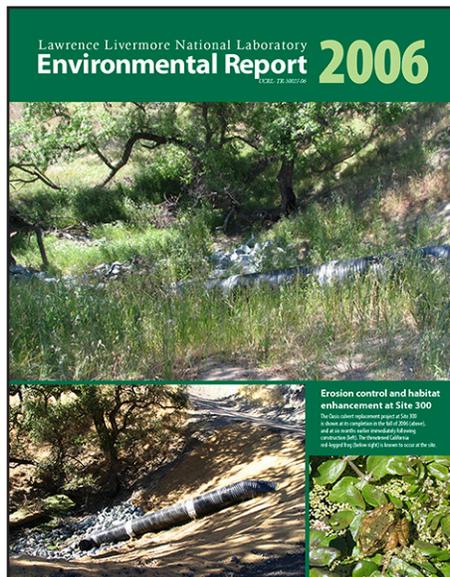




## Erosion control and habitat enhancement at Site 300

The Oasis culvert replacement project at Site 300 is shown at its completion in the fall of 2006 (above), and at six months earlier immediately following construction (left). The threatened California red-legged frog (below right) is known to occur at the site.





## About the cover

The Oasis culvert replacement project at LLNL's Experimental Test Site (Site 300) was undertaken to maintain safe access to remote areas of the site for emergency response personnel. Upland runoff was cutting through the fire trail, and the toe of the embankment where water flowed from an elevated culvert had eroded. Repair of the culvert and fire trail presented an excellent opportunity to improve both safety and environmental quality.

Control of erosion is an important element of LLNL's water quality program. This project reduced erosion and the resultant transport of sediment into surface water drainages, improving both water quality and habitat for wildlife, including the threatened California red-legged frog (*Rana aurora draytonii*), which is known to inhabit the project site.

To accomplish the project, LLNL used environmentally preferable techniques that met the engineering design requirements. The techniques included:

- extending the culvert pipe to the bottom of the slope and providing loose rock to reduce the energy of the water exiting the culvert
- installing woven coconut fiber erosion control blankets to protect the slopes until vegetation grows—woven blankets do not use nets, which can trap amphibians and reptiles
- using a Site 300-specific native seed mix with a blend of a sterile grass; the sterile grass, which does not reproduce, provides quick vegetative coverage to protect slopes in the first year until the slower growing native vegetation is established

LLNL wildlife biologists built a temporary refuge for California red-legged frogs adjacent to the project site, and prior to and during construction, monitored the site and trapped frogs so they would not be harmed by the construction operations. When the project was completed, the frogs were released to recolonize the project area.

The project was completed under permits and authorizations issued by the Central Valley Regional Water Quality Control Board, the U.S. Fish and Wildlife Service, and the Army Corps of Engineers.

## Photo credits

### Cover

*Oasis culvert replacement project at its completion:*  
Sandra Mathews, LLNL Environmental Analyst

*Oasis culvert replacement project six months earlier immediately following construction:*  
Duane Rueppel, LLNL Environmental Analyst

*Juvenile California red-legged frog:*  
Sandra Mathews, LLNL Environmental Analyst

### Chapters

LLNL staff

Chapter 7 photos of fruit trees and jogger,  
© 2004 PhotoSpin, Inc.

### Art

Brett S. Clark

### Technical assistance

Beverly L. Chamberlain

Kathryn O'Connor

For further information about this report contact:

Lynda Seaver, LLNL Public Affairs Department,  
P.O. Box 808, Livermore, CA 94551 / (925) 423-3103

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:

National Technical Information Service  
U.S. Department of Commerce  
5285 Port Royal Road, Springfield, VA 22161

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

Lawrence Livermore National Laboratory  
**Environmental Report 2006**

**Sandra Mathews**

Nicholas A. Bertoldo  
Richard A. Brown  
Chris G. Campbell  
Steven Cerruti  
Cynthia L. Conrado  
Allen Grayson

Henry E. Jones  
John A. Karachewski  
Gene Kumamoto  
Jennifer Larson  
Donald H. MacQueen  
Lisa Paterson

S. Ring Peterson  
Michael A. Revelli  
Duane Rueppel  
Michael J. Taffet  
Kent Wilson  
Jim Woollett

**Editor**

Diana C. Burke





**Department of Energy**  
National Nuclear Security Administration  
Livermore Site Office  
PO Box 808, L-293  
7000 East Avenue  
Livermore, California 94551-0808



SEP 18 2007

5480  
COR-ES-9/13/2007-299

To: Distribution

Subject: 2006 Annual Site Environmental Report for the Lawrence Livermore National Laboratory

The Annual Site Environmental Report (ASER) was prepared by the Lawrence Livermore National Laboratory (LLNL) for the Department of Energy National Nuclear Security Administration (NNSA) Livermore Site Office, and provides a comprehensive summary of the environmental program activities at LLNL for calendar year 2006. 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 Environmental Management System based on International Organization for Standardization 14001 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,

Michael G. Brown  
Assistant Manager for  
Environmental Stewardship



## Preface

The purposes of the *Lawrence Livermore National Laboratory Environmental Report 2006* are to record Lawrence Livermore National Laboratory's (LLNL's) compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring at the two LLNL sites—the Livermore site and Site 300. The report is prepared for the U.S. Department of Energy (DOE) by LLNL's Environmental Protection Department. Submittal of the report satisfies requirements under DOE Order 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, Radiation Protection of the Public and Environment.

The report is distributed in printed form and on compact disc and is also available at <http://www.llnl.gov/saer/>, the website for the LLNL annual environmental report. Previous LLNL annual environmental reports beginning in 1994 are also on the website.

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

The majority of the report covers LLNL's environmental monitoring programs and monitoring data for 2006: effluent and ambient air (Chapter 4); waters, including wastewater, storm water runoff, surface water, rain, and groundwater (Chapter 5); and terrestrial, including soil, sediment, vegetation, foodstuff, ambient radiation, and special status wildlife and plants (Chapter 6). Complete monitoring data, which are summarized in the body of the report, are provided in Appendix B.

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

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

The report is the responsibility of LLNL's 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, Materials and Life Sciences Environmental Services' Environmental Monitoring Radiation Laboratory, and the Hazards Control Department.

Special recognition is given to 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; to the data management personnel—Hildy Kiefer, Kimberley A. Swanson, Beth Schad, Suzanne Chamberlain, Nancy Blankenship, Connie Wells, Lisa Graves, Courtney Cook, Della Burruss, and Susan Lambaren; and to the staff who duplicated and distributed the drafts—Rosanne Depue and Monique de Vasconcelos. Special thanks to Emily Ruby for coordinating the quality assurance reviews of tables and figures, and to Richard Blake and Gretchen Gallegos for their strong support and for reviewing the multiple drafts.

# Table of Contents

<b>Executive Summary</b> .....	<b>EX-1</b>
Purpose and Scope of the Environmental Report .....	EX-2
Regulatory Permitting and Compliance .....	EX-3
Integrated Safety Management System and Environmental Management System .....	EX-3
Pollution Prevention .....	EX-4
Air Monitoring .....	EX-4
Water Monitoring .....	EX-5
Terrestrial Radiological Monitoring .....	EX-6
Biota .....	EX-7
Radiological Dose .....	EX-8
Groundwater Remediation .....	EX-9
Comparison of Tritium Levels in Various Environmental Media .....	EX-9
Conclusion .....	EX-10
<b>Chapter 1. Introduction</b> .....	<b>1-1</b>
1.1 Location .....	1-3
1.1.1 Livermore Site .....	1-3
1.1.2 Site 300 .....	1-3
1.2 Meteorology .....	1-4
1.2.1 Temperature .....	1-5
1.2.2 Wind and Rainfall .....	1-6
1.3 Topography .....	1-8
1.3.1 Livermore Site .....	1-8
1.3.2 Site 300 .....	1-9
1.4 Hydrogeology .....	1-9
1.4.1 Livermore Site .....	1-9
1.4.2 Site 300 .....	1-11
1.5 Conclusion .....	1-12
<b>Chapter 2. Compliance Summary</b> .....	<b>2-1</b>
2.1 Environmental Restoration and Waste Management .....	2-2
2.1.1 Comprehensive Environmental Response, Compensation and Liability Act .....	2-2
2.1.1.1 Livermore Site Ground Water Project .....	2-2
2.1.1.2 Site 300 CERCLA Project .....	2-3
2.1.1.3 Site Evaluations Prior to Construction .....	2-5
2.1.2 Emergency Planning and Community Right-to-Know Act and Toxics Release Inventory Report .....	2-6
2.1.3 Resource Conservation and Recovery Act and Related State Laws .....	2-6
2.1.3.1 Hazardous Waste Permits .....	2-6
2.1.3.2 Hazardous Waste Reports .....	2-12
2.1.3.3 Hazardous Waste Transport Registration .....	2-12
2.1.3.4 Waste Accumulation Areas .....	2-12
2.1.4 California Medical Waste Management Act .....	2-12
2.1.5 Radioactive Waste and Mixed Waste Management .....	2-13

2.1.6	Federal Facility Compliance Act	2-13
2.1.7	Toxic Substances Control Act	2-13
2.2	Air Quality and Protection	2-14
2.2.1	Clean Air Act	2-14
2.2.2	National Emission Standards for Hazardous Air Pollutants, Radionuclides	2-15
2.3	Water Quality and Protection	2-16
2.3.1	Clean Water Act and Related State Programs	2-16
2.3.2	Tank Management	2-16
2.4	Other Environmental Statutes	2-17
2.4.1	National Environmental Policy Act	2-17
2.4.2	National Historic Preservation Act	2-19
2.4.3	Antiquities Act	2-20
2.4.4	Endangered Species Act and Sensitive Natural Resources	2-20
2.4.5	Federal Insecticide, Rodenticide, and Fungicide Act	2-22
2.5	Environmental Occurrences	2-22

**Chapter 3. Environmental Program Information** . . . . . **3-1**

3.1	Environmental Protection Department	3-2
3.1.1	Operations and Regulatory Affairs Division	3-2
3.1.2	Radioactive and Hazardous Waste Management Division	3-3
3.1.3	Environmental Restoration Division	3-4
3.1.4	Response to Spills and Other Environmental Emergencies	3-4
3.2	Integrated Safety Management System	3-5
3.2.1	Work Smart Standards	3-6
3.2.2	Environmental Management System	3-7
3.2.2.1	Overview and General Requirements	3-7
3.2.2.2	Environmental Policy	3-7
3.2.3	Identification of Significant Environmental Aspects and Their Impacts	3-8
3.2.3.1	Identification of LLNL Activities, Products, and Services	3-9
3.2.3.2	Identification of LLNL Environmental Aspects	3-9
3.2.3.3	Determination of Environmental Impacts	3-9
3.2.3.4	Identification of Significant Environmental Aspects	3-10
3.2.4	Identifying and Managing Environmental Objectives and Targets	3-12
3.2.5	Establishing and Maintaining Environmental Management Plans	3-12
3.2.5.1	Directorate EMS Representatives	3-14
3.2.5.2	Senior Management Review	3-14
3.2.5.3	Recommendations for Improvement	3-14
3.2.6	LLNL's Self-Declaration Process	3-15
3.2.7	Path Forward	3-16
3.3	Pollution Prevention Program	3-16
3.3.1	Routine Hazardous and Radioactive Waste	3-17
3.3.2	Diverted Waste	3-17
3.3.2.1	Routine Nonhazardous Waste	3-17
3.3.2.2	Nonroutine Nonhazardous Waste	3-17
3.3.3	Pollution Prevention Activities	3-18
3.3.4	Review of New Processes, Programs, or Experiments	3-19
3.3.5	Pollution Prevention Employee Training and Awareness Programs	3-19

<b>Chapter 4. Air Monitoring Programs</b> .....	<b>4-1</b>
4.1 Air Effluent Monitoring .....	4-2
4.1.1 Methods .....	4-2
4.1.2 Air Effluent Radiological Monitoring Results .....	4-6
4.1.3 Nonradiological Results .....	4-7
4.1.4 Impact of Air Effluent and Nonradiological Releases on the Environment .....	4-8
4.2 Ambient Air Monitoring .....	4-8
4.2.1 Sampling Locations .....	4-9
4.2.2 Sample Collection and Analysis .....	4-9
4.2.3 Results .....	4-11
4.2.3.1 Gross Alpha and Gross Beta Concentrations .....	4-11
4.2.3.2 Gamma-Emitting Radionuclides .....	4-12
4.2.3.3 Plutonium Concentrations .....	4-12
4.2.3.4 Uranium Concentrations .....	4-13
4.2.3.5 Tritium Concentrations .....	4-14
4.2.3.6 Beryllium Concentrations .....	4-15
4.2.4 Environmental Impact of Ambient Air .....	4-16
<b>Chapter 5. Water Monitoring Programs</b> .....	<b>5-1</b>
5.1 Sanitary Sewer Effluent Monitoring .....	5-2
5.1.1 Livermore Site Sanitary Sewer Monitoring Complex .....	5-3
5.1.1.1 Radiological Monitoring Results .....	5-4
5.1.1.2 Nonradiological Monitoring Results .....	5-8
5.1.2 Categorical Processes .....	5-12
5.1.3 Discharges of Treated Groundwater .....	5-15
5.1.4 Environmental Impact of Sanitary Sewer Effluent .....	5-15
5.2 Site 300 Sewage Ponds .....	5-16
5.2.1 Sewage Evaporation and Percolation Ponds .....	5-16
5.2.2 Environmental Impact of Sewage Ponds .....	5-17
5.3 Storm Water Compliance and Surveillance Monitoring .....	5-17
5.3.1 LLNL Site-Specific Storm Water Thresholds .....	5-18
5.3.2 Storm Water Inspections .....	5-19
5.3.3 Livermore Site .....	5-20
5.3.3.1 Radiological Monitoring Results .....	5-21
5.3.3.2 Nonradiological Monitoring Results .....	5-22
5.3.4 Site 300 .....	5-24
5.3.4.1 Radiological Monitoring Results .....	5-24
5.3.4.2 Nonradiological Monitoring Results .....	5-25
5.3.5 Environmental Impact of Storm Water .....	5-27
5.4 Groundwater .....	5-27
5.4.1 Livermore Site and Environs .....	5-28
5.4.1.1 Livermore Valley .....	5-28
5.4.1.2 Livermore Site Perimeter .....	5-30
5.4.1.3 Livermore Site .....	5-32
5.4.2 Site 300 and Environs .....	5-34
5.4.2.1 Elk Ravine Drainage Area .....	5-35

5.4.2.2	Corral Hollow Creek Drainage Area	5-39
5.4.2.3	Off-site Surveillance Wells and Springs	5-43
5.4.3	Environmental Impact on Groundwater	5-44
5.5	Other Monitoring Programs	5-44
5.5.1	Rainwater	5-44
5.5.1.1	Livermore Site and Environs	5-44
5.5.1.2	Site 300 and Environs	5-45
5.5.2	Livermore Valley Surface Waters	5-45
5.5.3	Lake Haussmann Release	5-47
5.5.4	Site 300 Drinking Water System	5-49
5.5.5	Site 300 Cooling Towers	5-50
5.5.6	Percolation Pits	5-52
<b>Chapter 6.</b>	<b>Terrestrial Monitoring</b>	<b>6-1</b>
6.1	Soil and Sediment Monitoring	6-3
6.1.1	Radiological Monitoring Results	6-5
6.1.2	Nonradiological Monitoring Results	6-8
6.1.3	Environmental Impact on Soil and Sediment	6-9
6.1.3.1	Livermore Site	6-9
6.1.3.2	Site 300	6-11
6.2	Vegetation and Foodstuff Monitoring	6-12
6.2.1	Vegetation Monitoring Results	6-12
6.2.2	Wine Monitoring Results	6-14
6.2.3	Environmental Impact on Vegetation and Wine	6-15
6.2.3.1	Vegetation	6-15
6.2.3.2	Wine	6-16
6.3	Ambient Radiation Monitoring	6-16
6.3.1	Methods and Reporting	6-16
6.3.2	Monitoring Results	6-17
6.3.3	Environmental Impact from Laboratory Operations	6-18
6.4	Special Status Wildlife and Plants	6-19
6.4.1	Compliance Activities	6-21
6.4.1.1	Arroyo Seco	6-21
6.4.1.2	Habitat Enhancement Project	6-22
6.4.1.3	Oasis and Round Valley Culvert Replacement Projects	6-22
6.4.1.4	Surface Impoundment Closure and Mitigation Site	6-23
6.4.2	Invasive Species Control Activities	6-23
6.4.2.1	Drainage of Lake Haussmann to Control Bullfrogs	6-24
6.4.2.2	Rotenone Treatment of Lake Haussmann to Control Largemouth Bass	6-24
6.4.2.3	Arroyo Las Positas	6-25
6.4.2.4	Feral Pig Control at Site 300	6-25
6.4.3	Surveillance Monitoring	6-25
6.4.3.1	Wildlife Monitoring and Research	6-25
6.4.3.2	Rare Plant Research and Monitoring	6-27
6.4.4	Environmental Impacts on Special Status Wildlife and Plants	6-29

<b>Chapter 7. Radiological Dose Assessment</b> .....	<b>7-1</b>
7.1 Releases of Radioactivity from LLNL Operations .....	7-2
7.2 Radiation Protection Standards .....	7-2
7.3 Air Dispersion and Dose Models .....	7-3
7.4 Identification of Key Receptors .....	7-4
7.5 Results of 2006 Radiological Dose Assessment .....	7-4
7.5.1 Total Dose to Site-Wide Maximally Exposed Individuals .....	7-5
7.5.2 Doses from Unplanned Releases .....	7-6
7.5.3 Collective Dose .....	7-7
7.5.4 Doses to the Public Placed in Perspective .....	7-8
7.6 Special Topics on Dose Assessment .....	7-9
7.6.1 Compliance Demonstration for Minor Sources .....	7-9
7.6.2 Estimate of Dose to Biota .....	7-10
7.6.3 Modeling Dose from Tritium—Comparison of Approaches .....	7-11
7.7 Environmental Impact .....	7-13
<b>Chapter 8. Groundwater Investigation and Remediation</b> .....	<b>8-1</b>
8.1 Livermore Site Ground Water Project .....	8-2
8.1.1 Physiographic Setting .....	8-2
8.1.2 Hydrogeology of the Livermore Site .....	8-3
8.1.3 Remediation Activities and Monitoring Results .....	8-4
8.1.4 Groundwater Flow and Transport Modeling .....	8-9
8.1.5 Environmental Impacts .....	8-9
8.2 Site 300 CERCLA Project .....	8-10
8.2.1 Physiographic Setting and Geology of Site 300 .....	8-12
8.2.2 Contaminant Hydrogeology of Site 300 .....	8-12
8.2.3 Remediation Activities and Monitoring Results .....	8-14
8.2.4 Ongoing and Planned Investigations and Cleanup Activities .....	8-20
8.2.4.1 Pit 7 Complex .....	8-20
8.2.4.2 Building 865 Study Area .....	8-21
8.2.4.3 Building 812 Study Area .....	8-21
8.2.4.4 Sandia Test Site .....	8-21
8.2.5 Environmental Impacts .....	8-21
<b>Chapter 9. Quality Assurance</b> .....	<b>9-1</b>
9.1 Quality Assurance Activities .....	9-2
9.2 Analytical Laboratories and Laboratory Intercomparison Studies .....	9-4
9.3 Duplicate Analyses .....	9-8
9.4 Data Presentation .....	9-12
9.4.1 Radiological Data .....	9-12
9.4.2 Nonradiological Data .....	9-12
9.5 Statistical Comparisons and Summary Statistics .....	9-12
9.6 Reporting Uncertainty in Data Tables .....	9-13
9.7 Quality Assurance Process for the Environmental Report .....	9-15
9.8 Errata .....	9-16

<b>References</b> .....	<b>R-1</b>
<b>Glossary</b> .....	<b>GL-1</b>
<b>Reader Survey</b> .....	<b>RS-1</b>

**Appendices**

*Appendices are available electronically only (on CD or at <http://www.llnl.gov/saer/>)*

Appendix A. Environmental Management Plan .....	A-1
Appendix B. Data Tables .....	B-1
Appendix C. EPA Methods of Environmental Water Analysis .....	C-1
Appendix D. Constituents of Interest, Sampling Frequency, and Discharge Limits for Releases from Lake Haussmann .....	D-1
Appendix E. Wildlife Survey Results .....	E-1
Appendix F. Extra Resources .....	F-1
Appendix G. Errata .....	G-1

**Figures**

EX-1 Radiological dose to a hypothetical member of the public living at the perimeter of the Livermore site or Site 300 (site-wide maximally exposed individual or SW-MEI) in 2006 compared to common annual radiological doses potentially received by an average individual .....	EX-8
EX-2 Annual median concentrations of tritium in two environmental media at Livermore site locations compared with total annual releases of tritium from Livermore site operations .....	EX-10
1-1 Location of the two LLNL sites—the Livermore site and Site 300 .....	1-2
1-2 Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2006 .....	1-7
1-3 Groundwater elevation contours of hydrostratigraphic unit 2 (HSU-2) .....	1-10
1-4 Approximate groundwater elevations for the principal continuous water-bearing zone at Site 300 .....	1-11
4-1 Air effluent and ambient air monitoring locations at the Livermore site, 2006 .....	4-4
4-2 Air effluent and ambient air monitoring locations at Site 300, 2006 .....	4-4
4-3 Air particulate and tritium sampling locations in the Livermore Valley, 2006 .....	4-5
4-4 Tritium Facility combined HTO and HT emissions for the last 23 years (1984–2006) .....	4-6
4-5 Calculated annual median concentrations of plutonium-239+240 at locations VIS and HOSP for the past 23 years (1984–2006) .....	4-12
4-6 Median concentration of beryllium in air particulate samples taken at the Livermore site perimeter over the last 23 years (1984–2006) .....	4-15
5-1 Livermore site sanitary sewer system, monitoring stations, and diversion facility .....	5-2
5-2 Historical tritium concentrations in the Livermore site sanitary sewer effluent and the average level of sensitivity (LOS) for tritium analysis .....	5-5
5-3 Average monthly plutonium-239 (Pu-239) and cesium-137 (Cs-137) concentrations in LLNL sanitary sewer effluent .....	5-7
5-4 Monthly 24-hour composite sample concentrations for eight of the nine regulated metals in LLNL sanitary sewer effluent showing historical trends .....	5-10
5-5 The results shown in Figure 5-4 are shown here as percentages of effluent pollutant limits for eight of the nine regulated metals in LLNL sanitary sewer effluent, 2006 .....	5-11
5-6 Site 300 sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations, 2006 .....	5-16
5-7 Surface waterways in the vicinity of the Livermore site .....	5-20

## Figures (cont.)

5-8	Storm water runoff and Lake Haussmann sampling locations, Livermore site, 2006	5-21
5-9	Storm water and rainwater sampling locations at Site 300, 2006	5-25
5-10	Off-site tritium monitoring wells in the Livermore Valley, 2006	5-29
5-11	Routine surveillance groundwater monitoring wells at the Livermore site, 2006	5-30
5-12	Surveillance groundwater wells and springs at Site 300, 2006	5-35
5-13	Pit 7 compliance groundwater monitoring wells, Site 300, 2006	5-36
5-14	Pit 1 compliance groundwater monitoring wells, Site 300, 2006	5-38
5-15	Pit 6 compliance groundwater monitoring wells and springs, Site 300, 2006	5-40
5-16	Building 829 closed burn pit compliance groundwater monitoring wells, Site 300, 2006	5-42
5-17	Rain sampling locations, Livermore site and Livermore Valley, 2006	5-45
5-18	Livermore Valley surface and drinking water sampling locations, 2006	5-46
5-19	Cooling tower and receiving water monitoring locations, Site 300, 2006	5-51
6-1	Sampling locations and populations of the California red-legged frog, a threatened species, Livermore site, 2006	6-4
6-2	Soil and vegetation sampling locations and gamma dosimeter locations, Livermore Valley, 2006	6-5
6-3	Sampling locations at Site 300 and off-site, 2006	6-6
6-4	Median plutonium-239+240 activities in surface soils at LWRP, downwind and upwind of the Livermore site (1977–2006), and at Site 300 (1977–1997)	6-9
6-5	Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2006	6-14
6-6	Comparison of the average quarterly dose for the Livermore site, Livermore Valley, and Site 300 monitoring locations from 2002 to 2006	6-18
6-7	Distribution of special status wildlife, Site 300, 2006	6-20
6-8	Distribution of special status plants, Site 300, 2006	6-21
6-9	Number of large-flowered fiddleneck plants in Site 300 experimental and native populations, 1986–2006	6-27
7-1	Location of the site-wide maximally exposed individual (SW-MEI) at the Livermore site and Site 300, 2006	7-5
8-1	Map and cross section of the Livermore site showing hydrostratigraphic units and the location of the treatment facilities	8-3
8-2	Isoconcentration maps showing reductions in total VOCs above MCLs for HSU-2 between 2001 and 2006	8-6
8-3	Estimated total VOC mass removed from groundwater at the Livermore site subsurface since 1989	8-7
8-4	Estimated total VOC mass removed from soil vapor at the Livermore site subsurface since 1995	8-7
8-5	Site 300 environmental restoration operable units, investigation areas, and contaminants of concern	8-10
8-6	Site 300 stratigraphy and hydrologic characteristics	8-13
8-7	Tritium plume in combined Qal and Tnbs <sub>0</sub> HSUs during four time periods	8-18
9-1	Example of data points that demonstrate good agreement between collocated sample results using beryllium concentrations in air	9-11
9-2	Example of data with an outlier using collocated groundwater uranium-238 concentrations	9-11
9-3	Example of variability using sewer gross beta concentrations from collocated samples	9-11

## Tables

1-1	Summary of temperature, rainfall, and wind speed data at the Livermore site and Site 300 during 2006 . . . . .	1-5
2-1	Compliance with Emergency Planning and Community Right-to-Know Act (EPCRA) . . . . .	2-7
2-2	Active permits in 2006 at the Livermore site and Site 300 . . . . .	2-8
2-3	Inspections and tours of Livermore site and Site 300 by external agencies in 2006 . . . . .	2-10
2-4	Environmental Occurrence reported under the Occurrence Reporting System in 2006 . . . . .	2-23
3-1	Pollution prevention in LLNL's Environmental Management System . . . . .	3-8
3-2	LLNL environmental aspects and the significant environmental aspects for calendar year 2006 . . . . .	3-10
3-3	Environmental and business factors used in the evaluation of environmental aspects (ISO 14001:1996 guidelines) . . . . .	3-10
3-4	LLNL environmental aspect significance criteria . . . . .	3-11
3-5	Significant environmental aspects and their objectives . . . . .	3-13
3-6	Routine hazardous and radioactive waste at LLNL, FY 2004–2006 . . . . .	3-17
3-7	Routine nonhazardous waste in FY 2006, Livermore site and Site 300 combined . . . . .	3-18
3-8	Nonroutine nonhazardous waste in FY 2006, Livermore site and Site 300 combined . . . . .	3-18
4-1	Air effluent sampling locations, analytes, sampler types, and number of samplers at the Livermore site and Site 300 in 2006 . . . . .	4-3
4-2	Nonradioactive air emissions, Livermore site and Site 300, 2006 . . . . .	4-7
4-3	Ambient air sampling locations with type and frequency of analysis at the Livermore site and Site 300, 2006 . . . . .	4-10
4-4	Tritium in air samples at on- and off-site locations, 2006 . . . . .	4-14
5-1	Estimated total radioactivity in LLNL sanitary sewer effluent, 2006 . . . . .	5-4
5-2	Monitoring results and discharge limits for tritium in sanitary sewer effluents, LLNL and LWRP, 2006 . . . . .	5-5
5-3	Cesium and plutonium in LLNL and LWRP sanitary sewer effluents, 2006 . . . . .	5-6
5-4	Radioactivity of cesium and plutonium in LWRP sludge, 2006 . . . . .	5-7
5-5	Historical radioactive liquid effluent releases from the Livermore site, 1996–2006 . . . . .	5-8
5-6	Flow-weighted monthly concentrations for regulated metals in LLNL sanitary sewer effluent (mg/L), 2006 . . . . .	5-9
5-7	Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2006 . . . . .	5-13
5-8	Site-specific thresholds for selected water quality parameters for storm water runoff . . . . .	5-19
5-9	Radioactivity in storm water from the Livermore site, 2006 . . . . .	5-21
5-10	Water quality parameters in storm water runoff above LLNL site-specific thresholds, Livermore site in 2006 . . . . .	5-22
5-11	Seven-day chronic toxicity test results for fish (fathead minnow) assay from location WPDC, Livermore site, 1/18/06 and 12/12/06 . . . . .	5-24
5-12	Water quality parameters in storm water runoff above LLNL site-specific thresholds, Site 300, 2006 . . . . .	5-25
5-13	Radioactivity in surface and drinking waters in the Livermore Valley, 2006 . . . . .	5-47
5-14	Summary data from monitoring of primary cooling tower 801, Site, 300, 2006 . . . . .	5-52
6-1	Plutonium activity concentrations in Livermore Valley soil, 2006 . . . . .	6-7
6-2	Plutonium and americium activity concentrations in LWRP soil, 2006 . . . . .	6-8
6-3	Plutonium and tritium activity concentrations in surface sediment at four locations on the Livermore site, 2006 . . . . .	6-8
6-4	Uranium and beryllium concentrations in Site 300 soil, 2006 . . . . .	6-10

**Tables (cont.)**

6-5 Selected studies of radionuclides in local soils, 1971 to 2003 . . . . . 6-11

6-6 Quarterly concentrations of tritium in plant water for the Livermore site, Livermore Valley, and Site 300, and mean annual ingestion doses, 2006 . . . . . 6-13

6-7 Tritium in retail wine, 2006 . . . . . 6-15

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 2006 . . . . . 7-6

7-2 Doses calculated for SW-MEI for the Livermore site and Site 300, 1990 to 2006 . . . . . 7-7

7-3 Collective dose broken down by level of individual doses, 2006 . . . . . 7-8

7-4 Comparison of radiation doses from LLNL sources to average doses from background (natural and man-made) radiation, 2006 . . . . . 7-9

7-5 Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2006 . . . . . 7-10

7-6 Bulk transfer factors used to calculate inhalation and ingestion doses from measured concentrations in air, vegetation, and drinking water . . . . . 7-12

7-7 Comparison of hypothetical doses at the Livermore site VIS air tritium and vegetation monitoring location calculated from predicted and observed concentrations of HTO in air in 2006 . . . . . 7-13

8-1 VOCs removed from groundwater and soil at the Livermore site . . . . . 8-5

8-2 Major contaminants of concern found in soil, rock, and groundwater at Site 300 . . . . . 8-11

8-3 Calendar year 2006 deliverable and milestone dates for Site 300 environmental restoration activities outlined in the FFA and other agreements . . . . . 8-11

8-4 Volumes of groundwater and soil vapor extracted and masses of volatile organic compounds removed at Site 300 CERCLA Operable Units . . . . . 8-15

9-1 Sampling completeness in 2006 for the Livermore site and Site 300 . . . . . 9-3

9-2 EMRL performance in the MAPEP Intercomparison Program Studies for 2006 . . . . . 9-5

9-3 HCAL performance in the MAPEP Intercomparison Program Studies for 2006. . . . . 9-7

9-4 HCAL performance in the ERA Intercomparison Program Studies for 2006 . . . . . 9-7

9-5 Quality assurance collocated sampling: Summary statistics for analytes with more than eight pairs in which both results were above the detection limit . . . . . 9-9

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 . . . . . 9-10

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 . . . . . 9-10



## **Purpose and scope of the Environmental Report**

## **Regulatory permitting and compliance**

## **Integrated Safety Management System and Environmental Management System**

## **Pollution prevention**

## **Air monitoring**

## **Water monitoring**

## **Terrestrial radiological monitoring**

## **Biota**

## **Radiological dose**

## **Groundwater remediation**

## **Comparison of tritium levels in various environmental media**

## **Conclusion**



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

LLNL has been managed since its inception in 1952 by the University of California for the U.S. government. In May 2007, DOE selected Lawrence Livermore National Security, LLC (LLNS), to manage the Laboratory. The seven-year management contract term begins on October 1, 2007.

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

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. LLNL's radiological control program ensures that radiological exposures and releases are reduced to as low as reasonably achievable to protect the health and safety of its employees, contractors, the public, and the environment.

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

LLNL consists of two sites—an urban site in Livermore, California, referred to as the “Livermore site,” which occupies 3.3 square kilometers (1.3 square miles); and a rural Experimental Test Site, referred to as “Site 300,” near Tracy, California, which occupies 28.3 square kilometers (10.9 square miles). The Laboratory has a staff of more than 8000.

---

## **Purpose and Scope of the Environmental Report**

The purposes of the *Environmental Report 2006* are to record LLNL's compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring. Specifically, the report discusses LLNL's Environmental Management System; describes significant accomplishments in pollution prevention; presents the results of air, water, vegetation, and foodstuff monitoring; reports radiological doses from LLNL operations; summarizes LLNL's activities involving special status wildlife, plants, and habitats; and describes the progress LLNL has made in remediating groundwater contamination.

Environmental monitoring at LLNL, including analysis of samples and data, is conducted according to LLNL's Environmental Protection Department Quality Assurance Management Plan, which is based on U.S. Department of Energy (DOE) Order 414.1C, Quality Assurance.

This report is prepared for DOE by LLNL's Environmental Protection Department. Submittal of the report satisfies requirements under DOE Order 231.1A, Environmental Safety and Health Reporting, and DOE Order 5400.5, Radiation Protection of the Public and Environment. The report is distributed in printed form and on compact disc and is also available to the public at <http://www.llnl.gov/saer/>, the website for the LLNL annual environmental report. Previous LLNL annual environmental reports beginning in 1994 are also on the website.

---

## **Regulatory Permitting and Compliance**

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

---

## **Integrated Safety Management System and Environmental Management System**

In 1998, LLNL began the implementation of an Integrated Safety Management System (ISMS), which is designed to ensure the systematic integration of ES&H considerations into management and work practices so that missions are accomplished safely. Work Smart Standards (WSSs), based on applicable laws, regulations, and DOE orders, establish workplace ES&H controls and are an integral part of LLNL's ISMS. "Safety" in this context is synonymous with environment, safety, and health and encompasses protection of the public, workers, and the environment, including pollution prevention and waste minimization. LLNL regards protection of the environment as an essential component of its overall safety management system.

LLNL established its Environmental Management System (EMS) to meet the requirements of the International Organization for Standardization (ISO) 14001:1996, which was adopted by LLNL as a WSS in June 2004. Following internal audits, LLNL self-declared its conformance with ISO 14001:1996 in December 2005. The Livermore Site Office (LSO) of the NNSA subsequently validated LLNL's conformance with the condition that LLNL complete a corrective action plan (CAP), which was accomplished in 2006. The EMS

commits LLNL as an institution and all employees to responsible stewardship of all the environmental resources in their care.

In 2006, LLNL enhanced the environmental emphasis of its ISMS further by upgrading from ISO 14001:1996 to the ISO 14001:2004 EMS. Progress in 2006 includes the completion of various studies, implementation of exotic species control, and progress toward waste reduction targets for nine significant environmental aspects (environmental aspects are elements of an organization's activities, products or services that can interact with the environment). The significant environmental aspects are ecological resource disturbance, electrical energy use, fossil fuel consumption and renewable energy use, hazardous material use, mixed waste generation, municipal waste generation, nonhazardous materials use, radioactive materials use, and transuranic waste generation.

---

## **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, waste generation reporting, and coordination of institutional P2 programs and activities.

In December 2006, NNSA/Headquarters selected two LLNL projects to receive NNSA Best-in-Class awards. The first award was for initiatives at Site 300 that resulted in saving 9.7 million gallons of water per year through recycling, environmental conservation, and improved operations efficiency. The initiatives also saved 68,000 kilowatt hours in electric pumping. The second award was for a project at the Livermore site, but due to its subject matter, it was categorized as Official Use Only and the details are not discussed in this report.

LLNL also conducted activities to promote employee awareness of P2, including the annual Earth Expo held in April to coincide with Earth Day, articles in the LLNL newspaper, and training for procurement staff.

---

## **Air Monitoring**

LLNL operations involving radioactive materials had minimal impact on ambient air during 2006. Estimated nonradioactive emissions are small compared to local air district emission criteria.

Releases of radioactivity to the environment from LLNL operations occur through stacks and from diffuse area sources. In 2006, radioactivity released to the atmosphere was monitored at 69 air effluent sampling locations at six facilities on the Livermore site and one at Site 300. In 2006, 0.67 terabecquerels (TBq) (18 curies [Ci]) of tritium was released from the Tritium Facility, and  $1.0 \times 10^{-4}$  TBq of tritium (2.8 mCi) was released from the

Decontamination and Waste Treatment Facility. None of the facilities monitored for gross alpha and gross beta radioactivity had emissions in 2006.

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 2006 for the Livermore site were about 10% lower than those in 2005; estimated releases at Site 300 were higher in 2006 than in 2005 due primarily to the operation of emergency generators during unplanned power outages. In 2006, LLNL eliminated two operations that had an annual potential to emit more than 2200 pounds of volatile organic compounds (VOCs). Nonradiological releases from LLNL continue to be a very small fraction of releases from all sources in the Bay Area or San Joaquin County.

In addition to air effluent monitoring, LLNL samples ambient air for tritium, radioactive particles, and beryllium. Some samplers are situated specifically to monitor areas of known contamination; some monitor potential exposure to the public; and others, distant from the two LLNL sites, monitor the natural background. In 2006, ambient air monitoring data confirmed estimated releases from monitored stacks and were used to determine source terms for resuspended plutonium-contaminated soil and tritium diffusing from area sources at the Livermore site and resuspended uranium-contaminated soil at Site 300. In 2006, radionuclide particulate, tritium, and beryllium concentrations in air at the Livermore site and in the Livermore Valley were well below the levels that would cause concern for the environment or public health.

---

## Water Monitoring

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

Permits, including one for discharging treated groundwater from the Livermore site Ground Water Project, regulate discharges to the City of Livermore sanitary sewer system. During 2006, no discharges to the sanitary sewer exceeded any effluent limits for radioactive materials, and all the values were a fraction of the allowed limits. For nonradioactive materials, there was one excursion outside the permissible pH range (see *LLNL Environmental Report 2006*, **Section 5.1.1.2**); all other constituents were below allowed limits. All discharges to the Site 300 sewage evaporation and percolation ponds were within permitted limits, and groundwater monitoring showed no measurable impacts.

Storm water is sampled for constituents such as radioactivity, metals, oxygen, dioxins, polychlorinated biphenyls (PCBs), and nitrate both upstream and downstream from both the

Livermore site and Site 300. In 2006, no acute or chronic toxicity was seen in runoff, and data showed that the quality of Livermore site storm water effluent was similar to that entering the site (influent). At Site 300 in 2006, data continued to show that most constituents are transported sorbed to suspended sediments and that concentrations remained below levels of environmental concern.

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 off-site contamination quickly, the well water is sampled in the uppermost water-bearing layers. As in other years, all constituents in groundwater away from the Livermore site were below allowable limits for drinking water. Near Site 300, monitored constituents in off-site groundwater include explosives residue, nitrate, perchlorate, metals, volatile and semivolatile organic compounds, tritium, uranium, and other (gross alpha and beta) radioactivity; all constituents in off-site wells near Site 300 were below allowable limits for drinking water.

Rainwater is analyzed for tritium. In 2006, the maximum concentration of tritium in rain collected on the Livermore site was 1.7% of the drinking water standard, and no off-site concentrations were above the lower limit of detection (0.5% of the drinking water standard). At Site 300, tritium concentrations in all rain samples were below detection limits.

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

---

## Terrestrial Radiological Monitoring

The impact of LLNL operations on surface soil, sediment, and vadose zone soils in 2006 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 other sampled locations, but even this concentration was only 1.3% 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 2006, uranium-238 concentrations in soils

at Site 300 were below NCRP-recommended screening levels. Beryllium concentrations were representative of background levels.

Vegetation and Livermore Valley wine were sampled for tritium. In 2006, the median concentrations in all off-site vegetation samples were below the lower limit of detection of the analytical method. The highest concentration of tritium in Livermore Valley wines was 0.68% of the drinking water standard.

LLNL's extensive network of thermoluminescent dosimeters measures the natural terrestrial and cosmogenic background; in 2006, as in recent years, no impact from LLNL operations was detected.

---

## Biota

Through monitoring and compliance activities in 2006, LLNL avoided most impacts to special status species and enhanced some habitats. LLNL studies, preserves, and tries to improve the habitat of five species at Site 300 that are covered by the federal or California Endangered Species Acts—California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana aurora draytonii*), Alameda whipsnake (*Masticophis lateralis euryxanthus*), valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), and the large-flowered fiddleneck (*Amsinckia grandiflora*)—as well as species that are rare and otherwise of special interest. At Site 300, LLNL monitors populations of birds and rare species of plants and also continues restoration activities for the four rare plant species known to occur at Site 300—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*, also known as *Blepharizonia plumosa* subsp *plumosa*), the diamond-petaled poppy (*Eschscholzia rhombipetala*), and the round-leaved filaree (*Erodium macrophyllum*).

In February and March of 2006, LLNL translocated California red-legged frogs to two new pools in Elk Ravine that were created in 2005 to replace wetlands maintained artificially by discharge from several buildings. In 2006, LLNL completed culvert replacement projects at Round Valley and Oasis to maintain the safety of fire trails at Site 300, resulting in the creation of a 0.089-hectare (0.22-acre) habitat pool at the Round Valley site to mitigate in part for impacts at the Oasis site.

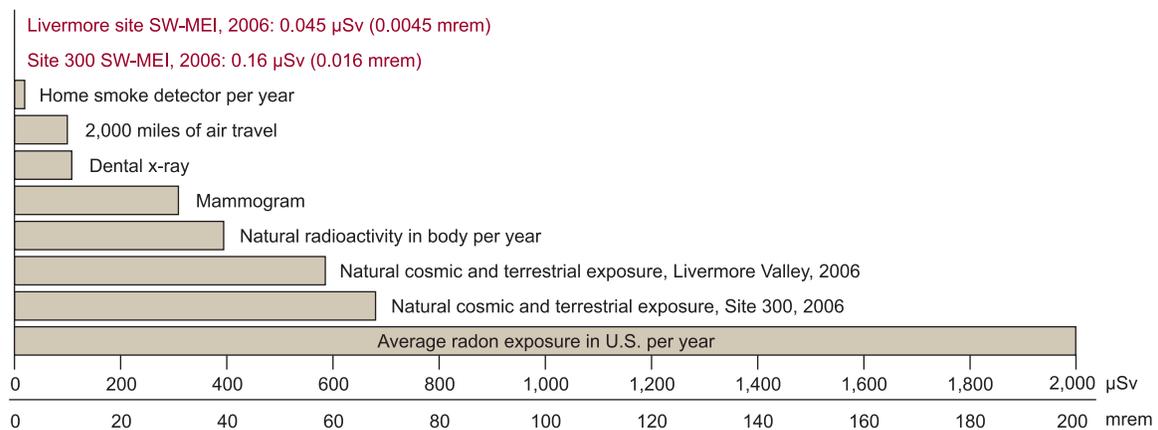
LLNL took several actions to control invasive species in 2006. Most significantly, LLNL collaborated with the California Department of Fish and Game to apply the fish pesticide rotenone to Lake Haussmann to remove largemouth bass (*Micropterus salmoides*). Water quality and sediment monitoring following the rotenone application confirmed no long-term water quality impacts. Observations following the application confirmed that invasive, nonnative fish species were successfully removed from Lake Haussmann. Site 300's invasive species control efforts have been focused largely on dispatching feral pigs. In December 2006, five adult pigs (four females, one male) were discovered and dispatched.

The 2006 radiological doses calculated for biota at the Livermore site or 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

Annual radiological doses at the Livermore site and Site 300 in 2006 were found to be well below the applicable standards for radiation protection of the public. Dose calculated to the site-wide maximally exposed individual (SW-MEI) for 2006 was 0.045 microsieverts ( $\mu\text{Sv}$ ) (0.0045 millirem [mrem]) for the Livermore site and 0.16  $\mu\text{Sv}$  (0.016 mrem) at Site 300. Four sources of tritium at LLNL contributed nearly 100% of the dose received by the SW-MEI. The dose for 2006 was about 70% of the 2005 dose for the Livermore site. The dose to the SW-MEI at Site 300 was about 89% of the 2005 dose. There was one unplanned incident at the Livermore site that had the potential to release tritium, but given that there was no dose to employees handling the material, any potential dose to the public was negligible (see *LLNL Environmental Report 2006*, **Section 7.5.2**). There were no unplanned releases to the atmosphere from Site 300. Other than the potential release noted, there were no unplanned releases to the atmosphere at the Livermore site.

In **Figure EX-1**, calculated radiological doses to the SW-MEI from operations at each site in 2006 are compared with doses potentially received from the environment and from common activities (e.g., dental x-rays). As can be seen, the contribution of LLNL operations to unavoidable dose in 2006 was inconsequential.



**Figure EX-1.** Radiological dose to a hypothetical member of the public living at the perimeter of the Livermore site or Site 300 (site-wide maximally exposed individual or SW-MEI) in 2006 compared to common annual radiological doses potentially received by an average individual.

---

## Groundwater Remediation

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

At the Livermore site, contaminants include volatile organic compounds (VOCs), fuel hydrocarbons, metals, and tritium, but only the VOCs in groundwater and saturated and unsaturated soils need remediation. VOCs are the main contaminant found at the 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.

In 2006, concentrations continued to decrease in most of the Livermore site VOC plumes due to active remediation and the removal of more than 255 kilograms (kg) of VOCs from both groundwater and soil vapor. VOC concentrations on the western margin of the site continued their decline, indicating effective hydraulic control of the boundary plumes. In the interior of the site, remediation activities, including soil vapor extraction, dual extraction, and groundwater extraction, have resulted in declines of VOC concentrations in source areas. In 2006, all of the “build out” milestones were completed, and the project was transferred from DOE’s Office of Environmental Management to the NNSA.

In 2006 at Site 300, perchlorate, nitrate, the high explosive RDX, and organosilicate oil were removed from groundwater in addition to about 50 kg of VOCs. Each Site 300 OU has a different profile of contaminants, but overall, groundwater and soil vapor extraction and natural attenuation continue to reduce the mass of contaminants in the subsurface. An additional four areas at Site 300 are under investigation; a final CERCLA remedy to address environmental contamination has not been reached.

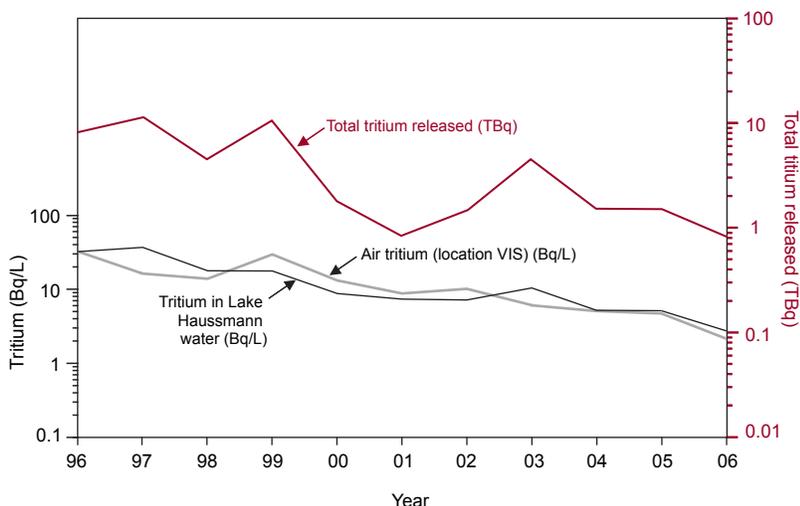
---

## Comparison of Tritium Levels in Various Environmental Media

In **Figure EX-2**, annual median concentrations of tritium in air moisture at sampling location VIS (on the eastern boundary of the Livermore site) and in Lake Haussmann water over the last eleven years are compared with total tritium releases to the atmosphere from Livermore site operations. Concentrations of tritium in air moisture at location VIS and water from Lake Haussmann in 2006 were less than 0.4% of the drinking water standard.

Generally, the correlation between concentrations in environmental media and annual releases of tritium to the atmosphere from LLNL site operations 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 an area source, the fraction of time the wind blew toward

**Figure EX-2.** Annual median concentrations of tritium in two environmental media at Livermore site locations compared with total annual releases of tritium from Livermore site operations.



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 Lake Haussmann.

## Conclusion

The combination of surveillance and effluent monitoring, source characterization, and dose assessment showed that the radiological dose to the hypothetical, most-exposed member of the public caused by LLNL operations in 2006 was more than 15,000 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 showed minimal contributions from LLNL operations. Remediation efforts at both the Livermore site and Site 300 further reduced concentrations of contaminants of concern in groundwater and soil vapor.

## 1.1 Location

- 1.1.1 Livermore site
- 1.1.2 Site 300

## 1.2 Meteorology

- 1.2.1 Temperature
- 1.2.2 Wind and rainfall

## 1.3 Topography

- 1.3.1 Livermore site
- 1.3.2 Site 300

## 1.4 Hydrogeology

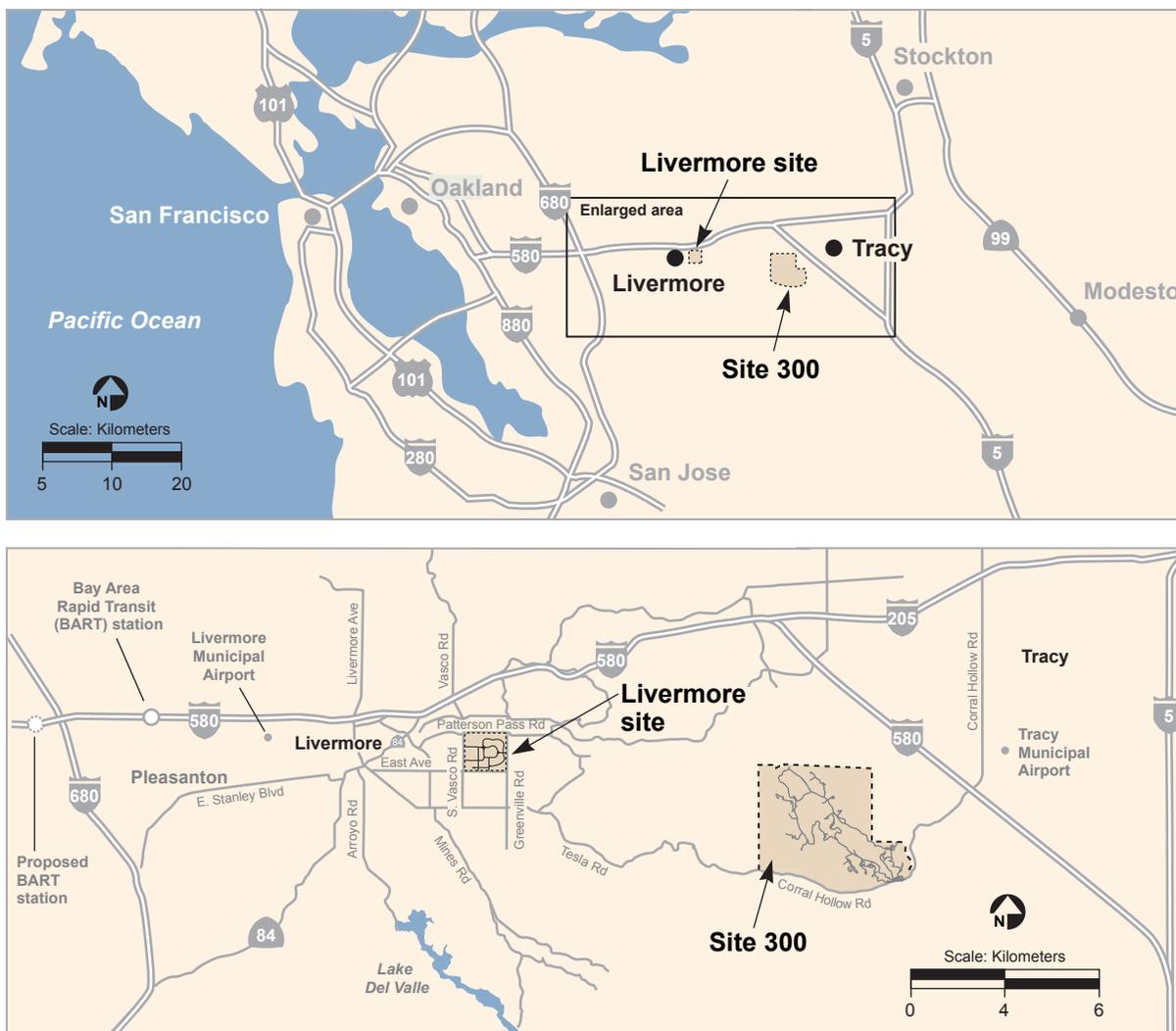
- 1.4.1 Livermore site
- 1.4.2 Site 300

## 1.5 Conclusion



Lawrence Livermore National Laboratory is a premier applied science laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). LLNL has been managed since its inception in 1952 by the University of California for the U.S. government. In May 2007, DOE selected Lawrence Livermore National Security, LLC (LLNS), to manage the Laboratory. The seven-year management contract term, which begins on October 1, 2007, may be extended for up to an additional 13 years for successful performance.

As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth,



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

environmental, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory serves as a scientific resource to the U.S. government and a partner to industry and academia. The Laboratory has a staff of more than 8000.

LLNL operations release a variety of contaminants into the environment via atmospheric, surface water, and groundwater pathways. Some of the contaminants, such as particles from diesel engines, are common at many types of facilities while others, such as radionuclides, are unique to facilities like LLNL. All releases are carefully monitored and regulated. Local meteorology, topography, and hydrogeology affect the dispersion of the contaminants. Health impacts of the dispersed contaminants, if any, are dependent on where people and biota are situated with respect to LLNL.

---

## 1.1 Location

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

### 1.1.1 Livermore Site

The Livermore site is just east of Livermore, a city of about 80,000 in Alameda County. The site occupies 3.3 square kilometers (km<sup>2</sup>) (1.3 square miles [mi<sup>2</sup>]), including the land that serves as a buffer zone around most of the site. The areas surrounding the Livermore site are:

- south—Sandia National Laboratories/California (Sandia/California), operated by Lockheed-Martin for DOE, adjacent to the Livermore site; south of Sandia/California—mostly low-density residential areas and agricultural land devoted to grazing, orchards, and vineyards; farther south—open space and ranchettes with some agricultural use
- southwest—small business park
- west—residential developments, including houses and apartments
- north—extensive business park
- northeast—200-hectare (ha) (500-acre [ac]) parcel of open space, rezoned for light industry
- east—small amount of very low-density residential development; agricultural land extending to the Altamont Hills, which define the eastern margin of the Livermore Valley

Within an 80-km (50-mi) radius of the Livermore site are communities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 7.1 million people within 80 km (50-mi) of the Laboratory, only about 10% are within 32 km (20 mi).

### 1.1.2 Site 300

Site 300, LLNL’s Experimental Test Site, was established in 1955. It is located in the Altamont Hills of the Diablo Range and straddles the San Joaquin and Alameda county line. The site is 20 km (12 mi) east of the Livermore site and occupies 28.3 km<sup>2</sup> (10.9 mi<sup>2</sup>). The areas surrounding Site 300 are:

- south—agricultural land; a testing site operated by SRI International, approximately 1 km (0.62 mi) south
- southwest—Carnegie State Vehicular Recreation Area for off-road vehicles, open to the public
- northwest—agricultural land; wind turbine generators on the hills

- east—property owned by Fireworks America, which uses it storing fireworks components; property leased by Teledyne/RISI from Fireworks America, where detonation initiators are manufactured
- northeast—land proposed for residential development
- southeast—Corral Hollow Ecological Reserve, 40 ha (99 ac) of riparian woodland and annual grassland, and a protected refuge area for wildlife; formerly southeastern corner of Site 300, transferred to the California Department of Fish and Game in 1974 because of its unique assemblage of rare amphibian and reptile species

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 approximately 10 km (6 mi) to the northeast (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 6.2 million people who live within 80 km (50 mi) of Site 300, 95% are more than 32 km (20 mi) away in distant metropolitan areas such as Oakland, San Jose, and Stockton.

---

## 1.2 Meteorology

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

A new 52-meter (m) (170-foot [ft]) meteorological tower, identical to the tower at the Livermore site, was installed at Site 300 in September 2006, and instrumentation of the tower began in late December. The new tower, which will eventually replace an 8-m (26-ft) tower in use since 1979, has three measurement levels as compared to the older tower's one level. The multiple levels allow redundant measurements, improved data quality control, and better characterization of wind direction and speed, turbulence, and temperature through a deeper layer above the ground. The instruments can be lowered and raised by an electric elevator, which allows for safer and faster maintenance. Current plans are for both towers to provide simultaneous measurements through 2007, after which the older tower will be taken down. Measurements from the two towers will be compared for differences.

Temperature, rainfall, and wind speed data for the Livermore site and Site 300 during 2006 are summarized in **Table 1-1**. More detailed information is provided below.

### 1.2.1 Temperature

Daily temperature measurements have been analyzed at the Livermore site since 1990 and at Site 300 since 1992. The mean daily maximum, minimum, and average temperatures for the two sites during 2006 are listed in **Table 1-1**.

Nighttime temperatures at Site 300 are typically higher (and the diurnal temperature range smaller) than at the Livermore site; stronger winds at Site 300's higher elevation prevent formation of strong nighttime inversions near the ground. At the Livermore site, temperatures typically range from  $-4$  degrees centigrade ( $^{\circ}\text{C}$ ) (25 degrees Fahrenheit [ $^{\circ}\text{F}$ ]) during the coldest winter mornings to  $40$   $^{\circ}\text{C}$  ( $104$   $^{\circ}\text{F}$ ) during the warmest summer afternoons. At Site 300, the typical temperature range is somewhat smaller, ranging from  $-1$   $^{\circ}\text{C}$  ( $30$   $^{\circ}\text{F}$ ) during the coldest winter mornings to  $39$   $^{\circ}\text{C}$  ( $102$   $^{\circ}\text{F}$ ) during the warmest afternoons.

While the mean annual temperature was near normal during 2006, several individual months experienced large departures from normal. The combination of frequent rain and several very cold nights caused March to be the coldest at the Livermore site since at least 1989 and at Site 300 since at least 1991. Overnight lows dipped to freezing or below on three mornings at the Livermore site during March.

A strong high-pressure system developed over the western U.S. in mid-June and persisted through August, causing record heat through much of the period. During the second half of June, the high temperature reached at least  $32.2$   $^{\circ}\text{C}$  ( $90$   $^{\circ}\text{F}$ ) on 11 days at the Livermore site and on 12 days at Site 300. The high temperatures reached  $39.6$  and  $39.8$   $^{\circ}\text{C}$  ( $103$  and  $104$   $^{\circ}\text{F}$ ) at the Livermore site on June 22 and 23, respectively. The high temperature of  $38.7$   $^{\circ}\text{C}$  ( $102$   $^{\circ}\text{F}$ ) on June 23 was the highest ever recorded at Site 300 during June since at least 1990. The

average temperature of  $33.8$   $^{\circ}\text{C}$  ( $93$   $^{\circ}\text{F}$ ) on this date was also the highest daily average ever recorded at Site 300.

The upper high pressure ridge in the western U.S. intensified further and at times extended to the East Coast, causing widespread record heat. The heat wave became extreme from July 21 through July 25 as a layer of hot and moist air originating in the southwestern U.S. deserts warmed further as it dried out while moving over the California Sierra. The high temperature reached at least  $42.2$   $^{\circ}\text{C}$  ( $108$   $^{\circ}\text{F}$ ) at the Livermore site and  $40$   $^{\circ}\text{C}$  ( $104$   $^{\circ}\text{F}$ ) at Site 300 on each of these five days, with the highest temperature reaching  $44.2$   $^{\circ}\text{C}$  ( $112$   $^{\circ}\text{F}$ ) at the Livermore site on July 23

**Table 1-1.** Summary of temperature, rainfall, and wind speed data at the Livermore site and Site 300 during 2006.

Temperature	Livermore Site		Site 300	
	$^{\circ}\text{C}$	$^{\circ}\text{F}$	$^{\circ}\text{C}$	$^{\circ}\text{F}$
Mean daily maximum	22.1	71.8	21.2	70.2
Mean daily minimum	7.5	45.6	12.5	54.6
Average	14.8	58.7	16.9	62.4
High	44.2 <sup>(a)</sup>	112 <sup>(a)</sup>	42.6 <sup>(a)</sup>	109 <sup>(a)</sup>
Low	$-4.0$	25	$-0.2$	32
Rainfall	cm	in.	cm	in.
Total for 2006	38.7	15.24	32.2	12.68
Normal <sup>(b)</sup>	34.6	13.62	27.0	10.64
Wind	m/s	mph	m/s	mph
Average speed	2.3	5.1	5.4	12.1

(a) Record high.

(b) Based on the mean, 1971–2000, at both sites.

and 42.6 °C (109 °F) at Site 300 on July 25. All of the high temperatures on these five days were the highest ever recorded at Site 300 in any month since record keeping began in 1992. The previous record highs for Site 300 were 40.0 °C (104 °F) on August 4, 1998, and July 17, 2005. The previous record high temperature at the Livermore site for July was 41.0 °C (106 °F) on July 2, 1991, and the previous record high for any month was 41.7 °C (107 °F) on August 4, 1998. Both sites also set new records for the highest daily average temperature (average of high and low daily temperature): 34.8 °C (95 °F) on July 23 at the Livermore site (previous record: 32.1 °C [90 °F] on July 12, 1999), and 36.7 °C (98 °F) on four consecutive days ending on July 25 at Site 300 (previous record: 35.9 °C [97 °F] on August 4, 1998). Finally, it was the warmest July and the warmest month on record for the Livermore site since at least 1989 and Site 300 since at least 1991.

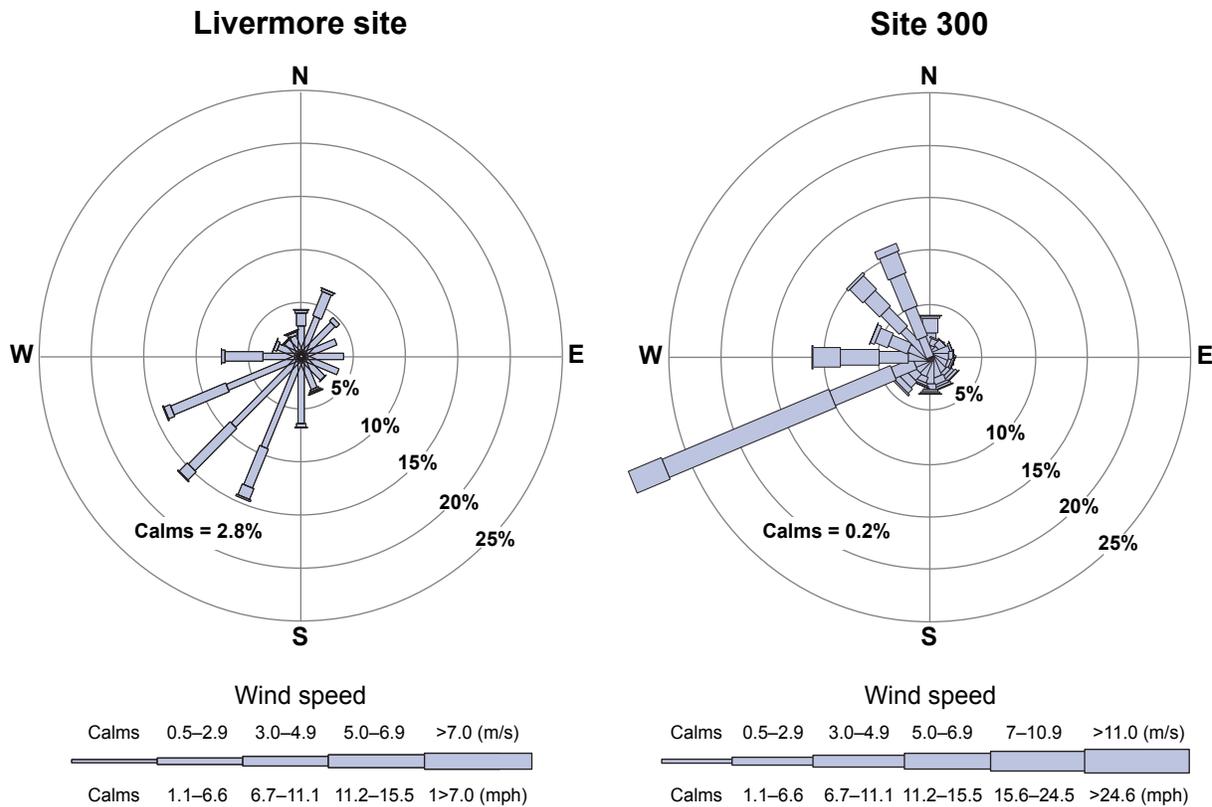
Typical sea breezes returned in August and provided welcome relief from the intense heat. Even with near-normal temperatures in August, the record heat in June and July made the summer (June through August) the warmest at the Livermore site since at least 1989. While Site 300 had many above-normal temperatures during the summer, it did not set a record although the average daily maximum temperature at Site 300 became the highest recorded since at least 1991, exceeding the previous high set in the previous summer (2005).

September had typical mild weather although the low temperature dipped to a chilly 5.8 °C (43 °F) at the Livermore site on the morning of September 16. This was the lowest recorded temperature in the month of September at the Livermore site since at least 1989. Several early-season polar air masses caused October to be much colder than normal. The low temperatures reached 4.1 °C (39 °F) on four of the last five mornings of the month. The last two months of the year had near-normal average temperatures although several days in December had record warmth or cold. The high temperature reached 20.5 °C (69 °F) at both the Livermore site and Site 300 on December 8. It was the highest temperature recorded at the Livermore site in December since at least 1989. A blast of polar air during the third week of December prevented daily high temperatures to exceed 10 °C (50 °F) at the Livermore site on three days. Overnight temperatures at the Livermore site dipped to below freezing on five consecutive days, including -4 °C (25 °F) on December 19.

The highest temperature recorded at the Livermore site during 2006 was 44.2 °C (112 °F) on July 23; the peak temperature at Site 300 of 42.6 °C (109 °F) occurred on July 25. The lowest temperatures during the year were -4.0 °C (25 °F) at the Livermore site on February 16 and December 19 and -0.2 °C (32 °F) at Site 300 on March 11.

### **1.2.2 Wind and Rainfall**

Both wind and rainfall exhibit strong seasonal patterns. Wind patterns at both sites tend to be dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley during the warm season, increasing in intensity as the valley heats up. During the winter, the wind blows from the northeast more frequently as cold, dense air spills out of the San Joaquin Valley. Approximately 55% of the seasonal



**Figure 1-2.** Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2006. 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 2006 at the Livermore site was 2.3 m/s (5.1 mph); at Site 300 it was 5.4 m/s (12.1 mph).

rain at both sites falls in January, February, and March and approximately 80% falls in the five months from November through March, with very little rain falling during the warmer months.

Annual wind data for the Livermore site are shown in **Figure 1-2**. These data show that winds blow from the south–southwest through west–southwest about 45% of the time and more frequently during the summer. During the winter, winds from the northeast are more common. The peak wind gusts at the Livermore site of 19.6 meters per second (m/s) (44 miles per hour [mph]) occurred on January 1 (from the south) and on February 27 (from the south–southwest) and were associated with storms.

Based on a 49-year record, the highest and lowest annual rainfalls were 85.2 and 16.7 centimeters (cm) (33.57 and 6.57 inches [in.]). Normal annual rainfall, which is based on the mean for 1971–2000, is 34.6 cm (13.62 in.). In 2006, the Livermore site received 38.7 cm (15.24 in.) of rain, or 112% of normal. A long series of storms caused heavy and frequent rain in March and April, with monthly rainfall equaling approximately 185% and 370% of their respective normals. Measurable rainfall occurred on 23 and 13 days in March and April,

respectively. March was the rainiest month of the year with 10.9 cm (4.31 in.) of rainfall. The maximum daily rainfall of 2.4 cm (0.96 in.) fell on December 12.

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 for Site 300 are presented in **Figure 1-2**. The data show that winds are stronger and have less directional variation than at the Livermore site. Winds from the west–southwest through west occurred 42% of the time during 2006. The peak wind gust at Site 300 reached 31.5 m/s (71 mph) from the south–southeast on January 1.

As at the Livermore site, precipitation at Site 300 is seasonal, with most rainfall occurring between October and April. Because Site 300 is downwind of more extensive elevated terrain to the south and southwest (i.e., upper winds are typically southerly and southwesterly during storms) than at the Livermore site, rainfall amounts at Site 300 are typically 20 to 25% lower. Based on a 47-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 2006, Site 300 received 32.2 cm (12.68 in.) of rain, or 119% of normal. The April rainfall of 6.8 cm (2.67 in.) was more than four times the normal and the most recorded in April since record keeping began in 1960. Measurable rainfall occurred on 19 and 13 days in March and April, respectively. The rainiest month at Site 300 was also March, with accumulation of 7.0 cm (2.76 in.) or about 157% of normal. The maximum daily rainfall of 3.3 cm (1.28 in.) fell on January 2.

---

## 1.3 Topography

### 1.3.1 Livermore Site

The Livermore site is located in the southeastern portion of the Livermore Valley, a prominent topographic and structural depression oriented east–west within the Diablo Range. The most prominent valley in the Diablo Range, the Livermore Valley is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 22.6 km (14 mi) long and varies in width generally between 4 and 11.3 km (2.5 and 7 mi). The valley floor is at its highest elevation of 220 m (720 ft) above sea level along the eastern margin near the Altamont Hills and dips gradually to 92 m (300 ft) at the southwestern corner. The valley floor is covered primarily by alluvial and floodplain deposits consisting of gravels, sands, silts, and clays with an average thickness of about 100 m (325 ft).

The major streams passing through the Livermore Valley are the Arroyo del Valle and the Arroyo Mocho, which drain the southern highlands. Ephemeral waterways flowing through the Livermore site include Arroyo Seco along the southwestern corner and Arroyo Las Positas along the eastern and northern perimeters. Lake Del Valle, about 10 km (6 mi) south of the Livermore site, is the closest large body of surface water.

### 1.3.2 Site 300

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 southeastern portion. Corral Hollow Creek, an ephemeral stream, which drains toward the San Joaquin Basin, runs along the southern and eastern boundaries of Site 300.

---

## 1.4 Hydrogeology

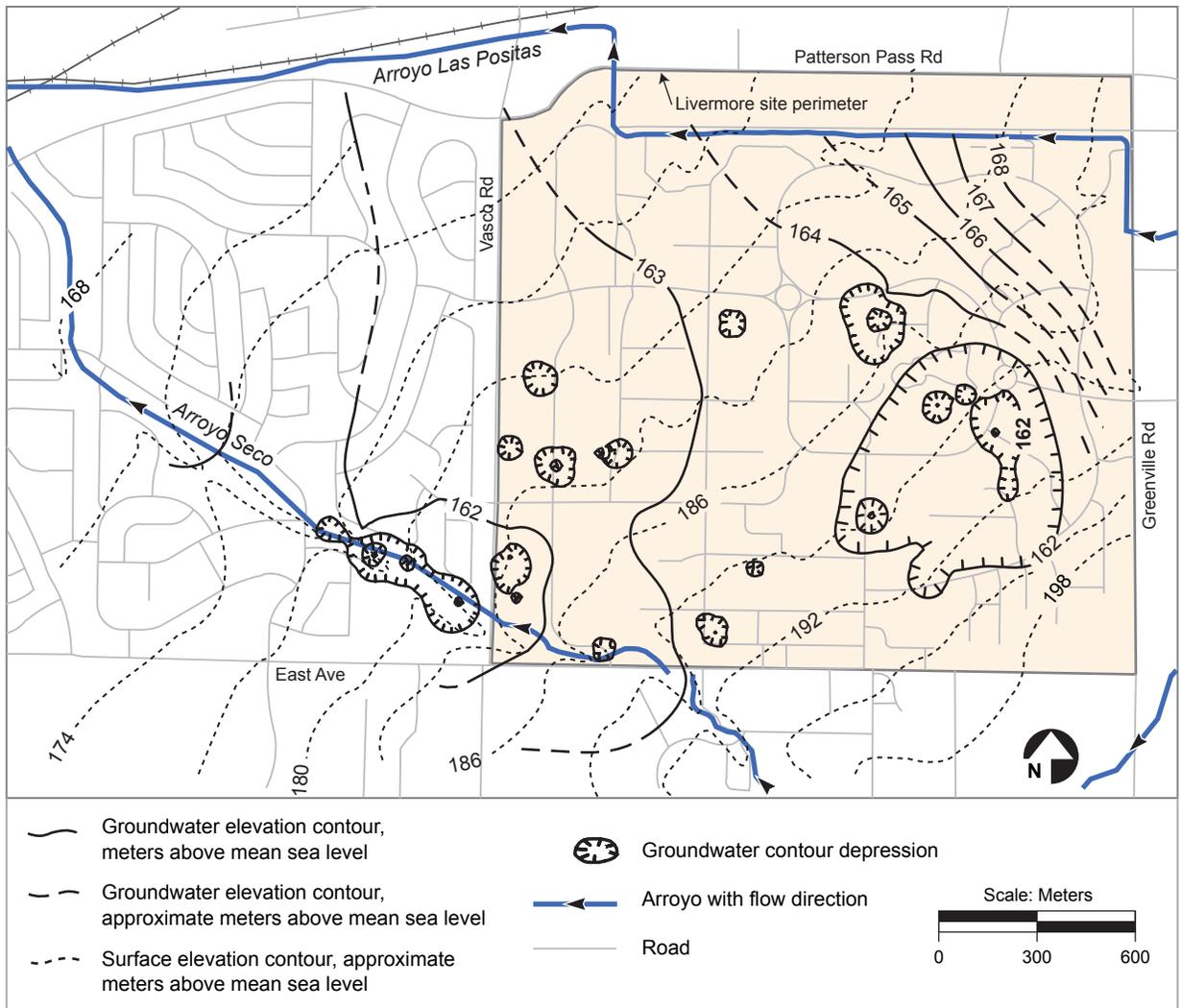
### 1.4.1 Livermore Site

The hydrogeology near the Livermore site has been the subject 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 these investigations and the data supplied by Alameda County Flood Control and Water Conservation District Zone 7, the agency responsible for the groundwater monitoring network in the Livermore Valley (SFBRWQCB 2006). The Zone 7 Water Agency also manages the groundwater supply in the Livermore Valley and adjacent basins (<http://www.zone7water.com/>).

The Livermore Formation and overlying alluvial deposits contain the primary aquifers of the Livermore Valley groundwater basin. Natural recharge occurs primarily along the basin margins and arroyos during wet winters. In general, groundwater flows toward the central east–west axis of the valley and then westward through the central basin. Groundwater flow in the basin is primarily horizontal, although a significant vertical component probably exists along the basin margins under localized sources of recharge and near heavily used extraction or water production wells.

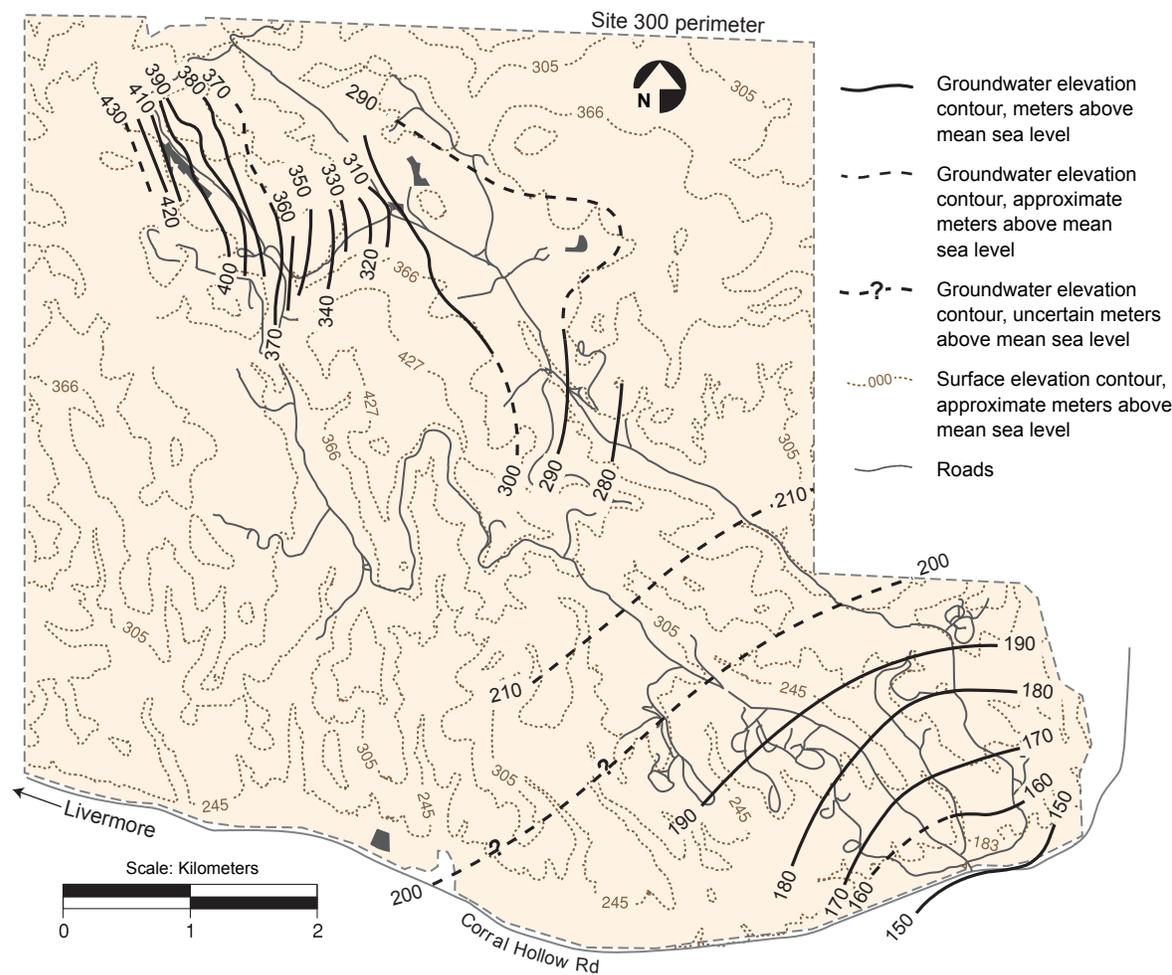
Beneath the Livermore site, the depth to the water table varies from about 10 to 40 m (30 to 130 ft) below the ground surface. **Figure 1-3** is a groundwater elevation contour map of the Livermore site's shallowest laterally extensive water-bearing unit (hydrostratigraphic unit or HSU), HSU-2. Hydrostratigraphic units are described further in **Chapter 8**. Although groundwater elevations vary from seasonal and year-to-year differences in both recharge and groundwater withdrawal from the basin, the overall pattern shown in **Figure 1-3** persists through time. 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, they flatten to a gradient of approximately 0.003.

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



**Figure 1-3.** Groundwater elevation contours of hydrostratigraphic unit 2 (HSU-2), the shallowest laterally extensive water-bearing unit beneath the Livermore site, October 2006.

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 at 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). This variability reflects the heterogeneity typical of the more permeable alluvial sediments that underlie the area. The hydraulic conductivities, in combination with the observed groundwater gradients, yields an estimated average groundwater velocity of about 20 meters per year (m/y) (66 feet per year [ft/y]) (Thorpe et al. 1990).



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

### 1.4.2 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 occurs primarily in the Neroly Formation upper and lower blue sandstone units and in the underlying Cierbo Formation. Stratigraphic units that occur beneath Site 300 are described further in **Chapter 8** (see **Figure 8.5**). **Figure 1-4** is a map of the potentiometric surface for the first continuous water-bearing zone at Site 300, which occurs principally 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 is generally 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 some groundwater flow therefore 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 northwestern 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.

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 Site 300 General Services Area pump water from this aquifer, which is 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.

---

## 1.5 Conclusion

Meteorology, topography, and geology affect the dispersal of released constituents 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 takes into account the features of the Livermore site and Site 300 discussed in this chapter to tailor the environmental monitoring and assessment programs discussed in the remainder of this report.

### Contributing Authors

*Brent Bowen, John Karachewski, Donald MacQueen, Sandra Mathews, Michael Taffet*

## 2.1 Environmental restoration and waste management

- 2.1.1 Comprehensive Environmental Response, Compensation and Liability Act
- 2.1.2 Emergency Planning and Community Right-to-Know Act and Toxics Release Inventory Report
- 2.1.3 Resource Conservation and Recovery Act and related state laws
- 2.1.4 California Medical Waste Management Act
- 2.1.5 Radioactive waste and mixed waste management
- 2.1.6 Federal Facility Compliance Act
- 2.1.7 Toxic Substances Control Act

## 2.2 Air quality and protection

- 2.2.1 Clean Air Act
- 2.2.2 National Emission Standards for Hazardous Air Pollutants, radionuclides

## 2.3 Water quality and protection

- 2.3.1 Clean Water Act and related state programs
- 2.3.2 Tank management

## 2.4 Other environmental statutes

- 2.4.1 National Environmental Policy Act
- 2.4.2 National Historic Preservation Act
- 2.4.3 Antiquities Act
- 2.4.4 Endangered Species Act and sensitive natural resources
- 2.4.5 Federal Insecticide, Rodenticide, and Fungicide Act

## 2.5 Environmental occurrences



Lawrence Livermore National Laboratory participates in numerous activities to comply with federal, state, and local environmental regulations, internal requirements, and applicable U.S. Department of Energy (DOE) orders. This chapter describes the regulations and guidance applicable to LLNL during 2006, the active permits in 2006, and the inspections of the Livermore site and Site 300 by external agencies. References that contain additional information are provided.

---

## 2.1 Environmental Restoration and Waste Management

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

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

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

#### 2.1.1.1 Livermore Site Ground Water Project

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

Significant GWP restoration activities in 2006 included installing 7 dual (groundwater and soil vapor) extraction wells, 2 groundwater extraction wells, 2 groundwater monitoring wells, 11 soil vapor wells, and 1 anode well; decommissioning 3 wells; and conducting 2 hydraulic tests, 3 soil vapor extraction tests, and 4 dual extraction tests. LLNL met all regulatory and DOE milestones on schedule by constructing or upgrading treatment facilities and beginning remediation at Treatment Facility D East Traffic Circle North Source Area, Building 419 Source Area, Treatment Facility C Hotspot, Buildings 511/514 Source Area, and Treatment Facility 5475 South.

LLNL completed all 87 of the milestones specified in the Remedial Action Implementation Plan, which defined "build out" according to DOE's Office of Environmental Management. Responsibility for the Livermore Site GWP was subsequently transferred from DOE's Office of Environmental Management to the National Nuclear Security Administration (NNSA).

**Treatment Facilities.** In 2006, LLNL operated 27 groundwater treatment facilities in the TFA, TFB, TFC, TFD, TFE, TFG, and TFH areas (see **Figure 8-1** in **Chapter 8** for a map of the

Livermore site showing the location of these areas). The 92 groundwater extraction wells and 34 dual extraction wells produced nearly 1.1 billion liters (L) of groundwater and removed approximately 78 kilograms (kg) of VOCs. In comparison, in 2005 the groundwater treatment facilities removed approximately 71 kg of VOCs. The higher VOC mass removal in 2006 was due to adding new extraction wells to existing or upgraded treatment facilities in contaminant source areas. Since remediation began in 1989, more than 11.8 billion L of groundwater has been treated, resulting in the removal of more than 1246 kg of VOCs. See **Chapter 8** for more information.

In 2006, LLNL also operated 9 soil vapor treatment facilities in the TFD, TFE, and TFH areas. The 19 soil vapor extraction wells and 34 dual extraction wells produced nearly 2.4 million cubic meters (m<sup>3</sup>) of soil vapor, and the treatment facilities removed more than 177 kg of VOCs. In comparison, in 2005 the soil vapor treatment facilities removed approximately 196 kg of VOCs. The lower mass removal in 2006 was due to decreasing VOC concentrations and cleanup of the vadose zone in the TFD and TFE source areas. In contrast, there was a significant increase in VOC mass removed in the TFH source area—from 110.5 kg in 2005 to 151.2 kg in 2006 due to the ongoing operation of soil vapor treatment facility VTF406 Hotspot and startup of a new treatment facility at VTF511. Since initial operation, more than 7.3 million m<sup>3</sup> of soil vapor has been extracted and treated, removing over 1052 kg of VOCs from the subsurface. See **Chapter 8** for more information.

**Community Relations.** Livermore site community relations activities in 2006 included communication and meetings with neighbors and local, regional, and national interest groups and other community organizations; public presentations; production of LLNL's *Environmental Community Letter*; maintenance of information repositories and administrative record; tours of site environmental activities; and responses to public and news media inquiries. In addition, DOE/LLNL met with members of Tri-Valley Communities Against a Radioactive Environment (Tri-Valley CAREs) and the organization's scientific advisor as part of the activities funded by an EPA Technical Assistance Grant (TAG). Community questions were also addressed via electronic mail, and project documents, letters, and public notices were posted on a public website: <http://www-envirinfo.llnl.gov>.

**Documentation.** In 2006, DOE/LLNL submitted the *LLNL Ground Water Project 2005 Annual Report* (Karachewski et al. 2006) and quarterly self-monitoring reports on schedule. In addition, DOE/LLNL completed all 2006 Remedial Action Implementation Plan (Dresen et al. 1993) milestones on schedule.

#### **2.1.1.2 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 (OUs) at the site. See Webster-Scholten (1994) and Ferry et al. (1999) for background information on LLNL environmental characterization and restoration activities at Site 300. See Ferry et al. (2006c) for the current status of remediation progress at sites that have achieved an Interim Record of Decision as identified in U.S. DOE (2001).

**Treatment Facilities and Field Investigations.** Common VOCs (primarily TCE) are the main contaminants at Site 300. High explosives, tritium, depleted uranium, organosilicate oil, nitrate, and perchlorate are also found in the groundwater. During 2006, 19 treatment facilities at Site 300 were in operation. At these facilities, 40 groundwater extraction wells and 18 dual phase extraction wells extracted about 116 million L of groundwater during 2006. The 18 dual phase extraction wells and 2 soil vapor extraction wells together removed 2.25 million m<sup>3</sup> of soil vapor.

In 2006, the Site 300 treatment facilities removed about 50 kg of VOCs, 0.18 kg of perchlorate, 1000 kg of nitrate, 0.15 kg of the high explosive compound RDX, and 0.029 kg of organosilicate oil. Since remediation efforts began in 1990, more than 1317 million L of groundwater and approximately 7.53 million m<sup>3</sup> of soil vapor have been treated to yield about 441 kg of removed VOCs, 0.58 kg of perchlorate, 4400 kg of nitrate, 0.71 kg of RDX, and 9.4 kg of organosilicate oil. See **Chapter 8** for more information.

During 2006, the following field activities were completed by agreed-upon regulatory due dates:

- expansion of the B832-SRC groundwater extraction wellfield to the distal portion of the plume in the Building 832 Canyon Operable Unit (OU)
- connection of B830-PRX extraction wells to the B830-SRC groundwater treatment system in the Building 832 Canyon OU
- expansion of B854-SRC groundwater extraction wellfield in the Building 854 OU
- construction of the B854-DIS groundwater extraction and treatment facility in the Building 854 OU

In 2006, 20 boreholes were drilled at Site 300—5 were drilled to collect soil and rock for chemical analysis, 4 were completed as extraction wells for groundwater treatment systems, 3 were completed as guard wells to monitor downgradient of contaminant plumes, and 8 were completed as monitoring wells for tracking of groundwater contaminant plumes.

**Community Relations.** The Site 300 CERCLA Project maintains continuing communications with the community of Tracy and nearby neighbors. Community relations activities in 2006 included maintenance of information repositories and administrative records; participation in community meetings and workshops; 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 OUs 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. A public meeting in Tracy for the proposed plan for the Pit 7 Complex was held on April 5, 2006, and a public workshop for the *Draft Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2006b) was held in Tracy on May 15, 2006.

**Documentation.** In 2006, LLNL submitted all required documentation to oversight agencies by agreed-upon regulatory submission dates or by extended dates requested by the regulatory agencies. Submitted documents were:

- *2005 Annual Compliance Monitoring Report Lawrence Livermore National Laboratory Site 300* (Dibley et al. 2006c)
- *Characterization Summary Report for the Building 865 Study Area at Lawrence Livermore National Laboratory Site 300* (Ferry and Holtzapple 2006)
- *Draft Amendment to the Interim Site-Wide Record of Decision for the Lawrence Livermore National Laboratory Site 300 Pit 7 Complex* (U.S. DOE 2006a)
- *Draft, Draft Final, and Final Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2006b, 2006a, 2006c)
- *Draft Final and Final Proposed Plan for Environmental Cleanup at the Pit 7 Complex Lawrence Livermore National Laboratory Site 300* (U.S. DOE 2006d, 2006f)
- *Draft and Final Five-Year Review Report for the Lawrence Livermore National Laboratory Site 300 General Services Area* (Dibley and Valett 2006; Dibley et al. 2006a)
- *Draft Site-Wide Proposed Plan for the Lawrence Livermore National Laboratory Site 300 Final Record of Decision* (U.S. DOE 2006e)
- *First Semester 2006 Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300* (Dibley et al. 2006b)
- *Interim Remedial Design Document for the Building 832 Operable Unit Lawrence Livermore National Laboratory Site 300* (Madrid et al. 2006)

#### **2.1.1.3 Site Evaluations Prior to Construction**

The Livermore site Record of Decision (U.S. DOE 1992) requires that before any construction begins, the project site must be evaluated to determine whether soil or rubble (concrete and asphalt) is contaminated. Soil is sampled and analyzed for potential radioactive and/or hazardous contamination under this requirement and in accordance with LLNL's *Environment, Safety and Health (ES&H) Manual*, Document 33.3, Management of Soil and Debris, for both the Livermore site and Site 300. Depending on the potential for radioactive contamination, rubble may be either surveyed or analyzed for radioactivity. During 2006, soil and/or rubble were

evaluated at 82 construction sites. Based on the evaluations, the soil and/or rubble were either reused on site or disposed of according to established procedures.

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

Title III of SARA, known as the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), requires owners and operators of facilities who handle certain hazardous chemicals on site to provide information on the release, storage, and use of these chemicals to organizations responsible for emergency response planning. Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management, directs all federal agencies to comply with the requirements of the EPCRA, including SARA, Section 313, Toxics Release Inventory (TRI) Program.

On June 13, 2006, LLNL submitted to DOE/NNSA the TRI Form R for lead, detailing environmental release estimates for both the Livermore site and Site 300. Form R is used for reporting TRI chemical releases including waste management and waste minimization activities. The data on lead release estimates show a continued decline in lead releases at Site 300. In fact, the continued increase in the use of non-lead ammunition at the Protective Forces Division pistol and rifle ranges at Site 300 has contributed directly to the greater than 22% reduction from the previous reporting year and an 88% reduction in lead releases since reporting year 2001. For TRI reporting year 2005, the TRI data also show zero lead releases at the Livermore site. EPCRA requirements and LLNL compliance are summarized in **Table 2-1**.

### **2.1.3 Resource Conservation and Recovery Act and Related State Laws**

The Resource Conservation and Recovery Act of 1976 (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 Title 22 of the *California Code of Regulations* (CCR) set requirements for managing hazardous wastes and implementing 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.

#### **2.1.3.1 Hazardous Waste Permits**

**Livermore Site.** The hazardous waste management facilities at the Livermore site consist of permitted units in Area 612 and Buildings 693, 695 and 696 of the Decontamination and Waste Treatment Facility (DWTF). The units that were operated under interim status, Area 514 Facility and the Building 233 Container Storage Facility, have been relocated to permitted facilities. Area 514 and Building 233 are currently undergoing RCRA closure. Permitted waste

**Table 2-1.** Compliance with Emergency Planning and Community Right-to-Know Act (EPCRA).

<b>EPCRA requirement</b>	<b>Brief description of requirement</b>	<b>LLNL action</b>
302 Planning Notification	Notify State Emergency Response Commission (SERC) of presence of extremely hazardous substances.	Originally submitted 5/87.
303 Planning Notification	Designate a facility representative to serve as emergency response coordinator.	Update submitted 3/15/06.
304 Release Notification	Report releases of certain hazardous substances to SERC and Local Emergency Planning Committee (LEPC).	No EPCRA-listed extremely hazardous substances were released above reportable quantities in 2006.
311 MSDS/ Chemical Inventory	Submit MSDSs or chemical list to SERC, LEPC, and Fire Department.	Update submitted 3/15/06.
312 MSDS/ Chemical Inventory	Submit hazardous chemical inventory to local administering agency (county).	Business plans and chemical inventory submitted to San Joaquin County on 1/26/06 and to Alameda County on 3/1/06.
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 for both Livermore site and Site 300 were submitted to DOE 6/13/06; DOE forwarded it to U.S. EPA and California EPA on 6/29/06.

management units include container storage, tank storage, and various treatment processes (e.g., wastewater filtration, blending, and size reduction). During 2005/2006, LLNL also submitted several Class 1, Class 1\* and Class 2 permit modification requests to DTSC (Class 1, Class 1\*, and Class 2 are defined in the glossary). The six Class 2 permit modifications have not been approved, but all of the requested Class 1 permit modifications have been approved and are being implemented. The approval dates for the Class 1 modifications were June 30, 2006; February 9, 2007; and February 23, 2007. 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.

**Table 2-2** is a summary of active permits in 2006 at the Livermore site and Site 300. **Table 2-3** lists inspections, tours, and preliminary and final notices of violations at both LLNL sites in 2006.

**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 respectively to store and treat explosives waste only. The

**Table 2-2.** Active permits in 2006 at the Livermore site and Site 300.

Type of permit	Livermore site <sup>(a)</sup>	Site 300 <sup>(a)</sup>
Hazardous waste	<p>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.</p> <p>Conditionally Exempt Specified Wastestream permit to mix resin in Unit CE231-1.</p> <p>Conditional Authorization Permit to operate sludge dewatering unit in Building 322A.</p>	<p>EPA ID No. CA2890090002.</p> <p>Hazardous Waste Facility Permit—Container Storage Area (Building 883) and Explosives Waste Storage Facility.</p> <p>Hazardous Waste Facility Permit —Explosives Waste Treatment Facility.</p> <p>Hazardous Waste Facility Post-Closure Permit—Building 829 High Explosives Open Burn Treatment Facility.</p>
Medical waste	<p>ACDEH issued two permits:</p> <p>(1) for large quantity medical waste generation and treatment covering the Building 360 and Building 150 Complexes, CLMS Biowatch Laboratory, SEP Health Services Department, NHI Forensic Science Center, E&amp;E Tissue Culture Laboratory, and PAT M Division.</p> <p>(2) for medical waste generation and treatment activities planned for the Biosafety Level 3 (BSL-3) Facility.</p>	<p>Limited Quantity Hauling Exemption for small quantity medical waste generator.</p>
Air	<p>BAAQMD issued 182 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.</p>	<p>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.</p>
Storage tanks	<p>Six operating permits covering 9 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; 365-D1U2 Permit No. 6492; and 611-D1U1, 611-G1U1, 611-G2U1, and 611-O1U1 Permit No. 6505.</p>	<p>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.</p>
Sanitary sewer	<p>Discharge Permit 1250<sup>(b)</sup> (2005/2006 and 2006/2007<sup>(c)</sup>) for discharges of wastewater to the sanitary sewer.</p> <p>Permit 1510G (2004/2006<sup>(d)</sup>) for discharges of groundwater from CERCLA restoration activities to the sanitary sewer.</p>	

**Table 2-2 (cont).** Active permits in 2006 at the Livermore site and Site 300.

Type of permit	Livermore site <sup>(a)</sup>	Site 300 <sup>(a)</sup>
Water	<p>WDR Order No. 88-075 for discharges of treated groundwater from Treatment Facility A to recharge basin.<sup>(e)</sup></p> <p>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.</p> <p>WDR Order No. 99-08-DWQ, NPDES California General Construction Activity Permit No. CAS000002; 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/Z5S Parking Lots, Site ID No. 201C333137; for discharges of storm water associated with construction activities affecting 0.4 hectares (1 acre) or more.</p> <p>FFA for groundwater investigation/remediation.</p> <p>NWPs 27, 13, and 7 for the implementation of the Arroyo Seco Management Plan.</p>	<p>WDR Order No. 93-100 for post-closure monitoring requirements for two Class I landfills.</p> <p>WDR Order No. 96-248 for operation of a domestic sewage lagoon, and percolation pits.</p> <p>WDR Order No. 97-03-DWQ, NPDES California General Industrial Activity General Permit No. CAS000001 for discharge of storm water associated with industrial activities.</p> <p>WDR Order No. 5-00-175, NPDES Permit No. CAG995001 for large volume discharges from the drinking water system that reach surface waters.</p> <p>NWP 14 and 27 for installation of culverts at Round Valley and Oasis projects and for the construction of a habitat pool at Round Valley.</p> <p>Water Quality Certification for Round Valley and Oasis projects, WDID No. 5B01CR0007.</p> <p>FFA for groundwater investigation/remediation.</p> <p>34 registered Class V injection wells.<sup>(f)</sup></p>

(a) Numbers of permits are based on actual permitted units or activities maintained and/or renewed by LLNL during 2006.

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

(c) The Discharge Permit 1250 period is through July 15; therefore, two permits were active during the 2006 calendar year.

(d) Permit 1510G is a two-year (January to December) permit.

(e) Recharge basins referenced in WDR Order No. 88-075 are located south of East Avenue within Sandia National Laboratories/California boundaries.

(f) A new injection well was installed in August 2006.

**Table 2-3.** Inspections and tours of Livermore site and Site 300 by external agencies in 2006.

Site	Medium	Description	Agency	Date	Finding
Livermore site	Waste	Hazardous waste facilities CEI	DTSC	9/27/06, 9/28/06, 10/2/06, 10/6/06, and 10/11/06	Received a Class II violation for treatment of hazardous waste drums in unauthorized location on 10/18/06. LLNL received the final report dated 4/16/07, which identified three minor violations. LLNL responded to DTSC on 5/14/07. LLNL corrected one violation through a permit modification and requested that two violations be rescinded.
		Hazardous waste facilities ESI	DTSC	11/29/06	Received an initial inspection report on 11/29/06 detailing summary of observations (SOOs). LLNL received DTSC's final report on 3/13/07, and there were no violations.
		Medical waste	ACDEH	11/7/06, 11/21/06	No violations
	Air	44 emission sources	BAAQMD	3/27/06, 12/13/06	No violations
		Asbestos	BAAQMD	7/14/06	No violations
	Sanitary sewer	Annual compliance sampling	LWRP	10/3/06–10/4/06	No violations
		Categorical sampling/inspection Buildings 153 and 321C	LWRP	10/3/06	No violations
		Building 327		10/10/06	Tour of operation to confirm process was not regulated
		Quarterly BOD/TSS Monitoring	LWRP	3/1/06 6/13/06 8/8/06 12/6/06	Sampling for billing purposes, not compliance Sampling for billing purposes, not compliance Sampling for billing purposes, not compliance Sampling for billing purposes, not compliance
	Storage tanks	Compliance with underground storage tank requirements and operating permits	ACDEH	9/13/06, 9/19/06	No violations
Pesticides	Pest Control Records Inspections	ACCDA	6/1/06	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, and a review of hazardous waste-related documentation	DTSC	6/16/05 and 6/21/05 (2005 CEI)	Received no violations in initial 2005 Summary of Observation report. In the March 20, 2006, Inspection Report, DTSC issued two violations: (1) failure to use the original manifest to transport a rejected load to another disposal facility, and (2) falsely representing the waste on manifest 234440682 (which is directly related to violation #1). LLNL submitted a corrective action letter to DTSC on April 28, 2006. DTSC accepted the corrective actions and returned the facility to compliance in a letter dated May 15, 2006. This concluded the 2005 CEI.

**Table 2-3 (cont.).** Inspections and tours of Livermore site and Site 300 by external agencies in 2006.

Site	Medium	Description	Agency	Date	Finding	
Site 300 (cont.)	Waste (cont.)	Permitted hazardous waste operational facilities (EWTF, EWSF, Building 883 CSA), RCRA-closed, post-closure permitted facility Building 829 Open Burn Facility, and a review of hazardous waste-related documentation	DTSC	4/12/06 and 4/24/06 (2006 CEI)	<p>During the close-out meeting on 4/24/06, DTSC issued two violations in the Summary of Violations report: (1) failure to record deficiencies and corrective actions on the EWTF inspection log, and (2) failure to conduct the first quarter 2005 and third quarter 2006 inspections of the B829 post-closure facility well monitoring network. The violations were corrected and the corrective action certification was faxed to DTSC on 4/28/06. The original paper copy certification was mailed to DTSC on 6/2/06.</p> <p>DTSC issued two more violations in the Inspection Report dated 6/12/06: (3) failure to record the time of inspection on the B829 post-closure facility inspection log and (4) failure to track 55-gallon drums in EWSF M816 by attaching a barcode to each drum. Individual parcels inside each 55-gallon drum were barcoded; however, the outer 55-gallon containers were not barcoded.</p> <p>LLNL submitted the corrective action response letter to violations #3 and #4 on 8/17/06. The letter also requested DTSC to downgrade both violations from Class II to Minor. DTSC did not respond to the response letter during calendar year 2006. In a letter from DTSC to LLNL dated 1/16/07, the Building 829 violation for not recording the inspection time on the inspection log was downgraded from a Class II to Minor Violation. However, the request to downgrade the Building 816 violation from Class II to Minor was not accepted by DTSC. Based on the LLNL violation response letter, DTSC determined that all violations were appropriately remedied.</p>	
		Hazardous waste generator area inspection (WAAs, SAAs and hazardous waste-related records for hazardous waste generator activities only).	SJCEHD - CUPA	4/19/06	<p>During an inspection of the vehicle management operations at Building 879, two violations were issued for (1) failure to make a hazardous waste determination of metallic brake fine waste from rotor/drum machine turning operations and (2) failure to maintain waste analysis of the waste at the facility for three years. The violations were faxed to LLNL in an amended inspect report dated 4/24/06. Corrective actions were implemented, which were described in a violation response letter to SJCEHD dated 5/18/06.</p>	
		Air	1 emission source	SJVAPCD	3/9/06	No violations
		Water	Permitted operations	CVRWQCB	3/27/06 11/20/06	No violations
Storage tanks	Compliance with underground storage tank requirements and operating permits	SJCEHD	9/14/06 9/18/06	No violations		

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 2006.

#### **2.1.3.2 Hazardous Waste Reports**

LLNL completed two annual hazardous waste reports, one for the Livermore site and the other for Site 300, which addressed the 2006 transportation, storage, disposal, and recycling of hazardous wastes at the respective sites. The “2006 Hazardous Waste Report—Main Site” and “2006 Hazardous Waste Report—Site 300” were submitted to the DTSC by April 1, 2007.

#### **2.1.3.3 Hazardous Waste Transport Registration**

Transportation of hazardous waste over public roads requires DTSC registration (22 CCR 66263.10). DTSC renewed LLNL’s registration on November 29, 2006, which will be in effect for one year.

#### **2.1.3.4 Waste Accumulation Areas**

LLNL programs maintain waste accumulation areas (WAAs) in compliance with waste generator requirements specified in Title 40 of the *Code of Federal Regulations*, Part 262 (40 CFR Part 262), and 22 CCR 66262.34 for the temporary storage (less than 90 days) of hazardous waste prior to transfer to a treatment, storage, or disposal facility. In January 2006, there were 27 WAAs at the Livermore site. During 2006, two temporary WAAs and two permanent WAAs were put into service, while six temporary WAAs and two permanent WAAs 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, 1196 prescribed WAA inspections were conducted.

At Site 300 during 2006, one WAA was in operation. Program representatives conducted 52 prescribed WAA inspections at Site 300.

#### **2.1.4 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 the 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 November 2006 ACDEH inspection of the Chemistry, Materials, and Life Sciences Directorate Building 360 Complex (Building 361) and Building 150 Complex (Buildings 151, 152, and 154), Building 132N of the Forensic Science Center, and the Biowatch Laboratory in Building 241.

### **2.1.5 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 for the Lawrence Livermore National Laboratory* (LLNL 2006b), which summarizes radioactive waste management controls relating to waste generators and treatment and storage facilities.

### **2.1.6 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, which was signed in February 1997. LLNL completed 13 milestones during 2006, and of those, eight had dates beyond 2006 (ranging from 2007 to 2010).

There was a major emphasis to complete the characterization and disposition of legacy low-level waste. The increased focus on legacy waste and also on safety improvements resulted in LLNL's requesting and being granted extensions for 12 additional milestones due in 2006. The milestones were associated with 20.6 m<sup>3</sup> of waste.

LLNL successfully removed approximately 155 m<sup>3</sup> of mixed waste from the STP in 2006. An additional 69 m<sup>3</sup> of newly generated mixed waste was added to the STP, resulting in an overall reduction of 86 m<sup>3</sup> of mixed waste being stored by 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.

### **2.1.7 Toxic Substances Control Act**

The Federal Toxic Substances Control Act (TSCA) and implementing regulations found in 40 CFR Parts 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.

All TSCA-regulated waste was disposed of 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.

---

## 2.2 Air Quality and Protection

### 2.2.1 Clean Air Act

All activities at LLNL are evaluated to determine the need for air permits. Air permits are obtained from the Bay Area Air Quality Management District (BAAQMD) for the Livermore site and from the San Joaquin Valley Air Pollution Control District (SJVAPCD) and/or BAAQMD for Site 300. Both agencies are overseen by the California Air Resources Board (CARB).

In 2006, LLNL operated 182 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 two Livermore site source inspections of 44 emission sources, and the SJVAPCD performed one Site 300 source inspection of one emission source. 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 listed in **Table 2-3**.

The BAAQMD also performed an asbestos inspection of 13 buildings and trailers at the Livermore site to ensure that asbestos was removed from the facilities and/or demolition of the facilities was performed in accordance with applicable air district and federal National Emissions Standards for Hazardous Air Pollutants (NESHAPs) requirements. The BAAQMD found that the asbestos removal and demolition activities were performed in accordance with applicable local air district and federal regulations. Dates and findings of the inspections are listed 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 Clean Air Act 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 a facility's operations to ensure that the emissions 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 metric tons (MT) (35 tons) per year for nitrogen oxides (NO<sub>x</sub>), 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.

In 2006, several potentially significant air pollutant emission sources at the Livermore site were eliminated to reduce overall pollutant emissions. In addition, LLNL obtained approvals from the CARB and BAAQMD to construct an alternative fuel dispensing facility at the Livermore site.

LLNL evaluated usage necessity of its older, permitted diesel-powered portable generators and compressors in its fleet of 17 pieces of permitted portable diesel equipment, and

determined that five such generators could be eliminated without replacement. The five portable, diesel-powered generators were manufactured between 1954 and 1990 and were significant contributors to combustion pollutants emitted from the fleet.

LLNL also eliminated two permitted solvent cleaning operations. The two operations had the combined potential of emitting over 1 MT (2200 pounds [lbs]) per year of VOC pollutants.

In addition, LLNL obtained approvals from the CARB and BAAQMD to construct an alternative fuel (i.e., an E85) dispensing facility at the Livermore site. E85 fuel is a blend of 85% ethanol and 15% unleaded gasoline fuel, and meets Executive Order 13149, Greening the Government Through Federal Fleet and Transportation Efficiency, to implement the use of alternative fuels that enhance the nation's economy and energy independence. The new E85 dispensing facility will not increase the fuel throughput at LLNL since it is intended to provide a substitute for gasoline fuel.

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

To demonstrate compliance with 40 CFR Part 61, Subpart H (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 2006 Annual Report* (Larson et al. 2007), submitted to EPA, reported that the estimated maximum radiological doses that could have been received by a member of the public in 2006 were 0.045 microsievert ( $\mu\text{Sv}$ ) (0.0045 millirem [mrem]) for the Livermore site and 0.16  $\mu\text{Sv}$  (0.016 mrem) for Site 300. The reported doses include contributions from both point and diffuse sources. The totals are well below the 100  $\mu\text{Sv}/\text{year}$  ( $\mu\text{Sv}/\text{y}$ ) (10 mrem/year [mrem/y]) dose limits defined by the NESHAPs regulations. See **Chapter 7** for additional information on the data.

In 2006, LLNL continuously monitored radionuclide emissions from the Tritium Facility, the Plutonium Facility, and portions of five other facilities (see **Chapter 4**). Using ambient air monitoring, LLNL also continuously monitored releases of depleted uranium used in explosives testing at Site 300 (see **Chapter 4**). There was one unplanned incident at the Livermore site in 2006 that had the potential to result in a small release of tritium to air. However, because LLNL personnel with the most exposure did not receive any measurable dose attributable to the incident, any potential dose to a member of the public would have been negligible (see **Section 7.5.2** for details). There were no unplanned atmospheric releases at Site 300 in 2006. Monitoring activities and results related to air are described further in **Chapter 4**.

---

## 2.3 Water Quality and Protection

### 2.3.1 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 water quality 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. No enforcement actions were taken against LLNL by water-related regulatory agencies in 2006.

At Site 300, LLNL completed the construction of two culverts at Round Valley and Oasis. A habitat pool built at Round Valley served in part to compensate for the loss of habitat that was a result of the two drainage improvement projects. These projects were authorized under nationwide permits (NWP) 27 and 14 and certified by the Central Valley RWQCB.

To satisfy a concern that the cooling tower blowdown from Building 801 at Site 300 might reach a surface water tributary during winter storms, LLNL constructed a new percolation pit and registered it as a Class V injection well with the U.S. EPA. The new system was put into service on October 9, 2006.

Monitoring activities and results related to water permits are described in **Chapter 5**.

### 2.3.2 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. The Alameda County Department of Environmental Health (ACDEH) and the 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 and aboveground storage tanks. All permitted underground storage tanks were inspected by regulating agencies in 2006. No violations were noted during the inspections. See **Table 2-3** for a summary of inspections.

In December 2006, LLNL applied for a permit from ACDEH to install a new 45,425-L (12,000-gallon [gal]) underground storage tank (UST) to store E85 motor vehicle fuel. The new UST and all underground piping are double-walled and continuously leak monitored. The new tank system was installed as part of the new E85 alternative fuel dispensing facility that will serve the 281 Flexible Fuel Vehicles (FFVs) that can run on either E85 (85% ethanol and 15% unleaded gasoline) or E10 (10% ethanol and 90% unleaded gasoline).

In 2006, LLNL continued to conduct extensive, site-wide building surveys at both the Livermore site and Site 300 for aboveground oil containers of 208 L (55 gal) or more. 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 are scheduled to be completed in 2007.

---

## **2.4 Other Environmental Statutes**

### **2.4.1 National Environmental Policy Act**

The National Environmental Policy Act (NEPA) is the U.S. government's basic environmental charter. When considering a proposed project or action, the federal government is required by NEPA to (1) consider how the action would affect the environment and (2) make certain that environmental information is available to public officials and citizens before decisions are made and actions are taken. Because LLNL activities are generally funded by the federal government, these activities must comply with NEPA requirement.

A federal agency meets the first NEPA requirement by determining what impact, if any, 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 include air, water, soil, biological resources, socioeconomics, aesthetics, noise, or cultural resources. Results of the studies are recorded in "NEPA documents."

The federal agency meets the second requirement, to inform public officials and citizens, by distributing the NEPA documents by making them available in public reading rooms and on the Internet and sometimes by mailing them directly to interested parties. Federal agencies often involve the public in decisions about proposed projects by holding public meetings and asking for comments on the NEPA documents.

NEPA documents include environmental impact statements (EISs) and environmental assessments (EAs). EISs are prepared for proposed major federal actions that would

significantly affect the quality of the human environment. In contrast, EAs are prepared for federal actions that would not have a significant impact on the environment or when all of the potential impacts of a proposed action could be reduced to insignificant levels. Federal agencies decide which type of document should be prepared after studying the impact to the environment.

Some projects do not require either an EIS or an EA. 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/NNSA 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 categorical exclusions, CXs, or Cat Xs. Technically, categorical exclusions are not NEPA documents.

The NEPA documents and categorical exclusions that were prepared for LLNL projects in 2006 are described below.

In March 2005, DOE published the *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* (U.S. DOE 2005) (LLNL SW/SPEIS), and a Record of Decision was filed on November 29, 2005 (U.S. DOE/NNSA 2005). In response to national security needs, DOE prepared a supplemental analysis to the LLNL SW/SPEIS and in February 2006 published *The Proposed Construction and Operation of Evidence Receiving and Temporary Storage Facilities in Support of the Nuclear and Radiological Attribution Program and Forensic Science Center's Analyses Program at the Livermore Site and Site 300, Lawrence Livermore National Laboratory* (U.S. DOE 2006g). This project would allow construction and operation of facilities at Site 300 and expand forensic science activities to additional buildings at the Livermore site.

In 2006, one LLNL project required a DOE EA. The project would provide environmental remediation of a historical landfill area in the northwest corner of Site 300 that periodically releases contaminants to shallow groundwater during heavy rainfall events. A *Draft Environmental Assessment for the Proposed Environmental Remediation at Lawrence Livermore National Laboratory Site 300 Pit 7 Complex* was published in August 2006 (U.S. DOE 2006b). Public comments were received on the draft until September 21, 2006. In January 2007, DOE issued the final version of the EA (U.S. DOE 2007), which included responses to the public comments. In February 2007, DOE issued a Finding of No Significant Impact (FONSI) as a result of the analysis contained in the final EA. No further NEPA documentation is required on this project.

Ten 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 Part 1022.

Since November 1992, the University of California (UC) and LLNL have implemented mitigation measures identified in the *Environmental Impact Statement and Environmental Impact*

*Report* (U.S. DOE and UC 1992), or 1992 EIS/EIR. A California Environmental Quality Act addendum to the 1992 EIS/EIR was prepared in 1997 for the UC Regents (UC 1997). The measures are being implemented in accordance with the approved 1992 Mitigation Monitoring and Reporting Program associated with the 1992 EIS/EIR. The last mitigation monitoring report was published in 2003.

#### **2.4.2 National Historic Preservation Act**

The National Historic Preservation Act (NHPA) (as amended) provides for the protection and preservation of historic properties that are significant in the nation's history. LLNL resources subject to NHPA consideration range from prehistoric archeological sites to remnants of LLNL's own history of scientific and technological endeavors. The responsibility to comply with the provisions of NHPA rests solely with federal agencies. DOE/NNSA is the lead federal agency in this undertaking. LLNL and UC, as LLNL's contract operator, support DOE/NNSA's NHPA responsibilities. LLNL does so with direction from DOE/NNSA. At the end of 2006, the two draft treatment plans were under consideration by DOE and SHPO.

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 federal agencies must allow and consider comments of the federal Advisory Council on Historic Preservation (ACHP). 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 streamlining historic preservation efforts and focusing on important historic properties under its management. First, DOE/NNSA, 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 of the agreement 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 specified in the agreement, was to complete within a reasonable time frame an inventory of places (prehistoric, historic, archeological, and architectural) meeting a statutory threshold of historic importance. The inventory of historic architectural resources was completed in 2004. In 2005, LLNL prepared an inventory of prehistoric and historic archaeological resources. Recommendations were provided in both documents for resources that appeared to meet the statutory threshold of historic importance for listing in the National Register of Historic Places (NRHP). In consultation with the SHPO, DOE/NNSA used the information in the document to formally determine that five of LLNL's archaeological resources qualified for listing in the NRHP. Also in consultation with the SHPO, DOE/NNSA formally determined that five buildings, two historic districts, and selected objects in one

building at LLNL were eligible for listing in the NRHP. In August 2006, the SHPO staff toured two buildings at the Livermore site.

With the inventory and assessment complete, DOE, UC, the SHPO, and the ACHP initiated discussions toward the development of a new agreement that would govern how DOE/NNSA would manage the NRHP-eligible properties. 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. These plans describe specific resource management and treatment strategies that could be implemented by DOE/NNSA, in cooperation with LLNL, to ensure that important historic properties are managed in a manner that considers their historic value.

### **2.4.3 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 2006.

### **2.4.4 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.

- The USFWS issued a biological opinion for the Arroyo Seco Management Plan 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 by this biological opinion for five years after the completion of this project. The first year of the five-year monitoring plan was completed in 2006.
- A site-wide biological assessment for the LLNL SW/SPEIS was prepared and submitted to the USFWS on April 9, 2004. A revised site-wide biological assessment was prepared in 2006 and submitted to the USFWS on February 26, 2007.
- 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 because these artificial wetlands provided suitable habitat for California red-legged frogs. Water discharge to the artificial wetland near Building 865 was terminated in 2006.
- California red-legged frog dispersal and breeding were monitored in 2006 as a requirement of the biological opinion for the Mid-Elk Ravine Wetland Enhancement Project. California red-legged frogs were relocated from the Building 865 artificial wetland to the Mid-Elk Ravine wetlands in March 2006.
- The Oasis Culvert Replacement Project was completed in the fall of 2006. This project is included in the May 17, 2002, *Biological Opinion for Routine Maintenance and Operations of Site 300*. Fifteen California red-legged frogs were relocated during the construction of this project.
- The Round Valley Culvert Replacement Project was also completed in the fall of 2006. A large pool designed as breeding habitat for the California tiger salamander and California red-legged frog was constructed upstream of the Round Valley culvert as part of the project. This pool served in part as mitigation for impacts to wetlands during the Oasis Culvert Replacement Project.
- In October 2006, application of rotenone, a piscicide, to Lake Haussmann was carried out to eradicate invasive, nonnative species of fish (i.e., largemouth bass and channel catfish) to protect California red-legged frogs. This project is included in the August 8, 2002, *Biological Opinion for Bullfrog Management Plan Amendment for LLNL* and the October 2, 2006, *Amendment to Biological Opinion for the Arroyo Maintenance Project at LLNL*. This collaborative project between the California Department of Fish and Game and LLNL's Environmental Protection Department successfully eradicated these species without any unforeseen issues arising.

In 2006, the USFWS published two critical habitat designations that are pertinent to LLNL. On April 13, 2006, the USFWS published a final rule designating critical habitat for the California red-legged frog (USFWS 2006a). The new critical habitat designation does not include any portion of the Livermore site or Site 300. A critical habitat designation was also issued for the Alameda whipsnake on October 2, 2006 (USFWS 2006b). This designation includes the southwestern portion of Site 300 (see **Figure 6-7** in **Chapter 6**). 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**.

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

LLNL complies with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which provides federal control of the distribution, sale, and use of pesticides. The EPA has given the California Department of Pesticide Regulations (DPR) enforcement responsibility for FIFRA in California; DPR has in turn given enforcement responsibility to county departments of agriculture. All pesticides at LLNL are applied, stored, and used in compliance with FIFRA and other California and Alameda County regulations governing the use of pesticides.

FIFRA also requires that commercial users of pesticides maintain certification as pesticide applicators. The staff of the LLNL Landscape and Pest Management Shop includes eight individuals who are certified pesticide applicators. The certification is issued by the State of California and is maintained through an annual training and inspection program. The Alameda County Community Development Agency (ACCD) conducts an annual inspection of the Livermore site Landscape and Pest Management Shop to ensure that all storage and use of pesticides at LLNL is in accordance with applicable regulations.

LLNL also reviews pesticide applications to ensure they do not result in impacts to water quality or special status species.

---

## **2.5 Environmental Occurrences**

In 2006, 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 categorize occurrences and provide guidelines to contractor facilities regarding categorization of and reporting environmental occurrences to DOE.

LLNL's response to environmental occurrences is part of the larger on-site emergency response organization that includes representatives from LLNL's Hazards Control Department (including the LLNL Fire Department), Health Services Department, Plant Engineering, Public Affairs Office, Safeguards and Security Organization, and Environmental Protection Department. In 2006, seven environmental incidents, summarized in **Table 2-4**, were reportable under DOE Order 232.1A. One incident was categorized under Significance Category 1, Group 1, Operational Emergency, while one incident was categorized as a Significance Category 4 reportable occurrence under Group 5, Environmental. Five occurrences were categorized under Significance Category 4, Group 9, Noncompliance Notifications. DOE was notified of the incidents.

### **Contributing Authors**

*Lily Baldwin, Shari Brigdon, Richard Brown, Karl Brunckhorst, Joseph G. Byrne, Steven Cerruti, Patrick Epperson, Allen Grayson, Rod Hollister, John Karachewski, Sandra Mathews, Paul McGuff, Jennifer Nelson-Childs, Lisa Paterson, Ring Peterson, Vicki Salvo, William Schwartz, Michael Taffet, Stan Terusaki, Jim Woollett, Joseph Woods, Peter Yimbo*

**Table 2-4.** Environmental Occurrence reported under the Occurrence Reporting System in 2006.

Date <sup>(a)</sup>	Occurrence category/group	Description
4/5/06	Significance Category SC4 Occurrence under Group 5A(4)	An LLNL vehicle was accessing a security post when the pop-up barrier was activated, causing a rupture to the vehicle gasoline tank. Approximately 20 gallons of gasoline was released to the asphalt and the barrier sump. Although the spill response was quickly activated, an undetermined amount of gasoline entered the adjacent storm drain and flowed to the Arroyo Las Positas. OR 2006-0013
4/5/06	Significance Category SC4 Occurrence under Group 9(2)	On 4/5/06, the DTSC issued LLNL an SOV for findings from a 6/16/05 inspection at Site 300. The SOV identified two findings pertaining to the documentation associated with a single shipment of hazardous waste from Site 300 to an off-site TSDF. OR 2006-0014
4/24/06	Significance Category SC4 Occurrence under Group 9(2)	LLNL received an NOV from the San Joaquin County Environmental Health Department for findings noted during the 4/19/06 scheduled inspection of the vehicle management operations at Site 300, Building 879. The two findings pertained to the management of metal grindings from brake rotors and drums. OR 2006-0015
4/24/06	Significance Category SC4 Occurrence under Group 9(2)	LLNL received an SOV from the DTSC for two violations discovered during the Annual Compliance Evaluation Inspection of permitted facilities at Site 300. One finding identified information that was lacking from a weekly inspection log. The second finding described a failure to follow a facilities operation plan and conduct the quarterly inspection for wells. OR 2006-0016
6/14/06	Significance Category SC1 Occurrence Under Group 1(1)	On 6/14/06, LLNL declared an Operational Emergency when Mutual Aid was requested for a grass fire that burned approximately 20 acres of Site 300 land. The fire started off site on the westbound shoulder of Corral Hollow Road and burned onto Site 300 property. OR 2006-0029
9/11/06	Significance Category SC4 Occurrence under Group 9(2)	On 9/11/06, LLNL received an NOV from the DTSC for findings noted during the April 2005 Compliance Evaluation Inspection conducted at RHWM-permitted facilities. The report detailed five Class 2 violations, including; (1) Exceeding the 90-day storage time limit in a WAA (2) Failure of two individuals to complete annual RCRA training (3) Date discrepancy between a label and the RHWM database (4) Failure to fix cracks in the bermed area of Building 695 (5) Failure to provide complete transaction information for legacy chlorosolvent waste. OR 2006-0044
10/18/06	Significance Category SC4 Occurrence under Group 9(2)	LLNL received an SOV from the DTSC for findings derived from the 9/06 Compliance Evaluation Inspection conducted at RHWM-permitted facilities. The SOV identified one Class 2 violation for crushing hazardous waste drums at a non-permitted location. On 4/18/07, LLNL received the final inspection report, which included three additional minor violations: one for training and two for incomplete administrative records. OR 2006-0053

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



### 3.1 Environmental Protection Department

- 3.1.1 Operations and Regulatory  
Affairs Division
- 3.1.2 Radioactive and Hazardous  
Waste Management Division
- 3.1.3 Environmental Restoration  
Division
- 3.1.4 Response to spills and other  
environmental emergencies

### 3.2 Integrated Safety Management System

- 3.2.1 Work Smart Standards
- 3.2.2 Environmental Management  
System
- 3.2.3 Identification of significant  
environmental aspects and their  
impacts
- 3.2.4 Identifying and managing  
environmental objectives and  
targets
- 3.2.5 Establishing and maintaining  
Environmental Management  
Plans
- 3.2.6 LLNL's self-declaration process
- 3.2.7 Path forward

### 3.3 Pollution Prevention Program

- 3.3.1 Routine hazardous and  
radioactive waste
- 3.3.2 Diverted waste
- 3.3.3 Pollution prevention activities
- 3.3.4 Review of new processes,  
programs, or experiments
- 3.3.5 Pollution prevention employee  
training and awareness  
programs



**L**awrence Livermore National Laboratory is committed to enhancing its environmental stewardship and to reducing any impacts its operations may have on the environment.

The Environmental Protection Department (EPD) is LLNL's lead organization in environmental protection and provides environmental expertise to the Laboratory. EPD's major activities are described in this chapter. In 2006, one of EPD's most important undertakings was integrating the requirements of the International Organization for Standardization (ISO) 14001:2004 Environmental Management Systems (EMS) into LLNL's Integrated Safety Management System (ISMS). The development of LLNL's EMS is described in this chapter.

Pollution prevention, a significant component of the EMS, plays an important role at LLNL. The progress the Pollution Prevention Program (P2 Program) has made in meeting U.S. Department of Energy (DOE) pollution prevention goals, diverting waste, and reducing generated waste is described in this chapter.

Award-winning projects and training and awareness programs are also described.

---

## 3.1 Environmental Protection Department

EPD is responsible for environmental monitoring, environmental regulatory interpretation and implementation guidance, environmental restoration, and waste management in support of LLNL's programs. EPD also works with the Public Affairs Office to implement an environmental community relations program. EPD prepares and maintains environmental plans, reports, and permits; maintains the environmental portions of the *Environment, Safety and Health Manual (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 monitors air, sanitary sewer discharges, groundwater, surface water, rain, soil, sediment, vegetation, foodstuff, and direct radiation; evaluates possible contaminant sources; and models the impact of LLNL operations on humans and the environment. The monitoring activities in 2006 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 impact and that they are in compliance with regulatory requirements. Specifically, EPD helps LLNL programs manage and minimize hazardous, radioactive, and mixed wastes and identify opportunities for pollution prevention, including minimization of nonhazardous waste. EPD also determines the concentrations of environmental contaminants remaining from past activities, cleans up environmental contamination to acceptable standards, responds to emergencies to minimize and assess impact on the environment and the public, and provides training programs to improve the ability of LLNL employees to comply with environmental regulations.

EPD is divided into three divisions: Operations and Regulatory Affairs (ORAD), Radioactive and Hazardous Waste Management (RHWM), and Environmental Restoration (ERD).

### 3.1.1 Operations and Regulatory Affairs Division

ORAD specializes in environmental compliance and monitoring and provides LLNL programs with a wide range of information, data, and guidance to enable managers to make informed environmental decisions. Specifically, ORAD

- prepares 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 National Environmental Policy Act (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 P2 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
- develops new methods and innovative applications of existing technologies to improve environmental practices and assist LLNL in achieving its mission
- supports the development and implementation of EMS

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, seven days a week, and coordinate emergency response with the first responders and environmental specialists.

### **3.1.2 Radioactive and Hazardous Waste Management Division**

RHWM manages all hazardous, radioactive, and mixed wastes generated at LLNL facilities in accordance with local, state, and federal requirements. RHWM processes, stores, packages, treats, and prepares waste for shipment and disposal, recycling, or discharge to the sanitary sewer. As part of its waste management activities, RHWM tracks and documents the movement of hazardous, mixed, and radioactive wastes from waste accumulation areas (WAAs), which are typically located near the waste generator, to final disposition; develops and implements approved standard operating procedures; decontaminates LLNL equipment; ensures that containers for shipment of waste meet the specifications of the U.S. Department

of Transportation and other regulatory agencies; responds to emergencies; and participates in the cleanup of potential hazardous and radioactive spills at LLNL facilities. RHWMM prepares numerous reports, including the annual and biennial hazardous waste reports required by the California and U.S. Environmental Protection Agencies. RHWMM also prepares waste acceptance criteria documents, safety analysis reports, and various waste guidance and management plans.

RHWMM 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. The Legacy Waste program was officially completed in November 2005.

### **3.1.3 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 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 Comprehensive Environmental Response Compensation and Liability Act (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. Public workshops are held regularly, and information is provided to the public as required in the ERD CERCLA Community Relations Plans. CERCLA activities in 2006 are summarized in **Section 2.1 (Chapter 2)**. ERD's groundwater remediation activities in 2006 are described further in **Chapter 8**.

### **3.1.4 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 whether 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, seven days a week, to maximize efficient and effective emergency environmental response. Specialized EDO training includes simulated incidents to provide 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 working 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 EOG environmental analysts also notify and consult with program management and have seven-day-a-week, 24-hour-a-day access to the Office of Laboratory Counsel for questions concerning regulatory reporting requirements.

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

---

## **3.2 Integrated Safety Management System**

LLNL implements an Integrated Safety Management System (ISMS), which is 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” in this context is synonymous with environment, safety, and health and encompasses protection of the public, workers, and the environment, including pollution prevention and waste minimization. LLNL regards protection of the environment as an essential component of its overall safety management system.

The core requirements of the ISMS are based on DOE’s Seven Guiding Principles: (1) line management is responsible for safety, (2) roles and responsibilities are clear, (3) competence is commensurate with responsibilities, (4) priorities are balanced, (5) safety standards and requirements are identified, (6) hazard and environmental aspect controls are tailored to the work being performed, and (7) operations are authorized.

How LLNL manages and performs work can be described by DOE’s Five Core Functions: (1) define the scope of work, (2) analyze the hazards and environmental aspects, (3) develop and implement hazard and environmental aspect controls, (4) perform work within controls, and (5) provide feedback and continuous improvement.

In 2006, LLNL enhanced the environmental emphasis of the ISMS even further by upgrading from ISO 14001:1996, Environmental Management Systems (EMS), to ISO 14001:2004. ISO 14001 defines an EMS as that “part of the overall management system used to develop and implement its environmental policy and manage its environmental aspects.” 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 EMS with the objective of improving overall environmental performance.

An EMS that is based on these principles and functions results in accountability at all levels, project planning that includes environmental protection, and excellence in program execution. The ISMS 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 in effect at LLNL in 2006 was *Integrated Safety Management System Description, Version 8* (LLNL 2005) and is available at [http://www.llnl.gov/es\\_and\\_h/ism/ism-descriptionv8.pdf](http://www.llnl.gov/es_and_h/ism/ism-descriptionv8.pdf).

### **3.2.1 Work Smart Standards**

The Work Smart Standard (WSS) set is a comprehensive set of standards that are derived from statutes, regulations, DOE orders, University of California (UC) and LLNL policies, and industry work standards. An integral part of the LLNL ISMS, the WSS set establishes workplace ES&H controls and defines the ES&H requirements at LLNL. ES&H professionals at LLNL use WSSs to identify hazards and environmental aspects<sup>(a)</sup> and to establish standards of operation for specific work environments.

The original WSSs were selected using a process that included review and recommendation by LLNL and DOE subject matter experts. Currently, the WSS set is revised through a formal process managed by the WSS Change Control Board, which consists of representatives from DOE, UC, and LLNL. WSSs may need to be revised when DOE orders, regulations, and other applicable standards are issued or revised or as a result of the periodic review of the WSS set by LLNL subject matter experts to ensure that it is current and complete.

This environmental report was developed in accordance with the WSSs in place during 2006 in the DOE/UC/LLNL Prime Contract W-7405-ENG-48, Appendix G. In May 2007, DOE selected Lawrence Livermore National Security (LLNS), LLC, to manage the Laboratory. LLNS takes over the management of the Laboratory on October 1, 2007. At that time, the

---

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

requirements in the contract will change but should not have a significant impact on the requirements related to the preparation of this report.

### **3.2.2 Environmental Management System**

LLNL established its Environmental Management System (EMS) to meet the requirements of ISO 14001:1996, which was adopted by LLNL as a WSS in June 2004. LLNL self-declared its conformance with ISO 14001:1996 in December 2005. The National Nuclear Security Administration/Livermore Site Office (NNSA/LSO) subsequently validated LLNL's conformance with the condition that LLNL complete a corrective action plan (CAP) on 13 minor nonconformances. LLNL's completion of the CAP is described in **Section 3.2.6**. In 2006, LLNL began the process of upgrading its EMS to meet the requirements of ISO 14001:2004.

LLNL's 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 achieving continuous improvement in operational and environmental performance through P2 and other sustainable business tools.

#### **3.2.2.1 Overview and General Requirements**

The LLNL EMS is applicable to all on- and off-site activities, products, and services that LLNL 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 the management of environmental aspects in accordance with ISMS requirements. All LLNL organizations are responsible for supporting institutional environmental objectives and targets where appropriate, as well as for managing and reducing the negative impacts of significant environmental aspects that are specific to the organization and its work activities, products, and services. All LLNL environmental aspects and regulatory or other identified requirements are managed according to the *ES&H Manual*.

P2 is a critical part of the LLNL EMS. **Table 3-1** describes the connection between P2 and the elements of the EMS.

#### **3.2.2.2 Environmental Policy**

On July 22, 2004, the Laboratory Director issued LLNL's environmental policy, which was distributed to all LLNL employees. The policy is the basis on which the EMS was developed and is as follows:

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 has committed to

- work to continuously improve the efficient and effective performance of the EMS
- comply with applicable environmental laws and regulations
- incorporate pollution prevention, waste minimization, and resource conservation into the planning and decision-making processes
- ensure that interactions with regulators, DOE, and community are based on integrity, openness, and adherence to national security requirements
- establish appropriate environmental objectives and performance indicators to guide these efforts and measure progress (*ES&H Manual*, Document 1.2, ES&H Policies of LLNL, Section 3.0)

### 3.2.3 Identification of Significant Environmental Aspects and Their Impacts

The ISO 14001 standard requires the identification, determination of significance, and mitigation of environmental aspects to drive and measure improvements in environmental protection performance within work activities, products, and services. Significant

**Table 3-1.** Pollution prevention in LLNL's Environmental Management System.

<b>EMS Element</b>	<b>Connection to Pollution Prevention (P2)</b>
Environmental commitment and policy	P2 is included in LLNL's environmental policy signed by the Laboratory Director.
Planning	<p>P2 principles are assimilated into environmental planning and decision-making at the institutional and directorate levels.</p> <p>The P2 Opportunity Assessment (PPOA) is part of a process to identify significant aspects.</p> <p>PPOAs are also employed to evaluate EMS objectives, targets, and mitigation approaches in terms of environmental benefit and technical and economic feasibility.</p>
Implementation and operation	The P2 Team provides support to the EMS Team in project expertise, database interface, financial support identification, document preparation, self-assessments, interfacing with the community, and performance testing.
Checking and corrective action	Corrective actions are accomplished through return-on-investment 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	The P2 Team provides support for the self-assessment process and use of self-assessment reports in generating P2 documents.

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 an emphasis on those that are significant, is key to the success of an EMS. The initial set of significant environmental aspects were identified through the process described below.

#### **3.2.3.1 Identification of LLNL Activities, Products, and Services**

A comprehensive list of LLNL activities, products, and services was developed using several existing resources, beginning 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 and 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 integration work sheets (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) (U.S. DOE 2005), other ISMS environmental and safety documents, and LLNL personnel knowledge. The initial list of the activities, products, and services was evaluated further by LLNL program and facility personnel, as well as environmental analysts supporting those programs and facilities. In 2006, the list of activities, products, and services was reviewed and revised accordingly.

#### **3.2.3.2 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 section. 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 (see **Table 3-2**) was evaluated further by LLNL program and facility personnel and environmental analysts supporting those programs and facilities. Significant environmental aspects are discussed in **Section 3.2.3.4**. In 2006, the list of environmental aspects was reviewed, and there were no significant changes.

#### **3.2.3.3 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

**Table 3-2.** LLNL environmental aspects and the significant environmental aspects for calendar year 2006.

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

impacts associated with each aspect. In 2006, there were no major changes to the identified environmental impacts.

**3.2.3.4 Identification of Significant Environmental Aspects**

LLNL developed significance criteria that are used to identify which of the environmental aspects are significant. Development of the criteria included a consideration of both environmental and business factors, as recommended by ISO 14001:1996. See **Table 3-3**.

**Table 3-3.** Environmental and business factors used in the evaluation of environmental aspects (ISO 14001:1996 guidelines).

<b>Environmental factor</b>	<b>Business factor</b>
Scale of impact	Potential regulatory and legal exposure
Severity and duration of impact	Difficulty of changing impact
Frequency and probability of occurrence	Cost of changing impact Concerns of external and internal interested parties

In 2006, LLNL reviewed and updated its significance criteria to the ISO 14001:2004 guidelines. These criteria are slightly different from those in the ISO 14001:1996 guidelines, which included “ability and cost of change” and “operational and technical limitations.” Both of these criteria, however, are considered when setting environmental objectives and targets and are therefore not considered separately. The updated criteria include the following

seven factors: scale; severity and duration; frequency and probability; laws, regulations, and standards; controls; perceptions; and reuse and recycling opportunities. The updated factors and description of low, moderate, and high impacts are listed in **Table 3-4**. Scoring environmental aspects includes the following assumptions:

**Table 3-4.** LLNL environmental aspect significance criteria.

Criteria, Requirements, and Concerns	Factor	IMPACTS		
		Low	Moderate	High
<b>Environmental criteria</b>	Scale	Potential impact is localized to the work area or is limited to personnel involved in the work area; OR an accident could result in "Alert" emergency status on site.	Potential impact is contained within LLNL site boundaries; impacts Laboratory population only; OR an accident could result in "Site Area Emergency" on site.	Potential impact is not limited to LLNL sites; impacts surrounding community or region; OR an accident could result in "General Emergency" in surrounding communities.
	Severity and duration	No long-term impact; OR impact is self-remediating.	Impact is recoverable over a long period of time.	Impact is not recoverable or is permanent.
	Frequency and probability	Frequency of occurrence is low (i.e., 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).
<b>Applicable legal requirements</b>	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.
	Controls	No controls needed to mitigate impact.	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.
<b>Concerns of internal and external interested parties</b>	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.
	Reuse and recycling opportunities	Minimal or no resource depletion is expected; reuse, 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.

- 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

The specific assumptions used to score each LLNL environmental aspect were documented. LLNL's significant environmental aspects for the calendar year 2006 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.

### **3.2.4 Identifying and Managing Environmental Objectives and Targets**

ISO 14001:2004 requires the establishment and maintenance of documented environmental objectives and targets at relevant functions and levels within the organization. When establishing and reviewing its objectives and targets, 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 objectives and targets for its significant environmental aspects, the environmental performance indicators (metrics) that will be used to track each target, as well as the projected cost of implementation. Where appropriate, LLNL uses activities and programs that are already in place to achieve objectives and targets. When targets for measuring management of significant environmental aspects cannot be identified easily, 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. **Table 3-5** is a summary of the objectives for LLNL's significant environmental aspects. Targets are listed in **Appendix A**. In 2006, the list of objectives and targets were reviewed and there were no major changes.

### **3.2.5 Establishing and Maintaining Environmental Management Plans**

The objectives and targets for each significant environmental aspect are managed through an Environmental Management Plan (EMP), which assigns tasks and responsibilities for achieving environmental performance goals. The EMP Lead is responsible for collecting information and working with the appropriate LLNL directorate representative(s) to negotiate actions

**Table 3-5.** Significant environmental aspects and their objectives.

<b>Significant environmental aspect</b>	<b>Objective summary</b>
Ecological resource disturbance	<ul style="list-style-type: none"> <li>• Establish an LLNL policy prohibiting the introduction of exotic species</li> <li>• Educate LLNL employees about the consequences of exotic species introduction</li> <li>• Control exotic species, e.g., feral pig, largemouth bass</li> </ul>
Electrical energy use	<ul style="list-style-type: none"> <li>• Meet the objectives provided in DOE Order 430.2A, Departmental Energy and Utilities Management</li> <li>• Implement President's Initiative for Hurricane Relief (September 2005)</li> </ul>
Fossil fuel consumption/renewable energy use	<ul style="list-style-type: none"> <li>• Meet the DOE Vehicle Fleet Efficiency goal, in I.106 DEAR 970.5223-5</li> </ul>
Hazardous materials use	<ul style="list-style-type: none"> <li>• Prioritize hazardous materials used and perform PPOA to evaluate potential for reduction or substitution</li> </ul>
Mixed waste generation	<ul style="list-style-type: none"> <li>• Reduce the amount of mixed and California combined solid waste generated from routine LLNL programmatic operations when economically and technologically feasible</li> </ul>
Municipal waste generation	<ul style="list-style-type: none"> <li>• Maintain compliance with applicable regulatory requirements</li> <li>• Prevent/reduce waste generation and increase reuse/recycling of routine and nonroutine waste that would otherwise be disposed of at a municipal landfill</li> </ul>
Nonhazardous materials use	<ul style="list-style-type: none"> <li>• Incorporate affirmative procurement site-wide</li> <li>• Increase site-wide use of products with recycled content</li> </ul>
Radioactive material use	<ul style="list-style-type: none"> <li>• Conduct study to evaluate radioactive material impacts at LLNL and identify potential opportunities for reduction</li> </ul>
Transuranic waste generation	<ul style="list-style-type: none"> <li>• 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.</li> </ul>

to be incorporated in the EMP. Each EMP includes tasks with schedules, resources, operational controls, generated records, environmental performance indicators, monitoring and measurement, and task responsibility and authority. Where appropriate, documents that define operational controls applicable to the EMP (e.g., IWSs, studies, mitigations required by NEPA) are referenced. The EMP Lead works with the directorate representative(s) and the EMS Team when preparing the EMP.

The EMS Coordinator and the EMS Team review progress on each EMP annually (or more frequently if needed) and work with EMP Leads to revise EMPs as necessary. The EMS Coordinator and EMS Team ensure that new EMPs are developed and implemented as needed. In 2006, progress was made on the existing EMPs, including completion of studies (see **Appendix A**).

### **3.2.5.1 Directorate EMS Representatives**

In December 2006, the Director of LLNL issued a memo requiring that each directorate identify a representative to coordinate implementation of ISO 14001 within the directorate. The roles and responsibilities of the directorate representatives are to

- participate in EMS Team meetings and related activities
- work within their directorates to develop appropriate objectives, targets, and EMPs to achieve those targets
- integrate the ISO requirements into business/operational planning, as well as the continued integration into activity planning
- implement a means to measure and document successes in meeting the directorate's objectives and targets and track areas needing improvement within the directorate and provide reports on a periodic basis
- incorporate environmental considerations as a full partner in the directorate's decision-making process
- work with the EMS Team to review institutional procedures and representing the organization's perspective in the management of ISO responsibilities
- encourage directorate staff's environmental awareness

In 2007, the directorates will begin to incorporate ISO 14001:2004 within all relevant functions and levels of their organization.

### **3.2.5.2 Senior Management Review**

ISO 14001:2004 requires senior management reviews of the EMS at least annually (more frequently if needed). Each review must be comprehensive but not all elements of the EMS are required.

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

### **3.2.5.3 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, objectives and targets, and other elements of the EMS.

A senior management review was not conducted in 2006; it was postponed by the EMS Coordinator due to the initial implementation of the Laboratory's EMS and the desire to have the review coincide with the Directorates' annual self-assessments.

### **3.2.6 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 on November 9 and 10, 2005.

Subsequent to the internal audit, NNSA/LSO also conducted an independent audit of LLNL's existing EMS against the requirements specified in ISO14001:1996. The purpose of the audit was to fulfill the NNSA/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. The NNSA/LSO audit resulted in the following findings:

- 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)
- 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)

NNSA/LSO agreed to validate the self-declaration of LLNL's EMS upon submittal of a draft CAP that contained corrective actions specific to the minor nonconformances identified in the NNSA/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 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 NNSA/LSO and the draft CAP that was submitted.

During 2006, LLNL completed all but one of the corrective actions that address the minor nonconformances identified in the NNSA/LSO audit; the final item was completed in January 2007. In addition, LLNL submitted the ISO 14001:2004 standard to the WSS Change Control Board, and it was added as a WSS. Subsequently, LLNL began the process of updating the existing EMS to meet the requirements of the ISO 14001:2004 standard.

### **3.2.7 Path Forward**

During 2007, LLNL will continue to incorporate EMS at relevant functions and levels of the organization with the assistance of the newly appointed directorate EMS representatives. The representatives' goal is to develop directorate-specific environmental objectives and targets by April 2007 and begin implementation of the directorate-specific EMPs by September 1. LLNL will continue to work toward meeting its institutional-level environmental objectives and targets and will perform reviews and measurements to ensure they are appropriate and that progress is being made.

---

## **3.3 Pollution Prevention Program**

The LLNL Pollution Prevention (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 by the DOE/UC/LLNL 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 and facilitation of source reduction and/or reclamation, recycling, and reuse programs for hazardous and nonhazardous waste, facilitation of environmentally preferable procurement, preparation of P2 opportunity assessments, and development and management of high return-on-investment projects. LLNL's P2 Program is described in the *ES&H Manual*, Document 30.1, Managing Environmental Aspects Through Pollution Prevention.

The P2 Program at LLNL strives to systematically reduce solid, hazardous, radioactive, and mixed-waste generation, and to eliminate or minimize pollutant releases to all environmental media from all aspects of the operations at the Livermore site and Site 300. These efforts help protect public health and the environment by reducing or eliminating waste, improving resource usage, and reducing inventories and releases of hazardous chemicals. These efforts also benefit LLNL by reducing compliance costs and minimizing potential civil and criminal

**Table 3-6.** Routine hazardous and radioactive waste at LLNL, FY 2004–2006.

<b>Waste category</b>	<b>FY 2004</b>	<b>FY 2005</b>	<b>FY 2006</b>
Routine hazardous waste generated	141.3 MT	127 MT	153 MT
Routine low-level waste generated	151.3 m <sup>3</sup>	54 m <sup>3</sup>	66 m <sup>3</sup>
Routine mixed waste generated	18.8 m <sup>3</sup>	16 m <sup>3</sup>	18 m <sup>3</sup>
Routine TRU / mixed TRU waste generated	1.2 m <sup>3</sup>	1 m <sup>3</sup>	1 m <sup>3</sup>

liabilities under environmental laws. In accordance with Environmental Protection Agency (EPA) guidelines and DOE policy, the P2 Program uses a hierarchical approach to waste reduction (i.e., source elimination or reduction, material substitution, reuse and recycling, and treatment and disposal), which is applied, where feasible, to all types of waste. The P2 Team tracks waste generation using the HazTrack database. By reviewing the information in this database, program managers and P2 Team staff can monitor and analyze waste streams to determine cost-effective improvements to LLNL operations.

### **3.3.1 Routine Hazardous and Radioactive Waste**

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 LLNL. Periodic laboratory or facility clean-outs and spill cleanups as a result of these processes are also considered normal operations. Residues, resulting from the treatment of routine waste, are not included to avoid double counting.

### **3.3.2 Diverted Waste**

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

#### **3.3.2.1 Routine Nonhazardous Waste**

Together, the Livermore site and Site 300 generated 4107 metric tons (MT) of routine nonhazardous solid waste in fiscal year (FY) 2006. This volume includes diverted waste (e.g., material diverted through recycling and reuse programs) and landfill waste.

Both sites diverted a combined total 2601 MT of routine nonhazardous waste in 2006, which represents a diversion rate of 63%. The diverted routine nonhazardous waste includes waste recycled by RHW and materials diverted through the surplus sales program. The portion of routine nonhazardous waste sent to landfill was 1506 MT. See **Table 3-7**.

#### **3.3.2.2 Nonroutine Nonhazardous Waste**

Nonroutine nonhazardous solid wastes include excavated soils, wastes and metals from construction, and decontamination and demolition activities. The Livermore site and Site 300

**Table 3-7.** Routine nonhazardous waste in FY 2006, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2006 (in MT)
Diverted	Batteries, small <sup>(a)</sup>	1
	Batteries, lead-acid <sup>(a)</sup>	31
	Beverage containers	5
	Cardboard	135
	Compost	504
	Cooking grease	2
	Magazines, newspapers, phone books	19
	Metals	1412
	Paper	207
	Street sweepings	93
	Tires and scrap	20
	Toner cartridges	12
	Wood	160
	<b>TOTAL diverted</b>	
Landfill	Compacted (landfill)	1506
	<b>TOTAL landfill</b>	
<b>TOTAL routine nonhazardous waste</b>		<b>4107</b>

(a) Batteries are managed as universal waste.

**Table 3-8.** Nonroutine nonhazardous waste in FY 2006, Livermore site and Site 300 combined.

Destination	Waste description	Amount in FY 2006 (in MT)
Diverted	Class II cover (soil reused at landfill)	1234
	Asphalt/concrete	10,545
	Nonroutine metals	2544
	<b>TOTAL diverted</b>	
Landfill	Construction demolition (noncompacted landfill)	1502
	Industrial (HazTrack) <sup>(a)</sup>	159
	Non-friable asbestos	8
<b>TOTAL landfill</b>		<b>1669</b>
<b>TOTAL nonroutine nonhazardous waste</b>		<b>15,992</b>

(a) RHWM Waste Data Management Systems

generated a total of 15,992 MT of nonroutine nonhazardous solid waste in 2006.

In FY 2006, 14,323 MT of nonroutine nonhazardous solid waste was diverted through reuse or recycling, which represents a diversion rate of 90%. Diverted nonroutine nonhazardous solid waste includes soil reused either on site for other projects or as cover soil at Class II landfills, and metals recycled through the metals recycling programs. Only 10% of nonroutine nonhazardous waste was sent to landfill. See **Table 3-8**.

### 3.3.3 Pollution Prevention Activities

In December 2006, NNSA/Headquarters selected one project at the Livermore site and one project at Site 300 to receive P2 awards. Both projects received NNSA Best-In-Class awards, and the Site 300 project was recommended for submittal to the White House 2006 Closing-the-Circle (CTC) competition. The CTC program recognizes outstanding efforts and achievements of federal employees and their facilities in promoting environmental stewardship.

The Livermore site Best-in-Class award was categorized as Official Use Only and was recognized only at the NNSA level due to the classified subject matter.

The Site 300 Best-in-Class award recognized four recent measures that resulted in significant reductions in water use through recycling, environmental conservation, and improved efficiency of operations. Overall, the project saved about 9.7 million gallons a year (gal/yr), representing 41% of the total average water use at Site 300. The project also saved over 68,000 kilowatt-hours (kWh) in electric power annually from reduced pumping activities.

The first measure involved implementing a series of innovative approaches to water use and recycling at the Contained Firing Facility. These efforts save nearly 100,000 gal/yr of potable water through recycling. These improvements also reduced the amount of solid waste generated by 67% from the previous year.

The second measure saved 5790 kWh in electric power from pumping activities by replacing two nonhazardous wastewater impoundments with surface storage tanks.

A third measure focused on rehabilitating selected areas as wetlands, allowing the site to discontinue maintenance of an artificial wetland. This saves approximately 8 million gal of potable water annually and 58,780 kWh/yr of electric power used for pumping. The California red-legged frog, a federally threatened species, is thriving in the rehabilitated in-stream pool habitats created in Elk Ravine, validating the project's success.

A fourth measure, replacing four cooling towers with closed loop-systems, resulted in a recurring annual savings of 3590 kWh of electric power.

These combined efforts represent proper stewardship of Site 300 environmental resources, improved operations and a cost-effective approach to regulatory compliance. Each action provides for lasting impacts by reducing or eliminating potable water usage and wastewater discharges.

Another water savings project was implemented at the Livermore site during FY 2006. This involved the installation of a waterjet equipped with a water recycling system. The waterjet cutting system was selected to replace existing labor-intensive cutting equipment, such as lathes, milling equipment, and saws. The water recycling unit was installed in conjunction with the waterjet equipment as a proactive P2 effort, potentially saving over 40,000 gal/yr.

### **3.3.4 Review of New Processes, Programs, or Experiments**

During 2006, a significant portion of the P2 Team effort was in support of the planning and implementation of LLNL's EMS. See **Table 3-1** for an overview of the interrelationship between P2 and the EMS. The EMS Team included representatives from Pollution Prevention; their efforts during 2006 are described in **Section 3.2.2**.

### **3.3.5 Pollution Prevention Employee Training and Awareness Programs**

In 2006, 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. The 2006 focus was "Environmental Stewardship of LLNL." An array of on-site organizations presented posters to increase LLNL staff awareness of the environmental functions carried out by EPD, Business Services, and the Energy Management Program. The P2 Team also participated in the on-site Environmental, Health, and Safety Fair in June.

The P2 team also conducts other awareness activities during the year. Articles on pollution prevention appeared in *Newsline* (the LLNL newspaper) and *NewsOnLine* (the LLNL electronic newsletter). 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.

The P2 Team maintains an internal P2 website for LLNL employees. The website is a resource for employees regarding pollution prevention, energy efficiency, reuse and recycling of materials, green building, and other environmental topics. Employees can also use the site to suggest P2 ideas, ask questions about P2 planning and implementation, and find out about P2 current events. The P2 Team also operates the Earth Hotline for employees to call with questions, suggestions, or ideas regarding LLNL's pollution prevention and waste diversion endeavors.

**Contributing Authors**

*Lily Baldwin, Bruce Campbell, Li-Yang Chang, Jennifer Doman, Patrick Epperson, Katharine Gabor, C. Susi Jackson, Hank Khan, Judy Steenhoven*

**Kent Wilson**

*Steven Cerruti*

*S. Ring Peterson*

## 4.1 Air effluent monitoring

- 4.1.1 Methods
- 4.1.2 Air effluent radiological monitoring results
- 4.1.3 Nonradiological results
- 4.1.4 Impact of air effluent and nonradiological releases on the environment

## 4.2 Ambient air monitoring

- 4.2.1 Sampling locations
- 4.2.2 Sample collection and analysis
- 4.2.3 Results
- 4.2.4 Environmental impact of ambient air



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 Part 61* (40 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).

LLNL conducts air effluent monitoring of atmospheric discharge points to measure the quantity of radionuclides released from individual facilities during routine and nonroutine operations. LLNL also conducts ambient air monitoring at on- and off-site locations to determine whether airborne radionuclides or beryllium are being released to the environs in measurable quantities by LLNL operations. Ambient air monitoring also serves to verify the air concentrations predicted by air dispersion modeling and to determine compliance with NESHAPs regulations. See Larson et al. (2007).

---

## 4.1 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. A number of facilities at the Livermore site have air effluent samplers to detect the release of tritium, uranium, and transuranic aerosols. The air effluent samplers 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 nonroutine operations and to confirm the operation of facility emission control systems. Air effluent and ambient air monitoring measurements are compared to confirm their expected relationship and to help resolve unexpected ambient air monitoring results when necessary. 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 and gas 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. For LLNL operations with nonradiological discharges, LLNL obtains permits from local air districts (i.e., BAAQMD and SJVAPCD) when applicable. Current permits do not require monitoring of air effluent but do require monitoring of equipment usage, material usage, and record keeping during operations. Based on air toxics emissions inventory and risk assessment required by the California Air Toxics “Hot Spots” Information and Assessment Act of 1987, BAAQMD and SJVAPCD have ranked LLNL as a low-risk facility for nonradiological air emissions.

### 4.1.1 Methods

LLNL evaluates all discharge points with the potential to release radionuclides to the air according to 40 CFR Part 61, Subpart H, of the NESHAPs regulations. Subpart H regulations require continuous monitoring of facility radiological air effluents if the potential off-site dose

**Table 4-1.** Air effluent sampling locations, analytes, sampler types, and number of samplers at the Livermore site and Site 300 in 2006.

Site	Facility	Analytes	Sampler type	No. of samplers
Livermore site	Chemistry, Materials, and Life Sciences	Gross $\alpha$ , $\beta$ on particles	Filter	1
	Heavy Element Facility	Gross $\alpha$ , $\beta$ on particles	Stack CAM <sup>(a,b)</sup>	2
		Gross $\alpha$ , $\beta$ on particles	Filter	28
	Tritium Facility	Tritium	Stack ionization chamber <sup>(a)</sup>	4
		Gaseous tritium and tritiated water vapor	Molecular sieves	2
			Glycol bubbler	2
	Plutonium Facility	Gross $\alpha$ , $\beta$ on particles	Stack CAM <sup>(a,b)</sup>	12
		Gross $\alpha$ , $\beta$ on particles	Filter	15
	Laser Isotope Separation Facility <sup>(c)</sup>	Gross $\alpha$ , $\beta$ on particles	Filter	1
	Decontamination and Waste Treatment Facility	Gross $\alpha$ , $\beta$ on particles	Filter	1
Gaseous tritium and tritiated water vapor		Glycol bubbler	1	
Site 300	Contained Firing Facility	Gross $\alpha$ , $\beta$ on particles	Filter	1

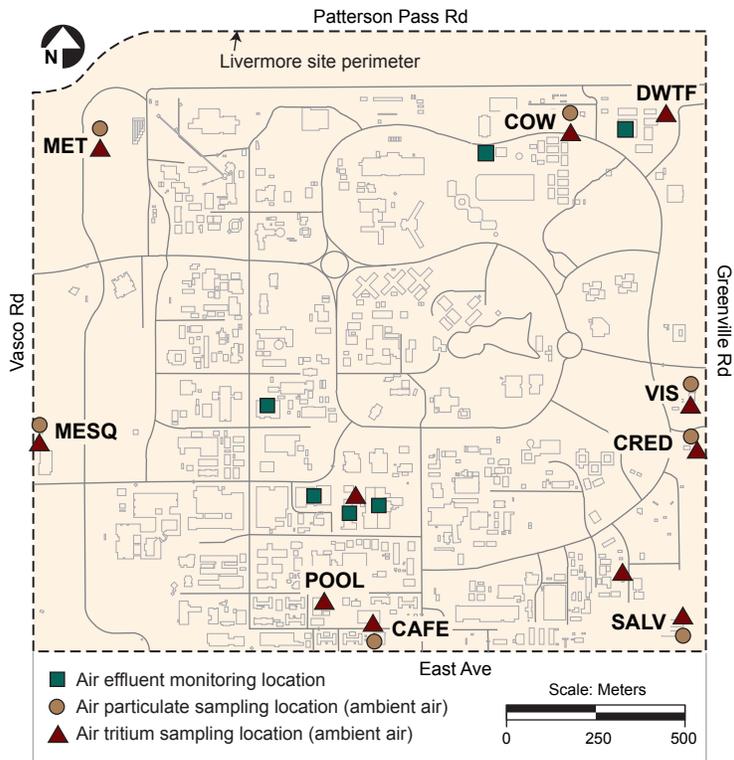
(a) Alarm systems (real-time).

(b) CAM = Eberline continuous air monitor (real-time).

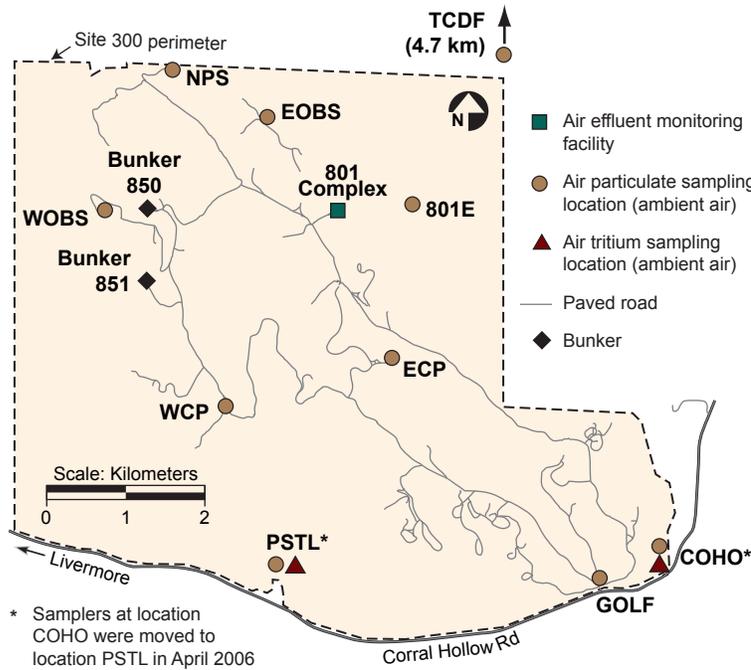
(c) Isotopic separation operations have been discontinued; area now used for storage of contaminated parts.

equivalent is greater than 1 microsievert per year ( $\mu\text{Sv}/\text{y}$ ) (0.1 millirem per year [mrem/y]), as calculated using the EPA-mandated air dispersion dose model and assuming there are no emission control devices. Results of monitoring air discharge points provide the actual emission source information for modeling, which is used to ensure that the NESHAPs standard, 100  $\mu\text{Sv}/\text{y}$  (10 mrem/y) total site effective dose equivalent, is not exceeded (see **Chapter 7** for further information on radiological dose assessment). 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 the doses are ALARA.

In 2006, LLNL measured releases of radioactivity from air exhausts at six facilities at the Livermore site and at one facility at Site 300. The Livermore site has a total of 69 samplers and Site 300 has one. **Table 4-1** lists the facilities, analytes, sampler type, and number of samplers at each facility. Air monitoring locations at the Livermore site and Site 300 are shown in **Figures 4-1** and **4-2**, respectively. LLNL periodically reassesses the need for continuous monitoring at these facilities and also assesses new operations or changes in operations for the need for continuous monitoring.



**Figure 4-1.** Air effluent and ambient air monitoring locations at the Livermore site, 2006.

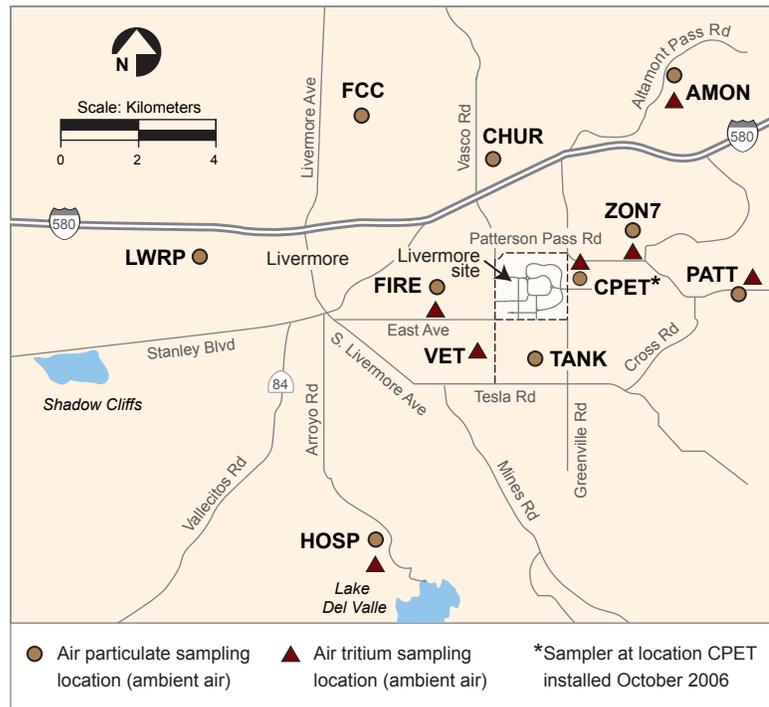


**Figure 4-2.** Air effluent and ambient air monitoring locations at Site 300, 2006.

Sampling for radioactive particles was conducted in all facilities except the Tritium Facility, where only tritium was measured. Both radioactive particulates and tritium were sampled at the Decontamination and Waste Treatment Facility (DWTF). 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.

In addition to continuous samplers 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 were reported as a measured concentration per volume of air or as less than the minimum detectable concentration (MDC) when no activity was detected. In all cases, the MDC was more than adequate for demonstrating compliance with the pertinent regulatory requirements for radionuclides that may be or are present in the sampled air. Air effluent samples were obtained in accordance with written, standardized procedures that are summarized in Woods (2005).

To establish the background levels of gross alpha and beta activity that are used to determine whether a particulate release has occurred from monitored stacks, LLNL operated three low-volume radiological air particulate samplers at locations HOSP and FCC in the Livermore Valley (see **Figure 4-3**) and at location NPS at Site 300 (see **Figure 4-2**). These samplers



**Figure 4-3.** Air particulate and tritium sampling locations in the Livermore Valley, 2006.

collected particulate on membrane filters at a continuous rate of 0.03 cubic meters per minute ( $\text{m}^3/\text{min}$ ).

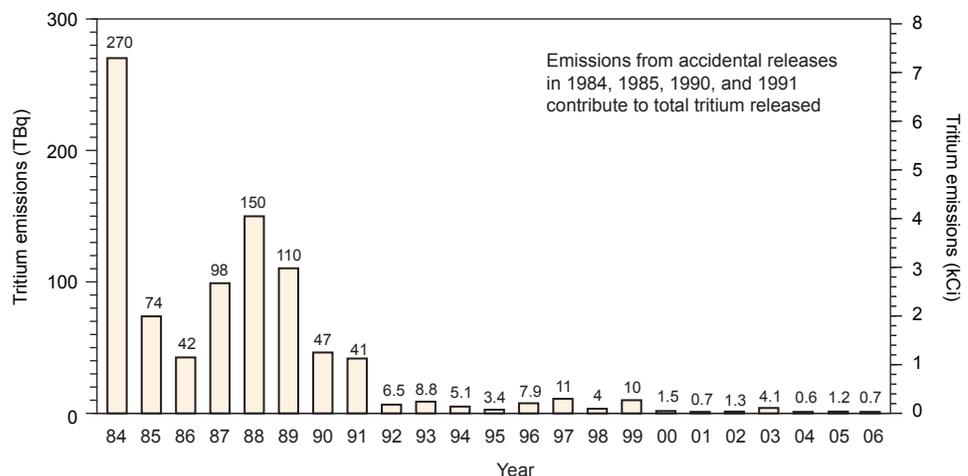
The following sections discuss the radiological air emissions from facilities that have continuously monitored discharge points. All effluent air analytical results are summarized in **Appendix B, Section B.1**.

#### 4.1.2 Air Effluent Radiological Monitoring Results

In 2006, a total of 0.67 terabecquerel (TBq) (18 curie [Ci]) of tritium was released from the Tritium Facility. Of this, approximately 0.41 TBq (11 Ci) was released as tritiated water vapor (HTO). The remaining released tritium, 0.26 TBq (7.1 Ci), was gaseous tritium (HT). The highest single stack emission occurred over a two-week sample interval and was 0.16 TBq (4.2 Ci), of which approximately 85% was HTO. Emissions from the Tritium Facility for 2006 continued to remain considerably lower than those during the 1980s. **Figure 4-4** illustrates the combined HTO and HT emissions from the facility over the last 23 years.

Continuous monitoring of the stack effluent of the DWTF for the potential release of tritium began in February 2005. In 2006, a total of  $1.0 \times 10^{-4}$  TBq (2.8 millicurie [mCi]) of measured tritium was released as HT. There were no reportable HTO emissions from the DWTF in 2006. Similar to the previous year, the tritium emissions from the DWTF were more than 100 times below the level of regulatory requirement for monitoring. The monitoring is in place as part of a best management practice and also for potential tritium waste from planned activities at the National Ignition Facility intended for treatment at the DWTF.

In 2006, most results from the continuously sampled discharge points that have the potential for releasing particulate radionuclides were below the MDC of the gross alpha and gross beta analysis. Some sampling systems exhibited 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 sampling systems sometimes sample air from the atmosphere in addition to HEPA-filtered air from facility



**Figure 4-4.** Tritium Facility combined HTO and HT emissions for the last 23 years (1984–2006).

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. Additionally, ambient monitoring locations are placed upwind from the site and are used to demonstrate comparable results to effluent alpha and beta detections. 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 affected significantly.

None of the facilities monitored for gross alpha and gross beta had reportable emissions in 2006.

#### 4.1.3 Nonradiological Results

In 2006, the Livermore site emitted approximately 141 kilograms per day (kg/day) of regulated air pollutants as defined by the Clean Air Act, including nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>), particulate matter (PM-10), carbon monoxide (CO), and reactive organic gases/precursor organic compounds (ROGs/POCs) (see **Table 4-2**). The stationary emission sources that released the greatest amount of regulated pollutants at the Livermore site were natural gas fired boilers, internal combustion engines (such as diesel generators), solvent cleaning,

and surface coating operations (such as painting). In 2006, the ROGs/POCs emissions from the Livermore site decreased a significant 8.8 kg/day from 2005 due primarily to the intentional elimination of several ROGs/POCs solvent cleaning operations, as well as the active substitution of solvents, paints, and adhesives with reduced concentrations of ROGs/POCs constituents.

LLNL air pollutant emissions were very low in 2006 compared to the daily releases of air pollutants from all sources in the entire Bay Area. For example, the average daily emission of NO<sub>x</sub> in the Bay Area was approximately  $4.52 \times 10^5$  kg/day, compared to the estimated daily release from the Livermore site of 67.2 kg/day,

which is 0.015% of total Bay Area source emissions for nitrogen oxides. The 2006 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was  $3.35 \times 10^5$  kg/day, while the daily emission estimate for 2006 from the Livermore site was 16.1 kg/day, or 0.005% of the total Bay Area source emissions for ROGs/POCs.

Certain operations at Site 300 require permits from the SJVAPCD. The estimated daily air pollutant emissions during 2006 from operations (permitted and exempt stationary sources) at Site 300 are listed in **Table 4-2**. The stationary emission sources that release the greatest

**Table 4-2.** Nonradioactive air emissions, Livermore site and Site 300, 2006.

Pollutant	Estimated releases (kg/day)	
	Livermore site	Site 300
ROGs/POCs	16.1	0.44
Nitrogen oxides	67.2	1.20
Carbon monoxide	50.3	0.27
Particulates (PM-10)	5.4	0.32
Sulfur oxides	1.6	0.15
Total	140.6	2.48

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. Combustion pollutant emissions, such as NO<sub>x</sub>, CO, and SO<sub>x</sub>, increased at Site 300 in 2006 primarily from the operations of five emergency stand-by diesel generators (at approximately 12 hours each for the year) during unplanned electrical power outages.

#### **4.1.4 Impact of Air Effluent and Nonradiological Releases on the Environment**

In 2006, 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  $1.4 \times 10^{-2}$   $\mu\text{Sv}/\text{y}$  ( $1.4 \times 10^{-3}$  mrem/y), and the dose from DWTF (modeling HT emissions as HTO) was  $8.7 \times 10^{-6}$   $\mu\text{Sv}/\text{y}$  ( $8.7 \times 10^{-7}$  mrem/y). As shown in **Chapter 7**, the estimated radiological dose caused by measured air emissions from LLNL operations was minimal.

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

---

## **4.2 Ambient Air Monitoring**

LLNL monitors ambient air to determine whether radionuclides or beryllium are being released by Laboratory operations, what the concentrations are, and what the trends in the environs are. Beryllium is the only nonradiological emission from LLNL that is monitored in ambient air. LLNL requested and was granted a waiver by the BAAQMD for source-specific monitoring and record keeping for beryllium operations, provided that LLNL can demonstrate that monthly average beryllium concentrations in air are well below regulatory limits of 10,000 picograms per cubic meter (pg/m<sup>3</sup>) 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) 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 millisievert per year (mSv/y) (100 mrem/y) effective dose equivalent. The data tables in **Appendix B** that are referred to in this chapter present the DCG and the percentage of the DCG for the given isotope.

#### 4.2.1 Sampling Locations

Monitoring networks are established for air surveillance of radioactive particulates, HTO, and beryllium. Sampling locations for each monitoring network are listed in **Table 4-3** and shown in **Figures 4-1, 4-2, and 4-3**. The particulate and tritium sampling systems in 2006 were:

- particulate samplers: Livermore site (7), Livermore Valley (10), Site 300 (8), just west of the outskirts of Tracy (1)
- tritium samplers: Livermore site (11), Livermore Valley (7), Site 300 (1)

The above total number of samplers include the following additions and changes:

- samplers for particulate (1) and tritium (1) at location CPET in the Livermore Valley, installed October 2006
- one sampler each for particulate and tritium moved in April 2006 from location COHO to location PSTL (Site 300)

Beryllium is monitored at six 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 three on-site locations and one off-site location north of Site 300. All monitoring networks use continuously operating samplers.

Air sampling locations are grouped into the following categories: site perimeter, upwind, downwind, diffuse sources on site, 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.

#### 4.2.2 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<sup>3</sup>/min, and samples are collected weekly.

Tritium samplers, operating at a flow rate of 500 cubic centimeters per minute (cm<sup>3</sup>/min), draw air through sampling flasks containing silica gel that absorbs the air moisture. The 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

**Table 4-3.** Ambient air sampling locations with type and frequency of analysis at the Livermore site and Site 300, 2006.

Site	Location	Target location	Ambient air analysis frequency and type				
			Network: Air particulate Collection medium: Cellulose filter			Network: HTO Collection medium: Silica gel	
			Weekly gross $\alpha$ , $\beta$ (high volume)	Monthly $^{239+240}\text{Pu}$	Monthly $\gamma$ and $^{235}, ^{238}\text{U}$ (a)	Monthly beryllium	Biweekly tritium
Livermore site	SALV, MET, MESQ, COW, CAFE, VIS <sup>(b)</sup>	On site	X	X	X	X	X
	DWTF, POOL	On site					X
	Tritium Facility, B624	Diffuse/on site					X
	CRED <sup>(b)</sup>	SW-MEI <sup>(c)</sup>	X	X			X
	ZON7, PATT, AMON, CPET	Downwind	X	X			X
	CHUR, FCC <sup>(d)</sup> , TANK	Upwind	X	X			
	FIRE, HOSP <sup>(d)</sup>	Upwind	X	X			X
	VET	Upwind					X
	LWRP	Historical interest	X	X			
				Monthly $\gamma$ and $^{239+240}\text{Pu}$ (a)	Monthly $^{235}, ^{238}\text{U}$		
Site 300	EOBS, GOLF, 801E	On site <sup>(b)</sup>	X	X	X	X	
	ECP, WCP, NPS <sup>(d)</sup> , WOBS	On site <sup>(b)</sup>	X	X	X		
	COHO <sup>(e)</sup> , PSTL	On site <sup>(b)</sup>	X		X		X
	TCDF	Off site	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 for 2006.

(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.

(e) Samplers at location COHO were moved to location PSTL in April 2006 due to difficult access at PSTL (see **Figure 4.2**).

during the sampling process. Ambient air samples are obtained in accordance with written, standardized procedures that are summarized in Woods (2005).

An LLNL state-certified analytical laboratory performs 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 Woods (2005). Beryllium concentration is determined by inductively coupled plasma-mass spectrometry. See **Table 4-3** 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. Because plutonium is not used at Site 300, a composite from all locations is analyzed.

Emissions from uranium use at the Livermore site are 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.

### **4.2.3 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. Radionuclides known to be released from a facility must be analyzed for specifically; at LLNL the radionuclides are plutonium, uranium, and tritium. 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 listed in **Appendix B, Section B.2**.

#### **4.2.3.1 Gross Alpha and Gross Beta Concentrations**

The primary sources of alpha and beta activities are naturally occurring radioisotopes. Routine isotopic gamma results of site composite samples indicate the activities are the result of naturally occurring isotopes (uranium, thorium, potassium, and lead), which are also routinely found in local soils.

The gross alpha activity (annual median value) in 2006 was as follows:

- Livermore site perimeter: 14 microbecquerels per cubic meter ( $\mu\text{Bq}/\text{m}^3$ ) (0.38 femtcurie per cubic meter [ $\text{fCi}/\text{m}^3$ ])
- upwind and downwind Livermore Valley stations: 14  $\mu\text{Bq}/\text{m}^3$  (0.38  $\text{fCi}/\text{m}^3$ )
- Site 300: 14  $\mu\text{Bq}/\text{m}^3$  (0.38  $\text{fCi}/\text{m}^3$ )

The gross beta activity (annual median value) in 2006 was as follows:

- all upwind and downwind locations: 273  $\mu\text{Bq}/\text{m}^3$  (7.4  $\text{fCi}/\text{m}^3$ )
- Livermore site perimeter: 251  $\mu\text{Bq}/\text{m}^3$  (6.8  $\text{fCi}/\text{m}^3$ )
- Site 300: 304  $\mu\text{Bq}/\text{m}^3$  (8.2  $\text{fCi}/\text{m}^3$ )

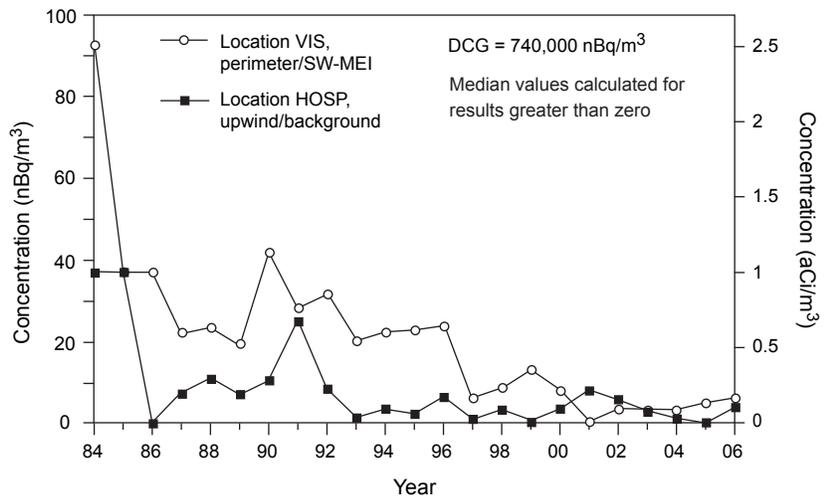
These values are all typical annual median values. All ambient air analytical results are summarized in **Appendix B, Section B.2**.

#### 4.2.3.2 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 above-ground 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. The isotopes 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 in 2006. The results are within known background levels.

#### 4.2.3.3 Plutonium Concentrations

Environmental plutonium-239+240 activity for the past 23 years is shown in **Figure 4-5**. Locations HOSP and VIS represent typical upwind and on-site 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.



**Figure 4-5.** Calculated annual median concentrations of plutonium-239+240 at locations VIS and HOSP for the past 23 years (1984–2006).

Plutonium-239+240 was detected in 3 of the 195 samples tested in Livermore area air samples in 2006; 2 of the positive samples came from on-site samplers. The highest recorded on-site plutonium-239+240 detection of 26 nanobecquerels per cubic meter (nBq/m<sup>3</sup>) (0.70 attocurie per cubic meter [aCi/m<sup>3</sup>]) was at location CRED and was 0.0035% of the DCG (see **Section 4.2** for a description of DCGs), while the highest off-site plutonium value of 12 nBq/m<sup>3</sup> (0.32 aCi/m<sup>3</sup>) was recorded at location FCC and was 0.0016% of the DCG. Plutonium was detected in 3 of the 12 composite samples collected from Site 300 with the highest detection of 17 nBq/m<sup>3</sup> (0.46 aCi/m<sup>3</sup>), which was 0.0023% of the DCG. See **Appendix B, Section B.2**.

#### **4.2.3.4 Uranium Concentrations**

Uranium ratios are used to determine the type of uranium present in the environment. Natural uranium (NU) has a mathematical uranium-235/uranium-238 ratio of 0.00725, and depleted uranium (DU) has a uranium-235/uranium-238 ratio of 0.002. Uranium isotopes are naturally occurring.

In 2006, all of the uranium-235 and uranium-238 samples had positive detections for both the Livermore site and Site 300. The Livermore site monthly composites had a uranium-235 median concentration of 0.12 pg/m<sup>3</sup> (0.00026% of the DCG; see **Section 4.2** for a description of DCGs) and a uranium-238 median concentration of 17 pg/m<sup>3</sup> (0.0057% of the DCG). The uranium-235/uranium-238 median ratio was 0.0073, which is considered NU and typical of what has been recorded in the past.

For all Site 300 on-site locations, the annual median uranium-235 concentration was 0.15 pg/m<sup>3</sup> (0.00032% of the DCG) and the uranium-238 median concentration was 27 pg/m<sup>3</sup> (0.009% of the DCG). The annual median for the uranium-235/uranium-238 ratio for all Site 300 locations was 0.0071, which is indicative of NU.

In 2006, seven DU atmospheric shot experiments were conducted on Site 300 at Bunker 851. In March, the sampling station TCDF, located 4.7 kilometers (km) off site in Tracy (see **Figure 4-2**), had a uranium-235/uranium-238 isotopic ratio of 0.0058. This ratio corresponds to approximately 72% NU and 28% DU. The measured concentration of uranium-235 during March was 0.11 pg/m<sup>3</sup> (0.00023% of the DCG), and the measured concentration of uranium-238 was 18.9 pg/m<sup>3</sup> (0.0063% of the DCG).

The measurements at on-site locations at Site 300 in March also indicated the presence of DU. The median uranium-235/uranium-238 isotopic ratio of these locations during March was 0.0042, or approximately 41% NU and 59% DU. The highest measured uranium-235 value was 0.53 pg/m<sup>3</sup> (0.0011% of the DCG), and the highest measured uranium-238 value was 246 pg/m<sup>3</sup> (0.082% of the DCG). Both values were from the 801E sample location.

However, the highest measured uranium-235 concentration for the off-site TCDF location in 2006 occurred in July and was 0.65 pg/m<sup>3</sup> (0.0014% of the DCG), and the highest uranium-238 concentration also occurred in July and was 88 pg/m<sup>3</sup> (0.029% of the DCG). The uranium-235/uranium-238 isotopic ratio for July at the TCDF location was 0.0074 and

is indicative of NU from resuspension of naturally occurring uranium in soil (there were no atmospheric DU shots at Site 300 in July 2006). This illustrates that the potential dose from the small amount of DU present in March at TCDF is actually less than the potential dose at the same location from NU in July.

The highest measured uranium-235 value for all on-site sampled locations at Site 300 in 2006 was 0.82 pg/m<sup>3</sup> (0.0017% of the DCG) at location WCP in January. The highest measured uranium-238 value was 246 pg/m<sup>3</sup> (0.082% of the DCG) at 801E in March. See **Appendix B, Section B.2.**

#### 4.2.3.5 Tritium Concentrations

**Table 4-4** is a summary of the biweekly data for tritium in air that are provided in **Appendix B, Section B.2.** (Inhalation doses, calculated for each ambient air tritium monitoring location, are included in **Appendix B, Section B.2.**) Locations (see **Figures 4-1, 4-2, and 4-3**) are grouped by expected concentrations of tritium. In 2006, the highest concentrations of tritium were found near area (diffuse) sources near the Tritium Facility and in the Building 612 yard on the Livermore site. Area sources include stored containers of tritium waste or tritium-contaminated equipment from which HTO diffuses into the atmosphere. Concentrations at the area source monitored at the Tritium Facility were higher and more variable in 2006 than in recent years because of the ongoing cleanup of the Tritium Facility.

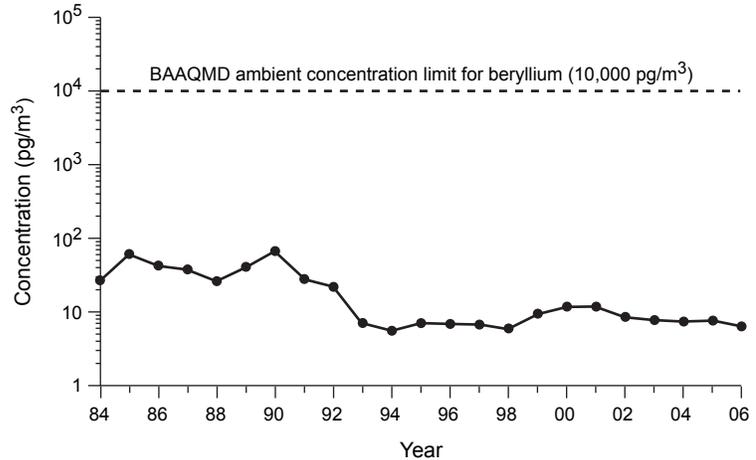
Air concentrations measured at sampler locations near the Livermore site perimeter were the next highest after those near diffuse sources; the concentrations near the perimeter were, on average, less than 5% of those near the diffuse sources. Location CAFE exhibited the highest biweekly concentration of the perimeter locations. This concentration was correlated with a release from the Tritium Facility when winds were blowing towards the CAFE sampler. Median concentrations for 2006 for perimeter locations were somewhat lower than in 2005. The effect of lower emissions from the Tritium Facility in 2006 compared with 2005 was seen particularly at locations VIS and CRED, which are downwind.

**Table 4-4.** Tritium in air samples at on- and off-site locations, 2006.

Sampling locations	Detection frequency	Concentration (mBq/m <sup>3</sup> )				Median percent of DCG <sup>(a)</sup>
		Mean	Median	IQR	Maximum	
Diffuse on-site sources	50 of 50	2940	802	1120	36,900	0.022%
Livermore site perimeter <sup>(b)</sup>	170 of 231	54.3	34.5	56.6	1150	0.00093%
Livermore Valley	50 of 161	9.27	7.62	18.4	62.2	0.00021%
Site 300	7 of 26	7.83	3.36	15.1	65.1	0.000091%

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

(b) Locations COW, DWTF, MET, and POOL are not strictly on the perimeter of the site.



**Figure 4-6.** Median concentration of beryllium in air particulate samples taken at the Livermore site perimeter over the last 23 years (1984–2006).

All of the median concentrations in the Livermore Valley and at Site 300 were below the MDC in 2006 (see **Table 4-4** and **Appendix B, Section B.2**). 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 MDC. Similarly, because no operations at Site 300 released tritium to the environment in 2006, concentrations at locations COHO or PSTL are expected to be below the MDC. Detections that occurred at these sampling locations are artifacts of scintillation counting with a high counter background.

#### 4.2.3.6 Beryllium Concentrations

LLNL measures the monthly concentrations of airborne beryllium at the Livermore site, Site 300, and the off-site sampler north of Site 300 (see **Appendix B, Section B.2**). The highest value at the Livermore site in 2006 for airborne beryllium was 20 pg/m<sup>3</sup>, which was recorded at two locations, CAFE and VIS, both in October. This value is only 0.20% of the BAAQMD ambient concentration limit for beryllium (10,000 pg/m<sup>3</sup>). These data are similar to data collected from previous years.

**Figure 4-6** is a plot of the median beryllium concentrations at the Livermore site perimeter over the last 23 years (1984–2006). The decrease in 1993 and the slight increase in 1999 are likely the result of a change in the analytical laboratory used to perform the 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<sup>3</sup>. The highest value for Site 300 area sampling occurred at the off-site location TCDF in October with a value of 29 pg/m<sup>3</sup>.

#### 4.2.4 Environmental Impact of Ambient Air

LLNL operations involving radioactive materials had minimal impact on ambient air during 2006. 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 the Tritium Facility and the Building 612 yard had a small, localized effect with no direct 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. Furthermore, doses calculated from air concentrations at the perimeter will be higher than any dose that could be received by a member of the public. Both mean and median annual concentrations of tritium in the Livermore Valley and at Site 300 were all well below MDCs. For a location at which the mean concentration is at or below the MDC, inhalation dose from tritium is assumed to be less than 5 nanosievert per year (nSv/y) (0.5 microrem per year [ $\mu\text{rem}/\text{y}$ ]) (i.e., the annual dose from inhaling air with a concentration at the MDC of about  $25 \text{ mBq}/\text{m}^3$  [ $0.675 \text{ pCi}/\text{m}^3$ ]).

Two Livermore site locations have public access during working hours (CRED and VIS). If it were assumed that a member of the public inhaled air continuously for a year at the maximum biweekly concentration at CRED ( $86.2 \text{ mBq}/\text{m}^3$ ) or VIS ( $79.2 \text{ mBq}/\text{m}^3$ ), the resulting doses would still be tiny (18.1 nSv/y [ $1.81 \mu\text{rem}/\text{y}$ ] and 16.6 nSv/y [ $1.66 \mu\text{rem}/\text{y}$ ], respectively). Put another way, the maximum concentration at CRED is just 0.16% of concentration limits for minor sources (see **Section 7.6.1**).

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 part per million (ppm) of beryllium, and the air of the Livermore area and the San Joaquin Valley typically contains 10 to  $100 \mu\text{g}/\text{m}^3$  of particulates. Using a value of  $50 \mu\text{g}/\text{m}^3$  for an average dust load and 1 ppm for beryllium content of dust, a conservative airborne natural beryllium concentration of approximately  $50 \text{ pg}/\text{m}^3$  can be predicted. The overall medians for the on-site locations at the Livermore site and Site 300 are  $6 \text{ pg}/\text{m}^3$  and  $7 \text{ pg}/\text{m}^3$ , respectively. 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.

***Duane Rueppel***

*Richard A. Brown*

*Chris G. Campbell*

*Allen Grayson*

*Henry E. Jones*

*Michael A. Revelli*

**5.1 Sanitary sewer effluent monitoring**

- 5.1.1 Livermore site sanitary sewer monitoring complex
- 5.1.2 Categorical processes
- 5.1.3 Discharges of treated groundwater
- 5.1.4 Environmental impact of sanitary sewer effluent

**5.2 Site 300 sewage ponds**

- 5.2.1 Sewage evaporation and percolation ponds
- 5.2.2 Environmental impact of sewage ponds

**5.3 Storm water compliance and surveillance monitoring**

- 5.3.1 LLNL site-specific storm water thresholds
- 5.3.2 Storm water inspections
- 5.3.3 Livermore site
- 5.3.4 Site 300
- 5.3.5 Environmental impact of storm water

**5.4 Groundwater**

- 5.4.1 Livermore site and environs
- 5.4.2 Site 300 and environs
- 5.4.3 Environmental impact on groundwater

**5.5 Other monitoring programs**

- 5.5.1 Rainwater
- 5.5.2 Livermore Valley surface waters
- 5.5.3 Lake Haussmann release
- 5.5.4 Site 300 drinking water system
- 5.5.5 Site 300 cooling towers
- 5.5.6 Percolation pits



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

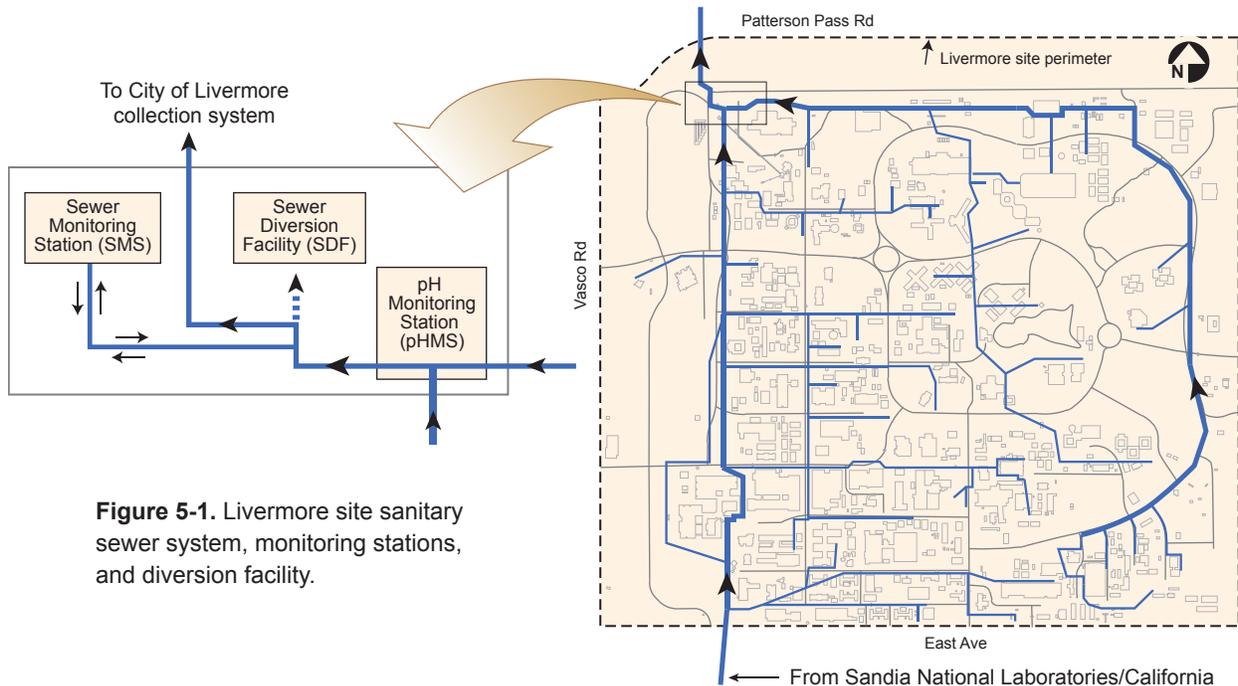
In general, water samples are collected according to written, standardized procedures appropriate for the medium (Woods

2005). Sampling plans are prepared by the LLNL network analysts who are responsible for developing and implementing monitoring programs or networks. Network analysts decide which analytes are sampled (see **Appendix C**) and at what frequency, incorporating any permit-specified analyses. Except for analyses of certain sanitary sewer and retention tank analytes, analyses are usually performed by off-site, California-certified contract analytical laboratories.

## 5.1 Sanitary Sewer Effluent Monitoring

In 2006, the Livermore site discharged an average of 1.04 million liters per day (million L/day) (271,739 gallons per day [gal/day]) of wastewater to the City of Livermore sewer system, or 3.7% of the total flow into the City's system. This volume includes wastewater generated by Sandia National Laboratories/ California (Sandia/California) and a very small quantity from Site 300 (227,118 L [60,000 gal]). In 2006, Sandia/California generated approximately 11% of the total effluent discharged from the Livermore outfall. Wastewater from Sandia/California and Site 300 is discharged to the LLNL collection system and combined with LLNL sewage before it is released at a single point to the municipal collection system (see **Figure 5-1**).

LLNL's wastewater contains both sanitary sewage and process wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below. Most of the process wastewater generated at the Livermore site is



**Figure 5-1.** Livermore site sanitary sewer system, monitoring stations, and diversion facility.

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.

### **5.1.1 Livermore Site Sanitary Sewer Monitoring Complex**

LLNL's sanitary sewer discharge permit (Permit 1250, 2005/2006 and 2006/2007) requires continuous monitoring of the effluent flow rate and pH. Samplers at the Sewer Monitoring Station (SMS) (see **Figure 5-1**) 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 analyzed continuously 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) (see **Figure 5-1**) and an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day, 7 days a week. The monitoring system provides a continuous check on sewage effluent, and the LWRP is notified of contaminant alarms. Trained LLNL staff respond to all alarms to evaluate the cause and take appropriate action.

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 monitors pH continuously during peak flow hours (7 a.m. to 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 farther 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 (204,733 gal) of potentially contaminated sewage can be held, pending analysis to determine the appropriate handling method. If the diverted effluent meets LLNL's wastewater discharge permit limits, it may be returned to the sanitary sewer. If not, it may be treated at LLNL's Radioactive and Hazardous Waste Management (RHWM) facilities and then released to the sanitary sewer, or shipped for off-site disposal. All diverted sewage in 2006 was returned to the sanitary sewer.

### 5.1.1.1 Radiological Monitoring Results

Work Smart Standards (WSSs) establish the standards of operation at LLNL (see **Chapter 2**), including the standards for sanitary sewer discharges. Some of the standards for radioactive material releases are contained in complementary (rather than overlapping) sections of the U.S. Department of Energy (DOE) Order 5400.5, Radiation Protection of the Public and the Environment, and Title 10 of the *Code of Federal Regulations*, Part 20 (10 CFR Part 20).

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

The WSSs from 10 CFR Part 20 for sanitary sewer discharge numerical limits include the following annual discharge limits for radioactivity: tritium, 185 gigabecquerel (GBq) (5 curies [Ci]); carbon-14, 37 GBq (1 Ci); and all other radionuclides combined, 37 GBq (1 Ci). The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq [5 Ci]) takes precedence over the DOE Order 5400.5 concentration-based limit for tritium for facilities that generate wastewater in large volumes, such as LLNL. In addition to complying with the 10 CFR Part 20 annual mass-based discharge limit for tritium and the DOE monthly concentration-based discharge limit for tritium, LLNL also complies with the daily effluent concentration-based discharge limit for tritium established by LWRP for LLNL in 1999. The LWRP limit is smaller by a factor of 30 than the DOE monthly limit and the limits are therefore essentially equivalent, but the LWRP limit is more stringent in the sense that it is daily rather than annual. The radioisotopes with the potential to be found in sanitary sewer effluent at LLNL and their discharge limits are discussed below. All analytical results are provided in **Appendix B, Section B.3.**)

**Table 5-1.** Estimated total radioactivity in LLNL sanitary sewer effluent, 2006.

Radioactive emitter	Estimate based on effluent activity (GBq)	Limit of sensitivity (GBq)
Tritium	19.9	1.01
Gross alpha sources	0.02	0.06
Gross beta sources	0.32	0.15

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 2006 combined release of alpha and beta sources was 0.34 GBq (0.01 Ci), which is 0.9% 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 19.9 GBq (0.54 Ci), which is 11% of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

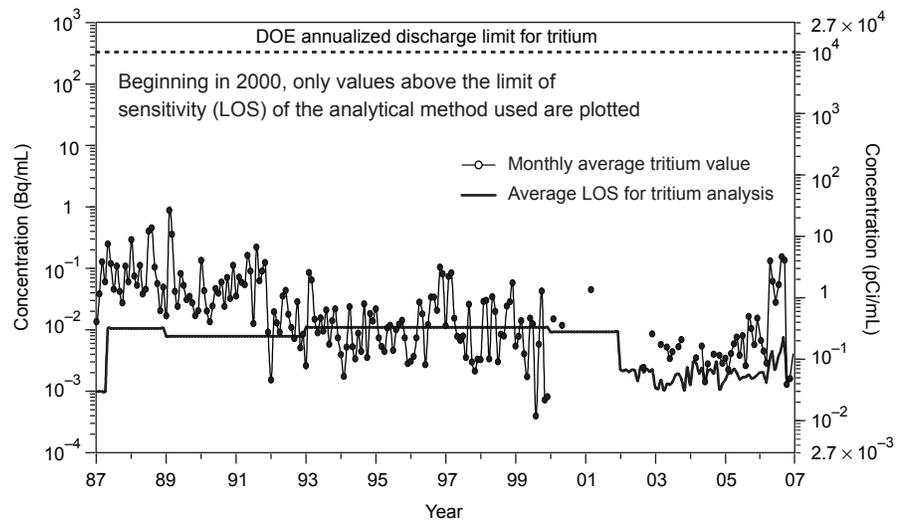
Discharge limits and a summary of the measurements of tritium in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 5-2**. The total monthly activity is calculated by multiplying each monthly concentration by the total flow volume over which

**Table 5-2.** Monitoring results and discharge limits for tritium in sanitary sewer effluents, LLNL and LWRP, 2006.

		Daily (Bq/mL)		Monthly (Bq/mL)		Annual	Monitoring results as percent of limit	
		Maximum	Median	Maximum	Median		Maximum	Median
Monitoring results	LLNL	1.502 <sup>(a)</sup>	0.002	0.157 <sup>(b)</sup>	0.019	19.9 GBq		
	LWRP			0.005 <sup>(c)</sup>	0.002			
Discharge limits for LLNL effluent	LWRP permit daily	12					12.5%	0.02%
	DOE annualized <sup>(d)</sup>					370 Bq/mL	0.042% <sup>(e)</sup>	0.005%
	10 CFR 20 annual total					185 GBq		11%

- (a) Occurred in September.
- (b) Occurred in August. All monthly values above limit of sensitivity are plotted in **Figure 5-2**.
- (c) Occurred in August.
- (d) DOE annualized discharge limit for application of best available technology, which 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 maximum monthly sample concentration and the DOE annualized discharge limit.

**Figure 5-2.** Historical tritium concentrations in the Livermore site sanitary sewer effluent and the average level of sensitivity (LOS) for tritium analysis. The DOE annualized discharge limit for application of best available technology is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.



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 they are above the detection limit. The maximum daily concentration for tritium of 1.5 becquerels per milliliter (Bq/mL) was far below the permit discharge limit of 12 Bq/mL (333 picocuries per milliliter [pCi/mL]).

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

**Table 5-3.** Cesium and plutonium in LLNL and LWRP sanitary sewer effluents, 2006.<sup>(a)</sup>

Month	Cesium-137 (µBq/mL)				Plutonium-239 (nBq/mL)			
	LLNL		LWRP		LLNL		LWRP	
	Radioactivity	MDC	Radioactivity	MDC	Radioactivity	MDC	Radioactivity	MDC
Jan	4.40 ± 5.8	5.2	0.97 ± 5.1	4.6	20.9 ± 7.1	9.8	-0.60 ± 3.7	8.0
Feb	6.48 ± 5.2	4.8	5.81 ± 5.3	4.9	11.0 ± 5.5	6.5	0.94 ± 2.3	3.7
Mar	-0.83 ± 6.0	5.1	5.55 ± 5.2	4.8	20.3 ± 5.1	8.6	4.29 ± 3.9	4.4
Apr	-1.17 ± 5.2	4.6	2.27 ± 5.1	4.6	19.8 ± 5.1	8.5	1.85 ± 3.9	4.3
May	2.02 ± 5.9	5.1	-0.85 ± 4.9	4.4	11.7 ± 4.8	6.3	-0.35 ± 2.1	4.6
Jun	-1.80 ± 8.1	7.0	1.46 ± 5.6	5.0	33.5 ± 9.7	14.9	-0.32 ± 2.0	4.3
Jul	1.23 ± 5.5	4.9	7.14 ± 5.3	4.7	12.1 ± 4.1	6.2	0.09 ± 2.8	5.1
Aug	-1.85 ± 5.7	4.9	-0.91 ± 5.6	4.9	35.3 ± 11.3	15.8	0.67 ± 2.6	6.0
Sep	2.60 ± 5.3	4.8	-1.79 ± 5.1	4.4	12.1 ± 7.4	7.6	-0.82 ± 2.0	5.2
Oct	1.21 ± 6.4	5.6	-2.91 ± 5.6	4.8	38.9 ± 7.6	14.9	103 ± 1461 <sup>(b)</sup>	1598 <sup>(b)</sup>
Nov	1.33 ± 4.7	4.2	0.37 ± 5.1	4.6	13.1 ± 4.4	6.5	0.00 ± 2.4	4.7
Dec	-1.42 ± 4.9	4.2	5.81 ± 7.4	6.7	7.2 ± 6.9	6.4	2.25 ± 3.9	5.7
Median	0.19		1.21		16.4		0.38	

**Annual LLNL total discharge by radioisotope**

	Cesium-137	Plutonium-239
Bq/y <sup>(c)</sup>	$3.91 \times 10^5$	$7.56 \times 10^3$
Ci/y <sup>(c)</sup>	$1.06 \times 10^{-5}$	$2.04 \times 10^{-7}$

**Fraction of limit<sup>(d)</sup>**

DOE 5400.5 DCG	$1.84 \times 10^{-6}$	$5.39 \times 10^{-8}$
----------------	-----------------------	-----------------------

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

(b) Due to low tracer recovery this sample has a higher detection limit.

(c)  $1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$

(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.

Measured concentrations of cesium-137 and plutonium-239 in the sanitary sewer effluent from LLNL and LWRP are listed in **Table 5-3**, and in LWRP sludge, in **Table 5-4**. Cesium and plutonium results are from monthly composite samples of LLNL and LWRP effluent and from quarterly composites of LWRP sludge. For 2006, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCGs. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The highest plutonium concentration observed in 2006 sludge (see **Table 5-4**) is many times lower than the U.S.

**Table 5-4.** Radioactivity of cesium and plutonium in LWRP sludge, 2006.<sup>(a)</sup>

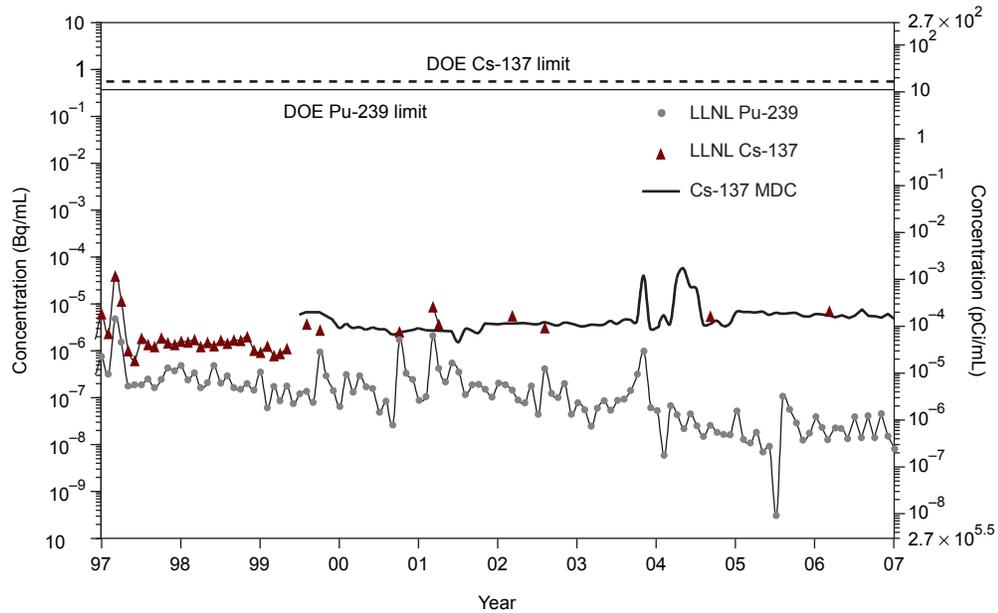
Month	Cesium-137 (mBq/dry g) <sup>(b)</sup>	Plutonium-239 (mBq/dry g) <sup>(b)</sup>
Mar	21.3	0.234 ± 0.046
Jun	<2.29	0.359 ± 0.086
Sep	1.19	3.119 ± 0.503
Dec	<0.69	1.084 ± 0.184

- (a) 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.
- (b) 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**.

Environmental Protection Agency (EPA) preliminary remediation goal for residential soil (93 mBq/dry grams (dry g) [2.5 pCi/dry g]) and is 0.84% of the remediation goal for industrial or commercial soil (370 mBq/dry g [10 pCi/dry g]).

**Figure 5-3** summarizes the plutonium-239 and cesium-137 monitoring data over the past 10 years. The historical levels for plutonium-239 observed since 1996 averaged approximately 1 microbecquerel per milliliter (μBq/mL) ( $3 \times 10^{-5}$  pCi/mL). The historical levels are generally 0.0003% of the DOE DCG for plutonium-239. The cyclic nature of the data in **Figure 5-3** suggests a relationship between radionuclide buildup in LLNL sewer lines and subsequent liberation by line cleaning. The highest plutonium and cesium concentrations are still well below 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 2006, a total of 19.9 GBq (0.54 Ci) of tritium was discharged to the sanitary sewer, an amount that is



**Figure 5-3.** Average monthly plutonium-239 (Pu-239) and cesium-137 (Cs-137) concentrations in LLNL sanitary sewer effluent. The DOE annualized discharge limit for application of best available technology is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

**Table 5-5.** Historical radioactive liquid effluent releases from the Livermore site, 1996–2006.<sup>(a)</sup>

Year	Tritium (GBq)	Plutonium-239 (GBq)
1996	12	$4.2 \times 10^{-4}$
1997	9.1	$2.1 \times 10^{-4}$
1998	10	$0.77 \times 10^{-4}$
1999	7.1	$0.68 \times 10^{-4}$
2000	5.0	$0.96 \times 10^{-4}$
2001	4.9	$1.1 \times 10^{-4}$
2002	0.74	$0.42 \times 10^{-4}$
2003	1.11	$0.51 \times 10^{-4}$
2004	1.34	$1.16 \times 10^{-5}$
2005	3.12	$9.64 \times 10^{-6}$
2006	19.9	$7.56 \times 10^{-6}$

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

well within environmental protection standards and is comparable to the amounts discharged during the past 20 years.

#### 5.1.1.2 Nonradiological Monitoring Results

LLNL monitors sanitary sewer effluent for chemical and physical parameters at different frequencies depending on the intended use of the result. For example, LLNL’s wastewater discharge permit requires LLNL to collect monthly grab samples and 24-hour composites, weekly composites, and daily composites. Once a month, a 24-hour, flow-proportional composite is collected and analyzed; this is referred to as the monthly 24-hour composite in the discussion below. The weekly composite refers to the flow-proportional samples collected over a 7-day period continuously throughout the year. The daily composite refers to the flow-proportional sample collected over a 24-hour period, also collected continuously

throughout the year. LLNL’s wastewater discharge permit specifies that the effluent pollutant limit (EPL) is equal to the maximum pollutant concentration allowed per 24-hour composite sample. Only when a weekly composite sample concentration is at or above 50% of its EPL are the daily samples that were collected during the corresponding period analyzed to determine whether any of the concentrations are above the EPL.

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 2006. 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 2006 weekly composites are provided in **Appendix B, Section B.3**.) This flow-weighted monthly concentration represents the characteristic concentration for that month. During 2006, the month-to-month characteristic concentrations for each metal closely resemble the 2005 results, showing generally lower concentration values and less variation than the annual trends observed prior to 2005. These results follow from the improved homogeneity of composite effluent samples, made possible by the upgraded sampling system within the SMS that was completed at the end of 2004. In **Table 5-6**, the 2006 median flow-weighted concentration for each metal is shown and compared with the EPL. These median values were less than 5% of their respective EPLs for eight of the nine regulated metals. Only arsenic, with a median value at 7% of its EPL, showed a small increase over 2005.

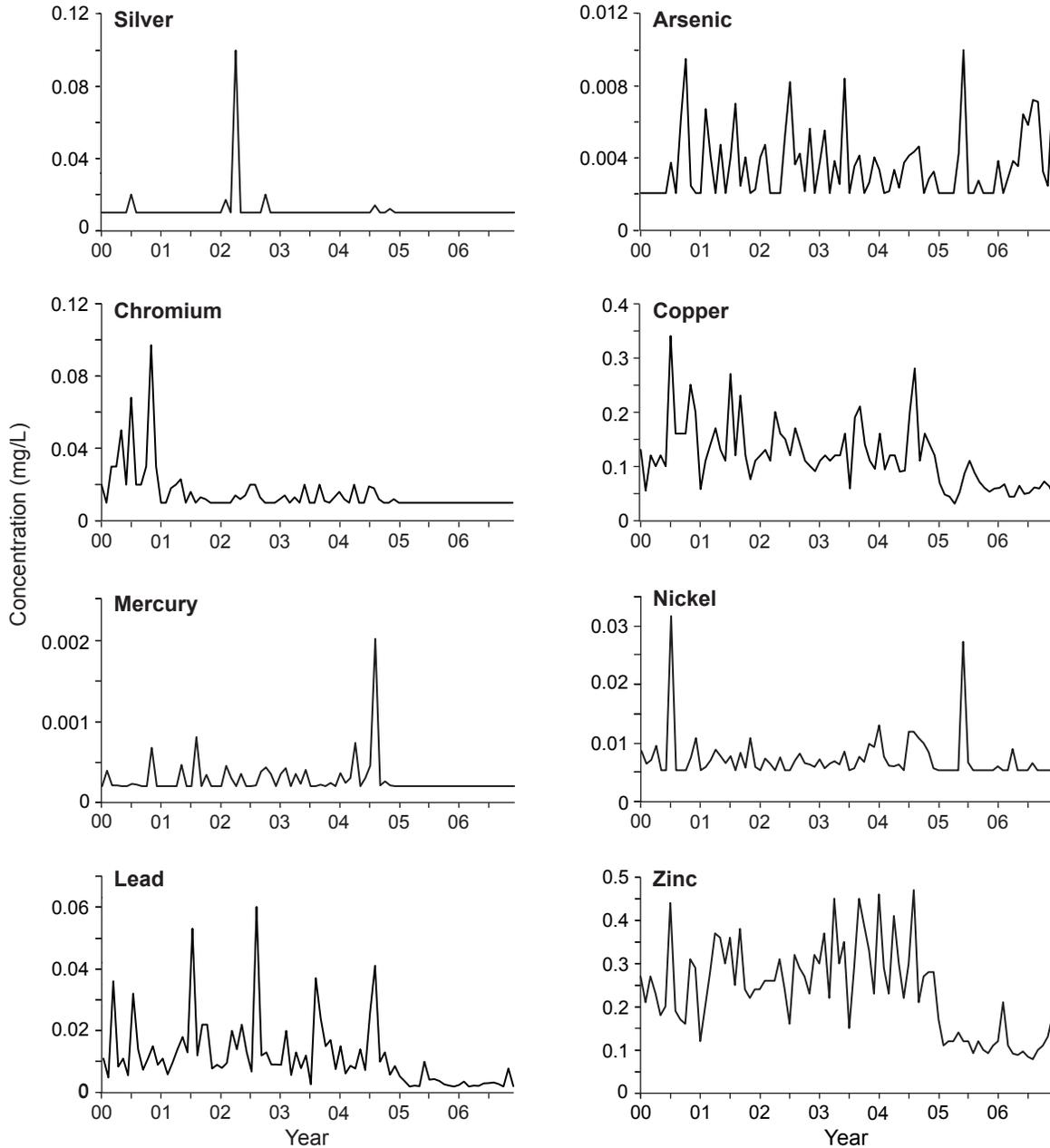
**Figure 5-4** presents historical trends for the monthly 24-hour composite sample results from 2000 through 2006 for eight of the nine regulated metals; cadmium is not presented

**Table 5-6.** Flow-weighted monthly concentrations for regulated metals in LLNL sanitary sewer effluent (mg/L), 2006.<sup>(a)</sup>

Month	Regulated metal								
	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
Jan	<0.010	0.0032	<0.0050	<0.010	0.039	<0.00020	0.0057	0.0022	0.073
Feb	<0.010	0.0031	<0.0050	<0.010	0.047	<0.00020	<0.0050	0.0022	0.088
Mar	<0.010	0.0040	<0.0050	<0.010	0.041	<0.00020	<0.0050	0.0021	0.082
Apr	<0.010	0.0025	<0.0050	<0.010	0.039	<0.00020	<0.0050	0.0025	0.084
May	<0.010	0.0042	<0.0050	<0.010	0.039	<0.00020	<0.0050	0.0023	0.073
Jun	<0.010	0.0067	<0.0050	<0.010	0.041	0.00022	0.0053	0.0027	0.065
Jul	<0.010	0.0073	<0.0050	<0.010	0.058	<0.00020	<0.0050	0.0047	0.065
Aug	<0.010	0.0071	<0.0050	<0.010	0.053	<0.00020	<0.0050	0.0030	0.074
Sep	<0.010	0.0040	<0.0050	<0.010	0.045	<0.00020	0.0062	0.0022	0.079
Oct	<0.010	0.0032	<0.0050	<0.010	0.041	<0.00033	0.0053	<0.0020	0.074
Nov	<0.010	0.0026	<0.0050	<0.010	0.038	<0.00020	<0.0050	0.0045	0.069
Dec	<0.010	0.0068	<0.0050	<0.010	0.034	<0.00020	<0.0050	0.0021	0.070
Median	<0.010	0.0040	<0.0050	<0.010	0.041	<0.00020	<0.0050	0.0023	0.074
IQR	— <sup>(b)</sup>	0.0036	— <sup>(b)</sup>	— <sup>(b)</sup>	0.006	— <sup>(b)</sup>	— <sup>(b)</sup>	0.0006	0.010
EPL <sup>(c)</sup>	0.20	0.06	0.14	0.62	1.0	0.01	0.61	0.20	3.00
Median fraction of EPL	<0.05	0.07	<0.04	<0.02	0.04	<0.02	<0.01	0.01	0.02
PQL <sup>(d)</sup>	0.010	0.0020	0.0050	0.010	0.010	0.00020	0.0050	0.0020	0.050

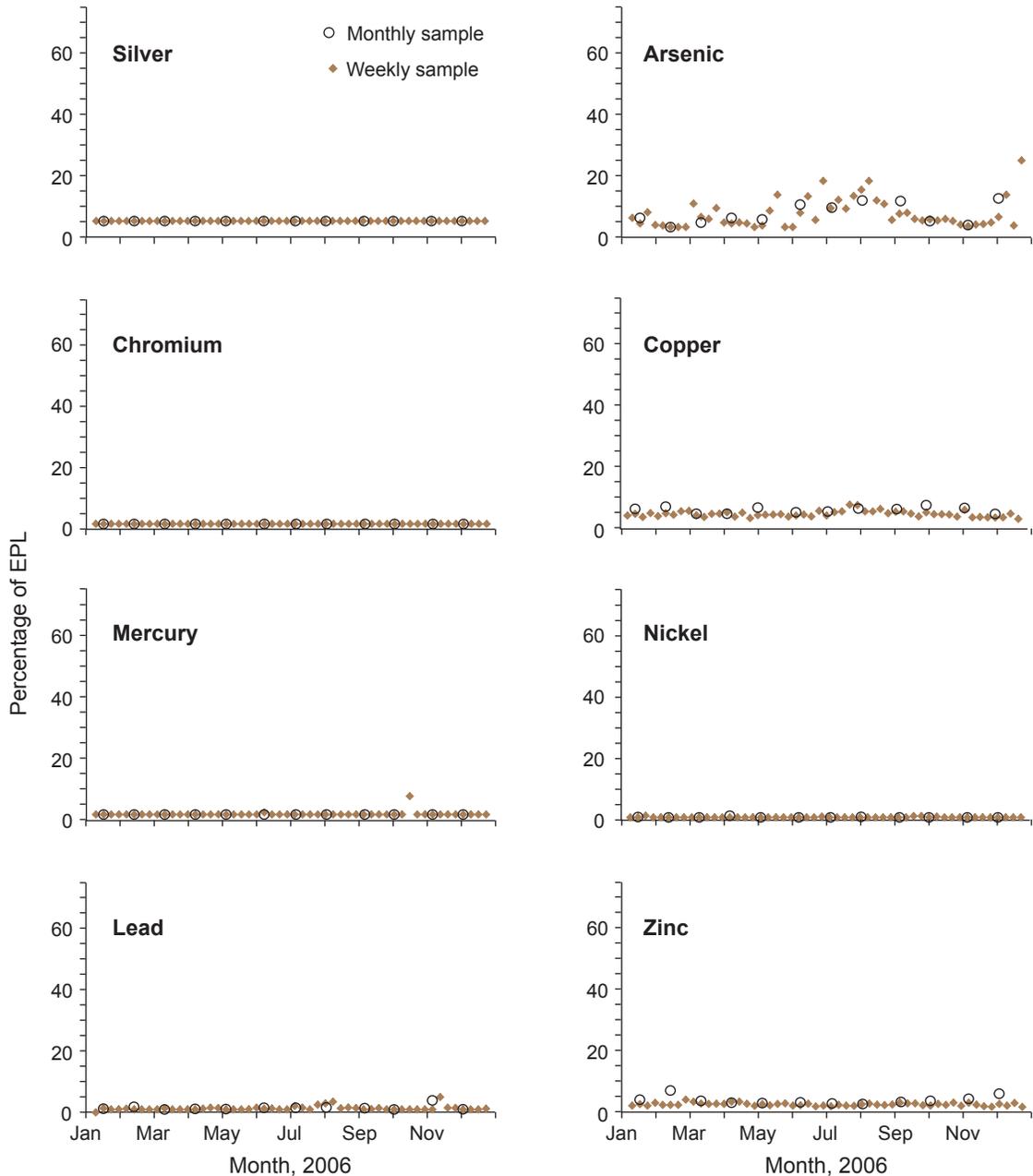
- (a) Monthly values are presented with less-than signs when all weekly composite sample results for the month are below the detectable concentration.
- (b) Because of the large number of nondetects, the interquartile range cannot be calculated (see **Chapter 9**).
- (c) EPL = Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2005/2006, and 2006/2007).
- (d) PQL = Practical quantitation limit (these limits are typical values for sanitary sewer effluent samples).

because this metal was not detected above the practical quantitation limit (PQL) in any of the 2000 through 2006 monthly sampling events. Typical PQLs for the regulated metals in LLNL sanitary effluent are shown in **Table 5-6**. (Sample results for the 2006 monthly 24-hour composites are provided in **Appendix B, Section B.3**.) All of the monthly 24-hour composite samples were in compliance with LLNL's wastewater discharge permit limits. The 2006 results routinely show concentrations of arsenic, copper, lead, and zinc at levels above their respective PQLs; nickel was detected in 3 of 12 samples, while silver, chromium, and mercury showed no detections above their respective PQLs. These observations are generally consistent with the 2000 through 2004 data; however, with the exception of arsenic, the concentrations of those metals detected in 2005 and 2006 have shown an overall downward



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

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 7.2% and 7%, respectively, of those same EPLs in 2006. The range of monthly 24-hour composite concentrations reported for arsenic in 2006, although never exceeding 13% of its EPL, has not shown a similar downward trend.



**Figure 5-5.** The results shown in **Figure 5-4** are shown here as percentages of effluent pollutant limits (EPLs) for eight of the nine regulated metals in LLNL sanitary sewer effluent, 2006.

The monthly 24-hour composite and weekly composite concentrations for 2006 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 2006, an additional two (silver and chromium) 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 LLNL 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, and analysis of daily samples was therefore not required. The highest percentage of EPL reported during 2006 was for arsenic (at 25% of EPL) in the December 21–27 weekly composite. All other reported metal concentrations were <20% of the respective EPLs, with most being <10%.

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 provided in **Appendix B, Section B.3**.) The 2006 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 “d” superscript in **Table 5-7**), and all other nonregulated parameters. Cyanide (permit limit 0.04 milligrams per liter [mg/L], sampled semiannually) was below the analytical detection limit (0.02 mg/L) in both the April and October samples. The monthly TTO values ranged from 0.013 mg/L to <0.050 mg/L (with a TTO median value of 0.021 mg/L), well below the TTO permit limit of 1.0 mg/L. In addition to the organic compounds regulated under the TTO standard, three nonregulated organics were detected in LLNL’s sanitary sewer effluent: one volatile organic compound (acetone) and two semivolatile organic compounds (benzyl alcohol, and 3- and 4-methylphenol [m- and p-Cresol]).

In 2006, the SMS continuous monitoring system detected a total of six inadvertent discharges outside the permitted pH range of 5 to 10. Five of these events, three with a pH below 5 and two with a pH above 10, were completely captured by the SDF. The remaining event occurred off-hours (Wednesday, April 12, 2006, 10:26 p.m.) when the upstream pHMS was off-line. As a result, a small quantity of sanitary effluent outside the permitted pH range was released to the LWRP system before a diversion to the SDF could be initiated. Approximately 757 L (200 gal) of pH 10.0 to 10.5 effluent were released to the LWRP and another 7571 L (2000 gal) captured. The highest pH recorded during the diversion was 11.75. The LWRP was notified immediately of the low-volume, high pH discharge, but the incident did not represent a threat to the integrity of LWRP operations.

### 5.1.2 Categorical Processes

The EPA has established pretreatment standards for categories of industrial processes that EPA has determined are major contributors to point-source water pollution. These federal standards include numerical limits for the discharge of industry-specific pollutants. At

**Table 5-7.** Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2006.<sup>(a)</sup>

Sample	Parameter	Detection frequency <sup>(b)</sup>	Minimum	Maximum	Median	Interquartile range
<b>24-hour composite</b>	<b>Alkalinity (mg/L)</b>					
	Bicarbonate alkalinity (as CaCO <sub>3</sub> )	12 of 12	210	260	235	15.0
	Carbonate alkalinity (as CaCO <sub>3</sub> )	3 of 12	<2.5	34	<5	— <sup>(c)</sup>
	Total alkalinity (as CaCO <sub>3</sub> )	12 of 12	210	270	240	20.0
	<b>Anions (mg/L)</b>					
	Bromide	8 of 12	<0.1	1.5	<0.4	1.5
	Chloride	12 of 12	42	71	56	18
	Fluoride	8 of 12	<0.05	0.22	0.094	— <sup>(c)</sup>
	Orthophosphate	12 of 12	13	18	16	2.0
	Sulfate	12 of 12	10	18	13	3.0
	<b>Nutrients (mg/L)</b>					
	Ammonia nitrogen (as N)	12 of 12	40	57	52	6.8
	Total Kjeldahl nitrogen	12 of 12	42	92	67	20
	Total phosphorus (as P)	12 of 12	5.3	12	7.2	1.8
	<b>Oxygen demand (mg/L)</b>					
	Biochemical oxygen demand	12 of 12	82	120	100	14.8
	Chemical oxygen demand	12 of 12	200	650	225	25.0
	<b>Solids (mg/L)</b>					
	Settleable solids	3 of 12	<0.1	<0.5	<0.1	— <sup>(c)</sup>
	Total dissolved solids	12 of 12	180	390	245	27.5
	Total suspended solids	12 of 12	42	170	67	17.2
	Volatile solids	12 of 12	64	190	130	42.5
	<b>Total metals (mg/L)</b>					
	Aluminum	12 of 12	0.092	0.84	0.16	0.11
	Calcium	12 of 12	9.8	18	12	2.2
	Iron	12 of 12	0.41	1.3	0.53	0.18
Magnesium	12 of 12	2.1	3.8	2.4	0.32	
Potassium	12 of 12	15	26	20	1.5	
Selenium	2 of 12	<0.002	0.0024	<0.002	— <sup>(c)</sup>	
Sodium	12 of 12	33	50	39	5.0	
<b>Total organic carbon (mg/L)</b>	11 of 12	<10	53	27	11	
<b>Grab sample</b>	<b>Semivolatile organic compounds (µg/L)</b>					
	Benzyl alcohol	2 of 12	<10	<100	<10	— <sup>(c)</sup>
	Bis(2-ethylhexyl)phthalate <sup>(d)</sup>	6 of 12	<5	<50	<5.8	— <sup>(c)</sup>
	Diethylphthalate <sup>(d)</sup>	9 of 12	<5	<50	<16	— <sup>(c)</sup>
	Pheno <sup>(d)</sup>	5 of 12	<5	<50	<5	— <sup>(c)</sup>
	m- and p-Cresol	6 of 12	<5	<50	<7.4	— <sup>(c)</sup>
	<b>Total oil and grease (mg/L)<sup>(e)</sup></b>	6 of 8	<5	23	15.5	11.2

**Table 5-7 (cont.).** Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2006.<sup>(a)</sup>

Sample	Parameter	Detection frequency <sup>(b)</sup>	Minimum	Maximum	Median	Interquartile range
<b>Grab sample (cont.)</b>	<b>Volatile organic compounds (µg/L)</b>					
	Acetone	12 of 12	200	580	440	180
	Bromodichloromethane <sup>(d)</sup>	2 of 12	<1	<1	<1	— <sup>(c)</sup>
	Chloroform <sup>(d)</sup>	12 of 12	5.2	18	9.2	6.4
	Methylene chloride <sup>(d)</sup>	2 of 12	<1	1.3	<1	— <sup>(c)</sup>
	Toluene <sup>(d)</sup>	2 of 12	<1	3.3	<1	— <sup>(c)</sup>
	Trichloroethene <sup>(d)</sup>	1 of 12	<0.5	1.1	<0.5	— <sup>(c)</sup>

- (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) 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.
- (d) 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, 2005/2006, and 2006/2007.
- (e) 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.

LLNL, the categorical pretreatment standards are incorporated into the wastewater discharge permit (Permit 1250, 2005/2006 and 2006/2007), which is administered by the LWRP.

The processes at LLNL that fall under the standards may change as programmatic requirements dictate. During 2006, the LWRP identified 15 wastewater-generating processes at LLNL that fell under either 40 CFR Part 469, Electrical and Electronic Components Point Source Category, or 40 CFR Part 433, Metal Finishing Point Source Category.

Only processes that discharge to the sanitary sewer require semiannual sampling, inspection, and reporting. Three of the 15 processes discharge wastewater to the sanitary sewer: (1) semiconductor processes (e.g., wafer cleaning/etching, photolithography) in the Building 153 microfabrication facility, (2) gallium arsenide saw cutting in Building 153, and (3) abrasive jet machining in Building 321C. In 2006, LLNL analyzed compliance samples for all regulated parameters from the three discharging processes and demonstrated compliance with all federal categorical discharge limits. Of the three processes, the Building 153 microfabrication facility released the largest volume of water to the sanitary sewer. The wastewater is retained in tanks and then discharged to the sanitary sewer. As a further environmental safeguard, LLNL sampled the wastewater in the each tank prior to discharge to the sanitary sewer. These monitoring data were reported to the LWRP in July 2006 and January 2007 semiannual wastewater reports (Grayson et al. 2006, 2007).

The remaining 12 processes, which do not discharge wastewater to the sanitary sewer, are regulated under 40 CFR Part 433, Metal Finishing; wastewater from these processes is evaluated semiannually. The processes include printed circuit board manufacturing,

electrolysis plating, chemical etching, electroplating, anodizing, coating, electrical discharge machining, and abrasive jet machining. Wastewater from these processes is recycled or contained for eventual removal and appropriate disposal by RHW. Because the processes do not discharge directly or indirectly to the sanitary sewer, they are not subject to the monitoring and reporting requirements contained in the applicable standard. See Grayson et al. (2006, 2007).

As required in LLNL's wastewater discharge permit, LLNL demonstrated compliance with permit requirements by semiannual sampling and reporting in 2006. In addition, LWRP source control staff performed their required annual inspection and sampling of the three discharging categorical processes in 2006. The compliance samples were analyzed for all regulated parameters, and the results demonstrated compliance with all federal and local pretreatment limits.

### **5.1.3 Discharges of Treated Groundwater**

LLNL's groundwater discharge permit (1510G, 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 2006, there were seven discharges to the sanitary sewer from the GWP. The total volume of treated groundwater discharged to the sanitary sewer was 5680 L (1501 gal). In each of the 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 on-site wells in conjunction with GWP drilling and treatment operations. The seven events were separately sampled and discharged to the sanitary sewer during 2006, all in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in Revelli (2007a).

### **5.1.4 Environmental Impact of Sanitary Sewer Effluent**

During 2006, 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 excellent compliance with the provisions of its wastewater discharge permit; there was one release with a 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 2006 reflect an effective year for LLNL's wastewater discharge control program and indicate no adverse impact to the LWRP or the environment from LLNL sanitary sewer discharges.

## 5.2 Site 300 Sewage Ponds

Wastewater samples collected from the influent to the sewage evaporation pond, within the sewage evaporation pond, and flow to the sewage percolation pond were obtained in accordance with the written, standardized procedures summarized in Woods (2005).

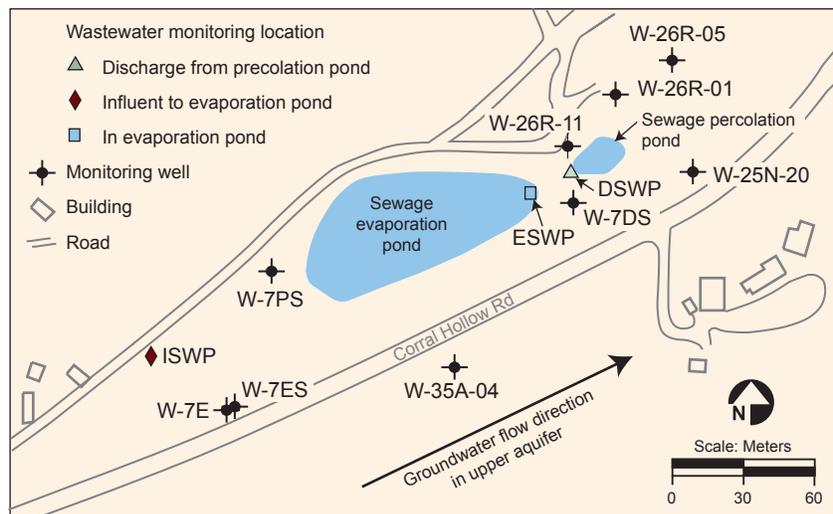
### 5.2.1 Sewage Evaporation and Percolation Ponds

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 discharge 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 pipe running into the sewage pond and within the sewage evaporation pond (ESWP). (Sampling locations are shown in **Figure 5-6**.) Discharges into the adjacent percolation pond are also permitted under WDR 96-248 and are sampled as needed in the discharge pipe (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. The wells are screened in three geological formations: Qal, Tnbs<sub>1</sub>, and Tnsc<sub>1</sub> (see **Chapter 8**). The Tnbs<sub>1</sub> (Neroly Formation lower blue sandstone unit) is the regional aquifer.

**Figure 5-6.** Site 300 sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations, 2006.



All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2006. There was one continuous discharge from the sewage evaporation pond to the percolation pond that began in January 2006 and continued for about six weeks. This permitted discharge was sampled once in January and reported to the Central Valley Regional Water Quality Control Board (CVRWQCB). For details, see Brown (2007).

### 5.2.2 Environmental Impact of Sewage Ponds

All discharges from the Site 300 sewage evaporation pond to the percolation pond were in compliance with discharge limits. Groundwater monitoring related to this area indicated there were no measurable impacts to the groundwater from the sewage pond operations (Brown 2007).

---

## 5.3 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 Activities (WDR 97-03-DWQ), NPDES Permit No. CAS000001, State Water Resources Control Board (SWRCB 1997). For construction projects that disturb 0.4 hectares (ha) (1 acre [ac]) 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 C** 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.

For the purpose of evaluating the overall impact of the Livermore site and Site 300 operations on storm water quality, storm water samples are collected 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 permits.

NPDES permits for storm water require that LLNL sample locations specified in the permit two times per rainy season. Influent sampling is also required at the Livermore site. In addition, LLNL is required to visually inspect the storm drainage system during one storm event per month in the wet season (defined as October through April for the Livermore site and October through May for Site 300) to observe runoff quality and twice during the dry season to identify any dry weather flows. Annual facility inspections are also required to ensure that the best management practices for controlling storm water pollution are implemented and adequate.

### **5.3.1 LLNL Site-Specific Storm Water Thresholds**

To maintain compliance with permits and as directed by the LLNL industrial storm water programs, samples from a minimum of two storms per year are collected at both LLNL sites. Various laboratory analyses are performed on the samples collected for each storm. There are no numeric concentration limits for constituents in LLNL's storm water effluent. The EPA has established benchmark concentration values but stresses that the benchmarks are not intended to be interpreted as limits (EPA 2000). The EPA uses the values to determine whether storm water discharged from a facility merits further monitoring. Although the benchmark values are not directly applicable, they are compared to LLNL storm water data to help LLNL evaluate its storm water management program.

To further evaluate the program, LLNL has established site-specific thresholds for selected parameters (Campbell and Mathews 2006). A value exceeds a parameter's threshold when it is greater than the 95% confidence limit for the historical mean value for that parameter (see **Table 5-8**). The thresholds are used to identify out-of-the-ordinary data that merit further investigation to determine whether concentrations of that parameter are increasing in the storm water runoff. These site-specific thresholds are recalculated and changed as additional data become available. For example, in 2006, the copper value was changed to 36 µg/L; see Campbell and Mathews (2006) for details of the calculation. For a better understanding of how LLNL storm water data relate to other target values, LLNL also

**Table 5-8.** Site-specific thresholds for selected water quality parameters for storm water runoff.<sup>(a)</sup>

Parameter	Livermore site	Site 300
Total suspended solids	750 mg/L <sup>(b)</sup>	1,700 mg/L <sup>(b)</sup>
Chemical oxygen demand	200 mg/L <sup>(b)</sup>	200 mg/L <sup>(b)</sup>
pH	<6.0, >8.5 <sup>(b)</sup>	<6.0, >9.0 <sup>(c)</sup>
Nitrate (as NO <sub>3</sub> )	10 mg/L <sup>(b)</sup>	Not monitored
Orthophosphate	2.5 mg/L <sup>(b)</sup>	Not monitored
Beryllium	1.6 µg/L <sup>(b)</sup>	1.6 µg/L <sup>(b)</sup>
Chromium(VI)	15 µg/L <sup>(b)</sup>	Not monitored
Copper	36 µg/L <sup>(b)</sup>	Not monitored
Lead	15 µg/L <sup>(d)</sup>	30 µg/L <sup>(b)</sup>
Zinc	350 µg/L <sup>(b)</sup>	Not monitored
Mercury	above RL <sup>(e)</sup>	1 µg/L <sup>(b)</sup>
Diuron	14 µg/L <sup>(b)</sup>	Not monitored
Oil and grease	9 mg/L <sup>(b)</sup>	9 mg/L <sup>(b)</sup>
Tritium	36 Bq/L <sup>(b)</sup>	3.17 Bq/L <sup>(b)</sup>
Gross alpha radioactivity	0.34 Bq/L <sup>(b)</sup>	0.90 Bq/L <sup>(b)</sup>
Gross beta radioactivity	0.48 Bq/L <sup>(b)</sup>	1.73 Bq/L <sup>(b)</sup>

- (a) If data exceed a site-specific threshold, an investigation is initiated to assess whether data are indicative of a water quality problem.
- (b) Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for copper, chemical oxygen demand (COD), total suspended solids (TSS), and zinc.
- (c) EPA benchmark.
- (d) California and EPA drinking water action level.
- (e) RL (reporting limit) = 0.0002 mg/L for mercury.

For each construction project permitted by WDR 99-08-DWQ, LLNL conducts visual monitoring of construction sites before, during, and after storms to assess the effectiveness of the best management practices. Annual compliance certifications summarize the inspections. Annual compliance certifications for 2006 covered the period of June 2005 through May 2006. When requested by a regional water quality control board, LLNL completes annual compliance status reports covering the same reporting period. During the 2005/2006 reporting period, LLNL had active permits for six projects at the Livermore site and two at Site 300 (see **Chapter 2, Table 2-3**). LLNL terminated the permits for two projects at the Livermore site in 2006—the Building 583 Project and the Arroyo Seco Management Plan (work was completed in 2005 but termination documentation was submitted in early 2006).

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), EPA ambient water quality criteria (AWQC), and EPA benchmark values. However, the greatest importance is placed on the site-specific thresholds calculated from historical concentrations in storm water runoff.

### 5.3.2 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 2006 that their facilities complied with the provisions of LLNL's SWPPPs. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Campbell and Brunckhorst 2006) and to the CVRWQCB (Brown 2006) with the results of sampling, observations, and inspections.

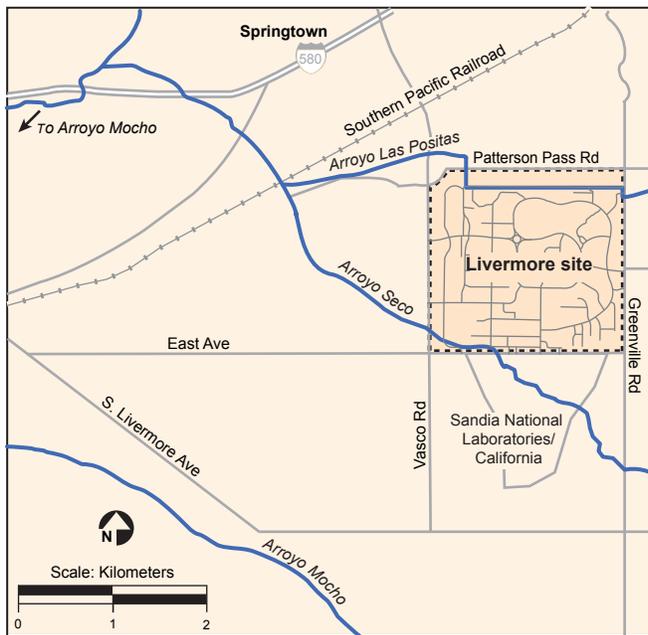


Figure 5-7. Surface waterways in the vicinity of the Livermore site.

### 5.3.3 Livermore Site

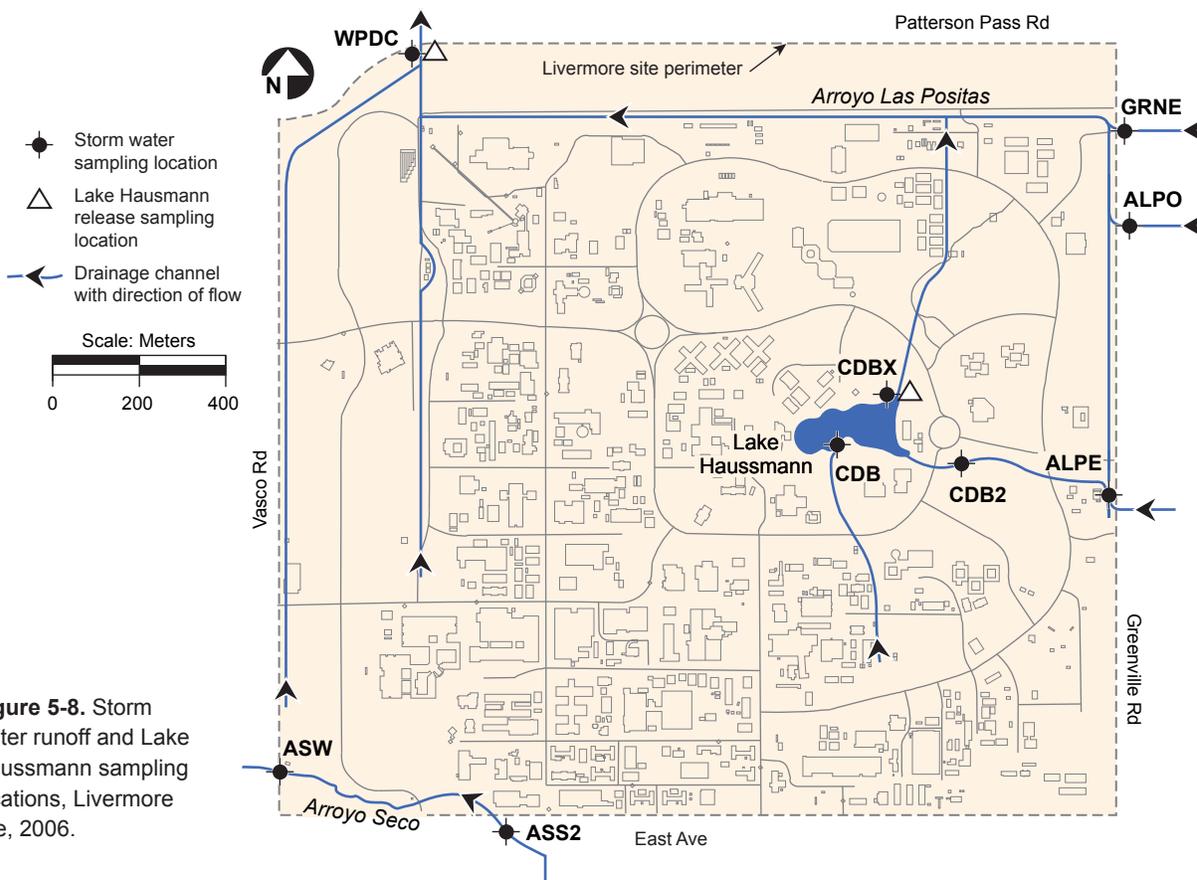
As is common in urban areas, surface water bodies and runoff pathways at LLNL do not represent natural conditions. The drainage at the Livermore site was altered by construction activities several times up to 1966 (Thorpe et al. 1990) so that the current northwest flow of Arroyo Seco and the westward flow of Arroyo Las Positas do not represent historical flow paths. About 1.6 kilometers (km) west of the Livermore site, Arroyo Seco merges with Arroyo Las Positas, which continues to the west and eventually merges with Arroyo Mocho (see Figure 5-7).

Lake Haussmann, known prior to 2006 as the Drainage Retention Basin (DRB),

was excavated and lined in 1992. Lake Haussmann was constructed and is operated as part of LLNL's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remediation activities. Although the lake is not a "treatment unit," as the term is used in restoration, the lake was lined to prevent the displacement and dispersion of aquifer contamination actively being treated by the LLNL Environmental Restoration Division. In addition, the lake provides a "polishing" effect on the quality of storm water flowing on to the Livermore site. Lake Haussmann has been determined not to be a "water of the US" (Rauhut 2006) and is therefore managed as such. The lake also serves storm water diversion and flood control purposes, collecting less than one fourth of the surface water runoff from the site and a portion of the Arroyo Las Positas drainage (see Figure 5-8). When full, Lake Haussmann discharges north to a culvert that leads to Arroyo Las Positas. The remainder of the Livermore site drains directly or indirectly into the two arroyos by way of storm drains and swales. Arroyo Seco cuts across the southwest corner of the site, and Arroyo Las Positas follows the northeast and north boundaries of the site and exits near the northwest corner.

The Livermore site storm water runoff monitoring network consists of nine sampling locations (see Figure 5-8). 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 outside the requirements of the storm water permit to characterize storm water runoff quality entering Lake Haussmann; location CDBX characterizes water leaving Lake Haussmann. LLNL collected samples at all nine locations on January 18, March 3, and December 12, 2006.

Toxicity tests for WDR 95-174 were performed using water samples from the first major runoff event of the water year occurring during normal work hours (Monday through Friday,



**Figure 5-8.** Storm water runoff and Lake Hausmann sampling locations, Livermore site, 2006.

**Table 5-9.** Radioactivity in storm water from the Livermore site, 2006.<sup>(a)</sup>

Parameter	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Median	0.28	0.052	0.235
Minimum	-3.40	0.016	0.067
Maximum	5.40	0.290	0.740
Effluent			
Median	1.14	0.032	0.135
Minimum	-1.50	-0.012	0.091
Maximum	4.10	0.046	0.170

(a) See **Chapter 9** for an explanation of calculated values.

8 a.m. to 5 p.m.). Because the first major storms for both 2005–2006 and 2006–2007 water years occurred during calendar year 2006 (sample dates: January 18 and December 12, 2006), they are reported in this document.

### 5.3.3.1 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 provided in **Appendix B, Section B.4**.) Tritium activities at the site effluent sampling locations were less than 1% of the MCL. Gross alpha and gross beta radioactivity in the storm water samples collected during 2006 were also generally low, less than 53% and 40% of their MCLs, respectively.

**Table 5-10.** Water quality parameters in storm water runoff above LLNL site-specific thresholds, Livermore site, 2006.

Nonradioactive/ Radioactive	Parameter	Date	Location	Influent / Effluent	Result	LLNL threshold
Nonradioactive	Chromium(VI) (mg/L)	12/12	GRNE	Influent	0.032	0.015
		1/18	ALPO	Influent	0.019	0.014
	Diuron (mg/L)	1/18	ASW	Effluent	0.037	0.014
		1/18	GRNE	Influent	3.200	0.014
		3/3	GRNE	Influent	0.620	0.014
		3/3	CDB2	Internal	0.016	0.014
		12/12	WPDC	Effluent	0.018	0.014
		12/12	ALPO	Influent	0.620	0.014
	Nitrate (NO <sub>3</sub> ) (mg/L)	1/18	GRNE	Influent	25.0	10.0
		3/3	ASW	Effluent	31.0	10.0
3/3		GRNE	Influent	23.0	10.0	
12/12		GRNE	Influent	16.0	10.0	
pH	3/3	CDBX	Internal	8.60	8.50	
Radioactive	Gross beta (Bq/L)	3/3	ALPE	Influent	0.74 ± 0.17	0.48

Gross beta activities exceeded LLNL-specific thresholds on March 3, 2006, in water samples collected at influent location ALPE along Arroyo Las Positas. However, gross beta activities in samples collected from the effluent location WPDC were well below the thresholds (see **Table 5-10**). Therefore, this result was unlikely to be related to LLNL activities.

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 2006, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.10 pCi/L).

### 5.3.3.2 Nonradiological Monitoring Results

In addition to radioactivity, storm water was analyzed for other water quality parameters in 2006. Results were compared to the site-specific thresholds listed in **Table 5-8**. Of interest were the constituents that exceeded the thresholds at effluent points and whose concentrations were 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 provided in **Appendix B, Section B.4**.)

Constituents that exceeded site-specific thresholds for effluent and/or influent locations are listed in **Table 5-10**. All of the values above the site-specific thresholds for the Livermore site

during 2006 were found at influent tributaries at similar or higher concentrations than at effluent locations, except at location ASW for diuron on January 18 and nitrate on March 3. For example, the diuron concentration at effluent location WPDC is clearly explained by the high value at influent location ALPO (0.620 mg/L) on the same date. Diuron is a pre-emergent pesticide that is used both by LLNL and off site by other parties along roads and structures. The presence of diuron in runoff flowing onto the LLNL site has been documented by Campbell et al. (2004). LLNL pesticide records for January do not indicate that LLNL was using a diuron-containing pesticide in the vicinity of Arroyo Seco (influent location ASS2, 0.019 mg/L; effluent location ASW, 0.037 mg/L). An off-site source for the pesticide is therefore more likely. The elevated nitrate value in March (influent location ASS2, 1.1 mg/L; effluent location ASW, 31.0 mg/L) could have been the result of planting and vegetation management activities associated with a large restoration project in the reach of Arroyo Seco on the Livermore site. LLNL will continue to monitor diuron and nitrates in Arroyo Seco to determine whether these results are isolated.

Two results from storm water samples collected from internal sampling locations around Lake Haussmann contained elevated diuron and pH. The diuron occurred at the influent to the lake and was possibly a small contribution from off site. The pH was from the lake outlet sampling location; elevated pH values for the lake are not unusual (see discussion of Lake Haussmann in **Section 5.5.3**).

The remaining value that exceeded a site-specific threshold originated off site and flowed on site in the Arroyo Las Positas tributaries was the gross beta activity in a sample from location ALPE on March 3. The total suspended solids result was also slightly higher than typical at location ALPE on March 3 (290 mg/L), and because radioactive materials are most often associated with sediments, it is likely that the elevated gross beta activity is the result of the suspended sediments. Other than an elevated diuron result on December 12, the storm water from these upstream influent sampling locations did not significantly influence water quality in Arroyo Las Positas at the effluent sampling location WPDC.

LLNL conducted both 96-hour acute and 7-day chronic fish toxicity analyses on storm water samples collected on January 18 and December 12 from effluent location WPDC. The WDR 95-174 permit states that an acceptable survival rate for the chronic toxicity testing is 20% lower than a control sample. The testing laboratory provides water for the control sample, which consists of EPA synthetic moderately hard water. Thus, a difference of more than 20% between location WPDC and the control sample with the lowest survival rate is considered a failed test. If the test is failed, the permit requires LLNL to conduct toxicity testing during the next significant storm event. After failing two consecutive tests, LLNL must perform a toxicity reduction evaluation to identify the source of the toxicity. During 2006, survival in the 96-hour acute test for a solution of storm water sample from location WPDC was 100% for January 18 and 100% for December 12. The 7-day chronic toxicity tests using the fathead minnows exposed to different concentrations of the storm water also

**Table 5-11.** Seven-day chronic toxicity test results for fish (fathead minnow) assay from location WPDC, Livermore site, 1/18/06 and 12/12/06.

Percent storm water solution	Average percent survival	
	1/18/06	12/12/06
Lab control	95%	100%
12.5%	100%	87.5%
25%	100%	95%
50%	95%	85%
75%	100%	100%
100%	100%	95%

found no significant toxicity (see **Table 5-11**). The results show that LLNL’s effluent water sample shows no toxicity, either acute or chronic, to the fathead minnows.

### 5.3.4 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.

Site 300 has at least 23 springs; 19 are perennial and 4 are intermittent. Most of the springs have very low flow rates and are recognized only by small marshy areas, pools of water, or vegetation.

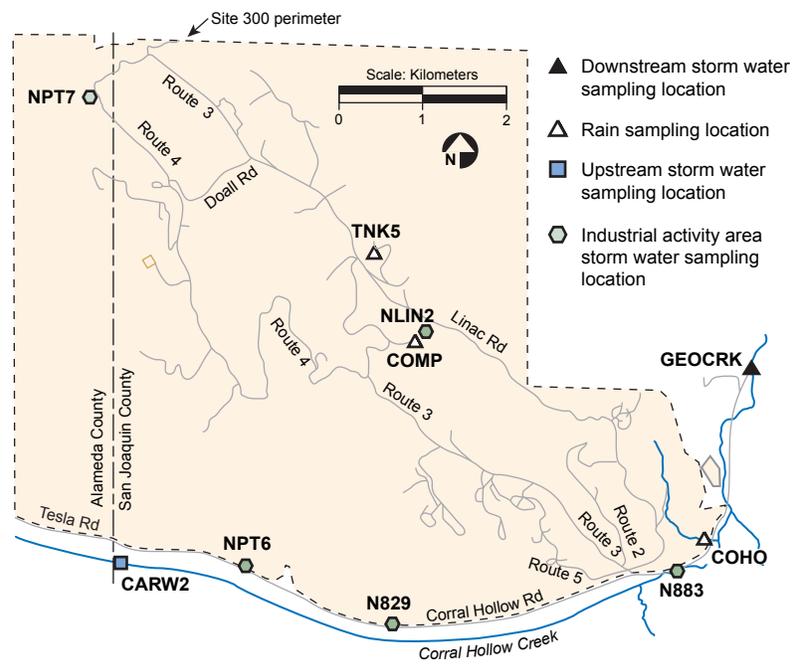
In 2006, storm water runoff was characterized at three sampling locations that could be affected by specific Site 300 industrial activities. In addition, samples from off-site location CARW2 are used to characterize Corral Hollow Creek upstream because the location is unaffected by Site 300 industrial storm water discharges. Samples from off-site location GEOCRK are used to characterize Corral Hollow Creek downstream of Site 300. Sampling locations are shown in **Figure 5-9**.

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 the site 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 occurs. At some of the sampling locations in some years, there has not been enough rain to generate runoff over an entire rainy season. On January 18 and March 7, 2006, storm water samples were collected and analyzed from all locations that normally have storm water flow.

#### 5.3.4.1 Radiological Monitoring Results

In 2006, storm water sampling and analysis were performed for gross alpha and gross beta radioactivity, uranium isotopes, and tritium, and results were compared with the site-specific thresholds listed in **Table 5-8**. (Complete analytical results are provided in **Appendix B, Section B.4**.) Tritium was detected in a storm water sample from location GEOCRK at 3.8 Bq/L (102 pCi/L) (see **Table 5-12**), the first detection of tritium in any storm water

**Figure 5-9.** Storm water and rainwater sampling locations at Site 300, 2006.



sample collected from Site 300 above the threshold limit. LLNL will continue to track this tritium to see whether any trends develop. No concentrations of gross alpha and gross beta radioactivity in the storm water samples collected from any location exceeded LLNL’s site-specific thresholds.

**5.3.4.2 Nonradiological Monitoring Results**

In 2006, Site 300 storm water samples were analyzed for nonradiological water quality parameters, and sample results were compared with the site-specific thresholds listed in **Table 5-8**. Constituents that exceeded the thresholds for sampled locations are listed in **Table 5-11**.

**Table 5-12.** Water quality parameters in storm water runoff above LLNL site-specific thresholds, Site 300, 2006.

Radioactive/ nonradioactive	Parameter	Date	Location	Upstream, downstream/ effluent	Result	LLNL threshold
Radioactive	Tritium (Bq/L)	3/7/06	GEOCRK	Downstream	3.8 ± 2.2	3.17
Nonradioactive	Beryllium (mg/L) <sup>(a)</sup>	1/18/06	CARW2	Upstream	0.0019	0.0016
		3/7/06	NLIN2	Effluent	0.0022	0.0016
	Lead (mg/L) <sup>(a)</sup>	1/18/06	CARW2	Upstream	0.033	0.030
	Chemical oxygen demand (mg/L)	1/18/06	NLIN2	Effluent	300	200

(a) Total metals including particulates.

Concentrations of beryllium and lead collected from upstream location CARW2, and of beryllium collected from effluent location NLIN2 exceeded their respective Site 300 threshold limits.

LLNL staff compared the monitored concentrations to those at the upstream (CARW2) and downstream (GEOCRK) receiving water monitoring locations in both the January and the March events. In the January event, the monitored concentration for beryllium of 0.0019 mg/L at the upstream monitoring location was just above the site-specific threshold of 0.0016 mg/L, and the concentration at the downstream location was below the detection limit. In March, the concentration of beryllium at the upstream monitoring location (CARW2) was just above the detection limit at 0.00021 mg/L, and the value at the downstream monitoring location (GEOCRK) was below the detection limit. Based on this evaluation, LLNL staff concluded that the on-site concentration of beryllium at NLIN2 in the March event was consistent with natural concentrations of this constituent within the measurement limits of error and did not adversely affect downstream runoff. Concentrations of both beryllium and lead in samples collected from upgradient location CARW2 have remained higher than Site 300-specific thresholds through January 2006.

LLNL noted that chemical oxygen demand concentrations (300 mg/L) in a sample collected from effluent location NLIN2 on January 18 exceeded the threshold (200 mg/L). In the autumn 2005, LLNL moved previous monitoring location NLIN upstream nearly 2 km to present location NLIN2 for logistical reasons to avoid delays in sample collection. LLNL staff believe that organic material is being mobilized by runoff from a wetland area immediately upstream of sample location NLIN2. (Complete analytical results are provided in **Appendix B, Section B.4.**)

Because of a 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 from locations CARW2, NLIN2 (sampling location downstream from Building 850), and GEOCRK. 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 provided in **Appendix B, Section B.4.**) No PCBs were detected in those samples. All dioxins detected were below the equivalent federal MCL of 30 picograms per liter (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-tetraCDD). The other dioxin and furan congeners have varying degrees of toxicity. EPA has assigned toxicity equivalency factors (TEFs) to specific dioxin and furan congeners. The congeners 2,3,7,8-tetraCDD and 1,2,3,7,8-pentaCDD have an assigned TEF of 1; the other dioxin and furan congeners have TEFs of <1. The toxicity equivalency (TEQ) is determined by multiplying the concentration of a dioxin and furan congener by its TEF. See **Appendix B, Section B.4,** for the concentrations of dioxin and furan compounds that have non-zero TEFs along with their calculated TEQs. If the very conservative approach of adding congeners that were not

detected at concentrations equal to one half the analytical reporting limits is used, total TEQs for each location and each sampling event (from 1.2 to 19 pg/L) are all below the federal MCL of 30 pg/L for 2,3,7,8-tetraCDD and are well below the concentrations of similar dioxins and furans measured at locations NLIN (slightly downstream from location NLIN2) and GEOCRK in 2002 (see Sanchez 2003). The highest total TEQ was 19 pg/L for samples collected from location NLIN2 for the March 7 sampling event. LLNL will continue to monitor storm water concentrations to determine whether trends are emerging.

### **5.3.5 Environmental Impact of Storm Water**

Storm water runoff from the Livermore site did not have any apparent environmental impact in 2006. Tritium activities in storm water runoff effluent were <1% of the drinking water MCL. Gross alpha and gross beta activities in effluent samples at the Livermore site were both far less than their respective MCLs. Site 300 storm water monitoring continues to show that most contaminants (including dioxins and furans, lead, and beryllium) are transported sorbed to suspended sediments in the water; however, these concentrations pose no threat to the environment.

---

## **5.4 Groundwater**

LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and at Site 300 through networks of wells and springs that include off-site private wells and on-site DOE CERCLA wells. The groundwaters that are monitored at the Livermore site and Site 300 are not connected; they are separated by a major drainage divide and numerous faults.

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 and perchlorate, to past operations, while the source of other contaminants, such as nitrate, is the object 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 sewage ponds and percolation pits; the latter are discussed in **Section 5.2.3**. Compliance monitoring is specified in WDRs issued by the CVRWQCB and in landfill closure and post-closure monitoring plans. (See **Chapter 2**, **Table 2-2** for a summary of LLNL permits.)

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

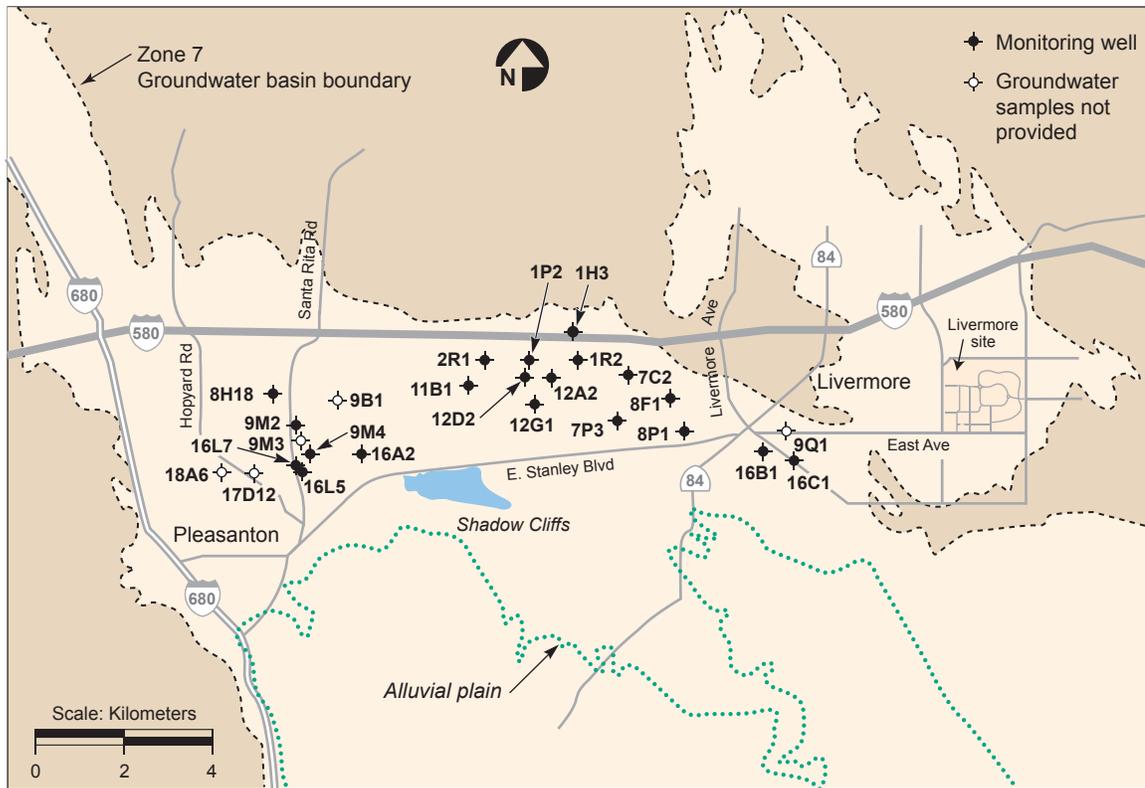
Typically, because they are both accurate and sensitive, analytical methods approved by EPA are used to measure dissolved constituents in water. **Appendix C** lists the analytical methods and reporting limits that are used to detect organic and inorganic constituents in groundwater (including specific 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 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 tailored to prevent releases of potential contaminants to the environment.

During 2006, representative samples of groundwater were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures* (Goodrich and Wimborough 2006). The procedures cover sampling techniques and information concerning the chemicals that are routinely analyzed for in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps or had to be bailed. All of the chemical and radioactivity analyses of groundwater samples were performed by California-certified analytical laboratories. For comparison purposes only, some of the results were compared with drinking water limits (MCLs); however, MCLs do not apply as regulatory limits to any of these groundwaters.

## **5.4.1 Livermore Site and Environs**

### **5.4.1.1 Livermore Valley**

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. Tritiated water (HTO) is potentially the most mobile groundwater contaminant



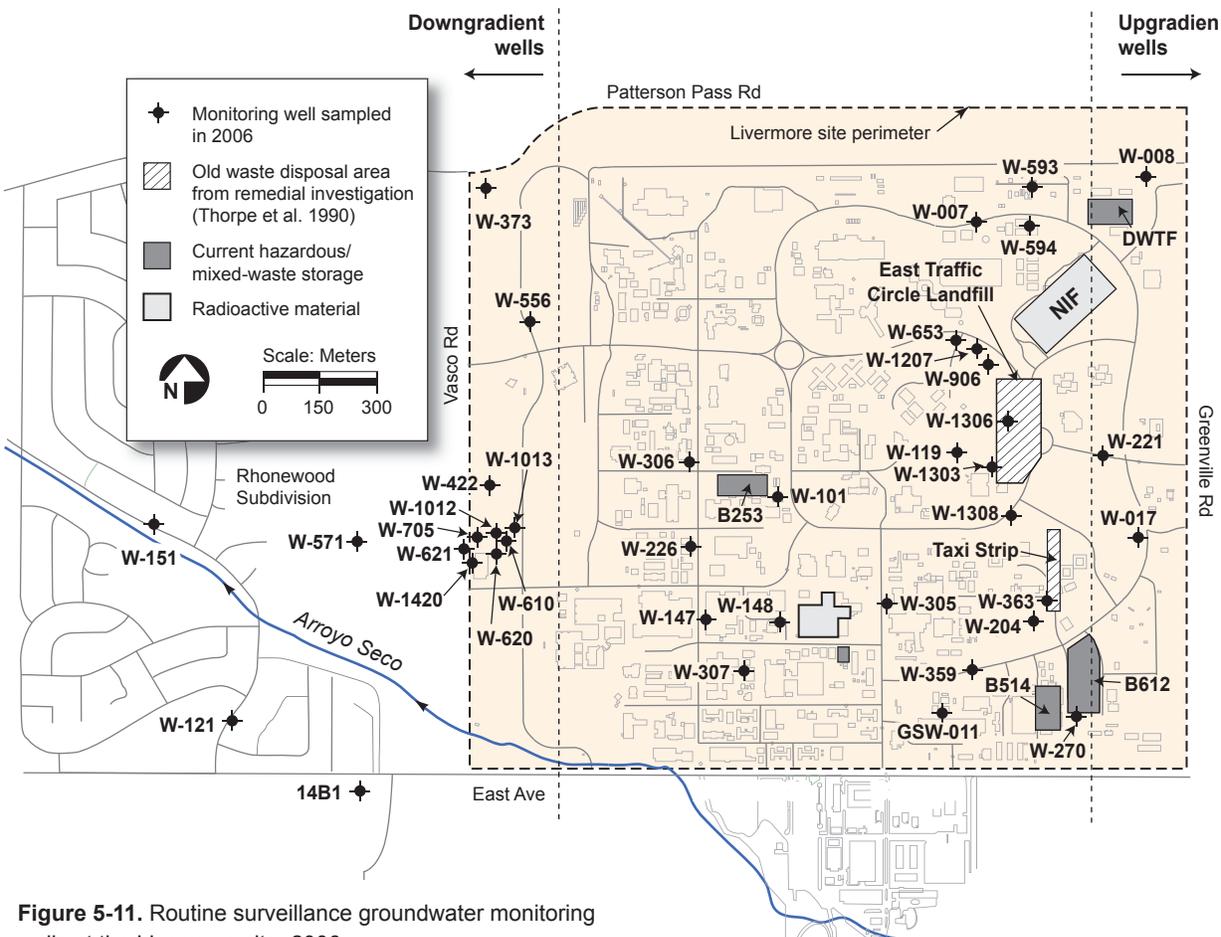
**Figure 5-10.** Off-site tritium monitoring wells in the Livermore Valley, 2006.

from LLNL operations. Rain and storm water runoff in the Livermore Valley, which recharge local aquifers, contain small amounts of HTO from natural sources, previous 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 Thorpe et al. (1990) and Karachewski et al. (2007).

Groundwater samples were obtained during 2006 from 20 of 25 water wells in the Livermore Valley (see **Figure 5-10**) and measured for tritium activity. Five wells were either dry or could not be sampled during 2006.

Tritium measurements of Livermore Valley groundwaters are provided in **Appendix B, Section B.5**. The measurements continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) MCL established for drinking water in California. The maximum tritium activity measured off site was in the groundwater at



**Figure 5-11.** Routine surveillance groundwater monitoring wells at the Livermore site, 2006.

well 9M2, located about 14 km west of LLNL (see **Figure 5-10**). The measured activity there was 2.7 Bq/L (72.6 pCi/L) in 2006, less than 0.5% of the MCL.

#### 5.4.1.2 Livermore Site Perimeter

LLNL’s groundwater surveillance monitoring program was designed to complement the Livermore Site GWP (discussed in **Chapter 8**). The intent of the program is to monitor for potential groundwater contamination from LLNL operations. The perimeter portion of the surveillance groundwater monitoring network uses three upgradient (background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven (downgradient) monitoring wells located near the western boundary (wells 14B1, W-121, W-151, W-1012, W-571, W-556, and W-373) (see **Figure 5-11**). The seven wells, located in the regions of groundwater treatment facilities A, B, and C (TFA, TFB, and TFC) (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.

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 2006 for pesticide and herbicide compounds that are used on and off site for nitrate, for hexavalent chromium [chromium(VI)], and for certain radioactive constituents including plutonium.

To detect contaminants as quickly as possible, the seven western downgradient wells (except well 14B1) were screened in shallower HSU-1B and HSU-2, the uppermost water-bearing HSUs at the western perimeter. (Because it was originally a production well, well 14B1 was screened over a depth range that includes HSU-2, HSU-3A, and HSU-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 perimeter wells are provided in **Appendix B, Section B.5**. One sample from the western perimeter (downgradient) well W-121 was reported to contain the pesticide merphos (1.2 micrograms per liter [ $\mu\text{g}/\text{L}$ ]); however, this result is suspect due to analytical quality-control complications reported by the analytical laboratory. An independent retest of this well in January 2007 failed to confirm the detection. No pesticide or herbicide organic compounds were detected above analytical reporting limits in groundwater samples from the other perimeter (upgradient or downgradient) wells during 2006. 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 2006 groundwater samples from the upgradient wells represent current background values.

Historically, chromium(VI) has been detected above the MCL (50  $\mu\text{g}/\text{L}$ ) in groundwater samples from western perimeter well W-373. Since well W-373 was first monitored in 1989, chromium(VI) concentrations have ranged from 160  $\mu\text{g}/\text{L}$  (in 1989) to 39  $\mu\text{g}/\text{L}$  (in 2005), with an overall downward trend that first dropped below the MCL in 2002. Although the 2006 sample from well W-373 showed a slight increase in the chromium(VI) concentration (52  $\mu\text{g}/\text{L}$ ), this change is consistent with previous year-to-year variability. An independent retest of this well in January 2007 reported a chromium(VI) concentration of 37  $\mu\text{g}/\text{L}$ .

From 1996 through 2004, concentrations of nitrate detected in groundwater samples from downgradient well W-1012 were greater than the MCL of 45 mg/L. The nitrate concentrations detected in samples from this well during 2006 (35 and 32 mg/L) were below the MCL, continuing the downward trend noted in the 2005 (43 and 41 mg/L). The highest concentration measured in the downgradient off-site wells (screened in HSU-1B and HSU-2)

remained below the MCL: 41 mg/L in monitoring well W-151. During 2006, concentrations of nitrate in on-site shallow background wells W-008 and W-221 ranged from 24 mg/L to 32 mg/L. Detected concentrations of nitrate in western perimeter wells ranged from 14 mg/L (in well W-373) to 43 mg/L (in well W-556).

In 2006, nitrate concentrations were also analyzed in groundwater samples collected from seven additional monitoring wells near well W-1012 (see **Figure 5-11**), similarly screened in HSU-1B and HSU-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).

No concentrations of plutonium radioisotopes were detected above the radiological laboratory's minimum detectable activities in any of the samples from LLNL's site perimeter wells in 2006. Gross alpha, gross beta, radium-226, and tritium were detected occasionally and at levels consistent with the results from recent years; however, the concentrations again remain well below drinking water MCLs.

#### **5.4.1.3 Livermore Site**

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past, where previously detected COCs have low concentrations that do not require CERCLA remedial action, and where baseline information needs to be gathered for the area near a new facility or operation. Wells selected for monitoring are screened in the uppermost aquifers and are downgradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 5-11**. All analytical results are provided in **Appendix B, Section B.5**.

The Taxi Strip and East Traffic Circle Landfill areas within the Livermore site (see **Figure 5-11**) are two potential sources of historical groundwater contamination. Samples from monitoring wells screened in HSU-2 (W-204) and HSU-3A (W-363) downgradient from the Taxi Strip Area were analyzed in 2006 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 the Taxi Strip Area. No concentrations of plutonium, americium, or radium radioisotopes were detected above the radiological laboratory's minimum detectable activities. Concentrations of tritium remained well below the drinking water MCL. Of the trace metals (copper, lead, and zinc), only zinc was detected in any of these seven monitoring wells during 2006. A zinc concentration of 22 µg/L was reported for well W-906, far 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 measures pH, conductivity, and tritium concentration of groundwater quality to establish a

baseline prior to the start of operations. During 2006, tritium analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSU-3A and HSU-2, respectively) downgradient of NIF. Samples were obtained downgradient from the Decontamination and Waste Treatment Facility (DWTF) from wells W-007, W-593, and W-594 (screened in HSU-2/3A, HSU-3A, and HSU-2, respectively) during 2006 and were analyzed for tritium.

Monitoring results from the wells near NIF and DWTF showed no detectable concentrations of tritium, above the limit of sensitivity of the analytical method, in the groundwater samples collected during 2006. 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. The area and facilities are monitored by wells W-270 and W-359 (both screened in HSU-5), and well GSW-011 (screened in HSU-3A). Groundwater from these wells was sampled and analyzed for general minerals, gross alpha, gross beta, americium-241, plutonium-238, plutonium-239, radium-226, and tritium in 2006. No significant contamination was detected in the groundwater samples collected from wells W-270, W-359, or GSW-011 downgradient from those areas in 2006.

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 the 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 would migrate from the site. In 2006, the monitoring results for well W-307 showed only slight variations from the concentrations reported in recent years.

Groundwater samples were obtained downgradient from a location where sediments containing metals (including cadmium, chromium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253. The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). In 2006, the samples obtained from monitoring wells W-226 and W-306 (screened in HSU-1B and HSU-2, respectively) contained dissolved chromium at elevated concentrations, but concentrations were essentially unchanged from last year. Concentrations of chromium(VI) were 27 µg/L at well W-226 and 38 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, are in areas surrounding the Plutonium Facility and Tritium Facility. Potential contaminants include plutonium and tritium from these facilities, respectively. Plutonium is much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, can migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305

is screened in HSU-2; downgradient wells W-101, W-147, and W-148 are screened in HSU-1B. Groundwater samples collected from these wells during 2006 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 detected in the groundwater sampled at well W-148 ( $115 \pm 5.0$  Bq/L [ $3100 \pm 135$  pCi/L]). The activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater in this area have been at or near the same level since then, but both samples collected from well W-148 in 2006 showed lower values—approximately one half the August 2000 value (64 Bq/L and 57 Bq/L). 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.

#### **5.4.2 Site 300 and Environs**

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses on-site DOE CERCLA wells and springs and off-site private wells and springs. Representative groundwater samples are obtained at least once a year at every monitoring location, and the samples are analyzed 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 surface and sub-surface operations at Site 300.

Twelve groundwater monitoring locations are off site (see **Figure 5-12**). Two, MUL2 and VIE1, are springs near the northern boundary of Site 300. Off-site surveillance well VIE2 is 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. Eight off-site surveillance locations are wells 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 closed explosives burn pit, and two operational, connected sewer ponds. The closed landfills—identified as Pit 1, Pit 2, Pit 7 Complex, Pit 8, and Pit 9—are in the northern portion of Site 300 in the Elk Ravine drainage area, while Pit 6, the former burn pit (Building 829), and the sewage ponds are 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

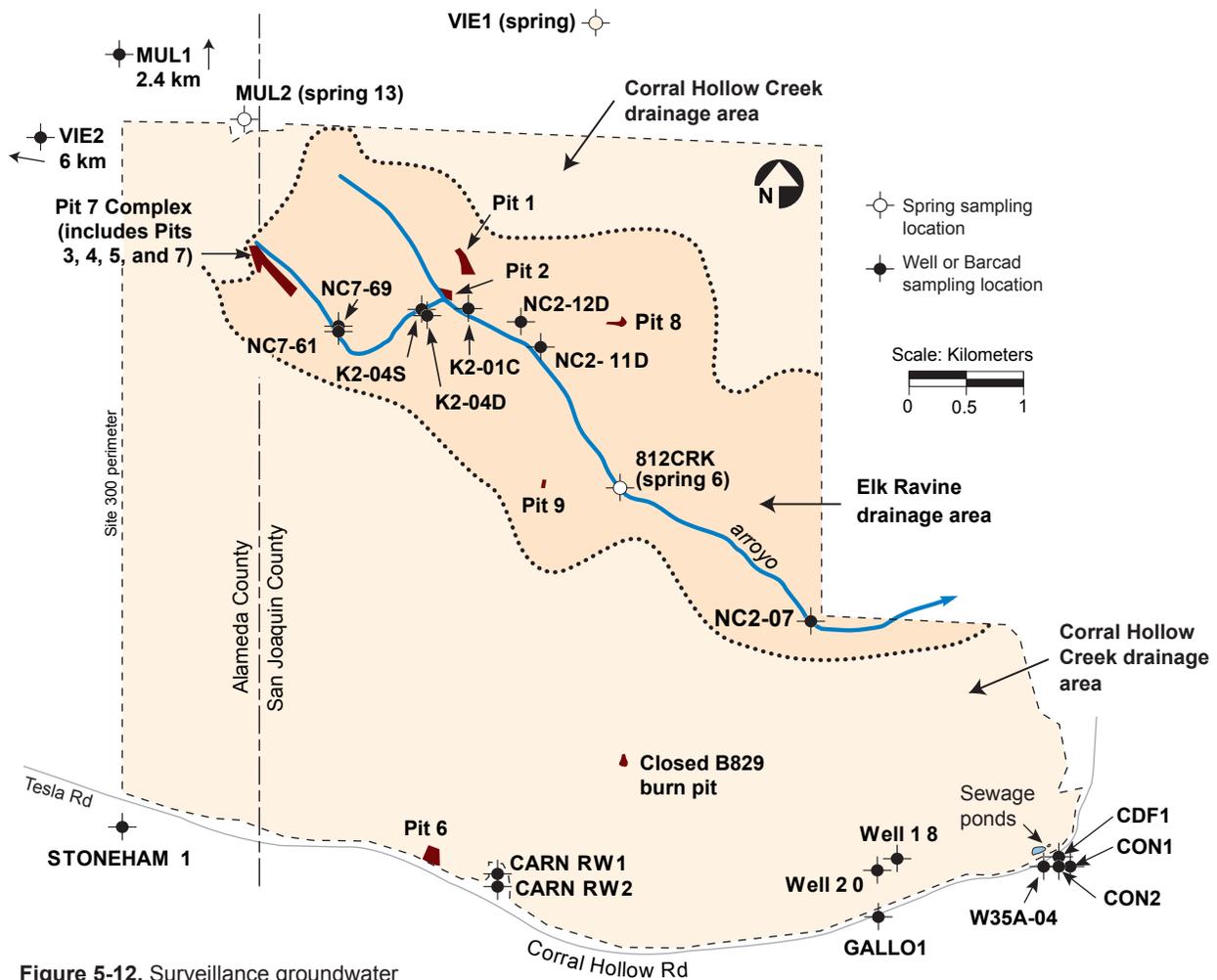


Figure 5-12. Surveillance groundwater wells and springs at Site 300, 2006.

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 2006 are provided in Appendix B, Section B.5.)

#### 5.4.2.1 Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see Figure 5-12). 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 the disposal practices when the landfills were constructed. The following descriptions

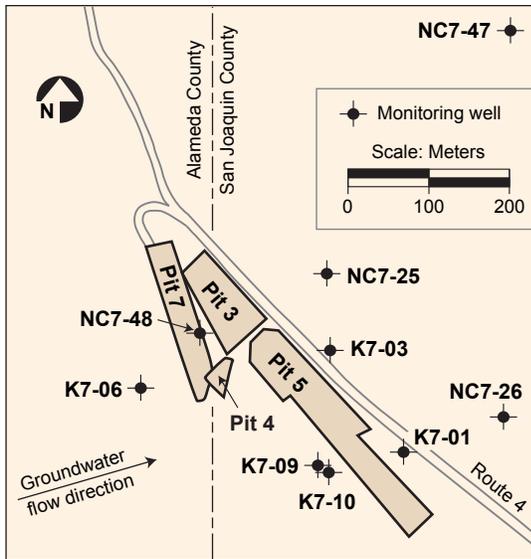
of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See **Chapter 8** for a review of groundwater contamination in this drainage area as determined from numerous CERCLA remedial investigations.)

**Pit 7 Complex.** Monitoring requirements for the Pit 7 landfill, which was closed under the Resource Conservation and Recovery Act of 1976 (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 at an elevation of about 400 meters (m) above sea level and is in the highest portion of the Elk Ravine drainage area. The complex consists of four adjacent landfills identified as Pits 3, 4, 5, and 7 (see **Figure 5-13**). 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 cubic meters (m<sup>3</sup>) of gravel were removed from six firing tables at Site 300 and placed in Pit 7 (Lamarre and Taffet 1989) and were the last solid wastes to be placed in any landfill at Site 300.

For compliance purposes, LLNL obtained groundwater samples quarterly during 2006 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 was evident in the chemical data obtained during 2006. The COCs detected in groundwater include several metals, depleted uranium, tritium, and several VOCs and are associated with releases that occurred prior to 2006. 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 (see **Figure 5-13**). 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



**Figure 5-13.** Pit 7 compliance groundwater monitoring wells, Site 300, 2006.

the release of COCs, mainly tritium in the form of HTO. Because of reduced rainfall since 1998, groundwater elevations have generally fallen 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 Campbell and MacQueen (2007).

**Elk Ravine.** Groundwater samples were obtained on various dates in 2006 from the widespread Elk Ravine surveillance monitoring network (see **Figure 5-12**). 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 2006. 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 C**.

Concentrations of arsenic range up to 42 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, see **Figure 5-12**), which is used by the indigenous wildlife, contains concentrations of naturally occurring arsenic (31 µg/L arsenic in 2006).

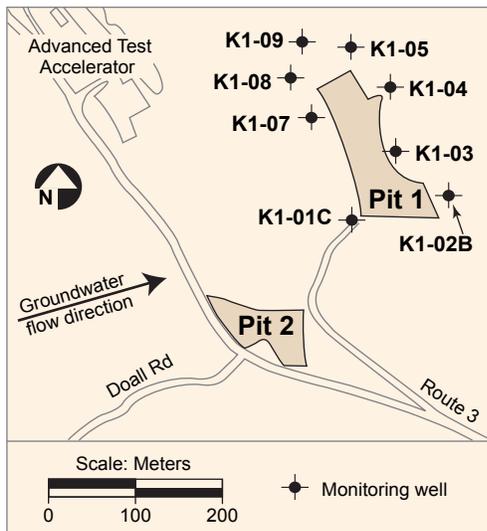
An elevated tritium activity was detected in one of five shallow groundwater surveillance samples collected from wells in Elk Ravine during 2006 (well NC7-61, 1200 Bq/L [ $3.2 \times 10^4$  pCi/L]). Tritium, as HTO, has been released in the past in the vicinity of Building 850. The largest HTO plume, which extends eastward more than 1 km 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 2006 support earlier CERCLA studies that show that the tritium in the plume is diminishing 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 ( $1.8 \times 10^5$  pCi/L) in 1996 to 1200 Bq/L ( $3.2 \times 10^4$  pCi/L) in 2006. 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 1.6 km upstream from where the Site 300 boundary crosses Elk Ravine.

Groundwater surveillance measurements of gross alpha, gross beta, and uranium radioactivity in Elk Ravine were all low in 2006 and 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, were 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, 1998a) 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.



**Figure 5-14.** Pit 1 compliance groundwater monitoring wells, Site 300, 2006.

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 5-14**. 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 2006 from the Pit 1 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA Methods 601 and 8260). Additional annual analyses were conducted on groundwater samples for extractable organics (EPA Method 625), as well as pesticides and PCBs (EPA Method 608). Field measurements of

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

No release of COCs to groundwater from Pit 1 was evident in the 2006 monitoring data. A detailed account of Pit 1 compliance monitoring during 2006, including tables and graphs of groundwater COC analytical data, is in Campbell and MacQueen (2007).

During 2006, average tritium activities above analytical background levels (about 4 Bq/L [100 pCi/L]) were measured in the groundwater at Pit 1 monitoring wells K1-01C (26 Bq/L [693 pCi/L]), K1-02B (147 Bq/L [3965 pCi/L]), K1-03 (35 Bq/L [951 pCi/L]), K1-04 (8 Bq/L [221 pCi/L]), K1-08 (7 Bq/L [183 pCi/L]), and K1-09 (5 Bq/L [140 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

2006 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 51 µg/L in 2006 in groundwater samples at Pit 1 monitoring well K1-09. Maximum annual Freon-113 concentrations at groundwater monitoring wells K1-05 and K1-08 were 18 µg/L and 34 µg/L, respectively. The drinking water MCL for this VOC is 1200 µg/L. CERCLA investigations have linked the Freon-113 detection in Pit 1 monitoring wells to area source at Building 865, about 300 m northwest of Pit 1 (Webster-Scholten 1994; Taffet et al. 1996; Ferry and Holtzaple 2006).

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

**Pit 6.** Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in Ferry et al. (1998, 2002). The closed Pit 6 landfill covers an area of about 1 ha (2.5 ac) at an elevation of approximately 215 m above sea level. From 1964 to 1973, approximately 1500 m<sup>3</sup> 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<sup>3</sup> of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 m<sup>3</sup> 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 floodplain. 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 5-15**. 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).

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 5-15** 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 2006 from specified Pit 6 monitoring wells. DMP samples were obtained quarterly and were

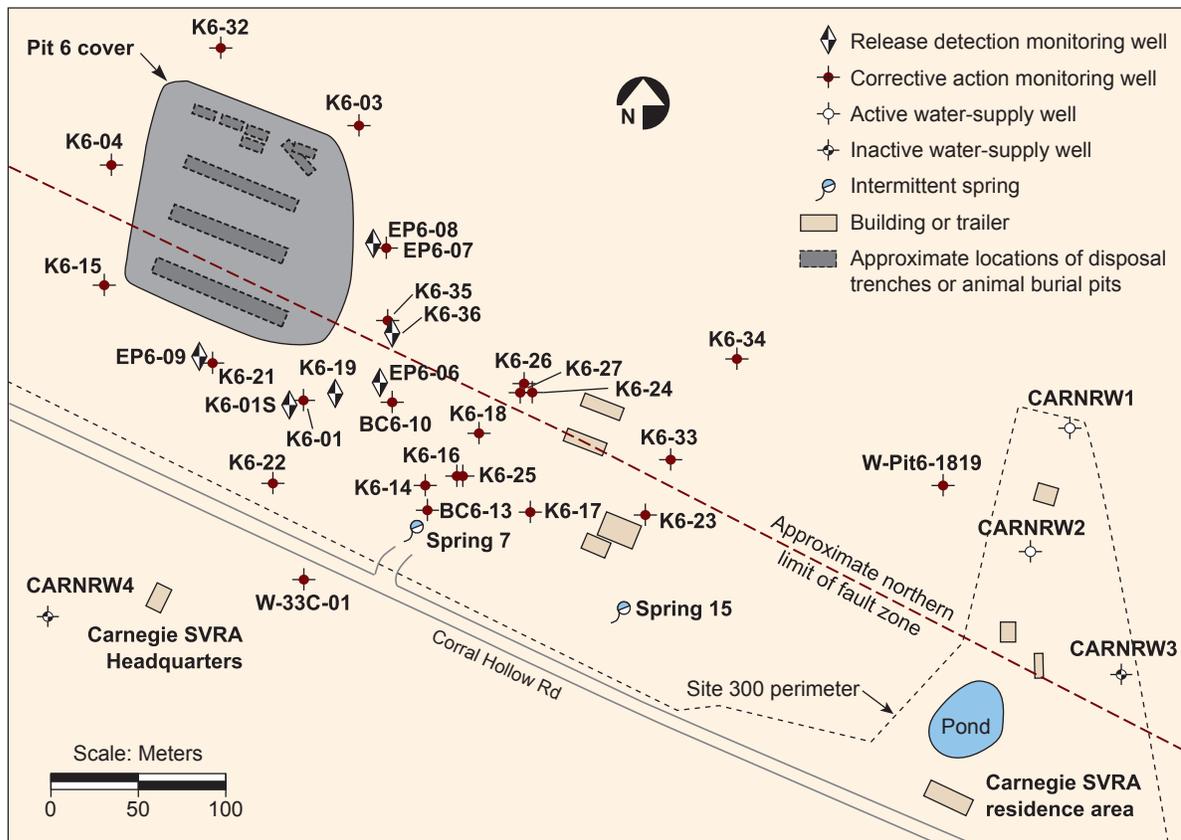


Figure 5-15. Pit 6 compliance groundwater monitoring wells and springs, Site 300, 2006.

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 was indicated by the chemical analyses of groundwater samples obtained from Pit 6 monitoring wells during 2006. 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 2006. 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 2006, including tables of groundwater analytical data and maps showing the distribution of COC plumes, see Campbell and Taffet (2007).

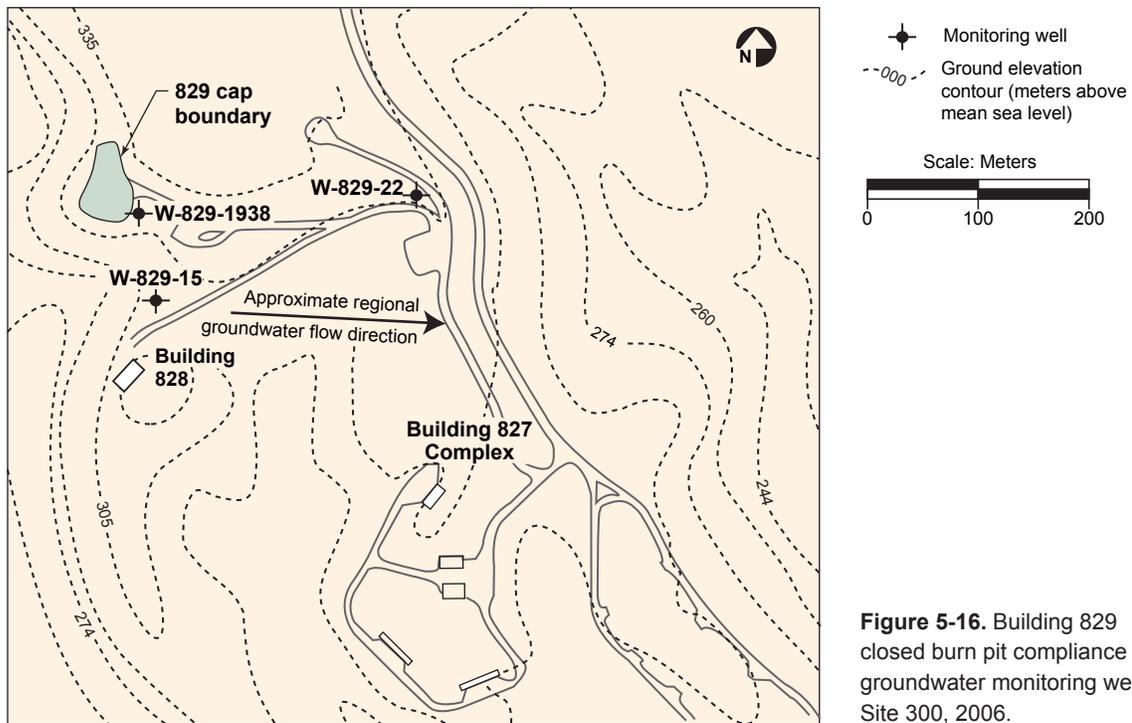
**Building 829 Closed High Explosives Burn Facility.** Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in Mathews and Taffet (1997), and in LLNL (2001), as modified by DTSC (2003).

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<sub>2</sub>). The deeper zone, at a depth of about 120 m, represents a regional aquifer within the Neroly upper sandstone member (Tnbs<sub>2</sub>). (See **Figure 8-5** for Site 300 stratigraphy.)

Based on groundwater samples recovered from boreholes, CERCLA remedial investigations have 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 implementing 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 3 m 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 2006, well W-829-1938 has been used for quarterly collection of groundwater samples from the regional aquifer as part of the permit-specified



**Figure 5-16.** Building 829 closed burn pit compliance groundwater monitoring wells, Site 300, 2006.

monitoring network (see **Figure 5-16**). Also shown in **Figure 5-16** are two previously existing wells, W-829-15 and W-829-22, which were each sampled once in 2006 in accordance with the DTSC-approved change in sampling frequency (from quarterly to annual) for these two wells (DTSC 2005).

As planned for compliance purposes, LLNL obtained groundwater samples during 2006 from the Building 829 monitoring well network. Groundwater samples from the wells screened in the deep regional aquifer were analyzed for inorganics (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.

During 2006, there were no confirmed COC detections above their respective statistical limits in groundwater samples from any of the three monitoring wells. Among the inorganic constituents, the metal COCs that were detected showed concentrations that are not significantly different from background concentrations for the deep aquifer beneath the High Explosives (HE) Process Area. Similarly, all results for gross alpha and gross beta (the radioactive COCs) were below their statistical limit values. The COC perchlorate was initially reported in one sample from well W-829-1938, but this result was subsequently invalidated. There were no organic or explosive COCs detected above reporting limits in any samples.

No new release of COCs to groundwater from the closed Burn Facility was indicated by the monitoring data obtained during 2006. For a detailed account of compliance monitoring of the closed burn pit during 2006, including tables and graphs of groundwater COC analytical data, see Revelli (2007b).

**Water Supply Well.** Water supply Well 20, located in the southeastern part of Site 300 (see **Figure 5-12**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer (Tnbs<sub>1</sub>) and can produce up to 1500 liters per minute (L/min) of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2006 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 did not differ significantly from previous years. As in past years, this Site 300 primary potable water supply well showed no evidence of contamination. Gross alpha, gross beta, and tritium activities were very low and are indistinguishable from background level activities.

#### **5.4.2.3 Off-site Surveillance Wells and Springs**

As planned for surveillance purposes, LLNL obtained groundwater samples from two off-site springs and ten off-site wells during 2006. 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 (see **Figure 5-12**). 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 floodplain.

Groundwater samples were obtained quarterly during 2006 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) for samples collected from CARNRW2 only.

Groundwater samples were obtained once (annually) during 2006 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 (metals, nitrate, and perchlorate), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs, and extractable organic compounds (EPA Method 625).

Generally, no 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. Radioactivity measurements of off-site groundwater are generally indistinguishable from background activities.

### **5.4.3 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 2006, neither radioactivity nor concentrations of elements or compounds detected in groundwater that could be affected by LLNL activities were confirmed to be above potable water MCLs.

---

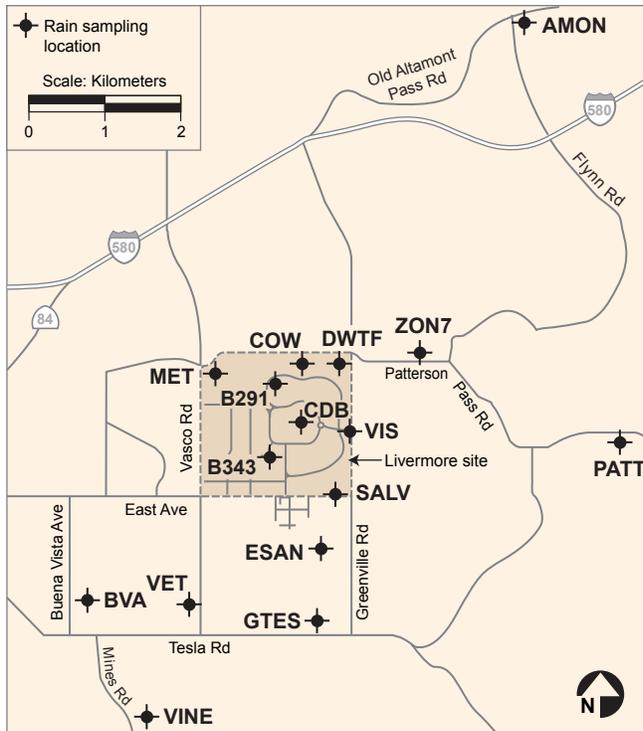
## **5.5 Other Monitoring Programs**

### **5.5.1 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 that are summarized in Woods (2005). Rainwater is collected in stainless-steel buckets at fixed locations. The buckets are in open areas and 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 provided in **Appendix B, Section B.7**.

#### **5.5.1.1 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, and prior to 1995, from the former Tritium Research Laboratory at Sandia/California. During 2006, 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 the Tritium Facility. Atmospheric emissions of tritium from the Tritium Facility are shown in **Figure 4-4**.



**Figure 5-17.** Rain sampling locations, Livermore site and Livermore Valley, 2006.

Other sources include the Waste Management Area (WMA) at Building 612 and the DWTF (see **Chapter 4**).

Rain sampling locations are shown in **Figure 5-17**. The fixed locations are used to determine the areal extent of detectable tritium activity in rainwater. During 2006, 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 Livermore site rainwater has exhibited elevated tritium activities in the past (Gallegos et al. 1994), during 2006, 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, 13 Bq/L

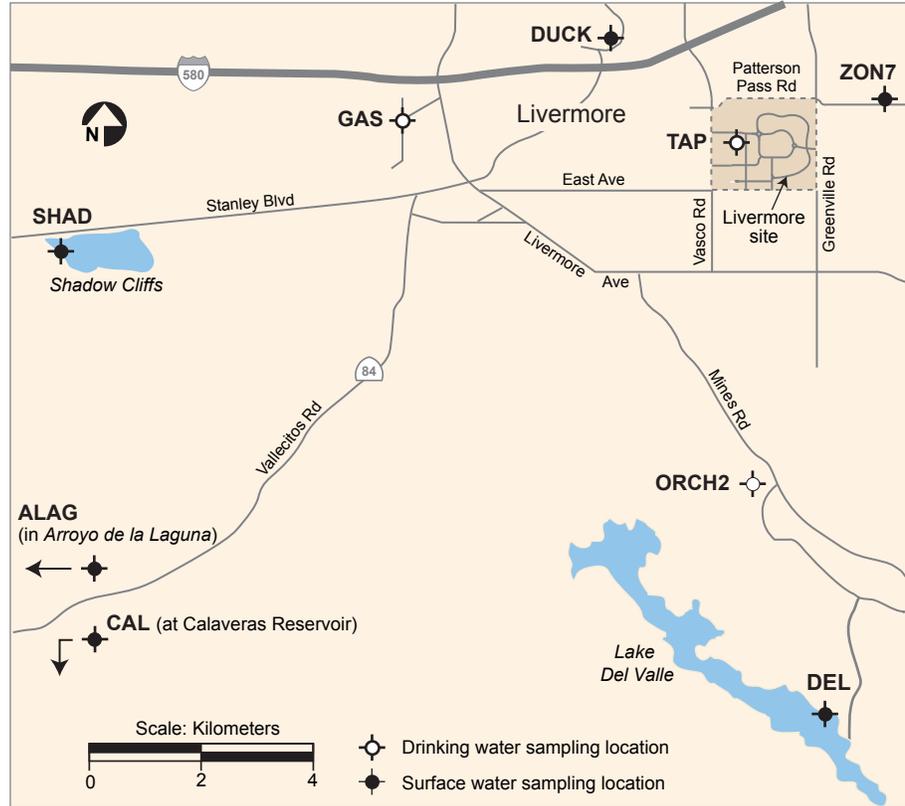
(351 pCi/L), for the rain event that was sampled on January 18. The maximum tritium activity measured in off-site rainwater samples during 2006 were estimated values below the minimum reporting limit of 3.7 Bq/L (100 pCi/L) in the rainwater sample obtained on March 3 and December 12 from locations AMON and VET, respectively (see **Figure 5-17**).

#### 5.5.1.2 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 2006 (see **Figure 5-9**). During 2006, two rain events were sampled. As in past years, none of the rainwater samples from monitoring locations at Site 300 during 2006 showed tritium activities above the analytical laboratory reporting limit of 3.7 Bq/L (100 pCi/L).

#### 5.5.2 Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5. Surface and drinking water near the Livermore site and in the Livermore Valley were sampled at the locations shown in **Figure 5-18** in 2006. 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, ORCH2 (note that this ORCH2 is a shallower well adjacent to the location of the original ORCH well), and TAP are drinking



**Figure 5-18.** Livermore Valley surface and drinking water sampling locations, 2006.

water outlets. Radioactivity data from drinking water sources are used to calculate drinking water statistics (see **Table 5-13**).

Samples are analyzed according to written, standardized procedures summarized in Woods (2005). LLNL sampled these locations semiannually, in January and July 2006, for gross alpha, gross beta, and tritium. All analytical results are provided in **Appendix B, Section B.7**.

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. The maximum tritium activity detected in any sample collected in 2006 was 5.62 Bq/L (152 pCi/L), less than 1% of the drinking water MCL. 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 radioactivity, respectively, were 0.042 Bq/L (1.13 pCi/L) and 0.206 Bq/L (5.58 pCi/L); both were less than 15% of their respective MCLs (see **Table 5-13**). Historically, concentrations of gross alpha and gross beta radiation have fluctuated around the laboratory’s minimum detectable activities. At these very low levels, the counting error associated with the measurements is nearly equal to, or in many cases greater than, the calculated values so that no trends are apparent in the data.

**Table 5-13.** Radioactivity in surface and drinking waters in the Livermore Valley, 2006.<sup>(a)</sup>

Location	Metric	Tritium (Bq/L)	Gross alpha (Bq/L)	Gross beta (Bq/L)
All locations	Median	0.13	-0.004	0.085
	Minimum	-1.91	-0.037	0.012
	Maximum	5.62	0.042	0.206
	Interquartile range	2.14	0.022	0.047
Drinking water locations	Median	0.741	-0.010	0.071
	Minimum	-1.22	-0.027	0.012
	Maximum	5.18	0.003	0.124
	Interquartile range	3.49	0.014	0.051
	Drinking water MCL	740	0.555	1.85

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

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 (now Lake Haussmann), reported on elsewhere in this chapter, became the closest routinely monitored surface water to the Tritium Facility.

### 5.5.3 Lake Haussmann Release

Lake Haussmann (formerly known as the Drainage Retention Basin or 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 near the center of the Livermore site, Lake Haussmann can hold approximately 45.6 million L (37 acre-feet) of water. Previous LLNL environmental reports detail the history of the construction and management of Lake Haussmann (see Harrach et al. 1995, 1996, 1997). Beginning in 1997, LLNL discharges to Lake Haussmann included routine treated groundwater from areas TFD and TFE (see **Figure 8-1**), and from related portable treatment units. These discharges contribute a year-round source of water entering and exiting Lake Haussmann. The discharge rate is approximately 380 L/min. Storm water runoff still dominates wet weather flows through Lake Haussmann, but discharges from the treatment facilities now constitute a substantial portion of the total water passing through the lake.

The SFBRWQCB regulates discharges from Lake Haussmann. 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 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 D** for the limits used.

The Lake Hausmann 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 Berg et al. (1997) (wet season December 1 through March 31, dry season April 1 through November 30).

To characterize wet-season discharges, LLNL samples Lake Hausmann 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 5-8**. LLNL collects samples at CDBX to determine compliance with discharge limits. Sampling at WPDC is performed to identify any change in water quality as Lake Hausmann discharges travel through the LLNL storm water drainage system and leave the site.

Written, standardized sample collection procedures are summarized in Woods (2005). State-certified laboratories analyze the collected samples for chemical and physical parameters. All analytical results are included in **Appendix B, Section B.7**.

In 2006, water releases typically occurred continuously to maintain relatively low nutrient levels in Lake Hausmann and because treatment facility discharge to Lake Hausmann exceeded the evaporation rate. Samples collected at CDBX and WPDC exceeded only the pH discharge limits. The higher pH readings seen in Lake Hausmann discharge samples during the summer correspond to the peak of the summer algal bloom within Lake Hausmann. During 2006, total dissolved solids and specific conductance continued to reflect the levels found in groundwater discharged to Lake Hausmann. While some metals were detected, none was above discharge limits. All organics and PCBs were below analytical detection limits. Pesticides, gross alpha, gross beta, and tritium levels were well below discharge limits.

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 capricornutum*]). 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 Lake Hausmann discharge water.

In early October 2006, the lake level was lowered and exits from the lake were sealed. On October 6, 2006, the piscicide (fish pesticide) rotenone was applied to Lake Haussmann to control non-native fish species and to protect native populations of the California red-legged frogs (*Rana aurora draytonii*). Water and sediment samples were collected from the lake according to a monitoring plan previously submitted to regulatory agencies. Rotenone and formulation by-products including rotenone, naphthalene, methyl pyrrolidone, and diethylene glycol ethyl ether were detected in early water samples, but none was detected after 17 days following the application. No water was released from the lake until November 27, 2006. No long-term side effects of rotenone application on water quality were observed, and all activities were performed in compliance with applicable water quality regulations. For a complete report and data, see Campbell et al. (2007).

#### **5.5.4 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 Mathews (2006). Grab samples are collected in accordance with written, standardized procedures summarized in 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.

Small volumes of water (less than 7500 L [2000 gal]) were discharged in the first quarter of 2006 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. Monitoring results for the larger discharges associated with tank cleaning (April 2006), construction (July 2006), and maintenance (September 2006) activities are detailed in the quarterly self-monitoring reports to the CVRWQCB, as are results from the annual pressure zone testing. The annual 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 2006 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.

### **5.5.5 Site 300 Cooling Towers**

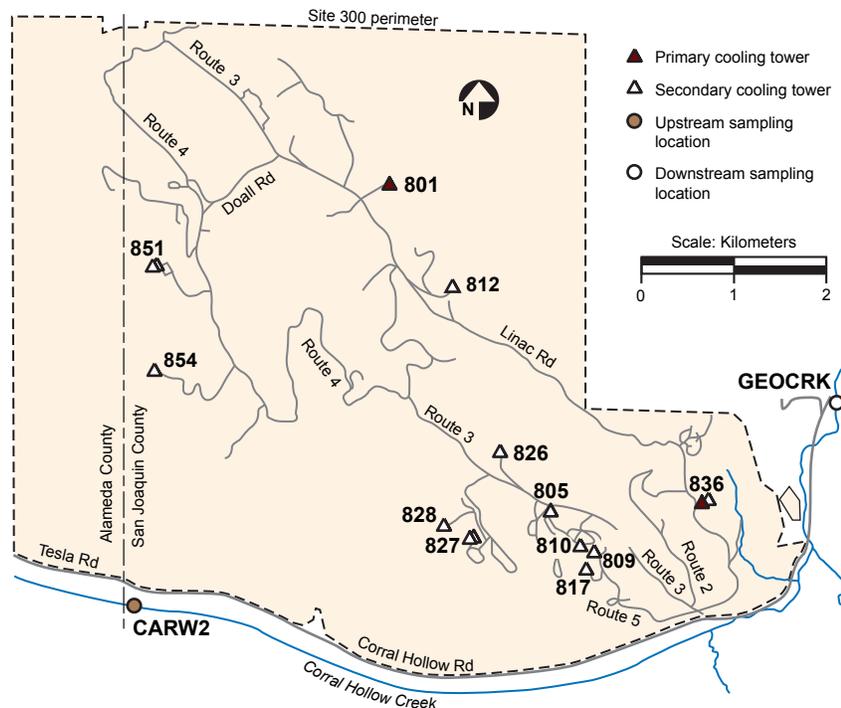
On August 4, 2000, the CVRWQCB rescinded WDR 94-131, NPDES Permit No. CA0081396, which had governed discharges from the two primary cooling towers at Site 300. The CVRWQCB determined that the cooling towers discharged to the ground rather than to surface water drainage courses. Therefore, the CVRWQCB will issue a new permit to incorporate the 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.

Prior to April 2005, the two primary cooling towers at Buildings 801 and 836A regularly discharged to the ground. 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. The biweekly flow and quarterly total dissolved solids (TDS) and pH monitoring at cooling tower 801 continued through October 9, 2006, at which time the cooling tower 801 blowdown discharges were diverted to a recently constructed percolation pit, and the monitoring program was discontinued. 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 5-19**.

Written, standardized sample collection procedures are summarized in Woods (2005). To determine the effects of the cooling tower 801 blowdown on Corral Hollow Creek, LLNL monitored pH quarterly, both upstream (background) and downstream of the cooling tower discharges, whenever the creek was flowing during the first three quarters of 2006. CARW2 is the upstream sampling location, and GEOCRK is the downstream sampling location (see **Figure 5-19**).

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

**Figure 5-19.** Cooling tower and receiving water monitoring locations, Site 300, 2006.



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 when discharging to the surface.

Monitoring results in 2006 indicated that all discharges from the Building 801 cooling tower 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 this tower were typical of volumes reported in recent years. **Table 5-14** summarizes the data from the quarterly TDS and pH monitoring, as well as the biweekly measurements of blowdown flow rate.

The biweekly observations at CARW2 and GEOCRK generally reported flowing conditions for both sampling locations during the months of March, April, and May, 2006. The resulting field pH measurements were between 7.68 and 8.94 at the CARW2 location, and between 7.72 and 8.99 at GEOCRK. These results indicate essentially no change in pH between the upstream and downstream locations. During other months of 2006, prior to termination of the monitoring program in October, dry or no flow conditions were reported. Visual observations of Corral Hollow Creek were performed in the first three quarters of 2006, and no visible oil, grease, scum, foam, or floating suspended materials were noted.

**Table 5-14.** Summary data from monitoring of primary cooling tower 801, Site 300, 2006.

Test	Minimum	Maximum	Median	Interquartile range	No. samples
Total dissolved solids (mg/L)	1500	1700	1500	— <sup>(a)</sup>	3 <sup>(b)</sup>
Blowdown (L/day)	0	15,475	5362	4603	20 <sup>(b)</sup>
pH	9.0	9.1	9.0	— <sup>(a)</sup>	3 <sup>(b)</sup>

(a) Too few data points to determine.

(b) Only 3 quarterly samples and 20 biweekly blowdown measurements were collected. The monitoring program at cooling tower 801 was discontinued October 9, 2006, after blowdown from that cooling tower was diverted to a percolation pit.

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 2006.

### 5.5.6 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 occurs, it is sampled and analyzed to determine concentrations of any metals present. During 2006, all of the percolation pits operated normally with no overflows., and there is no evidence of any environmental impact from the operation of the percolation pits.

**Cynthia L. Conrado**

*Nicholas A. Bertoldo*

*Richard A. Brown*

*Lisa Paterson*

*S. Ring Peterson*

*Jim Woollett*

## 6.1 Soil and sediment monitoring

- 6.1.1 Radiological monitoring results
- 6.1.2 Nonradiological monitoring results
- 6.1.3 Environmental impact on soil and sediment

## 6.2 Vegetation and foodstuff monitoring

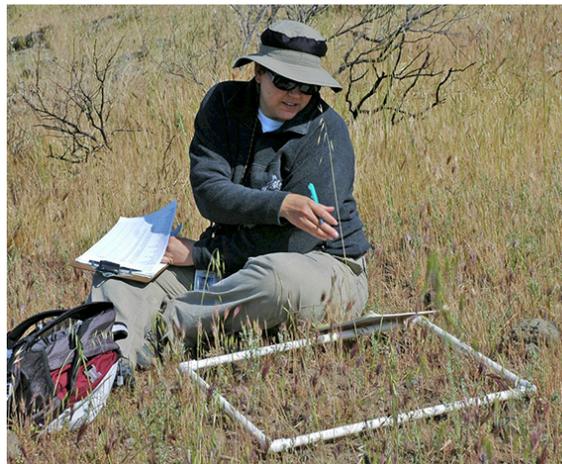
- 6.2.1 Vegetation monitoring results
- 6.2.2 Wine monitoring results
- 6.2.3 Environmental impact on vegetation and wine

## 6.3 Ambient radiation monitoring

- 6.3.1 Methods and reporting
- 6.3.2 Monitoring results
- 6.3.3 Environmental impact from laboratory operations

## 6.4 Special status wildlife and plants

- 6.4.1 Compliance activities
- 6.4.2 Invasive species control activities
- 6.4.3 Surveillance monitoring
- 6.4.4 Environmental impacts on special status wildlife and plants



**L**awrence 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 activities follow U.S. Department of Energy (U.S. DOE) guidance criteria. Monitoring activities on both LLNL sites (the Livermore site and Site 300) and in the vicinity of both sites detect radioactivity released from LLNL that may contribute to radiological dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation.

Terrestrial pathways from LLNL operations leading to potential radiological dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air. Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground-level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota (see **Chapter 7**) is calculated using a screening model that requires knowledge of radionuclide concentrations in soils, 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. The long-lived fission product cesium-137 provides information about global fallout from historical nuclear weapons testing. In addition, soils at Site 300 are analyzed for beryllium, a potentially toxic metal used there.

Sediments are analyzed for tritium in addition to the same nuclides as surface soils. Concentrations in soil taken from the vadose zone (the region below the land surface where 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 monitored 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 Woods (2005).

LLNL also monitors wildlife and plants at the Livermore site and Site 300 and conducts research relevant to the protection of rare plants and animals. Some monitoring and research programs are required by existing permits, while other 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, threatened, and other special status species, their habitats, and designated critical habitats that exist at both LLNL sites.

---

## 6.1 Soil and Sediment Monitoring

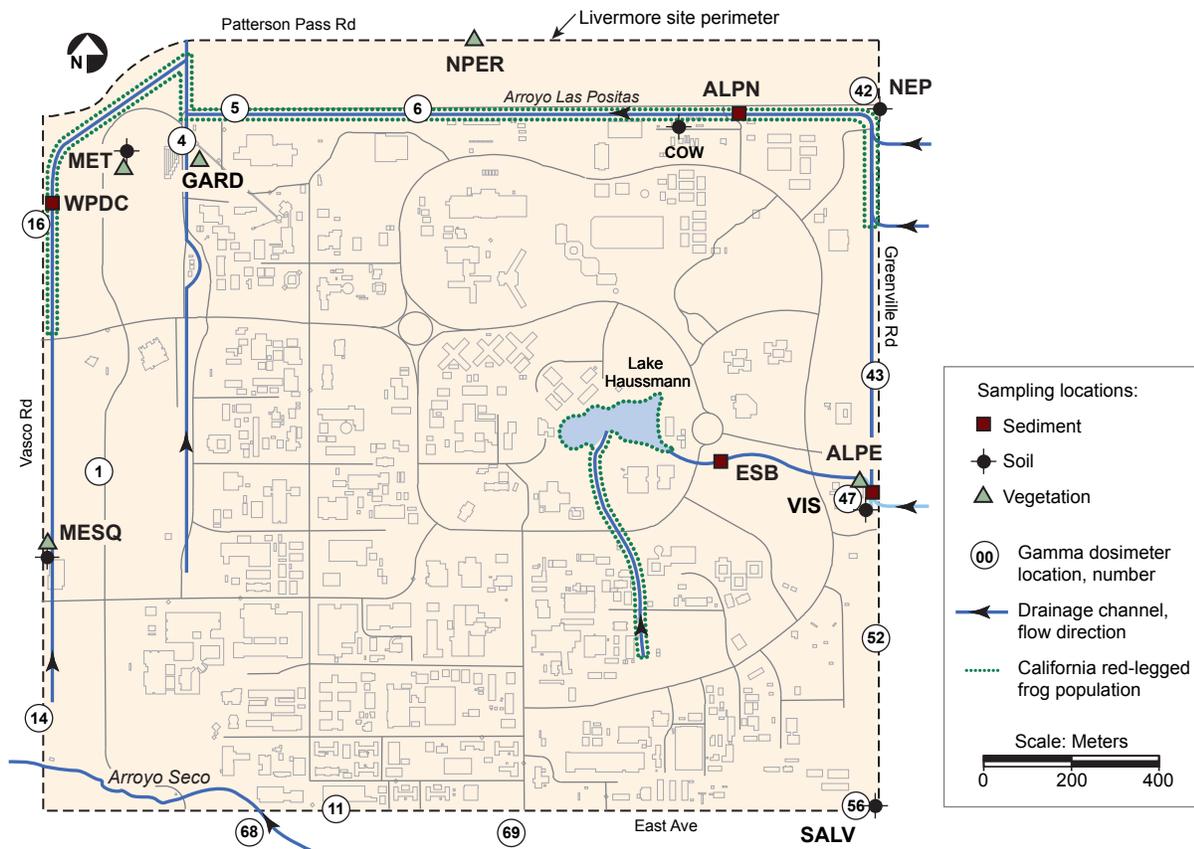
The number of soil and sediment sampling locations are as follows:

- Livermore site—6 soil, 4 sediment (see **Figure 6-1**)
- Livermore Valley—10 soil, including 3 at the Livermore Water Reclamation Plant (LWRP) (see **Figure 6-2**)
- Site 300—14 soil (see **Figure 6-3**)

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

Surface sediment and vadose zone soil samples are collected from selected arroyos and other drainage areas on and around the Livermore site. These sampling locations, shown in **Figure 6-1**, coincide largely with selected LLNL storm water sampling locations (see **Chapter 5**). 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 centimeters (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-meter (m) squares are chosen from which to collect the sample. Each sample is a



**Figure 6-1.** Sampling locations and populations of the California red-legged frog, a threatened species, Livermore site, 2006.

composite consisting of 10 subsamples that are collected at the corners and center of each square by an 8.25-cm-diameter, stainless-steel core sampler.

Surface sediment samples are collected in a similar manner. Ten subsamples, 5-cm deep, are collected at 1-m intervals along the transect of an arroyo or drainage channel. At one of the subsample locations, a 15-cm deep sample is taken for tritium analysis; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis. Vadose zone samples are collected at the same location as the tritium subsample. 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).

In 2006, 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-gram (g) sample aliquot is

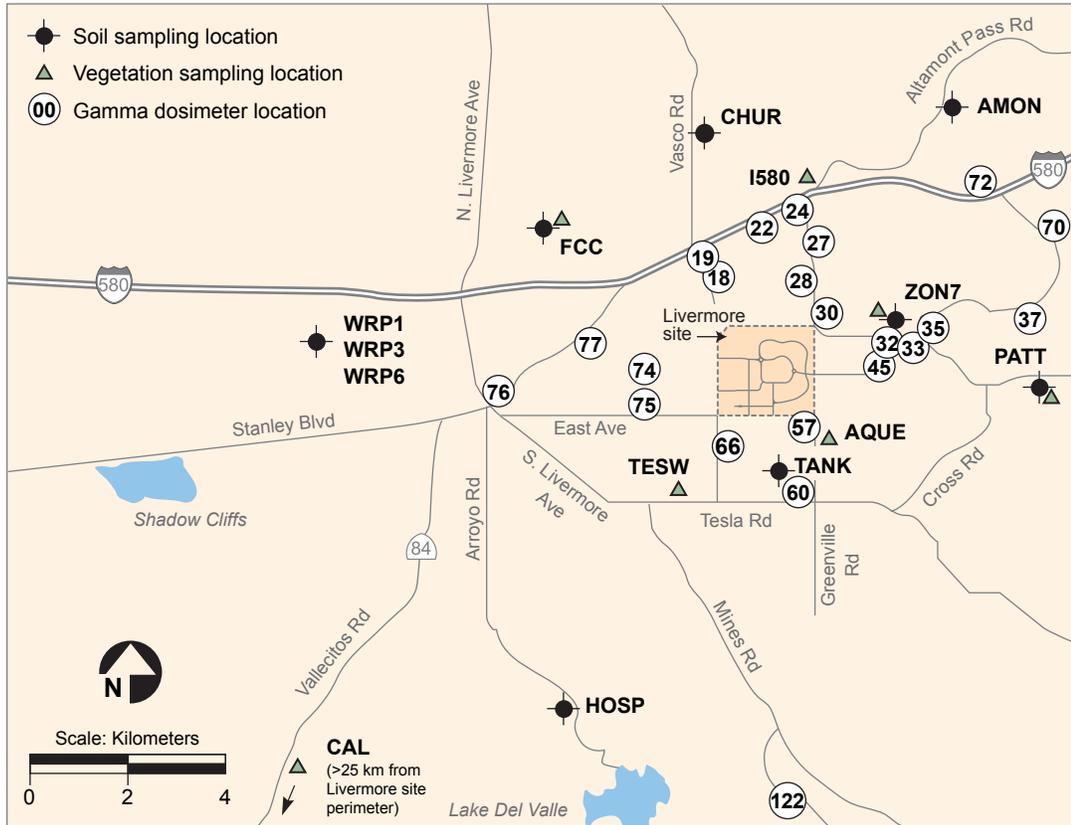


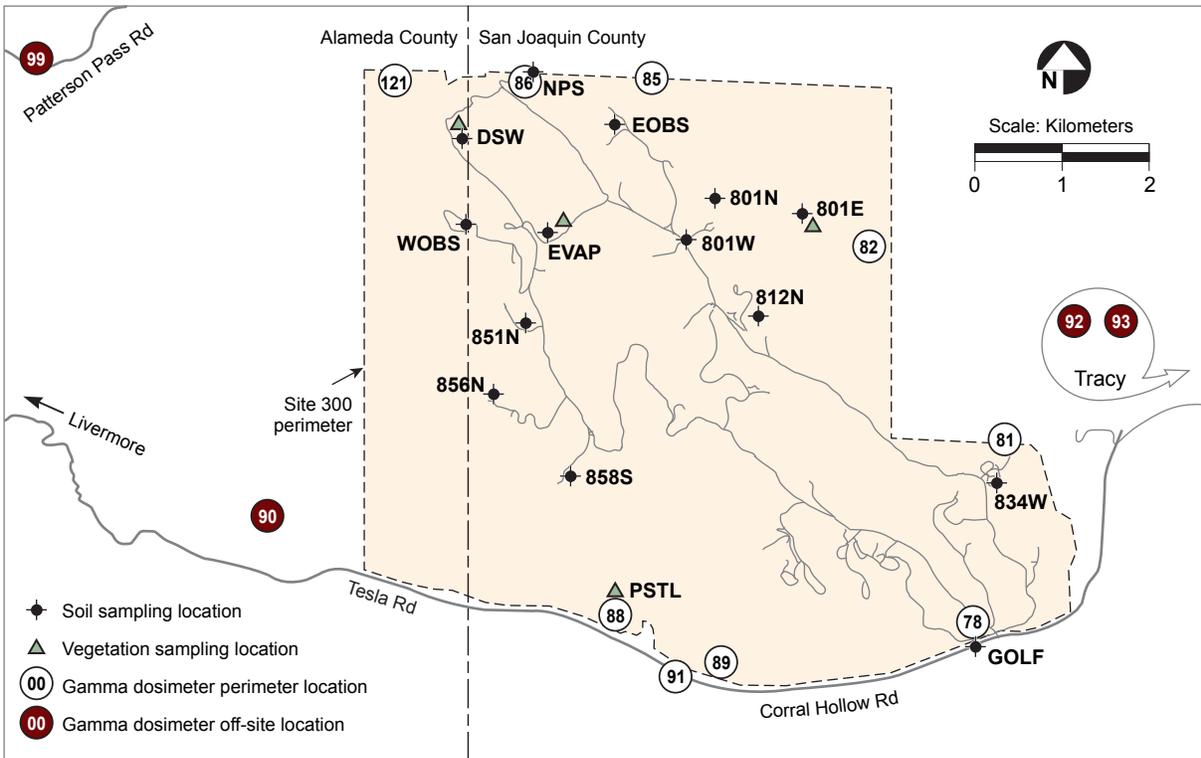
Figure 6-2. Soil and vegetation sampling locations and gamma dosimeter locations, Livermore Valley, 2006.

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. For beryllium, 10-g subsamples are analyzed by atomic emission spectrometry.

Vadose zone soil samples are analyzed by standard U.S. Environmental Protection Agency (EPA) methods. Since 2000, a vadose zone soil sample from location ESB (see Figure 6-1) has been analyzed for PCBs.

### 6.1.1 Radiological Monitoring Results

Tables 6-1 through 6-3 present 2006 data on the concentrations of plutonium-238 and plutonium-239+240 in Livermore Valley surface soils and sediments; data for americium-241, which is only detected at LWRP; and data for tritium, which is measured only 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 provided in Appendix B, Section B.7.



**Figure 6-3.** Sampling locations at Site 300 and off-site, 2006. Note that in 2006, the vegetation sampling location COHO was replaced by PSTL (at the location of the SW-MEI).

The concentrations and distributions of all observed radionuclides in soil for 2006 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. In the past, plutonium has been detected at levels above background at VIS, a perimeter sampling location near the east boundary of the Livermore site. In 2006, the measured plutonium-239+240 value for VIS was 0.35 millibecquerel (mBq)/dry g ( $9.5 \times 10^{-3}$  picocurie [pCi]/dry g), which is less than the 95% upper confidence level for the 95th percentile for background data (i.e., 0.48 mBq/dry g [ $1.3 \times 10^{-2}$  pCi/dry g]) (LLNL 1998, Appendix D). The slightly higher values at and near the Livermore site have been attributed to historical operations (Silver et al. 1974), including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant of the site. LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste.

Sediment sampling at location ESB, which is in the drainage area for the southeast quadrant of the Livermore site, also shows the effects of the historical operation of solar evaporators. The measured value for plutonium-239+240 at this location in 2006 was 1.9 mBq/dry g ( $5.1 \times 10^{-2}$  pCi/dry g).

The highest detected value for tritium in 2006 (10 becquerel per liter (Bq/L) [270 pCi/L]) was at location ESB, which is downwind of the Tritium Facility. In 2006, tritium emissions

**Table 6-1.** Plutonium activity concentrations in Livermore Valley soil, 2006.<sup>(a)</sup>

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)
L-AMON-SO	0.00045 ± 0.0012	0.047 ± 0.0097
L-CHUR-SO	0.0042 ± 0.0020	0.12 ± 0.021
L-COW-SO	0.0013 ± 0.0012	0.033 ± 0.0070
L-FCC-SO	0.0010 ± 0.0012	0.065 ± 0.012
L-HOSP-SO	0.00060 ± 0.0015	0.055 ± 0.011
L-MESQ-SO	0.0021 ± 0.0017	0.022 ± 0.0056
L-MET-SO	0.0027 ± 0.0020	0.047 ± 0.0097
L-NEP-SO	0.0047 ± 0.0025	0.047 ± 0.010
L-PATT-SO	0.00035 ± 0.0012	0.025 ± 0.0060
L-SALV-SO	0.014 ± 0.0043	0.16 ± 0.028
L-TANK-SO	0.0031 ± 0.0019	0.020 ± 0.0053
L-VIS-SO	0.018 ± 0.0049	0.35 ± 0.058
L-ZON7-SO	0.0019 ± 0.0014	0.020 ± 0.0047
Median	0.0021	0.047
Interquartile range	0.0032	0.040
Maximum	0.018	0.35

(a) Radioactivities are reported as the measured concentration and either an uncertainty ( $\pm 2\sigma$  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**.

were consistent with the Tritium Facility's associated operations, as described in **Chapter 4**. 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  $1.2 \times 10^9$  Bq [32 mCi] plutonium release to the sanitary sewer in 1967 and earlier releases were again detected at LWRP sampling locations in 2006. In addition, americium-241 was detected in one LWRP sample and was most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in these historical releases to the sewer.

**Figure 6-4** shows the historical (1977 to 2006) median plutonium-239+240 concentrations in surface soils at the LWRP, in the Livermore Valley upwind and downwind of the Livermore site, and at Site 300. Livermore Valley upwind concentrations have remained relatively constant since monitoring began and are generally indicative of worldwide fallout. Downwind concentrations show greater variability than upwind concentrations. In 2006, the downwind

locations were VIS, PATT, NEP, COW, AMON, SALV, and ZON7. Notable variability in plutonium-239+240 is also seen in samples from LWRP. Because 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. Plutonium is not used in operations at Site 300; analyses for plutonium in soils were suspended in 1997 given that fallout background was adequately characterized.

**Table 6-4** presents data on the concentrations of uranium-235, uranium-238, and beryllium in soil from the Site 300 sampling locations; 2006 soils data for Site 300 for cesium-137, potassium-40, and thorium-232 are provided in **Appendix B, Section B.7**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2006 lie within the ranges reported in all years since monitoring began. At 12 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 2006 occurred at location 812N. The uranium-235 to uranium-238 ratio in this sample equals the

**Table 6-2.** Plutonium and americium activity concentrations in LWRP soil, 2006.<sup>(a)</sup>

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Americium-241 (mBq/dry g)
L-WRP1-SO	0.31 ± 0.052	6.1 ± 0.97	4.6 ± 1.6
L-WRP3-SO	0.021 ± 0.0049	0.41 ± 0.067	<0.91
L-WRP6-SO	0.11 ± 0.019	2.0 ± 0.32	<0.79
Median	—(b)	—(b)	—(b)
Interquartile range	—(c)	—(c)	—(c)
Maximum	0.31	6.1	4.6

(a) Radioactivities are reported as the measured concentration and either an uncertainty ( $\pm 2\sigma$  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**.

(b) Median not calculated because of small number of samples.

(c) Interquartile range not calculated because of high incidence of nondetections.

**Table 6-3.** Plutonium and tritium activity concentrations in surface sediment at four locations on the Livermore site, 2006.<sup>(a)</sup>

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Tritium (Bq/L)
L-ALPE-SD	0.0017 ± 0.0013	0.0069 ± 0.0025	2.5 ± 1.6
L-ALPN-SD	0.00035 ± 0.00091	0.021 ± 0.0050	5.7 ± 1.7
L-ESB-SD	0.16 ± 0.028	1.9 ± 0.30	10 ± 2.6
L-WPDC-SD	0.00067 ± 0.00078	0.0060 ± 0.0021	2.4 ± 1.6
Median	0.0012	0.014	4.1
Interquartile range	—(b)	—(b)	—(b)
Maximum	0.16	1.9	10

(a) Radioactivities are reported as the measured concentration and either an uncertainty ( $\pm 2\sigma$  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**.

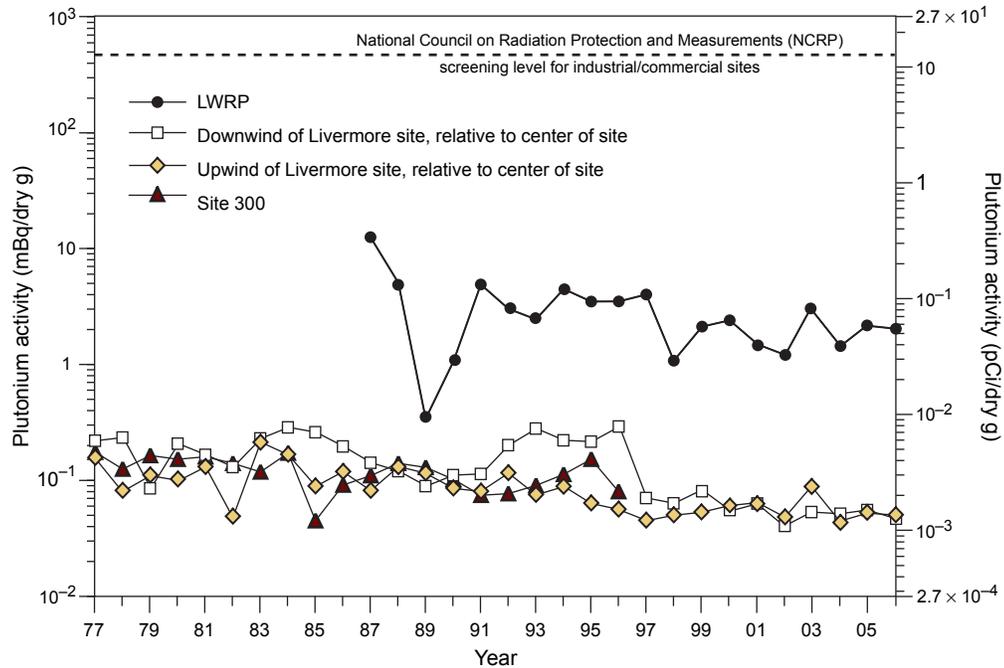
(b) Interquartile range not calculated because of high incidence of nondetections.

ratio for depleted uranium (0.002). Such values at Site 300 result from the use of depleted uranium in explosive experiments.

### 6.1.2 Nonradiological Monitoring Results

Analytical results for metals are compared with site-specific natural background concentrations for metals. (See **Appendix B, Section B.7**, for background concentrations for both the Livermore site and Site 300 and analytical results for metals.)

All metal concentrations at the Livermore site were within site background values with the exception of soluble copper and total and soluble zinc at location ESB. Livermore site



**Figure 6-4.** Median plutonium-239+240 activities in surface soils at LWRP, downwind and upwind of the Livermore site (1977–2006), and at Site 300 (1977–1997).

groundwater surveillance monitoring (see **Chapter 5**) determines the impact of these metals, if any, on site groundwater.

Aroclor 1260, a PCB, has been detected at location ESB since surveillance for PCBs began at this location in 2000. In 2006, the concentration was 20 milligrams per kilogram (mg/kg). The presence of PCBs suggests 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 (see **Table 6-4**) were within the ranges reported since sampling began in 1991. The highest value, 8.8 mg/kg, was found at B812, which is in an area that has been used for explosives testing. This value is much lower than the 110 mg/kg detected at B812 in 2003. The differing results reflect the particulate nature of the contamination.

### 6.1.3 Environmental Impact on Soil and Sediment

#### 6.1.3.1 Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2006 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.

**Table 6-4.** Uranium and beryllium concentrations in Site 300 soil, 2006.<sup>(a)</sup>

Location	Uranium-235 <sup>(b)</sup> ( $\mu\text{g}/\text{dry g}$ )	Uranium-238 <sup>(c)</sup> ( $\mu\text{g}/\text{dry g}$ )	Uranium-235/ uranium-238 ratio <sup>(d)</sup>	Beryllium ( $\text{mg}/\text{kg}$ )
3-801E-SO	0.021 $\pm$ 0.013	2.7 $\pm$ 2.2	0.0078 $\pm$ 0.0080	0.17 (<0.20) <sup>(e)</sup>
3-801N-SO	0.032 $\pm$ 0.0064	7.2 $\pm$ 2.2	0.0044 $\pm$ 0.0016	0.59
3-801W-SO	0.032 $\pm$ 0.0088	4.8 $\pm$ 1.2	0.0067 $\pm$ 0.0025	<0.20
3-812N-SO	0.29 $\pm$ 0.022	130 $\pm$ 9.8	0.0022 $\pm$ 0.00024	8.8
3-834W-SO	0.021 $\pm$ 0.013	1.9 $\pm$ 1.1	0.011 $\pm$ 0.0094	0.56
3-851N-SO	0.030 $\pm$ 0.012	4.5 $\pm$ 1.5	0.0067 $\pm$ 0.0035	0.62
3-856N-SO	0.026 $\pm$ 0.0099	2.1 $\pm$ 0.80	0.012 $\pm$ 0.0067	0.28
3-858S-SO	0.029 $\pm$ 0.015	2.4 $\pm$ 1.5	0.012 $\pm$ 0.0098	<0.20
3-DSW-SO	0.026 $\pm$ 0.013	2.8 $\pm$ 1.2	0.0093 $\pm$ 0.0061	<0.71
3-EOBS-SO	0.021 $\pm$ 0.012	2.5 $\pm$ 1.1	0.0084 $\pm$ 0.0061	0.19 (<0.20) <sup>(e)</sup>
3-EVAP-SO	0.037 $\pm$ 0.0075	4.1 $\pm$ 1.4	0.0090 $\pm$ 0.0036	0.21
3-GOLF-SO	0.025 $\pm$ 0.0068	2.1 $\pm$ 1.7	0.012 $\pm$ 0.010	0.27
3-NPS-SO	0.020 $\pm$ 0.0087	2.6 $\pm$ 2.1	0.0077 $\pm$ 0.0071	0.070 (<0.20) <sup>(e)</sup>
3-WOBS-SO	0.016 $\pm$ 0.010	1.5 $\pm$ 0.96	0.011 $\pm$ 0.0095	<0.20
Median	0.026	2.7	0.0087	<0.24
Interquartile range	0.010	2.2	0.0040	— <sup>(f)</sup>
Maximum	0.29	130	0.012	8.8

(a) Radioactivities are reported as the measured concentration and either an uncertainty ( $\pm 2\sigma$  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**.

(b) Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in  $\mu\text{g}/\text{dry g}$  by specific activity of uranium-235 (i.e., 0.080 Bq/ $\mu\text{g}$  or 2.15 pCi/ $\mu\text{g}$ ).

(c) Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in  $\mu\text{g}/\text{dry g}$  by specific activity of uranium-238 (i.e., 0.01245 Bq/ $\mu\text{g}$  or 0.3367 pCi/ $\mu\text{g}$ ).

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

(e) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis. If the analytical laboratory provided an estimated analytical result above the method detection limit and less than the reporting limit, that result is shown followed by the reporting limit in parentheses.

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

The highest value for plutonium-239+240 in 2006 (6.1 mBq/dry g [0.16 pCi/dry g]), measured at LWRP, is 1.3% 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 over time.

LLNL has investigated the presence of radionuclides in local soils frequently over the years; the studies have consistently shown that the concentrations of radionuclides in local

**Table 6-5.** Selected studies of radionuclides in local soils, 1971 to 2003.

Year	Study	Reference
1971–1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972, 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	Historical 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

soils are below levels of health concern. Selected LLNL studies, as well as studies by other agencies, are listed in **Table 6-5**.

### 6.1.3.2 Site 300

The concentrations of radionuclides and beryllium detected in soil samples collected at Site 300 in 2006 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occurred near the firing tables 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 (313 µg/g [3.9 Bq/g or 105 pCi/g]). Historically, some measured concentrations of uranium-238 near Building 812 (location 812N) have been greater than the screening level. A Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial investigation has been completed at the Building 812 firing table area, which defines the nature and extent of contamination (see **Chapter 8**).

---

## 6.2 Vegetation and Foodstuff Monitoring

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

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

Tritium from LLNL operations may be detected at the Near and Intermediate locations depending on wind direction and magnitude of the releases. Far locations are highly unlikely to be affected by LLNL operations.

Site 300 has four monitoring locations for vegetation (PSTL, 801E, DSW, and EVAP). See **Figure 6-3**. Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to occasional uptake of contaminated groundwater by the roots. The highest concentrations observed in the past ten years (5140 Bq/L [13,900 pCi/L] at EVAP and 3330 Bq/L [90,000 pCi/L] at DSW) occurred in 1998. At the other two locations, 801E and PSTL,<sup>(a)</sup> the only likely potential source of tritium uptake is the atmosphere, although groundwater in the vicinity of PSTL is contaminated with low levels of tritium.

Wines for sampling in 2006 were purchased from supermarkets in Livermore. The wines represent the Livermore Valley, two other 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. Between 1991 and 2005, wine samples were analyzed directly using helium-3 mass spectrometry, an extremely sensitive and costly method that analyzes for both HTO and OBT. Wines purchased in 2006 were prepared for sampling using a method under development that separates the water fraction from the other components of the wine, including the OBT, so that samples can be counted using an ultra-low-level scintillation counter.

### 6.2.1 Vegetation Monitoring Results

Concentrations of tritium in vegetation based on samples taken at the Livermore site, in the Livermore Valley, and Site 300 in 2006 are shown in **Table 6-6**. The highest mean tritium concentration for 2006 was at the Near location VIS, which is downwind of the Livermore site.

---

(a) Because accessing sampling location COHO (in use since 2001) was becoming increasingly difficult, vegetation sampling was moved to location PSTL, close to the location of the SW-MEI for Site 300 (see **Chapter 7**).

**Table 6 6.** Quarterly, median, and mean concentrations of tritium in plant water for the Livermore site Livermore Valley, and Site 300, and mean annual ingestion doses, 2006.<sup>(a)</sup>

Sampling locations		Concentration of tritium in plant water (in Bq/L)						Mean annual ingestion dose <sup>(b)</sup> (in nSv/yr)
		First quarter	Second quarter	Third quarter	Fourth quarter	Median	Mean	
NEAR (on site or <1 km from Livermore site perimeter)	AQUE	2.2 ± 1.6	4.8 ± 1.6	0.85 ± 1.8	4.1 ± 1.7	3.2	3.0	15
	GARD	1.6 ± 1.6	4.7 ± 1.6	0.084 ± 1.8	3.1 ± 1.7	2.4	2.4	12
	MESQ	1.6 ± 1.6	4.2 ± 1.6	1.4 ± 1.8	0.60 ± 1.6	1.5	2.0	10
	MET	1.4 ± 1.6	2.3 ± 1.5	1.3 ± 1.8	5.3 ± 1.7	1.8	2.6	13
	NPER	2.5 ± 1.6	2.4 ± 1.5	2.4 ± 1.9	3.5 ± 1.7	2.4	2.7	13
	VIS	1.0 ± 1.6	3.4 ± 1.5	2.1 ± 1.9	11 ± 1.8	2.8	4.4	22
INTERMEDIATE (1–5 km from Livermore site perimeter)	I580	–0.12 ± 1.5	2.1 ± 1.5	–0.32 ± 1.8	2.2 ± 1.6	0.99	0.97	<10 <sup>(c)</sup>
	PATT	–0.25 ± 1.5	1.3 ± 1.4	1.0 ± 1.8	0.16 ± 1.5	0.58	0.55	<10 <sup>(c)</sup>
	TESW	–0.054 ± 1.5	1.7 ± 1.5	1.4 ± 1.8	1.4 ± 1.6	1.4	1.1	<10 <sup>(c)</sup>
	ZON7	0.91 ± 1.6	2.3 ± 1.5	1.5 ± 1.8	1.5 ± 1.6	1.5	1.6	<10 <sup>(c)</sup>
FAR (>5 km from Livermore site perimeter)	CAL	0.80 ± 1.5	1.6 ± 1.5	0.061 ± 1.8	–0.17 ± 1.5	0.43	0.57	<10 <sup>(c)</sup>
	FCC	–0.70 ± 1.5	1.7 ± 1.5	0.091 ± 1.8	0.092 ± 1.5	0.092	0.30	<10 <sup>(c)</sup>
Site 300	PSTL	3.1 ± 1.7	1.9 ± 1.5	0.81 ± 1.8	0.20 ± 1.5	1.4	1.5	(d)
	801E	3.7 ± 1.7	4.3 ± 1.6	–1.1 ± 1.7	–0.27 ± 1.5	1.7	1.7	(d)
	DSW <sup>(e)</sup>	4.2 ± 1.8	9.4 ± 1.8	59 ± 3.3	860 ± 11	34	230	(d)
	EVAP <sup>(e)</sup>	0.39 ± 1.5	13 ± 1.9	0.037 ± 1.8	10 ± 1.9	5.2	5.9	(d)

(a) Radioactivities are reported as the measured concentration and an uncertainty ( $\pm 2\sigma$  counting error). If the concentration is less than or equal to the uncertainty, the result is considered to be a nondetection. See **Chapter 9**.

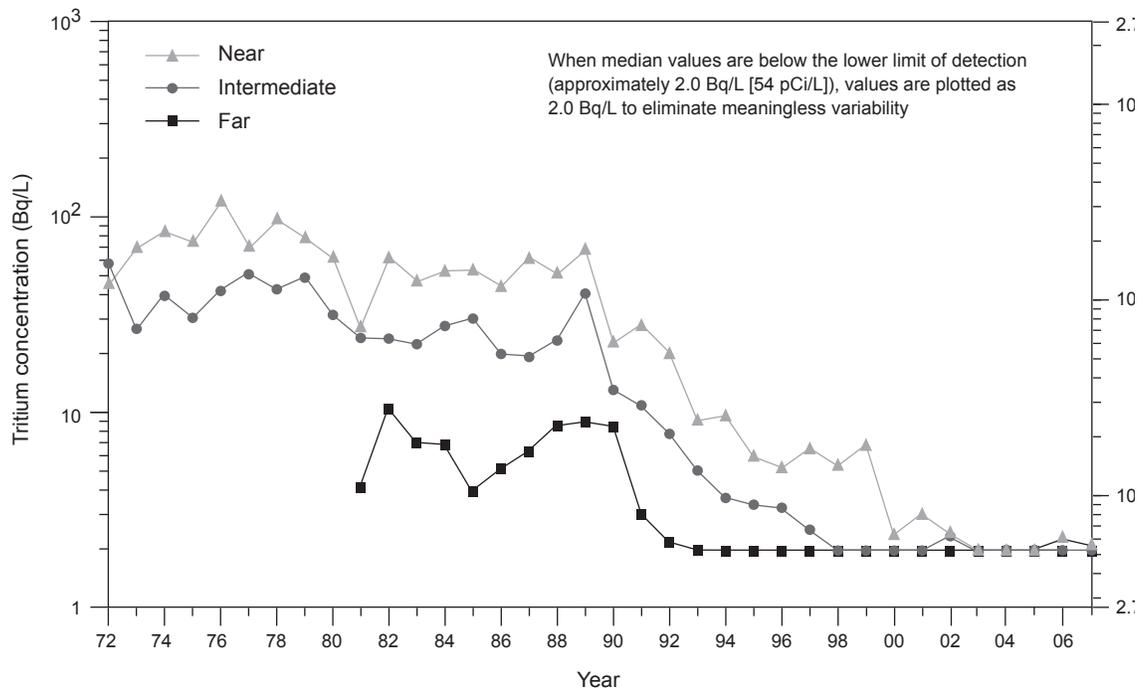
(b) Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 7-6**.

(c) 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.

(d) Dose is not calculated because there is no pathway to dose to the public from vegetation at Site 300.

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

Median concentrations of tritium in vegetation at sampling locations at the Livermore site and in the Livermore Valley have decreased noticeably since 1989 (see **Figure 6-5**). Median concentrations at the Far and Intermediate locations have been below detection limits for several years. Between 2003 and 2005, the median concentrations at Near locations were below detection limits, and, in 2006, the median concentration at Near locations, 2.4 Bq/L (65 pCi/L), was just above the detection limit. The lower limit of detection (LLD) of scintillation counting has varied over the years. 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. The highest concentration in plant water from Near locations in 2006 was just 1.5% of the drinking water MCL (740 Bq/L [20,000 pCi/L]).



**Figure 6-5.** Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2006.

At Site 300, the median concentration at location 801E was below detection limits, as it has been since 1991. The median concentration at location PSTL was also below detection limits. Tritium concentrations in vegetation at locations DSW and EVAP have been erratic since 1983, with concentrations being either high or below the LLD, depending upon whether the roots were taking up contaminated groundwater. The highest concentration (860 Bq/L [23,220 pCi/L]) was observed at DSW.

### 6.2.2 Wine Monitoring Results

Analysis of the wines sampled in 2006 demonstrates the same relationship between the Livermore Valley, California (other than the Livermore Valley), and the Rhone Valley (France) wines that has been seen routinely in the past. Concentrations of tritium in California wines are low and reflect residual historical bomb fallout and cosmogenic tritium levels; concentrations in Livermore Valley wines range from the low levels seen in California wines to the higher levels seen in Rhone Valley wines; and the concentration in one of the Rhone Valley wines is higher than any of the Livermore Valley wines (see **Table 6-7**). The highest concentration in a Livermore Valley wine sampled in 2006 (5.0 Bq/L [135 pCi/L]) was from a wine made from grapes harvested in 2002.

The Livermore Valley wines purchased in 2006 represent vintages from 2002 to 2004. Tritium concentrations must be decay-corrected to the year of harvest to correlate with tritium concentrations in air and soil to which the grape was exposed. The correlation

between decay-corrected concentrations and annual tritium releases from the Livermore site has never been a strong one. Concentrations for the sampled wines show the same relationships after they have been corrected for radiological decay. In 2006, decay-corrected concentrations for Livermore Valley wine samples ranged from 1.2 to 6.4 Bq/L; for the two California wine samples, 1.2 and 2.1 Bq/L; and for the two Rhone Valley wine samples, 3.0 and 7.7 Bq/L.

### 6.2.3 Environmental Impact on Vegetation and Wine

#### 6.2.3.1 Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 6-6**. These hypothetical doses, from ingestion of HTO in vegetables, milk, and meat, were calculated from annual mean measured concentrations of HTO in vegetation using the transfer factors from **Table 7-6 (Chapter 7)** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). The hypothetical annual ingestion dose, based on the highest observed mean HTO concentration in vegetation for 2006, was 22 nanosieverts (nSv) (2.2 microrems [ $\mu\text{rem}$ ]), which is slightly less than the highest dose estimated in 2005.

Doses calculated based on Regulatory Guide 1.109 neglect the contribution from organically bound tritium (OBT). However, according to a panel of tritium experts, “the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this” (ATSDR 2002, p. 27). Thus, the maximum estimated ingestion dose from LLNL operations for 2006, including OBT, is 44 nSv/year (yr) (4.4  $\mu\text{rem}/\text{yr}$ ). This maximum dose is about 1/68,000 of

the average annual background dose in the United States from all natural sources and about 1/230 the dose from a panoramic dental x-ray. Because it is based on highly conservative assumptions, this already extremely low dose is still considerably higher than any likely potential dose received.

During 2006 at Site 300, no tritium was released to the atmosphere from LLNL operations. Consequently, vegetation concentrations were near or below detection limits except at locations of contaminated groundwater (see **Chapter 8, Section 8.2.3**). Groundwater contaminated by past activities affects concentrations in vegetation

**Table 6-7.** Tritium in retail wine, 2006<sup>(a,b)</sup>

Sample	Concentration (in Bq/L) by area of production		
	Livermore Valley	California	Europe
1	0.95 ± 0.64	1.0 ± 0.64	2.6 ± 0.65
2	1.5 ± 0.63	1.8 ± 0.63	6.7 ± 0.95
3	1.8 ± 0.63		
4	2.3 ± 0.64		
5	2.7 ± 0.65		
6	5.0 ± 0.80		
Dose (nSv/yr) <sup>(c)</sup>	6.1	2.2	8.1

- (a) Radioactivities are reported here as the measured concentration and an uncertainty ( $\pm 2\sigma$  counting error).
- (b) Wines from a variety of vintages were purchased and analyzed for the 2006 sampling. Concentrations are those on May 17, 2007.
- (c) Calculated based on consumption of 52 L wine per year at maximum concentration (see **Chapter 7**). Doses account for contribution of organically bound tritium (OBT) as well as of HTO.

at locations DSW and EVAP. However, the dose does not need to be calculated from these elevated concentrations because neither people nor livestock ingest vegetation at Site 300.

### 6.2.3.2 Wine

For Livermore Valley wines purchased in 2006, the highest concentration of tritium (5.0 Bq/L [135 pCi/L]) was just 0.68% of the EPA's standard for maximal permissible level of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Drinking one liter per day of the Livermore Valley wine with the highest concentration purchased in 2006 would have resulted in a dose of 43 nSv/yr (4.3  $\mu$ rem/yr). A more realistic dose estimate, based on moderate drinking (one liter per week)<sup>(a)</sup> at the mean of the Livermore Valley wine concentrations (2.4 Bq/L [65 pCi/L]) would have been 2.9 nSv/yr (0.29  $\mu$ rem/yr). Both doses explicitly account for the added contribution of OBT.<sup>(b)</sup>

The potential dose from drinking Livermore Valley wines in 2006, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/310 of a single dose from a panoramic dental x-ray.

---

## 6.3 Ambient Radiation Monitoring

Gamma radiation in the environment has two natural sources—terrestrial and cosmic. The terrestrial source is the result of 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 daughter radiations. The other source is cosmic radiation, which induces secondary radiations from interactions with atmospheric nuclei in the upper atmosphere. The cosmic interactions produce meson, neutron, gamma, and electron radiations at the earth's surface (Eisenbud 1987).

LLNL's ambient radiation monitoring program is designed to distinguish naturally occurring gamma radiation from any ambient radiation that is the result of LLNL operations by sampling at enough locations to validate the large variance in the natural background from season to season and by location.

### 6.3.1 Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter that absorbs it. The roentgen (R) was adopted as the special unit of

---

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

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

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 ( $2.58 \times 10^{-4}$  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 thermoluminescent dosimeters (TLDs) placed in the community surrounding LLNL. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thallium-activated calcium sulfate ( $\text{CaSO}_4$ ), to measure environmental gamma dose.

As a 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 (is heated, releasing the trapped energy), which is calibrated to a known standard of cesium-137 gamma energy of 662 kilo-electronvolts (keV). The result of the TLD exposure is then reported in the Système International (SI) unit of sievert (Sv) from the calculated dose in mR ( $1 \times 10^{-3}$  R).

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

- comparison of the average quarterly dose (mSv) for the Livermore site, Livermore Valley, and Site 300 locations for the five-year period from 2002 to 2006
- comparison of the average quarterly dose (mSv) for the Livermore site and Livermore Valley locations in 2006
- comparison of average quarterly dose (mSv) for Site 300, city of Tracy, and Site 300 vicinity in 2006

As shown in **Figure 6-6**, these comparisons are made.

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

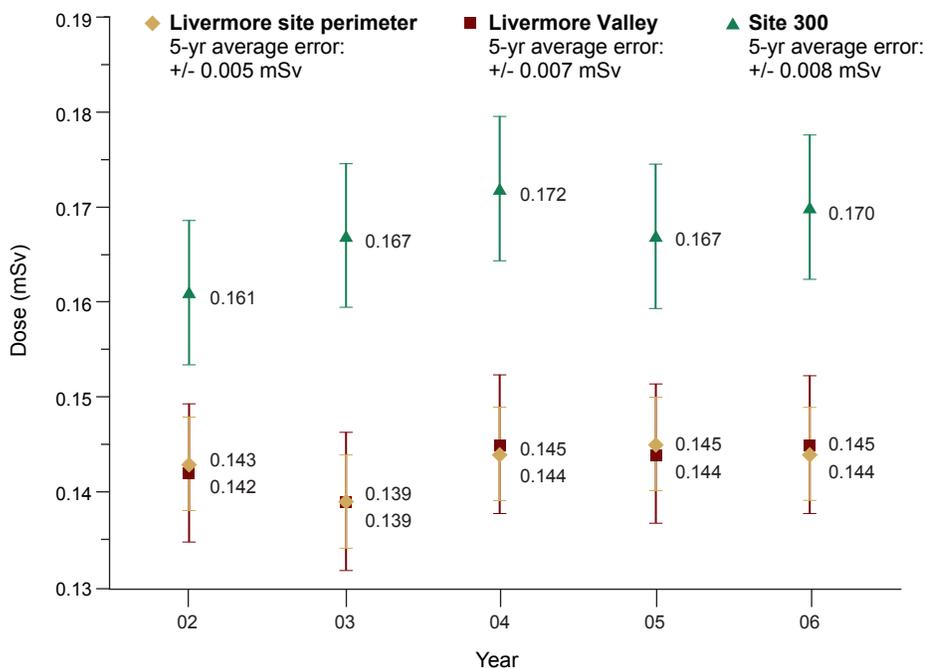
To obtain a true representation of local site exposure and determine any dose contribution from LLNL operations, an annual environmental monitoring compliance assessment is done in accordance with DOE Order 450.1, Environmental Protection Program, through a quarterly deployment cycle. TLDs are deployed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

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

### 6.3.2 Monitoring Results

**Figure 6-6** represents the average quarterly dose (in mSv) for the recent five-year period for the Livermore site perimeter, Livermore Valley and Site 300. Tabular data for each sampling

**Figure 6-6.** Comparison of the average quarterly dose for the Livermore site, Livermore Valley, and Site 300 monitoring locations from 2002 to 2006.



location are provided in **Appendix B, Section B.7**. Missing data are due to lost or damaged samples and are noted in these tables.

From year to year, the exposure of a TLD at any particular sampling location changes very little. Local variation of the Livermore site perimeter (see **Figure 6-6**) is due largely to changes in the local distribution of the radon flux and natural soil variability in the abundance of uranium and thorium, which produce gamma decay products for the given series on some small level and from changes in the cosmic radiation flux. Similar variability is seen within the other location groups. The difference in the doses at the Livermore site perimeter, Livermore Valley, and Site 300 can be attributed directly to the difference in the geological substrates. The Neroly Formation in the region around Site 300 has higher levels of naturally occurring uranium, which provides the higher concentration of thorium found in the soil data.

### 6.3.3 Environmental Impact from Laboratory Operations

The data do not suggest any environmental impact or increase in ambient radiation levels surrounding the Livermore site, Livermore Valley, or Site 300 as a direct result of LLNL operations for 2006. Radiation dose trends remain consistent with annual average levels for each sample location. As depicted in **Figure 6-6**, the annual average gamma radiation dose for the LLNL site perimeter and the Livermore Valley from 2002 to 2006 are statistically equivalent and show no discernible impact due to operations conducted at LLNL.

---

## 6.4 Special Status Wildlife and Plants

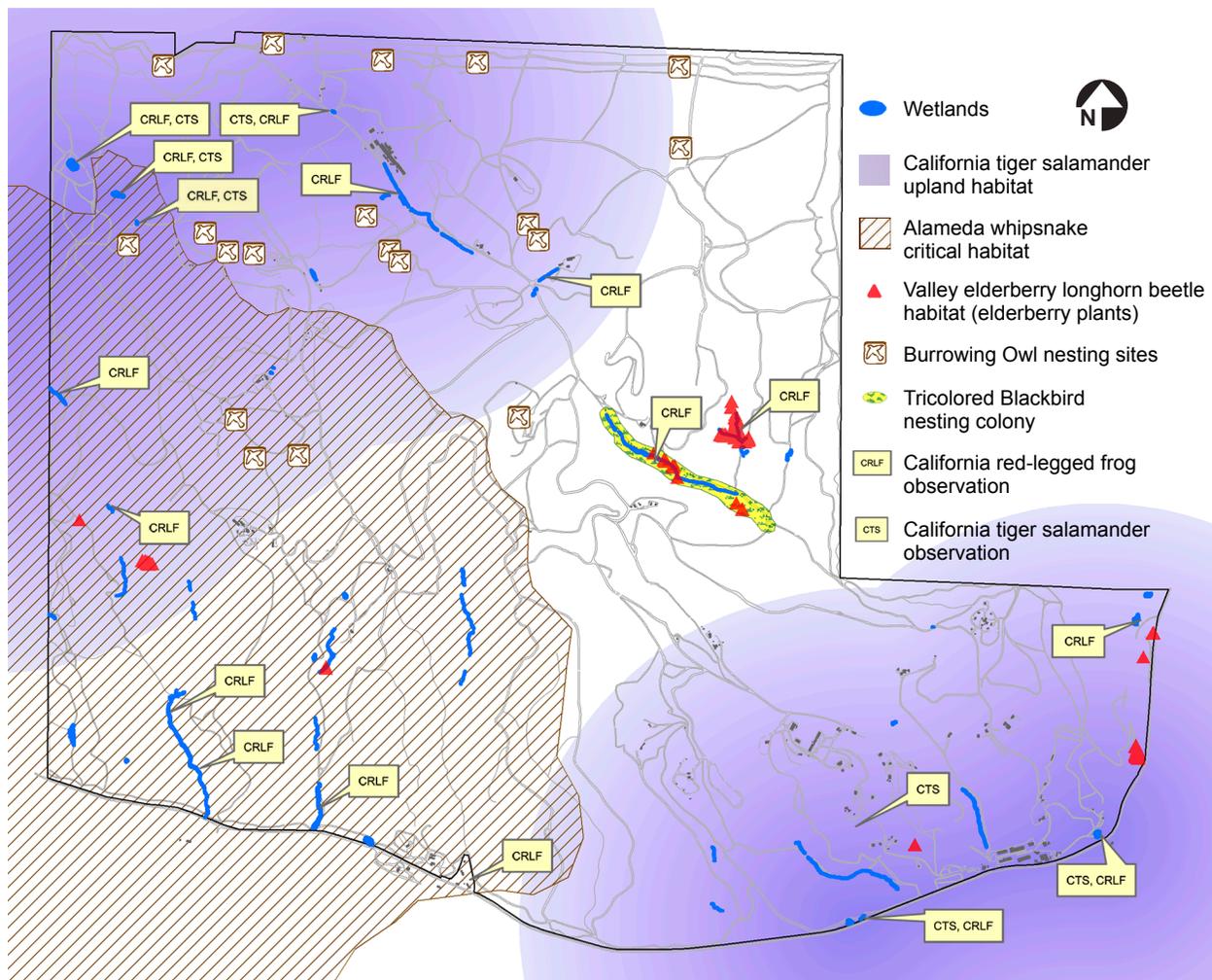
Special status wildlife and plant monitoring at LLNL is focused on species considered to be rare, threatened, and endangered, including species listed under the federal or California Endangered Species Acts; species considered of concern by the California Department of Fish and Game and the U.S. Fish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

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 (*Masticophis lateralis euryxanthus*), Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), and the large-flowered fiddleneck (*Amsinckia grandiflora*). 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 (see **Figure 6-1**).

Several species that are considered rare or otherwise of special interest by the federal and California state governments also occur at the Livermore site and Site 300. 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 species included in the California Native Plant Society's (CNPS's) *Inventory of Rare and Endangered Plants in California* (CNPS 2001).

Known observations of these five listed species and two California species of special concern (Burrowing Owl and Tricolored Blackbird) are shown in **Figure 6-7**. Vertebrate species and rare invertebrate species known to occur at Site 300, including state and federally listed species and other species of special concern are listed in **Appendix E**. A similar list has not been prepared for the Livermore site.

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 the rare 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. The fourth rare species, the round-leaved filaree (*Erodium macrophyllum*), is currently included on CNPS List 2 (CNPS 2001). This list includes species

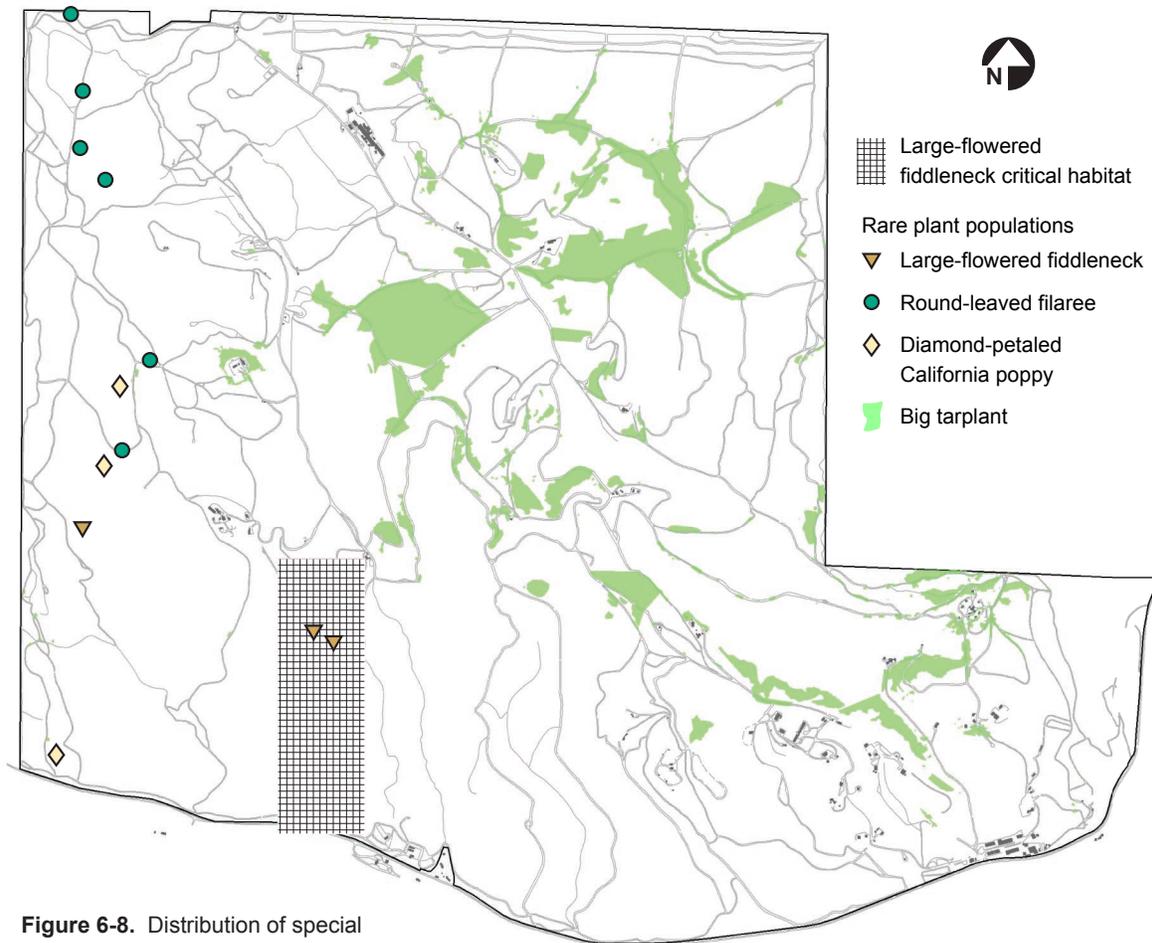


**Figure 6-7.** Distribution of special status wildlife, Site 300, 2006.

that are rare or endangered in California and elsewhere. The location of these four rare plant species on Site 300 is shown in **Figure 6-8**.

The four uncommon plant species—the gypsum-loving larkspur (*Delphinium gypsophilum* subsp. *gypsophilum*), California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperovax 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).

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 **Chapter 7, Section 7.6**.



**Figure 6-8.** Distribution of special status plants, Site 300, 2006.

## 6.4.1 Compliance Activities

### 6.4.1.1 Arroyo Seco

In June of 2005, the USFWS issued a biological opinion to DOE/National Nuclear Security Administration (NNSA) for the Arroyo Seco Management Plan. The biological opinion considered potential impacts to the California red-legged frog and the California tiger salamander.

The Arroyo Seco Management Plan was completed during the 2005 dry season. The project 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 Livermore site 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.

The first year of the five-year plan for monitoring the restoration of this site was conducted in 2006, as required by the Army Corps of Engineers permit for this project. Monitoring includes annually measuring the survivorship of plants that were installed as part of the restoration and estimating the percent cover of grasses and forbs, shrubs, and trees at the project site. In most portions of the project site, the percent cover of grasses and forbs was above the expected success criteria for year one (2006). On the terrace on the north side of the arroyo, the percent cover of grasses and forbs was 20%, which is 10% lower than the success criteria for year one (30%). The observed percent cover for shrubs met the success criteria of 5% in all areas. The percent cover of trees in both the south bank and terrace met the success criteria of 5%. The percent cover of trees on the north bank and terrace was less than the required 5%. To help correct deviations from the success criteria described above, approximately 145 plants were installed at the site in the winter of 2006/2007 to replace plants that did not survive the previous year, and additional measures were taken to control weeds at the site.

#### **6.4.1.2 Habitat Enhancement Project**

Prior to 2005, artificial wetlands had been maintained at Buildings 865, 851, 827, and 801 (Site 300) as a result of water discharge from cooling towers and potable water discharges. In 2005, water discharges were terminated at these locations.

In late August 2005, a habitat enhancement project was implemented at Site 300 in accordance with a 2002 biological opinion to compensate for habitat value loss from these artificial wetlands. 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 0.005 hectares [ha] [0.012 acres (ac)]), the protection of 0.75 ha (1.86 ac) 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.

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

In 2006, culvert replacement projects were completed at two Site 300 locations (the Oasis and Round Valley) where unpaved fire trails cross an intermittent drainage in Draney Canyon. The Oasis project resulted in impacts to an estimated 0.047 ha (0.115 ac) of jurisdictional waters as defined by the Army Corps of Engineers. The Round Valley project included the creation of a 0.089-ha (0.22-ac) pool upstream of the fire trail crossing and culvert replacement site in part as mitigation for the impacts at the Oasis site and to serve as enhanced habitat for amphibian species on site. In particular, it is hoped that the pool will be used by California red-legged frogs and California tiger salamanders. These projects were completed under the biological opinion for maintenance and operations of Site 300.

A temporary pool was created adjacent to the Oasis project site as a temporary refuge for California red-legged frogs that were captured within the construction area. After the completion of this project, California red-legged frogs were released from the temporary pool and allowed to recolonize the project site.

The Round Valley project was completed when the project site was dry and no water was present in the drainage at the project site, and no California red-legged frogs or California tiger salamanders were observed at the site during construction. As a result, it was not necessary to temporarily relocate any California red-legged frogs at the Round Valley location.

#### **6.4.1.4 Surface Impoundment Closure and Mitigation Site**

During the summer of 2005, closure of the Class II wastewater surface impoundments at Site 300 was executed. In the past, these impoundments had received rinse water from high explosives and photo processing activities and were now reaching the end of their service lifespan. Mitigation for the removal of the artificial impoundments was required because California tiger salamanders had been observed in the impoundments during site-wide amphibian surveys in the winter of 1996 and 1997. Under a biological opinion from the U.S. Fish and Wildlife Service, LLNL was to conduct searches for tiger salamanders returning to the area during the winter of 2006 (the season following the basin removal) and translocate these individuals to a mitigation site in the northwest corner of the property. The mitigation site was an enhanced seasonal pool that lacked sufficient depth as a successful salamander breeding site.

No California tiger salamanders were captured in the winter and spring of 2006 returning to the previous impoundment area; therefore, no salamander translocations were performed. The California tiger salamander mitigation pond, however, was colonized by California tiger salamanders that had already occurred in the area. Eggs, larvae, and newly metamorphosed individuals were recorded at the mitigation pool site in the spring and summer of 2006.

#### **6.4.2 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. Feral pigs (*Sus scrofa*) are an exotic species that are now present at Site 300. These formidable predators threaten the survival of this protected frog and other native species. They will prey on the California red-legged frog's eggs and tadpoles and usually compete with California red-legged frogs for food and other resources. Control of these invasive species is necessary to ensure the survival of California red-legged frogs at the Livermore site and Site 300. In addition, prevention of the downstream dissemination of invasive species is important to protect other local and regional native species populations relative to the Livermore Valley watershed.

#### **6.4.2.1 Drainage of Lake Haussmann to Control Bullfrogs**

Lake Haussmann (previously Drainage Retention Basin) was drained in 2000 and 2001 in an effort to eliminate bullfrog larvae. The habitat enhancement pool portion of Lake Haussmann and the Livermore site 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 Lake Haussmann during the bullfrog's breeding season (late spring to early fall each year between 2002 and 2006). One nighttime survey for adult bullfrogs was conducted in Lake Haussmann in the summer of 2006. During this survey, bullfrogs were identified by a qualified biologist and removed. In addition, two bullfrog egg masses were removed from Lake Haussmann during weekly surveys in 2006. In 2005, 14 bullfrog egg masses were removed from Lake Haussmann. These invasive species control measures were conducted under the 2002 amendment to the Arroyo Las Positas Maintenance Plan biological opinion.

Monitoring of the Mid-Elk Ravine enhancement pools in 2006 resulted in observations of colonization, breeding, egg-laying, larvae development, and young of the year recruitment of California red-legged frog at the new pools. Besides the translocation of 16 frogs to this site from the Building 865 wetland, other California red-legged frog adults colonized the upper and lower pool areas from surrounding areas. Several egg masses were observed in both pools by the end of March; larvae were abundant in both pools and some individuals were even present beyond October of 2006. In September 2006, recently metamorphosed, terrestrial California red-legged frogs numbered in the hundreds around the periphery of both the upper and lower pools.

#### **6.4.2.2 Rotenone Treatment of Lake Haussmann to Control Largemouth Bass**

LLNL's Environmental Protection Department (EPD) collaborated with the California Department of Fish and Game to apply the piscicide rotenone to Lake Haussmann in October 2006. Rotenone is commonly used for the removal of unwanted fish species, and proper use of it poses low risk to wildlife, such as frogs. A multidisciplinary team composed of EPD and other LLNL staff worked together in the months preceding and after the application to ensure a successful, environmentally safe operation. Due to the thorough planning and expertise of both LLNL staff and the California Department of Fish and Game, invasive, nonnative fish species were successfully eradicated without any unforeseen issues arising. Water quality and sediment monitoring conducted after the application determined that no long-term negative water quality impacts from the rotenone application occurred, and that all activities were performed in compliance with applicable water quality regulations (see **Section 5.5.3**). Observations following the application confirmed that invasive, nonnative fish species that prey on the federally listed California red-legged frog population were successfully removed from Lake Haussmann.

#### **6.4.2.3 Arroyo Las Positas**

In 2006, bullfrog tadpoles and adults were observed in the Arroyo Las Positas at the Livermore site. Adult bullfrogs were removed during nocturnal surveys. Subsequent to the rotenone treatment of Lake Haussmann, sections of Arroyo Las Positas were drained to remove bullfrog tadpoles and invasive fish, including largemouth bass.

#### **6.4.2.4 Feral Pig Control at Site 300**

Site 300's invasive species control efforts have been focused largely on dispatching feral pigs. Feral pigs occupy the rangelands surrounding the site and periodically move onto the property to breed and/or forage. Control efforts initiated in 1999 have successfully reduced the seasonal pig population to very low numbers on site. In December 2006, five adult pigs (4 females, 1 male) were discovered and dispatched from the eastern side of the property.

### **6.4.3 Surveillance Monitoring**

#### **6.4.3.1 Wildlife Monitoring and Research**

**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: the Alameda whipsnake (*Masticophis 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 operations 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.

During baseline monitoring in the spring and fall of 2002, a total of 18 California whipsnakes were captured (9 at the control site and 9 in the burn site). In the spring of 2003, 12 were captured (8 in the control site and 4 in the burn site). 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 were 10 California whipsnake captures during spring trapping (6 in the control area and 4 in the burn area), and no captures 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, initiated off site, jumped the Site 300 boundary and burned through both the treatment and control sites on July 20, 2005. Although no whipsnake fatalities were documented during post-burn surveys, both trapping areas were burned severely and little remnant vegetation was left in the shrubland. A total of 5 whipsnakes were captured during the spring 2006 trapping period (4 in the control and 1 in the burn area). No trapping was conducted in the fall of 2005 and 2006 due to previous low capture success rates. Although the affects of the prescribed burn and subsequent impacts of the wildfire on the whipsnake is not yet known, ongoing spring whipsnake captures from 2003 to 2006 in both study sites suggests habitat requirements are still available for a portion of the population in the study areas.

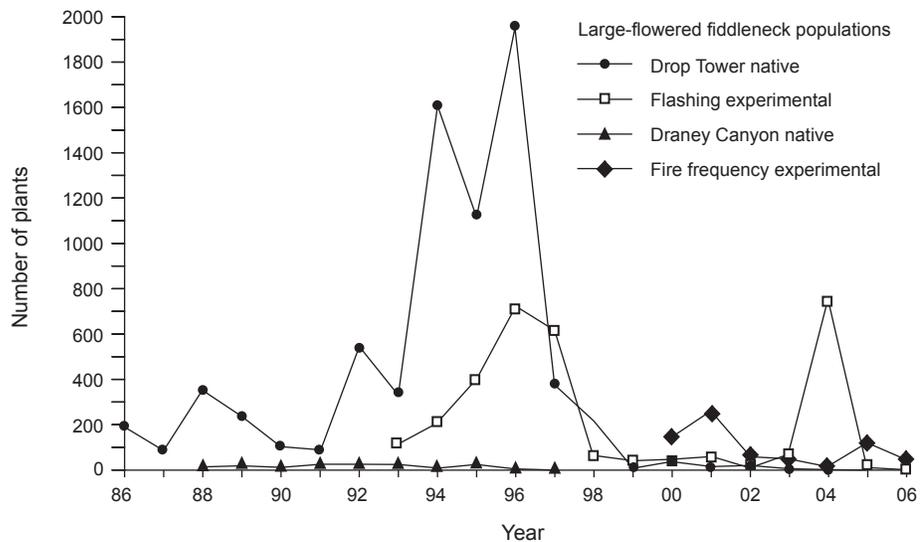
***Nesting Bird Surveys.*** LLNL conducts nesting bird surveys to ensure LLNL activities comply with the Migratory Bird Treaty Act and do not result in impacts to nesting birds. White-tailed Kites, a California fully protected species, annually nest in the trees along the north, east, and south perimeter of the Livermore site. LLNL staff surveyed potential White-tailed Kite nesting sites using binoculars or a spotting scope during the spring of 2006; three pairs of White-tailed Kites successfully fledged 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 2006 because 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* (U.S. DOE 2005) was continued in 2006. (See **Chapter 2, Section 2.4.1**, for more information on the environmental impact statement.) 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 2006). 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 E**.

***California Red-Legged Frog Egg Mass Surveys.*** Diurnal visual surveys for California red-legged frog egg mass were conducted every March from 2001 to 2006 in Arroyo Las Positas at the Livermore site. Location and habitat characteristics were recorded for each egg mass observed.

The number of egg masses observed were 37 (2001), 32 (2002), 31 (2003), 9 (2004), 7 (2005) and 2 (2006). Oviposition sites tended to be shallow ( $22.86 \text{ cm} \pm 9.40 \text{ cm}$ ), and all

**Figure 6-9.** Number of large-flowered fiddleneck plants in Site 300 experimental and native populations, 1986–2006.



egg masses were located in water shallower than 50 cm. Most egg masses were within 1 m of the shore ( $65.29 \text{ cm} \pm 40.75$ ) and near the surface ( $3.90 \text{ cm} \pm 6.25$ ). Egg masses were usually deposited on vegetation that provided structure and to a lesser extent rigidity.

#### 6.4.3.2 Rare Plant Research and Monitoring

LLNL conducted restoration and/or monitoring activities in 2006 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 detail in a biannual progress report (Paterson et al. 2007 [in press]).

**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. An approximate 65-ha (160-ac) 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 the Site 300 Drop Tower and on a nearby ranch. An additional population (the Draney Canyon native population) was known to occur historically 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 only 4 large-flowered fiddleneck plants in 2006, no plants in 2005, 3 plants in 2004, 5 plants in 2003, and 19 plants in 2002 (see **Figure 6-9**).

LLNL also established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. The experimental population is divided into two subpopulations known as the flashing and fire frequency 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 51 large-flowered fiddleneck plants in 2006, 127 plants in 2005, 768 plants in 2004, 119 plants

in 2003 and 67 plants in 2002 (see **Figure 6-9**). Large-flowered fiddleneck seeds were planted in the experimental population in 2006 in an attempt to boost numbers of this species in the experimental population. The exact combination of factors required to promote the success of large-flowered fiddleneck is still unknown. LLNL can promote the establishment of a native perennial grassland plant community preferred by large-flowered fiddleneck through frequent prescribed burns, but the frequent burning needed to promote native grasslands appears to negatively impact large-flowered fiddleneck. Predation of large-flowered fiddleneck seeds is quite high in burned areas and large-flowered fiddleneck is more common in area with less frequent burns.

LLNL is also beginning to see results in the long-term fire frequency experiment that began 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 decline in this population in recent years remain unclear. LLNL can promote the establishment of a native perennial grassland with prescribed burns, but seed predation is quite high in these burned areas.

**Big Tarplant.** The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September and October of 2006. The plant was less widely distributed at Site 300 in 2006 than in 2005.

**Diamond-Petaled California Poppy.** There are currently three populations of diamond-petaled California poppy (*Eschscholzia rhombipetala*) known to occur at Site 300; the population locations are referred to as Site 1, Site 2, and Site 3. Although the species is not listed under the federal or California Endangered Species Acts, it is extremely rare and is currently known to occur only at Site 300 and at one location in San Luis Obispo County. A census of the three Site 300 populations was conducted in March and April 2006, and the size and location of each diamond-petaled poppy plant were recorded. In addition, the composition of the plant community in which the species occurs was quantified.

In 2006, a total of 631 diamond-petaled California poppies were found at Site 300. The most recently discovered population, Site 3, contained by far the largest number (596 plants). Numbers of plants at Sites 1 and 2 have been very small in recent years. In 2006, Site 1 had no plants, and Site 2 had 35.

**Round-Leaved Filaree.** Six populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwest 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 2006, the extent of the six Site 300 populations was mapped using a handheld GPS, and the size of each population was estimated. The six populations were estimated to contain over 5000 plants.

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

Through monitoring and compliance activities in 2006, LLNL has been able to avoid most impacts to special status wildlife and plants. Although LLNL activities have not directly impacted the California red-legged frog at the Livermore site, a decline in the number of egg masses in Arroyo Las Positas has been observed from 2001 to 2006. The cause of the decrease is unknown.

Invasive species continue to be the largest threat to California red-legged frogs at the Livermore site. In an attempt to protect this endangered species and other native amphibians, LLNL has continued its program to remove invasive exotic species of amphibians and fish from the Livermore site. The treatment of Lake Haussmann with rotenone in the fall of 2006 was a safe and effective method of removing exotic fish from the Livermore site. Water and sediment samples were collected following the rotenone treatment. Samples were free of rotenone and its by-products 17 days following the application, and no rotenone or rotenone by-products were released from Lake Haussmann. LLNL also continued its bullfrog eradication program in 2006.

In the summer of 2005, a poorly performing breeding pool for California tiger salamanders was enhanced (deepened and widened) to more than double its original size (from 150 m<sup>2</sup> to 385 m<sup>2</sup>) as compensation for the loss of habitat due to closure of the surface impoundments. The location chosen for enhancement had historically been a “sink” habitat that allowed tiger salamanders to breed during the spring period and then quickly dried before larvae could survive and metamorphose to the terrestrial stage during the summer. Successful breeding and recruitment of young salamanders to the terrestrial phase was documented at the mitigation pool in 2006, demonstrating the potential long-term breeding value of the site for California tiger salamander populations in this remote area of the site.

In 2005 at Site 300, habitat enhancement pools were created in Elk Ravine as mitigation of the impact to California red-legged frog habitat that occurred from decreased cooling water discharge. The frogs’ use of the created wetlands was monitored in 2006. The pools appear to be very successful as mitigation for impacts to the Elk Ravine breeding habitat because the frogs were breeding at the enhancement pools in 2006 less than one year after their creation, and many adult frogs were observed at the pools during monitoring surveys conducted in March of 2006.

Monitoring was conducted at the Livermore site Arroyo Seco project site. Irrigation system repairs, additional planting, and weed control were conducted in 2007 to ensure the project meets the success criteria for the restoration of the site.

The Oasis and Round Valley culvert replacement projects were successfully completed in 2006, resulting in the creation of a new pool above the Round Valley project site. The pool is designed to serve as breeding habitat for California red-legged frogs and California tiger salamanders.

Although Site 300 activities did not impact the large-flowered fiddleneck in 2006, the number of large-flowered fiddleneck plants in the native Site 300 population was very low again in 2006. In 2006, LLNL continued efforts at Site 300 to maintain the experimental large-flowered population located at the Drop Tower. Through research conducted on the experimental population, LLNL is attempting to uncover the factors leading to the rarity of this species.

The 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. The 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 small fraction of the Site 300 tarplant population and are not considered to be significant to this species.

**Cynthia L. Conrado**

*S. Ring Peterson*

## 7.1 Releases of radioactivity from LLNL operations

## 7.2 Radiation protection standards

## 7.3 Air dispersion and dose models

## 7.4 Identification of key receptors

## 7.5 Results of 2006 radiological dose assessment

7.5.1 Total dose to site-wide exposed individuals

7.5.2 Doses from unplanned releases

7.5.3 Collective dose

7.5.4 Doses to the public placed in perspective

## 7.6 Special topics on dose assessment

7.6.1 Compliance demonstration for minor sources

7.6.2 Estimate of dose to biota

7.6.3 Modeling dose from tritium—comparison of approaches

## 7.7 Environmental impact

**L**awrence Livermore National Laboratory assesses potential radiological doses to biota, off-site individuals, and the population residing within 80 kilometers (km) of either of the two LLNL sites, the Livermore site and Site 300. These potential doses are calculated to determine the impact of LLNL operations, if any, on the general public and the environment, and to demonstrate compliance with regulatory standards set by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA).

The release of radioactive material to air is the major source of public radiological exposure from LLNL operations. Therefore, LLNL expends a significant effort monitoring stack air effluent for radiological releases and ambient air for evidence of any radiological impact due to LLNL operations (see **Chapter 4**). In addition, LLNL monitors radioactivity in a variety of media including soil, sediment, vegetation, and wine, and measures environmental gamma



radiation (see **Chapter 6**). LLNL also samples wastewaters, storm water, groundwater, rainfall, and local surface water (see **Chapter 5**). Releases to water systems are not a source of direct exposure to the public because the water is not consumed directly.

Measurements of radiological releases to air and modeling the dispersion of the released radionuclides are used to determine LLNL's dose to the public. Because LLNL is a DOE facility, it is subject to the requirements of Title 40 of the *Code of Federal Regulations*, Part 61, (40 CFR Part 61), Subpart H, the National Emission Standards for Hazardous Air Pollutants (NESHAPs). LLNL uses the EPA Clean Air Act Assessment Package-1988 (CAP88-PC) computer model to help demonstrate site compliance with NESHAPs regulations. CAP88-PC is used to evaluate the four principal exposure pathways: ingestion, inhalation, air immersion, and irradiation by contaminated ground surface.

The major radionuclides measured by LLNL in 2006 that contributed 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.

---

## 7.1 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, reliance on usage inventories declined in favor of increased utilization of ambient air monitoring data (see **Section 7.6.1**).

---

## 7.2 Radiation Protection Standards

The release of radionuclides from operations at LLNL and the resultant radiological impact to the public are regulated by both DOE and the EPA.

For protection of the public, DOE has set the limit for prolonged exposure of a maximally exposed individual in an uncontrolled area at 1 millisievert per year (1 mSv/y) whole-body effective dose equivalent (EDE), which equals 100 millirem per year (100 mrem/y) EDE. For occasional exposure, the limit is 5 mSv/y (500 mrem/y) EDE. EDEs and other technical terms are defined in the glossary and discussed in "Supplementary Topics on Radiological

Dose” (see **Appendix F** or Sanchez [2003], Appendix D). 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  $\mu\text{Sv}/\text{y}$  (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. NESHAPs regulations require that any operation with the potential to produce an annual average off-site dose greater than or equal to 1  $\mu\text{Sv}/\text{y}$  (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 continuous monitoring of emissions to air from a project is required. These requirements are described in the LLNL *Environment, Safety and Health (ES&H) Manual*, Document 31.2, Radiological Air Quality Compliance.

---

### 7.3 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 model used by LLNL to compute radiological individual or collective (i.e., population) dose resulting from radionuclide emissions to air.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six collocated sources. Input parameters used in the code include radionuclide type, emission rate in curies per year (Ci/y), 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 Parks (1992).

Calculated doses include the four principal exposure pathways. Internal exposures are inhalation of air and ingestion of foodstuff and drinking water; drinking water dose is calculated only for tritium. External exposures are irradiation from contaminated ground and immersion in contaminated air. Dose is calculated as a function of radionuclide, pathway, spatial location, and body organ.

CAP88-PC also provides the flexibility to adjust agricultural parameters (e.g., numbers of milk cows per  $\text{km}^2$ ) and the fractions of contaminated foods ingested. For the 2006 evaluation, as for 2004 and 2005, LLNL took advantage of this capability and used updated assumptions for agricultural and food source parameters for CAP88-PC (see Larson et al. 2007). Furthermore, an improved tritium model, NEWTRIT (Peterson and Davis 2002), which uses air concentrations predicted by CAP88-PC to address the dose from releases of

elemental tritium gas (HT) and from the ingestion of organically bound tritium (OBT), was again employed to compare with the tritium model in CAP88-PC.

---

## 7.4 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 equal to or greater than 100  $\mu\text{Sv}/\text{y}$  (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<sup>(a)</sup> that is affected by the same predicted or observed air concentration caused by releases of radioactivity from the site. Thus, the SW-MEI dose is not received by any actual individual and is a conservative estimate of the highest possible dose that might be received by any member of the public.

In 2006, the SW-MEI at the Livermore site was located at the UNCLE Credit Union, about 10 meters (m) outside the site’s controlled eastern perimeter, and 957 m east-northeast of the Tritium Facility. The SW-MEI at Site 300 was located on the site’s south-central perimeter, which borders the Carnegie State Vehicular Recreation Area. The location was 3170 m south–southeast of the firing table at Building 851. The two SW-MEI locations are shown in **Figure 7-1**.

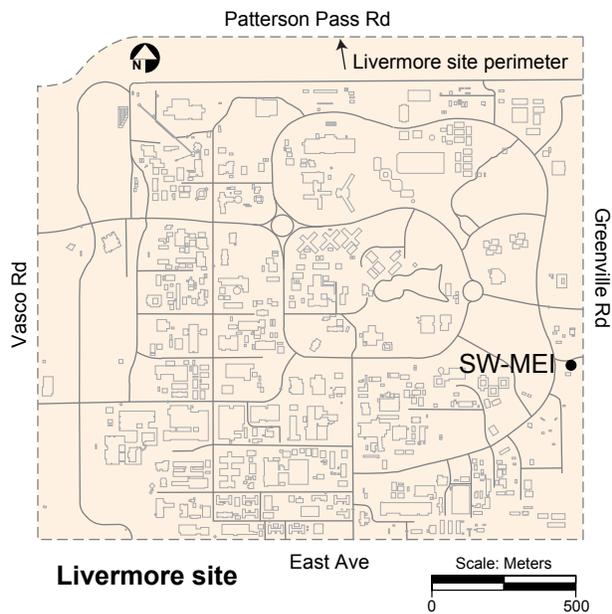
---

## 7.5 Results of 2006 Radiological Dose Assessment

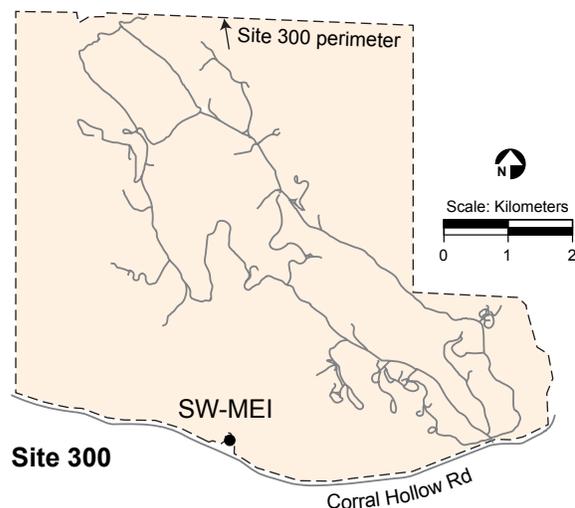
This section summarizes the doses to the most exposed public individuals from LLNL operations in 2006, shows the temporal trends compared with previous years, presents the potential doses to the populations residing within 80 km of either the Livermore site or Site 300, and places the potential doses from LLNL operations in perspective with doses from other sources.

---

(a) Calculated for tritium only.



**Livermore site**



**Site 300**

**Figure 7-1.** Location of the site-wide maximally exposed individual (SW-MEI) at the Livermore site and Site 300, 2006.

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

The total dose to the SW-MEI from Livermore site operations in 2006 was  $0.045 \mu\text{Sv}/\text{y}$  ( $0.0045 \text{ mrem}/\text{y}$ ). Of this, the dose attributed to diffuse emissions (area sources) totaled  $0.029 \mu\text{Sv}$  ( $0.0029 \text{ mrem}$ ) or 64%; the dose due to point sources was  $0.016 \mu\text{Sv}$  ( $0.0016 \text{ mrem}$ ) or 36% of the total. The point source dose includes Tritium Facility elemental tritium gas (HT) emissions modeled as tritiated water (HTO), as directed by EPA Region IX. Using NEWTRIT rather than CAP88-PC to calculate the dose for tritium emissions reduced the tritium component of the total dose from  $0.040 \mu\text{Sv}$  ( $0.0040 \text{ mrem}$ ) to  $0.030 \mu\text{Sv}$  ( $0.0030 \text{ mrem}$ ).

The total dose to the Site 300 SW-MEI from operations in 2006 was  $0.16 \mu\text{Sv}$  ( $0.016 \text{ mrem}$ ). Point source emissions from firing table explosives experiments totaled  $0.14 \mu\text{Sv}$  ( $0.014 \text{ mrem}$ ) accounting for 87.5% of the dose, while  $0.020 \mu\text{Sv}$  ( $0.0020 \text{ mrem}$ ), or about 12.5%, 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 2006. Although LLNL has nearly 150 sources with the potential to release radioactive material to air according to NESHAPs prescriptions, most are very

minor. Nearly the entire radiological dose to the public 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 fourth time in assessing 2006 operations (see Larson et al. 2007).

Dominant radionuclides at the two sites were the same as in recent years. Tritium accounted for about 89% of the Livermore site's calculated dose. At Site 300, practically the

**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 2006.

Site	Facility (source category)	CAP88-PC dose ( $\mu\text{Sv/y}$ ) <sup>(a)</sup>	CAP88-PC contribution to total dose
Livermore site	Tritium Facility stacks (point source)	0.016 <sup>(b)</sup>	36%
	Building 612 yard (diffuse source)	0.013 <sup>(b)</sup>	29%
	Tritium Facility outside (diffuse source)	0.011 <sup>(b)</sup>	25%
	Southeast quadrant soil resuspension (diffuse source)	0.0046	10%
Site 300	Soil resuspension (diffuse source)	0.020	12.5%
	Building 851 firing table (point source)	0.14	87.5%

(a) 1  $\mu\text{Sv}$  = 0.1 mrem

(b) When LLNL's NEWTRIT model is used in place of CAP88-PC's default tritium model, the dose for the Tritium Facility's stacks is reduced to approximately 57% of the value shown, and doses for the Building 612 yard and Tritium Facility outside are reduced to 89% of the values shown.

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. Air immersion and ground irradiation pathways 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 17 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.

### 7.5.2 Doses from Unplanned Releases

In June 2006 at the Livermore site, a solid titanium tritide source was transferred from one building to another for potential use as a check source. Subsequently, after routine radiation swipes identified tritium contamination in both buildings, it was determined that this legacy source had leaked tritiated particulate matter. During the transfer, the source was wrapped, but tritium contamination was inadvertently spread to the environment via personnel contact with the particulate matter. Contamination that measured above the DOE's release limit for tritium contamination was remediated. The bioassays performed for the personnel who

**Table 7-2.** Doses calculated for the site-wide maximally exposed individual (SW-MEI) for the Livermore site and Site 300, 1990 to 2006.

Site	Year	Dose ( $\mu\text{Sv/y}$ ) <sup>(a)</sup>		
		Total	Point source	Diffuse source
Livermore site	2006	0.045 <sup>(b)</sup>	0.016 <sup>(b)</sup>	0.029
	2005	0.065 <sup>(b)</sup>	0.027 <sup>(b)</sup>	0.038
	2004	0.079 <sup>(b)</sup>	0.021 <sup>(b)</sup>	0.058
	2003	0.44 <sup>(b)</sup>	0.24 <sup>(b)</sup>	0.20
	2002	0.23 <sup>(b)</sup>	0.10 <sup>(b)</sup>	0.13
	2001	0.17 <sup>(b)</sup>	0.057 <sup>(b)</sup>	0.11
	2000	0.38 <sup>(b)</sup>	0.17 <sup>(b)</sup>	0.21
	1999	1.2 <sup>(b)</sup>	0.94 <sup>(b)</sup>	0.28
	1998	0.55 <sup>(b)</sup>	0.31 <sup>(b)</sup>	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	2.34	— <sup>(c)</sup>	
1990	2.40	2.40	— <sup>(c)</sup>	
Site 300	2006	0.16	0.14	0.020
	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	— <sup>(d)</sup>	
1991	0.44	0.44	— <sup>(d)</sup>	
1990	0.57	0.57	— <sup>(d)</sup>	

(a) 1  $\mu\text{Sv}$  = 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.

had handled the source or worked in the rooms impacted by the incident indicated either no tritium intake or none attributable to the incident. Because the greatest potential dose would have been to these personnel, rather than to a member of the public, any potential dose to a member of the public from this incident would have been completely negligible.

At Site 300, there were no unplanned atmospheric releases of radionuclides in 2006.

### 7.5.3 Collective Dose

Collective dose for both LLNL sites was calculated using CAP88-PC for a radius of 80 km from the site centers. Population centers affected by LLNL emissions within the 80-km radius include the nearby communities of Livermore and Tracy; the more distant metropolitan areas of Oakland, San Francisco, and San Jose; and the San Joaquin Valley communities of Modesto and Stockton. Within the 80-km radius specified by DOE, there are 7.1 million residents included for the Livermore site collective dose determination and 6.2 million for Site 300. The source of the geographic population distribution data used for this report is Dobson et al. (2000).

The CAP88-PC result for potential collective dose attributed to 2006 Livermore site operations was 0.0075 person-Sv (0.75 person-rem); the corresponding collective dose from Site 300 operations was 0.033 person-Sv (3.30 person-rem). These values are both within the normal range of variation seen from year to year.

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 LLNL sites. However, a large dose to a small number of people

**Table 7-3.** Collective dose broken down by level of individual doses, 2006.

Site	Individual dose range ( $\mu\text{Sv/y}$ ) <sup>(a)</sup>	Collective dose (person-Sv/y) <sup>(b)</sup>	Percent total collective dose
Livermore site	0.01 to 0.1	0.000029	0.38%
	0.001 to 0.01	0.00047	6.27%
	0.0001 to 0.001	0.0067	88.8%
	0.00001 to 0.0001	0.00032	4.32%
	Total	0.0075 <sup>(c)</sup>	100%
Site 300 <sup>(d)</sup>	0.01 to 0.1	0.0029	8.8%
	0.001 to 0.01	0.022	67.0%
	0.0001 to 0.001	0.0076	23.0%
	0.00001 to 0.0001	0.00051	1.5%
	Total	0.033	100%

(a) 1  $\mu\text{Sv}$  = 0.1 mrem

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

(c) Collective dose output from CAP88-PC for each sector and each distance from the source is in two significant figures. When dose is calculated by summing outputs for each sector and distance, as is done for the disaggregation of collective dose, the total collective dose may be slightly different from the total calculated directly by CAP88-PC.

(d) Dose from Building 851 firing table.

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 shown **Table 7-3** demonstrates that about 92% of the population receives less than 0.01  $\mu\text{Sv/y}$  (1  $\mu\text{rem/y}$ ).

#### 7.5.4 Doses to the Public Placed in Perspective

As a frame of reference to gauge the size of the LLNL doses, **Table 7-4** compares them to average doses received in the United States from exposure to natural background radiation and other sources. These values vary with location. Collective doses from LLNL operations in 2006 are about 500,000 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 2006 are nearly 15,000 times smaller than ones received from background radiation in the natural environment.

**Table 7-4.** Comparison of radiation doses from LLNL sources to average doses from background (natural and man-made) radiation, 2006.

Location/source	Category	Individual dose <sup>(a)</sup> ( $\mu$ Sv) <sup>(c)</sup>	Collective dose <sup>(b)</sup> (person-Sv) <sup>(d)</sup>
LLNL			
Livermore site sources	Atmospheric emissions	0.045	0.0075
Site 300 sources	Atmospheric emissions	0.16	0.033
Other sources <sup>(e)</sup> (background)			
	Natural radioactivity <sup>(f,g)</sup>		
	Cosmic radiation	300	2,130
	Terrestrial radiation	300	2,130
	Internal (food and water consumption)	400	2,840
	Radon	2,000	14,200
	Medical radiation (diagnostic procedures) <sup>(f)</sup>	530	3,760
	Weapons test fallout <sup>(f)</sup>	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  $\mu$ Sv = 0.1 mrem

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

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

(f) These values vary with location.

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

## 7.6 Special Topics on Dose Assessment

### 7.6.1 Compliance Demonstration for Minor Sources

From 1991 through 2002, LLNL demonstrated compliance for minor sources of radiation 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  $\mu$ Sv/y (10 mrem/y) and did not justify the level of effort expended in accounting for them. To better allocate resources, in March 2003 LLNL made a request to EPA, pursuant to the NESHAPs regulations, to use existing ambient air monitoring to demonstrate compliance for minor sources. The request was granted by EPA in April 2003. This 2006 report marks the fourth 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 40 CFR Part 61, Table 2, Appendix E. The radionuclides for which the comparison is made are tritium and plutonium-239+240 for the

**Table 7-5.** Mean concentrations of radionuclides of concern at the location of the SW-MEI in 2006.

Location	Nuclide	EPA concentration standard (Bq/m <sup>3</sup> )	Detection limit (approximate) (Bq/m <sup>3</sup> )	Mean measured concentration (Bq/m <sup>3</sup> )	Measured concentration as a fraction of the standard
Livermore SW-MEI	Tritium	56	0.037	0.028 <sup>(a)</sup>	5.0 x 10 <sup>-4</sup>
Livermore SW-MEI	Plutonium-239	7.4 x 10 <sup>-5</sup>	1.9 x 10 <sup>-8</sup>	6.6 x 10 <sup>-9(b)</sup>	8.9 x 10 <sup>-5</sup>
Site 300 SW-MEI	Uranium-238	3.1 x 10 <sup>-4</sup>	1.1 x 10 <sup>-9</sup>	4.6 x 10 <sup>-7(c)</sup>	1.5 x 10 <sup>-3</sup>

Note: 1 Bq = 2.7 x 10<sup>-11</sup> Ci

- (a) The tritium value includes contributions from the Tritium Facility, Building 612 yard, Tritium Facility outside yard, and contributions from other minor sources.
- (b) The mean measured concentration for plutonium is less than the detection limit; only 1 of the 13 values composing the mean was a measured detection.
- (c) The ratio for the mean uranium-235 and uranium-238 concentrations for 2006 is 0.0065, which is less than 0.00725, the ratio of these isotopes for naturally occurring uranium. This results in approximately 86% of the resuspension being attributable to naturally occurring uranium and 14% being attributable to depleted uranium.

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 represents the SW-MEI. At Site 300, the minor source that has the potential to have a measurable effect is the resuspension of depleted uranium contaminated soil. Because this is a diffuse source, the average of the results for all monitoring locations at the site is used to represent the SW-MEI.

The standards contained in 40 CFR Part 61, Table 2, Appendix E, and the measured concentrations at the SW-MEI are presented in Système International (SI) units in **Table 7-5**. As demonstrated by the calculation of the fraction of the standard, LLNL-measured air concentrations for tritium and plutonium-239+240 and uranium-238 are 0.0015 or less than the health protective standard for these radionuclides.

### 7.6.2 Estimate of Dose to Biota

Biota (flora and fauna) also need to be protected from potential radiological exposure from LLNL operations since their exposure pathways are unique to their environment (e.g., a ground squirrel may be exposed to dose by burrowing in contaminated soil). Thus, LLNL calculates potential dose to biota from LLNL operations according to *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (U.S. DOE 2002) and by using the RESRAD-BIOTA computer code, a tool for implementing DOE's graded approach to biota dose evaluation. In 2004, DOE's Interagency Steering Committee on Radiation Standards (ISCORS) published a user's guide for the RESRAD-BIOTA (U.S. DOE 2004). The code was developed for DOE with support from the EPA, the U.S. Nuclear Regulatory Commission (NRC), and the informal, interagency Ecological Radiological Work Group (ECORAD-WG).

Limits on absorbed dose to biota are 10 milligray per day (mGy/d) (1 rad per day [rad/d]) for aquatic animals and terrestrial plants, and 1 mGy/d (0.1 rad/d) for terrestrial

animals. At LLNL in 2006, radionuclides contributing to dose to biota were americium-241, cesium-137, tritium, plutonium-239 (analyzed as plutonium-239+240 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 2006 LLNL assessment, the maximum concentration of each radionuclide measured in soils, sediments, and surface waters was used in the dose screening calculations; the maximum concentration may have occurred on the Livermore site, in the Livermore Valley, or on Site 300. This approach resulted in an assessment that was 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 is 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 ensure 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.

In the RESRAD-BIOTA code, each radionuclide in each medium (i.e., soil, sediment, and surface water) is assigned a derived concentration limit or Biota Concentration Guide (BCG). Radionuclide concentrations in each medium when entered are then divided by the BCG and a partial fraction for each nuclide and medium is summed. For aquatic and riparian animals, the sum of the fractions for water exposure is added to the sum of the fractions for sediment exposure. Similarly, fractions for water and soil exposures are summed for terrestrial animals. If the sums of the fractions for the aquatic and terrestrial systems are both less than 1 (i.e., the dose to the biota does not exceed the screening limit), the site has passed the screening analysis and biota are assumed to be protected. In 2006, the sum of the fractions for the aquatic system was 0.298, and the sum for the terrestrial system was 0.036. These ultraconservative results for the aquatic system are similar to those for 2003, 2004, and 2005. The sum of the fractions for the terrestrial system is similar to previous years.

A more realistic approach can be made using runoff or release concentrations from Lake Haussmann, combined with sediment from the East Settling Basin (location ESB). Using these concentrations, the sum of the fractions for the aquatic system is 0.093, which is about two thirds of the fractions from the ultraconservative approach. It is clear that dose to biota from LLNL operations is below levels of regulatory concern.

### **7.6.3 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

**Table 7-6.** Bulk transfer factors used to calculate inhalation and ingestion doses from measured concentrations in air, vegetation, and drinking water.

<b>Exposure pathway</b>	<b>Bulk transfer factors<sup>(a)</sup> times observed mean concentrations</b>
Inhalation and skin absorption	0.21 x concentration in air (Bq/m <sup>3</sup> ); see <b>Chapter 4</b>
Drinking water	0.013 x concentration in drinking water (Bq/L); see <b>Chapter 5</b>
Food ingestion	0.0049 x concentration in vegetation (Bq/kg) (see <b>Chapter 6</b> ); factor obtained by summing contributions of 0.0011 for vegetables, 0.0011 for meat and 0.0027 for milk

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

site operations (from a public dose standpoint), a comparison of potential doses for 2006, 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. This dose is calculated from air concentrations derived after modeling the dispersion of tritium released from the principal tritium-handling facilities on site. In addition, since 1979, using bulk transfer factors (see **Table 7-6**) derived from equations in the NRC Regulatory Guide 1.109 (U.S. NRC 1977), LLNL has calculated potential ingestion doses from measured HTO concentrations in vegetation (see **Chapter 6**) and drinking water (see **Chapter 5**), as well as doses from inhalation (see **Chapter 4**). Both CAP88-PC and Regulatory Guide 1.109 account for dose only 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.

Hypothetical tritium doses predicted at location VIS, the Livermore site air tritium and vegetation sampling location (see **Chapter 6, Figure 6-1**), 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 location VIS and eating 100% locally grown food. Because the air tritium monitor can sample only for HTO, only HTO releases were used to calculate air tritium concentrations using CAP88-PC.

The dose comparison shows a factor of about 5 between the lowest (NEWTRIT) and highest (CAP88-PC) dose predictions, each of which is based on valid assumptions. Differences are due primarily to predicted (0.0877 becquerel per cubic meter [Bq/m<sup>3</sup>]) versus observed (0.0236 Bq/m<sup>3</sup>) air concentrations and assumptions about intake rates and dose coefficients (see Sanchez et al. [2003], Appendix C). When predicted air concentrations drive

**Table 7-7.** Comparison of hypothetical doses at the Livermore site VIS air tritium and vegetation monitoring location calculated from predicted and observed concentrations of HTO in air in 2006.

Exposure pathway	Hypothetical dose (nSv/y)		
	CAP88-PC (from predicted air concentrations) <sup>(a)</sup>	NRC 1.109 (from mean air, vegetation, and tap water <sup>(b)</sup> concentrations)	NEWTRIT (from mean air tritium concentrations)
Inhalation and skin absorption	24	5.0	5.4
Food ingestion			
Vegetables	77	2.6	14
Milk	47	6.5	9
Meat	28	2.6	4.5
Total food ingestion dose	152	12	28
Drinking water	1.0	<27 <sup>(c)</sup>	2.3
Total	177	<44	35

(a) Doses from CAP88-PC are based on the sum of the predicted HTO concentrations at VIS for the Tritium Facility stacks ( $1.52 \times 10^{-2}$  Bq/m<sup>3</sup>), the Building 612 Yard ( $2.07 \times 10^{-2}$  Bq/m<sup>3</sup>), and the Tritium Facility area source ( $5.18 \times 10^{-2}$  Bq/m<sup>3</sup>).

(b) Tap water is measured on the Livermore site but not at location VIS.

(c) The mean concentration for tap waters measured for tritium in 2006 was below the limit of detection.

the doses, doses are normally higher than when observed air and vegetation concentrations drive the results. The mean observed tritium concentration in air at location VIS for 2006 is relatively uncertain because 58% of the samples were below the minimum detection limit.

Using assumptions about the fraction of diet that realistically could be contaminated by LLNL tritium rather than assuming, as in **Table 7-7**, that the entire diet is contaminated, reduces the dose by a factor of 4 or more.

## 7.7 Environmental Impact

The annual radiological doses from all emissions at the Livermore site and Site 300 in 2006 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  $\mu$ Sv/y (10 mrem/y) the EDE to any member of the public arising as a result of releases of radioactive material to air from DOE facilities. Using an EPA-mandated computer model and actual LLNL meteorology appropriate to the two sites, potential doses to the LLNL SW-MEI members of the public from LLNL operations in 2006 were:

- Livermore site: 0.045  $\mu$ Sv (0.0045 mrem)—36% from point-source emissions; 64% from diffuse-source emissions. The point source emissions include gaseous tritium modeled as HTO for compliance purposes, as directed by EPA Region IX.
- Site 300: 0.16  $\mu$ Sv (0.016 mrem)—87.5% from explosive experiments, which are classified as point-sources; 12.5% from diffuse-source emissions.

As noted earlier, the major radionuclides accounting for the doses were tritium at the Livermore site and the three isotopes of 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 2006 was estimated to be 0.0075 person-Sv (0.75 person-rem) for the Livermore site and 0.033 person-Sv (3.30 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 2006, were 0.04% and 0.16%, respectively, of the federal standard and were more than 15,000 times smaller than the dose from background radiation. The collective doses from LLNL operations in 2006 were about 500,000 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.

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. The maximum credible doses to the public indicate that LLNL's use of radionuclides had no significant impact on public health during 2006.

*John A. Karachewski  
Michael J. Taffet*

## 8.1 Livermore Site Ground Water Project

- 8.1.1 Physiographic setting
- 8.1.2 Hydrogeology of the Livermore site
- 8.1.3 Remediation activities and monitoring results
- 8.1.4 Groundwater flow and transport modeling
- 8.1.5 Environmental impacts

## 8.2 Site 300 CERCLA Project

- 8.2.1 Physiographic setting and geology of Site 300
- 8.2.2 Contaminant hydrogeology of Site 300
- 8.2.3 Remediation activities and monitoring results
- 8.2.4 Ongoing and planned investigations and cleanup activities
- 8.2.5 Environmental impacts



**D**uring 2006, groundwater investigations and remediations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. Lawrence Livermore National Laboratory samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology and nature and extent of the contamination and its source. Where necessary, remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants in groundwater and the progress LLNL has made in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300. The sites are similar in that the contamination is, for the most part, confined to on site. The sites differ in that Site 300,

with an area of 28.3 square kilometers (km<sup>2</sup>), is much larger than the Livermore site and has been divided into eight operable units based on the nature and extent of contamination, and topographic and hydrologic considerations. The Livermore site at 3.3 km<sup>2</sup> is effectively one operable unit.

---

## 8.1 Livermore Site Ground Water Project

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

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

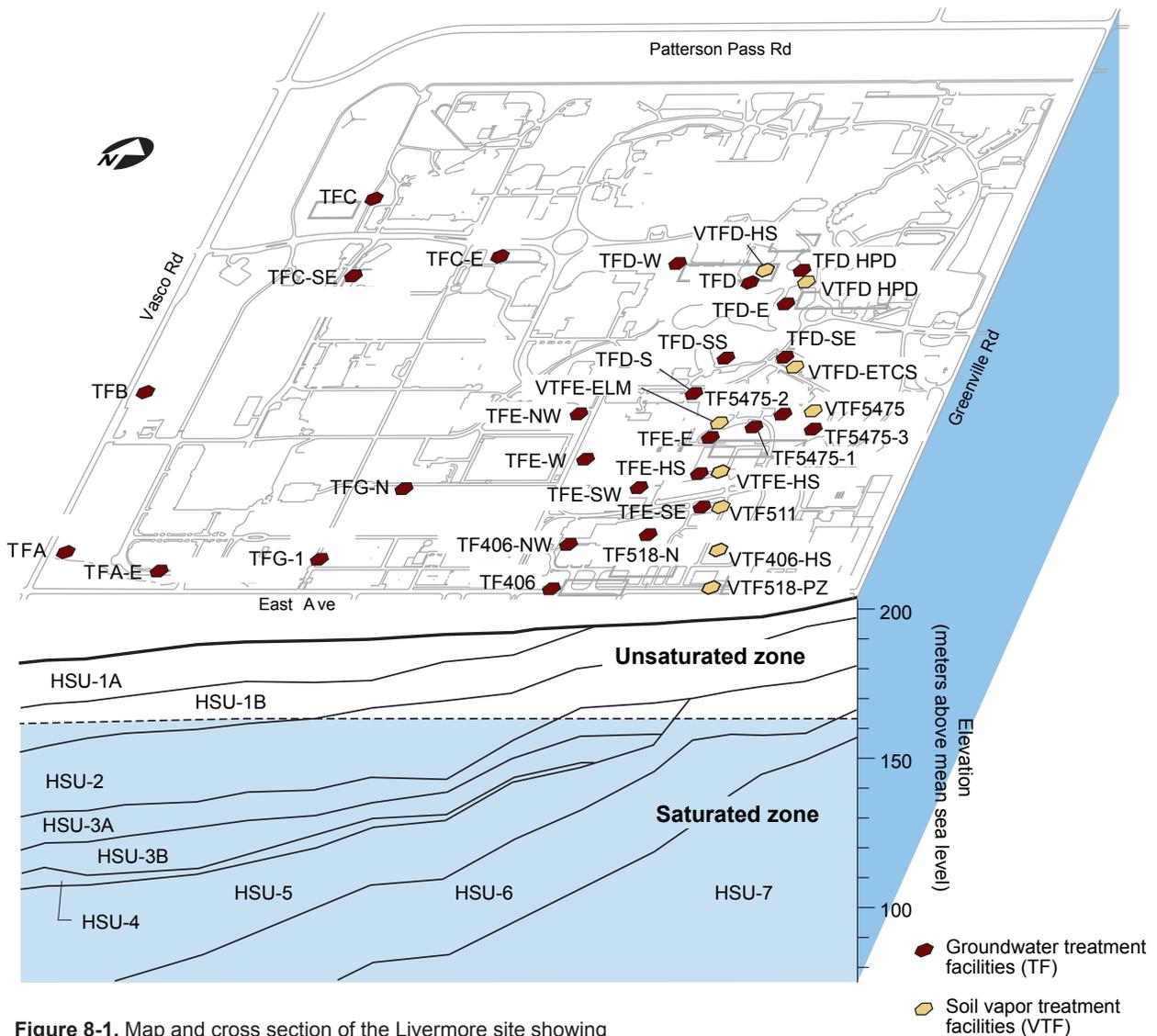
### 8.1.1 Physiographic Setting

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

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

### 8.1.2 Hydrogeology of the Livermore Site

Sediments at the Livermore site are grouped into four grain-size categories—clay, silt, sand, and gravel. Groundwater flow beneath the site occurs primarily in alluvial sand and gravel deposits, which are bounded by lower permeability clay and silt deposits. The alluvial sediments have been subdivided into nine 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: HSU-1B, -2, -3A, -3B, -4, and -5 (Blake et al. 1995; Hoffman et al. 2003). HSU-1A, -6, and -7 do not contain contaminants of concern above action levels and are therefore not discussed further.



**Figure 8-1.** Map and cross section of the Livermore site showing hydrostratigraphic units and the location of the treatment facilities.

### 8.1.3 Remediation Activities and Monitoring Results

This section summarizes the primary activities and results of the Livermore site Ground Water Project in 2006. Additional information is provided in Karachewski et al. (2007). In addition to discussing trends during the past year, this section also highlights the significant reduction of VOC concentrations at the Livermore site during the past five years.

In 2006, LLNL operated 27 groundwater treatment facilities (see **Table 8-1** and **Figure 8-1**). The 92 groundwater extraction wells and 34 dual extraction wells produced more than 1059 million liters (L) of groundwater and the treatment facilities removed nearly 78 kilograms (kg) of VOCs (see **Table 8-1**). In 2005, the groundwater treatment facilities removed approximately 71 kg of VOCs. The higher mass removal in 2006 is due to the addition of new extraction wells to existing or upgraded treatment facilities in contaminant source areas. Since remediation began in 1989, approximately 11,838 million L of groundwater have been treated, resulting in removal of more than 1246 kg of VOCs.

In 2006, LLNL also operated 9 soil vapor treatment facilities (see **Table 8-1** and **Figure 8-1**). The 19 soil vapor extraction wells and 34 dual extraction wells produced more than 2.3 million cubic meters (m<sup>3</sup>) of soil vapor and the treatment facilities removed more than 177 kg of VOCs (see **Table 8-1**). In 2005, the soil vapor treatment facilities removed approximately 196 kg of VOCs. The lower rate of mass removal in 2006 is due to decreasing VOC concentrations and cleanup of the vadose zone in the TFD and TFE source areas. However, there was a significant increase in VOC mass removed in the TFH source areas, from 110.5 kg in 2005 to 151.2 kg in 2006. This increase was due to the ongoing operation of existing treatment facilities, especially at VTF406 Hotspot, and startup of a new treatment facility at VTF511. Since initial operation, over 7 million m<sup>3</sup> of soil vapor has been extracted and treated, removing more than 1052 kg of VOCs from the subsurface.

Over the last five years, groundwater VOC concentrations in HSU-1B, -2, and -3A along the western and southern margins of the Livermore site have continued to decline, particularly in the off-site 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**. In 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 HSU-2, -3A, -3B, -4, and -5.

Over the last four years, remediation activities, including soil vapor extraction, dual extraction, and groundwater extraction, have focused increasingly on source area cleanup. The annual amount of VOC mass removed from source areas in response to these cleanup activities has nearly doubled over this period. **Figures 8-3** and **8-4** show the amount of VOC mass removed and volume of groundwater extracted at the Livermore site since remediation activities began in 1989.

In 2006, concentrations continued to decrease in most Livermore site VOC plumes. The decline in VOC concentrations is attributed primarily to active remediation and removal of

**Table 8-1.** VOCs removed from groundwater and soil at the Livermore site.

Groundwater/ soil vapor	Treatment facility area <sup>(a)</sup>	2006		Cumulative Total	
		Water treated (million L)	VOCs removed (kg)	Water treated (million L)	VOCs removed (kg)
Groundwater	TFA	365.5	5.7	5293.3	184.3
	TFB	97.3	2.7	1220.1	68.4
	TFC	148.2	6.2	1112.5	78.1
	TFD	280.7	46.4	2648.3	696.3
	TFE	99.1	11.1	947.4	183.5
	TFG	27.2	1.1	169.8	8.3
	TFH	41.1	4.6	446.3	27.2
	Total <sup>(b)</sup>	1059	78	11,838	1246
		Soil vapor treated (10 <sup>3</sup> m <sup>3</sup> )	VOCs removed (kg)	Soil vapor treated (10 <sup>3</sup> m <sup>3</sup> )	VOCs removed (kg)
Soil vapor <sup>(c)</sup>	TFD	584.9	14.3	1180.5	80.2
	TFE	1037.9	11.8	2912.7	134.8
	TFH	736.4	151.2	3228.9	837.3
	Total <sup>(b)</sup>	2359	177	7322	1052

(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

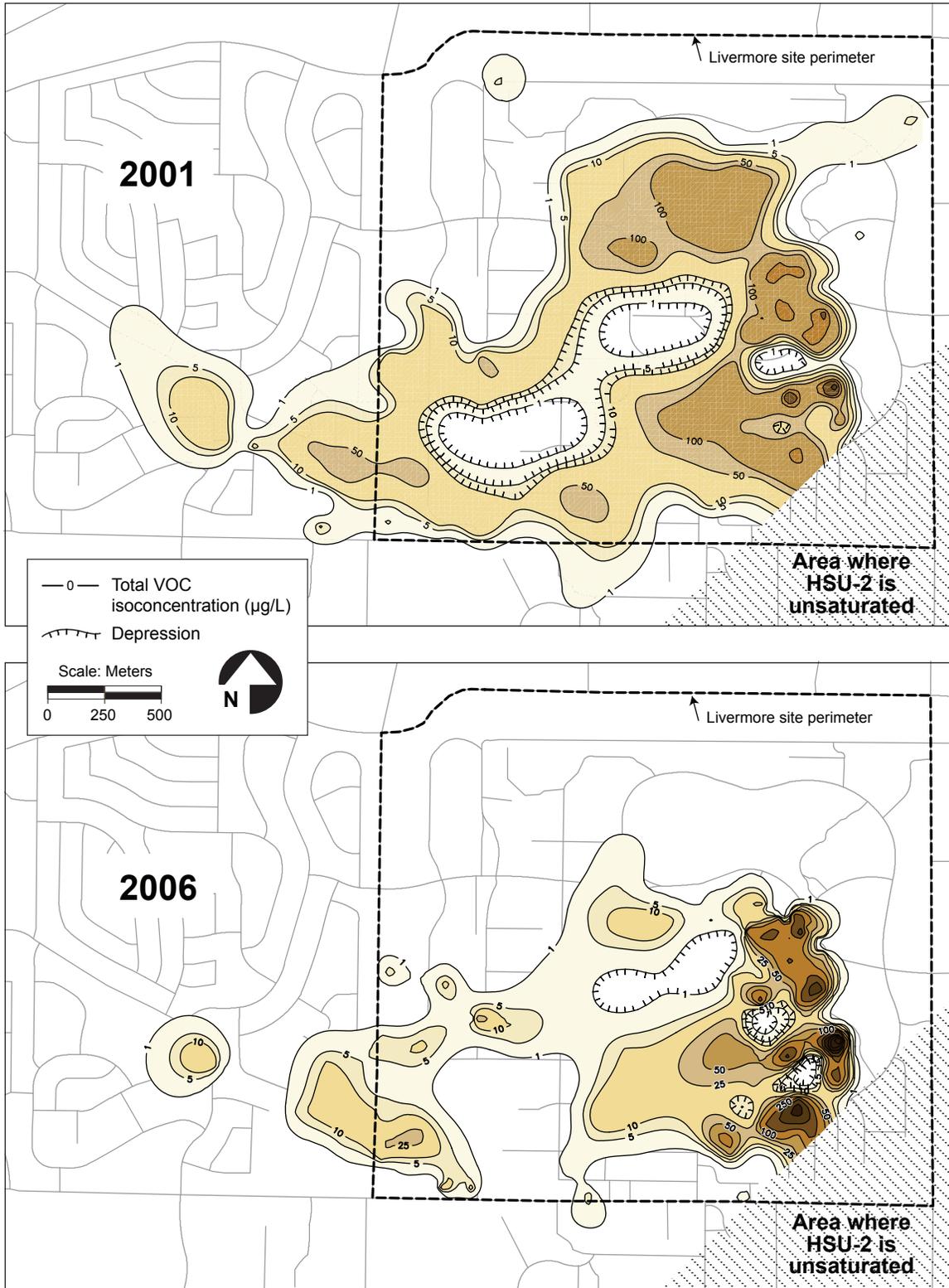
TFH area: TF406, TF406-NW, VTF406-HS, VTF511, TF518-N, VTF518-PZ, TF5475-1, TF5475-2, TF5475-3, VTF5475

(b) Totals rounded to nearest whole number.

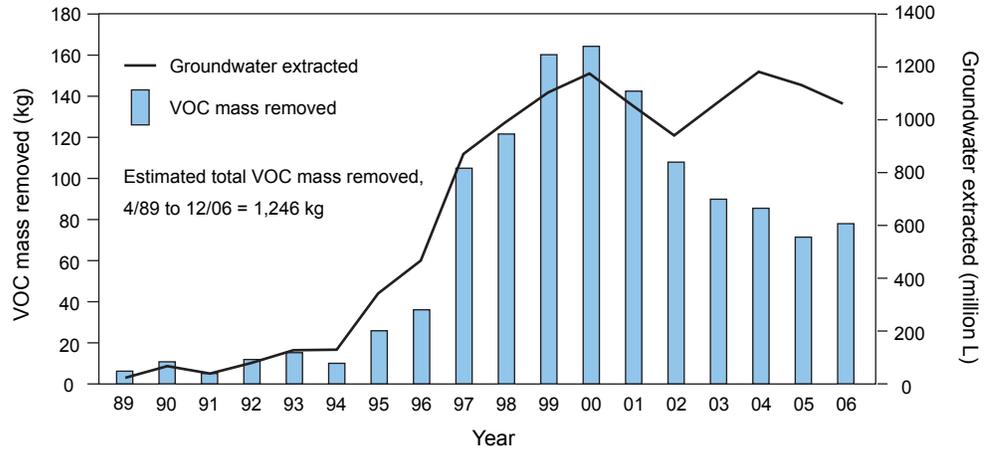
(c) Includes only those treatment areas at which vapor was extracted.

more than 255 kg of VOCs by the groundwater and soil vapor extraction wells and treatment facilities during the year. Notable trends and results are discussed below.

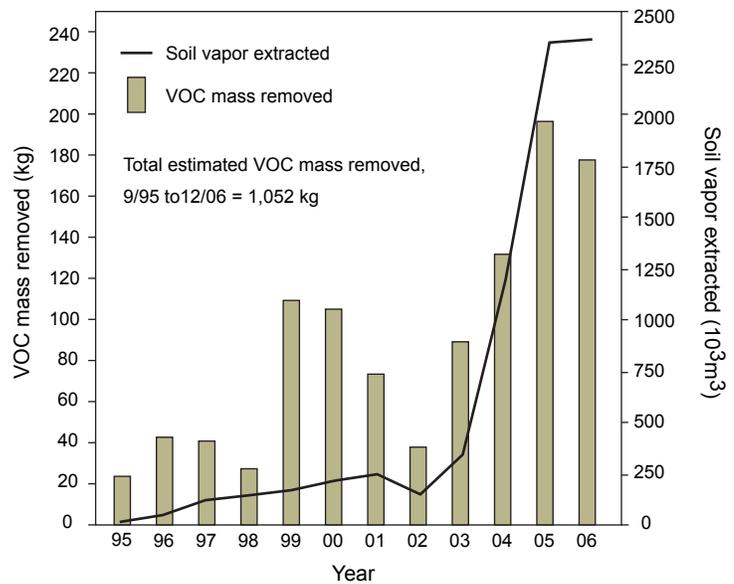
VOC concentrations on the western margin of the site generally continued to decline slowly, indicating continued hydraulic control of the boundary plumes in the TFA, TFB, and TFC areas. Off-site, VOCs in HSU-1B remained below MCLs, except at well W-1425, which is currently fluctuating above and below the PCE MCL (1.2 parts per billion [ppb] PCE, December 2006). A large area east of the TFA north pipeline (including wells W-115, W-213, and W-604) fell below MCLs for the first time. The entire off- and on-site TFA HSU-2 VOC plume remained below 25 ppb in 2006. The highest PCE levels off-site continue to be at wells W-404 and W-654, where maximum 2006 concentrations were 24 ppb and



**Figure 8-2.** Isoconcentration maps showing reductions in total VOCs above MCLs for HSU-2 between 2001 and 2006.



**Figure 8-3.** Estimated total VOC mass removed from groundwater at the Livermore site subsurface since 1989.



**Figure 8-4.** Estimated total VOC mass removed from soil vapor at the Livermore site subsurface since 1995.

13 ppb, respectively. To ensure hydraulic containment and to reduce the concentration of PCE at well W-404, TFA West was activated in January 2007. At TFB, concentrations rose along the western margin at well W-422 (9.6 ppb TCE, December 2006). A hydraulic test is being conducted to determine whether additional groundwater extraction will be required to prevent off-site migration of the VOC plume at this location. Concentrations in all TFA, TFB, and TFC source areas remained relatively unchanged, except at the TFC Hotspot area where TCE increased from 260 ppb (October 2005) to 300 ppb (July 2006) in HSU-1B well SIP-501-007. Groundwater remediation began in this area in April 2006 as part of the TFC Hotspot milestone.

VOC concentrations in a mobile HSU-2 plume located in the central TFE area increased slightly over the last year. Concentration increases observed at wells W-1202 (from 43 ppb to

79 ppb TCE), W-271 (from 23 ppb to 29 ppb TCE) and W-1508 (from 17 ppb to 32 ppb TCE) should be hydraulically captured and treated at downgradient treatment facility TFE-W. TCE concentrations in this plume's source area, TFE Eastern Landing Mat, declined over the last year from 1600 ppb to 1400 ppb in well SIP-543-101 due to ongoing operation of soil vapor and dual extraction wells.

The entire HSU-3A TFD area Freon-11 plume dropped below MCLs for the first time in response to groundwater extraction at TFD West. In the TFB area, PCE and TCE increased slightly in HSU-3A well W-310 (to 5.7 ppb and 3.4 ppb, respectively). Hydraulic testing is planned to determine the cause of this increase. After increasing for several years, TCE concentrations at TFE well W-276 declined slightly during 2006, probably due to ongoing groundwater extraction and treatment at TF406 Northwest. The W-276 area will continue to be evaluated to determine whether hydraulic containment and groundwater treatment is needed to prevent westward migration of this plume into an area with limited well control. In the Building 419 area, concentrations in source area well W-1414 declined from 3000 ppb to 1500 ppb TCE. Soil vapor cleanup in the Building 419 source area began in September 2006. Elsewhere in HSU-3A, VOC concentrations remained largely unchanged.

Concentrations in the HSU-3B plume emanating from the TFD Southeast area increased slightly during 2006. TCE concentrations at extraction well W-1403 rose from 420 ppb to 490 ppb, while TCE at downgradient monitor well W-1511 increased from 270 to 390 ppb, then decreased to 270 ppb again. Groundwater extraction and treatment at TFD Southeast and at TFD South are expected to reduce these concentrations over time. Elsewhere in HSU-3B, VOC concentrations remained relatively unchanged.

Concentrations in HSU-4 generally declined in several areas under remediation. Near the south side of Trailer 5475, where groundwater extraction and treatment began in June 2006, TCE in extraction well W-1604 dropped from 2400 ppb to 350 ppb. At TFD Southeast, TCE in extraction well W-314 declined from 300 ppb to 250 ppb. TFD Main TCE concentrations in HSU-4 extraction well W-351 decreased from 310 ppb to 100 ppb, while at TFD South-shore, TCE declined in extraction well W-1523 from 320 ppb to 230 ppb. Elsewhere, concentration levels were relatively unchanged.

Concentrations continued to decline in HSU-5 on Sandia National Laboratories/California property in response to continued groundwater extraction at TF406, with only TCE remaining above its MCL in two off-site wells (11 ppb in well W-509 and 5 ppb in well W-1113). At extraction well W-359, TCE increased from 310 ppb to 390 ppb. Soil vapor extraction and dual extraction that began in the Building 511 source area in September 2006 is expected to reduce concentrations at well W-359 over time. Elsewhere in HSU-5, very little change was evident during 2006.

During 2006, tritium activities in groundwater from all wells at the Livermore site, including those in the Trailer 5475 and Building 292 areas, remained below the 740 becquerels per liter (Bq/L) (20,000 picocuries per liter [pCi/L]) MCL and continued to decline by radioactive decay.

#### **8.1.4 Groundwater Flow and Transport Modeling**

Groundwater flow and contaminant transport models were 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.

The focus in 2006 was mainly on developing small-scale models that simulate multi-phase processes in the source areas. These models are capable of simulating the dual extraction remediation systems currently operating in the source areas. The source-area models, combined with the existing multi-dimensional regional-scale groundwater models, are used to optimize the operation of the dual extraction remediation systems. They also allow the evaluation of the potential benefit of using other conventional or innovative source-area cleanup technologies in the future. Pilot tests on one or more technologies are planned for 2007.

#### **8.1.5 Environmental Impacts**

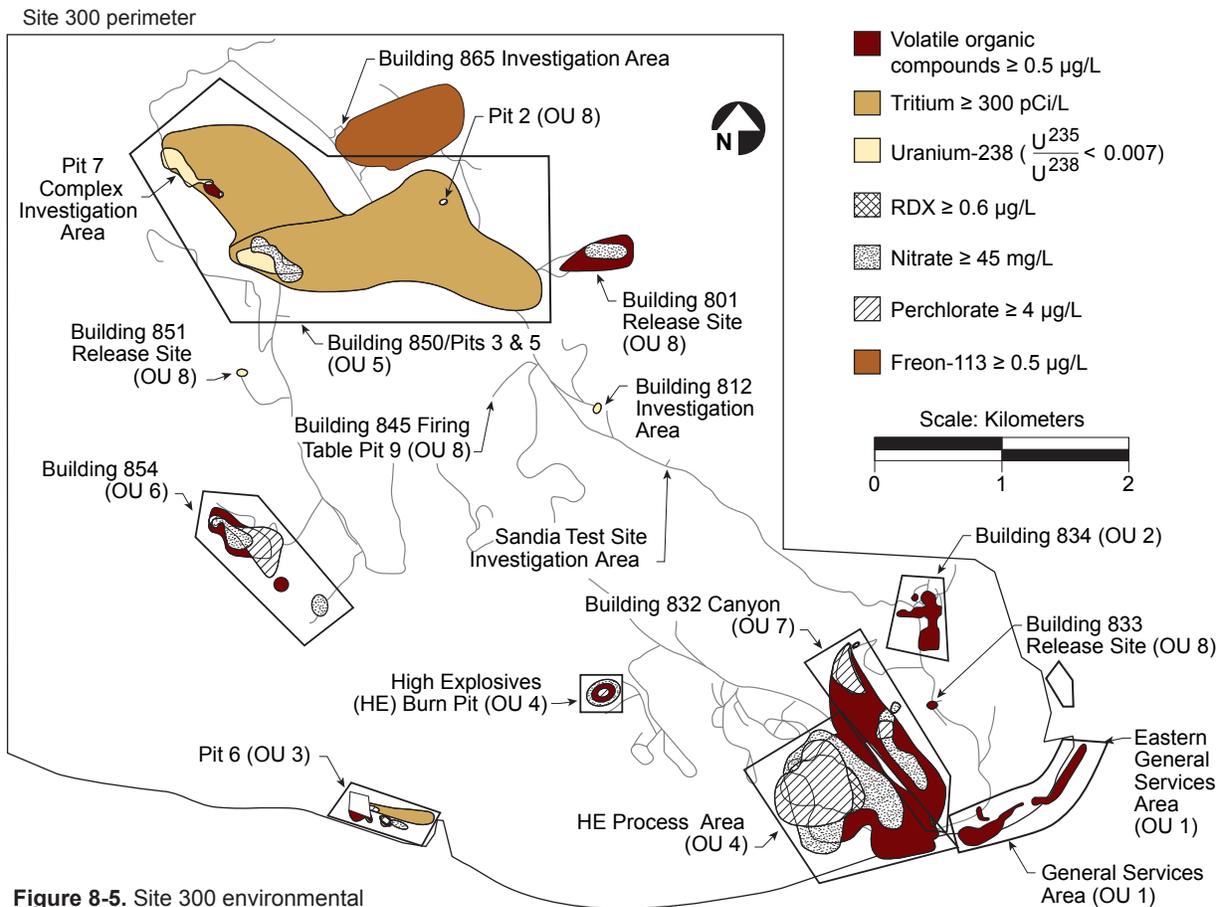
At the Livermore site, LLNL strives to reduce risks arising from chemicals released to the environment, to conduct all its restoration activities to protect environmental resources, and to preserve the health and safety of all site workers. LLNL's environmental restoration project is committed to preventing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

Remedial solutions 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 and soil vapor extraction and treatment.

Groundwater and soil vapor extraction and treatment at the Livermore site continue to reduce the mass of contaminants in the subsurface. **Figures 8-3** and **8-4** show the VOC mass removed at the Livermore site from groundwater (since 1989) and from soil vapor (since 1995), respectively. In 2006, the groundwater and soil vapor treatment facilities removed more than 255 kg of VOCs. Since remediation efforts began in 1989, more than 11,838 million L of groundwater and more than 7.3 million m<sup>3</sup> of soil vapor have been treated, yielding a total of more than 2298 kg of removed VOCs.

## 8.2 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 8-5**. All characterized contaminant release sites that have a CERCLA pathway have been assigned to one of eight OUs based on the nature, extent, and sources of contamination, and 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 Webster-Scholten (1994) and the *Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300* (SWESR) (Ferry et al. 2006a). Key milestone and deliverable due dates for 2006 are listed in **Table 8-3**. All milestone and deliverable due dates were met during 2006. These milestones included



**Figure 8-5.** Site 300 environmental restoration operable units, investigation areas, and contaminants of concern.

**Table 8-2.** Major contaminants of concern found in soil, rock, and groundwater at Site 300.

Site	Contaminant of concern
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
High Explosives Process Area (OU4)	VOCs (primarily TCE), high explosives (primarily RDX), nitrate, perchlorate
Building 850/Pit 7 Complex (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), nitrate, perchlorate, depleted uranium, tritium, metals, RDX
Building 865 Study Area	VOCs (primarily Freon-113)
Building 812 Study Area	Depleted uranium, nitrate, perchlorate
Sandia Test Site	None

**Table 8-3.** Calendar year 2006 deliverable and milestone dates for Site 300 environmental restoration activities outlined in the FFA and other agreements.

Deliverable/milestone	Due date
Final Building 832 Canyon Interim Remedial Design Report	2/23/06 (met)
Final Proposed Plan for the Pit 7 Complex	3/21/06 (met)
Draft Site-Wide Remediation Evaluation Summary Report	4/11/06 (met)
Public Meeting for the Proposed Plan for the Pit 7 Complex	4/20/06 (met)
Draft GSA 5-Year Review Report	5/3/06 (met)
Public Workshop for the Site-Wide Draft Remediation Evaluation Summary Report	5/16/06 (met)
Draft Amendment to the Interim Site-Wide Record of Decision (ROD) for the Pit 7 Complex	7/10/06 (met)
Expand B832-SRC groundwater extraction well field to the distal portion of the plume in the Building 832 Canyon OU	9/29/06 (met)
Hook-up B830-PRXN extraction well to the B830-SRC groundwater treatment system in the Building 832 Canyon OU	9/29/06 (met)
Expand B854-SRC groundwater extraction well field in the Building 854 OU	9/29/06 (met)
Expand B854-DIS groundwater extraction well field in the Building 854 OU	9/29/06 (met)
Building 865 (ATA) Characterization Summary Report	9/30/06 (met)
Final GSA 5-Year Review Report	10/30/06 (met)
Final Site-Wide Remedial Evaluation Summary Report	10/30/06 (met)
Draft Site-Wide Proposed Plan for the Final Record of Decision	12/8/06 (met)

submission of the SWESR, the *Draft Site-Wide Proposed Plan for the Lawrence Livermore National Laboratory Site 300 Final Record of Decision* (U.S. DOE 2006e), and the public workshop for the SWESR.

### **8.2.1 Physiographic Setting and Geology of Site 300**

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Range Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy and hydrologic characteristics are shown in **Figure 8-6**. 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 volcanoclastic 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)

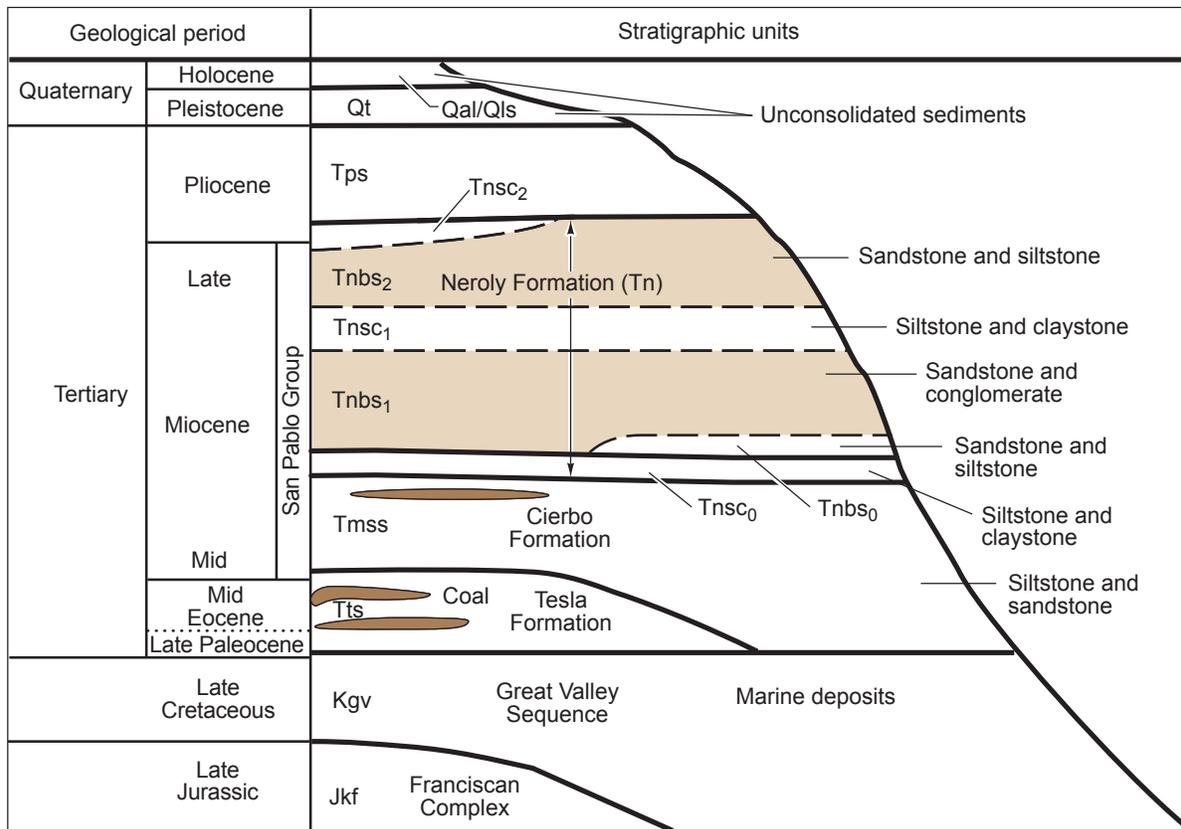
Distinctive volcanoclastic sandstone and sandy siltstone, interbedded with claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation. The Neroly Formation is also present in the subsurface beneath Site 300. It contains the principal hydrostratigraphic units (HSUs) within Site 300 and has been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in Webster-Scholten 1994). These HSUs are described in Ferry et al. (2006c). 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 High 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 slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence groundwater flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.

### **8.2.2 Contaminant Hydrogeology of Site 300**

Site 300 is semiarid, with an average annual rainfall of 27 cm (10.6 in.). The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists of interbedded conglomerates, sandstones, siltstones, and claystones. In addition to extensive water-bearing zones, some groundwater is present as perched water-bearing zones beneath



#### 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<sub>2</sub>): Absent beneath much of Site 300. Saturated beneath the Building 834 area.
- Upper blue sandstone unit (Tnbs<sub>2</sub>): Absent beneath much of Site 300. Saturated beneath Explosives Process Area.
- Lower siltstone/claystone unit (Tnsc<sub>1</sub>): Saturated beneath Explosives Process Area, and Building 832 Canyon.
- Lower blue sandstone unit of the Neroly Formation (Tnbs<sub>1</sub>): 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<sub>0</sub>): Saturated beneath the Pit 7 Complex, Pit 2, and Building 801/Pit 8 areas.
- Basal siltstone/claystone unit (Tnsc<sub>0</sub>): Saturated beneath the Building 854 area, and 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 8-6. Site 300 stratigraphy and hydrologic characteristics.

hilltops and valley bottoms. Groundwater flow in the bedrock follows the inclination, or dip, of the rock layers. 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. **Figure 1-4 (Chapter 1)** is a map of the potentiometric surface for the first continuous water-bearing zone at Site 300, which principally occurs in the Neroly lower blue sandstone aquifer (Tnbs<sub>1</sub>) and Tnbs<sub>0</sub>. 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. Bedrock-hosted groundwater is typically present under confined conditions in the southern half of the site but is often unconfined elsewhere. Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Low rainfall and high evapotranspiration rates, steep topography, and intervening aquitards generally preclude direct vertical recharge to the deeper bedrock aquifers.

All groundwater contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unnamed Pliocene non-marine sediments (Tps), or unconsolidated Quaternary sediments and weathered bedrock (Qal/WBR, Qls, or Qt) stratigraphic units. The extent of groundwater contamination at Site 300 is shown on **Figure 8-5**. **Figure 8-6** includes text that discusses the hydrologic conditions of strata at Site 300.

### **8.2.3 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, High Explosives Process Area, Building 850, Building 854, Pit 6, Building 832 Canyon, and site-wide OUs are presented in Dibley et al. (2006b, 2007 [see **Appendix F**]). The SWESR (Ferry et al. 2006c) provides a comprehensive analysis of progress in achieving remedial action objectives (RAOs) at these contaminant release sites over the last five years. The results of investigations at the Pit 7 Complex, Building 865, Building 812, and Sandia Test Site are not included in the CMP reports and SWESR. Current information for each of these portions of Site 300 is presented at the end of this section.

At Site 300, there are 3 dedicated (non-portable) groundwater and soil vapor extraction and treatment facilities at the eastern GSA, central GSA, and Building 834 areas. There are also 16 portable treatment facilities at Site 300. All 19 facilities operated during 2006. Forty wells that extract only groundwater, 2 wells that extract only soil vapor, and 18 wells that extract both groundwater and soil vapor (dual-phase) were pumped and fed into treatment systems during 2006. In 2006, the 40 wells that extract only groundwater and the 18 wells that extract both groundwater and soil vapor yielded about 116 million L of groundwater. During the year, the 18 wells that extract both vapor and groundwater and the 2 wells that extract only vapor removed 2.25 million m<sup>3</sup> of vapor. In 2006, the Site 300 treatment facilities

**Table 8-4.** Volumes of groundwater and soil vapor extracted and masses of volatile organic compounds removed at Site 300 CERCLA Operable Units.

Groundwater/ soil vapor treatment	Operable Unit	Startup date	2006		Cumulative total	
			Water treated (million L)	VOCs removed (kg)	Water treated (million L)	VOCs removed (kg)
Groundwater treatment	GSA (OU1)	1991, 1993	94.1	0.55	1218	31.5
	Building 834 Complex (OU2)	1995	0.522	3.40	1.99	37.0
	High Explosives Process Area (OU4)	1999	15.5	0.207	54.9	0.789
	Building 854 (OU6)	1999	3.65	0.352	24.1	4.96
	Pit 6 (OU3)	1998	—(a)	—(a)	0.268	0.0014
	Building 832 Canyon (OU7)	1999	1.99	0.371	17.5	1.98
Total <sup>(b)</sup>			116	4.84	1317	77.1
			Soil vapor treated (10 <sup>3</sup> m <sup>3</sup> )	VOCs removed (kg)	Soil vapor treated (10 <sup>3</sup> m <sup>3</sup> )	VOCs removed (kg)
Soil vapor treatment	Central GSA (OU1)	1994	256	0.700	2473	67
	Building 834 Complex (OU2)	1998	1336	35.0	3882	283
	Building 832 Canyon (OU7)	1999	121	3.90	553	5.7
	Building 854 (OU6)	2005	538	5.70	621	7.6
Total <sup>(b)</sup>			2251	45.1	7528	364

(a) 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.

(b) Total may not be a sum of the column because of rounding error. Total values are taken directly from the data set to avoid compounding the rounding error.

removed approximately 50 kg of VOCs, 0.18 kg of perchlorate, 1000 kg of nitrate, 0.15 kg of RDX high explosive compound, and 0.029 kg of organosilicate oil. Since remediation efforts began in 1990, more than 1317 million L of groundwater and approximately 7.53 million m<sup>3</sup> of vapor have been treated, to yield about 433 kg of removed VOCs, 0.58 kg of perchlorate, 4400 kg of nitrate, 0.71 kg of RDX high explosive compound, and 9.4 kg of organosilicate oil. The 2006 and cumulative total volumes of groundwater and vapor extracted to Site 300 treatment facilities and VOC masses removed are tabulated in **Table 8-4**.

The eastern GSA and B830-DISS groundwater treatment facilities discharge to surface drainage courses. The B854-PRX solar treatment unit/containerized wetland, B854-DIS aqueous phase granular activated carbon (GAC), B815-DSB aqueous phase GAC, and B830-PRXN GAC treatment systems discharge to infiltration trenches. The B815-SRC, B815-PRX, B817-SRC, B817-PRX, and B829-SRC discharge to injection wells. The other nine treatment systems discharge to air by misting.

The GSA contains maintenance and shop facilities. Dry well and liquid storage activities yielded contaminants to groundwater. At the eastern and central GSA, the extraction

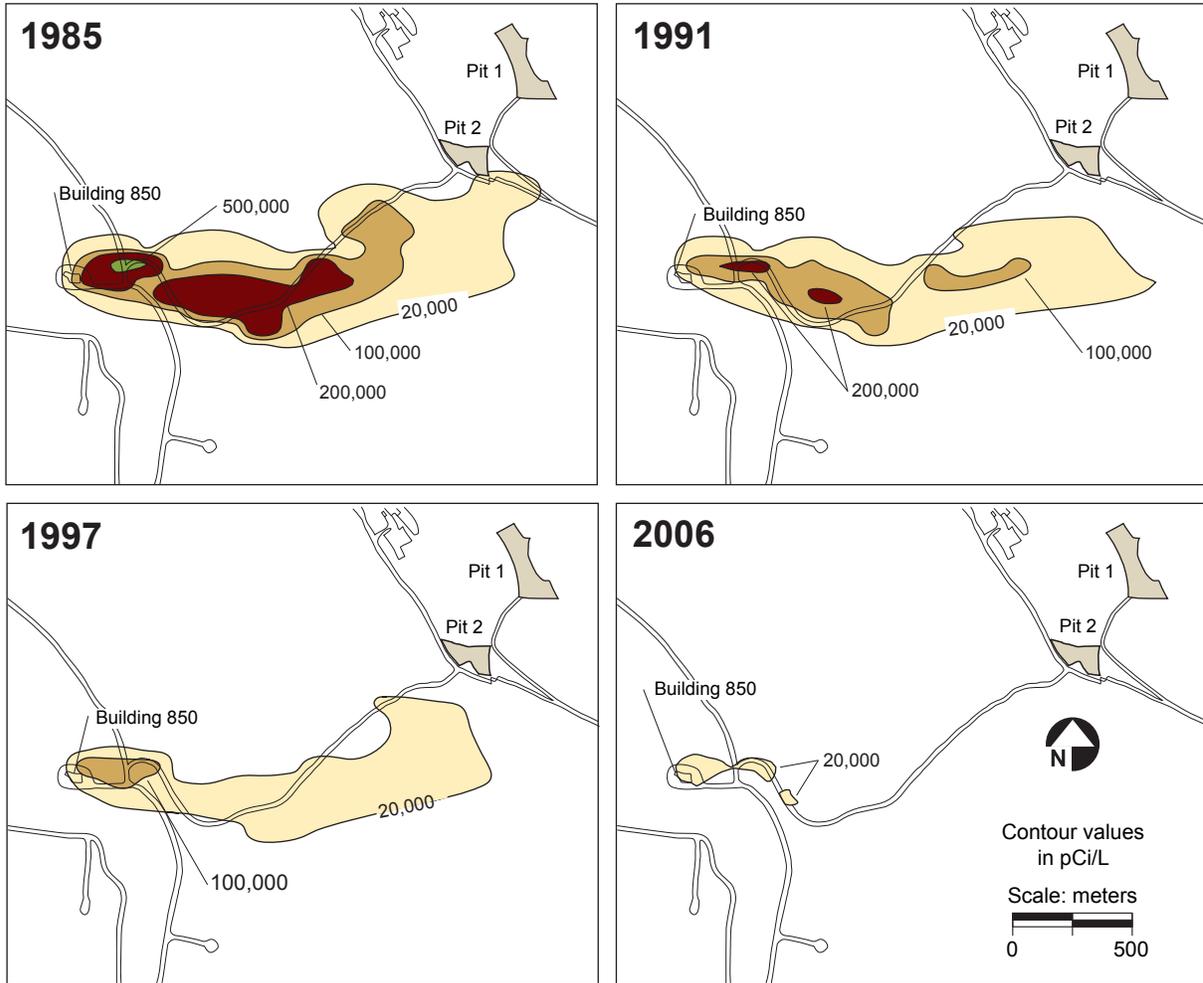
and treatment remedy continues to be effective and protective of human health and the environment, and to make progress toward cleanup. Groundwater total VOC concentrations in the Qal-Tnbs<sub>1</sub> HSU in the eastern GSA were reduced from a maximum of 74 µg/L in 1989 to 4.4 µg/L in December 2006. Current data indicate that pumping and treating groundwater from the three extraction wells in the eastern GSA has successfully reduced maximum concentrations of TCE and other VOCs in groundwater 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. Wells with water containing TCE concentrations exceeding the MCL have decreased from 18 to 0. DOE/LLNL has proposed to initiate the “Requirements for Closeout” described in the *Remedial Design Document for the General Services Area Operable Unit Treatment Facilities* (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.” During 2006, DOE/LLNL continued to await agency approval to shut off the treatment system and expects to shut off the eastern GSA treatment system in early 2007. As required, groundwater monitoring will be conducted to determine if VOC concentrations rise or “rebound” above cleanup standards after extraction ceases. No additional action is expected to be needed unless monitoring indicates that VOC concentrations rebound. Total VOC concentrations in Qal-Tnbs<sub>1</sub> HSU groundwater beneath the eastern GSA are shown of Dibley et al. (2007), Figure 2.1-5. The *Draft* and *Final Five-Year Review Report for the General Services Area* (Dibley et al. 2006a, 2006b) were submitted to the regulatory agencies by their due dates (see **Table 8-3**).

Contaminated groundwater is extracted from 8 wells and vapor is extracted from 7 wells screened in the Qt-Tnsc<sub>1</sub> HSU in the central GSA. Total VOC concentrations in central GSA groundwater have been reduced from 272,000 µg/L in 1993 to 360 µg/L in October 2006. From 1994 through the end of 2006, total VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 parts per million on a volume-per-volume basis (ppm<sub>v/v</sub>) to 13 ppm<sub>v/v</sub>. 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 in Dibley et al. (2007), Figure 2.1-6, and TCE concentrations in soil vapor in the central GSA are shown in Figure 2.1-7.

At Building 834, 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 sometimes leaked. There are three HSUs beneath the Building 834 OU. These are in descending order, the Tpsg, Tps-Tnsc<sub>2</sub>, and Tnbs<sub>1</sub> HSUs. The first two HSUs contain contaminants. The maximum 2006 total VOC concentration in groundwater at Building 834 was 221,000 µg/L. This concentration was found in dense claystones of the Tps-Tnsc<sub>2</sub> HSU, which underlies the Tpsg HSU, and is considered an

aquitard. The concentrations in this HSU have remained relatively stable, as no active remediation has been done within the HSU owing to 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 2006 were a maximum of 65,223 µg/L. The historical maximum total VOC concentration in the Tpsg HSU was 1,060,000 µg/L in 1993. This maximum 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 between 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 in Dibley et al. (2007), Figure 2.2-4. Groundwater and soil vapor extraction and treatment systems have been operating at Building 834 since 1995 and 1998, respectively. Thirteen wells that extract both groundwater and soil vapor compose the extraction network. The groundwater treatment system treats VOCs, nitrate, and organosilicate oil within the shallow Tpsg HSU and the vapor extraction system treats VOCs within shallow groundwater and the vadose zone. Maximum detected 2006 concentrations of nitrate and organosilicate oil in groundwater at Building 834 were 330 mg/L and 15,000 µg/L, respectively. Maps of the distribution of these two chemicals in Building 834 OU Tpsg HSU groundwater are depicted in Figures 2.2-6 and 2.2-8, respectively, of Dibley et al. (2007). Although VOC mass at Building 834 has been destroyed by *in situ* bioremediation, this mass has not been quantified.

At the High Explosives Process Area (HEPA) OU, high 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 high explosives (HE) waste water discharges to former unlined rinse-water lagoons. Nine extraction wells in the OU pump groundwater that is treated at 6 treatment facilities (B815-SRC, B815-PRX, B815-DSB, B817-SRC, B817-PRX, and B829-SRC). Total VOCs, the HE compound RDX, perchlorate, and nitrate concentrations in Tnbs<sub>2</sub> HSU groundwater beneath the HEPA are shown in Figures 2.4-4, 2.4-6, 2.4-7, and 2.4-9, respectively, of Dibley et al. (2007). Maximum 2006 total VOC concentrations of 44.3 µg/L were detected in groundwater in the Tnbs<sub>2</sub> aquifer. The maximum historical total VOC concentration in this HSU was 110 µg/L in a water sample collected in 1992. The total VOC concentrations in source area groundwater samples have been reduced by about 45% since remediation began in 1999. RDX concentrations in Tnbs<sub>2</sub> HSU groundwater have decreased from a maximum of 200 µg/L detected in 1992 to a maximum in 2006 of 77 µg/L. The maximum 2006 concentrations of nitrate and perchlorate in the Tnbs<sub>2</sub> HSU in the HEPA OU were 89 mg/L and 35 µg/L, respectively.



**Figure 8-7.** Tritium plume in combined Qal and Tnbs<sub>0</sub> HSUs during four time periods.

Building 850 is an explosives firing table. The distributions of tritium, uranium, nitrate, and perchlorate in Qal/WBR and Tnbs<sub>0</sub>/Tnbs<sub>1</sub> HSU groundwater beneath the Building 850 OU are shown in Figures 2.5-4 through 2.5-11 of Dibley et al. (2007). During 2006, the maximum detected tritium activity in groundwater at the Building 850 OU was 92,700 pCi/L. The maximum historical tritium activity was 566,000 pCi/L in 1985. 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 20,000 pCi/L MCL contour has greatly diminished with the highest tritium activities located immediately downgradient of the firing table source area (see **Figure 8-7**). The maximum 2006 total uranium activity in groundwater that contains some depleted uranium was 19 pCi/L and was collected from a well proximal to the firing table. Total uranium activities everywhere in the OU continue to be below the 20 pCi/L state MCL. The maximum nitrate and perchlorate concentrations detected in 2006 in Building 850

OU groundwater were 140 mg/L and 64 µg/L, respectively. Because groundwater samples from a number of wells contain perchlorate in excess of the 6 µg/L State Public Health Goal, a remedial strategy for the perchlorate is being developed. A treatability test of lactate-mediated *in situ* bioremediation of the perchlorate is planned for 2007. Excavation and on-site solidification of over 16,000 cubic yards (yd<sup>3</sup>) of PCB-bearing soil from the slopes around the firing table is planned for 2008.

The Building 854 OU is another site where weapons components were subjected to mechanical and thermal stresses and where pipes containing TCE leaked. Eight extraction wells pump Tnbs<sub>1</sub>/Tnsc<sub>0</sub> HSU groundwater that is treated at three treatment systems (B854-SRC, B854-PRX, and B854-DIS) to remove VOCs, nitrate, and perchlorate. B854-DIS began operation in July 2006 to limit the downgradient migration of VOCs at the foot of the VOC plume. The expansion of the B854-SRC and B854-DIS extraction well fields was completed by the regulatory due date of September 29, 2006 (see **Table 8-3**). A soil vapor rebound test will be conducted at B854-SRC during 2007. The 2006 maximum total VOC concentration in groundwater was 180 µg/L, down from a historical maximum total VOC concentration of 2900 µg/L detected in 1997. Maximum 2006 concentrations of perchlorate and nitrate detected in the OU were 30 µg/L and 52 mg/L, respectively. Total VOC concentrations, perchlorate, and nitrate in Tnbs<sub>1</sub>/Tnsc<sub>0</sub> HSU groundwater beneath the Building 854 OU are shown in Figure 2.6-3, 2.6-4, and 2.6-5, respectively, of Dibley et al. (2007).

Pit 6 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 2006 groundwater total VOC concentration was 8.5 µg/L and the maximum 2006 groundwater tritium activity was 1200 pCi/L. Historical maxima for these two contaminants were 290 pCi/L and 3,420 pCi/L, respectively. The maximum 2006 concentrations of perchlorate and nitrate in Pit 6 groundwater were 10 µg/L and 200 mg/L, respectively. The distributions of total VOCs, tritium, perchlorate, and nitrate in Qt-Tnbs<sub>1</sub> HSU groundwater at Pit 6 are shown in Figures 2.3-3 through 2.3-6 of Dibley et al. (2007).

Building 832 Canyon OU 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. Three groundwater extraction and treatment systems (B832-SRC, B830-SRC, and B830-DISS) operate in the OU to remove VOCs, nitrate, and perchlorate. B832-SRC and B830-SRC extract and treat both groundwater and soil vapor. The other facility only treats groundwater. A fourth treatment facility (B832-PRXN) operated in the OU from October 2000 through April 2006. The extraction well for the former facility B830-PRXN facility was connected to B830-SRC before the September 23, 2006, milestone date. The expansion of the B832-SRC groundwater extraction well field to the distal portion of the total VOC plume was also completed prior to this milestone date. There are 17 extraction wells in the OU. VOCs, nitrate, and perchlorate occur

principally in the Qal/WBR, Tnsc<sub>1a</sub>, Tnsc<sub>1b</sub>, and Upper Tnbs<sub>1</sub> HSUs. The maximum 2006 groundwater TVOC concentration of 9600 µg/L was found in the Tnsc<sub>1b</sub> HSU. Maximum 2006 TVOC concentrations of 60 µg/L, 481 µg/L, and 1200 µg/L were detected in the Upper Tnbs<sub>1</sub>, Tnsc<sub>1a</sub> and Qal/WBR HSUs, respectively. Total VOC concentrations during 2006 in groundwater from the four principal HSUs at the Building 832 Canyon OU are shown in Figures 2.7-6 through 2.7-9 of Dibley et al. (2007). Maximum perchlorate and nitrate concentrations detected in 2006 groundwater samples were 18 µg/L and 200 mg/L, respectively. Perchlorate and nitrate concentrations in HSUs at Building 832 are shown on Figures 2.7-10 through 2.7-17 of that document. The *Final Interim Remedial Design Report for the Building 832 Canyon OU* (Madrid et al. 2006) was submitted to the regulatory agencies by the February 23, 2006, milestone date.

The Site 300 Site-Wide OU 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 in Dibley et al. (2007), Section 2.8, and Chapter 3.

#### **8.2.4 Ongoing and Planned Investigations and Cleanup Activities**

The following sections describe the current status of investigations underway at four sites (Pit 7 Complex, Building 865 Study Area, Building 812 Study Area, and Sandia Test Site) that are still under investigation and have not yet reached the Record of Decision for a final remedy to address environmental contamination.

##### **8.2.4.1 Pit 7 Complex**

The Pit 7 Complex comprises 4 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 2006 in the OU was 328,000 pCi/L in the Tnbs<sub>0</sub> HSU. The maximum detected total uranium activity in groundwater that contained some depleted uranium was 110 pCi/L and was detected in a sample from the Qal/WBR HSU. Maximum concentrations of perchlorate, nitrate, and TCE detected in groundwater beneath the Pit 7 Complex in 2006 were 15 µg/L, 71 mg/L, and 4 µg/L, respectively. DOE/LLNL submitted the *Final Proposed Plan for Environmental Cleanup at the Pit 7 Complex Lawrence Livermore National Laboratory Site 300* (U.S. DOE 2006f) by the March 21, 2006, milestone date (see **Table 8-3**). The *Draft Amendment to the Interim Site-Wide Record of Decision for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300* (U.S. DOE 2006a) was also submitted by its milestone date of July 10, 2006. These two documents describe the contaminant hydrogeology at Pit 7 and the preferred alternative selected by the regulatory agencies and DOE. As discussed in these documents, DOE/LLNL will install a drainage

diversion system to prevent groundwater from entering the landfills and a treatment facility (PIT7-SRC) to remove uranium, nitrate, perchlorate, and VOCs from extracted groundwater.

#### **8.2.4.2 Building 865 Study Area**

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 2006 was 290 µg/L. Freon-11 has also been detected in Building 865 groundwater at a maximum 2006 concentration of 1.5 µg/L. These values are below the federal and state MCLs for Freon-113 and Freon-11 in drinking water of 1200 and 5 µg/L, respectively. During 2006, DOE/LLNL submitted the *Characterization Summary Report for the Building 865 Study Area* (Ferry and Holtzapple 2006) to the regulatory agencies by the due date (see **Table 8-3**). This report details the hydrogeology and nature and extent of contamination emanating from Building 865. In addition to Freon-113 and Freon-11, a maximum of 10 µg/L of PCE and 9.6 µg/L of perchlorate were detected in Building 865 groundwater in 2006.

#### **8.2.4.3 Building 812 Study Area**

Building 812 is an explosives test firing table that is still active. During 2006, a maximum detected groundwater activity of total uranium, in which some of the uranium was due to addition of depleted uranium, was 65 pCi/L. Other chemicals detected in groundwater in excess of regulatory guidelines include perchlorate, total VOCs, and nitrate at maximum 2006 concentrations of 11 µg/L, 52.6 µg/L, and 74 mg/L, respectively. In *Characterization Summary Report for Building 812*, Ferry and Holtzapple (2005a) identified a plume of depleted uranium in groundwater and surface soil containing uranium isotopes in excess of Preliminary Remediation Guidelines (PRGs). A treatability study of pumping and treating Building 812 groundwater containing depleted uranium and other chemicals will begin in 2007.

#### **8.2.4.4 Sandia Test Site**

The Sandia Test Site was used in the past for several open air explosives experiments. Anthropogenic contamination has not been observed in samples of water, soil, or rock collected from the Sandia Test Site (Ferry and Holtzapple 2005b).

### **8.2.5 Environmental Impacts**

LLNL strives to reduce elevated 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 are then negotiated by DOE and the regulatory agencies with public input. The agreed-upon actions are then 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.

All ground-disturbing activities, such as well drilling, constructing treatment systems, excavating and constructing drainage structures, and sampling groundwater are planned and conducted to minimize disturbance of animal and plant habitat. A biologist inspects all sites and makes recommendations that are incorporated into the plan for each activity. Erosion controls and other recommendations made by surface water hydrologists are also incorporated into the plans for ground-disturbing activities.

**Jennifer Larson**  
Gene Kumamoto  
Donald H. MacQueen

- 9.1 Quality assurance activities
- 9.2 Analytical laboratories and laboratory intercomparison studies
- 9.3 Duplicate analyses
- 9.4 Data presentation
  - 9.4.1 Radiological data
  - 9.4.2 Nonradiological data
- 9.5 Statistical comparisons and summary statistics
- 9.6 Reporting uncertainty in data tables
- 9.7 Quality assurance process for the environmental report
- 9.8 Errata



**Q**uality 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 2006 in accordance with the *Environmental Protection Department Quality Assurance Management Plan, Revision 6* (LLNL 2006a), which is based on the U.S. Department of Energy (DOE) Order 414.1C. This order sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that ensure quality in DOE programs using a risk-based, graded approach to QA. The 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 B**). 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. Commercial laboratories are also required to perform analysis in accordance with DOE's *Quality Systems for Analytical Services* (U.S. DOE 2006h), which is based on quality requirements from the National Environmental Laboratory Accreditation Program and on the ISO 17025 standard. 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.

---

## 9.1 Quality Assurance Activities

Nonconformance reporting and tracking is a formal process used to ensure that problems are identified, resolved, and prevented from recurring. The LLNL Environmental Protection Department (EPD) 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 EPD operations or that cast doubt on the quality of EPD reports, integrity of samples, or data *and* that are not covered by other reporting or tracking mechanisms. 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 as they arise. Many of the documented problems concern minor documentation errors and are corrected soon after they are identified. Other problems, such as missed holding times, late analytical results, and typographical errors on data reports, account for the remaining issues. These problems are corrected by reissuing reports or correcting paperwork and do not affect associated sample results.

LLNL participates in the DOE Consolidated Auditing Program (DOECAP). Annual, on-site visits to commercial laboratories under contract to LLNL are part of the auditing program to ensure that accurate and defensible data are generated. All commercial laboratories are approved for use as DOE-qualified vendors.

QA staff also track planned environmental monitoring samples that are not collected. The sampling protocol calls for samples to be collected in field containers that may have multiple tests performed on the contents. In turn, each test may produce results with multiple analytes. Sample completeness represents the number of tests performed. **Table 9-1** is a summary of sample completeness.

**Table 9-1.** Sampling completeness in 2006 for the Livermore site and Site 300.

Medium	Location	Parameter	No. samples planned / No. completed	Percentage completed	Reason for lost samples (no. lost samples)
Air particulate	Livermore site	Radiological	1064 / 1057	99%	Unit off (4); no access (3)
	Livermore site	Beryllium	72 / 72	100%	
	Site 300	Radiological	600 / 580	97%	No access (12); no power (8)
	Site 300	Beryllium	48 / 48	100%	
Air	Livermore site and vicinity	Tritium	448 / 440	98%	No/insufficient flow (8)
	Site 300	Tritium	26 / 26	100%	
Soil and sediment	Livermore site	Radiological	32 / 32	100%	
	Site 300	Radiological	28 / 28	100%	
Arroyo sediment	Livermore site	Radiological	25 / 25	100%	
Vegetation and foodstuffs	Livermore site and vicinity	Radiological	48 / 48	100%	
	Site 300	Radiological	16 / 16	100%	
	Wine (produced in Livermore and France)	Radiological	10 / 10	100%	
Air (TLDs)	Livermore site perimeter	Radiological	56 / 56	100%	
	Livermore Valley	Radiological	88 / 84	95%	Missing (4)
	Site 300	Radiological	52 / 46	88%	Missing (2); no access (4)
Rain	Livermore site	Radiological and chemical	43 / 42	98%	Missing (1)
	Site 300	Radiological and chemical	6 / 6	100%	
Storm water runoff	Livermore site	Radiological and chemical	385 / 385	100%	
	Site 300	Radiological and chemical	230 / 174	76%	No flow at location (56)
Water	Livermore site, Lake Haussmann	Lake level	95 / 95	100%	
		Field measurements	64 / 64	100%	
Wastewater	Livermore site, Building 196	Radiological and metals	950 / 946	99%	Unit malfunction (4)
	Livermore site, C196 (area around Building 196)	Radiological and chemical	283 / 238	100%	
	Livermore site, LWRP effluent	Radiological	48 / 48	100%	
	Livermore site, digester sludge	Radiological and metals	80 / 80	100%	
Sewage ponds wastewater	Site 300, Permit WDR 96-248	Chemical	31 / 30	99.5%	Cancelled (1)
Other surface water	Livermore Valley	Radiological	36 / 36	100%	
Water	Site 300, cooling towers	Chemical	6 / 6	100%	

---

## 9.2 Analytical Laboratories and Laboratory Intercomparison Studies

In 2006, LLNL had Blanket Service Agreements (BSAs) with eight commercial analytical laboratories and used two on-site analytical laboratories. All analytical laboratory services used by LLNL are provided by facilities certified by the State of California. LLNL works closely with these analytical laboratories to minimize problems and ensure that QA objectives are maintained.

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

In 2006, two LLNL laboratories participated in the DOE-sponsored Mixed Analyte Performance Evaluation Program (MAPEP). The participating laboratories were the Environmental Monitoring Radiological Laboratory (EMRL) and the Hazards Control Department's Analytical Laboratory (HCAL).

For EMRL, 54 of the 55 reported results were determined to be acceptable, one was acceptable with warning, and none were unacceptable (based on MAPEP-established control limits). See **Table 9-2**. For HCAL, four out of the five results fell within the acceptance control limits and one result fell within the warning limit. See **Table 9-3**.

HCAL also participated in two Environmental Resource Associates (ERA) performance evaluation studies in 2006. See **Table 9-4**. Fourteen of the 15 analytes fell within acceptable limits with one analyte (aluminum) falling outside the acceptable range (Study WP-121). A subsequent aluminum sample was analyzed (Study WP-138), and the reported value was 1030 micrograms per liter ( $\mu\text{g}/\text{L}$ ) for an assigned value of 975, well within the  $2\sigma$  control limit established by ERA for EPA Method 200.7.

Although laboratories with BSAs are also required to participate in laboratory intercomparison programs, permission to publish their results for comparison purposes was not granted for 2006. To obtain MAPEP reports that include the results from all participating laboratories, see <http://www.inl.gov/resl/mapep/reports.html>.

**Table 9-2.** EMRL performance in the MAPEP Intercomparison Program Studies for 2006.

Medium	Study	Analyte	Result	Reference value	Flag <sup>(a)</sup>	Acceptance range <sup>(b)</sup>	Uncertainty value	
Air filter (Bq/sample)	MAPEP-06-GrF15	Gross alpha	0.210	0.361	A	>0.000 – 0.722	0.00118	
		Gross beta	0.382	0.8481	A	0.241 – 0.722	0.00213	
	MAPEP-06-RdF15	Uranium-238	1.52	1.69	A	(c)	0.00358	
		Cesium-134	2.66	2.934	A	2.054 – 3.814	0.165	
		Cesium-137	2.43	2.531	A	1.772 – 3.290	0.196	
		Cobalt-57	4.21	4.096	A	2.867 – 5.325	0.242	
		Cobalt-60	2.19	2.186	A	1.530 – 2.842	0.183	
		Plutonium-238	0.0740	0.067	A	0.047-0.087	0.0129	
		Plutonium-239/240	0.000427	0.00041	A	(c)	0.000379	
		Zinc-65	3.46	3.423	A	3.03 – 5.63	0.790	
	MAPEP-06-GrF16	Gross alpha	0.0619	0.290	A	>0.0 – 0.580	0.00341	
		Gross beta	0.268	0.359	A	0.180 – 0.538	0.00853	
	MAPEP-06-RdF16	Cesium-134	2.75	3.147	A	2.20 – 4.09	0.170	
		Cesium-137	1.74	1.805	A	1.26 – 2.35	0.263	
		Cobalt-57	2.78	2.582	A	1.81 – 3.36	0.275	
		Cobalt-60	1.58	1.577	A	1.10 – 2.05	0.184	
		Manganese-54	1.97	1.92	A	1.34 – 2.50	0.311	
		Plutonium-238	0.138	0.118	A	0.08 – 0.15	0.0239	
		Plutonium-239/240	$6.63 \times 10^{-4}$	None	A	(c)	$5.20 \times 10^{-4}$	
	Aqueous (Bq/L)	MAPEP-06-MaW15	Cesium-134	88.7	95.10	A	66.57 – 123.63	7.15
			Cobalt-57	170	166.12	A	116.28 – 215.96	11.6
			Cobalt-60	148	153.50	A	107.45 – 199.55	7.86
			Hydrogen-3	923	952.01	A	666.41 – 1237.61	12.0
Manganese-54			317	315.00	A	220.50 – 409.50	24.4	
Plutonium-238			0.957	0.91	A	0.64 – 1.18	0.164	
Plutonium-239/240			0.00296	0.0071	A	(c)	0.00282	
Zinc-65			229	228.16	A	159.71 – 296.61	16.6	
MAPEP-06-GrW15		Gross alpha	0.241	0.581	A	>0.0 – 1.162	0.00608	
		Gross beta	1.09	1.13	A	0.56 – 1.70	0.0213	
MAPEP-06-MaW16		Cesium-134	105	112.82	A	78.97 – 146.66	5.22	
		Cesium-137	195	196.14	A	137.30 – 254.98	15.0	
		Cobalt-57	238	213.08	A	149.16 – 277.00	26.9	
		Cobalt-60	46.5	47.5	A	33.2 – 61.8	3.44	
		Hydrogen-3	442	428.85	A	300.20 – 557.50	13.2	
		Plutonium-238	1.33	1.39	A	0.97 – 1.81	0.226	
		Plutonium-239/240	1.84	1.94	A	1.36 – 2.52	0.308	

**Table 9-2 (cont.).** EMRL performance in the MAPEP Intercomparison Program Studies for 2006.

Medium	Study	Analyte	Result	Reference value	Flag <sup>(a)</sup>	Acceptance range <sup>(b)</sup>	Uncertainty value
		Zinc-65	189	176.37	A	123.46 – 229.28	38.5
	MAPEP-06-GrW16	Gross alpha	0.878	1.033	A	>0.0 – 2.066	0.0225
		Gross beta	1.06	1.03	A	0.52 – 1.54	0.0477
Soil (Bq/kg)	MAPEP-06-MaS15	Cesium-137	343	339.69	A	237.78 – 441.60	29.5
		Cobalt-57	643	656.29	A	459.40 – 853.18	37.0
		Cobalt-57	643	656.29	A	459.40 – 853.18	37.0
		Manganese-54	340	346.77	A	242.74 – 450.80	25.8
		Plutonium-238	62.1	61.15	A	42.80 – 79.50	10.2
		Potassium-40	585	604	A	423 – 785	88.3
		Zinc-65	663	657.36	A	460.15 – 854.57	52
	MAPEP-06-MaS16	Cesium-134	403	452.13	A	316.49 – 587.77	22.2
		Cesium-137	505	525.73	A	368.01 – 683.45	33.8
		Cobalt-57	721	676.33	A	473.43 – 879.23	60.3
		Manganese-54	593	594.25	A	415.98 – 772.52	61.7
		Plutonium-238	82.6	82	A	57 – 107	13.6
		Plutonium-239/240	0.331	0.93	A	(c)	0.193
		Potassium-40	584	604	A	423 – 785	80.5
		Zinc-65	956	903.61	A	632.53 – 1174.69	158

(a) Gross alpha flags:

A = Result acceptable. Bias  $\leq \pm 100\%$  with a statistically positive result at two standard deviations.

N = Result not acceptable. Bias  $> \pm 100\%$  or the reported result is not statistically positive at two standard deviations.

Gross beta flags:

A = Result acceptable. Bias  $\leq \pm 50\%$  with a statistically positive result at two standard deviations.

N = Result not acceptable. Bias  $> \pm 50\%$  or the reported result is not statistically positive at two standard deviations.

All other flags:

A = Result acceptable. Bias  $\leq 20\%$ .

W = Result acceptable with warning. Bias  $> 20\%$  and bias  $\leq 30\%$ .

N = Result not acceptable. Bias  $> 30\%$ .

(b) Significant figures shown are those of the MAPEP.

(c) Acceptance range not provided for this analysis.

**Table 9-3.** HCAL performance in the MAPEP Intercomparison Program Studies for 2006.

Medium	Study	Analyte	Result	Reference value	Flag <sup>(a)</sup>	Acceptance range	Uncertainty value
Air filter (Bq/sample)	MAPEP-06-GrF16	Gross alpha	0.125	0.290	A	>0.0 – 0.580	0.021
		Gross beta	0.49	0.359	A	0.180 – 0.538	0.04
Aqueous (Bq/L)	MAPEP-06-GrW16	Gross alpha	1.11	1.033	A	>0.0 – 2.066	0.134
		Gross beta	1.95	1.03	N	0.52 – 1.54	0.13
	MAPEP-06-MaW16	Hydrogen-3	543	428.85	W	300.20 – 557.50	29

(a) Gross alpha flags:

A = Result acceptable. Bias  $\leq \pm 100\%$  with a statistically positive result at two standard deviations.

N = Result not acceptable. Bias  $> \pm 100\%$  or the reported result is not statistically positive at two standard deviations.

Gross beta flags:

A = Result acceptable. Bias  $\leq \pm 50\%$  with a statistically positive result at two standard deviations.

N = Result not acceptable. Bias  $> \pm 50\%$  or the reported result is not statistically positive at two standard deviations.

All other flags:

A = Result acceptable. Bias  $\leq 20\%$ .

W = Result acceptable with warning. Bias  $> 20\%$  and bias  $\leq 30\%$ .

N = Result not acceptable. Bias  $> 30\%$ .

**Table 9-4.** HCAL performance in the ERA Intercomparison Program Studies for 2006.

Type of analysis	Study	Analyte	Reported value	ERA assigned value	Control limits	Warning limits	Performance evaluation
Radiological (pCi/L)	RAD-66	Gross alpha	11.8	9.96	1.30 – 18.6	4.19 – 15.7	Acceptable
		Gross beta	8.27	8.85	0.190 – 17.5	3.08 – 14.6	Acceptable
		Tritium	3800	4050	3350 – 4750	3580 – 4520	Acceptable
Nonradiological ( $\mu\text{g/L}$ )	WP-121	Aluminum	427	300	219 – 385	246 – 357	Not acceptable
		Arsenic	832	837	704 – 978	750 – 933	Acceptable
		Beryllium	693	726	618 – 820	652 – 786	Acceptable
		Cadmium	568	581	496 – 660	523 – 632	Acceptable
		Chromium	689	663	578 – 750	606 – 721	Acceptable
		Copper	690	703	633 – 773	661 – 749	Acceptable
		Iron	853	849	749 – 960	785 – 925	Acceptable
		Lead	730	760	665 – 852	696 – 821	Acceptable
		Mercury	27	26.4	16.2 – 35.6	19.5 – 32.3	Acceptable
		Nickel	973	962	866 – 1070	904 – 1040	Acceptable
Silver	105	106	90.4 – 122	95.6 – 116	Acceptable		
Zinc	1160	1120	963 – 1280	1020 – 1230	Acceptable		

### 9.3 Duplicate Analyses

Duplicate (collocated) samples are distinct samples of the same matrix collected as close to the same point in space and time as possible. Collocated samples that are processed and analyzed by the same laboratory provide intralaboratory information about the precision of the entire measurement system, including sample acquisition, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples that are processed and analyzed by different laboratories provide interlaboratory information about the precision of the entire measurement system (U.S. EPA 1987). Collocated samples may also 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 **Section 9.4**). **Table 9-7** is based on data pairs in which either or both values are nondetections.

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, 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.

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. Routine and collocated sample results show good %RSD—90% of the pairs have %RSD of 39% or better; 75% have %RSD of 19% or better.

Regression analysis consists of fitting a straight line to the collocated sample pairs. Good agreement is indicated when the data lie close to a line with a slope equal to 1 and an intercept equal to 0, as illustrated in **Figure 9-1**. Allowing for normal analytical 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.

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

**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.

Medium	Analyte	N <sup>(a)</sup>	%RSD <sup>(b)</sup>	Slope	r <sup>2(c)</sup>	Intercept
Air	Gross alpha <sup>(d)</sup>	37	70.7%	0.261	0.07	1.48 × 10 <sup>-5</sup> (Bq/m <sup>3</sup> )
	Gross beta	95	20.4%	0.847	0.88	3.19 × 10 <sup>-5</sup> (Bq/m <sup>3</sup> )
	Beryllium	12	7.39%	1.03	0.96	0.0839 (pg/m <sup>3</sup> )
	Uranium-235 <sup>(e)</sup>	12	18.5%	1.13	0.1	1.09 × 10 <sup>-5</sup> (µg/m <sup>3</sup> )
	Uranium-238 <sup>(e)</sup>	12	23.8%	0.561	0.08	5.69 × 10 <sup>-5</sup> (µg/m <sup>3</sup> )
	Uranium-235/ uranium-238 (ratio) <sup>(d)</sup>	12	4.89%	0.772	0.69	0.000971 (ratio)
	Tritium <sup>(e)</sup>	24	30.5%	0.59	0.98	0.11 (Bq/m <sup>3</sup> )
Dose (TLD)	90-day radiological dose	30	3.61%	0.983	0.84	0.345 (mrem)
Groundwater	Gross beta <sup>(d)</sup>	43	18.6%	0.963	0.75	0.019 (Bq/L)
	Arsenic	24	7.62%	1	1	-0.000188 (mg/L)
	Barium	21	3.63%	1	0.96	0.00217 (mg/L)
	Nitrate (as NO <sub>3</sub> )	19	2.53%	1	1	-0.187 (mg/L)
	Potassium <sup>(e)</sup>	22	43.5%	0.788	0.29	6.04 (mg/L)
	Tritium	11	6.42%	0.978	1	2.98 (Bq/L)
	Uranium-234+ uranium-233 <sup>(e)</sup>	16	7.89%	0.555	0.53	0.0332 (Bq/L)
	Uranium-235 <sup>(e)</sup>	15	27.7%	0.479	0.34	0.00195 (Bq/L)
	Uranium-238 <sup>(e)</sup>	16	6.07%	0.557	0.48	0.0244 (Bq/L)
	Vanadium	12	2.92%	1.02	1	-0.00186 (mg/L)
Sewer	Gross beta <sup>(d)</sup>	52	15.7%	0.826	0.5	0.000127 (Bq/mL)
	Tritium	15	2.9%	1.02	1	-0.00344 (Bq/mL)

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

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

(c) Coefficient of determination.

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

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

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.

Data sets that do not meet LLNL regression analysis criteria fall into one of two categories—outliers and high variability. Outliers can occur because of data transcription errors, measurement errors, or real but anomalous results. Of the 20 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.

**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.

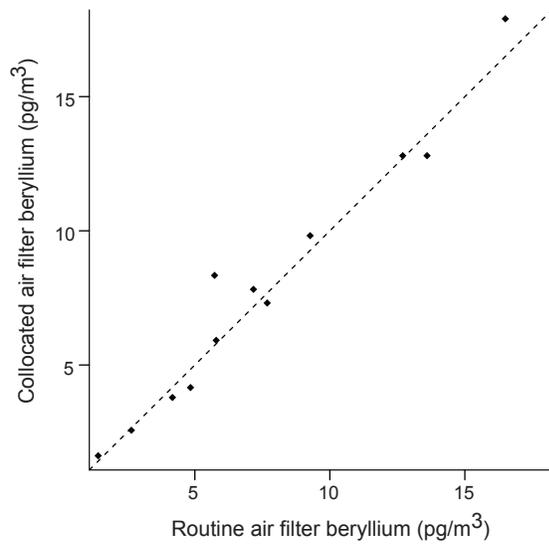
Media	Analyte	N <sup>(a)</sup>	Mean ratio	Minimum ratio	Maximum ratio
Drinking water	Gross beta	1	1.2	1.2	1.2
Groundwater	Gross alpha	4	1.2	0.96	1.2
	Radium 226	2	1.1	0.92	1.2
Runoff (from rain)	Gross alpha	2	1.2	1	1.3
	Gross beta	5	1.3	0.52	2.8
	Uranium-233+234	2	0.86	0.82	0.9
	Uranium-235+236	1	0.68	0.68	0.68
	Uranium-238	2	0.95	0.82	1.1
	Uranium-238 by mass measurement	1	0.79	0.79	0.79
Soil	Gross alpha	1	0.93	0.93	0.93
	Gross beta	1	1	1	1
	Cesium-137	3	0.9	0.62	1.1
	Tritium	1	4.8	4.8	4.8
	Tritium	1	3.1	3.1	3.1
	Potassium-40	4	0.97	0.94	1
	Plutonium-238	2	0.91	0.69	1.1
	Plutonium-239+240	3	0.88	0.73	1
	Radium-226	4	0.97	0.93	1
	Radium-228	4	0.96	0.92	1
	Thorium-228	4	0.94	0.86	0.99
	Uranium-235	4	0.95	0.74	1.1
	Uranium-238	4	0.94	0.78	1.1
Vegetation	Tritium	6	1.9	0.71	5.9

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

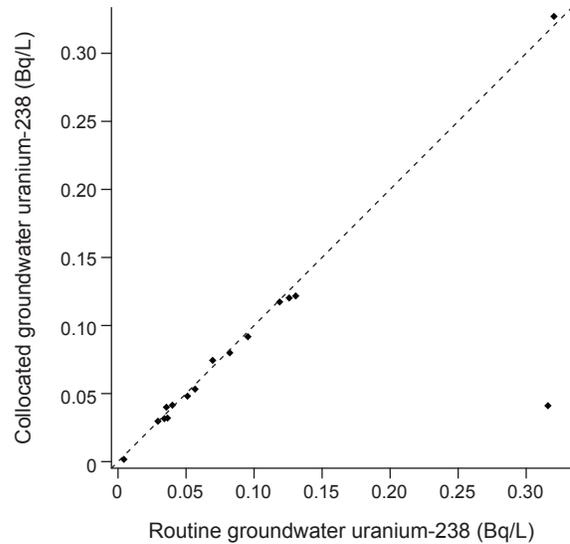
**Table 9-7.** Quality assurance collocated sampling. Summary statistics for analytes with at least four pairs in which one or both results were below the detection limit.

Medium	Analyte	No. inconsistent pairs <sup>(a)</sup>	No. pairs
Groundwater	Arsenic	1	18
Groundwater	Tritium	1	27
Sewer	Toluene	1	5
Sewer	Tritium	1	37

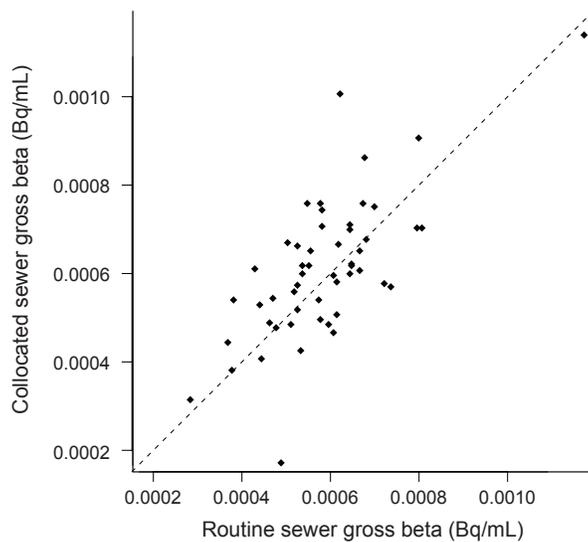
(a) Inconsistent pairs are those for which one of the results is more than twice the reporting limit of the other.



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



**Figure 9-2.** Example of data with an outlier using collocated groundwater uranium-238 concentrations.



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

The second category, high variability, tends to occur at extremely low concentrations (see **Figure 9-3** for an example). Low concentrations of radionuclides on particulates in air highlight this effect because a small number of radionuclide-containing particles on an air filter can significantly affect results. 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 20 data sets listed in **Table 9-5**, four show sufficient variability in the results to make them fall outside the acceptable range.

---

## 9.4 Data Presentation

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

### 9.4.1 Radiological Data

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

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

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

### 9.4.2 Nonradiological Data

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

---

## 9.5 Statistical Comparisons and Summary Statistics

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

Summary statistics are calculated according to 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 data tables may present other measures at the discretion of the analyst.

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

Summary statistics are calculated from values that, if necessary, have already been rounded, such as when units have been converted from picocuries (pCi) to becquerels (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, the middle value is reported as the median. Otherwise, the median is assigned a less-than (<) sign.

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

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

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

---

## 9.6 Reporting Uncertainty in Data Tables

The measurement uncertainties associated with results from analytical laboratories are represented in two ways. The first of these, significant digits, relates to the resolution of the

measuring device. For example, if an ordinary household ruler with a metric scale is used to measure the length of an object in centimeters (cm), and the ruler has tick marks every one-tenth of a centimeter, the length can reliably and consistently be measured to the nearest tenth of a centimeter (i.e., to the nearest tick mark). An attempt to be more precise is not likely to yield reliable or reproducible results because it would require a visual estimate of a distance between tick marks. The appropriate way to report a measurement using this ruler would be, for example, 2.1 cm, which would indicate that the “true” length of the object is nearer to 2.1 cm than to 2.0 cm or 2.2 cm (i.e., between 2.05 and 2.15 cm). A measurement of 2.1 cm has two significant digits. Although not stated, the uncertainty is considered to be  $\pm 0.05$  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  $\pm 0.005$  cm. A result reported as “3.0 cm” has two significant digits. That is, the trailing zero is significant and implies that the true length is between 2.95 and 3.05 cm—closer to 3.0 than to 2.9 or 3.1 cm.

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

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

The other method of representing uncertainty is based on random variation. For radiological measurements, there is variation due to the random nature of radioactive decay. As a sample is measured, the number of radioactive decay events is counted and the reported result is calculated from the number of decay events that were observed. If the sample is recounted, the number of decay events will almost always be different because radioactive decay events occur randomly. Uncertainties of this type are reported in this volume as  $2\sigma$  uncertainties. A  $2\sigma$  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, “ $2.6 \pm 1.2$  Bq/gram (g),” would indicate that with approximately 95% confidence, the “true” value is in the range of 1.4 to 3.8 Bq/g (i.e.,  $2.6 - 1.2 = 1.4$  and  $2.6 + 1.2 = 3.8$ ).

The concept of significant digits applies to both the radiological result and its uncertainty. So, for example, in a result reported as “ $2.6 \pm 1.2$ ,” both the measurement and its uncertainty have the same number of significant digits, that is, two. When expanding an interval reported in the “ $\pm$ ” form, for example “ $2.4 \pm 0.44$ ,” 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 “ $2.4 \pm 0.44$  Bq/g” would represent an interval of 2.0 to 2.8 Bq/g.

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

---

## 9.7 Quality Assurance Process for the Environmental Report

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

Analytical laboratories send reports electronically, which are loaded directly into the database. This practice should result in perfect agreement between the database and data in printed reports from the laboratories. In practice, however, laboratory reporting is not perfect, so the Data Management Team (DMT) carefully checks all incoming data throughout the year to make sure that electronic and printed reports from the laboratories agree. While not formally part of the QA process for the preparation of this environmental report, this aspect of QC is essential to the report’s accuracy. Because of this ongoing QC of incoming data, data stored in the database and used to prepare the annual environmental report tables are unlikely to contain errors.

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

For this 2006 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, and a coordinator kept track of the process. Items that were 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 responsible author, ensured that corrections were made.

---

## **9.8 Errata**

Appendix G contains the protocol for errata in LLNL *Environmental Reports* and the errata for LLNL *Environmental Report 2004* and *Environmental Report 2005*.

## References

- Arnold, R.A. (2002). *Report on the Threatened Valley Elderberry Longhorn Beetle and Its Elderberry Food Plant at the Lawrence Livermore National Laboratory – Site 300*. Pleasant Hill, CA: Entomological Consulting Services, Ltd.
- ATSDR. (2000). *Health Consultation, Lawrence Livermore National Laboratory, Big Trees Park 1998 Sampling, Livermore, California*. Atlanta: Federal Facilities Assessment Branch, Division of Health Assessment and Consultation, Agency for Toxic Substances and Disease Registry. CERCLIS No. CA2890012584.
- ATSDR. (2002). *Health Consultation, Tritium Releases and Potential Offsite Exposure, Lawrence Livermore National Laboratory (U.S. DOE), Livermore, Alameda County, California, EPA Facility ID: CA2890012584; and Lawrence Livermore National Laboratory (U.S. DOE); Tracy, San Joaquin County, California, EPA Facility ID: CA2890090002; and Savannah River Site (U.S. DOE), Aiken, Aiken, Barnwell and Allendale Counties, South Carolina, EPA Facility ID: SC1890008989*. Atlanta: Agency for Toxic Substances Disease Registry.
- ATSDR. (2003). *ATSDR Final Public Health Assessment Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community, Lawrence Livermore National Laboratory, Main Site (USDOE) Livermore, Alameda County, California, EPA Facility ID: CA2890012584*. Atlanta: Agency for Toxic Substances Disease Registry.
- Attix, F.H. and W.C. Roesch, eds. (1968). *Radiation Dosimetry, Second Edition, Volume I, Fundamentals*. New York: Academic Press.
- Avalos, G. (2005). “Vintners toast triumph as Supreme Court uncorks potential for out-of-state sales.” *Contra Costa Times*, May 17.
- Berg, L.L., E.N. Folsom, M.D. Dresen, R.W. Bainer, and A.L. Lamarre, eds. (1997). *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory Livermore Site*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-125927.
- Blake, R.G., C.M. Noyes, and M.P. Maley. (1995). *Hydrostratigraphic Analysis—The Key to Cost-Effective Ground Water Cleanup at Lawrence Livermore National Laboratory*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-JC-120614.
- Brown, R. (2006). *Lawrence Livermore National Laboratory Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ, Annual Report 2005–2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-144362-06.
- Brown, R. (2007). *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-125915-06-4.
- Campbell, C. and D.H. MacQueen. (2007). *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-10191-06-4.
- Campbell, C. and M.J. Taffet. (2007). *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report for 2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-132057-06-4.
- Campbell, C.G. and K. Brunckhorst. (2006). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174, Annual Report 2005–2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126783-06.
- Campbell, C.G. and S. Mathews. (2006). *An Approach to Industrial Stormwater Benchmarks: Establishing and Using Site-Specific Threshold Criteria at Lawrence Livermore National Laboratory*. CASQA Stormwater 2006 Conference, Sacramento, CA, September 25, 2006–September 27, 2006, UCRL-CONF-224278.
- Campbell, C.G., D.W. Rueppel, M. Cockrell, K. Brunckhorst, and C. Foster. (2007). *Lawrence Livermore National Laboratory Livermore Site, Summary of Water and Sediments Monitoring in Lake Haussmann Following Treatment with Rotenone*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-229232.

- Campbell, C.G., K. Folks, S. Mathews, and R. Martinelli. (2004). "Investigating Sources of Toxicity in Stormwater: Algae Mortality in Runoff Upstream of the Lawrence Livermore National Laboratory." *Environmental Practice* 6(1): 23–35. LLNL-UCRL-JC-147164.
- Carlsen, T.M., J.W. Menke, and B.M. Pavlik. (2000). "Reducing Competitive Suppression of a Rare Annual Forb by Restoring Native California Perennial Grasslands." *Restoration Ecology* 8(1): 18–30.
- Carpenter, D.W., J.J. Sweeney, P.W. Kasameyer, N.R. Burkhard, K.G. Knauss, and R.J. Shelmon. (1984). *Geology of the Lawrence Livermore National Laboratory Site and Adjacent Area*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-53316.
- Clark, H.O., D.A. Smith, B.L. Cypher, and P.A. Kelly. (2002). *Mesocarnivore Surveys on Lawrence Livermore National Laboratory Site 300*. California State University, Stanislaus, Endangered Species Recovery Program, Fresno, CA.
- CNPS. (2001). *Inventory of Rare and Endangered Plants of California, Sixth Edition*. Sacramento: Rare Plant Scientific Advisory Committee, D.P. Tibor, Convening Editor, California Native Plant Society.
- CVRWQCB. (1993). *Waste Discharge Requirements for Post-Closure Monitoring Requirements for Two Class I Landfills*. Order No. 93-100.
- CVRWQCB. (1998a). *Monitoring and Reporting Program No. 93-100, Revision 2*.
- CVRWQCB. (1998b). *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, the Sacramento River Basin and the San Joaquin River Basin, Fourth Edition*.
- Dibley, V. and J. Valett. (2006). *Draft Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-220827.
- Dibley, V., J. Valett, and L. Ferry. (2006a). *Final Five-Year Review Report for the General Services Area Operable Unit at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-220827.
- Dibley, V., M. Taffet, J. Valett, M. Denton, S. Gregory, T. Carlsen, W. Daily, Z. Demir, R. Goodrich, and S. Chamberlain. (2006b). *First Semester 2006 Compliance Monitoring Report, Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-206769-06.
- Dibley, V., M. Taffet, J. Valett, M. Denton, S. Gregory, T. Carlsen, Z. Demir, W. Daily, D. Mason, P. McKereghan, R. Goodrich, and S. Chamberlain. (2006c). *2005 Annual Compliance Report for Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-206319-05.
- Dibley, V., M. Taffet, J. Valett, M. Denton, S. Gregory, T. Carlsen, Z. Demir, W. Daily, D. Mason, P. McKereghan, R. Goodrich, and S. Chamberlain. (2007). *2006 Annual Monitoring Compliance Report for Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-206319-06.
- Dobson, J.E., E.A. Bright, P.R. Coleman, R.C. Durfee, B.A. Worley. (2000). *LandScan: A Global Population Database for Estimating Populations at Risk, Photogrammetric Engineering & Remote Sensing*, Vol. 66, No. 7. Accessible at <http://www.ornl.gov/sci/gist/landscan/index.htm>.
- Dresen, M.D., J.P. Ziagos, A.J. Boegel, and E.M. Nichols (eds.). (1993). *Remedial Action Implementation Plan for the LLNL Livermore Site*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-110532.
- DTSC. (2002). *Technical Completeness of Post-Closure Permit Application, Capped High Explosive Open Burn Treatment Facility, Lawrence Livermore National Laboratory, Site 300*. Berkeley: Department of Toxic Substances Control, EPA ID No. CA-2890090002 (letter, October 23).
- DTSC. (2003). *Transmittal of Documents Relating to the Final Post Closure Permit Decision for Lawrence Livermore National Laboratory, Site 300*. Berkeley: Department of Toxic Substances Control, EPA ID No. CA-2890090002 (letter, February 21).
- DTSC. (2005). *Class 1 Modifications to Post-Closure Operation Plan, Building 829, Lawrence Livermore National Laboratory (LLNL), Site 300*. Berkeley: Department of Toxic Substances Control, EPA ID No. CA-2890090002 (letter, July 20).
- Eisenbud, M. (1987). *Environmental Radioactivity from Natural, Industrial, and Military Sources* (third edition). San Diego: Academic Press, Inc.

- Ferry, L. and C. Holtzapple. (2005a). *Characterization Summary Report for the Building 812 Study Area at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory.
- Ferry, L. and C. Holtzapple. (2005b). *Characterization Summary Report for the Sandia Test Site at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory.
- Ferry, L. and C. Holtzapple. (2006). *Characterization Summary Report for the Building 865 Study Area at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory.
- Ferry, L., M. Dresen, Z. Demir, V. Dibley, V. Madrid, M. Taffet, S. Gregory, J. Valett, and M. Denton. (2006a). *Draft Final Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-220391-DRAFT.
- Ferry, L., M. Dresen, Z. Demir, V. Dibley, V. Madrid, M. Taffet, S. Gregory, J. Valett, and M. Denton. (2006b). *Draft Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-220391-DRAFT.
- Ferry, L., M. Dresen, Z. Demir, V. Dibley, V. Madrid, M. Taffet, S. Gregory, J. Valett, and M. Denton. (2006c). *Final Site-Wide Remediation Evaluation Summary Report for Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-220391.
- Ferry, L., R. Ferry, W. Isherwood, R. Woodward, T. Carlsen, Z. Demir, R. Qadir, and M. Dresen. (1999). *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-132609.
- Ferry, L., T. Berry, and D. MacQueen. (1998). *Post-Closure Plan for the Pit 6 Landfill Operable Unit, Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-128638.
- Ferry, R., L. Ferry, M. Dresen, and T. Carlsen. (2002). *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-147570.
- Gallegos, G.M. (1991). *Assessment of Sediment Monitoring at LLNL*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-121236.
- Gallegos, G.M. (1993). "Surveillance Monitoring of Soils for Radioactivity: Lawrence Livermore National Laboratory 1976 to 1992." *Health Physics* 69 (4), 487–493.
- Gallegos, G.M., B.K. Balke, K.A. Surano, W.G. Hoppes, P.J. Tate, J.C. Steenhoven, B.C. Fields, L.M. Garcia, and K.C. Lamson. (1992). *Environmental Report 1991*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-91.
- Gallegos, G.M., D. MacQueen, and K.A. Surano. (1999). *Livermore Big Trees Park: 1998 Summary Results*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-134581.
- Gallegos, G.M., P.J. Tate, B.K. Balke, E. Christofferson, R.J. Harrach, W.G. Hoppes, R.A. Failor, S. Wander, B.C. Fields, L.M. Garcia, and A.R. Grayson. (1994). *Environmental Report 1993*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-93.
- Galles, H.L. (1997). Letter to J. Cho re: Lawrence Livermore National Laboratory Drainage Retention Basin Monitoring Plan Amendment (WGMG97-439, December 9).
- Goodrich, R. and J. Wimborough. (2006). *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-109115 Rev. 12.
- Gouveia, F. and K.R. Chapman. (1989). *Climatology of Lawrence Livermore National Laboratory*. Livermore, CA: Lawrence Livermore National Laboratory, UCID-21686.
- Grayson A., K. Brunckhorst, and C. Foster. (2006). *Lawrence Livermore National Laboratory Livermore Site Semiannual Wastewater Point-Source Monitoring Report December 1, 2005 – May 31, 2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-10204-06-2.

- Grayson A., K. Brunckhorst, and C. Foster. (2007). *Lawrence Livermore National Laboratory Livermore Site Semiannual Wastewater Point-Source Monitoring Report June 1– November 30, 2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-10204-07-1.
- Gudiksen, P.H., C.L. Lindeken, C. Gatrousis, and L.R. Anspaugh. (1972). *Environmental Levels of Radioactivity in the Vicinity of the Lawrence Livermore Laboratory, January through December 1971*. Livermore, CA: Lawrence Livermore Laboratory, UCRL-51242.
- Gudiksen, P.H., C.L. Lindeken, J.W. Meadows, and K.O. Hamby. (1973). *Environmental Levels of Radioactivity in the Vicinity of the Lawrence Livermore Laboratory, 1972 Annual Report*, Livermore, CA: Lawrence Livermore Laboratory, UCRL-51333.
- Harrach, R.J, G.M. Gallegos, S.R. Peterson, K.R. Wilson, P.E. Althouse, J.M. Larson, N.A. Bertoldo, P.J. Tate, and B.M. Bowen. (2004). *LLNL NESHAPs 2003 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-113867-04.
- Harrach, R.J., G.M. Gallegos, P.J. Tate, E. Christofferson, E.R. Brandstetter, J.M. Larson, A.H. Biermann, B.C. Fields, L.M. Garcia, and K.A. Surano. (1997). *Environmental Report 1996*, Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-96. Accessible at <http://www.llnl.gov/saer/>.
- Harrach, R.J., G.M. Gallegos, R.A. Failor, E. Christofferson, P.J. Tate, E.R. Brandstetter, J.M. Larson, J. McIntyre, B.C. Fields, R.A. Brown, L.M. Garcia, and A.R. Grayson. (1995). *Environmental Report 1994*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-94. Accessible at <http://www.llnl.gov/saer/>.
- Harrach, R.J., R.A. Failor, G.M. Gallegos, P.J. Tate, E. Christofferson, E.R. Brandstetter, J.M. Larson, A.H. Biermann, R.A. Brown, B.C. Fields, L.M. Garcia, and A.R. Grayson. (1996). *Environmental Report 1995*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-95. Accessible at <http://www.llnl.gov/saer/>.
- Hoffman, F., R.G. Blake, Z. Demir, R.J. Gelinas, P.F. McKereghan, and C.D. Noyes. (2003). "A Conceptual Model and Remediation Strategy for Volatile Organic Compounds in Unconsolidated Sediments: A Lawrence Livermore National Laboratory Case Study." *Environmental & Engineering Geoscience* 9 (February 2003), no. 1:83–94.
- Holland, R.C., R.W. Buddemeier, and D.D. Brekke. (1987). *Environmental Monitoring at the Lawrence Livermore National Laboratory, 1986 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, Environmental Protection Guidance and Monitoring Series, UCRL-50027-86.
- International Commission on Radiological Protection. (1996). "Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5. Compilation of Ingestion and Inhalation Dose Coefficients." *Annals of the ICRP*, Vol. 26, No. 1, pp. 1–91.
- Isherwood, W.F., C.H. Hall, M.D. Dresen, and A.J. Boegel. (1991). *CERCLA Feasibility Study Report for the LLNL Livermore Site*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-104040.
- Jackson, C.S. (1997). Letter to the San Francisco Bay Regional Water Quality Control Board re: Lawrence Livermore National Laboratory Building 253 catch basin mercury residue. May 23.
- Jackson, C.S. (2002). *Drainage Retention Basin Monitoring Plan Change*, Letter to N. Feger, San Francisco Bay Regional Water Quality Control Board. Livermore, CA: Lawrence Livermore National Laboratory, WGMG02:175: CSJ:RW:kh (December 6).
- Karachewski, J., M. Dresen, E. Folsom, L. Berg, and J. Coty, eds. (2006). *LLNL Ground Water Project 2005 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126020-05.
- Karachewski, J., M. Dresen, L. Berg, E. Folsom, and J. Coty, eds. (2007). *LLNL Ground Water Project 2006 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-126020-06.
- Lamarre, A.L., and M.J. Taffet. (1989). *Firing Table Gravel Cleanup at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCAR-10282.
- Larson, J.M., S.R. Peterson, and K.R. Wilson. (2007). *LLNL NESHAPs 2006 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-TR-113867-07.

- LLNL. (1998). *Livermore Big Trees Park 1998 Sampling Plan*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-130551.
- LLNL. (2001). *Revisions to the Post-Closure Permit Application for the Building 829 HE Open Burn Treatment Facility—Volume 1* (Revised, December 2001). Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-139697-01.
- LLNL. (2002). Personal communication with J. Woollett and M. van Hattem, wildlife biologists, Lawrence Livermore National Laboratory, Livermore, CA.
- LLNL. (2003). *LLNL Avian Monitoring Program Variable Circular Plot Point Count and Constant Effort Mist Netting*. Livermore, CA: Lawrence Livermore National Laboratory.
- LLNL. (2005). *Integrated Safety Management System Description, Version 8*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-132791. Accessible at [http://www.llnl.gov/es\\_and\\_h/ism/ism-descriptionv8.pdf](http://www.llnl.gov/es_and_h/ism/ism-descriptionv8.pdf).
- LLNL. (2006a). *Environmental Protection Department Quality Assurance Management Plan (Revision 6)*. Livermore, CA: Lawrence Livermore National Laboratory.
- LLNL. (2006b). *Radioactive Waste Management Basis for the Lawrence Livermore National Laboratory, Revision 1*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-220455.
- MacQueen, D.H. (1995). *Livermore Big Trees Park January 1995 Soil Survey Results*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-121045.
- MacQueen, D.H., G. Gallegos, K.A. Surano. (2002). *Livermore Big Trees Park: 1998 Results*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-143311.
- Madrid, V., J. Valett, M. Denton, Z. Demir, B. Daily, and V. Dibley. (2006). *Interim Remedial Design Document for the Building 832 Operable Unit Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-214990.
- Mathews, S. (2006). *Water Suppliers' Pollution Prevention and Monitoring and Reporting Program*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-139704-Rev 1.
- Mathews, S., and M. Taffet. (1997). *Final Closure Plan for the High-Explosives Open Burn Facility at Lawrence Livermore National Laboratory Experimental Test Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-ID-111753 Rev. 1.
- Myers, D.S., W.J. Silver, D.G. Coles, K.C. Lamson, D.R. McIntyre, and B. Mendoza. (1976). "Evaluation of the Use of Sludge Containing Plutonium as a Soil Conditioner for Food Crops." *Transuranium Nuclides in the Environment*, International Atomic Energy Agency, IAEA-SM-199/42.
- NCRP. (1987a). *Ionizing Radiation Exposure of the Population of the United States*. Washington, DC: National Council on Radiation Protection and Measurements, Report No. 93.
- NCRP. (1987b). *Recommendations on Limits of Exposure to Ionizing Radiation*. Washington, DC: National Council on Radiation Protection and Measurements, Report No. 91.
- NCRP. (1999). *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies*. Bethesda, MD: National Council on Radiation Protection and Measurements, NCRP Report No. 129.
- Orloff, S. (1986). *Wildlife Studies of Site 300 Emphasizing Rare and Endangered Species: Lawrence Livermore National Laboratory, San Joaquin County, California*. Sausalito, CA: BioSystems Analysis, Inc.
- Parks, B.S. (1992). *User's Guide for CAP88-PC, Version 1*. Las Vegas: U.S. Environmental Protection Agency, Office of Radiation Programs, EPA 402-B-92-001.
- Paterson, L., E. Espeland, T. Carlsen, and T. Alfaro. (2007, in press). *Rare Plant Restoration and Monitoring at Lawrence Livermore National Laboratory, Site 300, Project Progress Report, Fiscal Years 2003 & 2004, October 2004 – October 2006*. Livermore, CA: Lawrence Livermore National Laboratory.
- Peterson, S-R., and P.A. Davis. (2002). "Tritium Doses from Chronic Atmospheric Releases: A New Model Proposed for Regulatory Compliance." *Health Physics*. UCRL-JC-141535.

- Preston, R.E. (1997). *Delineation of Waters of the United States for Arroyo Las Positas, Lawrence Livermore National Laboratory, Alameda County, California*. Sacramento: Jones & Stokes.
- Preston, R.E. (2002). *Special-status Plant Species Surveys and Vegetation Mapping at Lawrence Livermore National Laboratory*. Sacramento: Jones & Stokes.
- Raber, E. and D.W. Carpenter, eds. (1983). *An Evaluation of the Hydrogeology and Groundwater Chemistry Associated with Landfills at LLNL's Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-53416.
- Rainey, B. (2003). Personal communication to L. Paterson, Environmental Protection Department, Lawrence Livermore National Laboratory, July.
- Rauhut, K. (2006). Memo to S. Goodwin, Department Head, Environmental Protection Department, Lawrence Livermore National Laboratory, regarding the status of Lake Haussmann as not a "water of the U.S." Lawrence Livermore National Laboratory Office of Legal Counsel, August 8.
- Revelli, M.A. (2007a). *Groundwater Discharge Annual Self-Monitoring Report for 2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-143911-06.
- Revelli, M.A. (2007b). *Lawrence Livermore National Laboratory Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2006*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-143121-06.
- Rogers/Pacific Corporation. (1990). *Lawrence Livermore National Laboratory Site 300 Resource Conservation and Recovery Act Closure and Post-Closure Plans—Landfill Pits 1 and 7, Vols. I and II*. Van Nuys, CA, EPA No. CA2890090002.
- Rueth, L., R.A. Ferry, L.K. Green-Horner, and T.H. De Lorenzo. (1998). *Remedial Design for General Services Area Operable Unit Treatment Facilities*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-127465.
- Sanchez, L. (2003). *LLNL Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ Annual Report 2002–2003*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-144362-03.
- Sanchez, L., P.E. Althouse, N.A. Bertoldo, R.G. Blake, S.L. Brigdon, R.A. Brown, C.G. Campbell, T. Carlson, E. Christofferson, L.M. Clark, G.M. Gallegos, A.R. Grayson, R.J. Harrach, W.G. Hoppes, H.E. Jones, J. Larson, D. Laycak, D.H. MacQueen, S. Mathews, M. Nelson, L. Paterson, S.R. Peterson, M.A. Revelli, M.J. Taffet, P.J. Tate, R. Ward, R.A. Williams, and K. Wilson. (2003). *Environmental Report 2002*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-02.
- SFBRWQCB. (1995a). *Waste Discharge Requirements and National Pollutant Discharge Elimination System (NPDES) Storm Water Permit for: U.S. Department of Energy and Lawrence Livermore National Laboratory*. Oakland: San Francisco Bay Regional Water Quality Control Board, Order No. 95-174, NPDES No. CA030023.
- SFBRWQCB. (1995b). *Water Quality Control Plan, San Francisco Bay Basin, State of California*. Oakland: San Francisco Bay Regional Water Quality Control Board.
- SFBRWQCB. (2006). *Water Quality Control Plan (Basin Plan) for the San Francisco Bay Basin*. Accessible at <http://www.swrcb.ca.gov/rwqcb2/basinplan.htm#2004basinplan>.
- Silver, W.J., C.L. Lindeken, J.W. Meadows, W.H. Hutchin, and D.R. McIntyre. (1974). *Environmental Levels of Radioactivity in the Vicinity of the Lawrence Livermore Laboratory, 1973 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-51547.
- Silver, W.J., C.L. Lindeken, J.W. Meadows, W.H. Hutchin, and D.R. McIntyre. (1975). *Environmental Monitoring at the Lawrence Livermore Laboratory, 1974 Annual Report*. Livermore, CA: Lawrence Livermore Laboratory, UCRL-50027-74.
- Silver, W.J., C.L. Lindeken, K.M. Wong, E.H. Willes, and J.H. White. (1978). *Environmental Monitoring at the Lawrence Livermore Laboratory, 1977 Annual Report*. Livermore, CA: Lawrence Livermore Laboratory, UCRL-50027-77.
- Stone, R. and M.R. Ruggieri. (1983). *Groundwater Quality and Movement at Lawrence Livermore National Laboratory*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-53474.
- Swaim, K. (2002). *Results of Surveys for Special Status Reptiles at the Site 300 Facilities of Lawrence Livermore National Laboratory*. Livermore, CA: Swaim Biological Consulting.

- SWRCB. (1997). *Waste Discharge Requirements and National Pollutant Discharge Elimination System (NPDES) Discharges of Storm Water Associated with Industrial Activities Excluding Construction Activities*. Sacramento: State Water Resources Control Board, Order No. 97-03-DWQ, General Permit No. CAS000001.
- SWRCB. (1999). *Waste Discharge Requirements for Discharges of Storm Water Runoff Associated with Construction Activity*. NPDES General Permit No. CAS000002, Order No. 99-08-DWQ.
- Taffet, M.J., L. Green-Horner, L.C. Hall, T.M. Carlsen, and J.A. Orberdorfer. (1996). *Addendum to Site-Wide Remedial Investigation Report, Building 850/Pit 7 Complex Operable Unit, Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-108131, Add. 1.
- Thorpe, R.K., W.F. Isherwood, M.D. Dresen, and C.P. Webster-Scholten. (1990). *CERCLA Remedial Investigation Report for the LLNL Livermore Site, Vols. 1-5*. Livermore, CA: Lawrence Livermore National Laboratory, UCAR-10299.
- Toy, A.J., C.L. Lindeken, K.S. Griggs, and R.W. Buddemeier. (1981). *Environmental Monitoring at the Lawrence Livermore National Laboratory, 1980 Annual Report*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-50027-80.
- UC. (1997). *Environmental Impact Report Addendum for the Continued Operation of Lawrence Livermore National Laboratory*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-CR-125546.
- U.S. DOE. (1991). *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. Washington, DC: U.S. Department of Energy, DOE/EH-0173T.
- U.S. DOE. (1992). *Record of Decision for the Lawrence Livermore National Laboratory Livermore Site*. Washington, DC: U.S. Department of Energy, UCRL-AR-109105.
- U.S. DOE. (2001). *Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300, Lawrence Livermore National Laboratory*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-138470.
- U.S. DOE. (2002). *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. Washington, DC: U.S. Department of Energy, DOE-STD-1153-2002.
- U.S. DOE. (2004). *User's Guide, Version 1: RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation*. Washington, DC: U.S. Department of Energy, Interagency Steering Committee on Radiation Standards, DOE/EH-0676, ISCORS Technical Report 2004-02.
- U.S. DOE. (2005). *Final Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship Management Programmatic Environmental Impact Statement*. Washington, DC: U.S. Department of Energy, DOE/EIS-0348 and DOE/EIS-0236-S3.
- U.S. DOE. (2006a). *Draft Amendment to the Interim Site-Wide Record of Decision for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-222569-DRAFT.
- U.S. DOE. (2006b). *Draft Environmental Assessment for the Proposed Environmental Remediation at Lawrence Livermore National Laboratory Site 300 Pit 7 Complex*. Livermore, CA: Livermore Site Office, DOE/EA-1569.
- U.S. DOE. (2006c). *Draft Final Amendment to the Interim Site-Wide Record of Decision for the Pit 7 Complex at Lawrence Livermore National Laboratory Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-222569-DRAFT.
- U.S. DOE. (2006d). *Draft Final Proposed Plan for Environmental Cleanup at the Pit 7 Complex Lawrence Livermore National Laboratory Site 300*. Livermore, CA: U.S. Department of Energy, Livermore Site Office, UCRL-AR-215719-DRAFT.
- U.S. DOE. (2006e). *Draft Site-Wide Proposed Plan for the Lawrence Livermore National Laboratory Site 300 Final Record of Decision*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-226111-DRAFT.
- U.S. DOE. (2006f). *Final Proposed Plan for Environmental Cleanup at the Pit 7 Complex Lawrence Livermore National Laboratory Site 300*. Livermore, CA: U.S. Department of Energy, Livermore Site Office, UCRL-AR-215719.
- U.S. DOE. (2006g). *The Proposed Construction and Operation of Evidence Receiving and Temporary Storage Facilities in Support of the Nuclear and Radiological Attribution Program and Forensic Science Center's Analyses Program at the Livermore Site and Site 300, Lawrence Livermore National Laboratory*. Livermore, CA: U.S. Department of Energy, Livermore Site Office, DOE/EIS-0348-SA-01.

- U.S. DOE. (2006h). *Quality Systems for Analytical Services, Revision 2.2*. Washington, DC: U.S. Department of Energy.
- U.S. DOE. (2007). *Environmental Assessment for the Proposed Environmental Remediation at Lawrence Livermore National Laboratory Site 300 Pit 7 Complex*. Livermore, CA: Livermore Site Office, DOE/EA-1569.
- U.S. DOE/NNSA. (2005). "Record of Decision: Final Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement." *Federal Register*, Vol. 70, No. 228, pp. 71491-71500, November 29.
- U.S. DOE and UC. (1992). *Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories*. Livermore, CA: Lawrence Livermore National Laboratory, DOE/EIS-0157, SCH90030847.
- U.S. EPA. (1987). *Data Quality Objectives for Remedial Response Activities: Development Process*. Washington, DC: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, EPA 540/G-87/003, OSWER Directive 9355-0.
- U.S. EPA. (2000). "Notice: Final Reissuance of National Pollutant Discharge Elimination System (NPDES) Storm Water Multi-Sector General Permit for Industrial Activities." *Federal Register*, Volume 65, No. 210, October 30.
- U.S. EPA. (2002). *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition*. Washington, DC: U.S. Environmental Protection Agency, EPA-821-R-02-013.
- USFWS. (1998). *Recovery Plan for Upland Species of the San Joaquin Valley, California*. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Region 1.
- USFWS. (2006a). "Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the California Red-Legged Frog, and Special Rule Exemption Associated with Final Listing for Existing Routine Ranching Activities; Final Rule." *Federal Register*, Vol. 71, No. 71, pp. 19244–19346.
- USFWS. (2006b). "Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Alameda Whipsnake; Final Rule." *Federal Register*, Vol. 71. No. 190, pp. 58176–58231.
- U.S. NRC. (1977). *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluation Compliance with 10 Code of Federal Regulations, Part 50, Appendix 1*. Washington, DC: U.S. Nuclear Regulatory Commission, Regulatory Guide 1.109.
- Weber, W. (2002). *2001–2002 Wet Season Branchiopod Survey Report, University of California, Lawrence Livermore National Laboratory, Site 300, Alameda and San Joaquin Counties*. Hayward, CA: Condor Country Consulting.
- Webster-Scholten, C.P., ed. (1994). *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory, Site 300*. Livermore, CA: Lawrence Livermore National Laboratory, UCRL-AR-108131.
- Webster-Scholten, C.P., and C.H. Hall. (1988). *Work Plan, Lawrence Livermore National Laboratory, Livermore Site: CERCLA/SARA Remedial Investigations/Feasibility Studies*. Livermore, CA: Lawrence Livermore National Laboratory, UCAR-10225.
- West, E. (2002). *2002 Small Mammal Inventory at Lawrence Livermore National Laboratory, Site 300*. Sacramento: Jones & Stokes.
- Woods, N., ed. (2005). *Environmental Monitoring Plan*. Livermore, CA: Lawrence Livermore National Laboratory, Operation and Regulatory Affairs Division, Environmental Protection Department, UCRL-ID-106132, Rev. 4.
- Ziagos, J., and E. Reber-Cox. (1998). *Ground Water Tritium Plume Characterization Summary Report for the Building 850/Pits 3 and 5 Operable Unit, Site 300*. Livermore, CA: Lawrence Livermore National Laboratory.

# Glossary

## Metric and U.S. Customary Unit Equivalents

Category	From metric unit to U.S. customary equivalent unit		From U.S. customary unit to metric equivalent unit	
	Metric	U.S.	U.S.	Metric
Length	1 centimeter (cm)	0.39 inches (in.)	1 inch (in.)	2.54 centimeters (cm)
	1 millimeter (mm)	0.039 inches (in.)		25.4 millimeters (mm)
	1 meter (m)	3.28 feet (ft) 1.09 yards (yd)	1 foot (ft) 1 yard (yd)	0.3048 meters (m) 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 <sup>3</sup> )	35.32 cubic feet (ft <sup>3</sup> ) 1.35 cubic yards (yd <sup>3</sup> )	1 cubic foot (ft <sup>3</sup> ) 1 cubic yard (yd <sup>3</sup> )	0.028 cubic meters (m <sup>3</sup> ) 0.765 cubic meters (m <sup>3</sup> )
Weight	1 gram (g)	0.035 ounces (oz)	1 ounce (oz)	28.6 gram (g)
	1 kilogram (kg)	2.21 pounds (lb)	1 pound (lb)	0.373 kilograms (kg)
	1 metric ton (MT)	1.10 short ton (2000 pounds)	1 short ton (2000 pounds)	0.90718 metric ton (MT)
Area	1 hectare	2.47 acres	1 acre	0.40 hectares
Radioactivity	1 becquerel (Bq)	$2.7 \times 10^{-11}$ curie (Ci)	1 curie (Ci)	$3.7 \times 10^{10}$ becquerel (Bq)
Radiation dose	1 gray (Gy)	100 rad	1 rad	0.01 gray (Gy)
Radiation dose equivalent	1 sievert (Sv)	100 rem	1 rem	0.01 sievert (Sv)
Temperature	Metric to U.S. °Centigrade = (°Fahrenheit – 32) / 1.8		U.S. to metric. °Fahrenheit = (°Centigrade x 1.8) + 32	

## Symbols and Units of Measure

$\alpha$	alpha
$\beta$	beta
°C	degrees centigrade
°F	degrees Fahrenheit
$\gamma$	gamma
$\sigma$	sigma
aCi	attocurie
$\mu$ Bq	microbecquerel
$\mu$ Sv	microsievert
$\mu$ Sv/y	microsievert per year
ac	acre
Bq	becquerel
Bq/mL	becquerel per milliliter
Ci	curie
cm	centimeter(s)

cm <sup>3</sup> /min	cubic centimeter(s) per minute
ft	foot (feet)
fCi/m <sup>3</sup>	femtocurie per cubic meter
ft/y	foot (feet) per year
g	gram(s)
gal	gallon(s)
gal/yr	gallon(s) a year
GBq	gigabecquerel (10 <sup>9</sup> Bq)
ha	hectare
in.	inch(es)
kg	kilogram(s)
kg/day	kilogram(s) per day
km	kilometer(s)
kWh	kilowatt-hour(s)
L	liter(s)
lb	pound(s)
m <sup>3</sup> /min	cubic meter(s) per minute
m	meter(s)
mCi	millicurie (10 <sup>-3</sup> Ci)
mi	mile(s)
ML	million liters
mph	mile(s) per hour
mrem	millirem
mrem/y	millirem per year
m/s	meter(s) per second
mSv	millisievert (10 <sup>-3</sup> Sv)
m/y	meter(s) per year
nBq	nanobecquerel
nSv	nanosievert (10 <sup>-9</sup> Sv)
pg/m <sup>3</sup>	picogram(s) per cubic meter
ppb	part(s) per billion
ppm	part(s) per million
ppm <sub>v/v</sub>	part(s) per million on a volume-per-volume basis
Sv	sievert
TBq	terabecquerel

## Acronyms and Abbreviations

%RSD	Percent relative standard deviation
ACCDA	Alameda County Community Development Agency
ACDEH	Alameda County Department of Environmental Health
ACHP	Advisory Council on Historic Preservation
ACOE	Army Corps of Engineers

AFV	alternative fuel vehicle
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAAQMD	Bay Area Air Quality Management District
BCG	Biota Concentration Guide
BMP	best management practice
BOD	Biochemical (biological) oxygen demand
BSA	Blanket Service Agreement
BSL-3	Biosafety Level 3
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
CEI	Compliance Evaluation Inspection
CEQA	California Environmental Quality Act of 1970
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR	Code of Federal Regulations
Chromium(VI)	hexavalent chromium
CMP	Compliance Monitoring Program
CNPS	California Native Plant Society
CO	carbon monoxide
COC	constituent of concern
COD	chemical oxygen demand
CRLF	California red-legged frog
CSA	container storage area
CTC	Closing-the-Circle
CUPA	Certified Unified Program Agencies
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	(Federal) Clean Water Act
DCG	derived concentration guide
DHS	California Department of Health Services
DIS	distal
DMP	Detection Monitoring Program
DMT	Data Management Team
DOE	U.S. Department of Energy
DOECAP	U.S. Department of Energy Consolidated Auditing Program
DRB	Drainage Retention Basin (now Lake Haussmann)
DTSC	(California Environmental Protection Agency) Department of Toxic Substances Control
DU	depleted uranium

DWTF	Decontamination and Waste Treatment Facility
E85	Vehicle fuel, 85% ethanol and 15% gasoline
EA	environmental assessment
EDE	effective dose equivalent
EDO	Environmental Duty Officer
EIR	environmental impact report
EIS	environmental impact statement
EMP	Environmental Management Plan
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)
ES&H	Environment, Safety, and Health
ESB	East Settling Basin
ESI	enhanced surveillance inspection
EWSF	Explosives Waste Storage Facility
EWTF	Explosives Waste Treatment Facility
FFA	federal facility agreement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FONSI	Finding of No Significant Impact
FY	fiscal year
GPS	global positioning system
GSA	General Services Area (Site 300)
GWP	(Livermore site) Ground Water Project
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 "tritium" in Key Terms)
HTO	tritiated water or tritiated water vapor (see "tritium" in Key Terms)
HWCA	Hazardous Waste Control Act
HWFP	Hazardous Waste Facility Permit
IQR	interquartile range
ISCORS	Interagency Steering Committee on Radiation Standards
ISMS	Integrated Safety Management System

ISO	International Organization for Standardization
ITS	Issues Tracking System
IWS	integration work sheet
LCCE	life-cycle cost effective
LEPC	Local Emergency Planning Committee
LLD	lower limit of detection
LLNL	Lawrence Livermore National Laboratory
LLNL SW/SPEIS	<i>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</i>
LOS	limit of sensitivity
LRS	laws, regulations, standards
LSO	Livermore Site Office
LWRP	Livermore Water Reclamation Plant
MAPEP	Mixed Analyte Performance Evaluation Program
MCL	maximum contaminant level
MDC	minimum detectable concentration
MNA	monitored natural attenuation
MRP	Monitoring and Reporting Program
MSDS	material safety data sheet
MW	mixed waste
NCR	nonconformance report
NCRP	National Council on Radiation Protection
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
NRHP	National Register of Historic Places
NU	natural uranium
NWP	nationwide permit
OBT	organically bound tritium
OFI	opportunities for improvement
OR	occurrence report
ORAD	Operations and Regulatory Affairs Division (of the LLNL Environmental Protection Department)
OU	operable unit
P2	pollution prevention
PCB	polychlorinated biphenyl
PCE	perchloroethylene (or perchloroethene); also called tetrachloroethylene or tetrachloroethene

pHMS	pH Monitoring Station
PM-10	particulate matter, diameter equal to or less than 10 microns
PPOA	Pollution Prevention Opportunity Assessment
PQL	practical quantitation limit
PRX	proximal
QA	quality assurance
QC	quality control
R	Roentgen
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 LLNL Environmental Protection Department)
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
Sandia/California	Sandia National Laboratories/California
SARA	Superfund Amendment and Reauthorization Act of 1986 (see also CERCLA/SARA)
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
SMOP	Synthetic Minor Operating Permit
SMS	Sewer Monitoring Station
SOO	summary of observations
SOV	summary of violations
SOx	sulphur oxides
SPCC	Spill Prevention Control and Countermeasure
SRC	source
STP	Site Treatment Plan
SWESR	Site-Wide Remediation Evaluation Summary Report
SW-MEI	site-wide maximally exposed individual member (of the public)
SWPPP	Storm Water Pollution Prevention Plan
TAG	Technical Assistance Grant
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
TRR	technical release representative
TRU	transuranic (waste)
TSCA	Toxic Substances Control Act
TSS	total suspended solids
TTO	total toxic organics
UC	University of California
USFWS	U.S. Fish and Wildlife Service
UST	underground storage tank
VOC	volatile organic compound
VTF	vapor treatment facility
WAA	waste accumulation area
WDAR	Waste Discharge Authorization Requirement
WDR	Waste Discharge Requirement
WGMG	Water Guidance and Monitoring Group
WIPP	Waste Isolation Pilot Plant
WMA	Waste Management Area
WSS	Work Smart Standard
Zone 7	Alameda County Flood Control and Conservation District, Zone 7

## Key Terms

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

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

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

**Aerosol.** Gaseous suspension of very small particles of liquid or solid.

**Alameda County Flood Control and Water Conservation District Zone 7.** Also known as the Zone 7, the water agency for the Livermore-Amador Valley with responsibility for regional flood control and drinking water supply.

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

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

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

**Analysis of variance.** *T*-test of whether two or more sample means are statistically different.

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

**Anion.** Negatively charged ion, such as  $\text{Cl}^-$ .

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

**Aquitard.** Low-permeability geologic formation that bounds an aquifer.

**Atom.** Smallest particle of an element capable of entering into a chemical reaction.

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

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

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

**Biochemical (biological) oxygen demand (BOD).** 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 apparatus.

**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.

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

**Chain-of-custody.** 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.** LLNL laboratory that analyzes environmental samples.

**Class 1 permit modification.** Minor change to the Hazardous Waste Facility Permit (HWFP). May be implemented 30 days after the California Environmental Protection Agency Department of Toxic Substances Control (DTSC) has been notified of and concurs with the proposed change. Requires documented public and DTSC notification within 90 days after the modification has been put into effect.

**Class 1\* permit modification.** Change to HWFP that requires prior written approval from DTSC before implementation. Within seven days after DTSC has been notified, persons on the facility's mailing list must be notified of the proposed change by publishing the change in a major newspaper with general circulation. Proof of notification must be submitted to DTSC.

**Class 2 permit modification.** Change to HWFP that requires notification of persons of the facility's mailing list within seven days before or after notifying DTSC of the proposed change by publishing the proposed change in a major newspaper with general circulation and allowing a 60-day comment period. The permittee shall hold a public meeting 15 days after the start and no later than 15 days prior to the end of the comment period. Documented

proof of notification and the public meeting must be submitted to DTSC. DTSC may require a California Environmental Quality Act (CEQA) review or issue a Notice of Exemption from the CEQA review at the time of approval.

**Code of Federal Regulations (CFR).** Codification of all regulations promulgated by federal government agencies.

**Collective dose equivalent and collective effective dose equivalent.** 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."

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

**Daughter nuclide.** 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  $5 \times 10^{-4}$ , respectively. Depleted uranium is sometimes referred to as D-38 or DU.

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

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

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

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

**Dosimetry.** 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 (now Lake Haussmann).** Man-made, lined pond used to capture storm water runoff and treated water at the Livermore site.

**Effective dose equivalent (EDE).** Estimate of the total risk of potential effects from radiation exposure, it is the summation of the products of the dose equivalent and weighting factor for each tissue. The weighting factor is the

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

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

**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).** 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).** 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.

**EPA synthetic moderately hard water.** Water solutions prepared according to U.S. EPA standards used as a reference water sample for control comparisons in whole effluent toxicity testing. Synthetic waters are prepared in accordance with *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*, EPA-821-R-02-013 (U.S. EPA 2002).

**Evapotranspiration.** 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.

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

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

**Federal Register.** 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.

**Gabion.** Galvanized wire box filled with stones used to form retaining walls along a stream 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).** Standard metric measure of weight approximately equal to 0.035 ounce.

**Gray (Gy).** SI unit of measure for absorbed dose; the quantity of energy imparted by ionizing radiation to a unit mass of matter, such as tissue. 1 gray = 100 rads, or 1 joule per kilogram.

**Groundwater.** All subsurface water.

**Half-life (radiological).** 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.** Waste that exhibits ignitability, corrosivity, reactivity, and/or EP-toxicity (yielding toxic constituents in a leaching test), and waste that does not exhibit these characteristics but has been determined to be hazardous

by EPA. Although the legal definition of hazardous waste is complex, according to EPA the term generally refers to any waste that, if managed improperly, could pose a threat to human health and the environment.

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

**High-efficiency particulate air (HEPA) filter.** 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).** 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.** Science dealing with the properties, distribution, and circulation of natural water systems.

**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.** 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).** International organization that studies radiation, including its measurement and effects.

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

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

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

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

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

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

**Lower limit of detection.** Smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level.

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

**Metric units.** Except for temperature for which specific equations apply, U.S. customary units can be determined from metric units by multiplying the metric units by the U.S. customary equivalent. Similarly, metric units can be determined from U.S. customary equivalent units by multiplying the U.S. customary units by the metric equivalent.

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

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

**National Institute for Standards and Technology (NIST).** 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 doses from environmental measurements.

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

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

**Off site.** Outside the boundaries of the LLNL Livermore site or 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

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

**Parts per billion (ppb).** 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).** 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.

**pH.** 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.

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

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

**Quality factor.** 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.** Geologic era encompassing the last 2–3 million years.

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

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

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

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

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

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

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

**Revetment.** Facing (as of stone or concrete) to sustain an embankment

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

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

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

**San Joaquin County Health District (SJCHD).** Local agency that enforces under-ground-tank regulations in San Joaquin County, including Site 300.

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

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

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

**Secondary MCL.** Nonmandatory water quality standard set by the EPA California Department of Health Services to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor

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

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

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

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

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

**Superfund Amendments and Reauthorization Act (SARA).** 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.

**Swale.** Manmade or natural low-lying or depressed area of land used to convey storm water runoff.

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

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

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

**Total organic carbon (TOC).** Sum of the organic material present in a sample.

**Total organic halides (TOX).** Sum of the organic halides present in a sample.

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

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

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

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

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

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

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

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

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

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

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

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

**Wind rose.** Diagram that shows the frequency and intensity of wind from different directions at a specific location.

**Zone 7.** Common name for the Alameda County Flood Control and Water Conservation District, Zone 7.



## APPENDIX A

### Environmental Management Plan

Significant environmental aspect	Objective	Target	Status
<b>EMP 1 Ecological Resource Disturbance</b>	By 1/1/06, establish a Laboratory policy prohibiting the introduction of exotic species within the boundaries of LLNL.	(a) Modify the <i>ES&amp;H Manual</i> to specify that exotic species introductions contradict the LLNL environmental policy.	Completed. (a) Issued major revision to <i>ES&amp;H Manual</i> , Document 33.2, 9/27/05.
		(b) Include wording specific to LLNL employee responsibilities to uphold the environmental policy regarding species introductions.	(b) Issued major revision to <i>ES&amp;H Manual</i> , Document 33.2, 9/27/05.
		(c) Post signs at the Livermore site and Site 300 alerting LLNL staff of exotic species introduction and legalities associated with introductions.	(c) Installed signs at the Livermore site, completed 2/06. No signage currently needed at Site 300.
	Educate LLNL employees annually about the ecological and economical consequences of exotic species introductions.	Promote employee awareness about exotic species (e.g., write articles for <i>LLNL Newslines</i> ).	Ongoing.
	Control feral pig populations at Site 300, ongoing as need determined.	Control efforts occurring as needed, pre- and post-disturbance wetland monitoring.	Ongoing.
	Complete rotenone treatment of the Lake Haussmann (formerly known as the Drainage Retention Basin) late September 2006.	Complete rotenone treatment 2005–2006.	Completed 10/6/06.
<b>EMP 2 Electrical Energy Use</b>	Meet the objectives provided in Department of Energy (DOE) Order 430.2A, Departmental Energy and Utilities Management, Attachment 1, Contractor Requirements Document.  <i>Note:</i> Goals have changed with enactment of the Energy Policy Act of 2005.	Reduce greenhouse gas emissions by 30% by 2010 based on 1990 emissions.	In progress. 24.7% reduction achieved at end of FY 2006 from the fiscal year (FY) 1990 baseline (Executive Order 13123 goal). 3.17% reduction achieved at end of FY 2006 from the FY 2003 baseline (Energy Policy Act of 2005 goal).
		Reduce energy consumption in laboratory and industrial facilities, based on 1990 levels: 20% by 2005 and 25% by 2010.	In progress. 21.5% reduction achieved at end of FY 2006 from the FY 1990 baseline (Executive Order 13123 goals). 2.27% reduction achieved at end of FY 2006 from the FY 2003 baseline (meets Energy Policy Act of 2005 goal).

Significant environmental aspect	Objective	Target	Status
		Accomplish 80% of identified life-cycle cost effective (LCCE) water conservation actions by 2010.	In progress. Initial Energy Savings Performance Contract (ESPC) project proposal (10/06) included an irrigation control measure that was not LCCE. Submitted a small project, approximately \$160,000, for institutional funding to install dual-volume flushometers on women's toilets.
		Implement President's Initiative for Hurricane Relief (9/05): 10% reduction in electricity and petroleum fuel use per FY 2004 baseline.	Completed. Completed performance reporting to NNSA/LSO in FY 2006.
<b>EMP 3 Fossil Fuel Consumption/ Renewable Energy Use</b>	Meet the DOE vehicle fleet efficiency goal, as stated in I.106 DEAR 970.5223-5.	Reduce petroleum consumption by 20% by 2008 compared to 1999 baseline.	In progress. Reduced fossil fuel consumption on light-, medium-, and heavy-duty vehicles by 16% (comparing the FY 2006 consumption to the 1999 baseline)
		Of the annual replacements of light-duty vehicles, replace 75% with alternative fuel vehicles (AFVs).	Ongoing. For the FY 2007 vehicle exchange, LLNL requested 65% of its fleet to be AFVs. Many light-duty vehicles are not readily available as AFVs. LLNL will continue replacing every vehicle with AFVs depending on availability.
		Increase usage rate of alternative fuel in alternative fuel capable vehicles (80% use vs. total availability by 2008).	In progress. An E85 station is planned for early 2007, which will service approximately 90% of the E85 fleet.
<b>EMP 4 Hazardous Materials Use</b>	By 3/31/06, identify the hazardous materials used at LLNL by conducting a study to identify the database(s) or other information sources that provide a comprehensive list of hazardous materials.	(a) Identify hazardous materials used at LLNL. (b) Complete evaluation of hazardous materials databases and other information sources.	Completed. Submitted the draft decision process document to NNSA/LSO on 10/20/06. The final draft decision process to complete targets (a) and (b) to be submitted to the LLNL EMS Coordinator by 6/15/07.
		By 9/15/06, write a decision process to document how the hazardous materials are selected and the rationale for selection.	Complete decision process on selection of hazardous materials.

Significant environmental aspect	Objective	Target	Status
	By 9/15/06, complete hazardous materials identification evaluation.	Complete hazardous materials list.	Completed. See above.
	By 9/31/07, evaluate each selected hazardous material to determine whether substitution, reduction, reuse or a change in the process would decrease usage, waste generation, or other ES&H concerns. Each hazardous material evaluation will follow the Pollution Prevention Opportunity Assessment (PPOA) process.	Complete the PPOA.	In progress. After the final decision process is approved, the Environmental Protection Department P2 Team will evaluate the hazardous materials to determine the feasibility of conducting PPOAs. The P2 Team will complete PPOAs on selected hazardous materials during FY 2008.
<b>EMP 5 Mixed Waste Generation</b>	Reduce the amount of mixed and California combined solid waste generated from routine LLNL programmatic operations when economically and technologically feasible.	Reduce the amount of routine mixed and California combined solid waste generated by programmatic activities by 20% by 2007, using the 2004 pollution prevention report as a baseline. The FY 2004 generation baseline is 41,458 pounds.	In progress. Due to changes in the management of on-site analytical services, the largest single generator of mixed waste is no longer in operation. RHWM believes that when final closure activities are completed, the mixed waste generation rate will be significantly reduced.  <i>RHWM completed Review of LLNL Mixed Waste Streams for the Application of Potential Waste Reduction Controls in 1/07.</i>
		As an additional metric, evaluate waste streams in terms of cost per unit volume; target high-cost waste streams for reduction.	In progress. See above.
<b>EMP 6 Municipal Waste Generation</b>	Maintain compliance with applicable regulatory requirements.	Review federal, state, county and municipal laws, measures, codes, and incentives annually to verify compliance.  No violations of regulatory requirements.	Ongoing. Review conducted annually.
	Prevent/minimize and increase reuse and recycling of waste generated at facilities throughout their life cycles.	Modify Plant Engineering master Design Criteria Document to include design elements from the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System.	Completed 5/06.
	Minimize and increase reuse and recycling of routine nonhazardous waste generated during decommissioning, deactivation, decontamination, and deconstruction or demolition of facilities.	Perform Laboratory-wide assessment to revisit/identify all significant routine and non-routine nonhazardous waste.	In progress. A similar objective/target is being tracked in EMP 7, Nonhazardous Material Use. LLNL plans to merge EMPs 6 and 7 in 2007.

Significant environmental aspect	Objective	Target	Status
	Prevent/reduce generation and increase reuse and recycling of routine nonhazardous waste in the office and workplace.	Perform Laboratory-wide assessment to revisit/identify all significant routine and nonroutine nonhazardous waste.	In progress. See above.
	Improve effectiveness and efficiency of waste management, reuse, and recycling programs.	Perform Laboratory-wide assessment to revisit/identify all significant routine and nonroutine nonhazardous waste.	In progress. See above.
<b>EMP 7 Nonhazardous Materials Use</b>	Incorporate affirmative procurement site-wide.	Incorporate EPA's Comprehensive Procurement Guidelines into procedures for technical release representatives (TRRs).	Completed. Standard Practice 23.5, modifications to TRR manual and issuance of General Provisions for subcontracts revised by 2/07.
		Incorporate DOE's directive for environmentally preferable purchasing into procurement procedures.	Completed. See above.
	Make it possible to increase site-wide use of products with recycled content with procedures and training.	By Q2 of FY 2007, formalize LLNL Procurement Standard Practices, Section 23.5, to incorporate DOE's Affirmative Procurement Program for recycled content and biobased products.	Completed. See above.
		By Q3 of FY 2007, document available data on post-consumer content of purchased materials (e.g., office supplies).	In progress. To be completed during gathering of information for reporting in Q1 of FY 2008.
	Offer product that will reduce use of office paper.	By Q3 of FY 2007, establish printers and copiers with duplexing (i.e., two-sided) capability as preferred purchasing choice.	Completed. EPA Energy Star requirement added to Section 23.5 of the <i>Laboratory Procurement Standard Practices</i> and <i>TRR Policy Manual</i> in 02/07.
		By Q3 of FY 2007, establish duplexing for printers and copiers as default setting.	Completed. See above.
	Implement Energy Star requirements for energy consuming equipment	Implement purchase requirements in <i>TRR Policy Manual</i> .	Completed 8/26/06.
		By Q3 of FY 2007, implement requirement in Procurement Guidance and terms and conditions.	Completed. Section 23.5 of the <i>Laboratory Procurement Standard Practices</i> , modification of <i>TRR Policy Manual</i> and general provisions for subcontracts completed in 2/07.

Significant environmental aspect	Objective	Target	Status
		By Q3 of FY 2007, formalize the promotion of environmentally preferable electronic equipment by including this issue in employee awareness programs.	In progress. To be completed Q1 of FY 2008.
		By Q3 of FY 2007, formalize the promotion of environmentally preferable electronic equipment by including this issue in TRR training.	Completed. Section 23.5 of the <i>Laboratory Procurement Standard Practices</i> , modification of <i>TRR Policy Manual</i> and general provisions for subcontracts completed in 2/07.
	Improve affirmative procurement awareness and training for LLNL TRRs and Procurement Representatives.	Train all TRRs in FY 2006.	Completed.
		At least bi-annual communications to the TRRs.	Ongoing. P2 team provides bi-annual training to TRRs.
		By Q3 of FY 2007, train Procurement Representatives on Section 23.5 of the <i>Laboratory Procurement Standard Practices</i> after the section has been approved and implemented.	In progress. To be completed Q1 of FY 2008.
<b>EMP 8: Radioactive Materials Use</b>	Identify and reduce radioactive materials impacts at LLNL by an amount to be determined by this study	Conduct a study to determine the potential for reduction of the impacts of radioactive materials use. The study will be completed by 11/30/06.	Completed.
		Based on the potential for reductions, recommend an amount of impacts to be reduced as appropriate.	In progress. Defense and Nuclear Technologies, with assistance by EPD, will determine which reductions in usage, if any, are appropriate for programmatic operations.
<b>EMP 9: Transuranic Waste Generation</b>	Review the characterization of transuranic (TRU) waste to ensure generation of nonconforming waste is minimized and characterization is accurate to maximize the ability to disposition the waste.	By 6/30/06, review the Nonconformance and Corrective Action Reports (NCARs) developed during the Waste Isolation Pilot Plant (WIPP) characterization and certification project and make recommendations to the characterization and packaging of TRU waste.	Completed. Conducted and documented a series of meetings with representatives from LLNL programs, RHWM, WIPP to discuss the types of failures that were noted during the WIPP campaign and to discuss strategies for ensuring that the problems do not recur.
		BY 12/31/06, develop procedure(s) that implements the recommendations from the study.	Completed 12/7/06. Developed and approved a TRU packaging procedure that identified several new controls to respond to the NCARs written as a result of the WIPP characterization, certification, and shipping project.



## APPENDIX B

### Data Tables

The data tables listed in this appendix are accessible on CD or at <http://www.llnl.gov/saer>.

#### B.1 Air Effluent (Chapter 4)

- B.1.1 Summary of gross alpha and gross beta ( $\mu\text{Bq}/\text{m}^3$ ) in background locations for comparison to monitored air effluent emission points in 2006
- B.1.2 Summary of gross alpha and gross beta ( $\mu\text{Bq}/\text{m}^3$ ) in air effluent samples from monitored emission point at Livermore site, Building 235, 2006
- B.1.3 Summary of gross alpha and gross beta ( $\mu\text{Bq}/\text{m}^3$ ) in air effluent samples from monitored emission points at Livermore site, Building 251, 2006
- B.1.4 Summary of gross alpha and gross beta ( $\mu\text{Bq}/\text{m}^3$ ) in air effluent samples from monitored emission points at Livermore site, Building 491, 2006
- B.1.5 Summary of gross alpha and gross beta ( $\mu\text{Bq}/\text{m}^3$ ) in air effluent samples from monitored emission points at Livermore site, Building 695, 2006
- B.1.6 Summary of tritium ( $\text{Bq}/\text{m}^3$ ) in air effluent samples from the monitored emission point at Livermore site, Building 695, 2006
- B.1.7 Summary of gross alpha and gross beta ( $\mu\text{Bq}/\text{m}^3$ ) in air effluent samples from monitored emission points at Livermore site, Plutonium Facility, 2006
- B.1.8 Summary of tritium in air effluent samples ( $\text{Bq}/\text{m}^3$ ) from monitored emission points at Livermore site, Tritium Facility, 2006
- B.1.9 Summary of gross alpha and gross beta ( $\mu\text{Bq}/\text{m}^3$ ) in air effluent samples from monitored emission points at Site 300, Building 801, 2006

#### B.2 Ambient Air (Chapter 4)

- B.2.1 Tritium concentrations ( $\text{mBq}/\text{m}^3$ ) in air near diffuse sources on the Livermore site, 2006
- B.2.2 Weekly gross alpha and gross beta concentrations ( $\mu\text{Bq}/\text{m}^3$ ) from air particulate samples from the Livermore perimeter locations, 2006
- B.2.3 Tritium concentrations ( $\text{mBq}/\text{m}^3$ ) in air on the Livermore site, 2006
- B.2.4 Beryllium concentration ( $\text{pg}/\text{m}^3$ ) in Livermore site and Site 300 air particulate samples, 2006
- B.2.5 Beryllium-7 concentrations ( $\text{mBq}/\text{m}^3$ ) composite for Livermore site and Site 300 air particulate samples, 2006
- B.2.6 Plutonium-239+240 concentrations ( $\text{nBq}/\text{m}^3$ ) in air particulate samples from the Livermore perimeter and Site 300 perimeter composite, 2006
- B.2.7 Uranium mass concentrations ( $\text{pg}/\text{m}^3$ ) in air particulate samples, 2006
- B.2.8 Weekly gross alpha and gross beta concentrations ( $\mu\text{Bq}/\text{m}^3$ ) from air particulate samples from the Livermore Valley downwind locations, 2006
- B.2.9 Tritium concentrations ( $\text{mBq}/\text{m}^3$ ) in air, Livermore Valley, 2006
- B.2.10 Weekly gross alpha and gross beta concentrations ( $\mu\text{Bq}/\text{m}^3$ ) from air particulate samples from Livermore Valley and the special interest location, 2006
- B.2.11 Plutonium-239+240 concentrations ( $\text{nBq}/\text{m}^3$ ) in air particulate samples from the Livermore Valley and Site 300 perimeter, 2006

- B.2.12 Tritium concentrations ( $\text{mBq/m}^3$ ) in air, Site 300, 2006
- B.2.13 Weekly gross alpha and gross beta concentrations ( $\mu\text{Bq/m}^3$ ) from air particulate samples from Site 300 and off site, 2006

### **B.3 Livermore Site Wastewater (Chapter 5)**

- B.3.1 Daily monitoring results for gross alpha, gross beta, and tritium in the Livermore site sanitary sewer effluent, 2006
- B.3.2 Daily flow totals for Livermore site sanitary sewer effluent (ML), 2006
- B.3.3 Monthly and annual flow summary statistics for Livermore site sanitary sewer effluent (ML), 2006
- B.3.4 Monthly 24-hour composite results for metals in Livermore site sanitary sewer effluent, 2006
- B.3.5 Monthly monitoring results for physical and chemical characteristics of the Livermore site sanitary sewer effluent, 2006
- B.3.6 Monthly composite results for tritium for the Livermore site and LWRP effluent, 2006
- B.3.7 Weekly composite metals in Livermore site sanitary sewer effluent, 2006

### **B.4 Storm Water (Chapter 5)**

- B.4.1 Metals detected in storm water runoff, Livermore site, 2006
- B.4.2 Nonradioactive constituents (other than metals) detected in storm water runoff, Livermore site, 2006
- B.4.3 Routine tritium, gross alpha, and gross beta sampling in storm water runoff at the Livermore site, 2006
- B.4.4 Dioxins and furans in storm water, Site 300, 2006
- B.4.5 Metals in storm water runoff, Site 300, 2006
- B.4.6 Nonradioactive constituents detected in storm water runoff, Site 300, 2006
- B.4.7 Polychlorinated biphenyls (PCBs) in storm water runoff, Site 300, 2006
- B.4.8 Radioactivity in storm water runoff, Site 300, 2006
- B.4.9 Total toxicity equivalents of dioxin and furan congeners in storm water runoff ( $\text{pg/L}$ ) at Site 300, January 18 and March 7, 2006

### **B.5 Livermore Site Groundwater (Chapter 5)**

- B.5.1 Livermore site metals surveillance wells, 2006
- B.5.2 Livermore site Buildings 514 and 612 area surveillance wells, 2006
- B.5.3 Livermore site near Decontamination and Waste Treatment Facility (DWTF) surveillance wells, 2006
- B.5.4 Livermore site East Traffic Circle Landfill surveillance wells 1303 and 1308, 2006
- B.5.5 Livermore site East Traffic Circle Landfill surveillance wells 119 and 1306, 2006
- B.5.6 Livermore site East Traffic Circle Landfill surveillance well 906, 2006
- B.5.7 Nitrate concentrations in selected Livermore site surveillance wells, 2006
- B.5.8 Livermore site Tritium Facility surveillance wells, 2006
- B.5.9 Livermore site perimeter off-site surveillance wells, 2006
- B.5.10 Livermore site perimeter on-site surveillance wells, 2006
- B.5.11 Livermore site near the National Ignition Facility (NIF) surveillance wells, 2006
- B.5.12 Livermore site Plutonium Facility surveillance wells, 2006
- B.5.13 Livermore site Taxi Strip surveillance wells, 2006
- B.5.14 Livermore site background surveillance wells, 2006
- B.5.15 Tritium activity in Livermore Valley wells, 2006

## **B.6 Site 300 Groundwater (Chapter 5)**

- B.6.1 Site 300 annually monitored off-site surveillance wells, 2006
- B.6.2 Site 300 off-site surveillance well CDF1, 2006
- B.6.3 Site 300 off-site surveillance well CON1, 2006
- B.6.4 Site 300 off-site surveillance well CON2, 2006
- B.6.5 Elk Ravine surveillance wells, 2006
- B.6.6 Site 300 off-site surveillance well GALLO1, 2006
- B.6.7 Site 300 potable supply well 18, 2006
- B.6.8 Site 300 potable supply well 20, 2006

## **B.7 Other Water (Chapter 5)**

- B.7.1 Dry season (June 1 to September 30, 2006) monitoring data for releases from Lake Haussmann
- B.7.2 Wet season (January 1 to October 1 and May 31 to December 31, 2006) monitoring data for releases from Lake Haussmann
- B.7.3 Tritium activities in rain water samples collected in the vicinity of both the Livermore site and Site 300, 2006
- B.7.4 Radioactivity (Bq/L) in surface and drinking water in Livermore Valley, 2006

## **B.8 Soil (Chapter 6)**

- B.8.1 Background concentration values for metals in soils at the Livermore site, 2006
- B.8.2 Soluble metals in Livermore site vadose zone soil, 2006
- B.8.3 Total metals in Livermore site vadose zone soil, 2006
- B.8.4 Gamma-emitting background and fallout radionuclides in soil and sediment in the Livermore Valley, 2006
- B.8.5 Fallout and background radionuclides in soil at Site 300, 2006
- B.8.6 Background concentration values for metals in soils at Site 300, 2006

## **B.9 Ambient Radiation (Chapter 6)**

- B.9.1 Livermore site perimeter
- B.9.2 Livermore Valley
- B.9.3 Off-site locations near Site 300
- B.9.4 Site 300



## APPENDIX C

### EPA Methods of Environmental Water Analysis

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

Constituent of concern	Analytical method	Reporting limit <sup>(a,b)</sup>	
<b>Metals and minerals (mg/L)</b>	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 <sub>3</sub> )	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 <sub>3</sub> )	EPA 353.2, 354.1 or 300.0	0.5
	Nitrite (as NO <sub>2</sub> )	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
	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	

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

<b>Constituent of concern</b>	<b>Analytical method</b>	<b>Reporting limit<sup>(a,b)</sup></b>	
<b>Metals and minerals (mg/L) (cont.)</b>	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
<b>General indicator parameters</b>	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	
<b>Radioactivity (Bq/L)</b>	Gross alpha	EPA 900	0.074
	Gross beta	EPA 900	0.11
<b>Radioisotopes (Bq/L)</b>	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
	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 C-2.** Organic constituents of concern in water samples and their contractual reporting limits of concentration, sorted by analytical method.

Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>	Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>
<b>EPA Method 1664</b>		Dibromochloromethane	0.2
Oil & Grease	1000	Dibromomethane	0.2
<b>EPA Method 420.1</b>		Dichlorodifluoromethane	0.2
Phenolics	5	Ethylbenzene	0.2
<b>EPA Method 502.2 (or 524.2)</b>		Freon 113	0.2
1,1,1,2-Tetrachloroethane	0.2	Hexachlorobutadiene	0.2
1,1,1-Trichloroethane	0.2	Isopropylbenzene	0.2
1,1,2,2-Tetrachloroethane	0.2	<i>m</i> - and <i>p</i> -Xylene isomers	0.2
1,1,2-Trichloroethane	0.2	Methylene chloride	0.2
1,1-Dichloroethane	0.2	<i>n</i> -Butylbenzene	0.2
1,1-Dichloroethene	0.2	<i>n</i> -Propylbenzene	0.2
1,1-Dichloropropene	0.2	Naphthalene	0.2
1,2,3-Trichlorobenzene	0.2	<i>o</i> -Xylene	0.2
1,2,3-Trichloropropane	0.2	Isopropyl toluene	0.2
1,2,4-Trichlorobenzene	0.2	<i>sec</i> -Butylbenzene	0.2
1,2,4-Trimethylbenzene	0.2	Styrene	0.2
1,2-Dichlorobenzene	0.2	<i>tert</i> -Butylbenzene	0.2
1,2-Dichloroethane	0.2	Tetrachloroethene	0.2
1,2-Dichloropropane	0.2	Toluene	0.2
1,3,5-Trimethylbenzene	0.2	<i>trans</i> -1,2-Dichloroethene	0.2
1,3-Dichlorobenzene	0.2	<i>trans</i> -1,3-Dichloropropene	0.2
1,3-Dichloropropane	0.2	Trichloroethene	0.2
1,4-Dichlorobenzene	0.2	Trichlorofluoromethane	0.2
2,2-Dichloropropane	0.2	Vinyl chloride	0.2
2-Chlorotoluene	0.2	<b>EPA Method 507</b>	
4-Chlorotoluene	0.2	Alachlor	0.5
Benzene	0.2	Atraton	0.5
Bromobenzene	0.2	Atrazine	0.5
Bromochloromethane	0.2	Bromacil	0.5
Bromodichloromethane	0.2	Butachlor	0.5
Bromoform	0.2	Diazinon	0.5
Bromomethane	0.2	Dichlorvos	0.5
Carbon tetrachloride	0.2	Ethoprop	0.5
Chlorobenzene	0.2	Merphos	0.5
Chloroethane	0.2	Metolachlor	0.5
Chloroform	0.2	Metribuzin	0.5
Chloromethane	0.2	Mevinphos	0.5
<i>cis</i> -1,2-Dichloroethene	0.2	Molinate	0.5
<i>cis</i> -1,3-Dichloropropene	0.5	Prometon	0.5

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

Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>	Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>
<b>EPA Method 507 (cont.)</b>		Dibromomethane	1
Prometryn	0.5	Dichlorodifluoromethane	2
Simazine	0.5	Ethylbenzene	1
Terbutryn	0.5	Ethylene dibromide	1
<b>EPA Method 524.2</b>		Freon-113	1
1,1,1,2-Tetrachloroethane	1	Hexachlorobutadiene	1
1,1,1-Trichloroethane	1	Isopropylbenzene	1
1,1,2,2-Tetrachloroethane	1	<i>m</i> - and <i>p</i> -Xylene isomers	1
1,1,2-Trichloroethane	1	Methylene chloride	1
1,1-Dichloroethane	1	<i>n</i> -Butylbenzene	1
1,1-Dichloroethene	1	<i>n</i> -Propylbenzene	1
1,1-Dichloropropene	1	Naphthalene	1
1,2,3-Trichlorobenzene	1	<i>o</i> -Xylene	1
1,2,3-Trichloropropane	1	Isopropyl toluene	1
1,2,4-Trichlorobenzene	1	<i>sec</i> -Butylbenzene	1
1,2,4-Trimethylbenzene	1	Styrene	1
1,2-Dibromo-3-chloropropane	2	<i>tert</i> -Butylbenzene	1
1,2-Dichlorobenzene	1	Tetrachloroethene	1
1,2-Dichloroethane	1	Toluene	1
1,2-Dichloropropane	1	<i>trans</i> -1,2-Dichloroethene	1
1,3,5-Trimethylbenzene	1	<i>trans</i> -1,3-Dichloropropene	1
1,3-Dichlorobenzene	1	Trichloroethene	0.5
1,3-Dichloropropane	1	Trichlorofluoromethane	1
1,4-Dichlorobenzene	1	Vinyl chloride	2
2-Chlorotoluene	1	<b>EPA Method 525</b>	
4-Chlorotoluene	1	2,4-Dinitrotoluene	0.5
Benzene	1	2,6-Dinitrotoluene	0.5
Bromobenzene	1	4,4'-DDD	0.5
Bromodichloromethane	1	4,4'-DDE	0.5
Bromoform	1	4,4'-DDT	0.5
Bromomethane	2	Acenaphthylene	0.5
Carbon tetrachloride	1	Alachlor	0.5
Chlorobenzene	1	Aldrin	0.5
Chloroethane	2	Anthracene	0.5
Chloroform	1	Aroclor 1016 (PCB)	0.5
Chloromethane	2	Aroclor 1221 (PCB)	0.5
<i>cis</i> -1,2-Dichloroethene	1	Aroclor 1232 (PCB)	0.5
<i>cis</i> -1,3-Dichloropropene	1	Aroclor 1242 (PCB)	0.5
Dibromochloromethane	1	Aroclor 1248 (PCB)	0.5

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

<b>Constituent of concern</b>	<b>Reporting limit (µg/L)<sup>(a,b)</sup></b>	<b>Constituent of concern</b>	<b>Reporting limit (µg/L)<sup>(a,b)</sup></b>
<b>EPA Method 525 (cont.)</b>		Isophorone	0.5
Aroclor 1254 (PCB)	0.5	Lindane	0.5
Aroclor 1260 (PCB)	0.5	Merphos	0.5
Atraton	0.5	Methoxychlor	0.5
Atrazine	0.5	Metolachlor	0.5
Benzo(a)anthracene	0.5	Metribuzin	0.5
Benzo(a)pyrene	0.5	Mevinphos	0.5
Benzo(b)fluoranthene	0.5	Pentachlorobenzene	0.5
Benzo(g,h,i)perylene	0.5	Pentachlorophenol	0.5
Benzo(k)fluoranthene	0.5	Phenanthrene	0.5
Bis(2-ethylhexyl)phthalate	0.5	Prometon	0.5
Bromacil	0.5	Prometryne	0.5
Butachlor	0.5	Propachlor	0.5
Butylbenzylphthalate	0.5	Pyrene	0.5
Chlordane	0.5	Simazine	0.5
Chloroprotham	0.5	Stirophos	0.5
Chlorpyrifos	0.5	Terbutryn	0.5
Chrysene	0.5	Toxaphene	0.5
Di (2-ethylhexyl) adipate	0.5	<b>EPA Method 547</b>	
Di-n-butylphthalate	0.5	Glyphosate 20	20
Diazinon	0.5	<b>EPA Method 601</b>	
Dibenzo(a,h)anthracene	0.5	1,1,1-Trichloroethane	0.5
Dichlorvos	0.5	1,1,2,2-Tetrachloroethane	0.5
Dieldrin	0.5	1,1,2-Trichloroethane	0.5
Diethylphthalate	0.5	1,1-Dichloroethane	0.5
Dimethylphthalate	0.5	1,1-Dichloroethene	0.5
Disulfoton	0.5	1,2-Dichlorobenzene	0.5
Endosulfan I	0.5	1,2-Dichloroethane	0.5
Endosulfan II	0.5	1,2-Dichloroethene (total)	0.5
Endosulfan sulfate	0.5	1,2-Dichloropropane	0.5
Endrin	0.5	1,3-Dichlorobenzene	0.5
Endrin aldehyde	0.5	1,4-Dichlorobenzene	0.5
Ethoprop	0.5	2-Chloroethylvinylether	0.5
Fluorene	0.5	Bromodichloromethane	0.5
Heptachlor	0.5	Bromoform	0.5
Heptachlor epoxide	0.5	Bromomethane	0.5
Hexachlorobenzene	0.5	Carbon tetrachloride	0.5
Hexachlorocyclopentadiene	0.5	Chlorobenzene	0.5
Indeno(1,2,3-c,d)pyrene	0.5	Chloroethane	0.5

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

Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>	Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>
<b>EPA Method 601 (cont.)</b>		Endrin	0.1
Chloroform	0.5	Endrin aldehyde	0.1
Chloromethane	0.5	Heptachlor	0.05
<i>cis</i> -1,2-Dichloroethene	0.5	Heptachlor epoxide	0.05
<i>cis</i> -1,3-Dichloropropene	0.5	Methoxychlor	0.5
Dibromochloromethane	0.5	4,4'-DDD	0.1
Dichlorodifluoromethane	0.5	4,4'-DDE	0.1
Freon-113	0.5	4,4'-DDT	0.1
Methylene chloride	0.5	Toxaphene	1
Tetrachloroethene <i>trans</i> -1,2-	0.5	<b>EPA Method 615</b>	
Dichloroethene <i>trans</i> -1,3-	0.5	2,4,5-T	0.5
Dichloropropene	0.5	2,4,5-TP (Silvex)	0.2
Trichloroethene	0.5	2,4-D	1
Trichlorofluoromethane	0.5	2,4-Dichlorophenoxy acetic acid	2
Vinyl chloride	0.5	Dalapon	10
<b>EPA Method 602</b>		Dicamba	1
1,2-Dichlorobenzene	0.3	Dichloroprop	2
1,3-Dichlorobenzene	0.3	Dinoseb	1
1,4-Dichlorobenzene	0.3	MCPA	250
Benzene	0.4	MCPP	250
Chlorobenzene	0.3	<b>EPA Method 624</b>	
Ethylbenzene	0.3	1,1,1-Trichloroethane	1
<i>m</i> -Xylene isomers	0.4	1,1,2,2-Tetrachloroethane	1
<i>o</i> -Xylene	0.4	1,1,2-Trichloroethane	1
<i>p</i> -Xylene	0.4	1,1-Dichloroethane	1
Toluene	0.3	1,1-Dichloroethene	1
Total xylene isomers	0.4	1,2-Dichlorobenzene	1
<b>EPA Method 608</b>		1,2-Dichloroethane	1
Aldrin	0.05	1,2-Dichloroethene (total)	1
BHC, alpha isomer	0.05	1,2-Dichloropropane	1
BHC, beta isomer	0.05	1,3-Dichlorobenzene	1
BHC, delta isomer	0.05	1,4-Dichlorobenzene	1
BHC, gamma isomer (Lindane)	0.05	2-Butanone	20
Chlordane	0.2	2-Chloroethylvinylether	20
Dieldrin	0.1	2-Hexanone	20
Endosulfan I	0.05	4-Methyl-2-pentanone	20
Endosulfan II	0.1	Acetone	10
Endosulfan sulfate	0.1	Benzene	1

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

Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>	Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>
<b>EPA Method 624 (cont.)</b>		2,6-Dinitrotoluene	5
Bromodichloromethane	1	2-Chloronaphthalene	5
Bromoform	1	2-Chlorophenol	5
Bromomethane	2	2-Methylphenol	5
Carbon disulfide	1	2-Methyl-4,6-dinitrophenol	25
Carbon tetrachloride	1	2-Methylnaphthalene	5
Chlorobenzene	1	2-Nitroaniline	25
Chloroethane	2	3,3'-Dichlorobenzidine	10
Chloroform	1	3-Nitroaniline	25
Chloromethane	2	4-Bromophenylphenylether	5
<i>cis</i> -1,2-Dichloroethene	1	4-Chloro-3-methylphenol	10
<i>cis</i> -1,3-Dichloropropene	1	4-Chloroaniline	10
Dibromochloromethane	1	4-Chlorophenylphenylether	5
Dibromomethane	1	4-Nitroaniline	25
Dichlorodifluoromethane	2	4-Nitrophenol	25
Ethylbenzene	1	Acenaphthene	25
Freon 113	1	Acenaphthylene	5
Methylene chloride	1	Anthracene	5
Styrene	1	Benzo[ <i>a</i> ]anthracene	5
Tetrachloroethene	1	Benzo[ <i>a</i> ]pyrene	5
Toluene	1	Benzo[ <i>b</i> ]fluoranthene	5
Total xylene isomers	2	Benzo[ <i>g,h,i</i> ]perylene	5
<i>trans</i> -1,2-Dichloroethene	1	Benzo[ <i>k</i> ]fluoranthene	5
<i>trans</i> -1,3-Dichloropropene	1	Benzoic acid	25
Trichloroethene	0.5	Benzyl alcohol	10
Trichlorofluoromethane	1	Bis(2-chloroethoxy)methane	5
Vinyl acetate	1	Bis(2-chloroisopropyl)ether	5
Vinyl chloride	1	Bis(2-ethylhexyl)phthalate	5
<b>EPA Method 625</b>		Butylbenzylphthalate	5
1,2,4-Trichlorobenzene	5	Chrysene	5
1,2-Dichlorobenzene	5	Di- <i>n</i> -butylphthalate	5
1,3-Dichlorobenzene	5	Di- <i>n</i> -octylphthalate	5
1,4-Dichlorobenzene	5	Dibenzo[ <i>a,h</i> ]anthracene	5
2,4,5-Trichlorophenol	5	Dibenzofuran	5
2,4,6-Trichlorophenol	5	Diethylphthalate	5
2,4-Dichlorophenol	5	Dimethylphthalate	5
2,4-Dimethylphenol	5	Fluoranthene	5
2,4-Dinitrophenol	25	Fluorene	5
2,4-Dinitrotoluene	5	Hexachlorobenzene	5

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

Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>	Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>
<b>EPA Method 625 (cont.)</b>		1,1-Dichloroethane	0.5
Hexachlorobutadiene	5	1,1-Dichloroethene	0.5
Hexachlorocyclopentadiene	5	1,2,3-Trichloropropane	0.5
Hexachloroethane	5	1,2-Dibromo-3-chloropropane	0.5
Indeno[1,2,3- <i>c,d</i> ]pyrene	5	1,2-Dichloroethane	0.5
Isophorone	5	1,2-Dichloroethene (total)	0.5
<i>m</i> - and <i>p</i> -Cresol	5	1,2-Dichloropropane	0.5
<i>N</i> -Nitroso-di- <i>n</i> -propylamine	5	2-Butanone	0.5
Naphthalene	5	2-Chloroethylvinylether	0.5
Nitrobenzene	5	2-Hexanone	0.5
Pentachlorophenol	5	4-Methyl-2-pentanone	0.5
Phenanthrene	5	Acetone	10
Phenol	5	Acetonitrile	100
Pyrene	5	Acrolein	50
<b>EPA Method 632</b>		Acrylonitrile	50
Diuron	0.1	Benzene	0.5
<b>EPA Method 8082</b>		Bromodichloromethane	0.5
Polychlorinated biphenyls (PCBs)	0.5	Bromoform	0.5
<b>EPA Method 8140</b>		Bromomethane	0.5
Bolstar	1	Carbon disulfide	5
Chlorpyrifos	1	Carbon tetrachloride	0.5
Coumaphos	1	Chlorobenzene	0.5
Demeton	1	Chloroethane	0.5
Diazinon	1	Chloroform	0.5
Dichlorvos	1	Chloromethane	0.5
Disulfoton	1	Chloroprene	5
Ethoprop	1	Dibromochloromethane	0.5
Fensulfothion	1	Dichlorodifluoromethane	0.5
Fenthion	1	Ethanol	1000
Merphos	1	Ethylbenzene	0.5
Methyl Parathion	1	Freon-113	0.5
Mevinphos	1	Methylene chloride	0.5
Naled	1	Styrene	0.5
Phorate	1	Tetrachloroethene	0.5
Prothiophos	1	Toluene	0.5
Ronnel	1	Total xylene isomers	0.5
Stirophos	1	Trichloroethene	0.5
Trichloronate	1	Trichlorofluoromethane	0.5
<b>EPA Method 8260</b>		Vinyl acetate	20
1,1,1,2-Tetrachloroethane	0.5	Vinyl chloride	0.5
1,1,1-Trichloroethane	0.5	<i>cis</i> -1,2-Dichloroethene	0.5
1,1,2,2-Tetrachloroethane	0.5	<i>cis</i> -1,3-Dichloropropene	0.5
1,1,2-Trichloroethane	0.5	<i>trans</i> -1,2-Dichloroethene	0.5
		<i>trans</i> -1,3-Dichloropropene	0.5

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

Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>	Constituent of concern	Reporting limit (µg/L) <sup>(a,b)</sup>
<b>EPA Method 8290</b>		2,3,7,8-TCDD	0.0001
1,2,3,4,6,7,8-HpCDD	0.00025	2,3,7,8-TCDF	0.0001
1,2,3,4,6,7,8-HpCDF	0.00025	OCDD	0.0005
1,2,3,4,7,8,9-HpCDF	0.00025	OCDF	0.0005
1,2,3,4,7,8-HxCDF	0.00025	EPA Method 8330	5 or 1
1,2,3,6,7,8-HxCDD	0.00025	HMX <sup>(c)</sup>	5 or 1
1,2,3,6,7,8-HxCDF	0.00025	RDX <sup>(d)</sup>	5
1,2,3,7,8,9-HxCDD	0.00025	TNT <sup>(e)</sup>	0.0001
1,2,3,7,8,9-HxCDF	0.00025	<b>EPA Method 9131 or Standard Method 9221</b>	MPN <sup>(f)</sup> /100mL
1,2,3,7,8-PeCDD	0.0001	Fecal coliform bacteria	1 to 2
1,2,3,7,8-PeCDF	0.0001	Total coliform bacteria	1 to 2
2,3,4,6,7,8-HxCDF	0.00025		
2,3,4,7,8-PeCDF	0.0001		

- (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 C-3.** Radioisotopes and reporting limits for gamma spectroscopic analysis of constituents of concern in groundwater.<sup>(a)</sup>

<b>Constituent of concern<sup>(b)</sup></b>	<b>Typical reporting limit (Bq/L)</b>
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 D

### Constituents of Interest, Sampling Frequency, and Discharge Limits for Releases from Lake Haussmann

**Table D-1.** Lake Haussmann 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 <sup>(a)</sup>	WPDC Frequency <sup>(a)</sup>	Discharge limits	
			Dry season <sup>(b)</sup>	Wet season <sup>(c)</sup>
pH (units)	W & D	W & D	6.5–8.5	6.5–8.5
<b>Metals (µg/L)</b>				
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
<b>Organics (µg/L)</b>				
Volatile organic compounds (EPA Method 601)	W	— <sup>(d)</sup>	5	5
1,1-dichloroethane (1,1-DCA)	W	— <sup>(d)</sup>	5	5
1,1-dichloroethylene (1,1-DCE)	W	— <sup>(d)</sup>	5	5
1,2-dichloroethylene (1,2-DCE)	W	— <sup>(d)</sup>	NA	NA
cis-1,2-dichloroethylene (cis-1,2-DCE)	W	— <sup>(d)</sup>	5	5
trans-1,2-dichloroethylene (trans-1,2-DCE)	W	— <sup>(d)</sup>	5	5
1,2-dichloroethane (1,2-DCA)	W	— <sup>(d)</sup>	5	5
Carbon tetrachloride	W	— <sup>(d)</sup>	5	5
Total THM (chloroform, bromoform, chlorodibromomethane, bromodichloromethane)	W	— <sup>(d)</sup>	5	5
Tetrachloroethene	W	— <sup>(d)</sup>	4	4
Trichloroethylene (TCE)	W	— <sup>(d)</sup>	5	5
Vinyl chloride	W	— <sup>(d)</sup>	2	2

**Table D-1 (cont.).** Lake Haussmann 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 <sup>(a)</sup>	WPDC Frequency <sup>(a)</sup>	Discharge limits	
				Dry season <sup>(b)</sup>	Wet season <sup>(c)</sup>
<b>Acute toxicity</b>	Aquatic survival bioassay (96 hours)	W & D	W & D	90% survival median, 90 percentile value of not less than 70% survival	
<b>Chronic toxicity</b>	Fathead minnow	W	— <sup>(d)</sup>	NA	NA
	Water flea	W	— <sup>(d)</sup>	NA	NA
	Green algae	W	— <sup>(d)</sup>	NA	NA
<b>Radiological (pCi/L)</b>	Tritium	W	— <sup>(d)</sup>	20,000	20,000
<b>Special studies or by request of RWQCB</b>	Polychlorinated biphenyls	W & D	— <sup>(d)</sup>	NA	NA
	Herbicides (Bromicil by E507, Glyphosate by E547, Diuron by E632)	CDBX	— <sup>(d)</sup>	NA	NA
	Chemical oxygen demand	CDBX	— <sup>(d)</sup>	NA	NA
	Total organic carbon	CDBX	— <sup>(d)</sup>	NA	NA
<b>Physical</b>	Turbidity (NTU)(e)	W & D	— <sup>(d)</sup>	>15	>15
	Conductivity	W	W	NA	NA
	Total suspended solids	W & D	W & D	NA	NA
	Total dissolved solids	W	W	NA	NA
<b>General minerals</b>	Total alkalinity	W	— <sup>(d)</sup>	NA	NA
	Nitrate (as N)	W	— <sup>(d)</sup>	NA	NA
	Nitrite (as N)	W	— <sup>(d)</sup>	NA	NA
<b>Radiological (Bq/L)</b>	Alpha	W	— <sup>(d)</sup>	0.56	0.56
	Beta	W	— <sup>(d)</sup>	1.85	1.85

(a) W = Monitoring occurs at the first Lake Haussmann 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 E

### Wildlife Survey Results

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

Taxa	Common Name	Scientific Name	Regulatory Status <sup>(a)</sup>	Source
<b>Mammals</b>	Pallid bat	<i>Antrozous pallidus</i>	CASCS	Rainey 2003
	Western red bat	<i>Lasiurus blossevillii</i>		Rainey 2003
	Hoary bat	<i>Lasiurus cinereus</i>		Rainey 2003
	California myotis	<i>Myotis californicus</i>		Rainey 2003
	Western pipistrelle	<i>Pipistrellus hesperus</i>		Rainey 2003
	Brazilian free-tailed bat	<i>Tadarida brasiliensis</i>		Rainey 2003
	Desert cottontail	<i>Sylvilagus audubonii</i>		LLNL 2002; Clark et al. 2002
	Black-tailed jackrabbit	<i>Lepus californicus</i>		LLNL 2002; Clark et al. 2002
	Heermann's kangaroo rat	<i>Dipodomys heermanni</i>		LLNL 2002; West 2002
	California pocket mouse	<i>Chaetodipus californicus</i>	CASCS	LLNL 2002; West 2002
	San Joaquin pocket mouse	<i>Perognathus inornatus</i>		Clark et al. 2002
	California ground squirrel	<i>Spermophilus beecheyi</i>		LLNL 2002
	Valley pocket gopher	<i>Thomomys bottae</i>		LLNL 2002; West 2002
	California vole	<i>Microtus californicus</i>		LLNL 2002; West 2002
	House mouse	<i>Mus musculus</i>		LLNL 2002; West 2002
	Dusky-footed woodrat	<i>Neotoma fuscipes</i>		LLNL 2002; West 2002
	Brush mouse	<i>Peromyscus boylii</i>		LLNL 2002; West 2002
	Deer mouse	<i>Peromyscus maniculatus</i>		LLNL 2002; West 2002
	Western harvest mouse	<i>Reithrodontomys megalotis</i>		LLNL 2002; West 2002
	Coyote	<i>Canis latrans</i>		LLNL 2002; Clark et al. 2002
	Raccoon	<i>Procyon lotor</i>		LLNL 2002; Orloff 1986
	Long-tailed weasel	<i>Mustela frenata</i>		LLNL 2002 ; Orloff 1986
	Striped skunk	<i>Mephitis mephitis</i>		LLNL 2002; Orloff 1986
	Western spotted skunk	<i>Spilogale gracilis</i>		LLNL 2002; Orloff 1986
	American badger	<i>Taxidea taxus</i>	CASCS	LLNL 2002; Clark et al. 2002
	Bobcat	<i>Lynx rufus</i>		LLNL 2002; Clark et al. 2002
	Mountain Lion	<i>Felis concolor</i>		LLNL 2002
	Mule deer	<i>Odocoileus hemionus</i>		LLNL 2002; Clark et al. 2002
	Wild pig	<i>Sus scrofa</i>		LLNL 2002; Clark et al. 2002
	<b>Herpetofauna</b>	Arboreal salamander	<i>Aneides lugubris</i>	
California tiger salamander		<i>Ambystoma californiense</i>	FT, CASCS	LLNL 2002
California red-legged frog		<i>Rana aurora draytonii</i>	FT, CASCS	LLNL 2002
Pacific tree frog		<i>Hyla regilla</i>		LLNL 2002

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

<b>Taxa</b>	<b>Common Name</b>	<b>Scientific Name</b>	<b>Regulatory Status<sup>(a)</sup></b>	<b>Source</b>
<b>Herpetofauna (cont.)</b>	Western spadefoot toad	<i>Spea hammondi</i>	CASCS	LLNL 2002
	Western toad	<i>Bufo boreas</i>		LLNL 2002
	Alameda whipsnake	<i>Masticophis lateralis euryxanthus</i>	FT, ST	Swaim 2002
	San Joaquin coachwhip	<i>Masticophis flagellum</i>	CASCS	LLNL 2002
	Coast horned lizard	<i>Phrynosoma coronatum</i>	CASCS	LLNL 2002
	California legless lizard	<i>Anniella pulchra</i>	CASCS	Swaim 2002
	Side-blotched lizard	<i>Uta stansburiana</i>		LLNL 2002; Swaim 2002
	Western whiptail	<i>Cnemidophorus tigris</i>		LLNL 2002; Swaim 2002
	Western fence lizard	<i>Sceloporus occidentalis</i>		LLNL 2002; Swaim 2002
	Western skink	<i>Eumeces skiltonianus</i>		LLNL 2002; Swaim 2002
	Gilbert skink	<i>Eumeces gilberti</i>		LLNL 2002; Swaim 2002
	Southern alligator lizard	<i>Gerrhonotus multicarinatus</i>		LLNL 2002; Swaim 2002
	Western yellow bellied racer	<i>Coluber constrictor</i>		LLNL 2002; Swaim 2002
	Pacific gopher snake	<i>Pituophis melanoleucus</i>		LLNL 2002; Swaim 2002
	Common kingsnake	<i>Lampropeltis getulus</i>		LLNL 2002; Swaim 2002
	Western rattlesnake	<i>Crotalus viridis</i>		LLNL 2002; Swaim 2002
	Night snake	<i>Hypsiglena torquata</i>		LLNL 2002; Swaim 2002
	Glossy snake	<i>Arizona elegans</i>		LLNL 2002; Swaim 2002
	Long-nosed snake	<i>Rhinocheilus lecontei</i>		LLNL 2002; Swaim 2002
	California black-headed snake	<i>Tantilla planiceps</i>		Swaim 2002
<b>Birds</b>	Cooper's Hawk	<i>Accipiter cooperii</i>	CASCS, MBTA	LLNL 2003
	Sharp-shinned Hawk	<i>Accipiter striatus</i>	CASCS, MBTA	LLNL 2003
	Golden Eagle	<i>Aquila chrysaetos</i>	CAFPS, CASCS, MBTA	LLNL 2003
	Red-tailed Hawk	<i>Buteo jamaicensis</i>	MBTA	LLNL 2003
	Rough-legged Hawk	<i>Buteo lagopus</i>	MBTA	LLNL 2003
	Red-shouldered Hawk	<i>Buteo lineatus</i>	MBTA	LLNL 2003
	Ferruginous Hawk	<i>Buteo regalis</i>	CASCS, MBTA	LLNL 2003
	Swainson's Hawk	<i>Buteo swainsoni</i>	ST, MBTA	LLNL 2003
	Northern Harrier	<i>Circus cyaneus</i>	CASCS, MBTA	LLNL 2003
	White-tailed Kite	<i>Elanus leucurus</i>	CAFPS, MBTA	LLNL 2003
	Osprey	<i>Pandion haliaetus</i>	CASCS, MBTA	LLNL 2003
	Bushtit	<i>Psaltriparus minimus</i>	MBTA	LLNL 2003
	Horned Lark	<i>Eremophila alpestris</i>	CASCS, MBTA	LLNL 2003
	Northern Shoveler	<i>Anas clypeata</i>	MBTA	LLNL 2003
	Cinnamon Teal	<i>Anas cuamptera</i>	MBTA	LLNL 2003

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

Taxa	Common Name	Scientific Name	Regulatory Status <sup>(a)</sup>	Source
Birds (cont.)	Mallard	<i>Anas platyrhynchos</i>	MBTA	LLNL 2003
	Bufflehead	<i>Bucephala albeola</i>	MBTA	LLNL 2003
	Common Goldeneye	<i>Bucephala clangula</i>	MBTA	LLNL 2003
	White-throated Swift	<i>Aeronautes saxatalis</i>	MBTA	LLNL 2003
	Great Egret	<i>Ardea alba</i>	MBTA	LLNL 2003
	Virginia Rail	<i>Rallus limicola</i>	MBTA	U.S. DOE and UC 1992
	Cedar Waxwing	<i>Bombycilla garrulus</i>	MBTA	LLNL 2003
	Common Poorwill	<i>Phalaenoptilus nuttallii</i>	MBTA	LLNL 2003
	Blue-grosbeak	<i>Guiraca caerulea</i>	MBTA	LLNL 2003
	Black-headed Grosbeak	<i>Pheucticus melanocephalus</i>	MBTA	U.S. DOE and UC 1992
	Lazuli Bunting	<i>Passerina amoena</i>	MBTA	LLNL 2003
	Turkey Vulture	<i>Cathartes aura</i>	MBTA	LLNL 2003
	Killdeer	<i>Charadrius vociferus</i>	MBTA	LLNL 2003
	Rock Dove	<i>Columba livia</i>		U.S. DOE and UC 1992
	Mourning Dove	<i>Zenaida macroura</i>	MBTA	LLNL 2003
	Western Scrub Jay	<i>Aphelocoma californica</i>	MBTA	LLNL 2003
	American Crow	<i>Corvus brachyrhynchos</i>	MBTA	LLNL 2003
	Common Raven	<i>Corvus corax</i>	MBTA	LLNL 2003
	Greater Roadrunner	<i>Geococcyx californianus</i>	MBTA	LLNL 2003
	Bell's Sage Sparrow	<i>Amphispiza belli</i>	CASCS, MBTA	LLNL 2003
	Black-throated Sparrow	<i>Amphispiza bilineata</i>	MBTA	LLNL 2003
	Rufous Crowned Sparrow	<i>Aimophila ruficeps</i>	MBTA	LLNL 2003
	Grasshopper Sparrow	<i>Ammodramus savannarum</i>	MBTA	LLNL 2003
	Lark Sparrow	<i>Chondestes grammacus</i>	MBTA	LLNL 2003
	California Towhee	<i>Carpodacus mexicanus</i>	MBTA	LLNL 2003
	Oregon Junco	<i>Junco hyemalis</i>	MBTA	LLNL 2003
	Lincoln's Sparrow	<i>Melospiza lincolni</i>	MBTA	LLNL 2003
	Song Sparrow	<i>Melospiza melodia</i>	MBTA	LLNL 2003
	Vesper Sparrow	<i>Pooecetes gramineus</i>	MBTA	U.S. DOE and UC 1992
	Fox Sparrow	<i>Passerella iliaca</i>	MBTA	LLNL 2003
	Savannah Sparrow	<i>Passerculus sandwichensis</i>	MBTA	LLNL 2003
	Golden-crowned Sparrow	<i>Zonotrichia atricapilla</i>	MBTA	LLNL 2003
	White-crowned Sparrow	<i>Zonotrichia leucophrys</i>	MBTA	LLNL 2003
	American Kestrel	<i>Falco sparverius</i>	MBTA	LLNL 2003
	Prairie Falcon	<i>Falca mexicanus</i>	CASCS, MBTA	LLNL 2003
	House Finch	<i>Carpodacus mexicanus</i>	MBTA	LLNL 2003

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

Taxa	Common Name	Scientific Name	Regulatory Status <sup>(a)</sup>	Source
<b>Birds (cont.)</b>	Lesser Goldfinch	<i>Carduelis psaltia</i>	MBTA	LLNL 2003
	Cliff Swallow	<i>Petrochelidon pyrrhonota</i>	MBTA	LLNL 2003
	Northern Rough Winged Swallow	<i>Stelgidopteryx serripennis</i>	MBTA	LLNL 2003
	Tree Swallow	<i>Tachycineta bicolor</i>	MBTA	LLNL 2003
	Red-winged Blackbird	<i>Agelaius phoeniceus</i>	MBTA	LLNL 2003
	Tricolored Blackbird	<i>Agelaius tricolor</i>	CASCS, MBTA	LLNL 2003
	Brewer's Blackbird	<i>Euphagus cyanocephalus</i>	MBTA	LLNL 2003
	Bullock's Oriole	<i>Icterus bullockii</i>	MBTA	LLNL 2003
	Brown-headed Cowbird	<i>Molothrus ater</i>	MBTA	LLNL 2003
	Western Meadowlark	<i>Sturnella magna</i>	MBTA	LLNL 2003
	Loggerhead Shrike	<i>Lanius ludovicianus</i>	CASCS, MBTA	LLNL 2003
	Northern Mockingbird	<i>Mimus polyglottos</i>	MBTA	LLNL 2003
	California Thrasher	<i>Toxostoma redivivum</i>	MBTA	LLNL 2003
	California Quail	<i>Callipepla californica</i>		LLNL 2003
	Oak Titmouse	<i>Baeolophus inornatus</i>	FSC, MBTA	LLNL 2003
	Yellow-rumped Warbler	<i>Dendroica coronata</i>	MBTA	LLNL 2003
	Black-throated Gray Warbler	<i>Dendroica nigrescens</i>	MBTA	LLNL 2003
	Yellow Warbler	<i>Dendroica petechia</i>	CASCS, MBTA	LLNL 2003
	Common Yellowthroat	<i>Geothlypis trichas</i>	CASCS, MBTA	LLNL 2003
	MacGillivray's Warbler	<i>Oporornis tolmiei</i>	MBTA	LLNL 2003
	Orange-crowned Warbler	<i>Vermivora bachmanii</i>	MBTA	LLNL 2003
	Wilson's Warbler	<i>Wilsonia pusila</i>	MBTA	LLNL 2003
	Double-crested Cormorant	<i>Phalacrocorax auritus</i>	CASCS, MBTA	LLNL 2003
	Wild Turkey	<i>Meleagris gallopavo</i>		LLNL 2003
	Northern Flicker	<i>Colaptes auratus</i>	MBTA	LLNL 2003
	Nuttall's Woodpecker	<i>Picoides nuttallii</i>	MBTA	LLNL 2003
	Acorn Woodpecker	<i>Melanerpes formicivorus</i>	MBTA	U.S. DOE and UC 1992
	Pied-billed Grebe	<i>Podilymbus podiceps</i>	MBTA	LLNL 2003
	Phainopepla	<i>Phainopepla nitens</i>	MBTA	LLNL 2003
	Ruby-crowned Kinglet	<i>Regulus calendula</i>	MBTA	LLNL 2003
	Common Snipe	<i>Gallinago gallinago</i>	MBTA	LLNL 2003
	Greater Yellowlegs	<i>Tringa melanoleuca</i>	MBTA	LLNL 2003
	Burrowing Owl	<i>Athene cunicularia</i>	CASCS, MBTA	LLNL 2003
	Short-eared Owl	<i>Asio flammeus</i>	CASCS, MBTA	LLNL 2003
	Great horned Owl	<i>Bubo virginianus</i>	MBTA	LLNL 2003
	Western Screech Owl	<i>Otus kennicottii</i>	MBTA	LLNL 2003

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

Taxa	Common Name	Scientific Name	Regulatory Status <sup>(a)</sup>	Source
<b>Birds (cont.)</b>	European Starling	<i>Sturnus vulgaris</i>		LLNL 2003
	Western Tanager	<i>Piranga ludoviciana</i>	MBTA	LLNL 2003
	Anna's Hummingbird	<i>Calypte anna</i>	MBTA	LLNL 2003
	Costa's Hummingbird	<i>Calypte costae</i>	MBTA	LLNL 2003
	Rufous Hummingbird	<i>Selasphorus rufus</i>	MBTA	LLNL 2003
	Allen's Hummingbird	<i>Selasphorus sasin</i>	MBTA	U.S. DOE and UC 1992
	Rock Wren	<i>Salpinctes obsoletus</i>	MBTA	LLNL 2003
	Bewick's Wren	<i>Thyothorus ludovicianus</i>	MBTA	LLNL 2003
	House Wren	<i>Troglodytes aedon</i>	MBTA	LLNL 2003
	Hermit Thrush	<i>Catharus guttatus</i>	MBTA	LLNL 2003
	Swainson's Thrush	<i>Catharus ustulatus</i>	MBTA	LLNL 2003
	Varied Thrush	<i>Ixoreus naevius</i>	MBTA	LLNL 2003
	Mountain Bluebird	<i>Sialia currucoides</i>	MBTA	LLNL 2003
	Western Buebird	<i>Sialia mexicana</i>	MBTA	LLNL 2003
	American Robin	<i>Turdus migratorius</i>	MBTA	LLNL 2003
	Pacific-slope Flycatcher	<i>Empidonax difficillis</i>	MBTA	LLNL 2003
	Willow Flycatcher	<i>Empidonax traillii</i>	SE, MBTA	van Hattem 2005
	Ash-throated Flycatcher	<i>Myiarchus cinerascens</i>	MBTA	LLNL 2003
	Western Wood-pewee	<i>Contopus sordidulus</i>	MBTA	U.S. DOE and UC 1992
	Black Phoebe	<i>Sayornis nigricans</i>	MBTA	LLNL 2003
	Say's Phoebe	<i>Sayornis saya</i>	MBTA	LLNL 2003
	Western Kingbird	<i>Tyrannus verticalis</i>	MBTA	LLNL 2003
	Cassin's Kingbird	<i>Tyrannus vociferans</i>	MBTA	LLNL 2003
	Barn Owl	<i>Tyto alba</i>	MBTA	LLNL 2003
<b>Invertebrates</b>	Valley elderberry longhorn beetle	<i>Desmocerus californicus dimorphus</i>	FT	Arnold 2002
	California fairy shrimp	<i>Linderiella occidentalis</i>		Weber 2002
	California clam shrimp	<i>Cyzicus californicus</i>		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 F

### Extra Resources

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

#### [Livermore Site Storm Water Monitoring for Waste Discharge Requirements 95-174, 2005–2006](#)

Campbell, C.G. and K. Brunckhorst. (2006). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174, Annual Report 2005-2006*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-126783-06.

#### [Livermore Site Storm Water Monitoring for Waste Discharge Requirements 95-174, 2006–2007](#)

Campbell, C.G. and K. Brunckhorst. (2007). *Lawrence Livermore National Laboratory Livermore Site Annual Storm Water Monitoring Report for Waste Discharge Requirements 95-174, Annual Report 2006-2007*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-126783-07.

#### [LLNL Ground Water Project Annual Report, 2006](#)

Karachewski, J., M. Dresen, L. Berg, E. Folsom, and J. Coty, eds. (2007). *LLNL Ground Water Project 2006 Annual Report*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-126020-06.

#### [LLNL NESHAPs Annual Report, 2006](#)

Larson, J.M., S.R. Peterson, and K.R. Wilson. (2007). *LLNL NESHAPs 2006 Annual Report*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-TR-113867-07.

#### [Site 300 Building 829 Compliance Monitoring Annual Report, 2006](#)

Revelli, M.A. (2007). *Lawrence Livermore National Laboratory Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2006*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-143121-06.

#### [Site 300 Compliance Monitoring Annual Report, 2006](#)

Dibley, V., M. Taffet, J. Valett, M. Denton, S. Gregory, T. Carlsen, Z. Demir, W. Daily, D. Mason, P. McKereghan, R. Goodrich, and S. Chamberlain. (2007). *2006 Annual Monitoring Compliance Report for Lawrence Livermore National Laboratory Site 300*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-206319-06.

#### [Site 300 Compliance Monitoring for Waste Discharge Requirements 96-248 Annual Report, 2006](#)

Brown, R. (2007). *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2006*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-125915-06-4.

#### [Site 300 Storm Water Monitoring for Waste Discharge Requirements 97-03-DWQ Annual Report, 2006](#)

Brown, R. (2006). *Lawrence Livermore National Laboratory Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ, Annual Report 2005–2006*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-144362-06.

#### [Site 300 Storm Water Monitoring for Waste Discharge Requirements 97-03-DWQ Annual Report, 2007](#)

Brown, R. (2007). *Lawrence Livermore National Laboratory Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ, July 2007*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-144362-07.

#### [Site 300 Pit 6 Compliance Monitoring Annual Report, 2006](#)

Campbell, C. and M.J. Taffet. (2007). *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report for 2006*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-AR-132057-06-4.

#### [Site 300 Pits 1 and 7 Compliance Monitoring Annual Report, 2006](#)

Campbell, C. and D.H. MacQueen. (2007). *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2006*. Livermore, California: Lawrence Livermore National Laboratory, UCRL-10191-06-4.

#### [Supplementary Topics on Radiological Dose](#)

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

## APPENDIX G

### Errata

#### Protocol for Errata in LLNL Environmental Reports

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

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

LLNL environmental reports from 1994 through 2006 can be accessed at <http://www.llnl.gov/saer>.

#### Record of Changes to Environmental Reports 2004 and 2005

The following changes have been made to the Internet version of *Environmental Report 2004* and *Environmental Report 2005*. Additional errata for *Environmental Report 2004* are listed in *Environmental Report 2005*, Appendix D.

- “Derived Concentration Guide of  $2.7 \times 10^6$  mBq/m<sup>3</sup> for tritium in air” changed to “Derived Concentration Guide of  $3.7 \times 10^6$  mBq/m<sup>3</sup> for tritium in air” in:
  - *Environmental Report 2004*, Data Workbooks, Ch3 Ambient Air, Worksheets at-ls (tritium concentration in air on the Livermore site, 2004), footnote (d); at-s3 (tritium concentration in air, Site 300, 2004), footnote (c); and at-val (tritium concentration in air, Livermore Valley, 2004), footnote (d)
  - *Environmental Report 2005*, Data Workbooks, Ch4 Ambient Air, Worksheets at-ls (tritium concentrations in air on the Livermore site, 2005), footnote (e); at-s3 (tritium concentrations in air, Site 300, 2005), footnote (d); and at-val (tritium concentrations in air, Livermore Valley, 2005), footnote (e)



## READER SURVEY

### Lawrence Livermore National Laboratory Environmental Report 2006

The purposes of this annual report are to record LLNL's compliance with environmental standards and requirements, describe LLNL's environmental protection and remediation programs, and present the results of environmental monitoring at the two LLNL sites—the Livermore site and Site 300.

We strive to provide information that is understandable and clear and that communicates effectively the Laboratory's efforts to protect human health and the environment. We also try to make the electronic version of the report and the website where it is posted (<http://www.llnl.gov/saer/>) as user friendly as possible. Your feedback on this survey will help us gauge how successful we have been.

Your input will be carefully considered.

I  have  do not have technical knowledge in the environmental sciences.

The technical level was  too high  too low  inconsistent  just right.

The background information was  sufficient  insufficient  inconsistent  just right.

The writing was  too wordy  inconsistent  just right.

The illustrations and tables were  helpful  difficult to understand.

I  did  did not use the glossary.

If yes, the glossary  had  did not have what I was looking for.

I  did  did not access the report from the website.

If yes, I found the website navigation tools to be  sufficient  insufficient.

If yes, I found the navigation tools in the report to be  sufficient  insufficient.

I read the report  on screen  as a printed copy  on screen and as a printed copy.

I  did  did not print any or all of the report.

If yes, I  did  did not have problems printing.

Comments:

---

---

---

---

Thank you very much for completing the survey. Please return to:

Diana Burke, L-633  
Lawrence Livermore National Laboratory  
P.O. Box 808  
Livermore, CA 94551-0808

