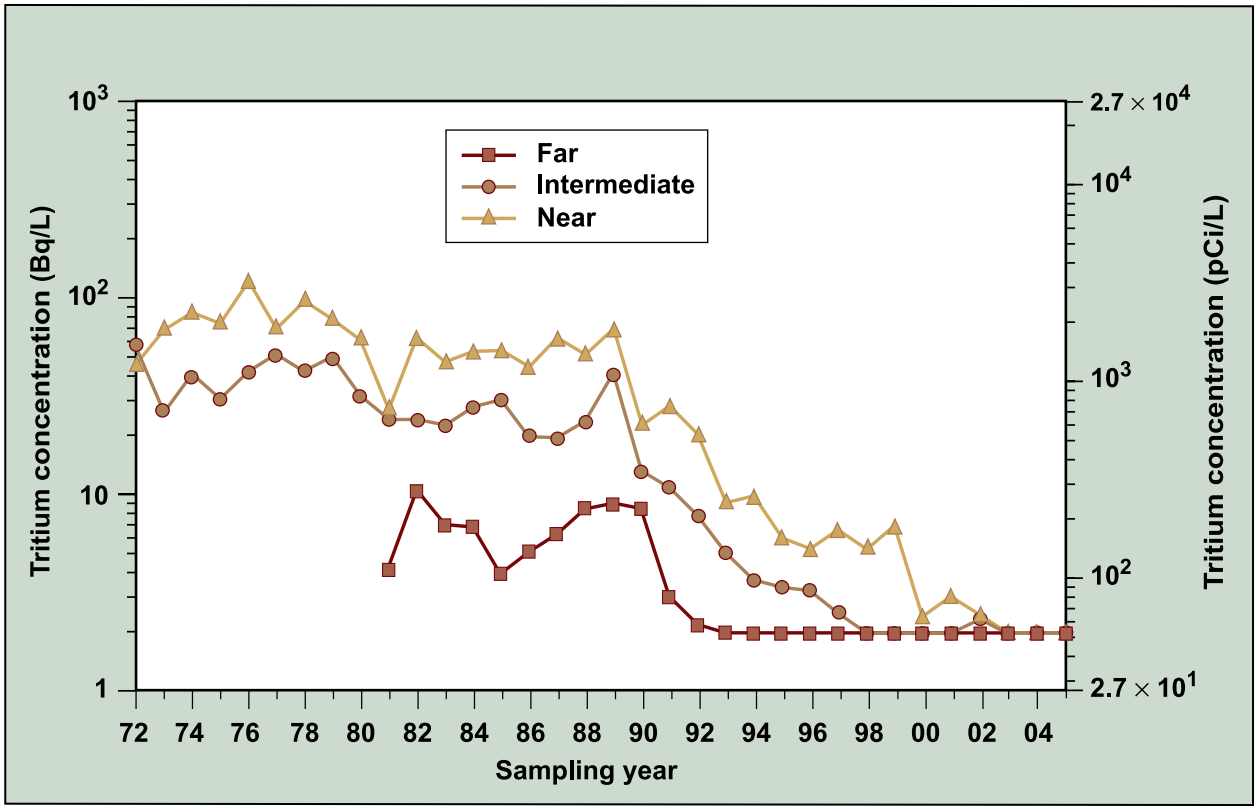
	First quarter	Second quarter	Third quarter	Fourth quarter	Median	Mean	Mean dose[a] (nSv/y)
Sampling locations within 1 km of the Livermore site perimeter							
AQUE	0.77 ± 1.4	–0.020 ± 1.7	0.93 ± 1.7	1.2 ± 2.3	0.85	0.72	< 10[b]
GARD	0.72 ± 1.4	0.34 ± 1.7	2.5 ± 1.8	9.3 ± 2.4	1.6	3.2	16
MESQ	1.2 ± 1.3	0.84 ± 1.8	4.5 ± 1.8	13 ± 2.5	2.9	4.9	24
MET	2.5 ± 1.5	1.3 ± 1.8	12 ± 2.0	5.2 ± 2.3	3.9	5.3	26
NPER	1.6 ± 1.4	3.2 ± 1.9	7.6 ± 1.9	6.3 ± 2.3	4.8	4.7	23
VIS	2.0 ± 1.4	0.21 ± 1.7	6.5 ± 1.9	0.75 ± 2.3	1.4	2.4	12
Sampling locations from 1 to less than 5 km from the Livermore site perimeter							
I580	1.1 ± 1.4	2.6 ± 1.8	2.2 ± 1.8	–0.0069 ± 2.2	1.7	1.5	< 10[b]
PATT	–0.39 ± 1.3	1.4 ± 1.8	0.63 ± 1.7	2.2 ± 2.3	1	0.96	< 10[b]
TESW	0.58 ± 1.3	0.83 ± 1.8	5.4 ± 1.8	–1.2 ± 2.2	0.71	1.4	< 10[b]
ZON7	0.43 ± 1.3	1.2 ± 1.8	2.3 ± 1.8	–1.9 ± 2.2	0.82	0.51	< 10[b]
Sampling locations more than 5 km from the Livermore site perimeter							
CAL	–0.92 ± 1.3	0.90 ± 1.8	0.084 ± 1.7	–0.46 ± 2.2	–0.19	–0.099	< 10[b]
FCC	–0.42 ± 1.3	0.75 ± 1.8	–0.38 ± 1.7	1.6 ± 2.3	0.19	0.39	< 10[b]
Sampling locations at Site 300							
COHO	–0.26 ± 1.2	1.1 ± 1.8	0.36 ± 1.7	1.5 ± 2.3	0.73	0.68	< 10[b]
801E	–1.0 ± 1.7	0.62 ± 1.8	0.68 ± 1.7	–1.2 ± 2.2	–0.19	–0.22	< 10[b]
DSW[c]	–0.20 ± 1.3	46 ± 3.1	5.5 ± 1.8	5.0 ± 2.4	5.3	14	69
EVAP[c]	0.20 ± 1.2	150 ± 4.9	150 ± 3.8	19 ± 2.6	85	80	390

Note: 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. See Chapter 9.

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 7-6**.

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 These plants are rooted in areas of known subsurface contamination.



Note: When median values are below the lower limit of detection (approximately 2.0 Bq/L [54 pCi/L]), values are plotted as 2.0 Bq/L to eliminate meaningless variability.

Figure 6-5. Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2005

All samples at Site 300 locations 801E and COHO were below detection limits. Median concentrations at locations 801E and COHO have been at or below detection limits since 1991. Tritium concentrations in vegetation at DSW and EVAP have been erratic since 1983, with concentrations being either high or below the LLD, depending upon whether or not the roots were taking up contaminated groundwater. The median concentrations at DSW and EVAP for 2005 were somewhat higher than those in 2004. The highest concentration (150 Bq/L [4050 pCi/L]) was observed at EVAP.

Wine Monitoring Results

The mean concentration of tritium (1.6 Bq/L [43 pCi/L]) in Livermore Valley wines sampled in 2005 is nearly double the mean for 2004, but it is still below the LLD for liquid scintillation counting; California wines continue to reflect residual historical bomb fallout and cosmogenic tritium levels (**Table 6-7**). The concentrations in the Rhone Valley (France) wines, vinted in 2003, are comparable to those vinted in 2001 that were sampled in 2004 (**Figure 6-6**);

this is expected because the Rhone Valley is home to numerous nuclear reactors used for power production. The highest concentration in a Livermore Valley wine sampled in 2005 (2.7 Bq/L [73 pCi/L]) was from a wine made from grapes harvested in 2002.

Table 6-7. Tritium in retail wine (Bq/L), 2005[a]

Sample	Area of production		
	Livermore Valley	California	Europe
1	0.62 ± 0.2	0.34 ± 0.19	4.6 ± 0.5
2	0.92 ± 0.21	0.40 ± 0.19	5.3 ± 0.56
3	1.1 ± 0.22		
4	1.5 ± 0.24		
5	2.7 ± 0.33		
6	2.7 ± 0.33		
	Dose (nSv/y)[b]		
	2.7	0.40	5.2

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

a Wines from a variety of vintages were purchased and analyzed for the 2005 sampling. Concentrations are those on January 20, 2006.

b This dose is calculated based on consumption of 52 L wine per year at maximum concentration (see Chapter 7). Doses account for contribution of OBT as well as of HTO.

Because only a small number of bottles of Livermore Valley, California, and European (Rhone Valley) wine were sampled in 2005 (**Table 6-7**), a statistical comparison cannot be made. However, it is clear that the Livermore Valley wine with the lowest concentration is indistinguishable from the two California wines. The tritium concentrations in the Rhone Valley wines sampled are distinctly higher than even the highest of the Livermore Valley wines sampled.

The Livermore Valley wines purchased in 2005 represent vintages from 2000 to 2003. Thus, to compare the effect of LLNL operations on local wines, concentrations at the time of laboratory analysis must be corrected for the radiological decay that has occurred since the approximate date of harvest. Decay-corrected concentrations of tritium in wine for the Livermore Valley, California, and Europe are shown in **Figure 6-6** for the years from 1991 to present. Concentrations are shown for all wines sampled. The concentration of tritium in rainfall at Portland, Oregon (IAEA/WMO 2004) is also shown to demonstrate the similarity between tritium concentrations in California wines and background tritium concentrations on the Pacific coast (no similar rainfall data exist for California).

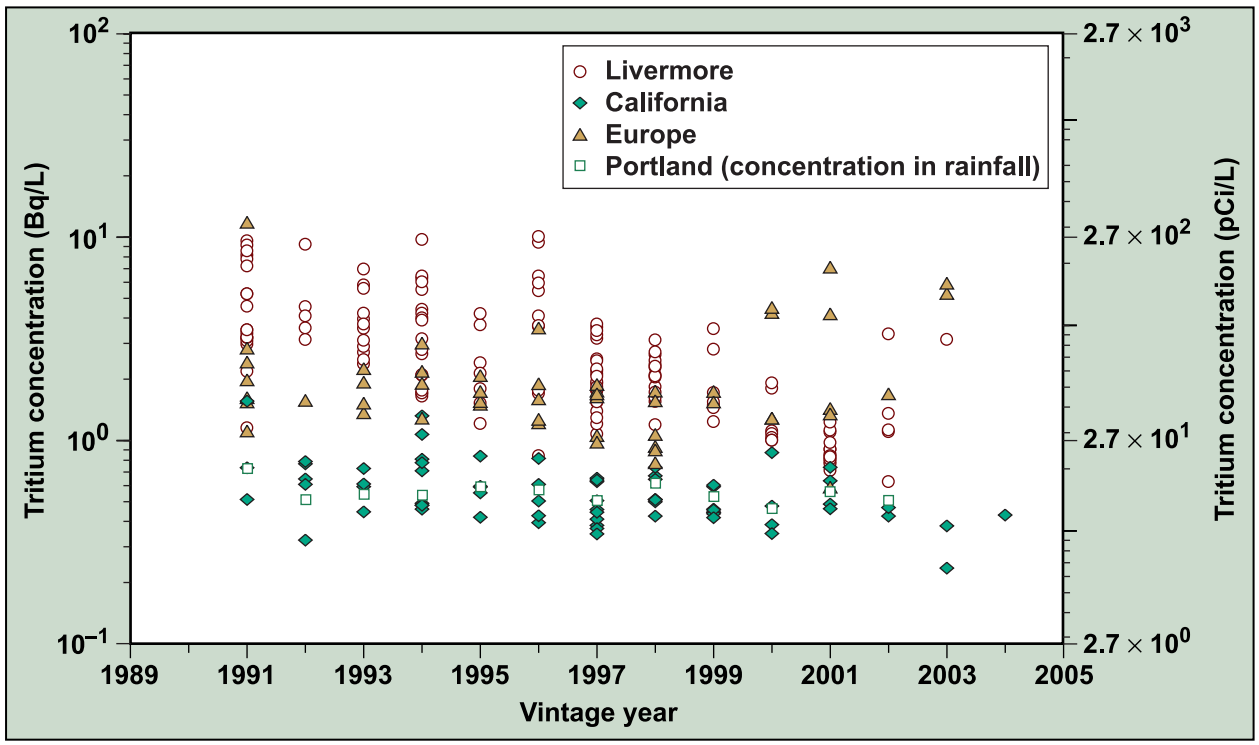


Figure 6-6. Tritium concentrations in all retail wines sampled since 1991 decay-corrected from the sampling year to the vintage year

Environmental Impact on Vegetation and Wine

Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 6-6**. These doses were calculated for historical continuity using the transfer factors from **Table 7-6** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). All doses are estimated based on measured concentrations of HTO in vegetation and consequent dose from HTO ingestion. The hypothetical annual ingestion dose, based on highest observed mean HTO concentration in vegetation for 2005, was 26 nSv (2.6 µrem), which is essentially the same as the estimated dose in 2004.

Doses calculated based on Regulatory Guide 1.109 neglect the increased contribution from OBT. However, according to a conclusion by 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). Thus, the maximum estimated ingestion dose from LLNL operations for 2005 is at most 52 nSv/y (5.2 µrem/y).

The estimated annual ingestion dose (52 nSv; 5.2 µrem) at the location with the highest mean air concentration for 2005, calculated from measured HTO concentrations in plant water and adjusted to account for dose from OBT, is about 1/58,000 of the average annual background dose in the United States from all natural sources and about 1/200 the dose from a panoramic dental x-ray. The ingestion dose is calculated on the assumption that all the vegetables, milk, and meat have concentrations that represent the location of the sampled vegetation. This is an improbable scenario because the average person lives farther from the Livermore site than the location of the highest vegetation concentrations and grows just a small fraction of total food ingested. Thus the likely potential dose received (see **Table 7-8**) will be considerably smaller than this already tiny dose.

Although the pine tree growing near Building 292 was disposed of at the Nevada Test Site, it posed no hazard to the public. Any inhalation dose to the public from the HTO released from the tree was taken into account by the tritium concentrations measured at the perimeter ambient air tritium monitors (see data table "at-ls" in file "Ch4 Ambient Air" on the report CD). If an individual could have eaten the wood of the entire tree, the ingestion dose would have been about 70 µSv[1] (7.0 mrem).

During 2005 at Site 300, no tritium was released to the atmosphere from LLNL operations. Consequently, vegetation concentrations were below detection limits except at locations of contaminated groundwater (see Chapter 8, "Remediation Activities and Monitoring Results" section). Contaminated groundwater resulting from past activities affects concentrations in vegetation at locations DSW and EVAP. The dose calculated from these elevated concentrations is entirely hypothetical, however, because neither people nor livestock ingest vegetation at Site 300. The mean annual ingestion dose for 2005 for location EVAP, which exhibited the higher concentrations of the two locations, would have been 390 nSv (39 µrem).

Wine

For Livermore Valley wines purchased in 2005, the highest concentration of tritium (2.7 Bq/L [73 pCi/L]) was just 0.36% of the Environmental Protection Agency's standard for maximal permissible levels of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Drinking 1 L per day of the Livermore Valley wine with the highest concentration purchased in 2005 would have resulted in a dose of 19 nSv/y (1.9 µrem/y). A more realistic dose estimate, based on moderate drinking (1 L per week)[2] at the mean of the Livermore Valley wine concentrations (1.6 Bq/L [43 pCi/L]) would have been 1.6 nSv/y

[1] This was estimated using the dose coefficients compiled for Federal Guidance Report No. 13 (Eckermann et al. 1999).

[2] Moderate consumption is higher than the average consumption of wine in California (15.7 L/y) (Avalos 2005).

(0.16 µrem/y). Both doses explicitly account for the added contribution of OBT[3].

Local wineries are sufficiently distant from the Livermore site that tritium in wines can only be detected reliably using an ultra-sensitive method. The potential dose from drinking Livermore Valley wines in 2005, including the contribution of OBT, even at the high consumption rate of 1 L per day, would have been about 1/580 of a single dose from a panoramic dental x-ray.

Ambient Radiation Monitoring

Gamma radiation in the environment comes from two natural sources. The first source is the *terrestrial component*, which is caused by the radioactive decay of parent elements formed in the earth's crust 4.5 billion years ago (e.g., uranium-238, thorium-232, and potassium-40) and their respective daughter radiations. The second source is from the *cosmic component* of external radiation, which induces secondary radiations from interactions with atmospheric nuclei in the upper atmosphere. These cosmic interactions result in the production of meson, neutron, gamma, and electron radiations at the earth's surface (Eisenbud 1987).

LLNL's ambient radiation monitoring program is designed to distinguish any LLNL operational contribution from these natural sources by sampling a significant number of locations to validate the large natural background.

Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter which absorbs it. The roentgen (R) was adopted as the special unit of exposure dose by the International Commission on Radiological Units in 1956 and is defined as the charge required to ionize a given volume of air (2.58×10^{-4} coulombs per kilogram of air) (Attix and Roesch 1968).

It is this equivalency that is used to determine the quantity of ambient radiation measured by portable thermoluminescent dosimeters (TLDs) placed in the surrounding community. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thallium-activated calcium sulfate ($CaSO_4$).

[3] Dose from wine is calculated by summing the dose from HTO in the water fraction of wine and the dose from OBT in the organic fraction of wine. Dose coefficients for HTO and OBT are those of the International Commission on Radiation Protection (1996). The organic component of wine (estimated from grape juice) increases the dose by 6% over what it would be had wine no organic fraction.

As the TLD absorbs ionizing energy, electron–hole pairs are created in the crystal lattice, trapping this absorbed energy in the crystal's excited state. The absorbed energy in the TLD crystal is released in the form of light emission upon heating the TLD to extreme temperature. This light emission, which is proportional to the TLD absorbed dose, is then collected by a photomultiplier tube and compared to its glow curve, as it is termed, which is calibrated to a known standard of cesium-137 gamma energy of 662 keV. The result of the TLD exposure is then reported in the International System (SI) unit of sievert (Sv) from the calculated dose in mR (1×10^{-3} R).

In order to compare LLNL dose contributions with the natural background, the TLD placement locations are divided into three groups:

- Livermore site locations—shown in **Figure 6-1**
- Livermore Valley locations—shown in **Figure 6-2**
- Site 300 and the local offsite vicinity, and sites in the city of Tracy—shown in **Figure 6-3**

In addition, the State of California Radiological Health Branch maintains several collocated TLD sample sites around the LLNL perimeter and Livermore Valley for independent monitoring comparison.

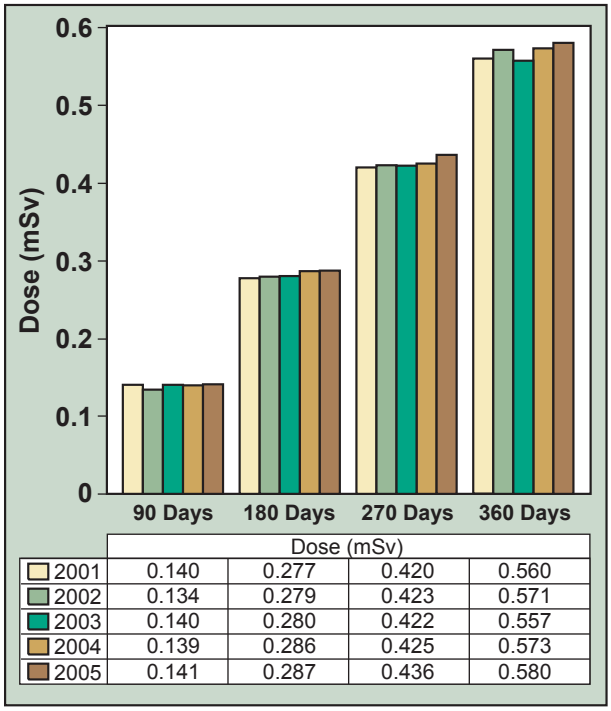
In order to obtain a true representation of the local site exposure and determine any dose contribution from LLNL operations, an annual environmental monitoring compliance assessment is done in accordance with DOE 450.1 through a quarterly deployment cycle. TLDs are deployed at a 1 meter height, adhering to the guidance of *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991).

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

Monitoring Results

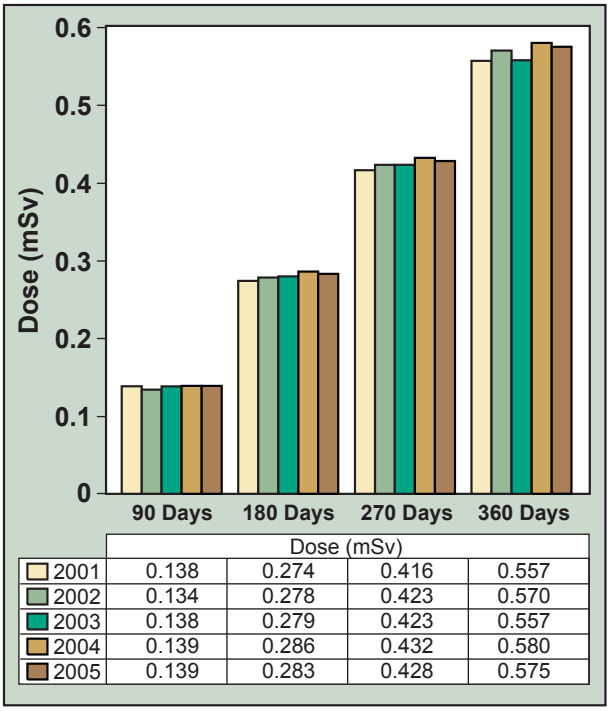
In **Figures 6-7** through **6-10**, the quarterly average cumulative doses in mSv for 2005 are presented for the Livermore site, the Livermore Valley, on-site at Site 300 and off-site at Site 300 along with five years of quarterly doses from 2001 to 2005.

Figure 6-7 illustrates the average cumulative dose for the Livermore site perimeter for successive 90 day periods for the entire year. The graph indicates a stable trend in the site-wide annual dose when compared to previous years. Similar trends are evident when comparing the data of **Figures 6-8**, **6-9** and **6-10**.



	Dose (mSv)			
2001	0.140	0.277	0.420	0.560
2002	0.134	0.279	0.423	0.571
2003	0.140	0.280	0.422	0.557
2004	0.139	0.286	0.425	0.573
2005	0.141	0.287	0.436	0.580

Figure 6-7. Livermore site perimeter quarterly cumulative dose (mSv), 2001 through 2005

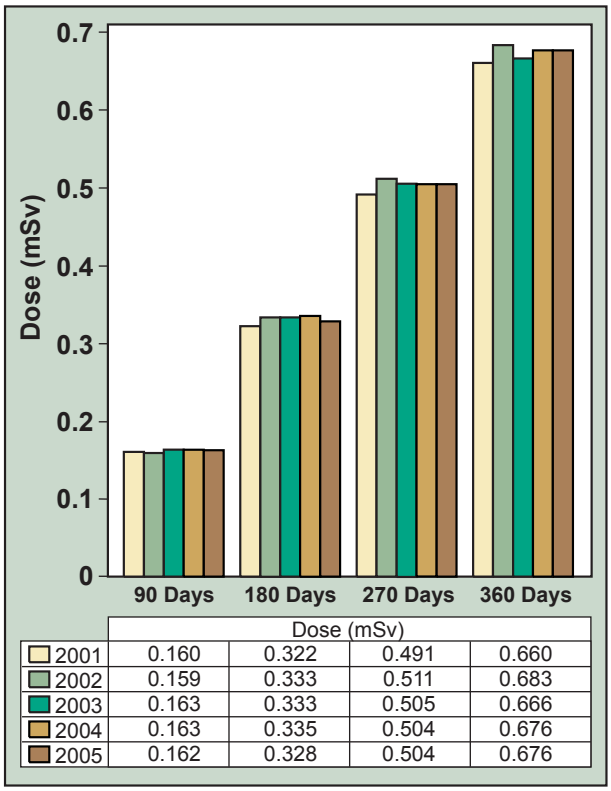


	Dose (mSv)			
2001	0.138	0.274	0.416	0.557
2002	0.134	0.278	0.423	0.570
2003	0.138	0.279	0.423	0.557
2004	0.139	0.286	0.432	0.580
2005	0.139	0.283	0.428	0.575

Figure 6-8. Livermore Valley quarterly cumulative dose (mSv), 2001 through 2005

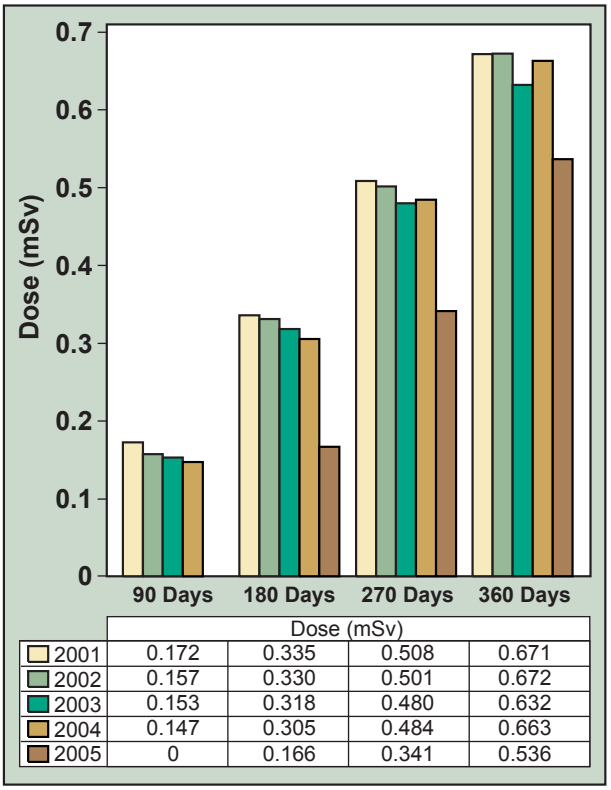
Tabular data for each individual sampling location illustrate the quarterly variation (see file "Ch6 Ambient Radiation" provided on the report CD). Missing data are due to lost or damaged samples.

Site variation is largely due to changes in the local distribution of the radon flux as a product of decay from the uranium and thorium series on some small level and from changes in the cosmic radiation flux. For example, when the data for the Livermore site perimeter are examined for the 5 year period by location (**Figure 6-11**), the local site variation is readily observed. Similar variability is seen within the other location groups (**Figures 6-12** and **6-13**).



	Dose (mSv)			
2001	0.160	0.322	0.491	0.660
2002	0.159	0.333	0.511	0.683
2003	0.163	0.333	0.505	0.666
2004	0.163	0.335	0.504	0.676
2005	0.162	0.328	0.504	0.676

Figure 6-9. Site 300 on-site quarterly cumulative dose (mSv), 2001 through 2005



	Dose (mSv)			
2001	0.172	0.335	0.508	0.671
2002	0.157	0.330	0.501	0.672
2003	0.153	0.318	0.480	0.632
2004	0.147	0.305	0.484	0.663
2005	0	0.166	0.341	0.536

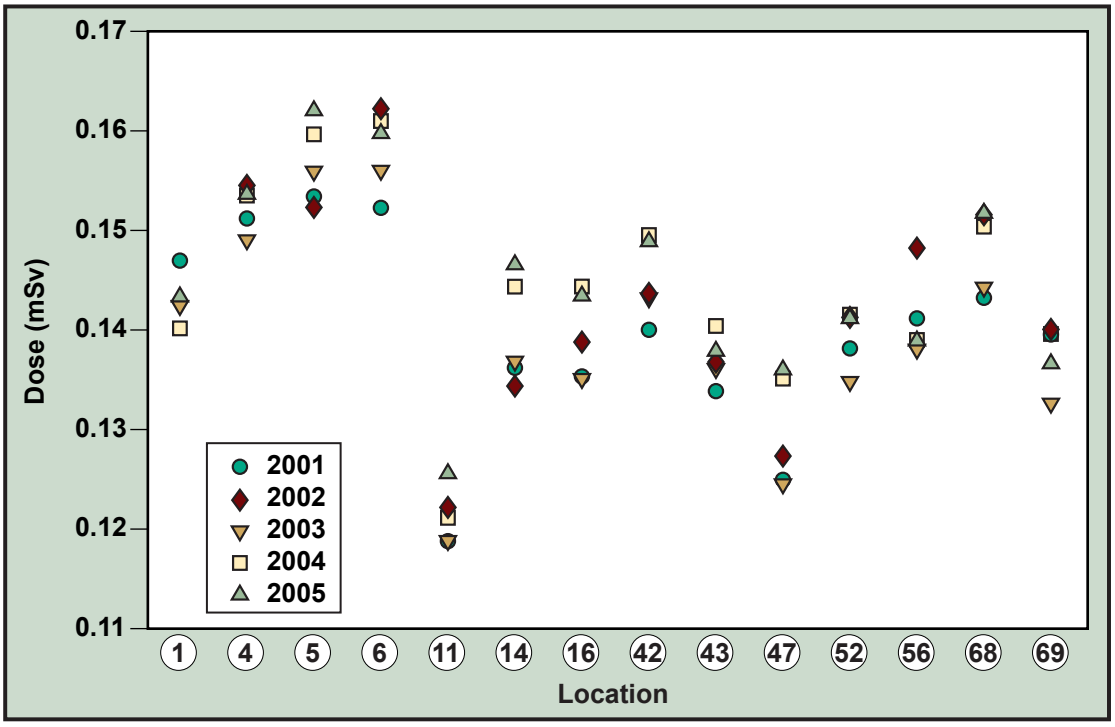
Note: First quarter data not available due to lost or damaged samples, which also affects the cumulative dose.

Figure 6-10. Site 300 environs quarterly cumulative dose (mSv), 2001 through 2005

Environmental Impact from Laboratory Operations

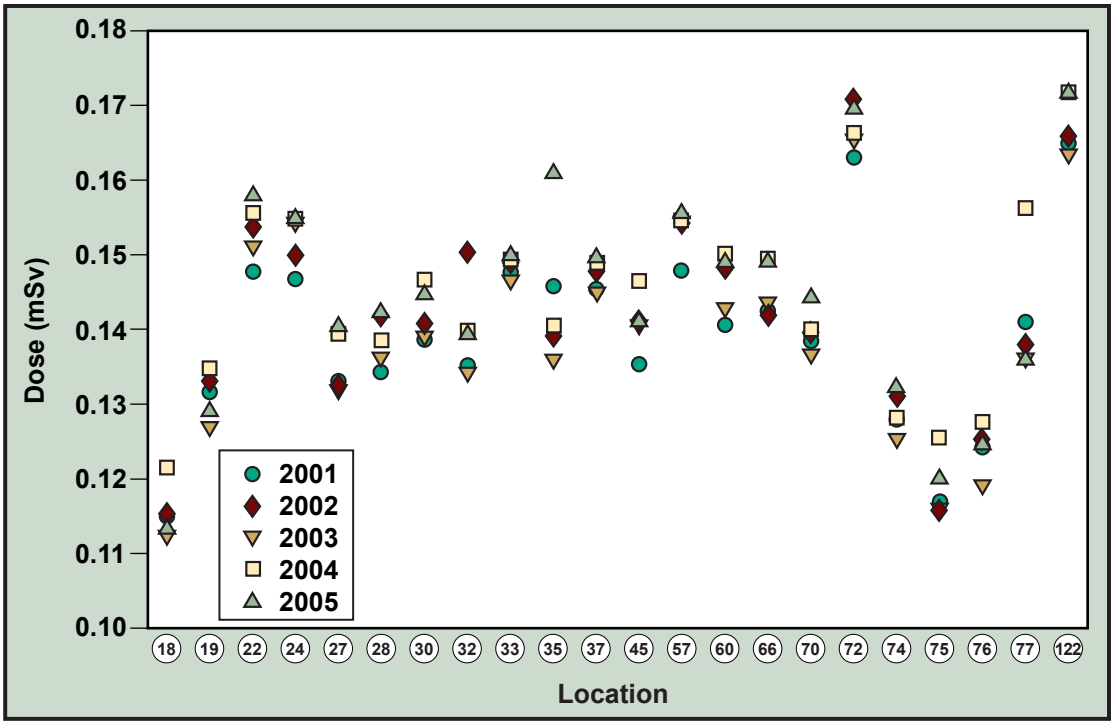
There is no evidence to conclude that there is any environmental impact or increase in direct gamma radiation as a result of LLNL operations as measured by the TLD network for the year 2005. The radiation dose trends remain annually consistent for each sample site. Although some locations have had anomalous annual values in comparison to the long term trend for these locations, the trends would have continued at those sample sites had there been any contamination affecting the dose at that site. This is the most important reason for long term trend analysis and why local spurious excursions such as at location 35 (**Figure 6-12**) are not considered alarming.

As depicted in **Figure 6-14**, the annual average gamma radiation dose from 2001 to 2005 is statistically equivalent and shows no discernible impact due to operations conducted at LLNL.



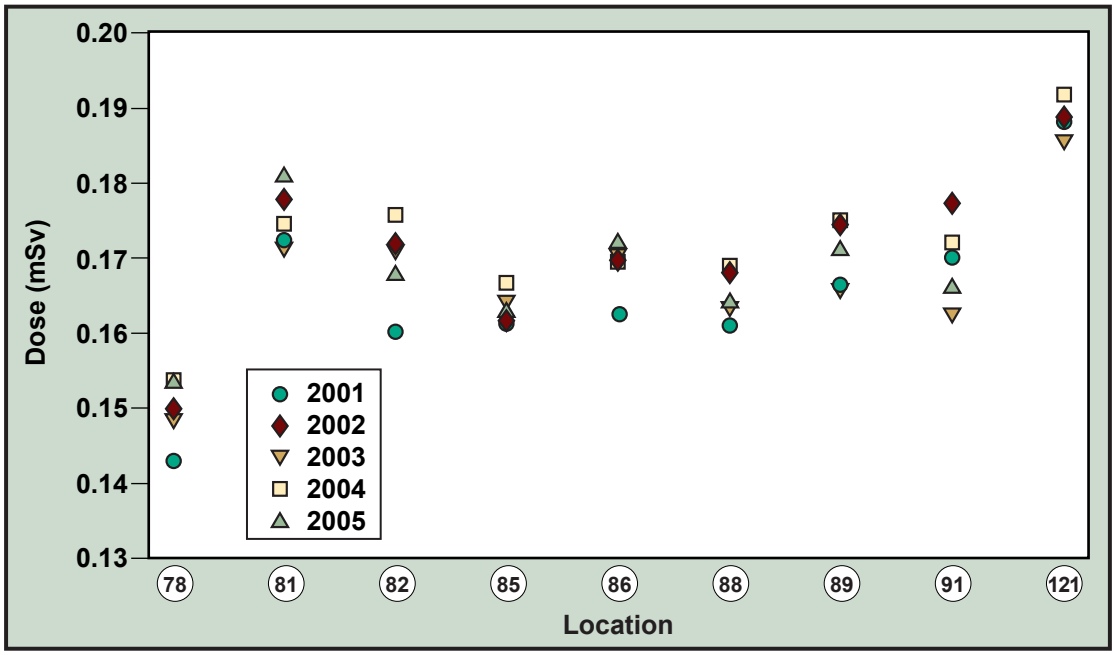
Note: See **Figure 6-1** for locations.

Figure 6-11. Livermore site perimeter annual average dose by location from 2001 to 2005



Note: See **Figure 6-2** for locations.

Figure 6-12. Livermore Valley annual average dose by location from 2001 to 2005



Note: See **Figure 6-3** for locations.

Figure 6-13. Site 300 annual average dose by location from 2001 to 2005

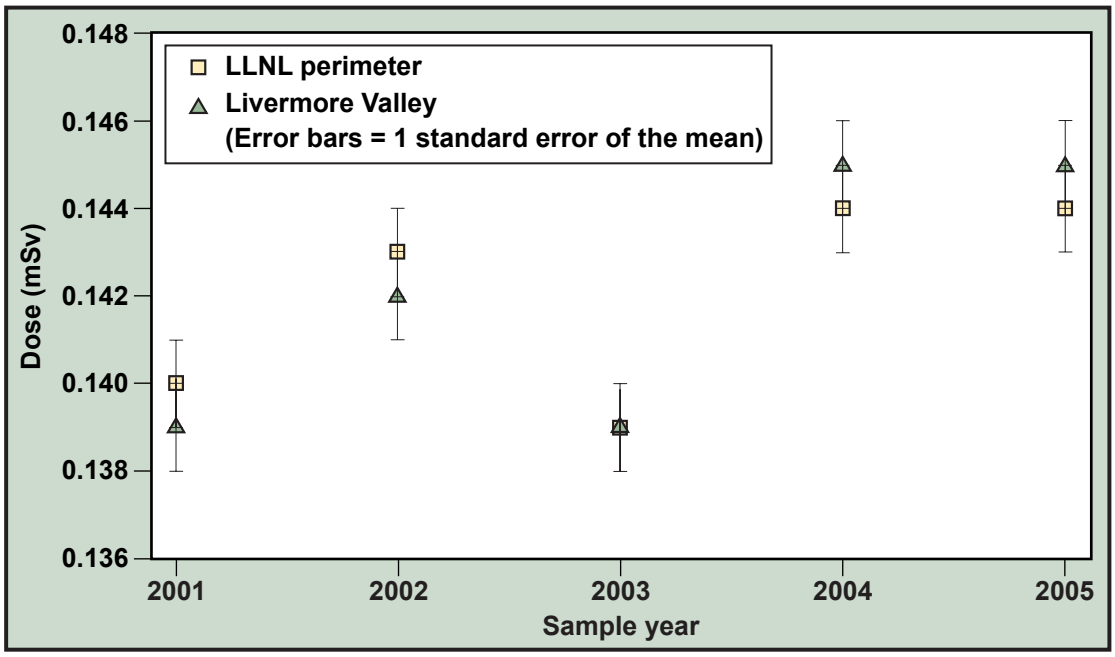


Figure 6-14. Annual average gamma radiation dose comparison for Livermore site and the Livermore Valley

Special Status Wildlife and Plants

Special status wildlife and plant monitoring efforts at LLNL are focused on species considered to be rare, threatened, or endangered. This includes species listed under the California or Federal Endangered Species Acts; species considered of concern by the California Department of Fish and Game, and the U.S. Fish and Wildlife Services (USFWS); and species that require inclusion in National Environmental Policy Act (NEPA) and California Environmental Quality Act of 1970 (CEQA) documents.

Locations of species of particular interest are shown in **Figure 6-1** for the Livermore site and **Figures 6-15** and **6-16** for Site 300. A list of species known to occur at Site 300, including state and federally listed species, is found in Appendix C. (A similar list has not been prepared for the Livermore site.)

Five species that are listed under the federal or California endangered species acts are known to occur at Site 300: the California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana aurora draytonii*), 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 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, but breeding habitat for these species does not occur at Site 300. The California red-legged frog is also known to occur at the Livermore site.

Several other species that are considered rare or otherwise of special interest by the federal and state governments also occur at Site 300 and the Livermore site. These species include California Species of Special Concern, California Fully Protected Species, federal Species of Concern, species that are the subject of the federal Migratory Bird Treaty Act, and those species included in the California Native Plant Society's (CNPS's) *Inventory of Rare and Endangered Plants* (CNPS 2001). In particular, monitoring programs have been developed at Site 300 for the Tricolored Blackbird (*Agelaius tricolor*), a California species of special concern, and at the Livermore site for the White-tailed Kite (*Elanus leucurus*), a California fully protected species.

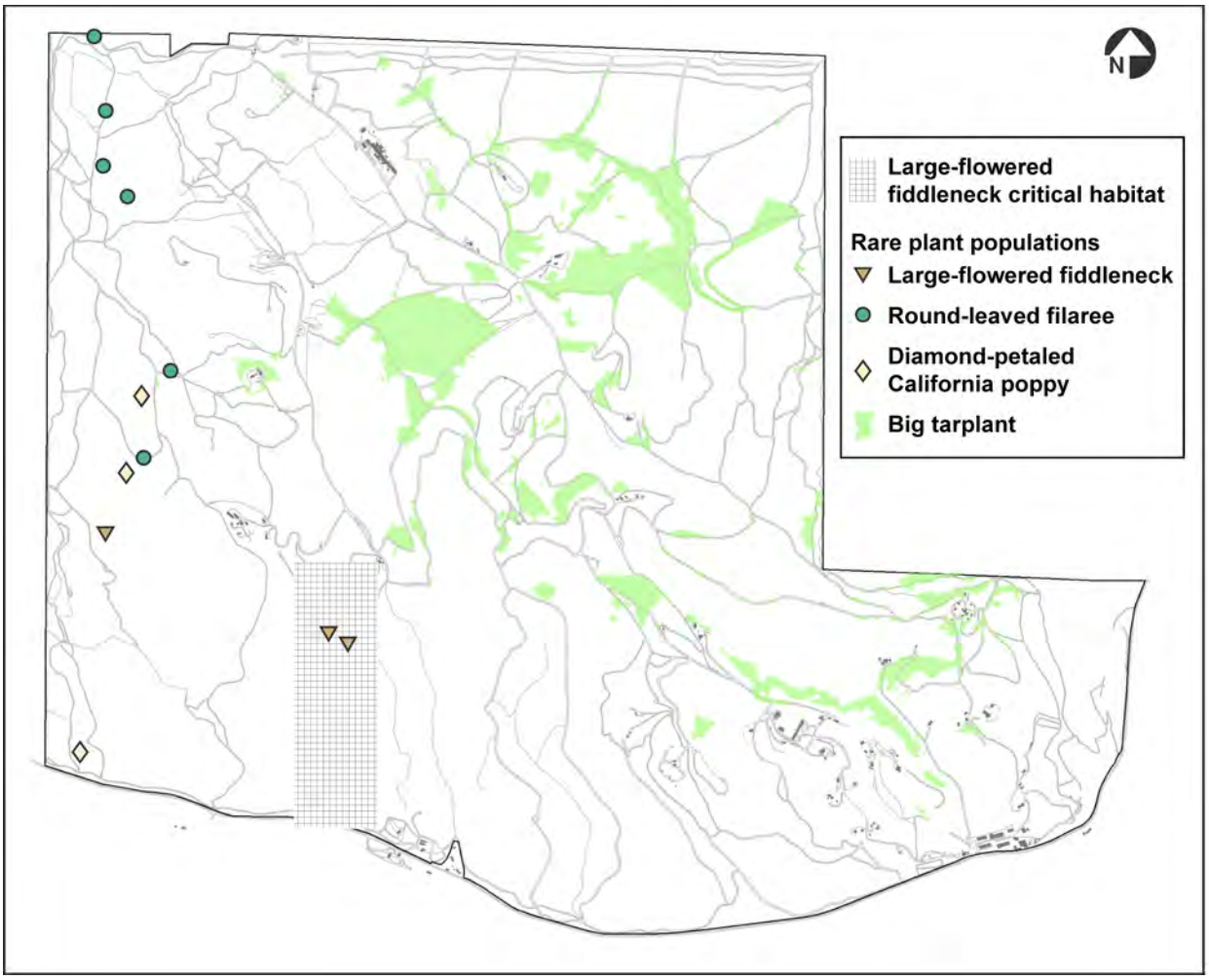


Figure 6-15 Distribution of federal and California threatened and endangered plants, Site 300, 2005

Including the federally endangered large-flowered fiddleneck, four rare plant species and four uncommon plant species are known to occur at Site 300. Three of these species, the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*, also known as *Blepharizonia plumosa* subsp *plumosa*), and the diamond-petaled poppy (*Eschscholzia rhombipetala*), are included in the CNPS List 1B (CNPS 2001). These species are considered rare and endangered throughout their range. An additional species, the round-leaved filaree (*Erodium macrophyllum*) is currently included on CNPS List 2 (CNPS 2001). This list includes species that are rare or endangered in California and elsewhere. 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 2001). List 4 plants are uncommon enough to warrant

monitoring, but are not considered rare. Past surveys have failed to identify any rare plants on the Livermore site (Preston 1997, 2002).

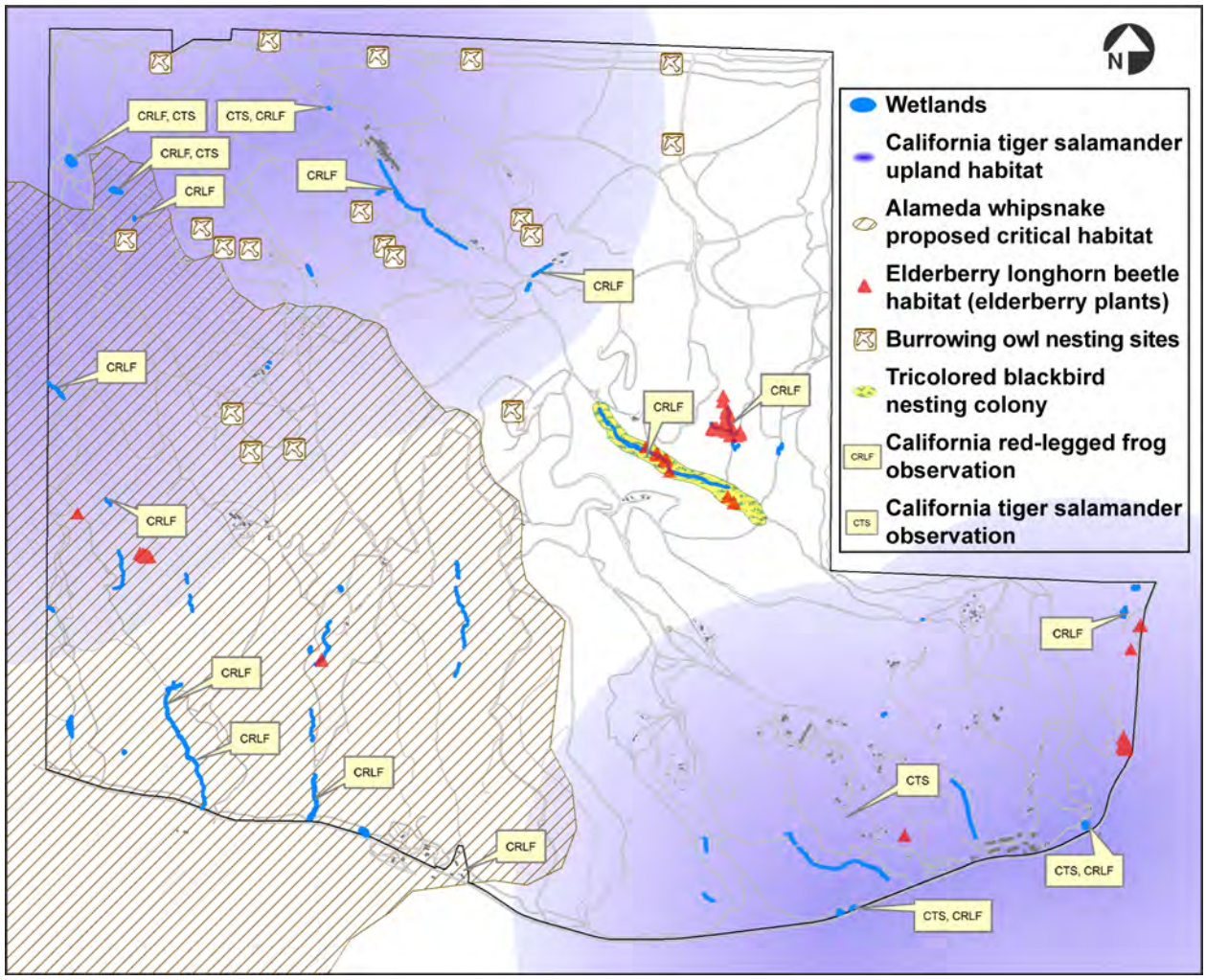


Figure 6-16 Distribution of federal and California threatened and endangered wildlife, Site 300, 2005

The following sections describe results from LLNL special status wildlife and plant studies and surveys. For an estimate of LLNL's dose to biota, see the "Special Topics on Dose Assessment" section in Chapter7.

Compliance Activities

Arroyo Las Positas

In 2000, LLNL began dredging sections of the Arroyo Las Positas to alleviate concerns about flooding of sensitive facilities within the Livermore site. No dredging was conducted in Arroyo Las Positas in 2005.

The Water Discharge Requirements for this project called for the implementation of a five-year Maintenance Impact Study (MIS) for this project. The final report for this MIS was submitted to the SFRWQCB in January 2006, and described monitoring completed between 2000 and 2005. The MIS included monitoring the status of three biological variables: California red-legged frog population, macro-invertebrate community, and wetland vegetation. (This monitoring was conducted in accordance with the 1997 and 1998 amended USFWS Biological Opinion for the Arroyo Las Positas Maintenance Project.)

Arroyo Seco

On June 10, 2005, the USFWS issued a biological opinion to DOE/NNSA for the Arroyo Seco Management Plan. The biological opinion for this project considers potential impacts to the California red-legged frog and the California tiger salamander. Although these species have not been observed at the project site, a biological assessment (BA) was prepared because there are multiple observations of these species 0.5 mile from the project site, and potential habitat for these species exists at the project site.

At the project site, Arroyo Seco is an intermittent stream, which typically receives water flow only after major rain events. The LLNL reach of Arroyo Seco occurs in an urban area. Public roads cross Arroyo Seco at the west and south boundaries of LLNL, and remnant orchards, LLNL structures, and landscaped areas occur above its banks. Prior to the implementation of the Arroyo Seco Management Plan, the channel of Arroyo Seco was deeply incised, and existing revetments were found in several locations. The banks of the stream were vegetated by a combination of ornamental and native riparian trees with an understory of annual grassland species.

The Arroyo Seco Management Plan was completed during the 2005 dry season. It included repairs to gully erosion around storm drain outfalls, installation of vegetated geogrids in eroding transition zones between existing gabion baskets and neighboring banks, and the addition of drop inlet structures to convey concentrated runoff down bank slopes at other gully erosion sites. In addition, the lower third of the LLNL reach of the Arroyo was realigned to increase the amount of meander in this area and decrease the slope of the creek banks. This involved constructing a new low flow channel and right and left in-channel terraces, and planting the channel terraces and bank slopes with native trees and shrubs.

LLNL was able to successfully implement the conservation and avoidance measures included in the Arroyo Seco Management Plan Biological Opinion. Although this project did not result in any direct impacts to California red-legged frogs or California tiger salamanders, it did result in a temporary decrease in the value of the habitat at the project site for California red-

legged frogs. As the native vegetation planted at the project site matures, it should shade portions of the channel and provide cover, thus improving the value of the habitat for California red-legged frogs. This project did not result in any significant temporary or long-term impacts to California tiger salamander habitat.

Habitat Enhancement Project

In late-August 2005, a habitat enhancement project was undertaken at Site 300 and, in accordance with the 2002 Biological Opinion, was implemented to compensate for habitat value loss from artificial wetlands created from discharges of blow down from cooling towers located at Buildings 865, 851, 827, and 801. These artificial wetlands were maintained with potable water when the blow down discharges were discontinued. Two areas within the Mid-Elk Ravine drainage were enlarged and deepened to create habitat pools where California red-legged frogs are known to occur and where pooling water features were limited in extent. The three primary goals of this effort were the creation of open water habitat (minimum of 0.012 acres), the protection of 1.86 acres of wetland and upland habitat, and the translocation of California red-legged frogs from the Building 865 wetland to the two new pools. In 2005, the first two goals were accomplished. The translocation of the California red-legged frog was conducted in February and March of 2006.

California Whipsnake

In 2002, LLNL began participating in a study, in cooperation with the USFWS and four other agencies, to determine the effects of prescribed burns on the federally threatened Alameda whipsnake. At Site 300, the Alameda whipsnake is classified as the California whipsnake (*Masticophis lateralis*) because it more closely resembles an intergrade between two species: Alameda whipsnake (*Masticpophis lateralis euryxanthus*) and the Chaparral whipsnake (*Masticophis lateralis lateralis*). In April 2002, the USFWS issued a biological opinion for this study that outlined the general conditions for conducting prescribed burns and gathering information about potential impacts to California whipsnakes. Through participation in this study, LLNL obtained USFWS approval to conduct prescribed burns necessary for Site 300 operation in areas that support California whipsnakes. The study area consists of a control site and a burn site that are vegetated by a mosaic of coastal scrub and annual grasslands. Baseline studies were conducted in spring and fall of 2002 and spring of 2003 at Site 300 and consisted of livetrapping California whipsnakes, recording the location of individuals, and marking the snakes for future identification.

There was a total of 18 California whipsnakes captures (9 at the control site and 9 in the burn site) during baseline monitoring in the spring and fall of

2002, and 12 captures (8 in the control site and 4 in the burn site) in the spring of 2003. A prescribed burn was conducted at the burn site in the summer of 2003, and the first season of post-burn monitoring was conducted in the fall of 2003. One California whipsnake was captured in the control site in the fall of 2003, and no California whipsnakes were captured in the burn site. Post-burn trapping of California whipsnakes continued in the spring and fall of 2004. In 2004, there was a total of 10 California whipsnake captures during spring trapping (6 in the control area and 4 in the burn area), and no California whipsnakes were captured during the fall trapping period. In 2005, a total of 8 California whipsnakes captures occurred during the spring trapping period (6 in the control area and 2 in the burn area). A wildfire that originated offsite in mid-July entered the Site 300 property and burned both whipsnake study areas. Effects of the burn will be evaluated during the 2006 trapping season. No trapping was conducted in the fall of 2005 due to previous low capture success rates. To date, no conclusions have been formulated about the effects of the Site 300 prescribed burns on California whipsnakes.

Class II Surface Impoundments

At Site 300, two interconnected Class II nonhazardous wastewater surface impoundments previously known to have been used by California tiger salamanders were removed. As mitigation for loss of suitable California tiger salamander habitat that occurred during the removal of these impoundments, a new pond was created in the northwest corner of Site 300, a remote area of the site. Construction of this new pond was completed successfully, and California tiger salamander activity at the previous location of the surface impoundments and the mitigation pond will be monitored in 2006.

Invasive Species Control Activities

Invasive species, including the bullfrog *(Rana catesbeiana)* and the largemouth bass *(Micropterus salmoides),* are a significant threat to the California red-legged frog at the Livermore site. The Drainage Retention Basin (DRB) was drained in 2000 and 2001 in an effort to eliminate bullfrog larvae. The Habitat Enhancement Pool portion of the DRB and the LLNL reach of Arroyo Las Positas were drained to control bullfrogs and largemouth bass in the fall of each year from 2002 through 2005. Adult bullfrogs and egg masses were also removed from the DRB during the bullfrog's breeding season (late spring to early fall). Two nighttime surveys for adult bullfrogs were conducted in the DRB in the summer of 2005. During these surveys, bullfrogs were identified by a qualified biologist and removed. In addition, 16 bullfrog egg masses were removed from the DRB during weekly surveys in 2005. These invasive species control measures were conducted under the 2002 amendment to the Arroyo Las Positas Maintenance Plan biological opinion.

Surveillance Monitoring

Wildlife

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, a California fully protected species, annually nest in the trees located along the north, east, and south perimeters of the Livermore site. LLNL staff surveyed potential White-tailed Kite nesting sites using binoculars or a spotting scope during the spring of 2005; two pairs of White-tailed Kites successfully fledged a total of eight young. Although White-tailed Kites are also known to occasionally nest at Site 300, site-wide kite surveys were not conducted at Site 300 in 2005 because the kites do not typically nest in areas where they may be affected by programmatic activities.

Avian Monitoring Program

An avian monitoring program, initiated in 2001 to obtain background information for the draft *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (see Chapter 2 for more information on the environmental impact statement), was continued in 2005. A constant effort mist netting station was also established spanning Elk Ravine and Gooseberry Canyon at Site 300. Birds were captured using ten standard passerine mist nets once every ten days throughout the breeding season (May through August 2005). Birds captured in the mist nets were identified to species, banded, aged, sexed, measured, and weighed before being released. All of the species identified in these surveys are listed in Appendix C.

Rare Plants

LLNL conducted restoration and/or monitoring activities in 2005 for the four rare plant species known to occur at Site 300: the large-flowered fiddleneck, the big tarplant, the diamond-petaled poppy, and the round-leaved filaree. The results of this work are described in more detail in a biannual progress report (Paterson et al. 2005).

Large-Flowered Fiddleneck

The only federally protected plant species known to occur at Site 300 is the large-flowered fiddleneck (*Amsinckia grandiflora*), a federally listed and state listed endangered species. A 160-acre portion of Site 300 has been designated as critical habitat for this plant. This species is known to exist naturally in only two locations: at Site 300 in the *Amsinckia grandiflora* Reserve (the

Drop Tower native population) and on a nearby ranch. An additional population (the Draney Canyon native population) historically was known to occur in a remote canyon at Site 300. This population was extirpated during a landslide in the 1997/1998 rainy season. The Drop Tower native population contained no large-flowered fiddleneck plants in 2005, 3 plants in 2004, 5 plants in 2003, and 19 plants in 2002 (see **Figure 6-17**).

LLNL also established an experimental population of the large-flowered fiddleneck within the *Amsinckia grandiflora* Reserve at Site 300 starting in the early 1990s. The experimental population is divided into two subpopulations known as the flashing (FL) and fire frequency (FF) experimental populations. The size of the experimental population fluctuates as a result of seed bank enhancement efforts conducted in this population. The two experimental subpopulations combined contained 127 large-flowered fiddleneck plants in 2005, 768 plants in 2004, 119 plants in 2003 and 67 plants in 2002 (see **Figure 6-17**).

LLNL is also beginning to see results in the long-term fire frequency experiment begun in 2001. The native perennial grass *Poa secunda* is most abundant in plots that are burned annually. Previous research shows that large-flowered fiddleneck is more successful in plots dominated by *P. secunda* compared to plots dominated by exotic annual grasses (Carlsen et al. 2000), but early results from the fire frequency experiment show that large-flowered fiddleneck is more abundant in the unburned control plots dominated by dense annual grasses than in the burned plots. Data from plots burned at an intermediate frequency are not yet available.

While LLNL has uncovered some clues to the successful restoration of large-flowered fiddleneck populations and continues to work to sustain the existing experimental and native populations, the reasons for the sharp declines in this population in recent years are still unclear. Seed bank enhancement efforts are more successful when plots are netted and seeds from greenhouse or controlled environment experiments are used, but the resulting plants can be small and produce little seed. LLNL can promote the establishment of a native perennial grassland with prescribed burns, but seed predation is quite high in these burned areas.

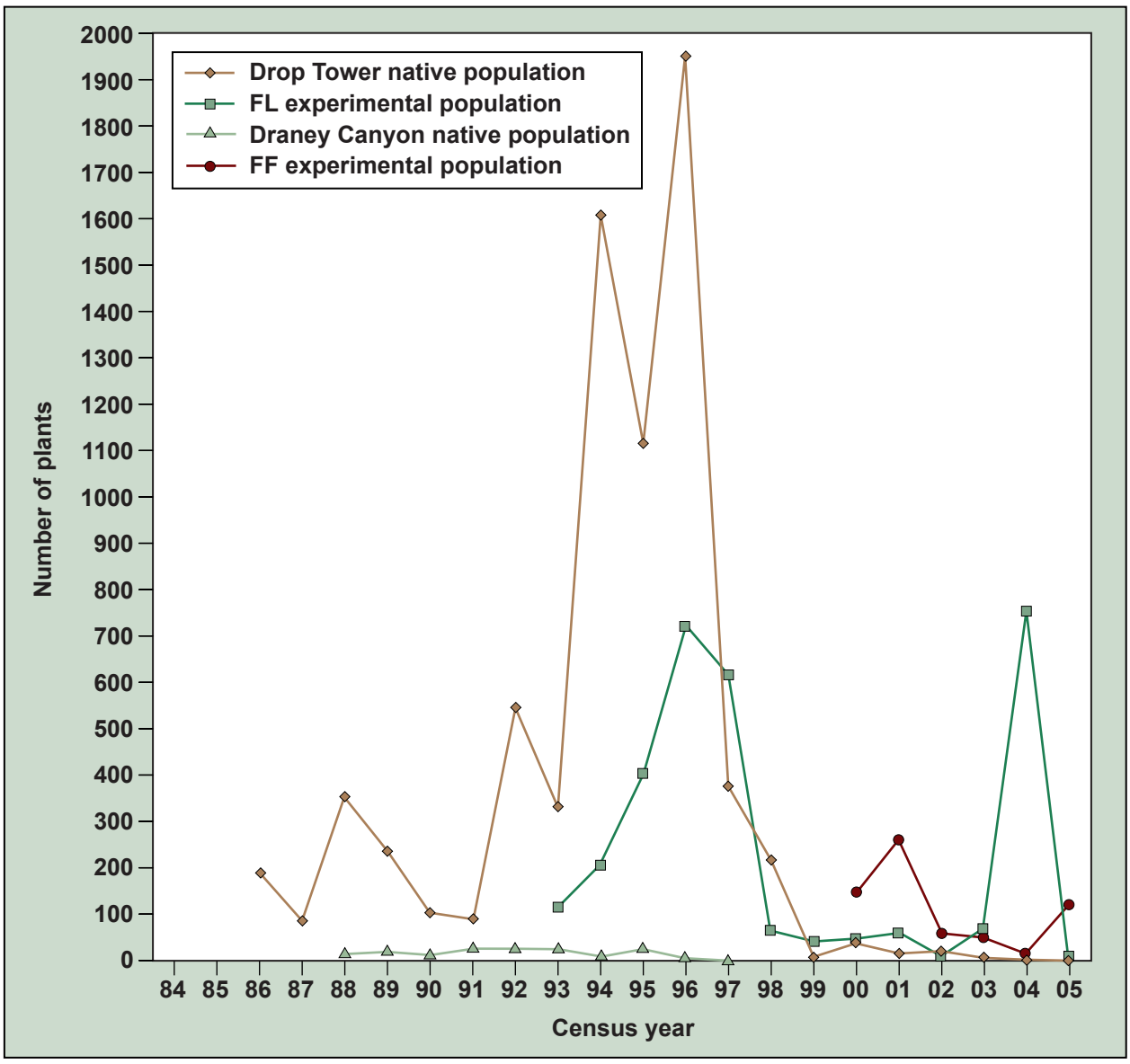


Figure 6-17. Number of large-flowered fiddleneck plants in Site 300 experimental and native populations, 1986–2005

Big Tarplant

The distribution of big tarplant was mapped using a handheld GPS in September and October 2005. The big tarplant was widely distributed at Site 300 in 2005 compared to 2006.

In 2005 a prescribed burn was conducted in the area surrounding Building 801 in an attempt to boost the big tar plant population in that area. This area had not burned for several years and the previous large population in this area had become quite small. (Since the construction of the contained firing facility at Building 801, it has not been necessary to conduct prescribed

burns in this area.) Prior to the Building 801 burn transects were established to measure big tarplant seedling recruitment. Using these transects and GPS mapping, LLNL hopes to determine if the 2005 prescribed burn had a positive impact of the big tarplant population.

Diamond-Petaled California Poppy

There are currently three populations of diamond-petaled California poppy (*Eschscholzia rhombipetala)* known to occur at Site 300. Although this species is not listed under the federal or California endangered species acts, it is extremely rare and is currently known to only occur at Site 300 and one additional location in San Luis Obispo County. A census of the three Site 300 populations was conducted in March and April 2005, during which time LLNL recorded the size and location of each diamond-petaled poppy plant and the composition of the vegetation community in which this species occurs.

In 2005, a total of 906 diamond-petaled California poppies were found at Site 300. The most recently discovered population, site 3, contained by far the largest number of diamond-petaled California poppies (853 plants) in 2005. Diamond-petaled California poppy populations at site 1 (28 plants) and site 2 (25 plants) have continued to be very small in recent years.

Round-Leaved Filaree

Six small populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwestern portion of Site 300. This species thrives in the disturbed soils of the annually graded fire trails at Site 300. Of the six populations, four occur on fire trails. During the spring of 2005, the extent of the six Site 300 populations was mapped using a handheld GPS and the size of each population was estimated. These six populations were estimated to contain approximately 3650 round-leaved filaree plants.

July 19, 2005, Wildfire

On July 19, after the spring census of Site 300 rare plants was completed, a wildfire occurred at Site 300. This fire included all diamond petaled California poppy, large-flowered fiddleneck, and round-leaved filaree populations that occur at Site 300. This fire occurred at a time when these spring flowering annual plants had already set seed, so the fire is not likely to result in direct impacts to these plants. Results of the spring 2006 census will help in determining the impacts of this wildfire.

Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2005, LLNL has been able to avoid most impact to special status wildlife and plants. LLNL activities, including the Arroyo Seco management plan, did not negatively impact

California red-legged frogs at the Livermore site. In the Livermore site population of California red-legged frogs, breeding decreased in 2005 compared to previous years although this decrease is not linked directly to LLNL activities. Invasive species continue to be the largest threat to California red-legged frogs at the Livermore site. In 2005 LLNL expanded efforts to educate LLNL employees on the problems of introducing any species to LLNL. LLNL also continued its bullfrog eradication program in 2005.

At Site 300, the habitat enhancement pools were created in Elk Ravine as mitigation of impact to California red-legged frog habitat that will occur as a result of decreased cooling water discharge. Construction was completed successfully and California red-legged frog use of the created wetlands will be monitored in 2006.

Large-flowered fiddleneck and diamond-petaled California poppy populations are located in remote areas of Site 300 away from programmatic impacts. Four of the six Site 300 round-leaved filaree populations are located in annually graded fire trails. In these fire trail populations, round-leaved filaree is restricted to the areas that are disturbed by grading. This disturbance appears to benefit the species and is not considered a negative impact. Although rare elsewhere, big tarplant is widely distributed throughout Site 300. Although individual big tarplants were disturbed by LLNL activities, including fire trail grading and well drilling, these impacts affected only a very small fraction of the Site 300 tarplant population and are not considered to be significant to this species.

Radiological Dose Assessment

CHAPTER 7

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Introduction

Lawrence Livermore National Laboratory (LLNL) assesses potential radiological doses to biota, off-site individuals, and the population residing within 80 km of either the Livermore site or 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. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA).

Releases of radioactive material to air are the major source of public radiological exposure from LLNL operations, and radiological monitoring of stack air effluent and ambient air (Chapter 4) represents a significant monitoring effort. In addition to ambient air and stack monitoring there is monitoring of radioactivity in a variety of media including soil, sediment, vegetation, wine and measured environmental gamma radiation (Chapter 6). Monitoring at LLNL also includes the sampling of wastewaters, storm water and groundwater as well as rainfall and local surface water (Chapter 5). Releases to these water systems are not sources of direct exposures to the public because they are not directly consumed.

Measurements of radiological releases to air and modeling the dispersion of the released radionuclides determine LLNL's dose to the public. Because LLNL is a DOE facility, it is subject to the requirements of Title 40 of the Code of Federal Regulations (CFR) Part 61 Subpart H, the National Emissions of Hazardous Air Pollutants (NESHAPs). LLNL uses the EPA Clean Air Act Assessment Package-1988 (CAP88-PC) computer model in

demonstrating site compliance with NESHAPs regulations. This dose code evaluates the four principal exposure pathways: ingestion, inhalation, air immersion, and irradiation by contaminated ground surface.

The major radionuclides measured by LLNL in 2005 that contribute to individual and collective dose were tritium at the Livermore site and three uranium isotopes (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.

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.

Releases of Radioactivity from LLNL Operations

Radiological releases to air are estimated by three principal means: continuous monitoring of stack effluent at selected facilities (described in Chapter 4); routine surveillance ambient air monitoring for radioactive particles and gases, both on and off LLNL property (also described in Chapter 4); and radioactive material usage inventories. Of these three approaches, stack monitoring provides the most definitive characterization. Beginning in 2003, the extent of reliance on usage inventories declined in favor of increased utilization of ambient air monitoring data (see the "Compliance Demonstration for Minor Sources" section below).

Radiation Protection Standards

The release of radionuclides from operations at LLNL and the resultant radiological impact to the public are regulated by both the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA).

The primary DOE radiation standards for protection of the public are 1 millisievert per year (1 mSv/y) (which equals 100 millirem per year [100 mrem/y]) whole-body effective dose equivalent (EDE) for prolonged exposure of a maximally exposed individual in an uncontrolled area and 5 mSv/y (500 mrem/y) EDE for occasional exposure of this individual. (EDEs and other technical terms are discussed in *Supplementary Topics on Radiological Dose* [available on report CD] and defined in the glossary of this report.) These limits pertain to the sum of the EDE from external radiation and the committed 50-year EDE from radioactive materials ingested or inhaled during a particular year that may remain in the body for many years.

The EPA's radiation dose standard for members of the public limits the EDE to 100 μSv/y (10 mrem/y) for air emissions. EPA regulations specify not only the allowed levels, but also the approved methods by which airborne emissions and their impacts must be evaluated. With respect to all new or modified projects, NESHAPs compliance obligations define the requirements to install continuous air effluent monitoring and to obtain EPA approval before the startup of new operations. NESHAPs regulations require that any operation with the potential to produce an annual average off-site dose greater than or equal to 1 μSv/y (0.1 mrem/y), taking full credit for emission-abatement devices such as high-efficiency particulate air (HEPA) filters, must obtain EPA approval prior to the startup of operations. This same calculation, but without taking any credit for emission abatement devices, determines whether or not continuous monitoring of emissions to air from a project is required. These requirements are spelled out in LLNL's *Environment, Safety, and Health (ES&H) Manual*, Document 31.2, "Radiological Air Quality Compliance."

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 DOE and EPA mandated computer code used by LLNL to compute radiological individual or collective (i.e., population) dose resulting from radionuclide emissions to air. This code operates on a personal computer and is relatively easy to use and understand.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six collocated sources (Parks 1992). Input parameters used in the model include radionuclide type, emission rate in curies per year, and stack parameters, such as stack height, inside diameter and exit velocity. A site-specific wind parameter file is prepared annually from meteorological data collected by LLNL. The mathematical models and equations used in CAP88-PC are described in *User's Guide for CAP88-PC, Version 1.0* (Parks 1992).

Calculated doses include the four principal exposure pathways: internal exposures from inhalation of air and ingestion of foodstuff and drinking water (only for tritium), and external exposures through irradiation from contaminated ground and immersion in contaminated air. Dose is calculated as a function of radionuclide, pathway, spatial location, and body organ.

In addition, CAP88-PC provides the flexibility to adjust agricultural parameters (e.g., numbers of milk cows per km^2) and the fractions of contaminated foods ingested. For the 2005 evaluation, LLNL took advantage of this capability and used updated assumptions for agricultural and food

source parameters for CAP88-PC (see Larson et al. 2006). This is the second year these updated assumptions have been used. Furthermore, an improved tritium model (NEWTRIT; Peterson and Davis 2002) that uses air concentrations predicted by CAP88-PC to address the dose from releases of HT and the dose from organically bound tritium was again employed to compare with the tritium model in CAP88-PC.

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; defined below) member of the public. Second is the collective or "population" dose received by people residing 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. For LLNL to comply with NESHAPs regulations, the LLNL SW-MEI must not receive an EDE as great or greater than 100 μSv/y (10 mrem/y) from releases of radioactive material to air. Public facilities that could be the location of the SW-MEI include schools, churches, businesses, and residences. This hypothetical person is assumed to remain at one 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 may be received by any member of the public.

At the Livermore site, the SW-MEI in 2005 was located at the UNCLE Credit Union, about 10 m outside the controlled eastern perimeter of the site. This location lies 957 m from the Tritium Facility (Building 331), in an east-northeast direction (the typical prevailing wind direction). At Site 300, the SW-MEI occupied a position on the south-central boundary of the site bordering the Carnegie State Vehicular Recreation Area, 3170 m south-southeast of the firing table at Building 851. These SW-MEI locations are depicted in **Figure 7-1**.

[1] This is calculated for tritium only.

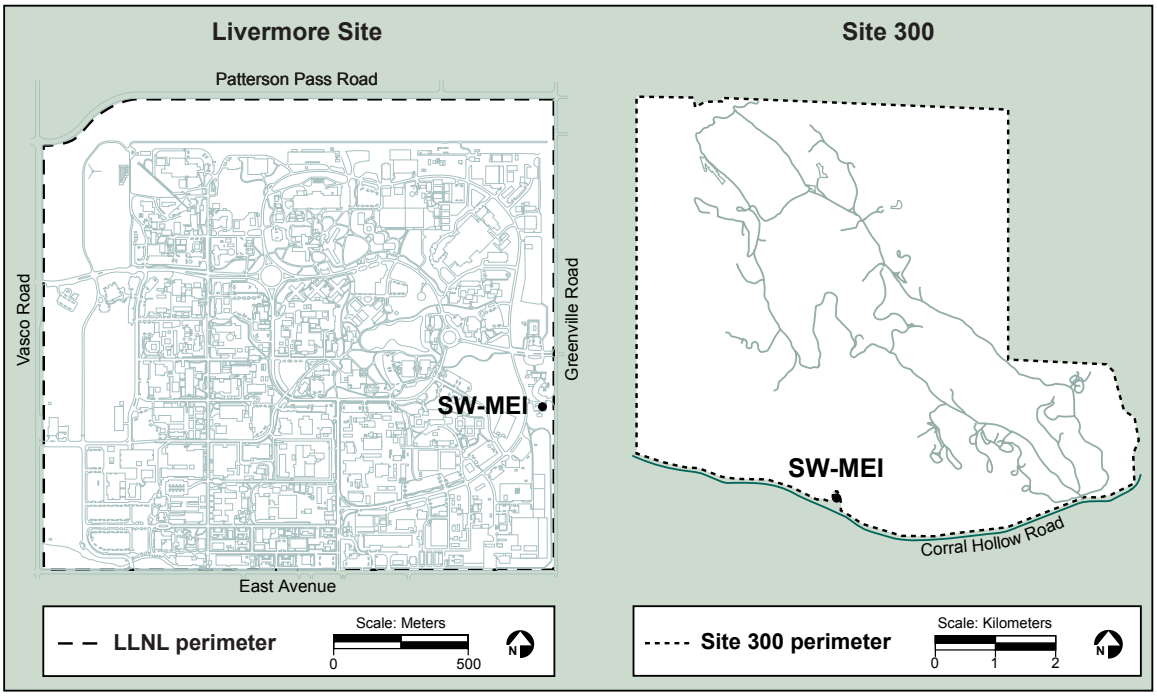


Figure 7-1. Location of the site-wide maximally exposed individual (SW-MEI) at the Livermore site and Site 300, 2005

Results of 2005 Radiological Dose Assessment

This section summarizes the doses to the most exposed public individuals from LLNL operations in 2005, 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.

Total Dose to Site-Wide Maximally Exposed Individuals

The total dose to the SW-MEI from Livermore site operations in 2005 was 0.065 μSv/y (0.0065 mrem/y). Of this, the dose attributed to diffuse emissions (area sources) totaled 0.038 μSv (0.0038 mrem) or 59%; the dose due to point sources was 0.027 μSv (0.0027 mrem) or 41% 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. Using NEWTRIT rather than CAP88-PC to calculate the dose for tritium emissions reduced the tritium component of the total dose from 0.059 μSv (0.0059 mrem) to 0.052 μSv (0.0052 mrem).

The total dose to the Site 300 SW-MEI from operations in 2005 was 0.18 µSv (0.018 mrem). Point source emissions from firing table explosives experiments totaled 0.088µSv (0.0088 mrem) accounting for 48% of the dose, while 0.094 µSv (0.0094 mrem), or about 52%, was contributed by diffuse emission sources.

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 2005. Although LLNL has nearly 150 sources with potential for releasing radioactive material to air according to NESHAPs prescriptions, most are very minor. Nearly the entire radiological dose to the public each year from LLNL operations comes from no more than six sources. In April 2003, EPA granted LLNL permission to use surveillance monitoring in place of inventory-based modeling to account for dose contributions from the numerous minor sources. This procedure was implemented for the third time in assessing 2005 operations (see also *LLNL NESHAPs 2005 Annual Report* [Larson et al. 2006]).

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 2005

Facility (source category)	CAP88-PC dose (µSv/y)[a]	CAP88-PC percentage contribution to total dose
Livermore site		
Building 331 stacks (point source)	0.026[b]	40
Building 612 Yard (diffuse source)	0.020[b]	31
Building 331 outside (diffuse source)	0.012[b]	18
Southeast Quadrant soil resuspension (diffuse source)	0.0061	9
Site 300		
Soil resuspension (diffuse source)	0.094	52
Building 851 Firing Table (point source)	0.088[c]	48

a 1 µSv = 0.1 mrem

b When LLNL's NEWTRIT model is used in place of CAP88-PC's default tritium model, the dose for the Building 331 stacks is reduced to approximately 86% of the value shown, and doses for the Building 612 Yard and Building 331 outside are reduced to 89% of the values shown.

c The Building 851 Firing Table had fewer explosive experiments in 2005 than in previous years.

Dominant radionuclides at the two sites were the same as in recent years. Tritium accounted for about 91% of the Livermore site's calculated dose. At Site 300, practically the entire calculated dose was due to the isotopes uranium-238, uranium-235, and uranium-234 from depleted uranium.

Regarding pathways of exposure, the relative significance of inhalation and ingestion depends on the assumptions made about the origin of food consumed and the predominant radionuclide contributing to dose. For individual doses calculated for tritium, the ingestion dose accounts for slightly more than the inhalation dose, approximately 53% and 47%, respectively. For uranium, the inhalation pathway dominates: 97% by the inhalation pathway versus 3% via ingestion. LLNL doses from air immersion and ground irradiation are negligible for both tritium and uranium.

The trends in dose to the SW-MEI from emissions at the Livermore site and Site 300 over the last 15 years are shown in **Table 7-2**. The general pattern, particularly over the last decade, shows year-to-year fluctuations around a low dose level, staying at or below about 1% of the federal standard. The SW-MEI dose estimates are intentionally conservative, predicting potential doses that are higher than actually would be experienced by any member of the public.

Doses from Unplanned Releases

There were no unplanned atmospheric releases of radionuclides to the atmosphere at the Livermore site or Site 300 in 2005.

Collective Dose

Collective dose for both LLNL sites was calculated out to a distance of 80 km in all directions from the site centers using CAP88-PC. Population centers affected by LLNL emissions 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 outer distance specified by DOE, there are 7.1 million residents included for the Livermore site collective dose determination, and 6.2 million for Site 300. Population data files (distribution of population with distance and direction) used for the present report are based on the LandScan Global Population 2001 Database (Dobson et al. 2000).

The CAP88-PC result for potential collective dose attributed to 2005 Livermore site operations was 0.0117 person-Sv (1.17 person-rem); the corresponding collective EDE from Site 300 operations was 0.0171 person-Sv (1.71 person-rem). These values are both within the normal range of variation seen from year to year.

Table 7-2. Doses (μSv/y)[a] calculated for the sitewide maximally exposed individual (SW-MEI) for the Livermore site and Site 300, 1990 to 2005

Year	Total dose	Point source dose	Diffuse source dose
Livermore site			
2005	0.065[b]	0.027[b]	0.038
2004	0.079[b]	0.021[b]	0.058
2003	0.44[b]	0.24[b]	0.20
2002	0.23[b]	0.10[b]	0.13
2001	0.17[b]	0.057[b]	0.11
2000	0.38[b]	0.17[b]	0.21
1999	1.2[b]	0.94[b]	0.28
1998	0.55[b]	0.31[b]	0.24
1997	0.97	0.78	0.19
1996	0.93	0.48	0.45
1995	0.41	0.19	0.22
1994	0.65	0.42	0.23
1993	0.66	0.40	0.26
1992	0.79	0.69	0.10
1991	2.34	—[c]	—[c]
1990	2.40	—[c]	—[c]
Site 300			
2005	0.18	0.088	0.094
2004	0.26	0.25	0.0086
2003	0.17	0.17	0.0034
2002	0.21	0.18	0.033
2001	0.54	0.50	0.037
2000	0.19	0.15	0.037
1999	0.35	0.34	0.012
1998	0.24	0.19	0.053
1997	0.20	0.11	0.088
1996	0.33	0.33	0.0045
1995	0.23	0.20	0.03
1994	0.81	0.49	0.32
1993	0.37	0.11	0.26
1992	0.21	0.21	—[d]
1991	0.44	0.44	—[d]
1990	0.57	0.57	—[d]

a 1 μSv = 0.1 mrem
b The dose includes HT emissions modeled as HTO as directed by EPA Region IX.
c Diffuse source doses were not calculated for the Livermore site for 1990 and 1991.
d No diffuse emissions were evaluated at Site 300 before 1993.

Although collective doses from LLNL operations are tiny compared with doses from natural background radiation, they may be high compared with other DOE facilities due to large populations within 80 km of the sites. However, a large dose to a small number of people is not equivalent to a small dose to many people, even though the collective dose may be the same. Given that the population centers potentially affected by LLNL operations are distant from both the Livermore site and Site 300, the collective doses from LLNL operations are better described by breaking them down into categories of dose received by individuals in the population affected. The breakdown (or disaggregation) of collective dose by the level of the individual dose in **Table 7-3** demonstrates that about 94% of the population receives less than 0.01 µSv/y (1 µrem/y).

Table 7-3. Collective dose broken down by level of individual doses, 2005

Individual dose range (µSv/y) [a]	Collective dose (person-Sv/y)[b]	Percent total collective dose
Livermore site		
0.01 to 0.1	0.0000517	0.444%
0.001 to 0.01	0.00716	61.0%
0.0001 to 0.001	0.00339	28.9%
0.00001 to 0.0001	0.00114	9.71%
Total[c]	0.0117	100%
Site 300[d]		
0.01 to 0.1	0.00107	6.25%
0.001 to 0.01	0.0106	62.0%
0.0001 to 0.001	0.00507	29.6%
0.00001 to 0.0001	0.000336	1.96%
0.00000001 to 0.00001	0.0000334	0.195%
Total	0.0171	100%

a 1 µSv = 0.1 mrem
b 1 person-Sv = 100 person-rem
c An additional 0.05% of the population received a dose less than 1×10^{-5} µSv.
d Dose from Building 851 Firing Table and Building 801A.

Doses to the Public Placed in Perspective

As a frame of reference to gauge the size of these LLNL doses, **Table 7-4** compares them to average doses received in the United States from exposure to natural background radiation and other sources. Collective doses from LLNL operations in 2005 are about 700,000 times smaller than ones from natural background radiation. The estimated maximum potential doses to

individual members of the public from operations at the two LLNL sites (combined) in 2005 are nearly 12,000 times smaller than ones received from background radiation in the natural environment.

Table 7-4. Comparison of background (natural and man-made) and LLNL radiation doses, 2005

Location/source	Individual dose[a] (μSv) [c]	Collective dose[b] (person-Sv) [d]
Livermore site sources		
Atmospheric emissions	0.065	0.0117
Site 300 sources		
Atmospheric emissions	0.18	0.0171
Other sources[e]		
Natural radioactivity[f,g]		
Cosmic radiation	300	2,130
Terrestrial radiation	300	2,130
Internal (food consumption)	400	2,840
Radon	2,000	14,200
Medical radiation (diagnostic procedures)[f]	530	3,760
Weapons test fallout[f]	10	71
Nuclear fuel cycle	4	28

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 7.1 million people for the Livermore site and 6.2 million for Site 300), calculated with respect to distance and direction from each site. The Livermore site population estimate of 7.1 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.

Special Topics on Dose Assessment

Compliance Demonstration for Minor Sources

From 1991 through 2002, LLNL demonstrated compliance for minor sources through a labor-intensive inventory and modeling process. The dose consequences to the public for these sources were 8 to 20 orders of magnitude below the regulatory standard of 100 μSv/y (10 mrem/y) and did not justify the level of effort expended in accounting for them. To better allocate resources, LLNL made a request to EPA, pursuant to the NESHAPs regulations, to use existing ambient air monitoring to demonstrate compliance for minor sources. This request was made in March 2003 and

granted by EPA in April 2003. This report marks the third year that LLNL is demonstrating 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 Table 2, Appendix E of 40 CFR 61. 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 locations VIS and CRED represent 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. Because this is a diffuse source, the average of the results for all monitoring locations at the site are used to represent the SW-MEI.

The Table 2, Appendix E of 40 CFR 61 standards and the measured concentrations at the SW-MEI are presented in SI units in **Table 7-5**. As demonstrated by the calculation of the fraction of the standard, LLNL-measured concentrations for tritium and plutonium-239+240, and uranium-238 in air are 0.0023 or less than the health protective standard for these radionuclides.

Table 7-5. Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2005

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	$0.048^{(a)}$	8.7×10^{-4}
Livermore SW-MEI	Plutonium-239	7.4×10^{-5}	1.9×10^{-4}	$8.9 \times 10^{-9(b)}$	1.2×10^{-4}
Site 300 SW-MEI	Uranium -238	3.1×10^{-4}	1.1×10^{-4}	$7.0 \times 10^{-7(c)}$	2.3×10^{-3}

Note: 1 Bq = 2.7×10^{-11} Ci

a The tritium value includes contributions from the Tritium Facility, Building 612 Yard, DWTF Stack and Area Source, and Building 331 Waste Accumulation Area.

b The mean measured concentration for plutonium is less than the detection limit; only 3 of the 24 values comprising the mean were measured detections.

c The ratio for the mean uranium-235 and uranium-238 concentrations for 2005 is 0.005 which is less than 0.00726, the ratio of these isotopes for naturally occurring uranium. This results in approximately 57% of the resuspension being attributable to naturally occurring uranium and 43% being attributable to depleted uranium.

Estimate of Dose to Biota

Although mankind is protected from excess radiation dose by the methods outlined in this chapter, biota are not necessarily protected because of different exposure pathways (e.g., dose to a ground squirrel burrowing in contaminated soil). Thus LLNL calculates potential dose to biota from LLNL operations using the DOE guidance document, "DOE Standard: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (U.S. DOE 2002), and the RAD-BCG (Biota Concentration Guides) Calculator

(Version 2) in an Excel spreadsheet. 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. Radionuclides contributing to dose to biota were americium-241, cesium-137, tritium, plutonium-239 (analyzed as plutonium-239 and also as a surrogate for gross alpha), thorium-232, uranium-235, and uranium-238; in addition, gross beta was represented by strontium-90.

In the RAD-BCG Calculator, each radionuclide in each medium (soil, sediment, surface water) is assigned a derived concentration limit. For each concentration entered in the spreadsheet, a fraction of the derived concentration limit for that radionuclide is automatically calculated; the fractions are summed for each medium. For aquatic and riparian environments, if a concentration for water is entered, the calculator automatically assigns an expected concentration to the sediment, and vice versa.

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 protected.

In the LLNL assessment, the maximum concentration of each radionuclide measured in soils, sediments, and surface waters during 2005, no matter whether measured on the Livermore site, in the Livermore Valley, or at Site 300, was entered into the screening calculation. This approach will result in an assessment that is unrealistically conservative, given that the maximum concentrations in the media are scattered over a very large area, and no plant or animal could possibly be exposed to them all. Other assumptions increase the possibility that the estimated dose will be conservative. For example, while only gross alpha and gross beta are measured in water, it is assumed that gross alpha is represented by plutonium-239 and gross beta by strontium-90 to assure maximum dose. 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 much higher concentrations of radionuclides are measured in runoff than in surface waters. Finally, when measurements were available for both runoff and sediment, the value that gave the highest fraction of the BCG was used.

In 2005, using the assumptions above, the aquatic system failed the screening test. This was due entirely to very high concentrations of gross alpha (from an upstream location) and gross beta (from a downstream location) in the runoff of February 15 at Site 300. These values were due to high levels of total suspended solids (TSS) in the runoff samples rather

than to concentrations in the runoff water, and thus they can be rejected as not representing runoff. (Suspended sediments at Site 300 contain significant quantities of naturally occurring uranium and its daughter decay products that account for elevated levels of gross alpha and beta activities.). The sum of the fractions for the aquatic system, after the highest runoff concentrations were rejected, was 0.280, and the sum for the terrestrial system was 0.035. These results for the aquatic system are similar to those in 2002, 2003, and 2004. The sum of the fractions for the terrestrial system is similar to previous years.

A less artificial assessment of dose to aquatic biota from LLNL operations can be made using runoff or release concentrations from the Drainage Retention Basin (DRB) combined with sediment concentrations from the East Settling Basin (ESB). Sediment samples are not collected in the DRB, and water is ephemeral at the ESB. Nevertheless, concentrations may be expected to be similar given that water drains through the ESB to the DRB. Using these concentrations in the RAD-BCG Calculator, the sum of the fractions for aquatic exposure is 0.034, which is about 12% of the fraction derived from the ultraconservative approach. It is clear that dose to biota from LLNL operations is below levels of regulatory concern.

Modeling Dose from Tritium — Comparison of Approaches

Dose predictions can vary due to different modeling approaches and assumptions. Because tritium has been and continues to be the principal radionuclide released to air in Livermore site operations (from a public dose standpoint), a comparison of potential doses for 2005, calculated from different approaches, is presented.

Since 1986, LLNL has calculated doses from releases of HTO (or total tritium modeled as HTO) to the atmosphere using the regulatory model CAP88-PC (since 1992) or its predecessor, AIRDOS-EPA. The dose calculated with AIRDOS-EPA or CAP88-PC uses source terms for the principal tritium sources at the site. As well, since 1979, using bulk transfer factors (**Table 7-6**) derived from equations in the Nuclear Regulatory Commission's (NRC) Regulatory Guide 1.109 (U.S. NRC 1977), LLNL has calculated potential ingestion doses from measured concentrations in vegetation (Chapter 6) and drinking water (Chapter 5), as well as doses from inhalation (Chapter 4). Both CAP88-PC and Regulatory Guide 1.109 only account for dose from HTO. More conceptually accurate assessments should account for dose from releases of HT and from ingestion of organically bound tritium (OBT); if OBT is ignored, ingestion dose may be underestimated by up to a factor of two (ATSDR 2002). In recent years, another model, NEWTRIT (Peterson and Davis 2002), has been used to estimate inhalation and ingestion doses from releases of both HT and HTO; the ingestion dose

accounts for both HTO and OBT. NEWTRIT uses observed or predicted air concentrations as input.

Table 7-6. Bulk transfer factors used to calculate inhalation and ingestion doses from measured concentrations in air, vegetation, and potential drinking water

Doses in μSv	Bulk transfer factors[a] times observed mean concentrations
Inhalation and skin absorption	0.21 x concentration in air (Bq/m^3) (See Chapter 4)
Drinking water	0.013 x concentration in drinking water (Bq/L) (See Chapter 5)
Food Ingestion	0.0049 x concentration in vegetation (Bq/kg) (See Chapter 6); (factor obtained by summing contributions of 0.0011 for vegetables, 0.0011 for meat and 0.0027 for milk)

a The derivation for these bulk transfer factors can be found in Appendix C of *Environmental Report 2002* (Sanchez et al. 2003).

Hypothetical tritium doses predicted at VIS, the on-site location of air tritium and vegetation sampling (see **Figure 4-1**), using the three modeling approaches are compared in **Table 7-7**. All predictions were made for a hypothetical person living 100% of the time adjacent to the air tritium monitor at VIS and eating 100% locally grown food. Because the air tritium monitor can only sample for HTO, only HTO releases were used to calculate air tritium concentrations using CAP88-PC.

Table 7-7. Comparison of hypothetical doses (nSv/y) at the VIS air tritium monitoring location calculated from predicted and observed concentrations of HTO in air in 2005

	CAP88-PC (from predicted air concentrations)[a]	NRC 1.109 (from mean air, vegetation, and tap water[b] concentrations)	NEWTRIT (from mean air tritium concentrations)
Inhalation and skin absorption	22	9.9	11
Food ingestion (vegetables; milk; meat)	71; 44; 26	2.6; 6.5; 2.6	28; 18; 8.9
Drinking water	1.3	< 27[c]	4.7
Food ingestion dose	141	12	54
Total dose	164	< 49	70

a Doses from CAP88-PC are based on the sum of the predicted HTO concentrations at VIS for the Tritium Facility stacks (3.70×10^{-2} Bq/m^3), the Building 612 Yard (3.48×10^{-2} Bq/m^3), and the Building 331 area source (8.14×10^{-3} Bq/m^3), the DWTF stack (1.07×10^{-3} Bq/m^3) and DWTF area source (8.14×10^{-4} Bq/m^3).

b Tap water is measured on the Livermore site but not at the VIS location.

c All tap waters measured for tritium in 2005 were below the limit of detection.

The dose comparison shows about a factor of about 3.5 between the lowest (NRC 1.109) and highest (CAP88-PC) dose predictions, each of which is based on valid assumptions. Differences are primarily due to predicted (0.0818 Bq/m^3) versus observed (0.0470 Bq/m^3) air concentrations and

assumptions about intake rates and dose coefficients (see Appendix C of *Environmental Report 2002* [Sanchez et al. 2003]). When predicted air concentrations drive the doses, doses are normally higher than when observed air and vegetation concentrations drive the results. The total dose from CAP88-PC is the highest, as expected, and the NEWTRIT dose is within a factor of 2.4 of the CAP88-PC dose.

A more realistic, but still highly conservative, set of assumptions about the lifestyle of the hypothetical member of the public residing at the VIS monitor location (**Table 7-8**) lowers the annual dose from tritium to as low as about 25% of the lowest dose in **Table 7-7**, even while including tiny potential doses from other dose pathways.

Table 7-8. Doses for the tritium exposure of an individual residing at the VIS location in 2005, based on observed HTO-in-air concentrations and using plausible but conservative assumptions (as indicated)

Source of dose	Annual dose (nSv/y)	Assumption
Inhalation and skin absorption	4.1	Breathes air at VIS 16 hours a day, all year at a lower rate than CAP88 or NEWTRIT
Ingesting food, including OBT	7.4	Raises and eats 25% homegrown leafy vegetables, fruit vegetables, fruits and root crops, no homegrown milk, beef, pork, or grain but 12 kg/y homegrown chickens and 20 kg/y homegrown eggs. Assume the feed for the chickens is 50% homegrown; chickens drink water from outdoor pans at 50% air moisture.
Drinking water	[5.9][a]	Drinks 440 L/y of well water at average concentration of California groundwater
Drinking wine, including OBT	1.6	Drinks one liter bottle of Livermore Valley wine each week at the mean concentration for 2005
All sources	13[a]	

a Drinking water dose is not included in a realistic estimate of the dose impacts of LLNL releases of tritium to the atmosphere because Livermore drinking water is unaffected by LLNL operations. Nevertheless, inclusion of a drinking water dose demonstrates that the dose attributable to LLNL is not much different than background, especially given that all doses shown include background.

Environmental Impact

The annual radiological doses from all emissions at the Livermore site and Site 300 in 2005 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, the potential doses to the LLNL SW-MEI members of the public from operations in 2005 were:

- Livermore site: 0.065 μSv (0.0065 mrem)—41% from point-source emissions, 59% from diffuse-source emissions. The point source emissions include gaseous tritium modeled as tritiated water vapor for compliance purposes, as directed by EPA Region IX.
- Site 300: 0.18 μSv (0.018 mrem)—48% from explosive experiments, which are classified as point-sources, 52% from diffuse-source emissions.

As noted earlier, the major radionuclides accounting for the doses were tritium at the Livermore site and the three isotopes in depleted 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 2005 was estimated to be 0.0117 person-Sv (1.17 person-rem) for the Livermore site and 0.0171 person-Sv (1.71 person-rem) for Site 300. These doses include potentially exposed populations of 7.1 million people for the Livermore site and 6.2 million people for Site 300 living within a distance of 80 km from 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 2005, were 0.07% and 0.18%, respectively, of the federal standard and were more than 16,000 times smaller than the dose from background radiation. The collective doses from LLNL operations in 2005 were about 700,000 times smaller than those caused by natural radioactivity in the environment.

Potential doses to aquatic and terrestrial biota from LLNL operations were assessed and found to be well below DOE screening dose limits.

In conclusion, 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 determinations of LLNL doses. These maximum credible doses to the public indicate that LLNL's use of radionuclides had no significant impact on public health during 2005.

Groundwater Investigation and Remediation

CHAPTER 8

John Karachewski
Michael J. Taffet

During 2005, groundwater investigations and remediation activities performed under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. LLNL collects and analyzes groundwater, soil, and soil vapor samples 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, nature and extent of the contamination, and source areas. 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 and LLNL's progress in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300. Contamination for the most part is confined to each site. Site 300, with an area of 28.3 km^2 (10.9 mi^2) has been divided into eight operable units based on the nature and extent of contamination and on topographic and hydrologic considerations. The Livermore site at 3.3 km^2 (1.3 mi^2) is effectively one operable unit.

Livermore Site Ground Water Project

Initial releases of hazardous materials occurred at the Livermore site in the mid-to-late 1940s when the site was the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed volatile organic compounds (VOCs), fuel hydrocarbons, metals, and tritium to the groundwater and unsaturated

zone 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 sediments are the only media that require remediation (Thorpe et al. 1990). The identified compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards (maximum contaminant levels [MCLs]), are trichloroethylene (TCE), perchloroethylene (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 above the MCL in several offsite plumes that extend from the southwestern corner of the Livermore site. LLNL operates groundwater extraction wells in this area. In addition, LLNL maintains an extensive network of monitoring wells in the offsite area west of Vasco Road.

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 recharges the groundwater system, which flows toward the east-west axis of the valley. Along the southwest portion of the Livermore Valley, the direction of groundwater flow changes from east-west to south and into the Sunol Valley Groundwater Basin.

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.

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 the less permeable clay and silt deposits. The alluvial sediments have been subdivided into nine hydrostratigraphic units (HSUs) beneath the Livermore site (see **Figure 8-1**). 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: HSUs 1B, 2, 3A, 3B, 4, and 5 (Blake et al. 1995; Hoffman et al. 2003). HSUs 1A, 6, and 7, on the other hand, do not contain contaminants of concern above action levels and are therefore not discussed further.

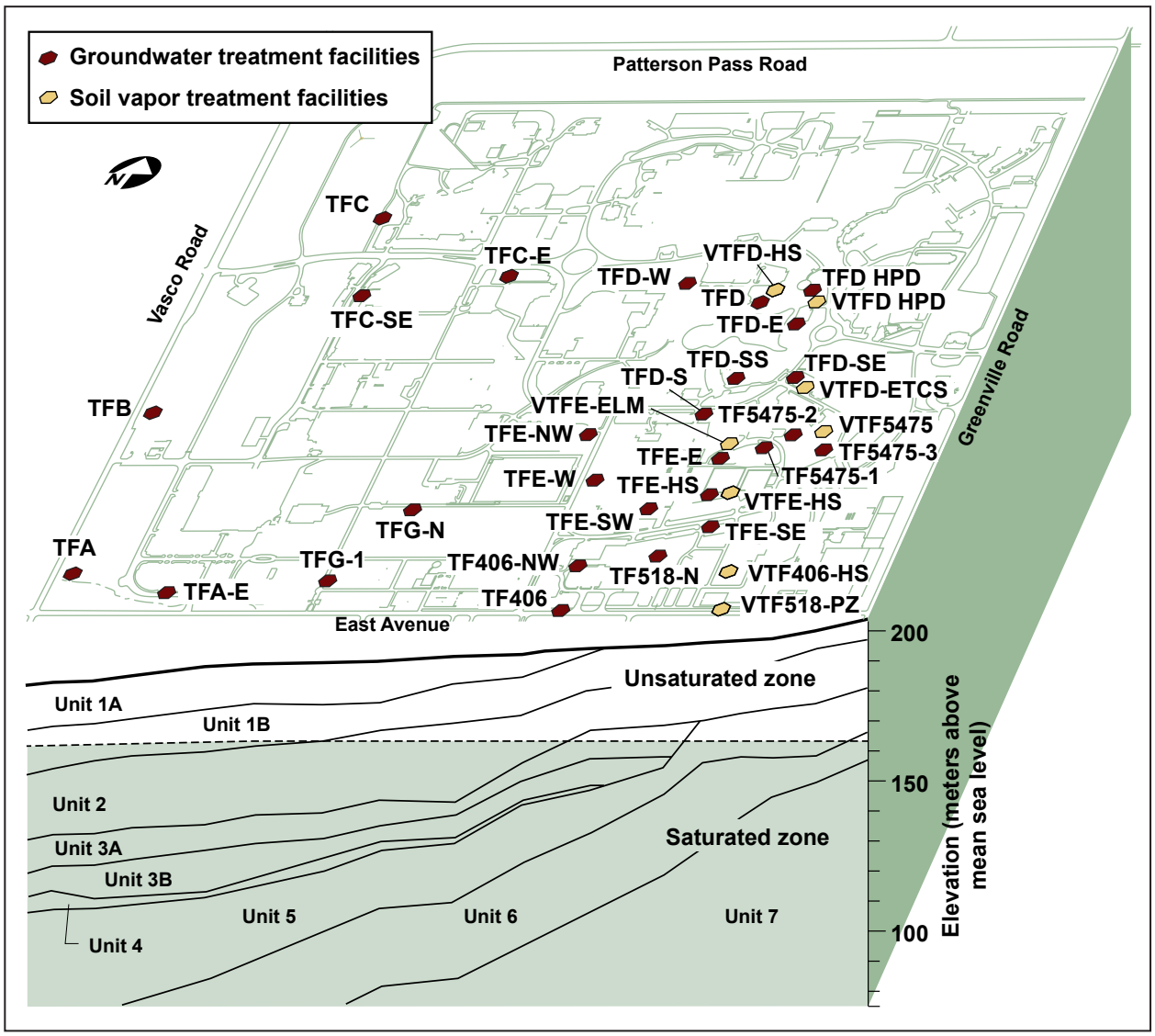


Figure 8-1. Map and cross section of the Livermore site showing hydrostratigraphic units and the locations of the treatment facilities

Remediation Activities and Monitoring Results

This section summarizes the primary activities and results of the Livermore site Ground Water Project in 2005. Additional information is provided in the *Ground Water Project 2005 Annual Report* (Karachewski et al. 2006). In addition to discussing trends during the past year, this section also highlights

the significant reduction of VOC concentrations at LLNL during the past five years.

In 2005, LLNL operated 27 groundwater treatment facilities in the TFA, TFB, TFC, TFD, TFE, TFG, and TFH (TF406, TF518, and TF5475) areas (see **Figure 8-1**). The 77 groundwater extraction wells and 22 dual extraction wells produced more than 1129 million liters of groundwater and the treatment facilities removed more than 71 kg of VOCs (**Table 8-1**) from this volume. For comparison, in 2004 the groundwater treatment facilities removed approximately 86 kg of VOCs. The lower quantity of mass removed in 2005 is partially due to decreasing concentrations in the TFD and TFE source areas and declining extraction well flow rates due to remediation-induced dewatering at the site. Since remediation began in 1989, more than 10,700 million liters of groundwater have been treated, resulting in removal of more than 1168 kg of VOCs.

Table 8-1. Volatile organic compounds removed from groundwater and soil at the Livermore site

Treatment facility area[a]	2005		Cumulative total	
Groundwater	**Water treated (ML)[b]**	**VOCs removed (kg)**	**Water treated (ML)**	**VOCs removed (kg)**
TFA	418.1	6.9	4,927.3	178.6
TFB	111.6	3.2	1,122.6	65.7
TFC	138.7	5.8	964.1	71.9
TFD	287.0	42.7	2,367.3	649.8
TFE	99.8	9.9	848.2	172.4
TFG	27.6	1.2	142.6	7.2
TFH	45.9	1.5	405.1	22.6
Total[c]	1,129	71	10,777	1,168
Soil vapor[d]	**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**	**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**
TFD	444.3	58.4	595.7	66.0
TFE	1,096.9	27.4	1,875.0	123.0
TFH	804.3	110.5	2,492.7	722.2
Total[c]	2,346	196	4,963	911

a Treatment areas and facilities:
TFA area: TFA, TFA-E
TFB area: TFB
TFC area: TFC, TFC-E, TFC-SE
TFD area: TFD, TFD-E, TFD-HPD, TFD-S, TFD-SE, TFD-SS, TFD-W, VTFD-ETCS, VTFD-HPD, VTFD-HS
TFE area: TFE-E, TFE-HS, TFE-NW, TFE-SE, TFE-SW, TFE-W, VTFE-ELM, VTFE-HS
TFG area: TFG-1, TFG-N
TFH area: TF406, TF406-NW, VTF406-HS, TF518-N, VTF518-PZ, TF5475-1, TF5475-2, TF5475-3, VTF5475
b ML = million liters
c Totals rounded to nearest whole number
d Includes only those treatment areas at which vapor was extracted.

In 2005, LLNL also operated eight soil vapor treatment facilities: VTFD East Traffic Circle South (VTFD-ETCS), VTFD Helipad (VTFD-HPD), VTFD Hotspot (VTFD-HS), VTFE Eastern Landing Mat (VTFE-ELM), VTFE Hotspot (VTFE-HS), VTF406 Hotspot (VTF406-HS), VTF518 Perched Zone (VTF518-PZ), and VTF5475 (see **Figure 8-1**). The 20 soil vapor extraction wells and 22 dual extraction wells produced more than 2.3 million cubic meters of soil vapor and the treatment facilities removed more than 196 kg of VOCs (**Table 8-1**). In 2004, the soil vapor treatment facilities removed approximately 133 kg of VOCs. The significantly higher rate of mass removal in 2005 (a 47% increase) is due to activation of new vapor treatment facilities VTFD-ETCS, VTFD-HS, VTFE-HS, and VTF406-HS. Since initial operation, about 5 million cubic meters of soil vapor has been extracted and treated, removing more than 911 kg of VOCs from the subsurface.

The *Ground Water Project 2005 Annual Report* (Karachewski et al. 2006) includes additional information, including regulatory compliance, field investigations, and a summary of the remedial action program.

Over the last five years, groundwater VOC concentrations in HSUs 1B, 2, and 3A along the western and southern margins of the Livermore site have continued to decline, particularly in the offsite areas, due to the combined effects of hydraulic capture and groundwater treatment. The concentration decline in HSU-2 over the last five years is shown in **Figure 8-2**. Within the interior of the site, aggressive implementation of pump and treat remediation using portable treatment units positioned downgradient of source areas has resulted in concentration declines in HSUs 2, 3A, 3B, 4, and 5.

Over the last three years, remediation activities, including soil vapor extraction, dual extraction, and groundwater extraction, have focused primarily on source area cleanup. **Figure 8-3** shows the increasing amount of mass removed in response to these cleanup activities.

In 2005, concentrations continued to decrease in most Livermore site VOC plumes. The decline in VOC concentrations is primarily attributed to active remediation and reflects the removal of more than 267 kg of VOCs by the groundwater and soil vapor extraction wells during the year. Notable trends and results are discussed below.

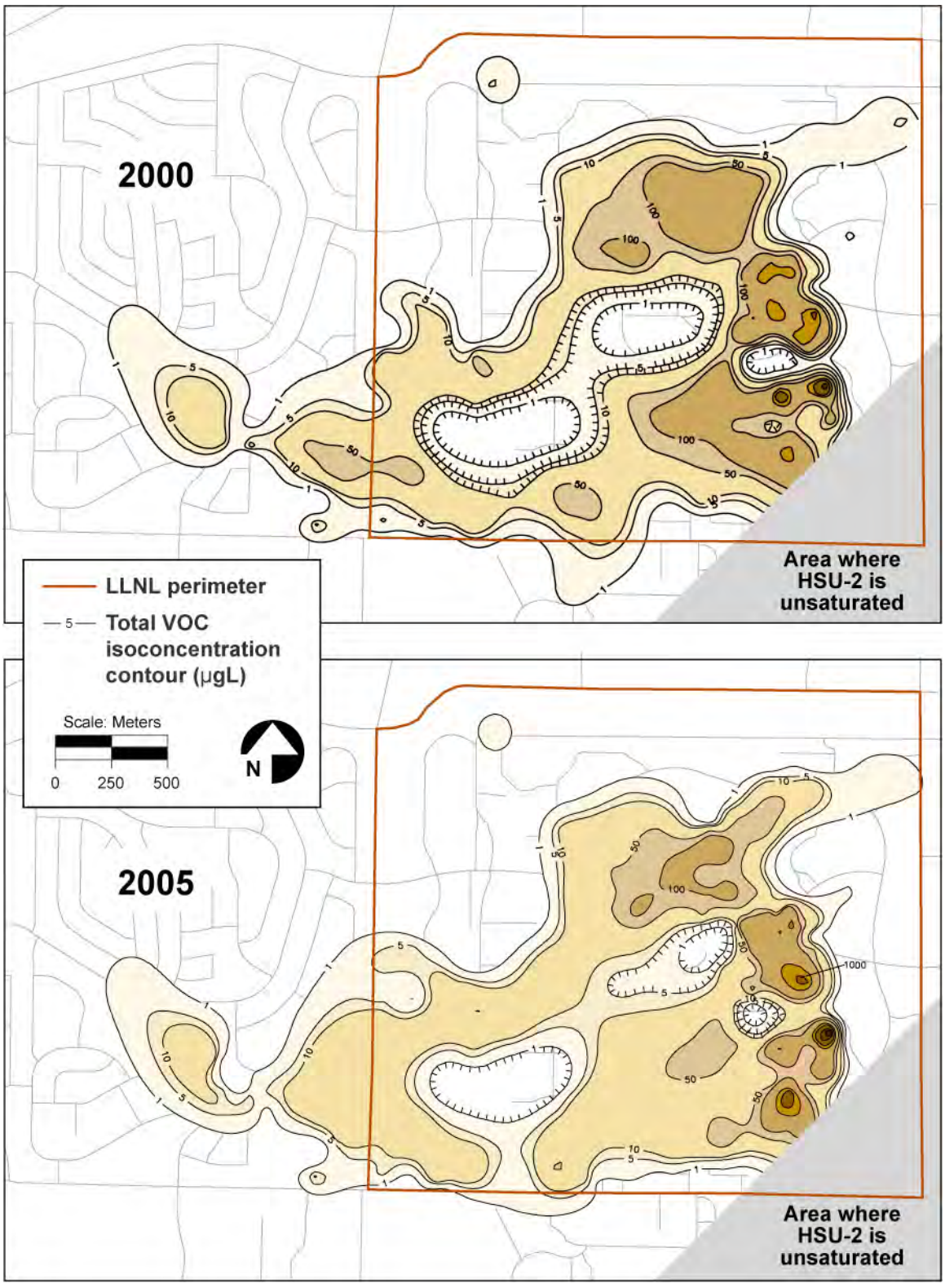


Figure 8-2. Isoconcentration maps showing reductions in total VOC concentrations for HSU-2 between 2000 and 2005

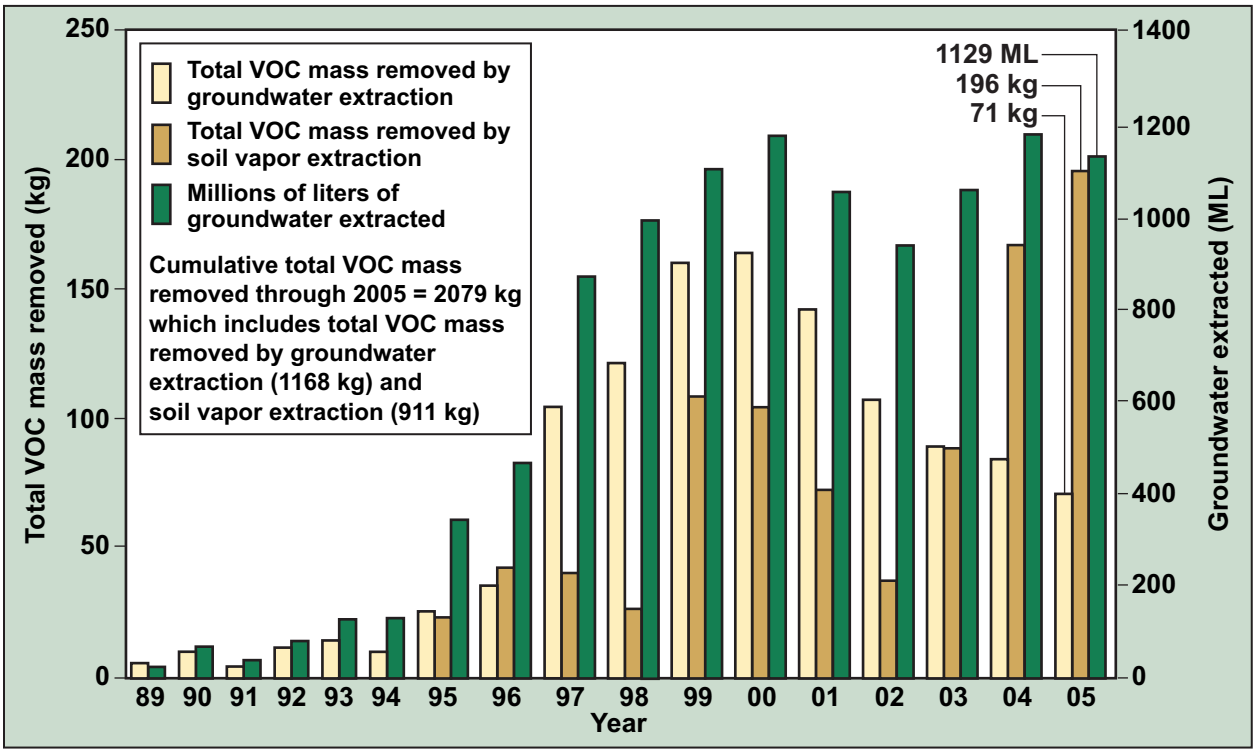


Figure 8-3. Total VOC mass removed and volume of groundwater extracted from the subsurface of the Livermore site, 1989–2005

VOC concentrations on the western margin of the site generally continued to decline gradually, indicating continued effective hydraulic control of the boundary plumes in the TFA, TFB, and TFC areas. The off-site HSU-1B VOC plumes were below MCLs except at one well, where a slight decrease in PCE concentration (from 11 ppb in July 2004 to 9.7 ppb at well W-1425 in August 2005) was observed. The entire offsite and onsite TFA HSU-2 total VOC plume remained below 50 ppb. The highest PCE levels offsite remain at wells W-404 and W-654, where third quarter 2005 concentrations were 20 ppb and 13 ppb, respectively. All TFA, TFB, and TFC source areas remained unchanged, except at the TFC Hotspot area. Concentrations of TCE in this area increased from 170 ppb (October, 2004) to 260 ppb (October 2005) in HSU-1B piezometer SIP-501-007. Groundwater remediation is scheduled to begin in this area during fiscal year (FY) 2006 as part of the TFC Hotspot Remedial Action Implementation Plan (RAIP) milestone.

VOC concentrations in a mobile HSU-2 plume located in the western TFE area continue to decline (see **Figure 8-2**). Downgradient from the source area, total VOC concentrations decreased below 100 ppb in TFE-W extraction well W-305. Total VOCs in piezometer SIP-331-001, located in the distal part of the plume, declined from 69 ppb in March 2004 to 36 ppb in June 2005 due

to continued groundwater extraction at the TFE West treatment facility. Concentrations in the VOC source area at the Eastern Landing Mat have remained relatively constant over the last two years (210 ppb TCE at extraction well W-1109 in July 2005).

PCE and TCE appeared in TFB HSU-3A well W-310 for the first time (3.5 ppb, and 1.3 ppb, respectively) in November 2004. Testing is planned to determine whether these VOCs represent the leading edge of an HSU-3A plume emanating from the TFD area or are due to faulty well completion. Total VOC concentrations in TFD Helipad HSU-3A source area extraction wells continued to decline, in part due to vacuum-enhanced groundwater extraction. For example, the VOC concentrations in well W-1657 declined from 884 ppb in July 2004 to 502 ppb in August 2005. A large concentration decline was observed in the Trailer 5425 area, where total VOCs in well W-206 were 1651 ppb in July 2004 and 378 ppb in August 2005. Farther downgradient to the southwest at well W-1201, total VOC concentrations increased from 230 ppb in August 2004 to 375 ppb in August 2005. These changes may be due in part to groundwater extraction at the TFE Hotspot (well W-2012), which began operation in 2005. Elsewhere in HSU-3A, VOC concentrations remained largely unchanged.

VOC concentrations in HSU-3B and HSU-5 remained largely unchanged during 2005. Concentrations in HSU-4 also remained relatively unchanged except for well W-351 in the TFD area, where TCE concentrations decreased from 470 ppb in July 2004 to 120 ppb in October 2005. This decrease may be due to groundwater extraction at the TFD Helipad (well W-1254), which began operation in June 2004. Concentrations continued to decline in HSU-5 on Sandia/California property in the TF406 South area, with only TCE remaining above MCLs in two offsite wells (10 ppb in well W-509 and 5.6 ppb in well W-1113 in October 2005). The ongoing cleanup at the TF406 South location indicates that construction of a new facility is not warranted at this time. Accordingly, a revised schedule of remedial actions was signed by the Remedial Project Managers on October 11, 2005, removing the TF406 South facility as an FY 2006 milestone.

During 2005, tritium activities in groundwater from all wells at the Livermore site, including those in the Trailer 5475 and Building 292 areas, were below the 20,000 pCi/L MCL and continued to decrease by natural decay.

Groundwater Flow and Transport Modeling

Groundwater flow and contaminant transport models are used at the Livermore site to optimize the design and operation of remediation systems; to support ongoing subsurface characterization activities; and to improve the ability to forecast, monitor, and interpret the progress of the remediation

program. In addition, site-specific models are developed to assess the potential impact to groundwater from residual contamination in sediments above the water table.

In 2005, ERD continued development and utilization of a comprehensive basin-scale groundwater flow and transport model to simulate all relevant subsurface hydrologic processes influencing contaminant transport at the Livermore site. The model is currently applied to improve the remediation efficiency for the distal plumes west of the site. This model will also be applied to better understand dewatering processes observed at the eastern portion of the site, predict the vertical migration of VOCs between adjacent HSUs, and incorporate the long-term impact of source areas where high concentrations of VOCs remain in low permeability sediments.

The model results are used by hydrogeologists to make decisions on where to place new extraction wells and how to adjust the extraction flow rates in existing wells to ensure complete capture of the VOC contamination in groundwater as well as to reduce the cleanup time and cost of remediation.

Environmental Impacts

At the Livermore site, LLNL strives to reduce risks arising from chemicals released to the environment and 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 day and future human exposure to contaminated soil and groundwater, preventing further contaminant migration of concentrations above drinking water standards, reducing concentrations in groundwater, and minimizing contaminant migration from the unsaturated zone to the underlying groundwater.

Remedial solutions are implemented that have been determined to be most appropriate for individual areas of contamination. The selected remedial solutions 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. These remedial solutions include groundwater extraction and treatment, soil vapor extraction and treatment, or a combination of both.

Groundwater and soil vapor extraction and treatment at the Livermore site continue to reduce the mass of contaminants in the subsurface. A graph of VOC mass removed at the Livermore site since 1989 is presented in **Figure 8-3**. In 2005, the groundwater and soil vapor treatment facilities removed more than 267 kg of VOCs. Since remediation efforts began in 1989,

more than 10,700 million liters of groundwater and approximately 4.9 million m^3 of soil vapor have been treated, yielding a total of more than 2079 kg of removed VOCs.

Site 300 CERCLA Project

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA site in 1990, when it was placed on the National Priorities List. The CERCLA environmental restoration operable units (OUs) and groundwater contaminant plumes are shown in **Figure 8-4**. All characterized contaminant release sites have been assigned to one of eight OUs based on the nature, extent, and sources of contamination, and

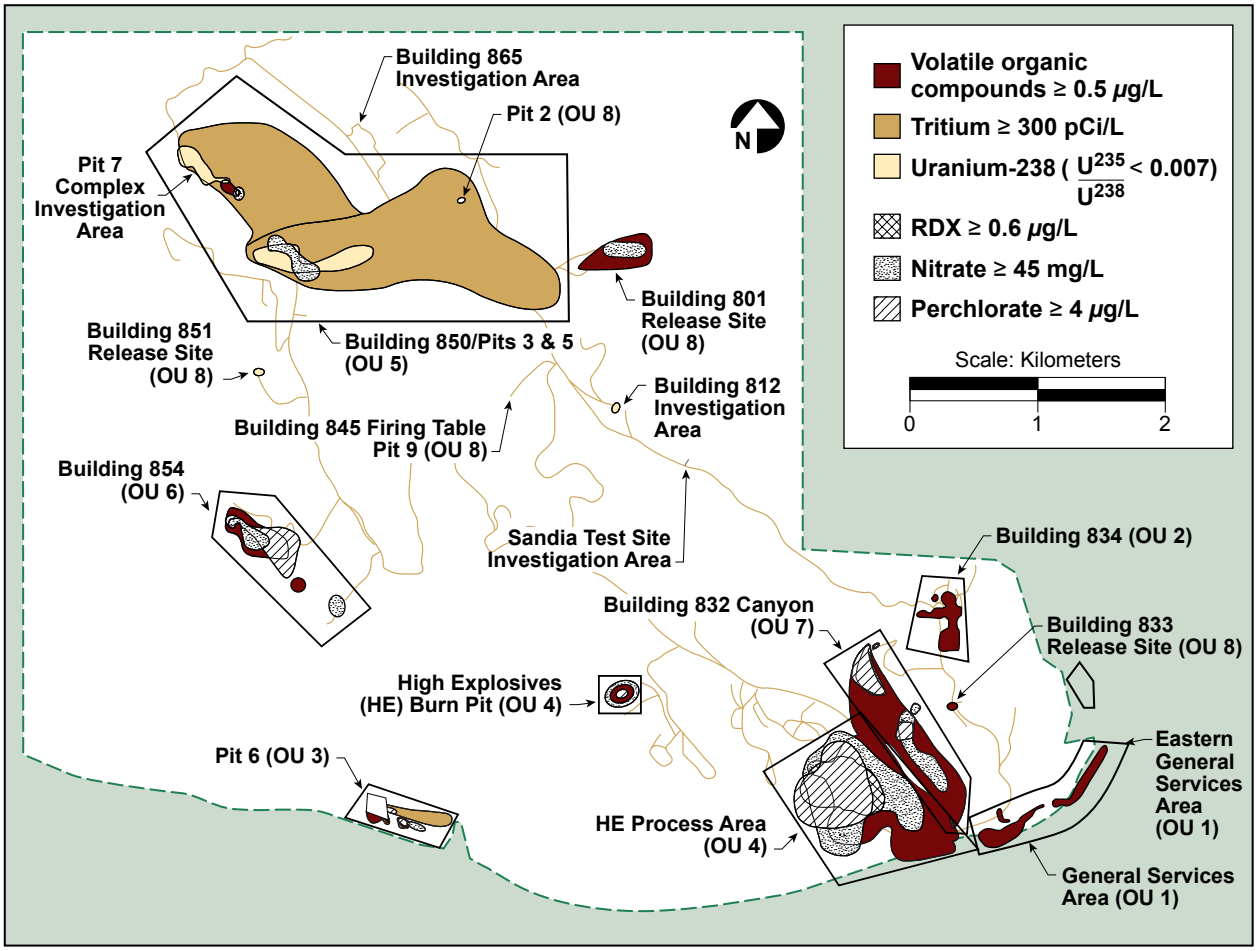


Figure 8-4. Environmental restoration operable units, investigation areas, and contaminants of concern

topographic and hydrologic considerations. The major contaminants of concern for each OU are listed in Table 8-2. CERCLA work at Site 300 is conducted under a Federal Facility Agreement (FFA) and other requirements. Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994). Key milestone and deliverable due dates for 2005 are listed in Table 8-3. All milestone and deliverable due dates were met during 2005.

Table 8-2. Major contaminants of concern found in soil, rock, and groundwater at Site 300

Operable Unit (OU)	Contaminant of concern[a]
General Services Area (GSA) (OU1)	VOCs (primarily TCE)
Building 834 Complex (OU2)	VOCs (primarily TCE), organosilicate oil, nitrate
Pit 6 (OU3)	VOCs (primarily TCE), tritium, nitrate, perchlorate
Explosives Process Area (OU4)	VOCs (primarily TCE), HE (primarily RDX), nitrate, perchlorate
Building 850/Pits 3 & 5 (OU5)	Tritium, depleted uranium, VOCs (primarily TCE), nitrate, perchlorate
Building 854 (OU6)	VOCs (primarily TCE), nitrate, perchlorate
Building 832 Canyon (OU7)	VOCs (primarily TCE), nitrate, perchlorate
Site-Wide Operable Unit (OU8)	VOCs (primarily TCE and Freon 113), nitrate, perchlorate, depleted uranium, tritium, metals, RDX

a See Acronyms and Abbreviations for list of acronyms.

Table 8-3. Calendar year 2005 deliverable and milestone dates for Site 300 environmental restoration activities outlined in the FFA and other agreements

Deliverable/Milestone[a]	Due Date
Final Remedial Investigation/Feasibility Study (RI/FS) for the Pit 7 Complex	June 27 (met)
Draft Interim Remedial Design Report for the Building 832 Canyon OU	September 9 (met)
Characterization Summary Report for the Building 812 Study Area	September 30 (met)
Install monitor wells for Building 865	September 30 (met)
Expand B832-SRC groundwater extraction wellfield in the Building 832 Canyon OU	September 30 (met)
Conduct surface soil sampling at Sandia Test Site	September 30 (met)
Construct B829-SRC groundwater extraction and treatment facility in HE Process Area OU	September 30 (met)
Construct B817-PRX groundwater extraction and treatment facility in HE Process Area OU	September 30 (met)
Draft Proposed Plan for the Pit 7 Complex	October 6 (met)
Characterization Summary Report for the Sandia Test Site	December 15 (met)

a See Acronyms and Abbreviations for list of acronyms.

Physiographic Setting and Geology of Site 300

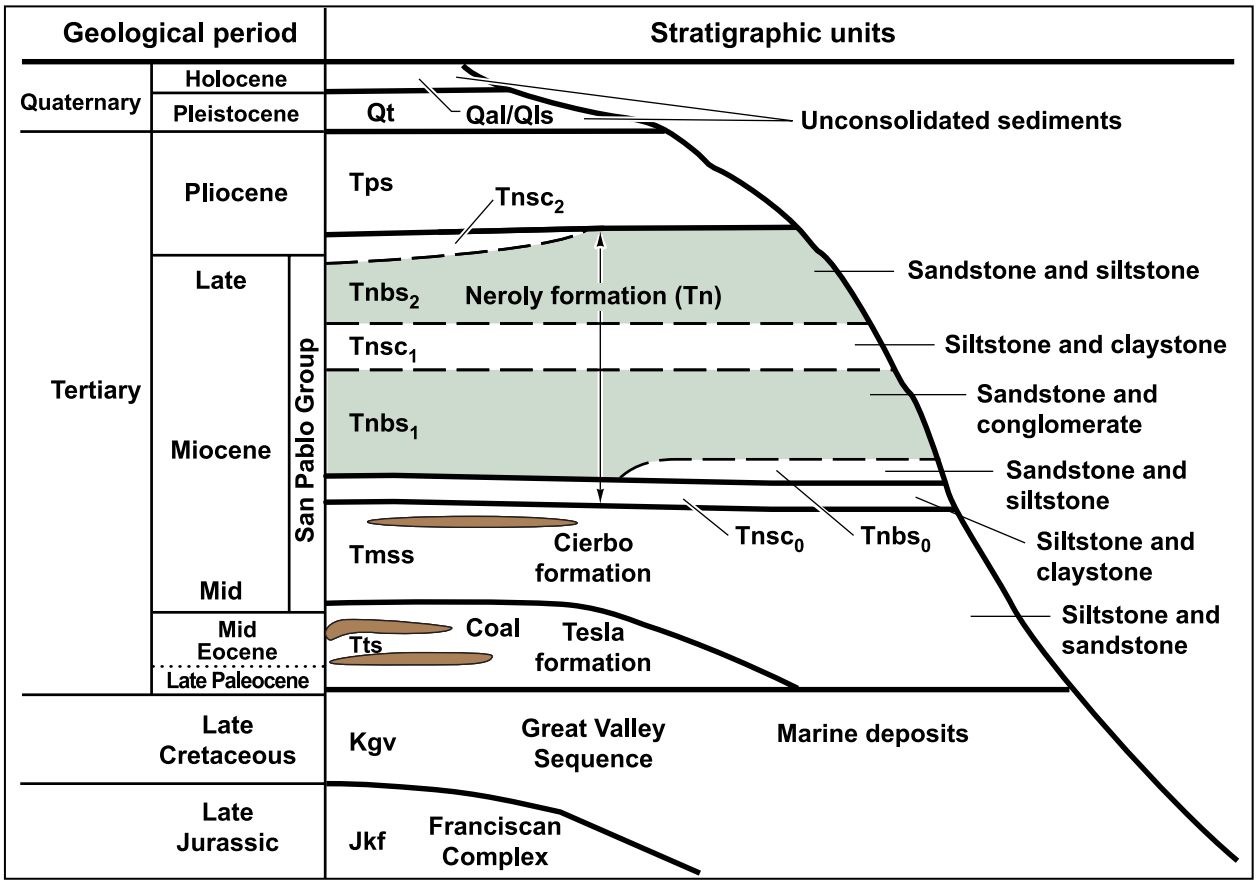
Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy is shown in **Figure 8-5**. Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—alluvium and semi-lithified sediments, mainly of continental origin
- Early to late Tertiary (5–65 million years ago)—shallow marine and continental sedimentary and volcaniclastic rocks
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites) and Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks)

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath Site 300. It contains the principal hydrostratigraphic units (HSUs) within Site 300 and has been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, [Webster-Scholten 1994]). The complete section of the Neroly Formation is about 150 m thick beneath Site 300.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300 and borders portions of the General Services Area (GSA), the Explosives Process Area, and the area of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble-bearing terrace gravel derived from sources to the south, with lenses and local coverings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been offset by regional faults and slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional faults and fracture patterns, locally influence groundwater flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.



Hydrologic characteristics of stratigraphic units:

Quaternary alluvium and underlying decomposed bedrock (Qal/WBR): Occurs in ravines and valley bottoms throughout Site 300. It is perennially saturated beneath Corral Hollow Creek, in Doall Ravine, and in southern Elk Ravine in the vicinity of Building 812. Groundwater also occurs in Qal/WBR in the Pit 7 Complex during the winter rainy season or during extended periods of higher than normal rainfall. Groundwater in this unit is unconfined.

Quaternary landslide deposits (Qls): Thin zones of unconfined groundwater occur locally beneath the Building 851 and Building 854 areas.

Quaternary terrace alluvium (Qt): Present and saturated at Pit 6, the GSA, and the Building 832 Canyon area; some of the groundwater occurrences are ephemeral.

Pliocene non-marine sediments (Tps/Tpsg): Saturated in the Building 833 and 834 areas and the Explosives Process area. This bedrock unit is generally present only on hilltops. Where present, groundwater is typically unconfined, perched, discontinuous, and ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation is significant.

Neroly Formation (Tn): Most extensive and saturated bedrock strata beneath Site 300. Unconfined to artesian conditions may exist. The formation is subdivided into the following units:

- **Upper claystone/siltstone unit ($Tnsc_2$):** Absent beneath much of Site 300. Saturated beneath the Building 834 area.
- **Upper blue sandstone unit ($Tnbs_2$):** Absent beneath much of Site 300. Saturated beneath Explosives Process Area.
- **Lower siltstone/claystone unit ($Tnsc_1$):** Saturated beneath Explosives Process Area, Building 832 Canyon.
- **Lower blue sandstone unit of the Neroly formation. ($Tnbs_1$):** Primary water-bearing strata within the Neroly Formation. Saturated throughout Site 300, except in northeast portion, where it is absent. Fine-grained siltstone and claystone interbeds act as aquitards, confining layers, or perching horizons.
- **Basal sandstone unit ($Tnbs_0$):** Saturated beneath the Pit 7 Complex, Pit 2, and Building 801/Pit 8 areas.
- **Basal siltstone/claystone unit ($Tnsc_0$)**: Saturated beneath the Building 854 area, Building 845/Pit 9.

Cierbo Formation (Tmss): Groundwater occurs beneath Doall Ravine, the Building 850, 851, and 854 areas and the East Firing Area. The continuity of saturation between the northwest and southeast areas of Site 300 is undetermined. Groundwater occurs under unconfined to artesian conditions. Where saturation does not occur, fine-grained siltstone and claystone interbeds may act as aquitards, confining layers, or perching horizons.

Tesla formation (Tts): Only found to contain groundwater immediately south of the Site 300 Pit 6 area.

Great Valley Sequence (Kgv): Groundwater not found in the few wells at Site 300 that penetrate the upper portion of the Great Valley Sequence.

Franciscan Complex (Jkf): No wells at Site 300 penetrate the Franciscan Complex.

Figure 8-5. Site 300 stratigraphy

Hydrogeology of Site 300

All groundwater contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unnamed Pliocene nonmarine sediments (Tps), or unconsolidated Quaternary sediment and weathered bedrock (Qal/WBR, Qls, or Qt) stratigraphic units. The extent of groundwater contamination at Site 300 is shown in **Figure 8-4**. The hydrogeology of Site 300 is described in more detail in Chapter 1. Within Site 300, groundwater-bearing strata have been grouped into hydrostratigraphic units that underlie various portions of Site 300. Contamination within these HSUs is decribed in the following section.

Remediation Activities and Monitoring Results

This section presents a summary of monitoring and remediation results for contaminant release sites at Site 300. Detailed monitoring and remediation results for the GSA, Building 834, Explosives Process Area, Building 850, Building 854, Pit 6, Building 832 Canyon, and Site-Wide OUs are presented in the Compliance Monitoring Program (CMP) reports for Site 300 (Dibley et al. 2005, 2006). The 2005 Annual CMP Report (Dibley et al. 2006) is included on the report CD. The *Site-Wide Remediation Evaluation Summary Report* (SWESR, Ferry et al. 2006) provides a comprehensive analysis of progress in achieving remedial action objectives at the contaminant release sites over the last five years. The Eastern GSA was not previously included in the CMP report, as it operated under a separate waste discharge requirements permit. Results for the first half of 2005 were presented both in two quarterly reports (Yow 2005a,b) and in the annual CMP report; in the future these results will be presented only in CMP reports. The results of investigations at the Pit 7 Complex, Building 865, Building 812, and Sandia Test Site are not included in the CMP and SWESR reports. Current information for each of these portions of Site 300 is presented at the end of this section.

At Site 300, there are 16 groundwater extraction and treatment facilities. During 2005, twelve of these facilities treated groundwater while four facilities treated soil vapor and groundwater. Twenty-five wells that extract only groundwater, 7 wells that extract only soil vapor, and 24 wells that extract both groundwater and soil vapor were pumped and the groundwater and soil vapor were fed into treatment systems during 2005. In 2005, the 25 wells that extract only groundwater and the 24 wells that extract both groundwater and soil vapor yielded 100.4 million L of groundwater. During the year, the 24 wells that extract both vapor and groundwater and the 7 wells that extract only vapor removed 1111 million m^3 of vapor. In 2005, the Site 300 treatment facilities removed 89.7 kg of VOCs, 0.09 kg of perchlorate, 739.7 kg of nitrate, 0.09 kg of RDX high explosive compound, and 0.41 kg of organic silicate oil. Since groundwater and vapor remediation

efforts began in 1990, more than 1176 million liters of groundwater and 5281 million m^3 of vapor have been treated, to yield about 379.9 kg of removed VOCs, 0.397 kg of perchlorate, 3391 kg of nitrate, 0.57 kg of RDX high explosive compound, and 9.41 kg of organic silicate oil. The 2005 and cumulative total volumes of groundwater and vapor extracted to Site 300 treatment facilities and VOC masses removed are shown in **Table 8-4**.

The central GSA, eastern GSA, and B830-Distal, South treatment facilities discharge to surface drainage courses. The B854-Proximal solar treatment unit/containerized wetland, B815-Distal aqueous phase granular activated carbon, and B830-Proximal, North granular activated carbon treatment systems discharge to an infiltration trench. The other 10 treatment systems discharge to air by misting or to the subsurface using injection wells.

Table 8-4. Volumes of groundwater and soil vapor extracted and masses of volatile organic compounds removed at Site 300 CERCLA Operable Units

Operable Unit	Startup date	2005		Cumulative total	
Groundwater Treatment		Water treated (ML)[a]	VOCs removed (kg)	Water treated (ML)[a]	VOCs removed (kg)
GSA	1991, 1993	81.7	0.552	1099	20.6
Building 834	1995	0.489	2.36	1.47	34.1
Explosives Process Area	1999	11.8	0.186	39.4	0.586
Building 854	1999	2.60	0.315	20.4	4.56
Pit 6	1998	—[b]	—[b]	0.268	0.0014
Buildings 830 and 832	1999	3.81	0.473	15.5	1.64
Total		100.4	3.89	1176	61.5
Vapor Treatment		**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**	**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**
Central GSA	1994	204	0.767	2216.7	66.7
Building 834	1998	730	82.8	2545.7	248
Building 832	1999	94	0.316	436.1	1.86
Building 854	2005	83	1.90	82.9	1.9
Total		1111	85.8	5281.4	318.4

a ML = 1 million liters

b Groundwater treatment is not routine at Pit 6. A hydraulic pump test with a portable treatment unit for TCE removal was conducted there in 1998.

The GSA (OU1) contains maintenance and shop facilities. Dry well and liquid storage activities mobilized contaminants to groundwater. Treatment reduced groundwater influent TCE concentrations to the eastern GSA from 69.5 µg/L in 1989 to 5.5 µg/L in October 2005. Data from July through December 2005 indicate that pumping and treating groundwater from three extraction wells in the Eastern GSA has successfully reduced concentrations of TCE and other VOCs to below their cleanup standard (MCL) of 5 µg/L. Since extraction and treatment activities began at the Eastern GSA in 1991, TCE concentrations in groundwater have decreased from an historical maximum of 74 µg/L to below analytical reporting limits of 0.5 µg/L in groundwater samples from most wells. The number of wells with water containing TCE concentrations exceeding the MCL have decreased from 18 to 0. At the Eastern GSA, LLNL has proposed initiating the "Requirements for Closeout" described in the Remedial Design for the GSA OU (Rueth et al. 1998). These requirements specify that "when VOC concentrations in groundwater have been reduced to cleanup standards, the groundwater extraction and treatment system will be shut off and placed on standby." As required, groundwater monitoring will be conducted to determine if VOC concentrations rise or "rebound" above cleanup standards after extraction ceases. No additional action besides monitoring is anticipated unless VOC concentrations rebound above cleanup standards. TCE concentrations in shallowest groundwater beneath the eastern GSA are shown Figure 2.1-5 of the *2005 Annual CMP Report* (Dibley et al. 2006).

Contaminated groundwater is extracted from eight wells and vapor is extracted from seven wells screened in the Qt-$Tnsc_1$ HSU in the central GSA. Total VOC concentrations in the central GSA have been reduced from 9400 µg/L in 1993 to 473.2 µg/L in July 2005. From 1994 through the end of 2005, total VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 $ppm_{v/v}$ to 11 $ppm_{v/v}$. VOC concentrations in individual central GSA soil vapor extraction wells have also been significantly reduced. Total VOC concentrations in groundwater beneath the central GSA are shown on Figure 2.1-6 of the *2005 Annual CMP Report* (Dibley et al. 2006). TCE concentrations in soil vapor in the central GSA are shown on Figure 2.1-7 of that document.

At Building 834 (OU2), prototype weapons components were subjected to a variety of environmental stresses including heat and pressure. TCE was used as a heat-exchange fluid and was circulated in piping that leaked. There are three HSUs that contain groundwater beneath Building 834. These are, in descending order, the Tpsg, Tps–$Tnsc_2$, and $Tnbs_1$ HSUs. The first two contain contaminants. The maximum 2005 total VOC concentration in groundwater at Building 834 was 190,000 µg/L. This concentration was found in dense claystones of the Tps-$Tnsc_2$ HSU, which underlie the Tpsg HSU. The concentrations in this HSU have remained relatively stable, as no active remediation has been done within the HSU because of the negligible water

yields of wells completed in it. Within the Tpsg HSU, which contains the bulk of the TCE in the OU, VOC concentrations in 2005 were a maximum of 58,000 µg/L. Maximum pre-remediation total VOC concentrations in this HSU were 1,060,000 µg/L in 1993. The maxima occurred in the Tpsg HSU within the core area of the OU where, despite pumping and treating of groundwater, VOC concentrations have stayed relatively stable over the last few years. This stability may be the result of continued dissolution of residual free-phase TCE. However, when compared to VOC concentrations prior to active groundwater and vapor extraction, the concentrations are lower. The average TCE concentration within the Tpsg HSU in the core area during 1993 and 1994 was 84,000 µg/L. This has dropped to an average core area TCE concentration of 8000 µg/L in the last two years. Total VOC concentrations in Tpsg-hosted groundwater beneath the Building 834 area are shown on Figure 2.2-3. of the *2005 Annual CMP Report* (Dibley et al. 2006). Groundwater and soil vapor extraction and treatment systems have been operating at Building 834 since 1995 and 1998, respectively. Twelve wells that extract both groundwater and soil vapor compose the extraction network. The groundwater treatment system treats VOCs, nitrate, and organic silicate oil within the shallow Tpsg HSU, and the vapor extraction system treats VOCs within shallow groundwater and the vadose zone. Maximum detected 2005 concentrations of nitrate and organic silicate oil in groundwater at Building 834 were 120 mg/L and 59,000 µg/L, respectively. Maps of the distribution of these two chemicals in Building 834 OU groundwater are shown in Figures 2.2-5 and 2.2-4 of the *2005 Annual CMP Report* (Dibley et al. 2006). Although VOC mass at Building 834 has been destroyed by in situ indigenous bacterial bioremediation, this mass has not been quantified.

At the Explosives Process Area OU (OU4), explosives are pressed and formed. Surface spills from 1958 to 1986 resulted in the release of contaminants at the former Building 815 steam plant. Subsurface contamination is also attributed to explosives wastewater discharges to former unlined rinse-water lagoons. Nine extraction wells in the OU pump groundwater that is treated at six treatment facilities. Construction of two treatment facilities was completed by the September 30, 2005, milestone date. Total VOC, the explosives compound RDX, perchlorate, and nitrate concentrations in $Tnbs_2$ HSU groundwater beneath the Explosives Process Area are shown on Figures 2.4-3, 2.4-4, 2.4-5, and 2.4-6, respectively, of the *2005 Annual CMP Report* (Dibley et al. 2006). Maximum 2005 total VOC concentrations of 51µg/L were detected in groundwater in the $Tnbs_2$ aquifer. The maximum historic total VOC concentration in this HSU was 110 µg/L in a water sample collected in 1992. The total VOC concentrations in source area wells have been reduced by about 40% since remediation began in 1999. RDX concentrations in groundwater have decreased from a maximum of 200 µg/L detected in 1992 to a maximum in 2005 of 91 µg/L. The maximum 2005 concentrations of nitrate and perchlorate in Explosives Process Area OU groundwater were 30 µg/L and 110 mg/L, respectively.

Building 850 (part of OU5) is an explosives firing table. The distributions of tritium, uranium, nitrate, and perchlorate in Qal/WBR and $Tnbs_0/Tnbs_1$ HSU groundwater beneath the Building 850 OU are shown on Figures 2.5-3 through 2.5-10 of the *2005 Annual CMP Report* (Dibley et al. 2006). During 2005, the maximum detected tritium activity in groundwater at the Building 850 OU was 3370 Bq/L (91,000 pCi/L). Monitored natural attenuation (MNA) is the selected remedy for the remediation of tritium in groundwater emanating from the Building 850 area. MNA continues to be effective for tritium in that the extent of the 740 Bq/L (20,000 pCi/L) MCL contour has diminished and receded back towards the firing table source with the highest tritium activities located immediately downgradient of the firing table (**Figure 8-6**). The maximum 2005 total uranium activity in groundwater that contains some depleted uranium was 0.67 Bq/L (18 pCi/L). Total

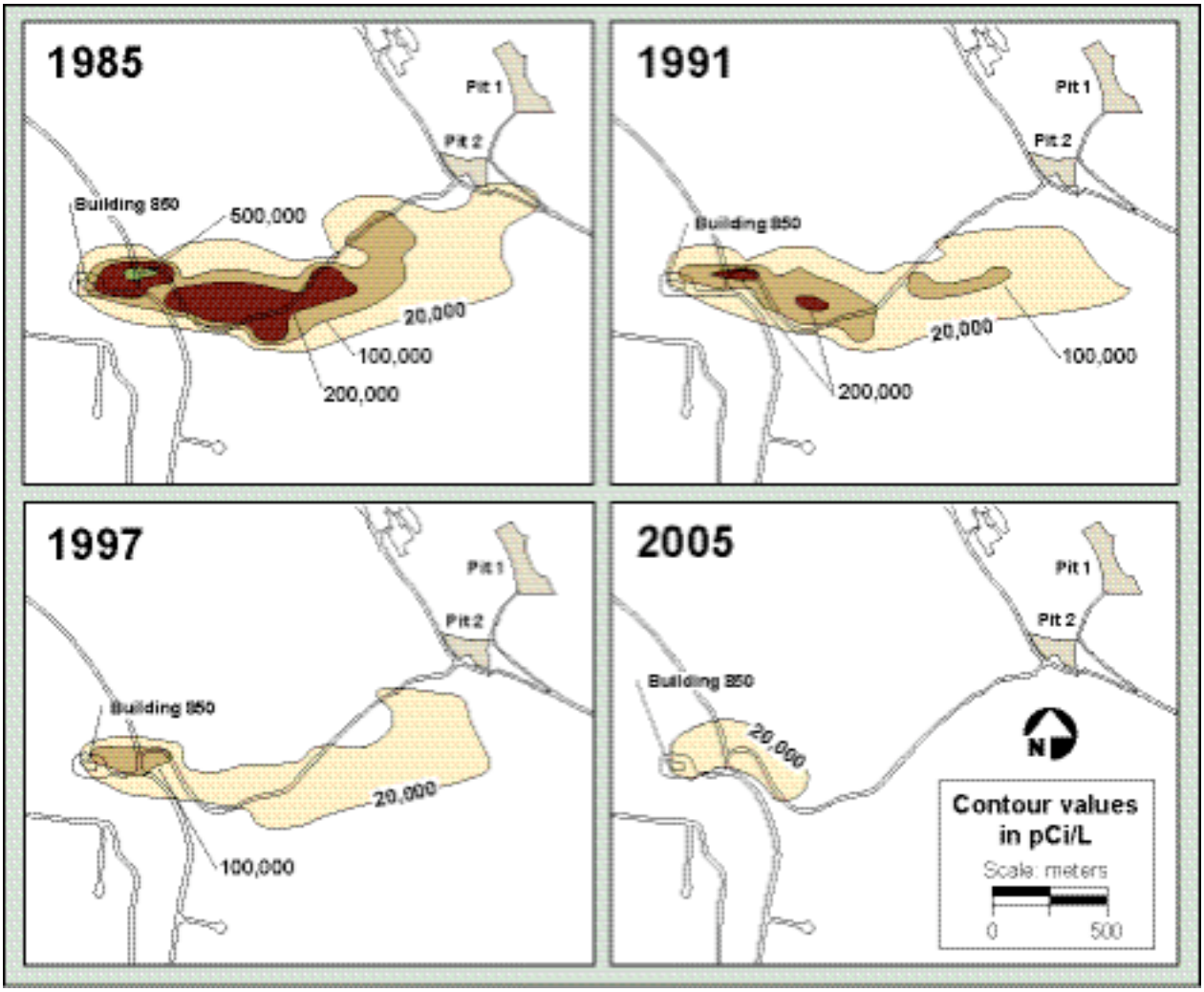


Figure 8-6. Tritium plume in combined Qal and $Tnbs_0$ HSUs during four time periods

uranium activity continues to be below the 0.74 Bq/L (20 pCi/L) state MCL. The maximum nitrate and perchlorate concentrations detected in 2005 in Building 850 OU groundwater were 140 mg/L and 75.2 µg/L, respectively.

Because a number of wells sample groundwater containing perchlorate in excess of the 6 µg/L state Public Health Goal, a remedial strategy for the perchlorate is being developed.

The Building 854 OU (OU6) is another site where weapons components were subjected to mechanical and thermal stresses and where pipes containing TCE leaked. Two extraction wells pump groundwater that is treated at two treatment systems (B854-SRC and B854-PRX) to remove VOCs, nitrate, and perchlorate. A soil vapor extraction system was installed at B854-SRC during 2005 and a treatability test is being conducted to determine if it is a viable method for increasing VOC mass removal at the source area. The 2005 maximum total VOC concentration in groundwater was 180 µg/L, down from a historic maximum total VOC concentration of 2900 µg/L detected in 1997. Maximum 2005 concentrations of perchlorate and nitrate detected in the OU were 15 µg/L and 55 mg/L, respectively. Total VOC concentrations, perchlorate, and nitrate in $Tnbs_1/Tnsc_0$ HSU groundwater beneath the Building 854 OU are shown on Figure 2.6-3, 2.6-4, and 2.6-5 of the *2005 Annual CMP Report* (Dibley et al. 2006).

Pit 6 (OU3) is a landfill that received waste from 1964 to 1973. The landfill was capped and closed under CERCLA in 1997. MNA is the selected remedy for the remediation of VOCs in groundwater emanating from Pit 6. The maximum 2005 groundwater total VOC concentration was 6.4 µg/L and the maximum 2005 groundwater tritium activity was 59 Bq/L (1590 pCi/L). Historic maxima for these two contaminants were 290 µg/L and 127 Bq/L (3420 pCi/L), respectively. The maximum 2005 concentrations of perchlorate and nitrate in Pit 6 groundwater were 6.6 µg/L and 200 mg/L, respectively. The distributions of total VOCs, tritium, perchlorate, and nitrate in groundwater at Pit 6 are shown on Figures 2.3-3 through 2.3-6 of the *2005 Annual CMP Report* (Dibley et al. 2006).

Building 832 Canyon OU (OU7) facilities were used to test the stability of weapons components under a variety of environmental stresses. Contaminants were released from Buildings 830 and 832 through piping leaks and surface spills. Four groundwater extraction and treatment systems operate in the OU to remove VOCs, nitrate, and perchlorate: B832-SRC, B830-SRC, B830-PRXN, and B830-DISS. B832-SRC and B830-SRC extract and treat groundwater and soil vapor. The other two facilities only treat groundwater. Nine extraction wells operate in the OU. The maximum 2005 groundwater total VOC concentration was 8800 µg/L. Maximum VOC concentrations occur in the $Tnsc_{1b}$ HSU. A maximum 2005 total VOC concentration of 1800 µg/L was detected in the Qal/WBR HSU. Total VOC

concentrations during 2005 in groundwater from these two HSUs at the Building 832 Canyon OU are shown on Figures 2.7-5 and 2.7-6 of the *2005 Annual CMP Report* (Dibley et al. 2006). Maximum perchlorate and nitrate concentrations detected in 2005 groundwater samples were 12 µg/L and 130 mg/L, respectively. Perchlorate and nitrate concentrations in these HSUs at Building 832 are shown on Figures 2.7-8, 2.7-9, 2.7-11, and 2.7-12 of the *2005 Annual CMP Report*. The *Draft Final Remedial Design for the Building 832 Operable Unit* (Madrid et al. 2005) was submitted ahead of its September 30, 2005, FFA milestone due date (**Table 8-3**). The document described the details of the final remedy for the contamination in the Building 832 Canyon OU. The construction of the B832-SRC treatment facility was completed by its September 30, 2005, milestone date (**Table 8-3**).

The Site 300 Site-Wide OU (OU8) is composed of release sites at which no significant groundwater contamination and no unacceptable risk to human health or the environment is present. For this reason, a monitoring-only remedy was selected for these release sites, which include the Building 801 Firing Table/Pit 8, Building 833, Building 845 Firing Table/Pit 9, Pit 2, and Building 851 Firing Table areas. The results of routine monitoring of these sites are included in Section 2.8 and Chapter 3 of the *2005 Annual CMP Report* (Dibley et al. 2006).

The following sections describe the current status of investigations under way at four sites that are still under investigation and have not yet reached the Record of Decision for a final CERCLA remedy to address environmental contamination. These areas are the Pit 7 Complex, Building 865, the Building 812 Firing Table, and the Sandia Test Site.

Ongoing and Planned Investigations and Cleanup Activities

Pit 7 Complex

The Pit 7 Complex (Figure 5-14) is composed of four landfills—Pits 3, 4, 5, and 7—that received waste from explosives experiments conducted at Site 300 firing tables. Pits 3 and 5 have released tritium to groundwater. Pits 3, 5, and 7 have released depleted uranium to groundwater. The maximum tritium activity detected in groundwater in 2005 in the OU was 14,741 Bq/L (398,000 pCi/L) in the $Tnbs_0$ HSU. The maximum detected total uranium activity in groundwater that contained some depleted uranium was 6.3 Bq/L (170 pCi/L) and was detected in a sample from the Qal/WBR HSU. Perchlorate, TCE, and nitrate also occur in Pit 7 Complex groundwater. Maximum concentrations of perchlorate, nitrate, and TCE detected in groundwater in 2005 were 28 µg/L, 98 mg/L, and 2.6 µg/L, respectively. LLNL submitted the *Final Remedial Investigation/Feasibility Study for the Pit 7 Complex* (Taffet et al. 2005) by the June 27, 2005, milestone date

established in the FFA (Table 8-3). The report presents details of the hydrogeology, nature and extent of contamination, and risk assessment, and specifies remedial alternatives that can be applied to the contamination.

LLNL submitted the *Draft Proposed Plan for the Pit 7 Complex* by the October 6, 2005, milestone date (Table 8-3). This document describes, for the public, the contaminant hydrogeology at Pit 7 and the preferred alternative for final CERCLA cleanup selected by the regulatory agencies and DOE.

Building 865

Building 865 is a former linear accelerator, the Advanced Testing Accelerator. Freon-113 was used as a de-greaser there and has been released to groundwater. The maximum Freon-113 concentration detected in groundwater during 2005 was 300 μg/L. Freon-11 has also been detected in Building 865 groundwater at a maximum 2005 concentration of 1.5 μg/L. The federal and state MCLs for Freon-113 and Freon-11 in drinking water are 1200 μg/L and 5 μg/L, respectively. During 2005, LLNL installed four additional monitoring wells as a part of the remedial investigation of Building 865. LLNL is scheduled to complete a Characterization Summary report detailing the hydrogeology and nature and extent of contamination emanating from Building 865 in 2007.

Building 812 Firing Table

Building 812 is an explosives test firing table. During 2005, a maximum detected groundwater activity of total uranium, in which some of the uranium was due to addition of depleted uranium, was 1.48 Bq/L (40 pCi/L). Prior to the September 30, 2005, due date, LLNL submitted to the regulatory agencies a Characterization Summary report detailing the hydrogeology and nature and extent of contamination emanating from Building 812 (Ferry and Holtzapple 2005a) (Table 8-3). A plume of depleted uranium in groundwater and surface soil containing uranium isotopes in excess of Preliminary Remediation Guidelines were identified.

Sandia Test Site

The Sandia Test Site was used in the past for several open air explosives experiments. During 2004, ten boreholes were drilled and soil and rock samples were collected and analyzed for metals and radionuclides. Two of these boreholes were completed as piezometers. Anthropogenic contamination has not been observed in samples of water, soil, or rock collected from the Sandia Test Site. LLNL completed surface soil sampling in advance of the September 30, 2005, milestone date (Table 8-3). Prior to the December 15, 2005, due date, LLNL submitted to the regulatory agencies a Characterization

Summary report (Ferry and Holtzapple 2005b) detailing the hydrogeology and nature and extent of contamination emanating at the site (**Table 8-3**).

Environmental Impact

LLNL strives to reduce risks arising from chemicals released to the environment at Site 300 and to conduct its activities to protect ecological resources. At each OU, LLNL proposes a range of remediation options that are applicable for each release site. The option that achieves the goals of reducing risks to human health and the environment and satisfying remediation action objectives, regulatory standards for chemicals in water and soil, and other state and federal requirements is then negotiated by DOE and the regulatory agencies with public input. The agreed upon actions are implemented.

These actions have included groundwater and soil vapor extraction and treatment, source area (lagoon and landfill) capping, monitored natural attenuation, monitoring, and institutional controls.

Groundwater and soil vapor extraction and treatment at Site 300 continue to reduce the mass of contaminants in the subsurface. In 2005, the Site 300 treatment facilities removed approximately 89.7 kg of VOCs, 0.09 kg of perchlorate, 739.7 kg of nitrate, 0.09 kg of RDX high explosive compound, and 0.41 kg of organic silicate oil. Since remediation efforts began in 1990, more than 1176 million liters of groundwater and approximately 5281 million m^3 of vapor have been treated, to yield about 379.9 kg of removed VOCs, 0.397 kg of perchlorate, 3391 kg of nitrate, 0.57 kg of RDX high explosive compound, and 9.41 kg of organic silicate oil.

All ground-disturbing activities, such as well drilling, construction and operation of treatment systems, and groundwater sampling are planned and conducted to minimize disturbance of animal and plant habitat. A biologist inspects all sites and recommendations are made and are incorporated into the plan for each activity. Erosion controls and other recommendations made by the surface water hydrologist are also incorporated into the plans for ground-disturbing activities.

Quality Assurance

CHAPTER 9

David Armstrong
Donald H. MacQueen
Beth Schad

Introduction

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. Lawrence Livermore National Laboratory conducted environmental monitoring activities during 2005 in accordance with the Environmental Protection Department Quality Assurance Management Plan (Revision 4), which is based on DOE Order 414.1A. This order sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality in DOE programs using a risk-based, graded approach to QA. This process promotes the selective application of QA and management controls based on the risk associated with each activity in order to maximize effectiveness and efficiency in resource use.

LLNL and commercial laboratories analyze environmental monitoring samples using U.S. Environmental Protection Agency (EPA) standard methods when available (see, for example, Appendix A). When EPA standard methods are not available, custom analytical procedures, usually developed at LLNL, are used. LLNL uses only State of California-certified laboratories to analyze its environmental monitoring samples. In addition, LLNL requires all analytical laboratories to maintain adequate QA programs and documentation of methods. The radiochemical methods used by LLNL laboratories are described in procedures created and maintained by the laboratory performing the analyses.

Quality Assurance Activities

Nonconformance reporting and tracking is a formal process used for ensuring that problems are identified, resolved, and prevented from recurring. EPD reports and tracks problems using Nonconformance Reports (NCRs). NCRs are initiated when items or activities are identified that do not comply with procedures or other documents that specify requirements for Environmental Protection Department (EPD) operations or that cast doubt on the quality of EPD reports, sample integrity, or data *and* that are not covered by other reporting or tracking mechanisms. Many sampling or data problems are resolved without an NCR 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 sampling and data management personnel to correct the errors.

LLNL addresses analytical laboratory problems with the appropriate laboratory as they arise. Many of the documented problems related to analytical laboratories concern minor documentation or paperwork errors, which are corrected soon after they are identified. Other problems—such as missed holding times, late analytical results, and typographical errors on data reports—account for the remaining analytical laboratory issues. These problems are corrected by reissued reports, or corrected paperwork; associated sample results are not affected.

The LLNL EPD generated 12 NCRs related to environmental monitoring in 2005. Four of the NCRs were related to problems with analytical laboratories, seven documented minor equipment malfunctions that did not result in lost samples, and the remaining one documented an error made by a sampling technologist.

QA staff also track and report planned environmental monitoring samples that are not collected. A summary of sample completeness appears in **Table 9-1**.

Analytical Laboratories

LLNL awarded Blanket Service Agreements (BSAs) to eight analytical laboratories in 2005. LLNL works closely with these analytical laboratories to minimize the occurrence of problems.

Table 9-1. Sampling completeness in 2005 for the Livermore site and Site 300

Environmental medium	Number of analyses planned	Number of analyses completed	Completeness (%)	Reason(s) for lost samples
Air particulate				
Radiological parameters (Livermore site)	1208	1188	98	GFI tripped (11), motor problems (5), no access (3), low flow (1)
Beryllium (Livermore site)	95	95	100	
Radiological parameters (Site 300)	740	726	98	No access (10), no power (2), GFI tripped (1), unsafe conditions (1)
Beryllium (Site 300)	52	52	100	
Air tritium				
Livermore site and vicinity	526	520	99	Insufficient flow (6)
Site 300	30	30	100	
Soil and Sediment				
Livermore site	42	42	100	
Site 300	30	30	100	
Arroyo sediment (Livermore site only)	31	31	100	
Vegetation and Foodstuffs				
Livermore site and vicinity	56	56	100	
Site 300	20	20	100	
Wine	12	12	100	
Thermoluminescent dosimeters (TLDs)				
Livermore site perimeter	98	97	99	Missing (1)
Livermore Valley	102	97	95	TLD found burned (5)
Site 300	65	53	82	Missing (7), no access (5)
Rain				
Livermore site	34	34	100	
Site 300	6	6	100	
Storm water runoff				
Livermore site	103	103	100	
Site 300	97	71	73	No flow at location (26)

Table 9-1. Sampling completeness in 2005 for the Livermore site and Site 300 (continued)

Environmental medium	Number of analyses planned	Number of analyses completed	Completeness (%)	Reason(s) for lost samples
Drainage Retention Basin				
Field measurements	208	206	99	Samples not collected, no explanation (2)
Samples	72	71	99	Samples not collected, no explanation (1)
Releases	51	50	98	Fish toxicity samples not taken due to holiday schedule (1)
Livermore site wastewater				
B196	950	946	99	Unit malfunction (4)
C196	305	305	100	
LWRP[a] effluent	48	48	100	
Digester sludge	135	105	78	Digester #1 closed May & June (4), #2 closed January, February, May & October (12), #3 closed July–October (14)
WDR 96-248				
Surface impoundment wastewater	17	17	100	
Surface impoundment groundwater	190	190	100	
Sewage ponds wastewater	42	42	100	
Sewage ponds groundwater	157	157	100	
Miscellaneous aqueous samples				
Other surface water (Livermore Valley only)	46	46	100	
Cooling towers (Site 300 only)	24	16	67	Samples not collected because 836 shut down April 2005 (8)

[a] LWRP = Livermore Water Reclamation Plant

Analytical Laboratory Intercomparison Studies

LLNL uses the results of intercomparison program data to identify and monitor trends in performance and to draw attention to the need to improve laboratory performances. If a laboratory performs unacceptably for a particular test in two consecutive performance evaluation studies, LLNL may choose to select another laboratory to perform the affected analyses until the original laboratory can demonstrate 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 will formally notify the laboratory of its unsatisfactory performance. If the problem persists, the off-site laboratory's BSA could be terminated. If an on-site laboratory continues to perform unacceptably, use of that laboratory could be suspended until the problem is corrected.

Two laboratories at Lawrence Livermore National Laboratory participated in the Mixed Analyte Performance Evaluation Program (MAPEP) sponsored by the U.S. Department of Energy (DOE) during 2005. The two LLNL laboratories that participated in MAPEP are the Environmental Monitoring Radiological Laboratory (EMRL) and the Hazards Control Department's Analytical Laboratory (HCAL).

The results of EMRL's participation in the studies are presented in **Table 9-2**. According to the results, 33 of 38 reported results were determined to be acceptable, 2 results were acceptable with warning, and 3 results were unacceptable, based on established control limits.

Unacceptable results for gross alpha and gross beta in the 05-GrF13 and 05-GrW13 studies were the result of reporting results in units of pCi/L, rather than the requested units of Bq/L. As a corrective action, computer software controls will be implemented that will warn the user when specified limits are exceeded. The unacceptable result for gross beta in the 05-GrW14 study was the result of an incorrect hand calculation, which will be corrected by the use of computerized calculation methods. The unacceptable result for Cesium-137 was determined to be a result of sample geometry and position, and has been corrected by a new protocol for sample positioning in the analytical instrument.

The results of HCAL's participation in the 2005 MAPEP studies (see **Table 9-3**) indicate that ten of ten sample results fell within the acceptance control limits.

Table 9-2. EMRL performance in the MAPEP Intercomparison Program Studies for 2005

Study	Analyte	Result	Ref Value	Flag[a]	Acceptance Range[b]	Uncertainty Value
Air filter (Bq/sample)						
MAPEP-05-GrF13	Gross alpha	2.16	0.232	N	0.000 – 0.464	0.0101
	Gross beta	9.51	0.297	N	0.148 – 0.446	0.0250
MAPER-05-RdF13	Cesium-134	3.76	3.51	A	2.46 – 4.56	0.225
	Cesium-137	2.94	2.26	N	1.58 – 2.94	0.351
	Cobalt-57	5.85	4.92	A	3.44 – 6.40	0.487
	Cobalt-60	3.38	3.03	A	2.12 – 3.94	0.228
	Manganese-54	4.01	3.33	W	2.33 – 4.33	0.413
	Plutonium-238	0.199	0.195	A	0.14 – 0.25	0.0228
	Plutonium-239/240	0.161	0.165	A	0.12 – 0.21	0.0186
	Zinc-65	4.26	3.14	N	2.20 – 4.08	0.733
MAPEP-05-GrF14	Gross alpha	0.239	0.482	A	>0.0 – 0.96	0.000499
	Gross beta	0.893	0.827	A	0.41 – 1.24	0.00119
MAPEP-05-RdF14	Cesium-134	3.43	3.85	A	2.69 – 5.01	0.172
	Cesium-137	2.94	3.23	A	2.26 – 4.20	0.363
	Cobalt-57	6.19	6.20	A	4.34 – 8.06	0.367
	Cobalt-60	2.74	2.85	A	1.99 – 3.70	0.231
	Manganese-54	4.10	4.37	A	3.06 – 5.68	0.427
	Plutonium-238	0.0902	0.0969	A	0.07 – 0.13	0.0149
	Plutonium-239/240	0.0835	0.0898	A	0.06 – 0.12	0.0138
	Zinc-65	4.32	4.33	A	3.03 – 5.63	0.790
Aqueous (Bq/L)						
MAPEP-05-MaW13	Cesium-134	109	127	A	88.90 – 165.10	7.61
	Cesium-137	324	332	A	232.40 – 431.60	34.0
	Cobalt-57	241	227	A	158.90 – 295.10	19.9
	Cobalt-60	253	251	A	175.70 – 326.30	14.3
	Manganese-54	328	331	A	231.70 – 430.30	35.0
	Plutonium-238	0.0156	0.018	A	(c)	0.00406
	Plutonium-239/240	2.60	2.4	A	1.68 – 3.12	0.209
	Zinc-65	534	496	A	347.20 – 644.80	47.9
MAPEP-05-GrW13	Gross alpha	3.56	0.525	N	0.000 – 1.050	0.0406
	Gross beta	37.7	1.67	N	0.835 – 2.505	2.44
MAPEP-05-MaW14	Cesium-134	153	167	A	116.90 – 217.10	7.76
	Cesium-137	313	333	A	233.10 – 432.90	23.8
	Cobalt-57	267	272	A	190.40 – 353.60	16.0
	Cobalt-60	249	261	A	182.70 – 339.30	15.1

Table 9-2. EMRL performance in the MAPEP Intercomparison Program Studies for 2005 (continued)

Study	Analyte	Result	Ref Value	Flag[a]	Acceptance Range[b]	Uncertainty Value
	Hydrogen-3	601	527	A	368.90 – 685.10	6.69
	Manganese-54	399	418	A	292.60 – 543.40	30.2
	Plutonium-238	1.68	1.67	A	1.34 – 2.48	0.269
	Plutonium-239/240	2.41	2.45	A	1.92 – 3.58	0.269
	Zinc-65	341	330	A	231.00 – 429.00	24.5
MAPEP-05-GrW14	Gross alpha	0.252	0.790	A	0.21 – 1.38	0.0958
	Gross beta	0.782	1.350	N	0.85 – 1.92	0.475
Soil (Bq/kg)						
MAPEP-05-MaS13	Cesium-134	644	759	A	531.30 – 986.70	30.1
	Cesium-137	311	315	A	220.50 – 409.50	31.5
	Cobalt-57	250	242	A	169.40 – 314.60	18.9
	Cobalt-60	212	212	A	148.40 – 275.60	14.0
	Manganese-54	511	485	A	339.50 – 630.50	50.8
	Plutonium-238	0.452	0.48	A	(c)	0.0672
	Plutonium-239/240	90.9	89.5	A	62.65 – 116.35	5.15
	Potassium-40	641	604	A	422.80 – 785.20	103
	Zinc-65	886	810	A	567.00 – 1053.00	79
MAPEP-05-MaS14	Cesium-134	500	568	A	397.60 – 738.40	19.9
	Cesium-137	456	439	A	307.30 – 570.70	49.9
	Cobalt-57	551	524	A	366.80 – 681.20	45.3
	Cobalt-60	294	287	A	200.90 – 373.10	16.1
	Manganese-54	464	439	A	307.30 – 570.70	55.5
	Plutonium-238	61.5	60.8	A	42.56 – 79.04	9.89
	Potassium-40	625	604	A	422.80 – 785.20	56.8
	Zinc-65	919	823	A	576.10 – 1069.09	80.9

a Gross alpha flags:
A = Result acceptable. Bias ≤ ±100% with a statistically positive result at two standard deviations.
N = Result not acceptable. Bias > ±100% or the reported result is not statistically positive at two standard deviations.

Gross beta flags:
A = Result acceptable. Bias ≤ ±50% with a statistically positive result at two standard deviations.
N = Result not acceptable. Bias > ±50% or the reported result is not statistically positive at two standard deviations.

All other flags:
A = Result acceptable. Bias ≤20%.
W = Result acceptable with warning. Bias >20% and bias ≤30%.
N = Result not acceptable. Bias >30%

b Significant figures shown are those of the MAPEP program.

c Acceptance range not provided for this analysis.

Table 9-3. HCAL performance in the MAPEP Intercomparison Program Studies for 2005

Study	Analyte	Result	Ref Value	Flag[a]	Acceptance Range	Uncertainty Value
Air filter (Bq/sample)						
MAPEP-05-GrF13	Gross alpha	0.116	0.232	A	0.000 – 0.464	0.013
	Gross beta	0.38	0.297	A	0.148 – 0.446	0.02
MAPEP-05-GrF14	Gross alpha	0.27	0.482	A	>0.0 – 0.96	0.04
	Gross beta	1.01	0.827	A	0.41 – 1.24	0.07
Aqueous (Bq/L)						
MAPEP-05-GrW13	Gross alpha	0.32	0.525	A	0.000 – 1.050	0.04
	Gross beta	1.60	1.67	A	0.835 – 2.505	0.09
MAPEP-05-MaW13	Hydrogen-3	285	280	A	196.00 – 364.00	15
MAPEP-05-GrW14	Gross alpha	0.803	0.790	A	0.21 – 1.38	0.090
	Gross beta	1.33	1.350	A	>0.0 – 0.96	0.08
MAPEP-05-MaW14	Hydrogen-3	543	527	A	0.41 – 1.24	29

a Gross alpha flags:
A = Result acceptable. Bias ≤ ±100% with a statistically positive result at two standard deviations.
N = Result not acceptable. Bias > ±100% or the reported result is not statistically positive at two standard deviations.

Gross beta flags:
A = Result acceptable. Bias ≤ ±50% with a statistically positive result at two standard deviations.
N = Result not acceptable. Bias > ±50% or the reported result is not statistically positive at two standard deviations.

All other flags:
A = Result acceptable. Bias ≤20%.
W = Result acceptable with warning. Bias >20% and bias ≤30%.
N = Result not acceptable. Bias >30%

HCAL also participated in two Environmental Resource Associates (ERA) performance evaluation studies in 2005. The results of these studies are presented in **Table 9-4**. Fourteen of fifteen analytes reported by HCAL in these studies fell within acceptable limits. The unacceptable tritium result was caused by the improper entry of the 95% uncertainty value in place of the tritium value.

Although contract laboratories are also required to participate in laboratory intercomparison programs, permission to publish their results for comparison purposes was not granted for 2005. See the following website to obtain MAPEP reports that include the results from all participating laboratories: http://www.inl.gov/resl/mapep/reports.html

Table 9-4. HCAL performance in the ERA Intercomparison Program Studies for 2005

Study	Analyte	Reported Value	ERA Assigned Value	Control Limits	Warning Limits	Performance Evaluation
Radiological (pCi/L)						
RAD-60	Gross alpha	68.7	67.9	38.5 – 97.3	48.3 – 87.5	Acceptable
	Gross beta	60.6	51.1	33.8 – 68.4	39.6 – 62.6	Acceptable
	Tritium	494	30200	25000 – 35400	26700 – 33700	Not Acceptable
Nonradiological (µg/L)						
WP-121	Aluminum	1200	1120	955 – 1280	1010 – 1220	Acceptable
	Arsenic	703	750	631 – 877	672 – 836	Acceptable
	Beryllium	409	405	344 – 457	363 – 439	Acceptable
	Cadmium	160	168	143 – 192	151 – 184	Acceptable
	Chromium	571	552	481 – 625	505 – 601	Acceptable
	Copper	594	607	551 – 666	570 – 647	Acceptable
	Iron	485	432	379 – 492	398 – 473	Acceptable
	Lead	314	326	281 – 370	296 – 355	Acceptable
	Mercury	7.4	7.14	5.28 – 8.97	5.90 – 8.36	Acceptable
	Nickel	197	194	169 – 220	178 – 212	Acceptable
	Silver	149	150	128 – 172	136 – 165	Acceptable
	Zinc	1120	1120	993 – 1260	1040 – 1210	Acceptable

Duplicate Analyses

Duplicate or collocated samples are distinct samples of the same matrix collected as closely to the same point in space and time as possible. Collocated samples processed and analyzed by the same laboratory provide intra-laboratory information about the precision of the entire measurement system, including sample acquisition, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples 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 be used to identify errors such as mislabeled samples or data entry errors.

Tables 9-5, **9-6**, and **9-7** present statistical data for collocated sample pairs, grouped by sample matrix and analyte. Samples from both the Livermore site and Site 300 are included. **Tables 9-5** and **9-6** are based on data pairs in which both values are detections (see "Data Presentation" in this chapter). **Table 9-7** is based on data pairs in which either or both values are nondetections.

Table 9-5. 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 alpha[d]	69	70.4	–0.482	0	4.64×10^{-5} (Bq/m^3)
	Gross beta[d]	99	19.8	0.841	0.45	8.55×10^{-5} (Bq/m^3)
	Beryllium[d]	11	19.8	0.606	0.83	2.09 (pg/m^3)
	Uranium-235[d]	11	10.2	0.385	0.82	7.58×10^{-8} (µg/m^3)
	Uranium-238[d]	11	13.1	0.221	0.73	1.46×10^{-5} (µg/m^3)
	Uranium-235/238[d]	12	4.95	0.318	0.36	0.00468 (ratio)
	Tritium	27	20.1	0.929	0.97	0.00388 (Bq/m^3)
Dose (TLD)	90-day radiological dose	27	2.38	1.07	0.9	–0.93 (mrem)
Groundwater	Gross alpha	10	30.6	0.928	0.9	0.00132 (Bq/L)
	Gross beta	34	26.7	1.07	0.81	–0.0339 (Bq/L)
	Arsenic	30	10.4	1.02	1	–0.000743 (mg/L)
	Barium	19	3.69	1.05	1	–0.0032 (mg/L)
	Bromide	9	6	0.912	0.97	0.0634 (mg/L)
	Chloride	9	0	1	1	6.8×10^{-14} (mg/L)
	Copper	9	29.8	0.776	0.86	0.00347 (mg/L)
	Molybdenum	11	2.62	1.02	1	–0.000149 (mg/L)
	Nitrate (as NO_3)	21	2.11	1.02	1	–0.695 (mg/L)
	Potassium	13	43.8	0.786	0.83	4.39 (mg/L)
	Sulfate	9	0	1	1	7.84×10^{-14} (mg/L)
	Tritium	14	6.42	1.01	1	1.78 (Bq/L)
	Uranium-234+233	18	8.2	1.03	0.99	–0.0028 (Bq/L)
	Uranium-235	13	16.8	0.765	0.95	0.000699 (Bq/L)
	Uranium-238	16	11	1.03	0.99	–0.00247 (Bq/L)
	Vanadium	9	1.35	1	1	-3.39×10^{-5} (mg/L)
	Zinc[d]	9	20.2	1.35	0.96	–0.0217 (mg/L)
Sewer	Gross beta[e]	52	15.3	0.681	0.36	0.000221 (Bq/mL)
	Chloroform[e]	9	15.7	1.08	0.59	–2.07 (µg/L)

a Number of collocated pairs included in regression analysis

b 75th percentile of percent relative standard deviations (%RSD) where

$$\%RSD = \left(\frac{200}{\sqrt{2}}\right)\frac{|x_1 \pm x_2|}{x_1 + x_2}$$ and x_1 and x_2 are the reported concentrations of each routine-duplicate pair

c Coefficient of determination

d Outside acceptable range of slope or r^2 because of outliers

e Outside acceptable range of slope or r^2 because of variability

Table 9-6. 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
Aqueous	Gross beta	2	0.83	0.71	0.95
Groundwater	Radium 226	3	0.86	0.52	1.2
	Radium 228	1	1.1	1.1	1.1
Rain	Tritium	1	0.69	0.69	0.69
Runoff (from rain)	Gross alpha	3	0.9	0.74	1
	Gross beta	3	0.9	0.85	0.98
	Uranium-234 and uranium-233	1	1	1	1
	Uranium-235 and uranium-236	1	0.85	0.85	0.85
	Uranium-238	1	0.97	0.97	0.97
Soil	Gross alpha	1	0.91	0.91	0.91
	Gross beta	1	1.2	1.2	1.2
	Cesium-137	3	1.1	0.83	1.2
	Tritium	1	0.95	0.95	0.95
	Tritium	1	1.2	1.2	1.2
	Potassium-40	4	0.97	0.85	1
	Plutonium-238	3	0.67	0.42	0.81
	Plutonium-239+240	3	0.99	0.91	1.1
	Radium-226	4	0.94	0.86	1
	Radium-228	4	0.97	0.87	1
	Thorium-228	4	0.98	0.89	1
	Uranium-235	4	0.99	0.88	1.1
	Uranium-238	3	1	0.96	1.1
Sewer	Gross alpha	2	0.74	0.7	0.78
	Tritium	1	0.94	0.94	0.94
Vegetation	Tritium	2	2.8	0.93	4.6

a Number of collocated pairs used in ratio calculations

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 9-5** are the 75th percentile of the individual precision values.

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 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.

Table 9-7. 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	Number of inconsistent pairs	Number of pairs	Percent of inconsistent pairs[a]
Air	Gross alpha	1	30	3.3
	Plutonium 239+240	2	24	8.3
	Plutonium 239+240	2	24	8.3
	Tritium	1	23	4.3
Groundwater	Copper	2	33	6.1
	Manganese	1	12	8.3
	Pentaerythritol tetranitrate	1	4	25
	Zinc	1	33	3
Runoff (from rain)	Cadmium	1	4	25
Vegetation	Tritium	1	10	10

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

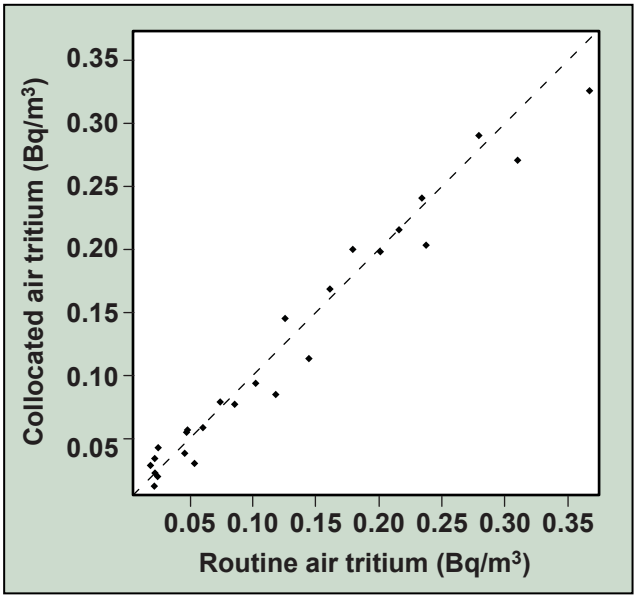


Figure 9-1. Example of data points that demonstrate good agreement between duplicate sample results using air tritium concentrations from collocated samples

When there were more than eight data pairs with both results in each pair considered detections, precision and regression analyses were performed; those results are presented in **Table 9-5**. 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 9-6**. The mean ratio

should be between 0.7 and 1.3. When either of the results in a pair is a nondetection, then the other result should be a nondetection or less than two times the detection limit. **Table 9-7** 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.

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 when more than one regulatory agency is involved.

Routine and collocated sample results show fairly good agreement: 90% of the pairs have a precision of 46% or better; 75% have a precision of 21% or better. Data sets not meeting our precision criteria fall into one of two categories. The first category, outliers, can occur because of data transcription errors, measurement errors, or real but anomalous results. Of the 27 data sets reported in **Table 9-5**, seven did not meet the criterion for acceptability because of outliers. **Figure 9-2** illustrates a set of collocated pairs with one outlier.

The second category is data sets that do not meet the criterion for acceptability because results are highly variable, as illustrated in **Figure 9-3**. This tends to be typical of measurements at extremely low concentrations. Low concentrations of radionuclides on particulates in air highlight this effect, because a small number or radionuclide-containing particles on an air filter can significantly affect results. Other causes of high variability are sampling and analytical methodology. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 27 data sets in **Table 9-5**, two show sufficient variability in results to make them fall outside the acceptable range.

Data Presentation

Data tables provided in the report CD were created using computer scripts that retrieve data from the database, convert to SI units when necessary, calculate summary statistics, format data as appropriate, lay out the table into the desired rows and columns, and present a draft table. Final tables are included after review by the responsible analyst. Analytical laboratory data, and values calculated from analytical laboratory data, are normally displayed with two or at most three significant digits. Significant trailing zeros may be omitted.

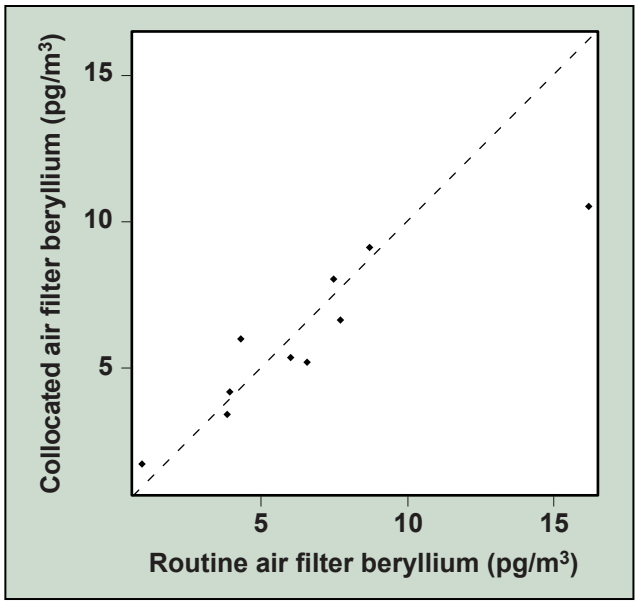


Figure 9-2. Example of data with an outlier using collocated air filter beryllium concentrations

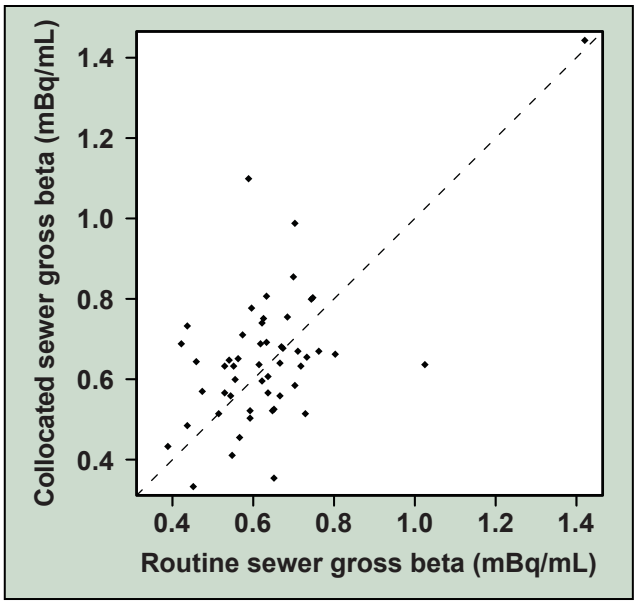


Figure 9-3. Example of variability using sewer gross beta concentrations from collocated samples

Radiological Data

Most of the data tables 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 also the section "Reporting Uncertainty in Data Tables" in this chapter). 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 to be 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 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.

Nonradiological Data

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

Statistical Comparisons and Summary Statistics

Standard comparison techniques (such as regression, t-tests, and analysis of variance) have been used where appropriate to determine the statistical significance of trends or differences between means. When such a comparison is made, it is explicitly stated in the text as being "statistically significant" or "not statistically significant." Other uses of the word "significant" in the text do not imply that statistical tests have been performed. Instead, these uses relate to the concept of practical significance and are based on professional judgment.

Summary statistics are calculated according to the *Environmental Monitoring Plan* (Woods 2005). 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 tables may present other measures, at the discretion of the responsible analyst.

The median indicates the middle of the data set. That is, 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. To calculate the median, at least four values are required; to calculate the IQR at least six values are needed.

Summary statistics are calculated from values that, if necessary, have already been rounded (such as when units have been converted from pCi to Bq) 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 then 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, then the median is reported. Otherwise, the median is assigned a less-than sign.

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

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

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 tenth centimeter, then the length can reliably and consistently be measured to the nearest tenth of a centimeter (i.e., to the nearest tick mark). However, an attempt to be more precise is not likely to yield reliable or reproducible results, because it requires a visual estimate of a distance between tick marks. The appropriate way to report such a measurement would be, for example, "2.1 cm." This 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). This result is said to have two significant digits. Although not explicitly 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 (mg) to micrograms (µg) 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 in this volume 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 1.4 to 3.8 Bq/g (i.e., 2.6 – 1.2 = 1.4 and 2.6 + 1.2 = 3.8).

The concept of significant digits applies to both the radiological result and its uncertainty. So, for example, in a result reported as "2.6 ± 1.2", both the measurement and its uncertainty have the same number of significant digits, that is, two. When expanding an interval reported in the "±" form, for example "2.4 ± 0.44", to a range of values, the rule described above for calculations involving significant digits must be followed. For example, 2.4 – 0.44 = 1.96. However, the measurements 2.4 and 0.44 each have two significant digits, so 1.96 must be rounded to two significant digits, i.e., to 2.0. Similarly, 2.4 + 0.44 = 2.84, and this must be rounded to 2.8. Therefore, a measurement reported as "2.4 ± 0.44 Bq/g" would represent an interval of 2.0 to 2.8 Bq/g.

When rounding a value having a final digit of "5", the software that prepared the tables follows the Institute of Electrical and Electronics Engineers (IEEE) Standard 754-1985, which is "go to the even digit". For example, 2.45 would round down to 2.4, and 2.55 would round up to 2.6.

Quality Assurance Process for the Environmental Report

Unlike the preceding sections, which focused on standards of accuracy and precision in data acquisition and reporting, the following discussion deals with actions to ensure that the content of this report is accurate and has not been corrupted during the publication process. Because publication of a large, data-rich document like this site annual environmental report involves many operations and many people, the chances of introducing errors are great.

Up to and including the 2003 Environmental Report, the formal QA procedure concentrated on ensuring that the data presented in tables and figures was the same as that reported by the analytical laboratory. Authors, contributors, and technicians were enlisted to check the accuracy of sections other than those with which they were routinely involved. Members of the Data Management Team (DMT) were excluded from this process because they prepared the tables. When checking values in tables and figures, checkers randomly selected 10% of the numbers and compared them to values in the reports provided by the analytical laboratories. If these values agreed with the reports, further checking was considered unnecessary. If there was disagreement, the checker compared another 10% of the data with the analytical values. If more errors were found, the entire table or figure was checked against hard copies of the analytical data. Unit conversions (e.g., from English to SI units) and summary calculations (e.g., mean, interquartile range, fractions of various limits) for each table or figure were also checked as part of this process.

The above procedure was extremely time-consuming. By the time the 2004 Environmental Report was being prepared, advances had been made that eliminated most of the potential for errors in simple supplementary data tables, such as are found primarily on the report CD. One of the advances was that, rather than sending printed reports that had to be hand-entered into the electronic database, the 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 DMT carefully checks all incoming data throughout the year, to make sure that electronic and printed reports from the laboratories agree. This aspect of QC, while not formally part of the QA process for the preparation of this environmental report, is essential to this 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.

Another advance is that scripts were written to pull data from the DMT database directly into the format of the table, including unit conversion and summary statistic calculations. All data tables found on the CD are prepared 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 they have received from DMT, and that the summary calculations have been done correctly.

For the 2005 Environmental Report, LLNL staff checked tables and figures in the body of the report as described above. Forms to aid in the QC of tables and figures were distributed along with the appropriate figure, table, and text; a coordinator kept track of the process. Items to be checked included figure captions and table titles for clarity and accuracy, 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 editors, who, in collaboration with the contributor, ensured that corrections were made.

Appendix A: EPA Methods of Environmental Water Analysis

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

Constituents of concern	Analytical method	Reporting limit[a,b]
Metals and minerals (mg/L)		
All alkalinities	EPA 310.1	1
Aluminum	EPA 200.7 or 200.8	0.05 or 0.2
Ammonia nitrogen (as N)	EPA 350.3, 350.2, or 350.1	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 213.2 or 200.8	0.0005
Calcium	EPA 200.7	0.5
Chloride	EPA 300.0	1 or 0.5
Chlorine (residual)	EPA 330.1 or 330.4	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	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 239.2 or 200.8	0.002 or 0.005
Magnesium	EPA 200.7 or 200.8	0.5
Manganese	EPA 200.7 or 200.8	0.03
Mercury	EPA 245.2 or 245.1	0.0002
Molybdenum	EPA 200.7 or 200.8	0.025
Nickel	EPA 249.2, 200.7 or 200.8	0.002, 0.005 or 0.1
Nitrate (as NO_3)	EPA 353.2, 354.1 or 300.0	0.5
Nitrite (as NO_2)	EPA 353.2, 354.1 or 300.0	0.5
Ortho-phosphate	EPA 300.0, 365.1 or 365.2	0.05
Perchlorate	EPA 314.0	0.004
Potassium	EPA 200.7	1
Selenium	EPA 270.2 or 200.8	0.002

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

Constituents of concern	Analytical method	Reporting limit[a,b]
Silver	EPA 272.2 or 200.8	0.001 or 0.0005
Sodium	EPA 200.7	1 or 0.1
Sulfate	EPA 300.0	1
Surfactants	EPA 425.1	0.5
Thallium	EPA 279.2 or 200.8	0.001
Total dissolved solids	EPA 160.1	1
Total suspended solids	EPA 160.2	1
Total Kjeldahl nitrogen	EPA 351.2 or 351.3	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)	EPA 150.1	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)	EPA 360.1	0.05
Total organic carbon (mg/L)	EPA 9060 or 415.1	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 908	0.0037

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

Constituents of concern	Analytical method	Reporting limit[a,b]
Uranium-235	EPA 908	0.0037
Uranium-238	EPA 908	0.0037

a The significant figures 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 A-2. Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method

Constituents of concern	Reporting limit (µg/L) [a,b]
EPA Method 1664	
Oil & Grease	1000
EPA Method 420.1	
Phenolics	5
EPA Method 502.2 (or 524.2)	
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

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

Constituents of concern	Reporting limit (µg/L) [a,b]
Molinate	0.5
Prometon	0.5
Prometryn	0.5
Simazine	0.5
Terbutryn	0.5
EPA Method 524.2	
1,1,1,2-Tetrachloroethane	1
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,1-Dichloropropene	1
1,2,3-Trichlorobenzene	1
1,2,3-Trichloropropane	1
1,2,4-Trichlorobenzene	1
1,2,4-Trimethylbenzene	1
1,2-Dibromo-3-chloropropane	2
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1
1,2-Dichloropropane	1
1,3,5-Trimethylbenzene	1
1,3-Dichlorobenzene	1
1,3-Dichloropropane	1
1,4-Dichlorobenzene	1
2-Chlorotoluene	1
4-Chlorotoluene	1
Benzene	1
Bromobenzene	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,2-Dichloroethene	1

Constituents of concern	Reporting limit (µg/L) [a,b]
cis-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1
Dichlorodifluoromethane	2
Ethylbenzene	1
Ethylene dibromide	1
Freon 113	1
Hexachlorobutadiene	1
Isopropylbenzene	1
m- and *p*-Xylene isomers	1
Methylene chloride	1
n-Butylbenzene	1
n-Propylbenzene	1
Naphthalene	1
o-Xylene	1
Isopropyl toluene	1
sec-Butylbenzene	1
Styrene	1
tert-Butylbenzene	1
Tetrachloroethene	1
Toluene	1
trans-1,2-Dichloroethene	1
trans-1,3-Dichloropropene	1
Trichloroethene	0.5
Trichlorofluoromethane	1
Vinyl chloride	2
EPA Method 525	
2,4-Dinitrotoluene	0.5
2,6-Dinitrotoluene	0.5
4,4'-DDD	0.5
4,4'-DDE	0.5
4,4'-DDT	0.5
Acenaphthylene	0.5
Alachlor	0.5
Aldrin	0.5
Anthracene	0.5
Aroclor 1016 (PCB)	0.5
Aroclor 1221 (PCB)	0.5

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

Constituents of concern	Reporting limit (µg/L) [a,b]
Aroclor 1232 (PCB)	0.5
Aroclor 1242 (PCB)	0.5
Aroclor 1248 (PCB)	0.5
Aroclor 1254 (PCB)	0.5
Aroclor 1260 (PCB)	0.5
Atraton	0.5
Atrazine	0.5
Benzo(a)anthracene	0.5
Benzo(a)pyrene	0.5
Benzo(b)fluoranthene	0.5
Benzo(g,h,i)perylene	0.5
Benzo(k)fluoranthene	0.5
Bis(2-ethylhexyl)phthalate	0.5
Bromacil	0.5
Butachlor	0.5
Butylbenzylphthalate	0.5
Chlordane	0.5
Chloropropham	0.5
Chlorpyrifos	0.5
Chrysene	0.5
Di (2-ethylhexyl) adipate	0.5
Di-n-butylphthalate	0.5
Diazinon	0.5
Dibenzo(a,h)anthracene	0.5
Dichlorvos	0.5
Dieldrin	0.5
Diethylphthalate	0.5
Dimethylphthalate	0.5
Disulfoton	0.5
Endosulfan I	0.5
Endosulfan II	0.5
Endosulfan sulfate	0.5
Endrin	0.5
Endrin aldehyde	0.5
Ethoprop	0.5
Fluorene	0.5
Heptachlor	0.5
Heptachlor epoxide	0.5

Constituents of concern	Reporting limit (µg/L) [a,b]
Hexachlorobenzene	0.5
Hexachlorocyclopentadiene	0.5
Indeno(1,2,3-c,d)pyrene	0.5
Isophorone	0.5
Lindane	0.5
Merphos	0.5
Methoxychlor	0.5
Metolachlor	0.5
Metribuzin	0.5
Mevinphos	0.5
Pentachlorobenzene	0.5
Pentachlorophenol	0.5
Phenanthrene	0.5
Prometon	0.5
Prometryne	0.5
Propachlor	0.5
Pyrene	0.5
Simazine	0.5
Stirophos	0.5
Terbutryn	0.5
Toxaphene	0.5
EPA Method 547	
Glyphosate 20	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

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

Constituents of concern	Reporting limit (µg/L) [a,b]
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
EPA Method 602	
1,2-Dichlorobenzene	0.3
1,3-Dichlorobenzene	0.3
1,4-Dichlorobenzene	0.3
Benzene	0.4
Chlorobenzene	0.3
Ethylbenzene	0.3
m-Xylene isomers	0.4
o-Xylene	0.4
p-Xylene	0.4
Toluene	0.3
Total xylene isomers	0.4
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
1,2-Dichloroethene (total)	1
1,2-Dichloropropane	1
1,3-Dichlorobenzene	1
1,4-Dichlorobenzene	1
2-Butanone	20

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

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

Constituents of concern	Reporting limit (µg/L) [a,b]
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
Bis(2-ethylhexyl)phthalate	5
Butylbenzylphthalate	5
Chrysene	5
Di-*n*-butylphthalate	5
Di-*n*-octylphthalate	5
Dibenzo[*a,h*]a nthracene	5

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

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

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

Constituents of concern	Reporting limit (µg/L) [a,b]
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
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 8330	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 significant figures 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)

Table A-3. Radioisotopes and reporting limits for gamma spectroscopic analysis of constituents of concern in groundwater[a]

Constituents of concern[b]	Typical reporting limit (Bq/L)
Actinium-228	3.1
Americium-241	1.8
Beryllium-7	3.7
Cesium-134	0.4
Cesium-137	0.3
Cobalt-57	0.2
Cobalt-60	0.4
Europium-152	0.9
Europium-154	1.0
Europium-155	1.0
Potassium-40	7.2
Radium-226	0.8
Thorium-228	0.5
Thorium-234	1.4
Uranium-235	1.3

a The significant figures displayed in this table vary by constituents of concern. These variations reflect the applicable analytical laboratory contract under which the work was performed.

b Not included are promethium-147 and thallium-208, reported above 46,000 and 72 Bq/L, respectively.

Appendix B: Constituents of Interest, Sampling Frequency, and Discharge Limits for Releases from the Drainage Retention Basin

Table B-1. DRB discharge analytes and sampling frequency for sampling locations CDBX and WPDC, and discharge limits from the amended CERCLA ROD applied at CDBX

Constituent	CDBX Frequency[a]	WPDC Frequency[a]	Discharge limits	
			Dry season[b]	Wet season[c]
pH (units)	W & D	W & D	6.5–8.5	6.5–8.5
Metals (µg/L)				
Antimony	W & D	W & D	6	NA
Arsenic	W & D	W & D	50	10
Beryllium	W & D	W & D	4	NA
Boron	W & D	W & D	NA	NA
Cadmium	W & D	W & D	5	2.2
Chromium (total)	W & D	W & D	50	NA
Chromium (VI)	W & D	W & D	NA	22
Copper	W & D	W & D	1300	23.6
Iron	W & D	W & D	NA	NA
Lead	W & D	W & D	15	6.4
Manganese	W & D	W & D	NA	NA
Mercury	W & D	W & D	2	2
Nickel	W & D	W & D	100	320
Selenium	W & D	W & D	50	10
Silver	W & D	W & D	100	8.2
Thallium	W & D	W & D	2	NA
Zinc	W & D	W & D	NA	220
Organics (µg/L)				
Volatile organic compounds (EPA Method 601)	W	_[d]	5	5
1,1-dichloroethane (1,1-DCA)	W	_[d]	5	5
1,1-dichloroethylene (1,1-DCE)	W	_[d]	5	5
1,2-dichloroethylene (1,2-DCE)	W	_[d]	NA	NA
cis-1,2-dichloroethylene (cis-1,2-DCE)	W	_[d]	5	5
trans-1,2-dichloroethylene (trans-1,2-DCE)	W	_[d]	5	5
1,2-dichloroethane (1,2-DCA)	W	_[d]	5	5
Carbon tetrachloride	W	_[d]	5	5
Total THM (chloroform, bromoform, chlorodibromomethane, bromodichloromethane)	W	_[d]	5	5
Tetrachloroethene	W	_[d]	4	4

Appendix B: Constituents of Interest, Sampling Frequency, and Discharge Limits for Releases from the Drainage Retention Basin

Table B-1. DRB discharge analytes and sampling frequency for sampling locations CDBX and WPDC, and discharge limits from the amended CERCLA ROD applied at CDBX (continued)

Constituent	CDBX Frequency[a]	WPDC Frequency[a]	Discharge limits	
			Dry season[b]	Wet season[c]
Trichloroethylene (TCE)	W	_[d]	5	5
Vinyl chloride	W	_[d]	2	2
Acute toxicity				
Aquatic survival bioassay (96 hours)	W & D	W & D	90% survival median, 90 percentile value of not less than 70% survival	
Chronic toxicity				
Fathead minnow	W	_[d]	NA	NA
Water flea	W	_[d]	NA	NA
Green algae	W	_[d]	NA	NA
Radiological (pCi/L)				
Tritium	W	_[d]	20,000	20,000
Special studies or by request of RWQCB				
Polychlorinated biphenyls	W & D	_[d]	NA	NA
Herbicides (Bromicil by E507, Glyphosate by E547, Diuron by E632)	CDBX	_[d]	NA	NA
Chemical oxygen demand	CDBX	_[d]	NA	NA
Total organic carbon	CDBX	_[d]	NA	NA
Physical				
Turbidity (NTU)[e]	W & D	_[d]	>15	>15
Conductivity	W	W	NA	NA
Total suspended solids	W & D	W & D	NA	NA
Total dissolved solids	W	W	NA	NA
General minerals				
Total alkalinity	W	_[d]	NA	NA
Nitrate (as N)	W	_[d]	NA	NA
Nitrite (as N)	W	_[d]	NA	NA
Radiological (Bq/L)				
Alpha	W	_[d]	0.56	0.56
Beta	W	_[d]	1.85	1.85

a W = Monitoring occurs at the first DRB discharge of the wet season and at one or more additional discharges associated with storm water runoff monitoring. Toxicity testing is required only on the first release.
D = Monitoring occurs at each dry season release. For purposes of discharge sampling, the dry season is defined to occur from June 1 through September 30.

b Dry season limits apply to CDBX from April 1 to November 30.

c Wet season limits apply to CDBX from December 1 to March 31.

d Sampling not required for this parameter

e NTU = Nephelometric turbidity units

NA No limit applicable for this parameter

Appendix C: Wildlife Survey Results

Table C-1 includes species for which there are verified observations. It is not intended to be a complete list of Site 300 species

Table C-1. Site 300 wildlife species list

Common Name	Scientific Name	Regulatory Status[a]	Source
Mammals			
Pallid bat	*Antrozous pallidus*	CASCS	Rainey 2003
Western red bat	*Lasiurus blossevillii*		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*	CASCS	LLNL 2002 West 2002
San Joaquin pocket mouse	*Perognathus inornatus*		Clark et al. 2002
California ground squirrel	*Spermophilus beecheyi*		LLNL 2002
Valley 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
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

Table C-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Western spotted skunk	*Spilogale gracilis*		LLNL 2002 Orloff 1986
American badger	*Taxidea taxus*	CASCS	LLNL 2002 Clark et al. 2002
Bobcat	*Lynx rufus*		LLNL 2002 Clark et al. 2002
Mountain Lion	*Felis 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, CASCS	LLNL 2002
California red-legged frog	*Rana aurora draytonii*	FT, CASCS	LLNL 2002
Pacific tree frog	*Hyla regilla*		LLNL 2002
Western spadefoot toad	*Spea hammondii*	CASCS	LLNL 2002
Western toad	*Bufo boreas*		LLNL 2002
Alameda whipsnake	*Masticophis lateralis euryxanthus*	FT, ST	Swaim 2002
San Joaquin coachwhip	*Masticophis flagellum*	CASCS	LLNL 2002
Coast horned lizard	*Phrynosoma coronatum*	CASCS	LLNL 2002
California legless lizard	*Anniella pulchra*	CASCS	Swaim 2002
Side-blotched lizard	*Uta stansburiana*		LLNL 2002 Swaim 2002
Western whiptail	*Cnemidophorus tigris*		LLNL 2002 Swaim 2002
Western fence lizard	*Sceloporus occidentalis*		LLNL 2002 Swaim 2002
Western skink	*Eumeces skiltonianus*		LLNL 2002 Swaim 2002
Gilbert skink	*Eumeces gilberti*		LLNL 2002 Swaim 2002
Southern alligator lizard	*Gerrhonotus multicarinatus*		LLNL 2002 Swaim 2002
Western yellow bellied racer	*Coluber constrictor*		LLNL 2002 Swaim 2002
Pacific gopher snake	*Pituophis melanoleucus*		LLNL 2002 Swaim 2002
Common kingsnake	*Lampropeltis getulus*		LLNL 2002 Swaim 2002
Western rattlesnake	*Crotalus viridis*		LLNL 2002 Swaim 2002
Night snake	*Hypsiglena torquata*		LLNL 2002 Swaim 2002
Glossy snake	*Arizona elegans*		LLNL 2002 Swaim 2002

Table C-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Long-nosed snake	*Rhinocheilus lecontei*		LLNL 2002 Swaim 2002
California black-headed snake	*Tantilla planiceps*		Swaim 2002
Birds			
Cooper's Hawk	*Accipiter cooperii*	CASCS, MBTA	LLNL 2003
Sharp-shinned Hawk	*Accipiter striatus*	CASCS, MBTA	LLNL 2003
Golden Eagle	*Aquila chrysaetos*	CAFPS,CASCS, MBTA	LLNL 2003
Red-tailed Hawk	*Buteo jamaicensis*	MBTA	LLNL 2003
Rough-legged Hawk	*Buteo lagopus*	MBTA	LLNL 2003
Red-shouldered Hawk	*Buteo lineatus*	MBTA	LLNL 2003
Ferruginous Hawk	*Buteo regalis*	CASCS, MBTA	LLNL 2003
Swainson's Hawk	*Buteo swainsoni*	ST, MBTA	LLNL 2003
Northern Harrier	*Circus cyaneus*	CASCS, MBTA	LLNL 2003
White-tailed Kite	*Elanus leucurus*	CAFPS, MBTA	LLNL 2003
Osprey	*Pandion haliaetus*	CASCS, MBTA	LLNL 2003
Bushtit	*Psaltriparus minimus*	MBTA	LLNL 2003
Horned Lark	*Eremophila alpestris*	CASCS, MBTA	LLNL 2003
Northern Shoveler	*Anas clypeata*	MBTA	LLNL 2003
Cinnamon Teal	*Anas cuamptera*	MBTA	LLNL 2003
Mallard	*Anas platyryynchos*	MBTA	LLNL 2003
Bufflehead	*Blucephala albeola*	MBTA	LLNL 2003
Common Goldeneye	*Bucephala clangula*	MBTA	LLNL 2003
White-throated Swift	*Aeronautes saxatalis*	MBTA	LLNL 2003
Great Egret	*Ardea alba*	MBTA	LLNL 2003
Virginia Rail	*Rallus limicola*	MBTA	U.S. DOE and UC 1992
Cedar Waxwing	*Bombycilla garrulus*	MBTA	LLNL 2003
Common Poorwill	*Phalaenoptilus nuttalii*	MBTA	LLNL 2003
Blue-grosbeak	*Guiraca caerulea*	MBTA	LLNL 2003
Black-headed Grosbeak	*Pheucticus melanocephalus*	MBTA	U.S. DOE and UC 1992
Lazuli Bunting	*Passerina amoena*	MBTA	LLNL 2003
Turkey Vulture	*Cathartes aura*	MBTA	LLNL 2003
Killdeer	*Charadrius vociferus*	MBTA	LLNL 2003
Rock Dove	*Columba livia*		U.S. DOE and UC 1992
Mourning Dove	*Zenaida macroura*	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
Greater Roadrunner	*Geococcyx californianus*	MBTA	LLNL 2003
Bell's Sage Sparrow	*Amphispiza belli*	CASCS, MBTA	LLNL 2003
Black-throated Sparrow	*Amphispiza bilineata*	MBTA	LLNL 2003
Rufous Crowned Sparrow	*Aimophila ruficeps*	MBTA	LLNL 2003
Grasshopper Sparrow	*Ammodramus savannarum*	MBTA	LLNL 2003
Lark Sparrow	*Chondestes grammacus*	MBTA	LLNL 2003

Table C-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
California Towhee	*Carpodacus mexicanus*	MBTA	LLNL 2003
Oregon Junco	*Junco hyemalis*	MBTA	LLNL 2003
Lincoln's Sparrow	*Melospiza lincolnii*	MBTA	LLNL 2003
Song Sparrow	*Melospiza melodia*	MBTA	LLNL 2003
Vesper Sparrow	*Pooecetes gramineus*	MBTA	U.S. DOE and UC 1992
Fox Sparrow	*Passerella iliaca*	MBTA	LLNL 2003
Savannah Sparrow	*Passerculus sandwichensis*	MBTA	LLNL 2003
Golden-crowned Sparrow	*Zonotrichia atricapilla*	MBTA	LLNL 2003
White-crowned Sparrow	*Zonotrichia leucophrys*	MBTA	LLNL 2003
American Kestrel	*Falco sparverius*	MBTA	LLNL 2003
Prairie Falcon	*Falca mexicanus*	CASCS, MBTA	LLNL 2003
House Finch	*Carpodacus mexicanus*	MBTA	LLNL 2003
Lesser Goldfinch	*Carduelis psaltia*	MBTA	LLNL 2003
Cliff Swallow	*Petrochelidon pyrrhonota*	MBTA	LLNL 2003
Northern Rough Winged Swallow	*Stelgidopteryx serripennis*	MBTA	LLNL 2003
Tree Swallow	*Tachycineta bicolor*	MBTA	LLNL 2003
Red-winged Blackbird	*Agelaius phoeniceus*	MBTA	LLNL 2003
Tricolored Blackbird	*Agelaius tricolor*	CASCS, MBTA	LLNL 2003
Brewer's Blackbird	*Euphagus cyanocephalus*	MBTA	LLNL 2003
Bullock's Oriole	*Icterus bullockii*	MBTA	LLNL 2003
Brown-headed Cowbird	*Molothrus ater*	MBTA	LLNL 2003
Western Meadowlark	*Sturnella magna*	MBTA	LLNL 2003
Loggerhead Shrike	*Lanius ludovicianus*	CASCS, MBTA	LLNL 2003
Northern Mockingbird	*Mimus polyglottos*	MBTA	LLNL 2003
California Thrasher	*Toxostoma redivivum*	MBTA	LLNL 2003
California Quail	*Callipepla californica*		LLNL 2003
Oak Titmouse	*Baeolphus inornatus*	FSC, MBTA	LLNL 2003
Yellow-rumped Warbler	*Dendroica coronata*	MBTA	LLNL 2003
Black-throated Gray Warbler	*Dendroica nigrescens*	MBTA	LLNL 2003
Yellow Warbler	*Dendroica petechia*	CASCS, MBTA	LLNL 2003
Common Yellowthroat	*Geothlypis trichas*	CASCS, MBTA	LLNL 2003
MacGillivary's Warbler	*Oporornis tolmiei*	MBTA	LLNL 2003
Orange-crowned Warbler	*Vermivora bachmanii*	MBTA	LLNL 2003
Wilson's Warbler	*Wilsonia pusila*	MBTA	LLNL 2003
Double-crested Cormorant	*Phalacrocorax auritus*	CASCS, MBTA	LLNL 2003
Wild Turkey	*Meleagris gallopavo*		LLNL 2003
Northern Flicker	*Colaptes auratus*	MBTA	LLNL 2003
Nuttal's Woodpecker	*Picoides nuttallii*	MBTA	LLNL 2003
Acorn Woodpecker	*Melanerpes formicivorus*	MBTA	U.S. DOE and UC 1992
Pied-billed Grebe	*Podilymbus podiceps*	MBTA	LLNL 2003
Phainopepela	*Phainopepla nitens*	MBTA	LLNL 2003
Ruby-crowned Kinglet	*Regulus calendula*	MBTA	LLNL 2003
Common Snipe	*Gallinago gallinago*	MBTA	LLNL 2003
Greater Yellowlegs	*Tringa melanoleuca*	MBTA	LLNL 2003

Table C-1. Site 300 wildlife species list (continued)

Common Name	Scientific Name	Regulatory Status[a]	Source
Burrowing Owl	*Athene cunicularia*	CASCS, MBTA	LLNL 2003
Short-eared Owl	*Asio flammeus*	CASCS, MBTA	LLNL 2003
Great horned Owl	*Bubo virginianus*	MBTA	LLNL 2003
Western Screech Owl	*Otus kennicottii*	MBTA	LLNL 2003
European Starling	*Sturnus vulgaris*		LLNL 2003
Western Tanager	*Piranga ludoviciana*	MBTA	LLNL 2003
Anna's Hummingbird	*Calypte anna*	MBTA	LLNL 2003
Costa's Hummingbird	*Calypte costae*	MBTA	LLNL 2003
Rufous Hummingbird	*Selasphorus rufus*	MBTA	LLNL 2003
Allen's Hummingbird	*Selasphorus sasin*	MBTA	U.S. DOE and UC 1992
Rock Wren	*Salpinctes obsoletus*	MBTA	LLNL 2003
Bewick's Wren	*Thyothorus ludovicianus*	MBTA	LLNL 2003
House Wren	*Troglodytes aedon*	MBTA	LLNL 2003
Hermit Thrush	*Catharus guttatus*	MBTA	LLNL 2003
Swainson's Thrush	*Catharus ustulatus*	MBTA	LLNL 2003
Varied Thrush	*Ixoreus naevius*	MBTA	LLNL 2003
Mountain Bluebird	*Sialia currucoides*	MBTA	LLNL 2003
Western Buebird	*Sialia mexicana*	MBTA	LLNL 2003
American Robin	*Turdus migratorius*	MBTA	LLNL 2003
Pacific-slope Flycatcher	*Empidonax difficillis*	MBTA	LLNL 2003
Willow Flycatcher	*Empidonax traillii*	SE, MBTA	van Hattem 2005
Ash-throated Flycatcher	*Myiarchus cinerascens*	MBTA	LLNL 2003
Western Wood-pewee	*Contopus sordidulus*	MBTA	U.S. DOE and UC 1992
Black Phoebe	*Sayornis nigricans*	MBTA	LLNL 2003
Say's Phoebe	*Sayornis saya*	MBTA	LLNL 2003
Western Kingbird	*Tyrannus verticalis*	MBTA	LLNL 2003
Cassin's Kingbird	*Tyrannus vociferans*	MBTA	LLNL 2003
Barn Owl	*Tyto alba*	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 CAFPS = California Department of Fish and Game Fully Protected Species (CA Dept. of Fish and Game 2006)
CASCS = California Special Concern species (CA Dept. of Fish and Game 2006)
FE = Endangered under the Federal Endangered Species Act
FT = Threatened under the Federal Endangered Species Act
PT = Proposed as 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
FSC = Federal Species of Concern for Alameda and San Joaquin Counties. May be endangered or threatened. Not enough biological information has been gathered to support listing at this time (U.S. Fish and Wildlife Service 1-1-03-SP-0162).

Appendix D: Errata

Protocol for Handling Errata in LLNL Environmental Reports

The primary form of publication for the LLNL site environmental annual report (SAER) is electronic, either on CD (compact disk) or on the Internet. The secondary form is hard copy, which is produced from the electronic copy. Hard copy is made available to the public at local libraries.

Because there are both publicly distributed and Internet versions of the report, the two versions must be fully equivalent, both in their original versions as first presented to the public, and as they are changed (noted as published errata) subsequent to the original publication.

In October 1998, LLNL developed a protocol for making post-publication revisions to the Internet versions of SAERs. The main criteria are that (1) the SAER home page must simply and clearly convey what revisions, if any, have been made to a particular report, and directly link to an errata information section; (2) the Internet version of the SAER must be accurately maintained; (3) each SAER accessible on the Internet at any time shall be the most current version of the report, incorporating all revisions; and (4) the content of the Internet and distributed versions of the SAER must be the same, in the sense that the published version plus its errata, if any, must provide the same information as the current (revised) Internet version.

This report and its supporting data can be accessed on the Internet at the address of the LLNL SAER homepage: http://www.llnl.gov/saer. SAERs covering calendar years 1994 through 2005 are available on the website. A link to an errata section provides a complete record of post-publication changes that have been made.

Record of Changes to 2004 SAER

The following changes have been made to the Internet version of the document.

- On page iii, in lines 1 and 3 of the last paragraph, “Operation” was changed to “Operations”.

- On page EX-4, in line 3 of the first paragraph "but is about 60% highter than releases in 2001 and 2002" was deleted.
- On page EX-5, the following changes were made.
  - — Figure EX-1 was changed to correctly show the data for Livermore Valley wine (data shown were for California wine).
  - — In line 4 of the second paragraph, "Livermore Valley wines and rain in Portland exhibit similar tritium concentrations." was deleted.
  - — In line 5 of the second paragraph, "median" was added, "concentrations" was changed to "concentration", and "were 120 times" was changed to "was 100 times".
- On page EX-7, in the first sentence of the last paragraph, "1981" was changed to "1991".

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Arnold, R. A. (2002), *Report on the threatened valley elderberry longhorn beetle and its elderberry food plant at the Lawrence Livermore National Laboratory – Site 300,* Entomological Consulting Services, Ltd. Pleasant Hill, CA.

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Acronyms and Abbreviations

See also the Glossary for further definition of selected terms.

A	**ACDEH**	Alameda County Department of Environmental Health
	ACHP	Advisory Council on Historic Preservation
	ACL	ambient concentration limit
	ACOE	Army Corps of Engineers
	AFV	alternative fuel vehicles
	ALARA	as low as reasonably achievable
	ANSI	American National Standards Institute
	ASE	accelerated solvent extraction
	ATCM	Airborne Toxic Control Measure
	ATSDR	Agency for Toxic Substances and Disease Registry
	AWQC	ambient water quality criteria
B	**BA**	biological assessment
	BAAQMD	Bay Area Air Quality Management District
	BAT	best available technology
	BMP	best management practice
	Bq	becquerel
	BSA	Blanket Service Agreement
	BSL-3	Biosafety Level 3
C	**CAM**	continuous air monitor
	CAMP	Corrective Action Monitoring Program
	CAP	Corrective Action Plan
	CARB	California Air Resources Board
	CCB	Change Control Board
	CCR	California Code of Regulations Container Content Report
	CD	compact disc
	CDF	California Department of Forestry
	CEI	Compliance Evaluation Inspection
	CEQA	California Environmental Quality Act of 1970
	CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
	CES	Chemistry and Materials Science Environmental Services
	CFR	Code of Federal Regulations

	CHP	California Highway Patrol
	Chromium(VI)	hexavalent chromium
	Ci	curie
	CMP	Compliance Monitoring Program
	CNPS	California Native Plant Society
	COC	constituent of concern
	COD	chemical oxygen demand
	CRLF	California red-legged frog
	CSA	container storage area
	CTC	Closing-the-Circle
	CVRWQCB	Central Valley Regional Water Quality Control Board
	CWA	(Federal) Clean Water Act
D	**D&D**	decommissioning and decontamination
	DCG	Derived Concentration Guide
	DDC	direct digital control
	DHS	Department of Health Services
	DMP	Detection Monitoring Program
	DMT	Data Management Team
	DOE	U.S. Department of Energy
	DRB	Drainage Retention Basin
	DTSC	(California Environmental Protection Agency), Department of Toxic Substances Control
	DWTF	Decontamination and Waste Treatment Facility
E	**EA**	environmental assessment
	EDE	effective dose equivalent
	EDO	Environmental Duty Officer
	EIR	environmental impact report
	EIS	environmental impact statement
	EMP	Environmental Management Program
	EMRL	Environmental Monitoring Radiation Laboratory
	EMS	Environmental Management System
	EOG	Environmental Operations Group
	EPA	Environmental Protection Agency
	EPCRA	Emergency Planning and Community Right-to-Know Act of 1986
	EPD	Environmental Protection Department (LLNL)
	EPL	effluent pollutant limit

	ERA	Environmental Resource Associates
	ERD	Environmental Restoration Division (of the Environmental Protection Department at LLNL)
	ERRC	Electronics Recycling and Reuse Challenge
	ES&H	Environment, Safety, and Health
	ESB	East Settling Basin
	ESI	enhanced surveillance inspection
	EWSF	Explosives Waste Storage Facility
	EWTF	Explosives Waste Treatment Facility
F	**F&I**	facility and infrastructure
	FEC	Federal Electronics Challenge
	FEMP	Federal Energy Management Program
	FFA	federal facility agreement
	FY	fiscal year
G	**GAB**	gross alpha and gross beta
	GBq	gigabecquerel (10^9 Bq)
	GIS	Geographic Information System
	GPS	global positioning system
	GSA	General Services Area (LLNL Site 300)
	GWP	Ground Water Project
H	**HAP**	hazardous air pollutants
	HCAL	Hazards Control Department's Analytical Laboratory
	HEPA	high-efficiency particulate air (filter)
	HMX	cyclotetramethyltetramine (high explosive). Also referred to as octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
	HPGe	high-purity germanium
	HSU	hydrostratigraphic unit
	HT	tritiated hydrogen gas (See also tritium in Glossary.)
	HTO	tritiated water and water vapor (See also tritium in Glossary.)
	HVAC	heating, ventilating, and air conditioning
	HW	hazardous waste
	HWCA	Hazardous Waste Control Act
	HWFP	Hazardous Waste Facility Permit
I	**IEEE**	Institute of Electrical and Electronics Engineers
	IQR	interquartile range
	ISMS	Integrated Safety Management System
	ISO	International Organization for Standardization

	ITS	Issue Tracking System
	IWS	integration work sheet
J	**JASPER**	Joint Actinide Shock Physics Experiment Research
L	**LEPC**	Local Emergency Planning Committee
	LLD	lower limit of detection
	LLNL	Lawrence Livermore National Laboratory
	LLW	low-level waste
	LOS	limit of sensitivity
	LRS	laws, regulations, standards
	LSO	Livermore Site Office
	LWRP	Livermore Water Reclamation Plant
M	**MAPEP**	Mixed Analyte Performance Evaluation Program
	mCi	millicurie (10^{-3} Ci)
	MCL	maximum contaminant level
	MDC	minimum detectable concentration
	MIS	Maintenance Impact Study
	ML	million liters
	MNA	monitored natural attenuation
	MRP	Monitoring and Reporting Program
	MSDS	material safety data sheet
	mSv	millisievert (10^{-3} Sv)
	MW	mixed waste
N	**NCR**	nonconformance report
	NCRP	National Council on Radiation Protection and Measurements
	NEPA	National Environmental Policy Act
	NESHAPs	National Emissions Standards for Hazardous Air Pollutants
	NHPA	National Historic Preservation Act
	NIF	National Ignition Facility
	NNSA	National Nuclear Security Administration
	NOD	notice of deficiency
	NOV	notice of violation
	NOx	nitrogen oxides
	NPDES	National Pollutant Discharge Elimination System
	NRC	Nuclear Regulatory Commission
	nSv	nanosievert (10^{-9} Sv)
	NWP	nationwide permit

O	**OBT**	organically bound tritium
	OFI	opportunities for improvement
	OR	occurrence report
	ORAD	Operations and Regulatory Affairs Division (of the Environmental Protection Department at LLNL)
	OU	operable unit
P	**P2**	pollution prevention
	PCB	polychlorinated biphenyl
	PCE	perchloroethylene (or perchloroethene). Also called tetrachloroethylene (or tetrachloroethene).
	PETN	pentaerythritol tetranitrate
	PHA	public health assessment
	pHMS	pH Monitoring Station
	PM-10	particulate matter
	ppb	parts per billion
	ppm	parts per million
	PPOA	Pollution Prevention Opportunity Assessment
	PQL	practical quantitation limit
Q	**QA**	quality assurance
	QC	quality control
R	**RAIP**	Remedial Action Implementation Plan
	RCRA	Resource Conservation and Recovery Act of 1976
	RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine (high explosive)
	REC	renewable energy credit
	RHWM	Radioactive and Hazardous Waste Management Division (of the Environmental Protection Department at LLNL)
	RI/FS	remedial investigtion/feasibility study
	RL	reporting limit
	ROD	Record of Decision
	ROGs/POCs	reactive organic gases/precursor organic compounds
	ROI	return on investment
	RWQCB	regional water quality control board
S	**Sandia/California**	Sandia National Laboratories/California
	SARA	Superfund Amendment and Reauthorization Act of 1986 (see also CERCLA/SARA)
	SAT	Space Action Team
	SDF	Sewer Diversion Facility

SERC	State Emergency Response Commission
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SHPO	State Historic Preservation Officer
SI	Système International d'Unités
Site 300	LLNL's Experimental Test Site, located approximately 24 km east of the Livermore site
SJCEHD	San Joaquin County Environmental Health Department
SJVAPCD	San Joaquin Valley Air Pollution Control District
SME	subject mattyer expert
SMOP	Synthetic Minor Operating Permit
SMS	Sewer Monitoring Station
SOO	summary of observations
SOP	standard operating procedure
SPCC	Spill Prevention Control and Countermeasure
SSTL	Small Scale Treatment Laboratory
STP	Site Treatment Plan
Sv	sievert
SVOC	semivolatile organic compound
SWESR	Site-Wide Remediation Evaluation Summary Report
SW-MEI	site-wide maximally exposed individual member (of the public)
SWPPP	Storm Water Pollution Prevention Plan
TAC	toxic air contaminant
TAG	Technical Assistance Grant
TBq	terabecquerel (10^{12} Bq)
TCE	trichloroethene (or trichloroethylene)
TDS	total dissolved solids
TEF	toxicity equivalency factor
TEQ	toxicity equivalency
TF	treatment facility
TLD	thermoluminescent dosimeter
TNT	trinitrotoluene
TOC	total organic carbon
TOX	total organic halides
TRI	Toxics Release Inventory
Tri-Valley CAREs	Tri-Valley Communities Against a Radioactive Environment
TRU	transuranic (waste)

	TSCA	Toxic Substances Control Act
	TSS	total suspended solids
	TTO	total toxic organics
	TWMS	Total Waste Management System
U	**UC**	University of California
	USFWS	U.S. Fish and Wildlife Service
V	**VFD**	variable frequency drive
	VOC	volatile organic compound
	VTF	vapor treatment facility
W	**WAA**	waste accumulation area
	WDR	Waste Discharge Requirement
	WMA	Waste Management Area
	WSS	Work Smart Standards
Z	**Zone 7**	Alameda County Flood Control and Conservation District, Zone 7

Glossary

A **Absorbed dose:** the 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 (l rad = 0.01 gray)

Accuracy: the 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

Aerosol: a gaseous suspension of very small particles of liquid or solid

Alameda County Flood Control and Water Conservation District: also known as Zone 7, the water management agency for the Livermore-Amador Valley with responsibility for water treatment and distribution, and responsible for management of agricultural and surface water and the ground water basin

Alluvium: sediment deposited by flowing water

Alpha particle: a 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: the surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures; not considered in monitoring purposes when immediately adjacent to emission sources

Anadromous: ascending rivers from the sea for breeding

Analysis of variance (ANOVA): a test of whether two or more sample means are statistically different

Analyte: the specific component measured in a chemical analysis

Anion: a negatively charged ion, such as Cl^-

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

Aquitard: low-permeability geologic formation that bounds an aquifer

Atom: the smallest particle of an element capable of entering into a chemical reaction

Atomic absorption (AA) spectroscopy: a method used to determine the elemental composition of a sample, where the sample is vaporized and its light absorbance measured

B

Barcad: device that samples water in a well in which water, collected in a discrete water-bearing zone, is forced to the surface by pressurized nitrogen

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

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

Beta particle: a negatively charged particle emitted from the nucleus of an atom, having charge, mass, and other properties of an electron

Biochemical (biological) oxygen demand (BOD): a measure of the amount of dissolved oxygen that microorganisms need to break down organic matter in water, used as an indicator of water quality

Blowdown: water discharged from cooling towers in order to control total dissolved solids concentrations by allowing make-up water to replenish cooling apparatuses

C

California Code of Regulations (CCR): codification of regulations promulgated by the State of California

California Environmental Quality Act of 1970 (CEQA): statute that requires that all California state, local, and regional agencies document, consider, and disclose to the public the environmental implications of their actions

CAP88-PC: computer code required by the EPA for modeling air emissions of radionuclides

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

Chain-of-custody: a method for documenting the history and possession of a sample from the time of its collection, through its analysis and data reporting, to its final disposition

Chemistry and Materials Science Environmental Services (CES): an LLNL laboratory that analyzes environmental samples

Chlorofluorocarbon (CFC): a compound that has fluorine and chlorine atoms on a carbon backbone, such as Freons

Chlorocarbon: a compound of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, and tetrachloroethene

Code of Federal Regulations (CFR): a codification of all regulations promulgated by federal government agencies

Collective dose equivalent and collective effective dose equivalent: the sums of the dose equivalents or effective dose equivalents to all individuals in an exposed population within 80 km (50 miles) of the radiation source. These are evaluated by multiplying the dose received by an individual at each location by the number of individuals receiving that dose, and summing over all such products for locations within 80 km of the source. They are expressed in units of person-rem or person-sievert. The collective EDE is also referred to as the "population dose."

Committed dose equivalent: the predicted total dose equivalent to a tissue or organ over a 50-year period after an intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem (or sievert; 100 rem equals one sievert).

Committed effective dose equivalent: the sum of the committed dose equivalents to various tissues in the body, each multiplied by an appropriate weighting factor representing the relative vulnerability of different parts of the body to radiation. Committed effective dose equivalent is expressed in units of rem or sievert.

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

Congener: any particular member of a class of chemical substances, such as dioxins. A specific congener is denoted by a unique chemical structure, for example 2,3,7,8-TCDD.

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

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

D

Daughter nuclide: a nuclide formed by the radioactive decay of another nuclide, which is called the parent

De minimis: shortened form of "de minimis non curat lex," which means, "The law does not care for, or take notice of, very small or trifling matters," meaning a level that is so inconsequential that it cannot be cause for concern

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

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)

Dewatering: the lowering of the water table due to groundwater extraction during site cleanup. Overdrafting at the Livermore site aquifer occurs when the rate of groundwater extraction exceeds the natural rate of recharge, thus resulting in a net loss of groundwater in the subsurface.

Dose: the 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 commitment: the dose that an organ or tissue would receive during a specified period of time (e.g., 50 or 70 years) as a result of one year's intake of one or more radionuclides

Dose equivalent: the 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 (l rem = 0.01 sievert)

Dosimeter: a portable detection device for measuring the total accumulated exposure to ionizing radiation

Dosimetry: the theory and application of the principles and techniques of measuring and recording radiation doses

Downgradient: in the direction of groundwater flow from a designated area; analogous to downstream

Drainage Retention Basin (DRB): man-made, lined pond used to capture storm water runoff and treated water at the LLNL Livermore site

E

Effective dose equivalent (EDE): an 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: a liquid or gaseous waste discharged to the environment

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 report (EIR): a detailed report prepared pursuant to CEQA on the environmental impacts from any action carried out, approved, or funded by a California state, regional, or local agency

Environmental impact statement (EIS): a 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.

Evapotranspiration: a process by which water is transferred from the soil to the air by plants that take the water up through their roots and release it through their leaves and other aboveground tissue

F

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

Federal Register: a document published daily by the federal government containing notification of government agency actions, including notification of EPA and DOE decisions concerning permit applications and rule-making

Fiscal year: LLNL's fiscal year is from October 1 through September 30.

Flushometer: toilet valve that automatically shuts off after it meters a certain amount of water flow

Freon 11: trichlorofluoromethane

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

G **Gabion:** a galvanized wire box filled with stones used to form retaining walls along a steam or bridge

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

Gram (g): the standard metric measure of weight approximately equal to 0.035 ounce

Granivory: feeding on seeds or grain

Gray (Gy): the SI unit of measure for absorbed dose; the quantity of energy imparted by ionizing radiation to a unit mass of matter, such as tissue. One gray equals 100 rads, or 1 joule per kilogram.

Groundwater: all subsurface water

H **Half-life (radiological):** the time required for one-half the radioactive atoms in a given amount of material to decay; for example, after one half-life, half of the atoms will have decayed; after two half-lives, three-fourths; after three half-lives, seven-eighths; and so on, exponentially

Hazardous waste: hazardous wastes exhibit any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test), but other wastes that do not necessarily exhibit these characteristics have 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.

Herbivory: feeding on nonwoody vegetation

(California) Hazardous Waste Control Act (HWCA): legislation specifying requirements for hazardous waste management in California

High-efficiency particulate air filter (HEPA): a throwaway, extended-media, dry type filter used to capture particulates in an air stream; HEPA collection efficiencies are at least 99.97% for 0.3 micrometer diameter particles

Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX): a high-explosive compound

High explosives (HE): materials that release large amounts of chemical energy when detonated

Hydraulic gradient: in an aquifer, the rate of change of total head (water-level elevation) per unit distance of flow at a given point and in a given direction

Hydrology: the science dealing with the properties, distribution, and circulation of natural water systems

I **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).

In situ: refers to the treatment of contaminated areas in place without excavation or removal, as in the in situ treatment of on-site soils through biodegradation of contaminants

Interim status: a legal classification allowing hazardous waste incinerators or other hazardous waste management facilities to operate while EPA considers their permit applications, provided that they were under construction or in operation by November 19, 1980 and can meet other interim status requirements

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

Interquartile range (IQR): the 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

L **Less than detection limits:** a 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.

Liter (L): the SI measure of capacity approximately equal to 1.057 quart

Livermore Water Reclamation Plant (LWRP): the 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

Lower limit of detection: the smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level

Lysimeter: an instrument for measuring the water percolating through soils and determining the dissolved materials

M **Matrix interference:** sample characteristics that interfere with the test method execution such that reliable data cannot be generated

Maximally exposed individual (MEI): a hypothetical member of the public at a fixed location who, over an entire year, receives the maximum effective dose equivalent (summed over all pathways) from a given source of radionuclide releases to air. Generally, the MEI is different for each source at a site.

Maximum Contaminant Level (MCL): the highest level of a contaminant in drinking water that is allowed by the U.S. Environmental Protection Agency regulation

Multiple completion: a borehole with water surveillance monitoring devices (Barcads) placed at various levels and separated by impermeable layers of material such as grout. Usually referred to as a well, the uppermost "completion" is accessible from the surface, making physical sample-taking possible (as opposed to Barcads).

Metric units: Metric system and U.S. customary units and their respective equivalents are shown in **Table GL-1**. 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.

Mixed waste: waste that has the properties of both hazardous and radioactive waste

N

National Emission Standards for Hazardous Air Pollutants (NESHAPs): standards found in the Clean Air Act that set limits for hazardous air pollutants

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 Institute for Standards and Technology (NIST): the federal agency, formerly known as the National Bureau of Standards, responsible for reference materials against which laboratory materials are calibrated

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

NEWTRIT: model used to calculate tritium doses from environmental measurements

Nonpoint source: any nonconfined area from which pollutants are discharged into a body of water (e.g., agricultural runoff, construction runoff, and parking lot drainage), or into air (e.g., a pile of uranium tailings)

Table GL-1. Metric and U.S. customary unit equivalents

Metric unit	U.S. customary equivalent unit	U.S. customary unit	Metric equivalent unit
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)
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)
Geographic area			
1 hectare	2.47 acres	1 acre	0.40 hectares
Radioactivity			
1 becquerel (Bq)	2.7×10^{-11} curie (Ci)	1 curie (Ci)	3.7×10^{-10} becquerel (Bq)
Radiation dose			
1 gray (Gy)	100 rad	1 rad	0.01 gray (Gy)
Radiation dose equivalent			
1 sievert (Sv)	100 rem	1 rem	0.01 sievert (Sv)
Metric	**Temperature**	**U.S. Customary**	
$^{\circ}C = (^{\circ}F–32)/1.8$		$^{\circ}F = (^{\circ}C \times 1.8) + 32$	

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

Nuclide: a 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.

O **Off-site:** outside the boundaries of the LLNL Livermore site and Site 300 properties

On-site: within the boundaries of the LLNL Livermore site or Site 300 properties

Ophiolite: Any of a group of igneous and metamorphic rocks found within the continental crust, thought to be formed by the uplift of oceanic crust

P **Part B permit:** the 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

Parts per billion (ppb): a unit of measure for the concentration of a substance in its surrounding medium; for example, one billion grams of water containing one gram of salt has a salt concentration of one part per billion

Parts per million (ppm): a unit of measure for the concentration of a substance in its surrounding medium; for example, one million grams of water containing one gram of salt has a salt concentration of one part per million

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

Performance standards (incinerators): specific regulatory requirements established by EPA limiting the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in incinerator emissions

pH: a measure of hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6; basic solutions have a pH greater than 7; and neutral solutions have a pH of 7.

Piezometer: instrument for measuring fluid pressure used to measure the elevation of the water table in a small, nonpumping well

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 microns

Point source: any confined and discrete conveyance (e.g., pipe, ditch, well, or 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

Pretreatment regulations: national wastewater pretreatment regulations, adopted by EPA in compliance with the 1977 amendments to the Clean Water Act, which required that EPA establish pretreatment standards for existing and new industrial sources

Priority pollutants: a set of organic and inorganic chemicals identified by EPA as indicators of environmental contamination

Q

Quality assurance (QA): a 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

Quality factor: the factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses (on a common scale for all ionizing radiation) the biological damage to exposed persons, usually used because some types of radiation, such as alpha particles, are biologically more damaging than others. Quality factors for alpha, beta, and gamma radiation are in the ratio 20:1:1.

Quaternary: the geologic era encompassing the last 2–3 million years

R

Rad: the 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: the 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: the spontaneous emission of nuclear radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope

Radionuclide: an unstable nuclide. See nuclide and radioactivity.

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

Rem: a 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. One rem equals 0.01 sievert.

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

Revetment: a facing (as of stone or concrete) to sustain an embankment

Risk assessment: the use of established methods to measure the risks posed by an activity or exposure by evaluating the relationship between exposure to radioactive substances and the subsequent occurrence of health effects and the likelihood for that exposure to occur

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

S

Sampling and Analysis Plan: a detailed document that describes the procedures used to collect, handle, and analyze groundwater samples, and details quality control measures that are implemented to ensure that sample-collection, analysis, and data-presentation activities meet the prescribed requirements

San Francisco Bay Regional Water Quality Control Board (SFBRWCB): the local agency responsible for regulating stationary air emission sources (including the Livermore site) in the San Francisco Bay Area

San Joaquin County Health District (SJCHD): the local agency that enforces under-ground-tank regulations in San Joaquin County, including Site 300

San Joaquin Valle Air Pollution Control District (SJVAPCD): the 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: a subsurface zone below which all rock pore-space is filled with water; also called the phreatic zone

Secondary MCL: a nonmandatory water quality standard set for 15 contaminants by the EPA to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor

Sensitivity: the capability of methodology or instrumentation to discriminate between samples having differing concentrations or containing varying amounts of analyte

Sewerage: the system of sewers

Sievert (Sv): the 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 Sv equals 100 rem.

Sitewide Maximally Exposed Individual (SW-MEI): a 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: the 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): act enacted in 1986, which amended and reauthorized CERCLA for five years at a total funding level of $8.5 billion

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. Examples of surface impoundments are holding, storage, settling and aeration pits, ponds, and lagoons.

Swale: a low-lying or depressed and often wet stretch of land

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

T

Thermoluminescent dosimeter (TLD): a 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): the portion of solid material in a waste stream that is dissolved and passed through a filter

Total organic carbon (TOC): the sum of the organic material present in a sample

Total organic halides (TOX): the sum of the organic halides present in a sample

Total suspended solids (TSS): the 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: the 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

U

Ultra-zero air: air containing less than 0.1 ppm of total hydrocarbons

Unsaturated zone: that 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): the federal agency responsible for conducting energy research and regulating nuclear materials used for weapons production

U.S. Environmental Protection Agency (EPA): the 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.

V

Vadose zone: the 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

W

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

Wastewater treatment system: a 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 table: the 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: a 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.

Wind rose: a diagram that shows the frequency and intensity of wind from different directions at a specific location

Z

Zone 7: the common name for the Alameda County Flood Control and Water Conservation District