Title
Site environmental report for 2003, Volume 1

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ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Site Environmental Report for 2003

Volume 1

Environment, Health, and Safety Division

July 2004

DISCLAIMER

Site Environmental Report for 2003

Volume I

JULY 2004

Ernest Orlando Lawrence Berkeley National Laboratory

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Preface

Each year, Ernest Orlando Lawrence Berkeley National Laboratory prepares an integrated report on its environmental programs to satisfy the requirements of United States Department of Energy Order 231.1, *Environment, Safety, and Health Reporting*.[1] The *Site Environmental Report for 2003* summarizes Berkeley Lab's environmental management performance, presents environmental monitoring results, and describes significant programs for calendar year 2003. (Throughout this report, Ernest Orlando Lawrence Berkeley National Laboratory is referred to as "Berkeley Lab," "the Laboratory," "Lawrence Berkeley National Laboratory," and "LBNL.")

The report is separated into two volumes. Volume I contains an overview of the Laboratory, the status of environmental programs, and summarized results from surveillance and monitoring activities. Volume II contains individual data results from these activities. This year, the *Site Environmental Report* was distributed on a CD as a PDF file that includes Volumes I and II and related documents. Both volumes of this report can be accessed on the Web from the Berkeley Lab Environmental Services Group (ESG) home page, which is located at http://www.lbl.gov/ehs/esg/. Many of the documents cited in this report are also accessible from the ESG Web page.

The report follows the Laboratory's policy of using the International System of Units (SI), also known as the metric system of measurements. Whenever possible, results are also reported using the more conventional (non-SI) system of measurements because it is referenced by several current regulatory standards and is more familiar to some readers. Two tables are provided at the end of the Glossary to help readers understand the prefixes used with SI units of measurement and conversions to non-SI units.

Readers are encouraged to comment on this report by completing either the survey card included with the distributed CD, or the survey form in the Web version of the report. Questions regarding this report can be directed to Michael Ruggieri (telephone: 510-486-5440; e-mail: mrruggieri@lbl.gov).

This report was prepared under the direction of Michael Ruggieri of ESG. The primary authors are Robert Fox, Iraj Javandel, Ginny Lackner, Michael Ruggieri, Patrick Thorson, and Linnea Wahl. Other key contributors include Steve Wyrick (Volume II and illustration support), Teresa Grossman (word processing and illustration support), and Netty Kahan (technical editing).

Cheryl Ventimiglia of Berkeley Lab managed the Technical and Electronic Information Department's support of the report, provided by Faye Jobes (printing and copy services), Flavio Robles Jr. (cover illustrations), and Robert Couto (photography).

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1

Executive Summary

The cupola of the Advanced Light Source with the city of San Francisco displayed in the background

1.1 INTRODUCTION

Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is a multiprogram scientific facility operated by the University of California for the Department of Energy (DOE). The Laboratory's research is directed toward the physical, biological, environmental, and computational sciences—in order to deliver the scientific knowledge and discoveries pertinent to DOE's missions (for more details, see Section 2.1).

To provide the highest degree of protection for its workers, the public, and the environment, Berkeley Lab employs a system called Integrated Safety Management (ISM). ISM is a comprehensive DOE management system that involves five core functions: work planning, hazard and risk analysis, establishment of controls, work performance in accordance with the controls, and feedback and improvement. These five core functions are applied to all activities at Berkeley Lab. (For further information, see Section 3.2.) Laboratory activities are planned and conducted with full regard to protecting the public and the environment and complying with appropriate environmental laws and regulations. Both radiological and nonradiological activities are thoroughly monitored to assess their potential impacts on public health and the environment.

Berkeley Lab has committed to developing a focused Environmental Management System (EMS), which will be integrated with the Lab's ISM System. When practical, ISM processes will be used to support environmental performance improvement and compliance management. In calendar year (CY) 2003, Berkeley Lab developed an EMS action plan, which was submitted to DOE, and program implementation began. To that end, training was provided to an EMS Core Team that was formed and to Environment, Health, and Safety Division staff who will support the Laboratory's EMS efforts. Implementation of the EMS will continue in CY 2004.

This annual *Site Environmental Report* covers activities conducted in CY 2003. The format and content of this report satisfy the requirements of DOE Order 231.1, *Environment, Safety, and Health Reporting,*[1] and the operating contract between the University of California Office of the President (UCOP) and DOE.[2]

1.2 OPERATING PERMITS

At the end of CY 2003, Berkeley Lab held the following 48 environmental operating permits from various regulatory agencies:

- Air emission sources (35)
- Hazardous waste handling and treatment operations (2)
- Stormwater discharges (2)
- Underground storage tanks (6)
- Wastewater discharges (3)

For further discussion of these permits, see Chapter 3.

1.3 INSPECTIONS

Nineteen inspections of Berkeley Lab's environmental programs occurred during CY 2003. Two minor violations were issued by the California Department of Toxic Substances Control; the violations were cited in the June 2003 inspection report and pertained to storage of waste containers at generator sites for more than one year.[3] For more details, see Section 3.4.4.1.

1.4 INCIDENT TRACKING

In 2003, there were no environmental incidents reportable under the DOE occurrence-reporting program used to track incidents across the DOE complex.

1.5 PERFORMANCE EVALUATION

Each year, UCOP and DOE perform an assessment of Berkeley Lab's environmental program, using measures developed jointly by Berkeley Lab, UCOP, and DOE.[4] In 2003, there were four environmental performance measures. Table 1-1 summarizes these measures and shows the ratings received from both UCOP and DOE.

Table 1-1 Environmental Performance Measure Ratings for 2003

Performance measure	UCOP rating	DOE rating
Tracking of environmental incidents	Outstanding	Outstanding
Waste reduction and recycling	Excellent	Excellent
Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
Completion of milestones for an Environmental Management System	Outstanding	Outstanding

For additional information on the performance review program, see Section 3.5.

1.6 ENVIRONMENTAL MONITORING

Berkeley Lab's environmental monitoring program serves several purposes:

- To demonstrate that Laboratory activities operate within regulatory and DOE requirements
- To provide a historical record of any Laboratory impacts on the environment
- To support environmental management decisions
- To provide information on the effectiveness of emission control programs

Both radiological and nonradiological contaminants are monitored in the local environment.[5] Sections 1.6.1 and 1.6.2 briefly summarize environmental monitoring results from CY 2003.

1.6.1 Radiological Monitoring

A significant portion of the environmental monitoring program measures radiological impacts from Laboratory activities. The Laboratory monitors and assesses two types of radiation: (1) direct penetrating radiation (gamma and neutron) from sources such as accelerators and (2) dispersible radionuclides from a wide range of Laboratory research activities. Specially designed shielding reduces the release of penetrating radiation into the environment, and capture systems minimize releases of dispersible radionuclides to the atmosphere. Discharges to the sanitary sewer are minimized by using strict administrative controls.

The primary radiological compliance standards affecting the Laboratory are based on the maximum potential dose that a member of the public would receive from both direct penetrating radiation and dispersible radionuclides from the site. During the past years, penetrating radiation doses due to Laboratory activities have trended down and have approached levels that are not discernible from natural background. In 2003, the maximum dose to a member of the public from direct radiation was 0.002 millisieverts (mSv) (0.2 millirem [mrem]) for a person residing near the 88-inch Cyclotron. This dose is 0.2% of the applicable DOE radiological standard of 1 mSv per year (mSv/yr) (100 mrem/yr)[6].

Dispersible radionuclide emission sources are regulated by the United States Environmental Protection Agency (US/EPA). US/EPA has set 0.1 mSv/yr (10 mrem/yr)[7] as the maximum allowable dose to the public from all exposure pathways (e.g., inhalation, ingestion, and skin absorption) resulting from airborne releases of radionuclides from a site. The maximum potential dose is based on a hypothetical member of the public who resides at the location of the Lawrence Hall of Science. The estimated maximum potential dose from all airborne radionuclides released from the Laboratory site in CY 2003 was 0.0001 mSv (0.01 mrem), with fluorine-18 accounting for 73% of that amount. This is 0.1% of the US/EPA dose limit for dispersible radionuclide emissions. See Figure 1-1.

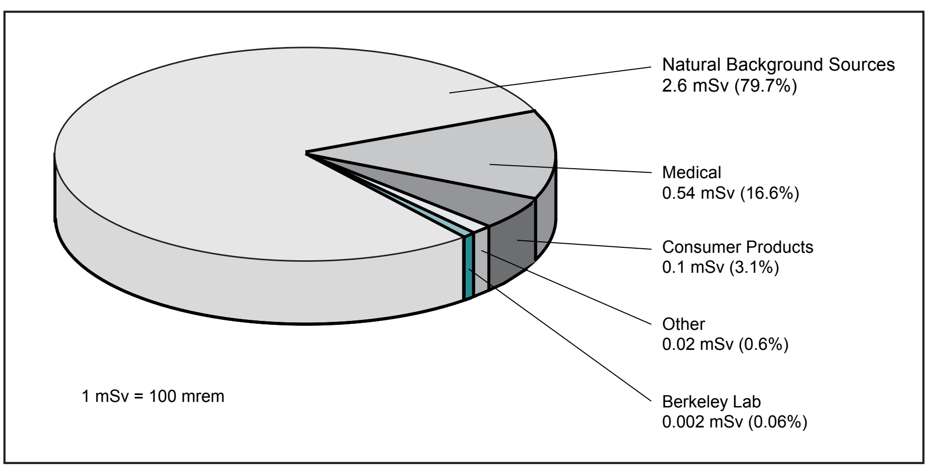


Figure 1-1 Typical Radiation Doses Received by the Public, Including Maximum Contribution from Berkeley Lab

Berkeley Lab also estimates the cumulative dose impact (collective effective dose equivalent) from its dispersible radionuclide emissions to the entire population found within an 80-kilometer (50-mile) radius of the Laboratory. This measure is the sum of all individual doses to the population residing or working within 80 kilometers of the Laboratory. The collective population dose for CY 2003 from dispersible radionuclide emissions was estimated at 0.002 person-sieverts (0.2 person-rem) (see Glossary). No regulatory standard exists for this measure.

For further discussion of the estimated dose impacts to the neighboring community from both direct and dispersible radiation, see Chapter 9.

1.6.2 Nonradiological Monitoring

Berkeley Lab's nonradiological monitoring program focuses primarily on water, soil, and sediment. (These environmental media types are also analyzed for radiological components.)

In compliance with the three wastewater discharge permits[8] issued to the Laboratory by the East Bay Municipal Utility District, Berkeley Lab samples for metals, chlorinated hydrocarbons, and other specified parameters in sanitary sewer discharges. All results were well within compliance limits in 2003. For details on the wastewater discharge sampling program, see Chapter 5.

Stormwater discharges at Berkeley Lab are regulated under a general permit[9] issued by the State Water Resources Control Board. Stormwater discharges are treated differently from wastewater in that no specific discharge limits are established in the permit. References in the permit to the limits set by the Water Quality Control Plan[10] for the San Francisco Bay Basin are intended as guidelines rather than measures of compliance for stormwater discharges. Berkeley Lab analyzes stormwater samples for a wide set of potential contaminants, including pH, oil and grease, total suspended solids, and some metals. All results for the year were below or near sample detection limits. For the results from stormwater sampling efforts throughout the year (along with the results from the routine sampling of rainwater and creeks), see Chapter 5.

Extensive groundwater monitoring has been conducted by Berkeley Lab since the early 1990s, and nine groundwater plumes have been identified. All these plumes are on-site. The groundwater in the vicinity of the Laboratory is not used for public drinking water. Four types of contaminant plumes exist on-site:

- Volatile organic compounds (five plumes)
- Petroleum hydrocarbon (two plumes)
- Freon (one plume)
- Tritium (one plume)

Berkeley Lab's Environmental Restoration Program is conducted under the requirements of the Resource Conservation and Recovery Act (RCRA) Corrective Action Program (see Chapter 6). An RCRA Facility Investigation was performed that evaluated 166 locations. Based on the results of the RCRA Facility Investigation, the Department of Toxic Substances Control (DTSC) determined that at 121 of the 166 locations there were either no chemical releases or the chemical concentration levels were low enough that no further action was needed. At the remaining 45 locations, human health and ecological risk assessments were performed in 2003. The risk assessments identified 4 areas of soil contamination and 11 areas of groundwater contamination that may require cleanup. An evaluation of potential cleanup measures has been performaed, and in 2004, Berkeley Lab will deliver to DTSC a draft report that identifies proposed final remedies for its review and approval.

The Laboratory continues to monitor these plumes while it develops long-term strategies to address the contamination. Until the Laboratory can implement these strategies, it has initiated several interim corrective-action measures to remediate the contaminated media or prevent movement of contamination. Concentrations of groundwater contaminants, along with other program developments and planned activities, are reported quarterly to regulatory agencies. For further information, see Chapter 6.

The soil and sediment monitoring program analyzes samples for metals, pH, and organic compounds at locations that complement sampling in other media such as air and surface water. Similar to results reported for other programs, most samples were below or near analytical detection limits. The exceptions were results for oil and grease in sediment samples collected near roadways and parking lots, and some mercury concentrations in soil at one location. In all instances, levels of contaminants were within regulatory limits. The levels of oil and grease in sediment measured at Berkeley Lab are typical for an urban setting. The level of mercury in soil at one location was slightly above established background values for the Berkeley Lab site.[11] Berkeley Lab will continue to monitor these locations. For more information on Berkeley Lab's soil and sediment monitoring, see Chapter 7.

2

Introduction

The Laboratory site and local environs in the Berkeley / Oakland Hills

2.1 HISTORY

Lawrence Berkeley National Laboratory was founded by Ernest O. Lawrence in 1931. Lawrence received the 1939 Nobel Prize in physics for his invention of the cyclotron (particle accelerator), and is generally credited with the modern concept of interdisciplinary science, in which scientists, engineers, and technicians from different fields work together on complex scientific projects addressing national needs and programs. Lawrence's pioneering work established a great tradition of scientific inquiry and discovery at the Laboratory, leading to the awarding of Nobel Prizes to eight more Berkeley Lab scientists.

The Laboratory supports work in such diverse fields as genomics, physical biosciences, life sciences, fundamental physics, accelerator physics and engineering, energy conservation technology, and materials science. Through its fundamental research in these fields, Berkeley Lab has achieved international recognition for its leadership and made numerous contributions to national programs. Its research embraces the United States Department of Energy (DOE) mission concepts of (1) exploring the complexity of energy and matter, (2) advancing the science needed to attain abundant clean energy, (3) understanding energy impacts on our living planet, and (4) providing extraordinary tools for multidisciplinary research.

Since its beginning, Berkeley Lab has been managed by the University of California (UC) Office of the President. Numerous Berkeley Lab scientists are faculty members on the campuses of either UC Berkeley or UC San Francisco. They and other Berkeley Lab researchers guide the work of graduate students pursuing advanced degrees through research at the Laboratory. High school students and teachers, as well as college and graduate students, participate in many Berkeley Lab programs designed to enhance science education.

2.2 LABORATORY

The following sections describe the physical location, population, space distribution, and water supply at Berkeley Lab.

2.2.1 Location

Berkeley Lab is located about 5 kilometers (km) (3 miles [mi]) east of San Francisco Bay (see Figure 2-1) on land owned by the University of California. The Laboratory's main site is situated on approximately 82 hectares (200 acres) of this land. The University of California provides long-term land leases to the DOE for its buildings at the Laboratory.

The main site lies in the hills above the UC Berkeley campus, on the ridges and draws of Blackberry Canyon (which forms the western part of the site) and adjacent Strawberry Canyon

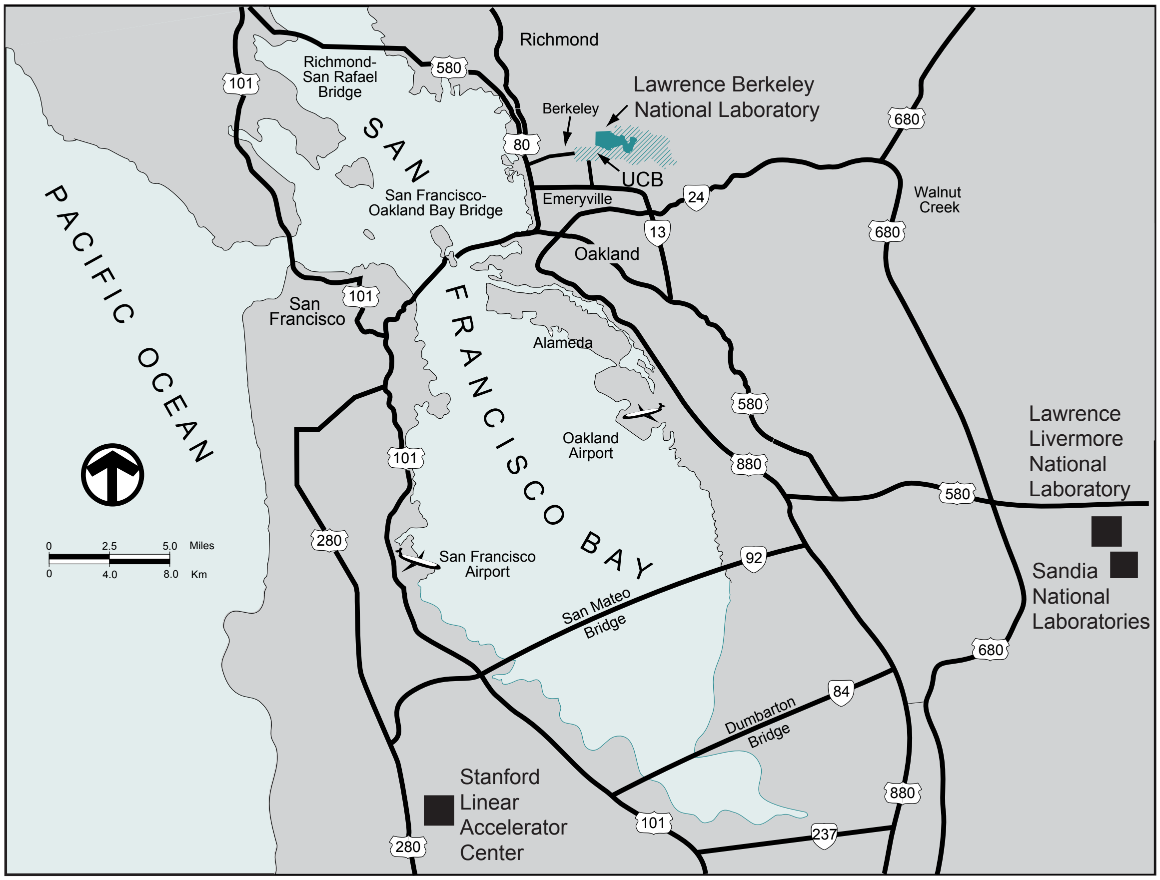
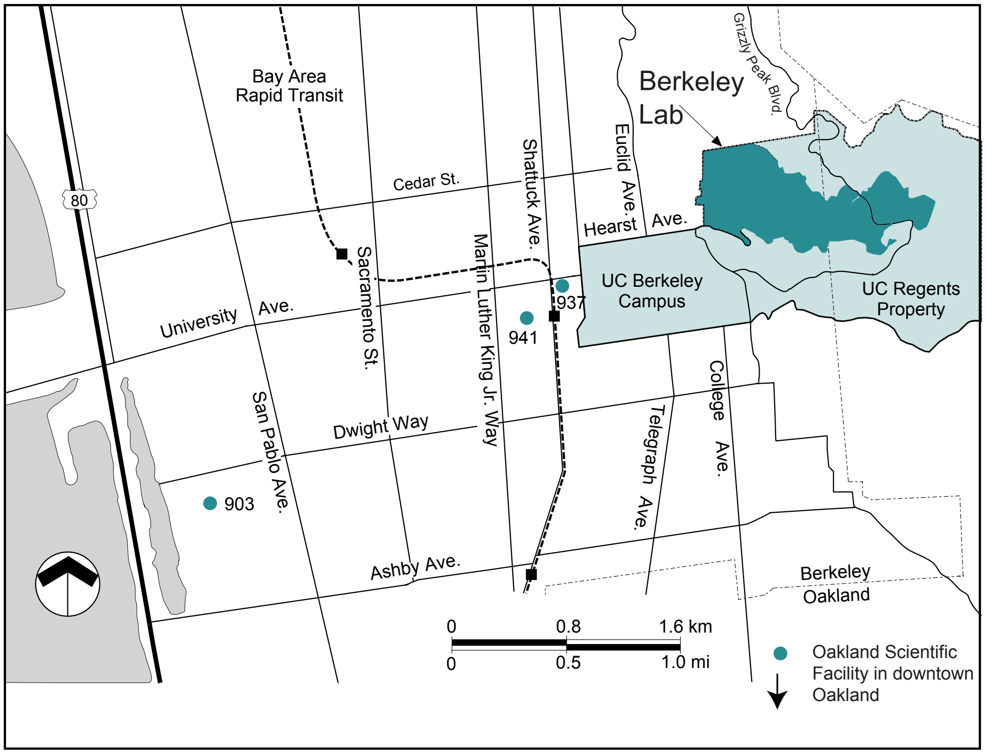


Figure 2-1 San Francisco Bay Area Map

(which forms the eastern part of the site), with elevations ranging from 135 to 350 meters (m) (450 to 1,150 feet [ft]) above sea level. The western portion of the site is in Berkeley, with the eastern portion in Oakland (see Figure 2-2). The population of Berkeley is estimated at 102,743, and that of Oakland at 370,736.[1]

Adjacent land use consists of residential, institutional, and recreation areas (see Figure 2-3). The area to the south and east of the Laboratory, which is University land, is maintained largely in a natural state but includes UC Berkeley's Strawberry Canyon Recreational Area and Botanical Garden. Northeast of the Laboratory are the University's Lawrence Hall of Science, Space Sciences Laboratory, and Mathematical Sciences Research Institute. Berkeley Lab is bordered on the north by single-family homes and on the west by the UC Berkeley campus, as well as by multiunit dwellings, student residence halls, and private homes. The area to the west of Berkeley Lab is highly urbanized.



Note: 903, 937, and 941 are Berkeley Lab off-site buildings.

Figure 2-2 Vicinity Map

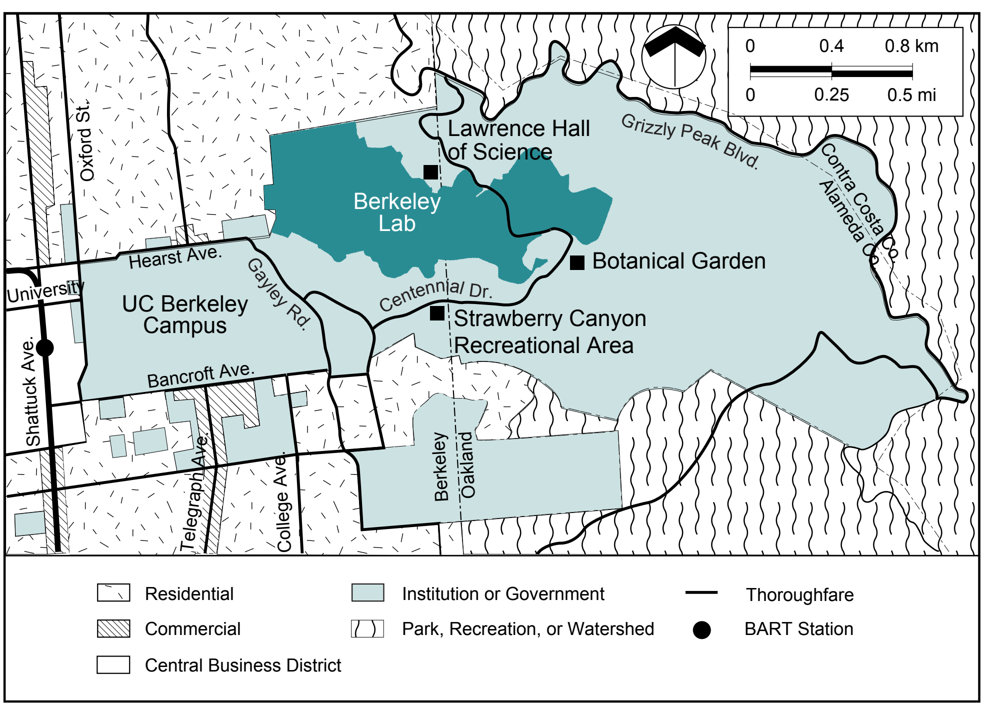


Figure 2-3 Adjacent Land Use

2.2.2 Population and Space Distribution

Approximately 3,900 scientists and support personnel work at Berkeley Lab, including about 600 students. In addition, the Laboratory hosts 2,000 participating guests each year, who use its unique scientific facilities for varying lengths of time. Berkeley Lab also supports 300 scientists and staff at off-site locations, including Walnut Creek, Oakland, and Washington, D.C. Approximately 300 of the Laboratory's scientists serve as faculty members at UC Berkeley and UC San Francisco.[2]

Berkeley Lab research and support activities are conducted in structures having a total area of 202,000 gross square meters (2.18 million gross square feet). About 81% of the total space is at the main site, 3% is on the UC Berkeley campus (i.e., Donner and Calvin Laboratories), and the remaining 16% is located in various other off-site leased buildings in Berkeley, Oakland, and Walnut Creek. Figure 2-4 shows the Berkeley Lab space distribution.[3]

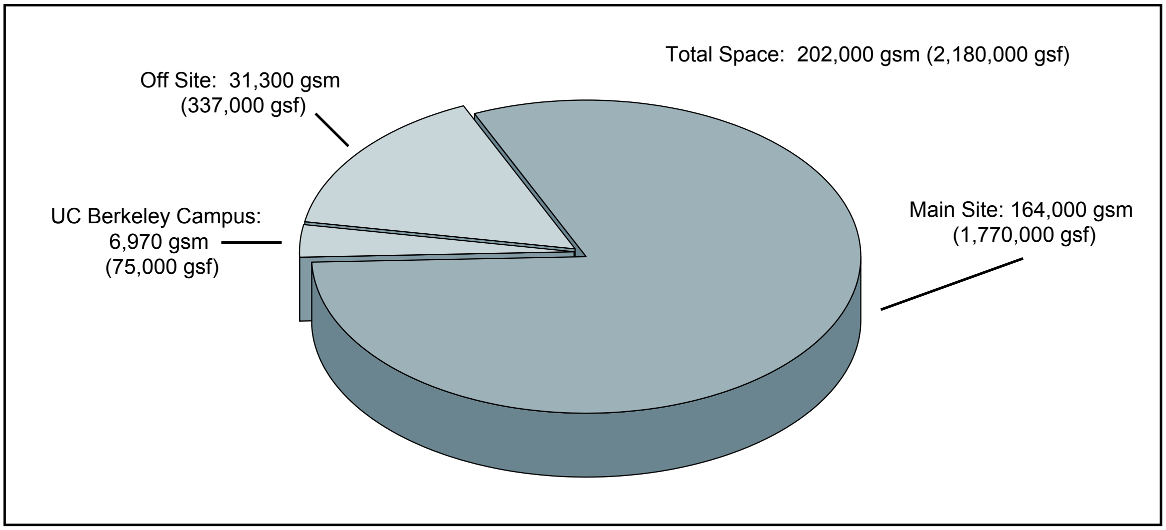


Figure 2-4 Space Distribution

2.2.3 Water Supply

All the Laboratory's domestic water is supplied by the East Bay Municipal Utility District (EBMUD). The site has no drinking-water wells.

Domestic water originates in Sierra Nevada watershed lands and is transported to the Bay Area and ultimately to Berkeley Lab through a system of lakes, aqueducts, treatment plants, and pumping stations. EBMUD tests for contaminants and meets disinfection standards required by the Safe Drinking Water Act.[4]

The water supply system is highly reliable for both domestic use and emergency purposes. The entire system has sufficient capacity to meet the flow-rate and duration requirements for fire protection. Reliability is enhanced by separate connections to two EBMUD sources (Shasta and Berkeley View tanks) and by two 760,000-liter (200,000-gallon) on-site storage tanks. Construction of a third storage tank in the East Canyon area was essentially completed in 2003, in conjunction with an upgrade of portions of the water distribution system. The project replaced about 0.9 mi (1.5 km) of cast iron pipe and upgraded the remaining 5 mi (8 km) of pipe. In addition, it provided corrosion protection, new valves, and pressure-reducing stations to the system and made improvements to the two existing storage tanks. All Laboratory water is supplied by gravity feed.

2.3 ENVIRONMENTAL SETTING

The following sections describe the meteorology, vegetation, wildlife, geology, and hydrogeology at Berkeley Lab.

2.3.1 Meteorology

The climate of the site is temperate, influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west, and on the east by the East Bay hills paralleling the eastern shore of this same bay. These physical barriers contribute significantly to the relatively warm, wet winters and cool, dry summers of the site. Figure 2-5 traces the monthly temperature average and extremes for the year, recorded at the on-site weather station.

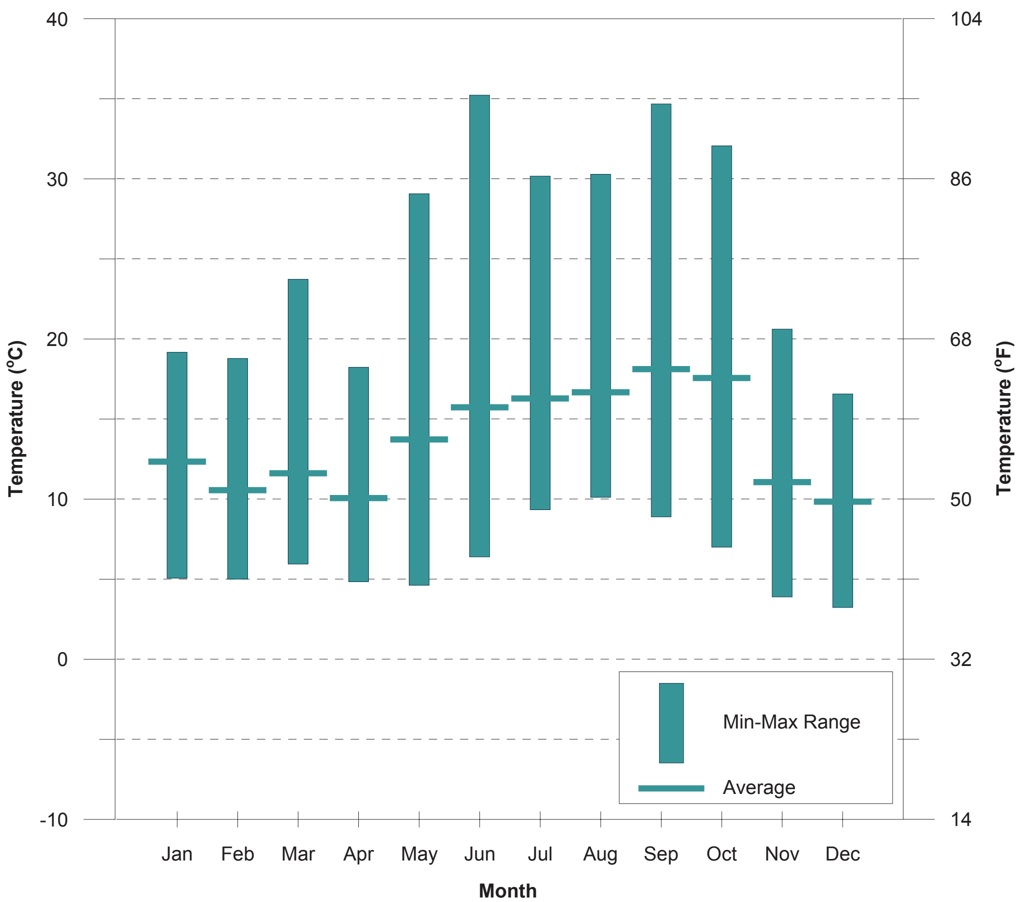


Figure 2-5 Temperature Summary by Month

On-site wind patterns change little from one year to the next. The most prevalent wind pattern occurs during fair weather, with daytime westerly winds blowing off the bay, followed by lighter nighttime southeasterly winds originating in the East Bay hills. The other predominant wind pattern is associated with storm systems passing through the region, which usually occur during the winter months. South-to-southeast winds in advance of each storm are followed by a shift to west or northwest winds after passage of the system. Figure 2-6, a graphical summary of the annual wind patterns (wind rose), illustrates the frequency of the two predominant wind patterns. Precipitation data are provided in Figure 2-7, which compares 2003 monthly precipitation totals to the average since 1974.

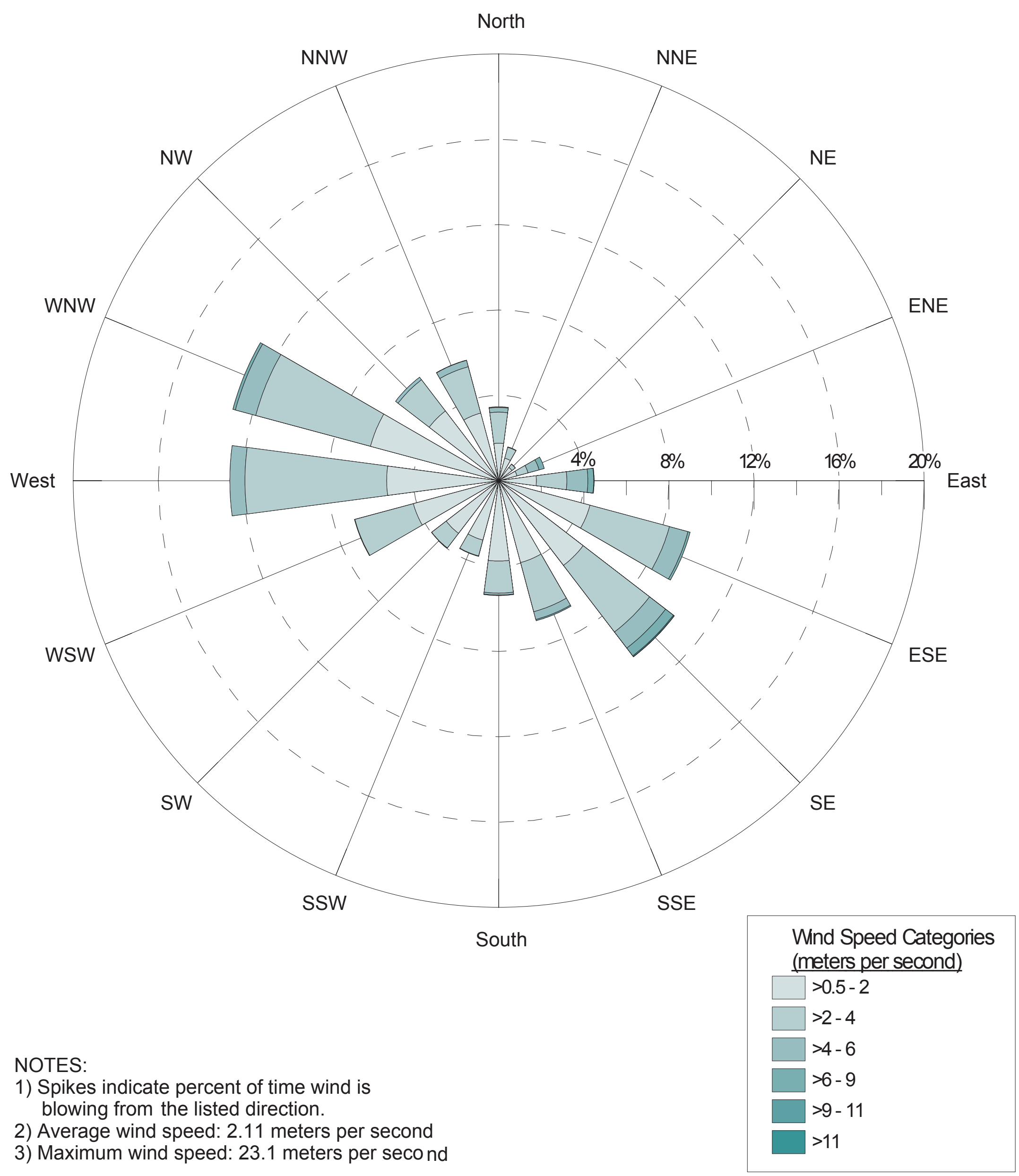


Figure 2-6 Annual Wind Patterns

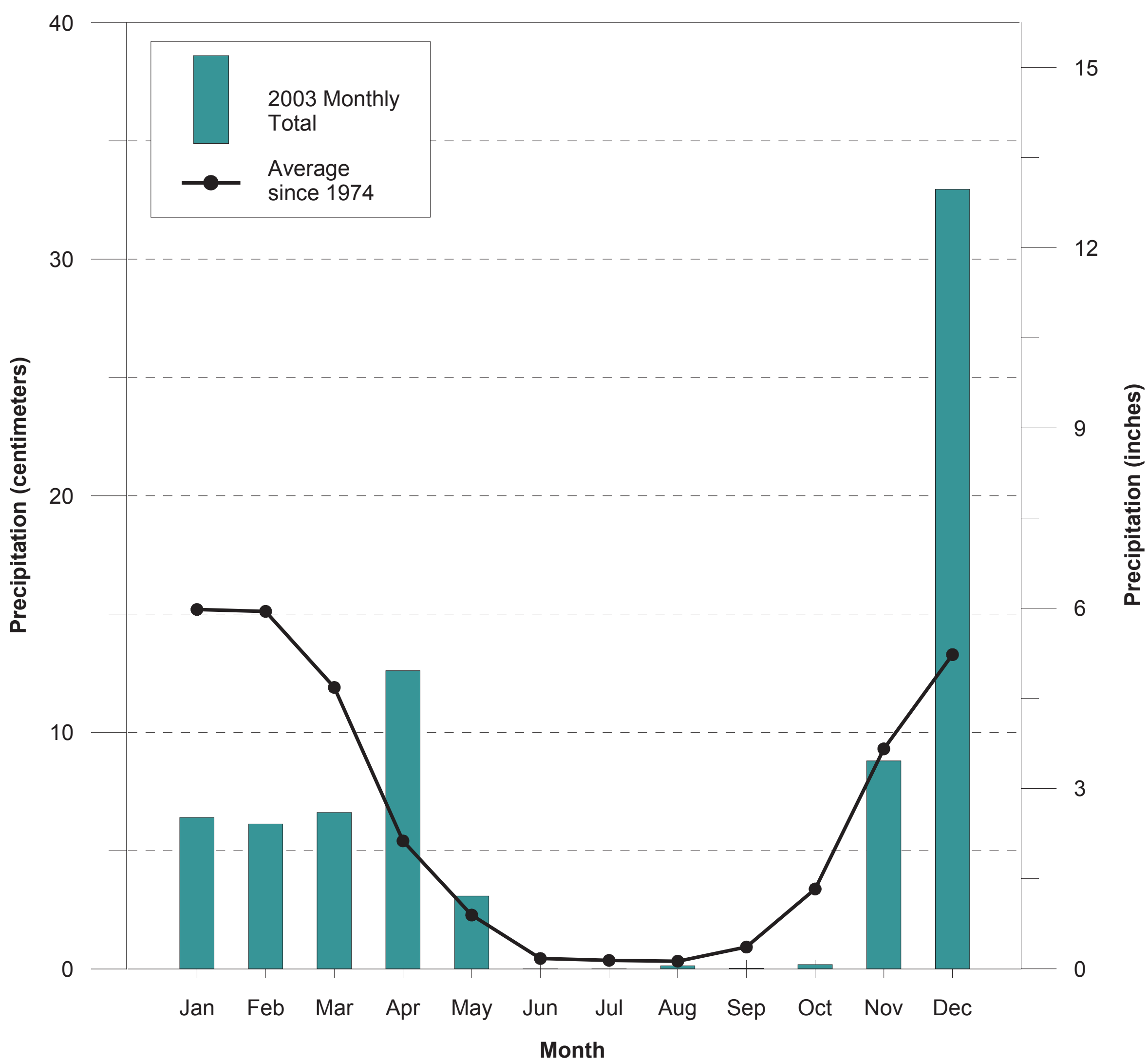


Figure 2-7 Precipitation Summary by Month

2.3.2 Vegetation

Vegetation on the Berkeley Lab site is a mixture of native plants, naturalized exotics, and ornamental species. The site was intensively grazed and farmed for approximately 150 years before the development of the Laboratory at this site in the late 1930s. The Laboratory's vegetation management program uses the natural succession of the native plant communities as a guide to the coordination of vegetation in outlying areas with the vegetation assemblies beyond the Laboratory site. Berkeley Lab also works to maintain a wooded and savanna character in the areas surrounding buildings and roads. Ornamental species are generally restricted to public spaces and courtyards and to areas adjacent to buildings. The site does not have any rare, threatened, or endangered species of plants present. Figure 2-8 shows the vegetation types and locations on-site.

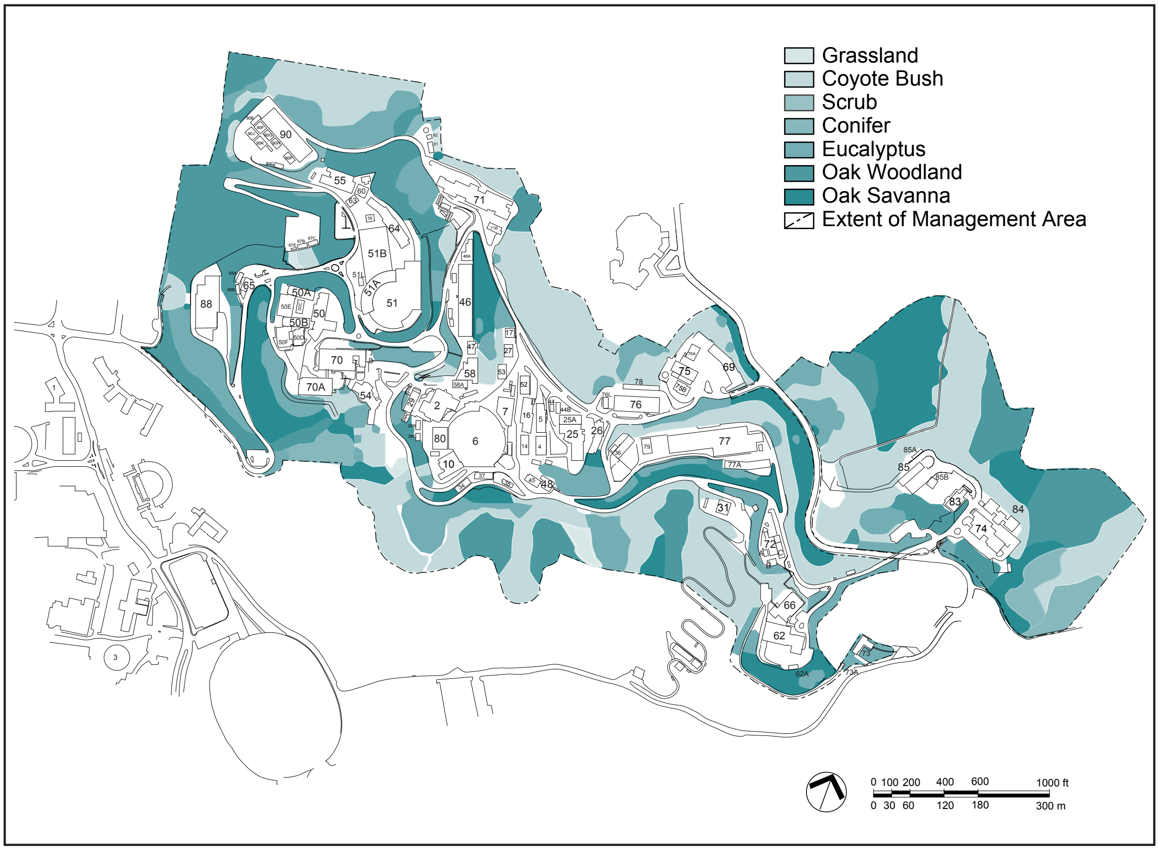


Figure 2-8 Vegetation Types (Map Revised 1999)

Berkeley Lab updated and intensified its wildland fire management efforts after the October 1991 fire in the Berkeley-Oakland Hills to the south. The Laboratory's vegetation management program is now specifically designed so that Laboratory buildings can survive a wind-driven firestorm similar in intensity to that of 1991. As part of this program, Berkeley Lab has also effectively removed a number of invasive exotic plants from the site, including French broom, artichoke thistle, Cape ivy, and pampas grass. In addition, eucalyptus stands across the site have been removed or thinned. Following removal and thinning operations, erosion control measures have been installed where necessary and these areas have been seeded with native grasses and broadleaf herbs.

Berkeley Lab also works with the Hills Emergency Forum (comprised of representatives from the neighboring cities of Berkeley and Oakland, the East Bay Regional Park District, EBMUD, and UC Berkeley) to improve vegetation management of the urban-wildland interface in the larger area.

2.3.3 Wildlife

Wildlife is abundant in the area surrounding Berkeley Lab because the site is adjacent to open spaces managed by the East Bay Regional Park District and the University of California. Wildlife that frequents the Laboratory site is typical of wildlife in disturbed (e.g., previously grazed) areas that have a Mediterranean climate and are located in midlatitude California. More than 120 species of birds, mammals, and reptiles/amphibians are thought to exist on the site. A portion of the site is within a 407,000-acre zone designated by the United States Fish and Wildlife Service (USF&WS) as critical habitat for the Alameda whip snake, which has been designated as "threatened" pursuant to the Endangered Species Act.[5] Due to a recent federal court decision, this USF&WS habitat designation is not enforced. Even so, although no Alameda whip snake sightings have been reported on or in the vicinity of the Berkeley Lab site, the Laboratory continues to take appropriate precautions during its construction projects. The most abundant large mammal is the Columbian black-tailed deer.

2.3.4 Geology and Hydrogeology

Three geologic formations underlie the majority of the site:

- The western and southern parts are underlain by Upper Cretaceous marine sediments belonging to the Great Valley Group. This group consists of siltstones and shales.
- The Upper Miocene or Lower Pliocene Orinda Formation overlies the Cretaceous rocks and underlies most of the site. It consists of clay stones, siltstones, sandstones, and conglomerates formed from river-deposited sediments.
- Ancient landslide deposits underlie most of the higher elevations of the Laboratory, as well as much of the area around the Advanced Light Source Facility (Building 6). These deposits consist primarily of rocks derived from the volcanic Upper Miocene Moraga Formation. The Moraga Formation consists of basalt and andesite, agglomerates, and pyroclastic tuffs.

In addition, the Miocene Claremont Formation and San Pablo Group underlie the far easternmost area of the site. The Claremont Formation consists of chert and shale. The San Pablo Group consists of marine sandstones.

Weathered detritus from the bedrock units has accumulated as soil deposits, generally from one to several meters thick. Because of the hilly terrain, up to tens of meters of cuts and fills have been necessary to provide suitable building sites.

The active Hayward Fault, a branch of the San Andreas Fault System, trends northwest to southeast along the base of the hills a short distance beyond the Laboratory's western edge. The inactive Wildcat Fault traverses the site north to south along the canyon at the Laboratory's eastern edge. In addition to the faulting, a complex geological structure has been created by landsliding, paleotopography, and tilting of the rock units underlying the site.

During the past 20 years, the Laboratory has carried out a successful program of slope stabilization to reduce the risk of property damage caused by potential soil movement. This program includes construction of subhorizontal drains (hydraugers), vegetation cover, and soil retention structures.

Groundwater flow is a concern at the Laboratory because of the potential effect on slope stability, as well as on underground movement of potential contaminants. "Hydraulic conductivity" is a term used to describe the properties of rock that control the velocity of groundwater. Hydraulic conductivity in the three major geologic formations is as follows:

- The Great Valley Group consists primarily of low-permeability rock material, which has moderately spaced open fractures that allow for groundwater movement. The hydraulic conductivity ranges between approximately 10^{-5} and 10^{-8} meters per second (m/s) (3.3×10^{-5} and 3.3×10^{-8} feet per second [ft/s]).
- The Orinda Formation consists primarily of fine-grained sediments with closed fractures. The hydraulic conductivity of the fine-grained sediments of this formation ranges between approximately 10^{-7} and 10^{-12} m/s (3.3×10^{-7} and 3.3×10^{-12} ft/s). The Orinda Formation typically has lower values of hydraulic conductivity than the underlying Great Valley Group or overlying Moraga Formation and therefore impedes the horizontal and vertical flow of groundwater.
- The volcanic rocks in the ancient landslide deposits constitute the main water-bearing unit at Berkeley Lab. The hydraulic conductivity within the Moraga Formation is relatively high, generally ranging between 10^{-4} and 10^{-6} m/s (3.3×10^{-4} and 3.3×10^{-6} ft/s). Although the rock matrix has low permeability, groundwater flows readily through the numerous open fractures. The presence of low-permeability interbeds of fine-grained sediments in the ancient landslide deposits, as well as zones with little fracturing, creates perched water conditions at many locations.

The fractured bedrock underlying Berkeley Lab allows percolation that augments groundwater. The water table depths vary from 0 to 30 m (98 ft) below the surface across the site.

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3

Environmental Program Summary

Waste management activities in the Hazardous Waste Handling Facility

3.1 INTRODUCTION

This chapter provides an overview of Lawrence Berkeley National Laboratory's environmental management program, reviews the status of various compliance programs and activities, and presents measures of the Laboratory's environmental performance in key areas for calendar year (CY) 2003.

3.2 OVERVIEW OF ENVIRONMENTAL RESPONSIBILITIES

To provide the highest degree of protection for the public and the environment, Berkeley Lab applies the principles of Integrated Safety Management (ISM). Applying ISM to the Laboratory activities involves the performance of five core functions:[1]

- Work Planning. Clear definition of the tasks that are to be accomplished as part of any given activity.
- Hazard and Risk Analysis. Analysis and determination of the hazards and risks associated with any activity, in particular risks to employees, the public, and the environment.
- Establishment of Controls. Controls that are sufficient to reduce to acceptable levels the risks associated with any activity. Acceptable levels are determined by responsible line management but are always in conformance with all applicable laws.
- Work Performance. Conduct that accomplishes the tasks in accordance with the established controls.
- Feedback and Improvement. Implementation of a continuous improvement cycle for the activity, including incorporation of employee suggestions, lessons learned, and employee and community outreach, as appropriate.

The Environment, Health, and Safety (EH&S) Division at Berkeley Lab is responsible for administering environmental protection and compliance programs at the Laboratory. The organizational structure of EH&S as of CY 2003 is shown in Figure 3-1.

The Environmental Services Group (ESG) oversees sitewide air and water quality compliance activities, provides technical assistance to Laboratory staff, and manages site characterization and cleanup. Environmental monitoring programs are an important component, providing critical information to demonstrate compliance and make programmatic decisions. For monitoring result summaries, see Chapters 4 through 10. The Waste Management Group manages hazardous, medical, radioactive, and mixed (hazardous and radioactive) waste generated at the Laboratory. The Radiation Protection Group is responsible for managing the safe use of radiation sources at Berkeley Lab, including both machine sources (e.g., accelerators) and radioisotopes.

3.2.1 ENVIRONMENTAL MANAGEMENT SYSTEM

To continually improve environmental performance, Berkeley Lab has committed to developing an environmental management system (EMS) within the next several years. An EMS is defined by the

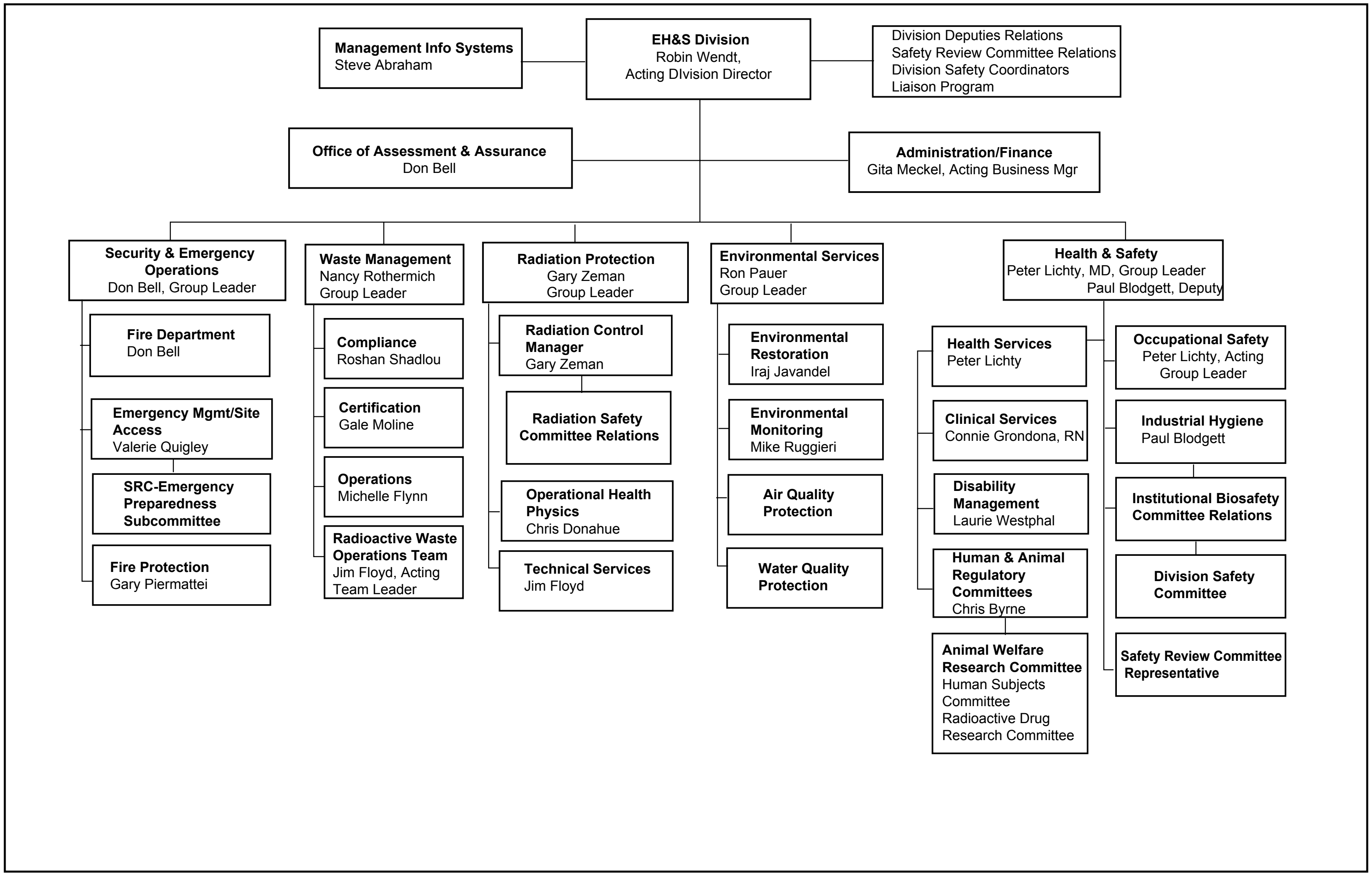

Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization in 2003

International Organization for Standardization (known as ISO) as follows: "That part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy."

At Berkeley Lab, a focused approach is being used for development of an EMS that emphasizes those elements of the ISO 14001 EMS[2] standard offering the greatest potential for performance improvement. The EMS will be integrated with the Berkeley Lab ISM system, which fundamentally defines environment, health, and safety programs within the Laboratory. To the extent that it is practical, ISM processes will be used to support environmental performance improvement and compliance management. Where it is not practical, new processes will be developed to support the Berkeley Lab EMS. This approach will allow the Laboratory to focus resources on making improvements while maintaining the strengths of its existing environmental compliance programs.

The goals of the Berkeley Lab EMS will be three-fold:

- Compliance with all applicable environmental protection and public health requirements
- Prevention of pollution
- Continual improvement of the Laboratory's environmental performance in a cost-effective manner

In CY 2002, a team of outside consultants performed an EMS analysis at Berkeley Lab based on the elements in the ISO 14001 EMS standard. Berkeley Lab then reviewed and evaluated potential improvements to determine the key elements needed for Berkeley Lab's EMS approach.

Based on this information, Berkeley Lab developed an EMS action plan in CY 2003, which was submitted to the United States Department of Energy (DOE), and began implementing the program. A cross-functional, interdepartmental EMS Core Team was formed to support implementation of the program. EMS training was provided to the Core Team participants and to EH&S staff who will support the Laboratory's EMS effort.

Implementation of the EMS will continue in CY 2004. Major activities planned include the following:

- Identifying significant environmental aspects
- Setting objectives and targets for improved performance
- Establishing environmental management programs
- Monitoring progress
- Preparing an EMS manual

Beginning in CY 2005, an internal review will be performed annually by Berkeley Lab staff who have received EMS training at the auditor level. The Laboratory's top management will also annually perform a review of the Laboratory's progress toward meeting its EMS environmental goals. In addition, a third-party validation audit will be performed by a contractor with relevant EMS experience and it will be repeated every three years.

3.3 PROGRAM SUMMARY

The following sections discuss environmental permits, audits, inspections, and DOE-reportable environmental incidents at Berkeley Lab for CY 2003.

3.3.1 Summary of Environmental Permits

Some Berkeley Lab activities require operating permits from environmental regulatory agencies. Table 3-1 summarizes, by area of environmental activity, the 48 active permits held by the Laboratory at the end of the year.

Table 3-1 Environmental Permits Held by Berkeley Lab at the End of 2003

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD[a]	Various activities with emissions to air	35	Section 3.4.1.2
Hazardous waste	DTSC[b]	Hazardous Waste Handling Facility operations	1	Section 3.4.4.1
Hazardous waste	City of Berkeley	Fixed Treatment Units	1	Section 3.4.4.1
Stormwater	SWRCB[c]	Sitewide stormwater discharges	1	Section 3.4.6.2
		Construction activity stormwater discharges	1	Section 3.4.6.2
Underground storage tanks	City of Berkeley	Underground storage tanks containing petroleum products	6	Section 3.4.6.4
Wastewater	EBMUD[d]	Sitewide and operation-specific wastewater discharges to sanitary sewer	3	Section 3.4.6.1

[a] Bay Area Air Quality Management District
[b] Department of Toxic Substances Control
[c] State Water Resources Control Board
[d] East Bay Municipal Utility District

3.3.2 Summary of Audits and Inspections

The agencies that regulate the environmental programs at Berkeley Lab periodically inspect the Laboratory. Table 3-2 lists the 19 inspections by these agencies that occurred at Berkeley Lab during CY 2003. The list includes self-monitoring inspections conducted by Berkeley Lab, as required by East Bay Municipal Utility District (EBMUD) wastewater discharge permits because these activities expose the Laboratory to potential regulatory violations.

The Department of Toxic Substances Control (DTSC) identified two minor violations during the April 2003 inspection of the Hazardous Waste Handling Facility (HWHF). These violations were for storage of containers longer than one year at the generator sites. No corrective actions were required by DTSC.

Table 3-2 Environmental Audits, Inspections, and Appraisals in Calendar Year 2003

Organization	Inspection title	Start date	Length (days)	Violations
BAAQMD	Permitted air emission sources	May 28	1	0
City of Berkeley	Underground storage tanks	October 29	1	0
DHS	Inspection of Medical Waste Management Program	January 13	2	0
DTSC	Inspection of Hazardous Waste Handling Facility	April 22	1	2
EBMUD	Wastewater monitoring inspections at Hearst and Strawberry outfalls	April 23 May 1 October 23	1 1 1	0 0 0
	Wastewater monitoring inspections at B25 treatment unit	August 26	1	0
	Wastewater monitoring inspections at B77 treatment unit	August 20	1	0
	Wastewater monitoring inspections at groundwater treatment units	July 30 September 17 October 6	1 1 1	0 0 0
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry outfalls	March 3 September 17	1 1	0 0
	EBMUD self-monitoring inspections at B77 treatment unit	May 19 August 19	1 1	0 0
	EBMUD self-monitoring inspections at B25 treatment unit	August 7	1	0
	EBMUD self-monitoring inspections at groundwater treatment units	March 14 October 7	1 1	0 0

Note: Two minor violations were received in 2003 from the California Department of Toxic Substances Control for two waste containers that were stored in a satellite accumulation area for more than one year. See Section 3.4.4.1 for details.

3.3.3 Summary of DOE-Reportable Environmental Incidents

In 2003, there were no environmental incidents reportable under the DOE occurrence-reporting program used to track incidents across the DOE complex.[3]

3.4 PROGRAM REVIEW

The following sections provide individual summaries of the environmental compliance programs at Berkeley Lab.

3.4.1 Air Quality (Clean Air Act)

The Clean Air Act[4] is the key statutory reference for federal, state, and local air pollution control programs. It classifies air pollutants into several main categories:

- Criteria air pollutants (e.g., carbon monoxide, nitrogen oxides, particulate matter)
- Hazardous air pollutants (e.g., radionuclides, air toxics)
- Ozone-depleting substances (e.g., chlorofluorocarbons or Freons)

The State of California's own air pollution control program[5] gives it additional powers to regulate sources of air emissions.

Berkeley Lab divides its air quality protection and compliance activities into two categories: radiological (see Section 3.4.1.1) and nonradiological (see Section 3.4.1.2).

3.4.1.1 Radiological

Radionuclides released to the atmosphere from Laboratory research activities must adhere to the standards in 40 CFR 61, Subpart H *(National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities)*,[6] as well as sections of DOE Orders 5400.1[7] and 5400.5.[8] The United States Environmental Protection Agency (US/EPA) administers the National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations.

To properly account for radiological air emissions, Berkeley Lab conducts a preliminary review of projects that could result in a dose to the public or environment. This review includes a determination of the dose to the nearest off-site member of the public (the maximally exposed individual) following NESHAPs regulations and DOE EH-0173T[9] guidance. It takes a conservative, or worst-case, approach by assuming that no portion of the radionuclides projected to be released is collected by emission controls, even if such controls exist. Berkeley Lab's method for determining the appropriate level of sampling, monitoring, and administrative control necessary to maintain compliance with NESHAPs has been approved by US/EPA and is summarized in Table 4-2 (see Section 4.2). Results of the emissions sampling and monitoring program are also presented throughout Chapters 4 and 9. The Laboratory documents its NESHAPs review and compliance http://www.lbl.gov/ehs/esg/.

3.4.1.2 Nonradiological

The Bay Area Air Quality Management District (BAAQMD) implements federal and state air quality requirements for most air emission activities that are not addressed by NESHAPs regulations.

At the end of CY 2003, Berkeley Lab held operating permits from BAAQMD for 35 activities.[10] Two of these permits cover activities located at the Production Genomics Facility in Walnut Creek, California. This facility is part of the Joint Genome Institute, a collaboration involving Berkeley Lab, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory research groups. On May 28, BAAQMD inspected the onsite permitted generators, which numbered 19 at the time. All generators complied with the permit requirements.

BAAQMD issued permits in 2003 for two additional activities at Berkeley Lab. The first permit was for a replacement diesel-powered standby emergency generator at Building 66. The generator previously serving this building was retained and permitted so that it could be converted to a portable unit for general use through the site. The second permit authorized the construction of an E85-fuel dispensing facility at the Building 76 Motor Pool. E85 fuel is a mixture of 85% ethanol and 15% unleaded fuel. Federal mandates require that Berkeley Lab increase the percentage of vehicles using alternative fuels according to a given time schedule. Construction of the new E85-fuel dispensing facility began late in the year, and it is expected to begin its dispensing operations in 2004. Operating permits are renewed annually, at which time BAAQMD also requests information required by the state's Air Toxics "Hot Spots" Information and Assessment Act of 1987.[11] For a list of active operating permits, see Table 3-3.

Table 3-3 Air Emission Sources Permitted by BAAQMD[a] at the End of 2003

BAAQMD category	Description	Building	Abatement type
Combustion equipment	Standby emergency generators	64,70	Catalytic converter
	Standby emergency generators	Various [b]	—
	Standby emergency generators	PGF [c]	—
Gasoline dispensing	Unleaded and E85 fueling stations	76	Vapor recovery
Surface coating and painting	Paint spray booth	76	Dry filter
	Paint spray booth	77	Dry filter
	Epoxy-mixing hood	53	—
Surface preparation and cleaning	Sandblast booth	77	Baghouse
	Vapor degreaser	52	Chiller
	Wipe-cleaning	Sitewide	—
Miscellaneous	Soil vapor extraction systems	7, 7E, 58	Activated carbon

[a] Bay Area Air Quality Management District
[b] Individual generators located at Buildings 2, 37, 48, 50A, 50B, 55, 62, 64, 66, 70A, 72, 74, 75, 77, 84B, and 85, plus four mobile locations.
[c] Two generators located at the Production Genomics Facility in Walnut Creek, California. The PGF is a joint venture between LBNL, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory.

Regulations affecting the phaseout of ozone-depleting substances are largely administered at the federal level by US/EPA. The Laboratory has made extensive progress in eliminating emissions of the Class I ozone-depleting substances from equipment and activities such as centrifugal chillers, refrigeration and freezer appliances, solvent-cleaning systems, fire-suppression operations, and research apparatus. Much of the reduction occurred during the mid-1990s. The aggressive reduction program began in 1991, when annual emissions of Class I ozone-depleting substances were estimated at nearly 6,000 kilograms (kg) (13,200 pounds [lb]). Currently, emissions are estimated at less than 10 kg (22 lb) each year, a reduction of more than 99% from levels a decade earlier. (For more information, see http://www.lbl.gov/ehs/wastemin/goals/haz_ozone.html.)

3.4.2 Environmental Restoration (Comprehensive Environmental Response, Compensation, and Liability Act of 1980; Resource Conservation and Recovery Act Corrective Action Program)

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)[12] was passed by Congress to regulate actual or threatened releases into the environment. There were no releases in 2003 reportable under CERCLA. Actions under CERCLA and related statutes include removal and/or remedial action if the release may present an imminent danger, as well as remedial investigations and feasibility studies that determine site cleanup options. Berkeley Lab conducted no remedial activities related to CERCLA in 2003, however Berkeley Lab continued to investigate and remediate specific areas of concern at the site under the requirements of the Corrective Action Program of the Resource Conservation and Recovery Act of 1976 (RCRA).[13] Because these areas of interest relate to groundwater protection, all monitoring efforts for the year are described in Chapter 6.

3.4.3 Hazardous Materials Regulations

The following sections discuss programs related to the Emergency Planning and Community Right-to-Know Act (EPCRA); Toxic Release Inventory (TRI); Risk Management and Prevention Plan; Federal Insecticide, Fungicide, and Rodenticide Act; and Toxic Substances Control Act.

3.4.3.1 Emergency Planning and Community Right-to-Know Act

EPCRA was passed in 1986 as Title III of the Superfund Amendments and Reauthorization Act (SARA).[14] The Act establishes requirements for emergency planning, notification, and reporting. In California, the requirements of SARA Title III are incorporated into the state's Hazardous Materials Release Response Plans and Inventory Law.[15] Berkeley Lab activities addressing these requirements are summarized in Sections 3.4.3.1.1 through 3.4.3.1.3.

3.4.3.1.1 Toxic Release Inventory

Under Executive Order 13148 (*Greening the Government through Leadership in Environmental Management*),[16] DOE is required to evaluate its facilities against the TRI reporting requirements of

EPCRA without regard to SIC code. TRI reporting consists of two steps: (1) Berkeley Lab determines chemical usage, and (2) DOE submits the US/EPA Form R if threshold quantities are exceeded.

Berkeley Lab determined that no chemical usage in CY 2003 exceeded the TRI criterion of 4,536 kg (10,000 lb) for a listed substance and that DOE was not required to submit a Form R on behalf of the Laboratory. Table 3-4 shows the highest usage levels of the chemicals from the Laboratory's assessments over the past several years.

Table 3-4 Trends in Highest Quantities of EPCRA[a] Toxic Release Inventory Reporting

Substance	2000 (kg)	2001 (kg)	2002 (kg)	2003 (kg)
Chlorofluorocarbons	246	260	164	61
Methanol	468	593	322	228
Nitric acid	746	861	778	582
1,1,1-trichloroethane	21	2	<1	7

[a] Emergency Planning and Community Right-to-Know Act

In 2002, US/EPA lowered reporting thresholds for 18 chemicals and chemical categories that meet the EPCRA Section 313 criteria for persistence, bioaccumulation, and toxicity (PBT). The thresholds were lowered to 100 lb (45.5 kg) for PBT chemicals and 10 lb for highly PBT chemicals. In May 2003, Berkeley Lab performed a sitewide survey on all 18 chemicals and chemical categories for which reporting thresholds had been lowered (PBT chemicals). It was found that either the PBT chemicals were not present at the Berkeley Lab or they were used in research experiments. Hence the use of the PBT chemical was exempt from reporting. It should be noted that even though the research exemption applies, the total inventory of PBT chemicals is below the usage thresholds by two orders of magnitude.

3.4.3.1.2 Hazardous Materials Business Plan

The City of Berkeley is the local administering agency for certain hazardous materials regulations falling under state law. Berkeley Lab voluntarily submits a *Hazardous Materials Business Plan* (HMBP)[17] to the City of Berkeley each year, although federal sovereign immunity from such regulations has not been waived.

The 2003 HMBP included a list of all hazardous materials present in amounts exceeding the state's aggregate threshold quantities (i.e., 208 liters [55 gallons] for liquids, 227 kg [500 lb] for solids, and 5.7 cubic meters [200 cubic feet] for compressed gases) on a building basis. The plan included annotated floor plans and summaries of emergency plans, procedures, and training.

3.4.3.1.3 Risk Management and Prevention Plan

The City of Berkeley requires a Risk Management and Prevention Plan (RMPP) for operations using acutely hazardous materials above certain thresholds established in 40 CFR Part 355. Berkeley Lab does not have any operations that contain acutely hazardous materials above the threshold quantities, and therefore no RMPP is required for the site.[18]

3.4.3.2 Federal Insecticide, Fungicide, and Rodenticide Act

Passed by Congress in 1972, the Federal Insecticide, Fungicide, and Rodenticide Act[19] restricts the registration, sale, use, and disposal of pesticides. Pesticides, including insecticides and herbicides, are applied at the Berkeley Lab site by licensed contractors only. The Laboratory operates a composting program to minimize the use of herbicides and to reduce solid waste. The mulch generated from composting is used on-site for weed screening and landscaping where herbicides were previously applied. The end products from the chipper and mulcher program are also used to control erosion.

3.4.3.3 Toxic Substances Control Act

The objective of the Toxic Substances Control Act (TSCA)[20] is to minimize the exposure of humans and the environment to chemicals found in manufacturing, processing, commercial distribution, and disposal activities. TSCA establishes a protocol for evaluating chemicals before they are introduced into the marketplace and controlling their use once they are approved for manufacturing. TSCA regulations are administered by the US/EPA.

Polychlorinated biphenyls (PCBs) are one of the principle substances at Berkeley Lab currently affected by the TSCA regulations. Since the TSCA program began, the Laboratory has removed all TSCA-regulated PCB transformers (PCB concentrations greater than 500 parts per million). The remaining equipment containing TSCA-regulated PCBs are four large low-voltage capacitors. These capacitors remain in use, containing an estimated 170 kg (375 lb) of regulated PCB dielectric fluid. Because the small amount of PCBs is below reporting thresholds, the Laboratory is not required to prepare an annual PCB report for the US/EPA.

A research project required the use of silicon tetrafluoride enriched with the stable isotope silicon-29, which was only available from another country. Under TSCA rules, this enriched material is considered to be a new chemical, and Berkeley Lab, as the importer, is a “manufacturer.” Berkeley Lab applied to the US/EPA for permission to “manufacture” (import) the small quantities of this material needed for the project as a “low volume exemption” to many of the TSCA pre-manufacture notification rules in 2002. The exemption was granted, and the material was imported in 2002 and 2003.

3.4.4 Hazardous Waste (Resource Conservation and Recovery Act)

The primary goal of the RCRA[21] is to ensure that hazardous waste management practices are conducted in a manner that protects human health and the environment. RCRA affects waste treatment, storage, and disposal activities at Berkeley Lab in two areas: hazardous waste (including the hazardous portion of mixed waste) and underground storage tanks.

3.4.4.1 Hazardous Waste

In California, DTSC administers the RCRA hazardous waste program. The California program incorporates the provisions of both the federal and state hazardous waste laws.[22] The state program includes both permitting and enforcement elements. The state's permitting program for hazardous waste treatment and storage facilities consists of five tiers. The state continues to oversee the "full permit" and the "standardized permit" tiers; the other three tiers have been delegated to the City of Berkeley for oversight under California's Certified Unified Program Agency program. The following list shows the tiers in decreasing order of regulatory complexity:

- Full permit
- Standardized permit
- Permit-by-rule
- Conditional authorization
- Conditional exemption

Berkeley Lab's HWHF operates under the "full permit" tier of the program. A full permit is also known as an RCRA Part B permit. The current permit for the HWHF [23] was approved by DTSC on May 4, 1993, and was valid until May 2003. Berkeley Lab submitted a timely permit-renewal application for operation of its HWHF and is continuing to operate under the previous permit conditions until the new permit will be issued. The permit authorizes storage and treatment of certain hazardous and mixed wastes at the HWHF. Authorized treatments include neutralization, consolidation, solidification, filtration, precipitation, phase separation, ultraviolet (UV) ozone and UV peroxide oxidation, reduction of Class 1–3 oxidizers, air or steam stripping, absorption, adsorption, ion exchange, metallic exchange, evaporation, distillation electrowinning, rinsing of empty containers, mixing of multicomponent resins, and desensitization. Berkeley Lab's waste management program sends hazardous, mixed, medical, and radioactive waste generated at the Laboratory off-site for disposal. Disposal of medical waste is managed in accordance with the state's Medical Waste Management Act (see Section 3.4.4.2). Low-level radioactive waste is managed in accordance with DOE orders. Specific low-level aqueous wastes at Berkeley Lab (containing only radioisotopes with short half-lives) are stored until the radioactivity has decayed to undetectable levels; then the wastes are discharged in conformance with the EBMUD wastewater discharge permits.

DTSC identified two minor violations during the April 2003 inspection.[24] These violations were for storage of two containers in generator-site satellite accumulation areas for more than one year. Waste may be stored in a satellite accumulation area for up to one year from the date of generation.

The waste is then transferred to the HWHF until aggregated for shipment. These containers had been transferred and properly stored in the HWHF by the time of the inspection, and no corrective actions were required.

Berkeley Lab has an additional hazardous waste permit[25] to operate five fixed treatment units (FTUs). The type and location of each unit are listed in Table 3-5. These treatment units operate independently of the HWHF. Three of these FTUs are authorized to operate under the "conditional authorization" tier, while the remaining two are authorized to operate under the "permit-by-rule" tier. The type of treatment determines which tier applies. The City of Berkeley requests renewal of this permit each year. In March 2003, the Laboratory submitted the 2003 FTU renewal package to the City of Berkeley.

Table 3-5 Fixed Treatment Units Subject to State's Tiered Permitting

FTU	Building	Description of treatment	Permit tier
002	25	Metals precipitation and acid neutralization	Permit-by-rule
003	76	Oil/water separation	Conditional authorization
004	70A/70F	Acid neutralization	Conditional authorization
005	2	Acid neutralization	Conditional authorization
006	77	Metals precipitation and acid neutralization	Permit-by-rule

Waste management permits and regulations require Berkeley Lab to prepare several reports for the year:

- The *Annual Hazardous Waste Report*,[26] prepared for DTSC, contains facility treatment and disposal information for all hazardous waste activities (including the hazardous waste portion of mixed waste) at the HWHF during the reporting year.
- The *Annual Report of Waste Generation and Pollution Prevention Progress*,[27] prepared for DOE, contains a detailed analysis of waste minimization efforts made by waste generators during the reporting year.
- Quarterly reports on the inventory of mixed waste more than one year old were submitted to meet a DTSC operating-permit requirement.

In October 1995, DTSC approved the Laboratory's *Mixed Waste Site Treatment Plan*,[28] which documents the procedures and conditions used by Berkeley Lab to manage its mixed-waste streams. The Laboratory prepares an annual report that quantifies the amount of mixed waste in storage at the end of the reporting period. This update is prepared in October for the previous fiscal year.

3.4.4.2 Medical Waste

Medical waste includes biohazardous waste (e.g., blood and blood-contaminated materials) and "sharps" waste (e.g., needles) produced in research relevant to the diagnosis, treatment, or immunization of human beings or animals or in the production of biological products used in medicine. In California, the state's Medical Waste Management Act[29] contains requirements designed to ensure the proper storage, treatment, and disposal of medical waste. The state program is administered by the Department of Health Services (DHS).

The Laboratory generates medical waste at about 100 different locations distributed over 14 buildings, including 2 off-site buildings. Berkeley Lab does not treat any medical waste; treatment of medical waste is performed at off-site vendor facilities. Medical waste is treated using either incineration or steam sterilization.

Berkeley Lab produced 15,575 kg (34,266 lb) of medical waste in calendar year 2003. Under the state's program, Berkeley Lab is considered a large-quantity generator because it generates more than 91 kg (200 lb) of medical waste each month. All large-quantity generators are required to register with the DHS and are subject to annual inspections. On January 13 and 14, the DHS inspected Berkeley Lab's medical waste management program and found no violations.

3.4.4.3 Resource Conservation and Recovery Act Corrective Actions Program (Site Environmental Restoration)

Berkeley Lab's Environmental Restoration Program is conducted under the requirements of the RCRA Corrective Action Program (see Chapter 6). It is intended to satisfy three criteria:

- Identification of areas of contamination that may have resulted from past releases of contaminants into the environment
- Determination of the sources and extent of contamination
- Development and implementation of plans to remediate contaminated areas

The *RCRA Facility Investigation Work Plan,*[30] which outlined environmental investigations necessary to characterize the site, was submitted to DTSC in October 1992. Between 1992 and 2000, Berkeley Lab submitted a series of work plans for detailed site investigations. After each of these submittals, the Laboratory carried out the investigations described in the work plans and reported results in Quarterly Progress Reports. In addition, results of the investigations were reported in the *RCRA Facility Investigation Phase I Progress Report*[31] and *Phase II Progress Report*,[32] and in the *Draft Final RCRA Facility Investigation Report*,[33] submitted to DTSC on September 29, 2000. DTSC approved the *Draft Final RCRA Facility Investigation Report* on July 27, 2001.

A *Corrective Measure Study (CMS) Plan*[34] was subsequently submitted to DTSC on May 24, 2002, and was approved on June 18, 2002. As part of the CMS, *Human Health Risk Assessment*[35] and *Ecological Risk Assessment*[36] reports were submitted to DTSC. The *Ecological Risk Assessment* concluded that there are no adverse impacts to ecological receptors from exposure to chemicals in soil, groundwater, sediment, or surface water at Berkeley Lab. This report was approved by DTSC on April 14, 2003. DTSC accepted the *Human Health Risk Assessment* on August 19, 2003. Throughout all phases of the corrective action process, Berkeley Lab implemented a series of interim measures to protect human health and the environment.

The Environmental Restoration Program maintains a proactive interaction with stakeholders, including DTSC, the Regional Water Quality Control Board (RWQCB), and the City of Berkeley. The program holds meetings at which completed and planned activities are discussed.

3.4.5 Pollution Prevention and Waste Minimization

The following sections discuss programs related to pollution prevention and waste minimization.

3.4.5.1 Executive Order 13101 (Greening the Government through Waste Prevention, Recycling, and Federal Acquisition)

United States Executive Order 13101 *(Greening the Government through Waste Prevention, Recycling, and Federal Acquisition)*[37] replaced Executive Order 12873 *(Federal Acquisition, Recycling, and Waste Prevention)*. Like its predecessor, Executive Order 13101 seeks to integrate recycled materials into the procurement and acquisition process. Identified categories of products include the following:

- Paper and paper products
- Vehicular products
- Construction products
- Transportation products
- Park and recreation products
- Landscaping products
- Miscellaneous products
- Nonpaper office products

In procuring these items, all federal agencies must, by December 31, 2004, buy only US/EPA-listed items with specified contents of recycled materials, unless a product is not available competitively within a reasonable time frame, does not meet appropriate performance standards, or is only available at an unreasonable price.

Berkeley Lab has had an affirmative procurement program since 1992. The Laboratory's Procurement staff has an ongoing program to search for products made from recycled materials and work with other federal facilities to enhance their power to purchase environmentally sound products. The Laboratory has implemented a "stepped" program to ensure that, by December 31, 2004, only US/EPA-listed products manufactured from recycled materials will be purchased as long as these materials are available at a reasonable cost and are compatible with the Laboratory's operating needs. Information on the affirmative procurement program can be found at http://www.lbl.gov/ehs/wastemin/programs/procurement.html.

3.4.5.2 Hazardous Waste Source Reduction and Management Review Act

The California State Legislature passed the Hazardous Waste Source Reduction and Management Review Act[38] in 1989. With an emphasis on minimizing waste and preventing pollution, the Act has the following goals:

- Reduce hazardous waste at its source
- Encourage recycling wherever source reduction is infeasible or impracticable
- Manage hazardous waste in an environmentally safe manner and minimize present and future threats to health and the environment if it is infeasible to reduce or recycle
- Document hazardous waste management information and make that information available to state and local government

Every four years, Berkeley Lab prepares a two-part report in compliance with this Act: the *Source Reduction Evaluation Review Plan and Plan Summary*,[39] and the *Hazardous Waste Management Report Summary*.[40] The last report was compiled in 2003 and submitted to DOE Oakland as part of the DOE-wide report.

3.4.5.3 Pollution Prevention Act of 1990

The Pollution Prevention Act of 1990[41] declares that source reduction is a national policy and directs US/EPA to study and encourage source reduction policies. Berkeley Lab's levels of pollution are below the de minimis thresholds identified in the Act, and therefore the Lab is not subject to its reporting requirements.

3.4.6 Water Quality (Clean Water Act)

The Clean Water Act (CWA)[42] regulates the discharge of pollutants from both point and nonpoint sources to the waters of the United States, using various means; these include development of pollutant discharge standards and limitations and a permit and licensing system to enforce the standards. California is authorized by US/EPA to administer the principal components of the federal water quality management program.

Additionally, the California Porter-Cologne Water Quality Control Act[43] established a comprehensive statewide system for regulating water use. This 1969 act provides for a three-tiered system of regulatory oversight and enforcement: the State Water Resources Control Board (SWRCB), the nine RWQCBs, and local governments.

For Berkeley Lab, the regional regulatory agency is the San Francisco Bay RWQCB. The local agencies are (1) the cities of Berkeley and Oakland for stormwater and (2) EBMUD for drinking-water supply and wastewater discharges.

3.4.6.1 Wastewater

The Laboratory has three wastewater discharge permits[44] issued by EBMUD for the following activities:

- General sitewide wastewater discharge
- Treatment unit discharge of rinse water from the metal finishing operations in Building 25 and 77
- Treatment unit discharge of groundwater from hydraugers and groundwater monitoring wells

The permits incorporate standard terms and conditions, as well as individual discharge limits, provisions, and monitoring and reporting requirements. Under each permit, Berkeley Lab submits periodic self-monitoring reports. The number of reports and their timing depend on the individual permit. No wastewater discharge limits were exceeded. For more information regarding the results of the Laboratory's annual self-monitoring program, see Chapter 5.

In 2003, EBMUD renewed the permits and increased the renewal term from one to four years, so that the current permits do not expire until 2007. EBMUD also elected to combine the permits from buildings 25 and 77 into one permit.

EBMUD also inspects the Laboratory's sanitary sewer discharge activities without prior notice, which includes the collection and analysis of wastewater samples. The agency conducted inspections on five separate occasions throughout the year. Table 3-2 lists these inspections, which were routine sample collections. No violations resulted from any inspections.

The wastewater discharge permit for Buildings 25 and 77 requires that each facility maintain a Toxic Organics Management Plan (TOMP).[45] Each TOMP outlines facility management practices designed to minimize the release of toxic organics to the sanitary sewers or external environment.

An Accidental Spill Prevention and Containment Plan (ASPCP)[46] is also required under the terms of the wastewater discharge permits. Specifically, Berkeley Lab must maintain this plan for areas where spills are most likely to occur. Berkeley Lab has prepared operation-specific plans for the following activities: sitewide photoprocessing, Buildings 25 and 77 metal finishing, Building 76 vehicle services, and Buildings 2 and 70A rinse water treatment. EBMUD requires that plan documents be maintained on file in the relevant areas and that essential emergency information be posted. These plans need not be submitted to the agency. The TOMP and ASPCP for Building 77 have been combined,[47] and the TOMP and ASPCP for Building 25 will also be combined to reduce duplication of information.

In 2003, the Contra Costa Central Sanitary District requested that the Genomics Facility submit an application for a wastewater discharge permit. An application was subsequently prepared and submitted in July of 2003.

3.4.6.2 Stormwater

Berkeley Lab's stormwater releases are permitted under the California-wide General Permit for Stormwater Discharges Associated with Industrial Activity.[48] The General Permit is issued by the SWRCB but administered and enforced by the RWQCB and the City of Berkeley. Under this permit, the Laboratory has implemented a *Storm Water Pollution Prevention Plan*[49] (SWPPP) and a *Stormwater Monitoring Program*.[50] Together, these documents represent the Laboratory's plan and procedures for identifying, monitoring, and reducing pollutants in its stormwater discharges.

The General Permit requires submission of an annual report on stormwater activities by July 1. Berkeley Lab transmitted its annual report to the RWQCB and the City of Berkeley in June.[51] No regulatory concerns were raised by either agency regarding the annual report. For a summary of the stormwater monitoring results, see Chapter 5.

The City of Berkeley has the authority to inspect Berkeley Lab's stormwater program. No inspections of this program took place in 2003. However, in August 2003, an unplanned discharge was reported by Berkeley Lab to the City of Berkeley and other agencies (California Department of Fish and Game, Office of Emergency Services) in accordance with Clean Water Act reporting requirements. An underground water supply pipe had broken and discharged undetected for several hours, ultimately spilling several thousand gallons of drinking water to the storm drain system and thus to Strawberry Creek. University of California (UC) Berkeley EH&S colleagues downstream were also notified as a courtesy. Since EBMUD drinking water contains chloramine as a disinfectant, this release posed a danger to fish and invertebrates in the creek, some of which were confirmed to have died as a result of the residual chlorine. Some scouring and flushing of the creek bed was also identified to have resulted from the increased water flow. No inspections or violations resulted from the incident, and Berkeley Lab has offered to assist UC Berkeley in restoring the creek and replanting fish should the university choose to undertake such actions.

The State of California has also issued a Stormwater General Permit for Construction Activity. In the latest revision (1999), the threshold that necessitates applying for the permit by submitting a Notice of Intent (NOI) was reduced to 1 acre. In October 2003, Berkeley Lab submitted an NOI for construction of its Molecular Foundry. In accordance with requirements, an SWPPP was prepared before construction began, and selected Best Management Practices have been implemented throughout the rainy season.

3.4.6.3 Aboveground Storage Tanks

Aboveground storage tanks (ASTs) also fall under the authority of the CWA.[42] The CWA and the state's Aboveground Petroleum Storage Act[52] outline the regulatory requirements for ASTs. Under the authority of the CWA, a *Spill Prevention, Control, and Countermeasures (SPCC) Plan*[53] is required for petroleum-containing tanks—aboveground and underground tanks. Berkeley Lab maintains an SPCC plan with the goal of preventing and, if needed, mitigating potential

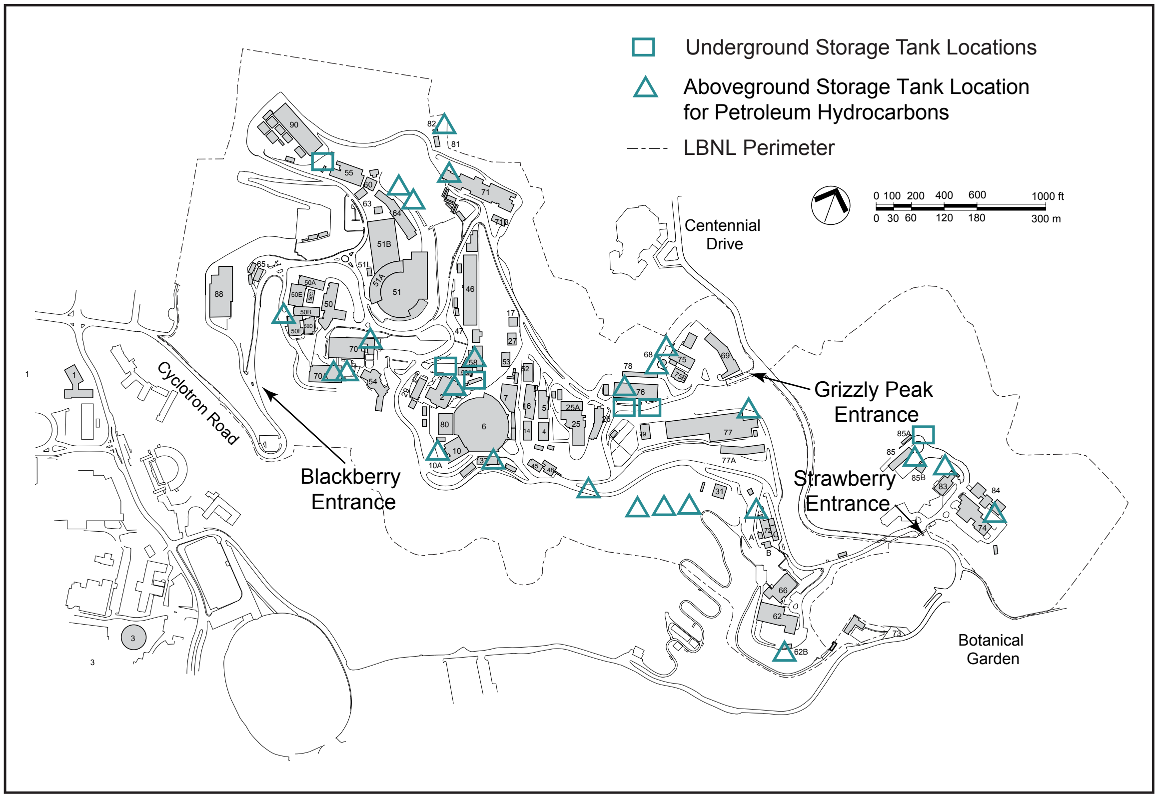

Figure 3-2 Aboveground and Underground Storage Tank Locations at the end of Calendar Year 2003

spills or leaks from petroleum-containing tanks. ASTs are provided with secondary containment or spill kits to capture any potential leaks, or other damage. The locations of ASTs are shown in Figure 3-2.

Nonpetroleum (i.e., chemical or hazardous) ASTs consist of FTU tanks, storage drums at Waste Accumulation Areas (WAA), and storage drums at product distribution areas. FTU tanks are inspected each operating day by operators of the FTU. WAAs are inspected weekly by EH&S staff. Product distribution areas, containing petroleum and nonpetroleum drums, are inspected by the Fire Department during routine inspections.

3.4.6.4 Underground Storage Tanks

In the early 1980s, California addressed the problem of groundwater contamination from leaking underground storage tanks (USTs) through a rigorous regulatory and remediation program.[54] The state program for USTs containing hazardous materials addresses permitting, construction design, monitoring, record keeping, inspection, accidental releases, financial responsibility, and tank closure.

The state's program satisfies the provisions of the federal RCRA requirements.[55] The City of Berkeley is the local administering agency for UST regulations that apply to Berkeley Lab.

At the end of 2003, six permitted USTs remained at the Laboratory (see Table 3-6 and Figure 3-2). The tanks contain either diesel fuel or unleaded gasoline. Two USTs (2,000-gallon and 4,000-gallon capacities) that previously stored diesel fuel at Building 66 were removed in July 2003. Upon excavation, the tanks and associated piping were found to be in excellent condition. No leaks were found, and the UST site at Building 66 was closed without further action. The Laboratory has removed nine USTs since 1993 and properly closed each site.

On October 29, leak-detection monitors were tested and recertified for all UST systems. During the recertification of the leak-detection monitors, the City of Berkeley inspected all six USTs and found no violations. In December 2003, all product piping (pressure and suction) was pressure-tested for all six UST systems. All piping passed the pressure tests. Also in December, every spill bucket at the fill port of each UST was tested for leaks. All spill buckets passed and were found free of leaks.

Table 3-6 Underground Storage Tank Operating Permits from the City of Berkeley

Registration tank ID number	Building	Stored material	Capacity in liters (gallons)	Construction	Year installed
Fiberglass tanks, double-walled					
2-1	2	Diesel	15,200 (4,000)	Fiberglass	1988
2-2	2	Diesel	3,800 (1,000)	Fiberglass	1988
85-1	85	Diesel	9,500 (2,500)	Fiberglass	1995
Steel tanks, double-walled, with fiberglass plastic corrosion protection					
55-1	55	Diesel	3,800 (1,000)	Glasteel	1986
76-1	76	Unleaded gasoline	38,000 (10,000)	Glasteel	1990
76-2	76	Diesel	38,000 (10,000)	Glasteel	1990

3.4.7 Safe Drinking Water Act

The Safe Drinking Water Act[56] established requirements to protect underground sources of drinking water and set primary drinking-water standards for public water systems. Berkeley Lab has no drinking-water wells on-site. The drinking water provided to the site comes from the EBMUD supply and distribution system. Berkeley Lab has taken measures to protect its distribution system for its drinking-water supply by installing backflow prevention devices on main supply lines throughout the site.

EBMUD now uses chloramine for disinfection of the drinking-water supply. Although chloramine improves the water supply for human consumption, it is toxic to fish and other aquatic organisms. To prevent damage to laboratory research involving such organisms, researchers have instituted measures to neutralize the chloramine to provide water in which these organisms can safely exist.

Additionally, to prevent damage to organisms living in neighboring creeks, Berkeley Lab has programs to prevent drinking water from being discharged to the Laboratory's storm drains. When responding to waterline breaks and testing and flushing fire hydrants, the Facilities Division and Fire Department neutralize the chloramine before the water reaches a storm drain.

3.4.8 National Environmental Policy Act and California Environmental Quality Act

The National Environmental Policy Act of 1969 (NEPA)[57] established national policy for assessing federal actions that have the potential to impact the environment. The NEPA process is intended to help officials of the federal government make decisions that are based on an understanding of environmental consequences and take actions that protect, restore, and enhance the environment. The California Environmental Quality Act of 1970 (CEQA) [58] is similar to NEPA. The California legislature established CEQA (1) to inform both state and local governmental decision makers and the public of potential significant environmental effects of proposed activities, (2) to identify ways to avoid or reduce environmental impacts, and (3) to disclose to the public the reasons why a project is approved if significant environmental effects are involved.

Lawrence Berkeley National Laboratory, as a federal facility located on land leased from the Regents of the University of California, complies with the provisions of both NEPA and CEQA. Since the DOE and the UC Regents have the ultimate decision-making authority on Berkeley Lab activities under NEPA and CEQA, respectively, Laboratory staff provides information to enable both entities to determine whether Berkeley Lab's proposed actions will have a significant effect on the environment.

During 2003, Berkeley Lab issued the following major NEPA and CEQA documents:

NEPA document:

- *Final Environmental Assessment for Construction and Operation of the Molecular Foundry at Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California.* DOE/EA-1441. February 2003.[59]

CEQA documents:

- *Final Tiered Initial Study Checklist and Mitigated Negative Declaration for the Construction and Operation of the Molecular Foundry at Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California.* State Clearinghouse No. 2002122051. April 2003.[60]
- *Construction and Operation of the Building 49 Project Draft and Final Environmental Impact Reports.* State Clearinghouse No. 2003062097. September 2003 and December 2003, respectively.[61]
- *Revised Notice of Preparation to prepare a Draft Environmental Impact Report for the 2004 LBNL Long Range Development Plan.* October 2003.[62]

3.5 PROGRAM PERFORMANCE

Since 1994, Berkeley Lab, DOE, and DOE's managing contractor, the University of California Office of the President (UCOP), have used a system to annually measure the effectiveness of the Laboratory's performance, including the performance of its environmental programs. These performance measures have been integrated directly into the operating contract for the site. Possible ratings include "unsatisfactory," "marginal," "good," "excellent," and "outstanding." Table 3-7 summarizes the UCOP and DOE ratings for each of the environmental performance measures for fiscal year (FY) 2003.[63]

Berkeley Lab has consistently received performance ratings of “outstanding” or “excellent” from both DOE and UCOP since the inception of environmental performance measures ten years ago.

Table 3-7 Environmental Performance Measure Ratings for Fiscal Year 2003

Performance measure	UCOP rating	DOE rating
Tracking of environmental incidents	Outstanding	Outstanding
Waste reduction and recycling	Excellent	Excellent
Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
Completion of milestones for an Environmental Management System	Outstanding	Outstanding

Due to the consistently positive results, many of last year’s environmental measures were retired from the FY 2003 performance contract. The remaining measures are related to environmental releases and regulatory violations, waste minimization efforts, and costs and schedule variance for environmental restoration activities. These measures are part of the overall evaluation of “performing work” under the contract requirements for ISM. Berkeley Lab is now also focused on developing and implementing a comprehensive EMS that has many of the valuable attributes found in the internationally recognized ISO 14001 EMS Standard. For FY 2003, the Laboratory prepared a multiyear plan to fully implement an EMS with independent validation by a third party. Progress is measured by the completion of scheduled milestones in the EMS plan. For more information on environmental performance objectives, criteria, and measures, go to Berkeley Lab’s Office of Assessment and Assurance home page at http://www.lbl.gov/ehs/oaa/.

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4

Air Quality

Laboratory analysis of stack air filters

4.1 BACKGROUND

Lawrence Berkeley National Laboratory's air monitoring program is designed to meet the requirements established by the United States Environmental Protection Agency (US/EPA) and the United States Department of Energy (DOE) that are contained in the following references:

- 40 CFR Part 61, Subpart H (*National Emission Standards for Hazardous Air Pollutants,* or NESHAPs) [1]
- DOE Order 5400.1 *(General Environmental Protection Program)* [2]
- DOE Order 5400.5 *(Radiation Protection of the Public and the Environment)* [3]

US/EPA's NESHAPs and DOE Order 5400.5 specify requirements for radiological air emissions, while DOE Order 5400.1 addresses nonradiological air emissions. The comprehensive *Environmental Monitoring Plan*[4] prepared by Berkeley Lab includes the basis and current scope of the air monitoring program at the Laboratory. Radiological substances measured in stack emissions and ambient air are presented in this chapter. Estimates of nonradiological air emissions generally use alternative methodologies such as engineering calculations, record keeping, and dose/risk modeling to satisfy regulatory requirements. Exceptions to this are periodic monitoring requirements placed on a few activities permitted by the Bay Area Air Quality Management District.

The air monitoring program consists of two elements: exhaust-emissions monitoring and ambient-air surveillance. Exhaust-emissions monitoring measures contaminants in building exhaust systems (e.g., stacks). Ambient-air surveillance measures contaminants in the outdoor environment. The data for both stack air and ambient air can be found in Volume II.

The number and placement of monitoring stations, as well as the substances collected and their collection frequencies, are routinely reviewed to address changes in Laboratory operations or external requirements.

4.2 EXHAUST-EMISSIONS MONITORING RESULTS

Berkeley Lab uses various radionuclides in its radiochemical and biomedical research programs. In addition, the operations of charged-particle accelerators generate radioactive materials. Radionuclide releases through building exhaust systems usually occur in the form of vapor or gas. Releases of solid particulate are the least common form, as high-efficiency particulate air filters are used to remove particulate in the exhaust systems.

Table 4-1 lists the most significant radionuclides used at Berkeley Lab and their decay characteristics. Radioactive gases produced by accelerator operations are mainly short-lived radionuclides, such as carbon-11, nitrogen-13, oxygen-15, and fluorine-18.

Table 4-1 Most Significant Radionuclides Used at Berkeley Lab[a]

Nuclide name (atomic number)	Symbol	Principal radiation types	Half-life
Carbon (6)	^{11}C ^{14}C	positron/gamma beta	20.5 minutes 5,730 years
Fluorine (9)	^{18}F	positron/gamma	109.7 minutes
Hydrogen/Tritium (1)	^{3}H	beta	12.3 years
Iodine (53)	^{123}I ^{125}I	gamma beta	13.1 days 60.14 days
Nitrogen (7)	^{13}N	positron/gamma	10.0 minutes
Phosphorus (15)	^{32}P	beta	14.3 days
Sulfur (16)	^{35}S	beta	87.2 days
Technetium (43)	^{99m}Tc	gamma	6.0 hours

[a] For a complete list of radionuclides evaluated under NESHAPs regulations, see the *Radionuclide Air Emission Annual Report for 2003*, found at Berkeley Lab's Environmental Services Group home page at http://www.lbl.gov/ehs/esg/.

The NESHAPs regulations require source measurement if the potential dose, or exposure over time, from emissions exceeds 1.0×10^{-3} millisieverts per year (mSv/yr) (0.1 millirem per year [mrem/yr]).[1] As mentioned in Section 3.4.1.1, Berkeley Lab uses a comprehensive strategy approved by the US/EPA to satisfy this requirement. This strategy involves three distinct levels of assessment:

- Real-time monitoring: sophisticated monitoring systems that provide nearly instantaneous measurements.
- Continuous sampling: collection of time-integrated air samples that undergo laboratory analysis following US/EPA protocols.
- Administrative controls: estimation of emissions based on limits on the laboratories' radionuclide inventories.

These assessment levels are assigned to each of six source compliance categories (see Table 4-2). The number and location of activities subject to each compliance category change in response to the current research at Berkeley Lab. In 2003, all sources evaluated for NESHAPs compliance were considered "small sources" of emissions (Category II through V). Most sources fall into Category V, which requires no monitoring but which requires the sources to adhere to strict inventory limits specified in individual work authorizations. In 2003, Berkeley Lab had 121 sources in Category V. Twenty-seven sources were assessed as Category II or III, which require continuous sampling. Three of these locations (Buildings 56, 70A, and 88) have more rigorous real-time monitoring systems to estimate emissions. In 2003, the real-time monitoring system for the former National Tritium Labeling Facility (NTLF) was shut down because the facility is no longer in operation. Table 4-3 lists the sampling and monitoring profile for the reporting year.

Table 4-2 US/EPA-Approved NESHAPs Compliance Strategy

Compliance category	Annual effective dose equivalent[a] (mSv/yr)[b]	Sampling/monitoring strategy
Noncompliant	AEDE ≥ 0.1	Reduction or relocation of the source and reevaluation before authorization.
I	0.1 > AEDE ≥ 0.001	Continuous sampling with telemetry to central computer for half-life less than 100 hours and weekly analysis for half-life greater than 100 hours. (US/EPA approval required to construct or modify emission source.)
II	0.001 > AEDE ≥ 0.0005	Continuous sampling with weekly analysis.
III	0.0005 > AEDE ≥ 0.0001	Continuous sampling with monthly analysis.
IV	0.0001 > AEDE ≥ 0.00001	Annual sampling during project activity.
V	0.00001 > AEDE	Control of inventory by administrative methods (Radiation Work Authorization/Permit): No monitoring required.

[a] Abbreviated as AEDE
[b] 1 mSv = 100 mrem

Stack exhaust samples collected during 2003 were analyzed for five radiological parameters: gross alpha, gross beta, carbon-14, iodine-125, and tritium. In past years, tritium in the form of tritiated water vapor was the predominant radionuclide emitted from Berkeley Lab activities; however, tritium emissions in 2003 were only 2% of those in 2002. In 2003, positron emitters fluorine-18 and carbon-11 were the predominant radionuclides emitted. The Building 56 accelerator was the main source of fluorine-18 emissions; the Building 88 accelerator was the primary source of carbon-11. Table 4-4 provides a list of the most significant radionuclide air emissions from site activities for the year. For information on the projected dose from all radionuclide emissions, see Chapter 9.

Table 4-3 NESHAPs Building Exhaust Sampling and Monitoring Profile in Calendar Year 2003

Monitoring type	Method	Location
Continuous real-time	Real-time monitoring of ^{11}C, ^{13}N, and ^{15}O	Building 88 accelerator exhaust
	Real-time monitoring of ^{11}C, ^{13}N, ^{15}O, and ^{18}F	Building 56 Biomedical Isotope Facility accelerator exhaust (2 locations)
	Real-time monitoring of gross alpha	Building 70A Heavy Element Research Laboratory
Continuous sampling	Sampling with weekly analysis	10 stacks
	Sampling with monthly analysis	16 stacks and 1 room
No monitoring	Inventory (administrative) control	121 rooms

Table 4-4 Summary of Berkeley Lab Radiological Air Emissions[a]

Nuclide	Total (Bq/yr[b])	Percentage
^{18}F	1.3×10^{11}	89.9%
^{11}C	9.0×10^{9}	6.1%
^{3}H	5.8×10^{9}	3.9%
^{14}C	2.4×10^{8}	0.2%
^{125}I	1.1×10^{7}	< 0.1%
^{32}P	8.1×10^{6}	< 0.1%
^{99m}Tc	6.6×10^{6}	< 0.1%
^{123}I	3.7×10^{6}	< 0.1%
^{35}S	7.6×10^{5}	< 0.1%
^{13}N	6.7×10^{5}	< 0.1%
All others	1.7×10^{6}	< 0.1%
Total	1.5×10^{11}	100%

[a] For a complete list of radiological air emissions, see NESHAPs *Annual Radionuclide Air Emission Report for 2003*, found at Berkeley Lab's Environmental Services Group home page at http://www.lbl.gov/ehs/esg/.
[b] Bq/yr= becquerels per year

Tritium emissions for the year 2003 continued to be well below regulatory levels of concern. The former NTLF annual emission of 3.52×10^9 becquerels (Bq) (0.095 curie [Ci]) was far below both the five- and ten-year averages for the facility. For information on trends in annual tritium releases from the former NTLF, see Table 4-5.

Table 4-5 Trends in Annual Tritium Releases from former National Tritium Labeling Facility

Units	1999	2000	2001	2002	2003
TBq[a]	1.1	0.9	0.7	0.3	0.0035
Ci	30	24	20	7	0.095

[a] TBq = terabecquerel

In addition to air emissions from exhaust systems, Berkeley Lab also collects and analyzes (for tritium) rainwater that drains down the stacks associated with the former NTLF. In 2003, the average concentration of tritium in drain water was 1.68×10^5 becquerels per liter (Bq/L) (4.55×10^6 picocuries per liter [pCi/L]) and the maximum was 6.00×10^5 Bq/L (1.62×10^7 pCi/L). In accordance with an internal authorization for this low-activity source, the stack drain water was disposed of in the sanitary sewer. The total activity of tritium in the stack drain water released to the sanitary sewer was 1.48×10^7 Bq (3.99×10^{-4} Ci), which is 0.008% of East Bay Municipal Utility District's annual limit of 1.9×10^{11} Bq (5 Ci) for tritium disposal in the sewer.

4.3 AMBIENT-AIR MONITORING RESULTS

The following sections discuss the results for ambient-air tritium and particulate gross alpha/beta monitoring.

4.3.1 Tritium

At the end of 2002, the former NTLF was closed, so tritium emissions decreased markedly. A significant portion of the remaining tritium waste from the former NTLF was soon shipped off-site for acceptable disposal. With those reductions in tritium emissions and tritium waste inventory, Berkeley Lab reduced the number of sampling locations in the ambient-air tritium monitoring network commensurately. At the beginning of 2003, the network contained ten sites, situated in various directions and distances from the former NTLF, including some at sampling points located on the path of less frequently occurring downwind currents. During the year, five of those sites were removed: ENV-31, ENV-44, ENV-SSL, ENV-AR, and ENV-13D. Figure 4-1 displays the locations of the sampling sites and identifies those that were removed. Instrumentation at each site operates on the principle of continuously drawing outdoor air through sampling media (i.e., silica gel) at a constant rate.

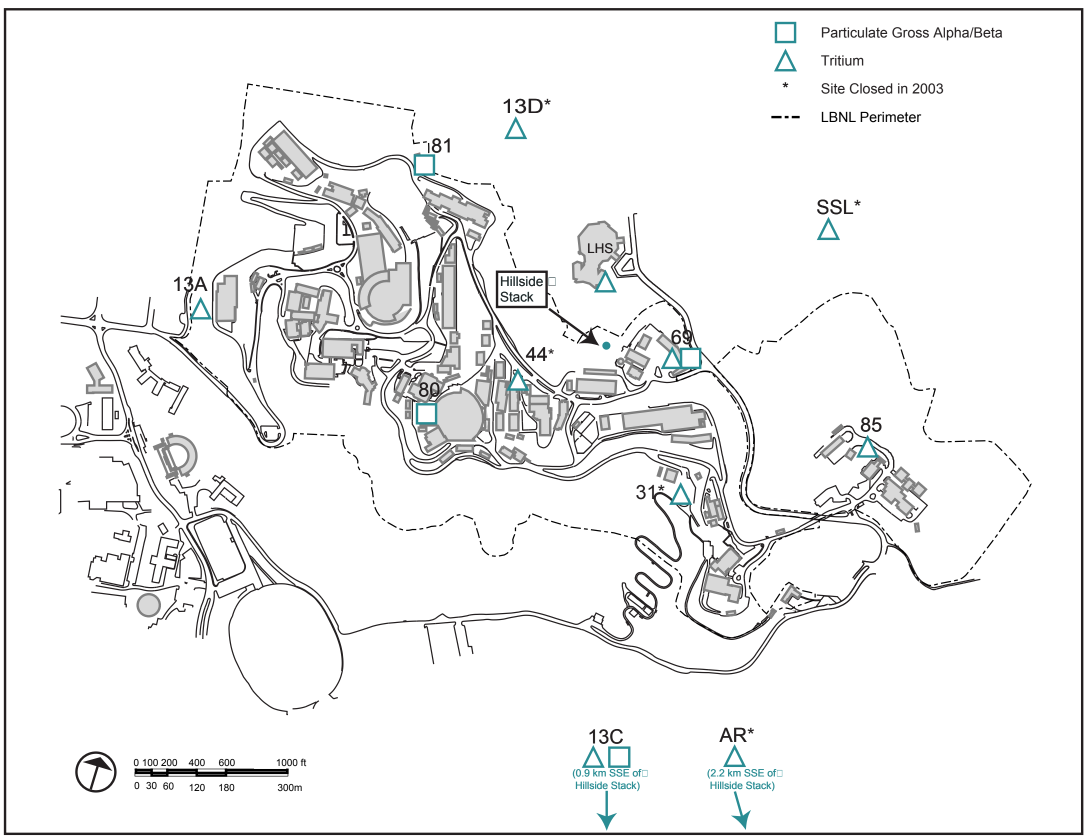


Figure 4-1 Ambient-Air Monitoring Network Sampling Locations

Berkeley Lab replaces the sampling media monthly and submits the samples to a certified laboratory for analysis. More than 90% of the samples collected and analyzed did not contain detectable levels of tritium, and the few samples with measurable concentrations were near the analytical detection limit. These results are consistent with the decrease in tritium emissions since the NTLF closed operations. The maximum monthly tritium concentration found throughout the network was 0.22 becquerel per cubic meter (Bq/m^3) (5.9 picocuries per cubic meter [pCi/m^3]),which was down significantly from the previous year's maximum of 1.74 Bq/m^3 (47.0 pCi/m^3). In comparison with standards, this concentration is far below both the DOE annual exposure standard for airborne tritium of 3.7×10^3 Bq/m^3 (1.0×10^5 pCi/m^3),[3] which equates to the DOE public dose limit for all exposure modes and radiation sources; and the reference concentration of 3.7×10^2 Bq/m^3 (1.0×10^4 pCi/m^3), which equates to the US/EPA NESHAPs dose standard for inhalation alone.[1] Table 4-6 summarizes the network's airborne tritium concentrations for the year.

Table 4-6 Summary of Ambient-Air Tritium Sampling

Station ID	Number of samples	Mean (Bq/m^3)[a]	Median (Bq/m^3)	Maximum (Bq/m^3)
ENV-B13A	12	<0.17	<0.17	<0.17[b]
ENV-B13C	12	<0.14	<0.14	<0.14[b]
ENV-B13D	12	<0.10	<0.10	<0.10[b]
ENV-31	3	<0.20	<0.20	0.22
ENV-44	3	<0.09[b]	<0.09	<0.09[b]
ENV-69	12	<0.15[b]	<0.15[b]	0.16
ENV-85	12	<0.10	<0.10	0.12
ENV-AR	4	<0.10	<0.10	<0.10[b]
ENV-LHS	12	<0.10	<0.10	<0.10[b]
ENV-SSL	4	<0.10	<0.10	0.16

[a] 1 Bq = 27 pCi
[b] Statistic was below the highest value for analytical sensitivity (minimum detectable amount) measured for this site.

4.3.2 Particulate Gross Alpha/Beta

The ambient-air sampling network includes stations with instrumentation designed to collect air particulate samples for measurement of gross alpha and gross beta levels. These sites are presented in Figure 4-1. This network complements the exhaust-system sampling program discussed earlier in this chapter. The air particulate sampling network remained unchanged from previous years: three sites on the main grounds of the Laboratory and a fourth at an off-site location, ENV-B13C. Similar to tritium sampling, each sampler draws air past collection media (i.e., filter paper) at a constant rate, with the media replaced monthly and samples analyzed by a certified laboratory.

Table 4-7 summarizes gross alpha and beta sample results from routine monitoring activities. Although DOE Order 5400.5 does not provide a standard for particulate gross alpha and beta radiation, several observations about these results are apparent:

- They are at or below the analytical detection limits for each parameter.
- There is little variability from station to station, including station ENV-B13C, located about 1.0 kilometer (0.6 mile) southeast of the site. There is some indication that gross beta levels vary from season to season, with wintertime levels slightly higher than other times of the year.
- The results for each parameter change little from one year to the next.

These observations indicate that environmental impacts from the Laboratory's radioactive releases of alpha- and beta-emitting isotopes to the atmosphere are negligible.

Table 4-7 Summary of Gross Alpha and Gross Beta Ambient-Air Particulate Sampling Network Results

Analyte	Station ID	Number of samples	Mean (Bq/m^3)[a]	Median (Bq/m^3)	Maximum (Bq/m^3)
Alpha	ENV-B13C[b]	12	$<9.0 \times 10^{-5}$	$<9.0 \times 10^{-5}$	2.2×10^{-4}
	ENV-69[b]	12	$<9.0 \times 10^{-5}$	$<9.0 \times 10^{-5}$	1.9×10^{-4}
	ENV-80[b]	12	9.2×10^{-5}	$<9.0 \times 10^{-5}$	1.6×10^{-4}
	ENV-81[b]	12	$<9.0 \times 10^{-5}$	$<9.0 \times 10^{-5}$	1.0×10^{-4}
Beta	ENV-B13C	12	4.8×10^{-4}	4.4×10^{-4}	7.7×10^{-4}
	ENV-69	12	4.9×10^{-4}	4.2×10^{-4}	7.1×10^{-4}
	ENV-80	12	5.0×10^{-4}	4.3×10^{-4}	7.6×10^{-4}
	ENV-81	12	4.6×10^{-4}	4.1×10^{-4}	7.6×10^{-4}

[a] 1 Bq = 27 pCi

[b] One or more summary statistic (mean, median, maximum) was below the highest value for analytical sensitivity (minimum detectable amount) for this site.

As reported last year,[5] using the analytical expertise of Berkeley Lab's Low Background Facility, a small amount of naturally occurring potassium-40 has been identified in the fresh, unused sampling media itself. To address this, beginning with the last quarter of 2003, quality assurance methods followed by Berkeley Lab's contract analytical laboratory now correct results for the presence of naturally occurring radioactivity found in air filters.

5

Surface Water and Wastewater

Collection of a rainwater sample

5.1 INTRODUCTION

This chapter discusses the surface water and wastewater monitoring programs conducted at Lawrence Berkeley National Laboratory. The following sections describe the monitoring requirements, sampling networks, and results. The individual sample data are presented in Volume II.

5.2 SURFACE WATER PROGRAM

Lawrence Berkeley National Laboratory's surface water monitoring in calendar year (CY) 2003 included rainwater, creeks, and stormwater. Rainwater and creeks are monitored primarily for gross alpha radiation, gross beta radiation, and tritium, based on United States Department of Energy (DOE) orders[1] that prescribe monitoring requirements for radioisotopes. Surface water is also monitored for nonradiological analytes as part of the Laboratory's ongoing efforts to characterize and manage its overall impact on the environment. Stormwater monitoring is performed under the California General Permit for Stormwater Discharges Associated with Industrial Activities[2] and includes monitoring for metals and other constituents.

To place the Laboratory's surface water results in a familiar context, this chapter uses drinking-water standards as conservative reference points. However, drinking-water standards are not directly applicable because the surface water being monitored is not a source of public drinking water. No standards exist for surface water other than sources of drinking water.

The federal and state maximum contaminant levels (MCLs) for alpha and beta radioactivity in drinking water are 0.6 becquerel per liter (Bq/L) (15 picocuries per liter [pCi/L]) and 1.9 Bq/L (50 pCi/L), respectively.[3] The United States Environmental Protection Agency (US/EPA) limit for tritium in drinking water is 740 Bq/L (20,000 pCi/L).[4]

Surface water samples were analyzed by both commercial and in-house state-certified laboratories.

5.2.1 Rainwater

In 2003, measurable rainfall occurred during January, February, March, April, May, November, and December. During each of those months, a composite rainfall sample was collected near Building 75 (see Figure 5-1) and analyzed.

Samples were analyzed for tritium and gross alpha and beta radiation. The November sample showed a small amount of alpha (0.1 Bq/L [2.7 pCi/L]) and beta (0.2 Bq/L [5.3 pCi/L]) activity. No tritium was detected in any samples.

5.2.2 Creeks

Given Berkeley Lab's location in the hills of the Strawberry Creek watershed, many streams and drainages, at and near the site, flow at varying intensities throughout the year. A grab sample is collected and analyzed quarterly for alpha and beta activity and tritium, if there is water flowing in the creek. Creeks routinely sampled during CY 2003 were Chicken Creek, the North Fork of Strawberry Creek, and Strawberry Creek (UC). For creek sampling locations, see Figure 5-1. No alpha activity was detected at any sampling site. Beta activity was barely above detection level in only two Strawberry Creek (UC) samples. Tritium was slightly above the detection level in only one Chicken Creek sample.

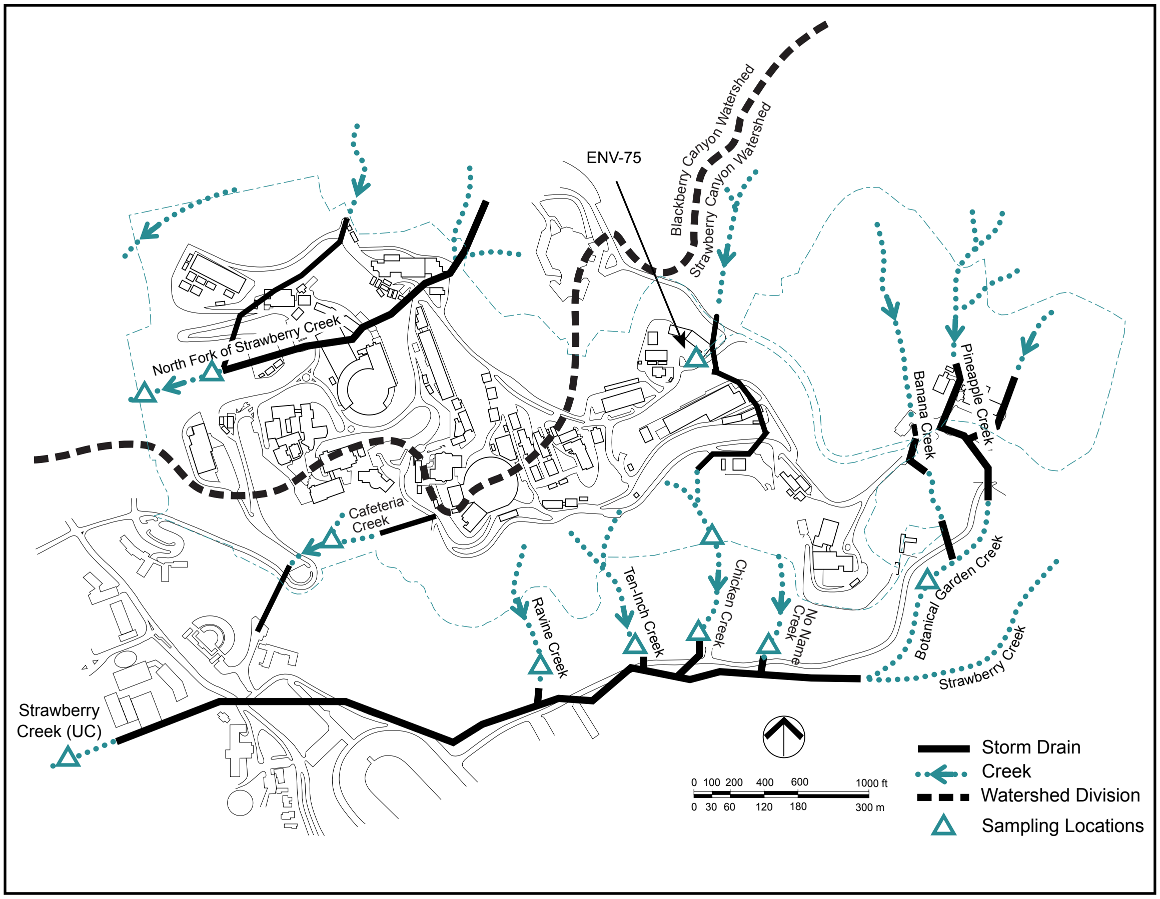


Figure 5-1 Creek and Rainwater Sampling Locations

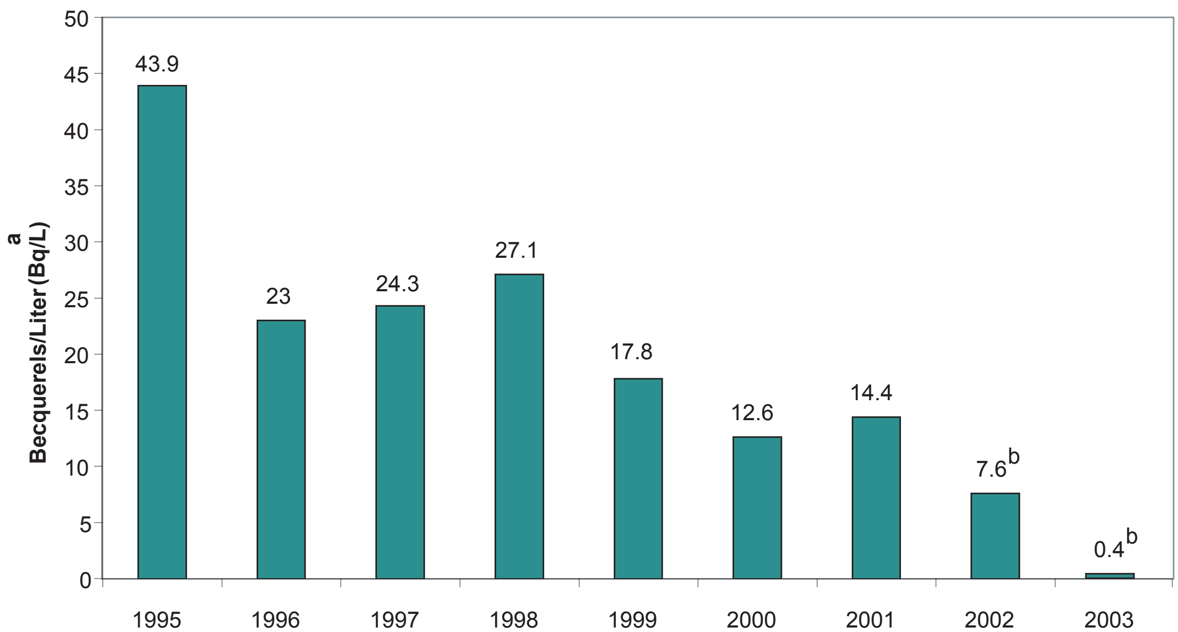
To comply with a community request, in CY 2003 the Environmental Services Group (ESG) sampled the North Fork of Strawberry for tritium monthly. In half the collected samples, tritium was measured at or slightly above the detection limit, which was approximately 7.5 Bq/L (200 pCi/L).

Creeks were also sampled by the Environmental Restoration Program (ERP) and analyzed for metals, volatile organic compounds (VOCs), and tritium. These creeks (also shown in Figure 5-1) include, in addition to various locations in Chicken Creek and the North Fork of Strawberry Creek, Botanical Garden Creek, Cafeteria Creek, No Name Creek, Ravine Creek, and Ten-Inch Creek. No VOCs were detected at any location. Background levels of arsenic, barium, thallium and vanadium were measured. The only metal that exceeded the level set by the San Francisco Bay Region Basin

Plan (Basin Plan)[5] was zinc, from a sample located upstream in the North Fork. The Basin Plan limits are not intended to be applied to creek water, but are referred to here for comparison purposes. See Section 5.2.3 for more information on these limits.

The ERP sampled for tritium once in most locations, and several times at various points on Chicken Creek and the North Fork of Strawberry Creek. In this effort, tritium was not detected in either Chicken Creek or the North Fork of Strawberry. It should be noted that these samples were analyzed by a different laboratory than the ESG samples, and the detection limit was higher, at about 11 Bq/L (300 pCi/L).

Chicken Creek is the only creek in which tritium has been found with any regularity in the past. Figure 5-2 presents a comparison of the annual mean for tritium in Chicken Creek over the past nine years. In 2003, the average tritium levels were once again below the detection limit.



[a] 1 Bq = 27 picocuries

[b] Sample mean was below the highest value for analytical sensitivity (minimum detectable amount) measured for this site

Figure 5-2 Annual Averages for Tritium in Chicken Creek (1995–2003)

5.2.3 Stormwater

Berkeley Lab lies within the Blackberry Canyon and Strawberry Canyon subwatersheds, which are part of the main Strawberry Creek watershed. There are two main creeks in these watersheds, the South Fork of Strawberry Creek (in Strawberry Canyon) and the North Fork of Strawberry Creek (in Blackberry Canyon), plus several small tributaries that generally do not flow all year long.

Surface runoff from Berkeley Lab is substantial because of the site's hillside location, the amount of paved or covered surface, and the moderate annual rainfall. All stormwater runoff from the site drains through its stormwater drainage system to either the south fork or the north fork of Strawberry Creek, which join below the Laboratory on the University of California (UC) Berkeley campus.

Under the State of California's National Pollutant Discharge Elimination System program, Berkeley Lab has obtained a General Permit for Stormwater Discharges Associated with Industrial Activities.[2] Permit holders must develop and maintain a *Storm Water Monitoring Plan* (SWMP)[6] and a *Storm Water Pollution Prevention Plan* (SWPPP).[7] These are the guiding documents for the Laboratory's compliance with stormwater regulations. For further discussion of this compliance program, see Section 3.4.6.2. Sampling points are shown in Figure 5-3.

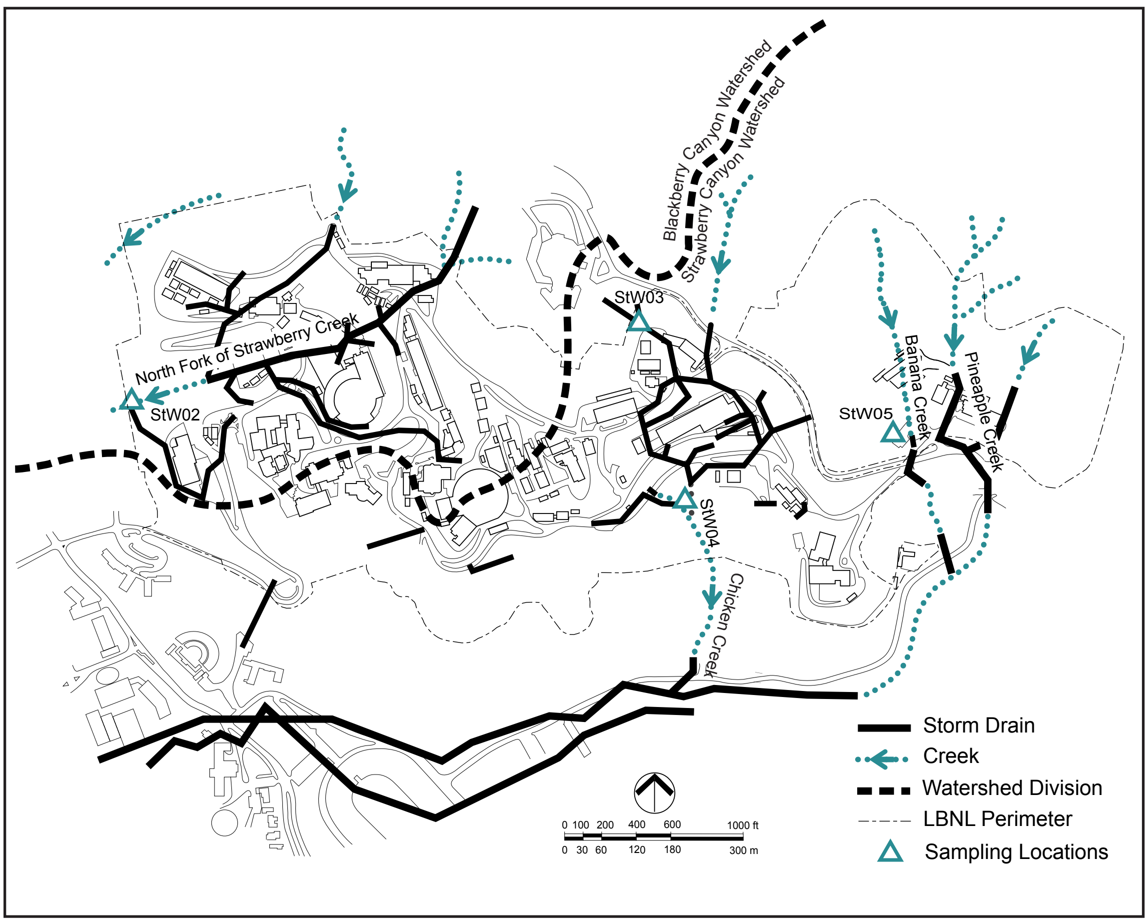


Figure 5-3 Stormwater Sampling Locations

Berkeley Lab's SWMP explains the rationale for sampling, sampling locations, and analytical parameters (radiological and nonradiological). The SWMP was revised and updated for the 2001–2002 stormwater year, as allowed for by the permit. Berkeley Lab conducted an in-depth assessment of monitoring results from the past several years; based on the conclusions from that assessment, one influent sampling point was eliminated and the number of metals analyzed was reduced for the 2001–2002 program.

In June 2002, the SWPPP was revised and updated. No substantive changes were required to be made to the previous best management practices identified in the SWPPP.

One of the monitoring points, StW03 (Building 69 Storm Drain Manhole), is an influent point, where stormwater comes onto the site from residential areas, roads, and UC Berkeley campus facilities located above Berkeley Lab. This monitoring point was chosen as a basis of comparison, to facilitate an investigation if contaminants were found. Data from this influent point could be compared to effluent data to help assess the source of contaminants.

Under the terms of the General Permit, sampling must take place at least twice each stormwater year under specific conditions. Monitoring also includes visual observation of one storm per month and quarterly observation of authorized and unauthorized non-stormwater discharges. All sampling points must be monitored for the following:

- Total suspended solids (TSS), pH, specific conductance, and total organic carbon (TOC). Oil and grease may be substituted for TOC.
- Certain substances as prescribed by the permit if specific operations are present.

In CY 2003, the measured pH was always near neutral, and total petroleum hydrocarbons (diesel) were always measured in small quantities at most sampling points. Oil and grease were not detected. Specific conductance, usually a measure of the mineralization of water, generally was low and below the MCL for domestic drinking water (1,600 micromhos per centimeter). The measure for TSS also was usually very low, indicating clear water. An exception was an East Canyon site sample, which measured 450 milligrams per liter (mg/L) in one storm. Chemical oxygen demand (COD) is a measure that can be correlated to the amount of organic matter in the water. The COD levels in stormwater discharge for the Laboratory generally were low, again with the highest being in the East Canyon site (90 mg/L). Nutrients such as ammonia nitrogen and nitrate plus nitrite also were measured at all stations at low levels.

For the four metals for which Berkeley Lab now analyzes, many results were below detection limits. Maximums were 21 mg/L at East Canyon for aluminum, 24 mg/L at East Canyon for iron, and 21 mg/L at Chicken Creek for magnesium. Zinc was not measured at all above detection level. The General Permit does not contain specific discharge limits for metals. For comparison purposes, the Basin Plan[5] gives effluent limitations for selected toxic pollutants discharged to shallow surface waters applicable to point source discharges from Publicly Owned Treatment Works (such as the East Bay Municipal Utility District [EBMUD]) and industrial effluent, although no levels are given for aluminum, iron, or magnesium.

Routine stormwater samples are also analyzed for alpha and beta emitters and tritium. No alpha or beta emitters were detected. The only tritium concentration detected in stormwater (28 Bq/L [760 pCi/L]) was measured in a Chicken Creek sample.

5.3 WASTEWATER DISCHARGE PROGRAM

The Laboratory's sanitary sewer system is based on gravity flow and discharges through one of two monitoring stations, Hearst or Strawberry (see Figure 5-4).

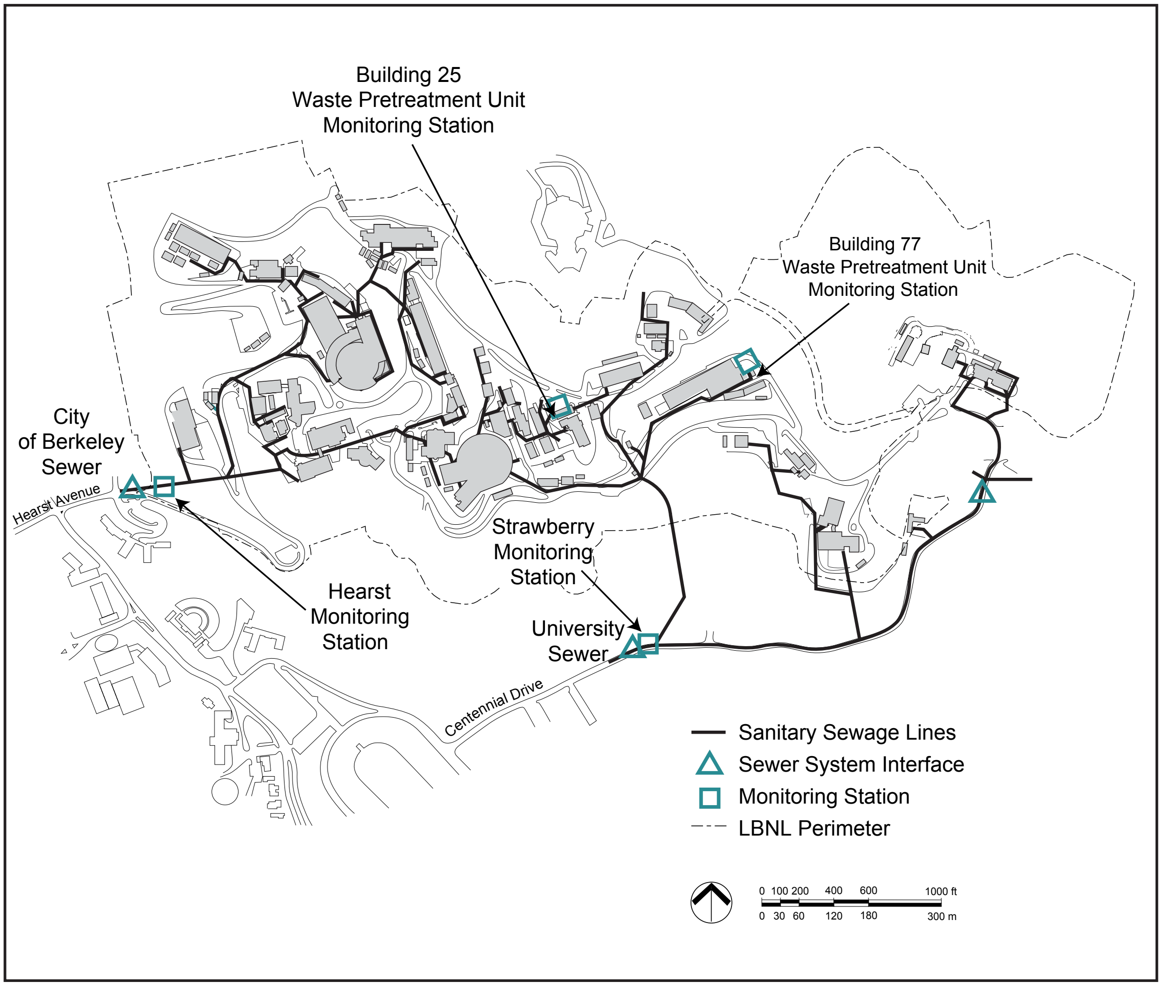


Figure 5-4 Sanitary Sewer System

- Hearst Station, located at the head of Hearst Avenue below the western edge of Berkeley Lab, monitors discharges from the western and northern portions of the site. The monitoring site is located at a point immediately before the Laboratory's sanitary sewer system's connection to the City of Berkeley's sewer main.

- Strawberry Station is located next to Centennial Drive in Strawberry Canyon and monitors discharges from the eastern and southern parts of the Laboratory. Downstream from the monitoring station, the discharge system first ties into University-owned piping and then into the City of Berkeley system. Because of the design of the network, the Strawberry Monitoring Station also receives effluent from several UC Berkeley campus facilities that are located above the Laboratory and are separate from the main UC Berkeley campus; those facilities are Lawrence Hall of Science, Space Sciences Laboratory, Mathematical Sciences Research Institute, Animal Research Facility, and Botanical Garden.

Self-monitoring of wastewater discharges within Berkeley Lab also occurs at Buildings 25 and 77 and at groundwater treatment units (see Table 6-5), according to the terms of their respective EBMUD permits.[8] EBMUD is the local Publicly Owned Treatment Works that regulates all industrial and sanitary discharges to its treatment facilities.

Berkeley Lab has had four wastewater discharge permits issued by EBMUD: one for general sitewide discharges, two for the metal finishing operations found in Buildings 25 and 77, and one for the discharge of treated groundwater from hydraugers. EBMUD had extended the three process-water 2001–2002 permits until April 2003. In April, EBMUD renewed the site's wastewater discharge permits for a period of four years, except for the treated groundwater permit, which in September was extended to 2006. EBMUD also rolled the two categorical permits for Building 25 and Building 77 into one permit, so that the site currently has three wastewater discharge permits. The frequency of monitoring for both the sitewide and the 25/77 permits was reduced, reflecting the Lab's recent good monitoring record.

As in previous years, the Laboratory's sitewide permit required periodic monitoring of wastewater discharges for various parameters and metals analysis once per year at times specified in the permit. In addition, EBMUD continued to perform unannounced monitoring of wastewater discharges four times per year. No changes in permit requirements occurred, and all sampling results were below discharge limits.

5.3.1 Hearst and Strawberry Sewer Outfalls

Sanitary sewer discharge monitoring is divided into two types: nonradiological and radiological. Nonradiological monitoring is generally termed "self-monitoring" and is mandated in the wastewater discharge permits granted by EBMUD. Sitewide samples are always analyzed for pH, total identifiable chlorinated hydrocarbons, TSS, and COD, with additional analyses for metals required once during the permit year.

Radiological monitoring is required by DOE orders[1] and guidance[9] but it also ensures compliance with radiological limits given in the California Code of Regulations[10] cited by the EBMUD wastewater discharge permit. California regulations now incorporate by reference the applicable federal regulations[11] and associated discharge limits.

Analyses are performed by both a state-certified commercial laboratory and, for certain radiological analyses, an accredited in-house laboratory. Results are compared against the discharge limits for each parameter given in the permits, and self-monitoring reports are submitted to EBMUD in compliance with permit requirements.

5.3.1.1 Nonradiological Monitoring

Two self-monitoring samples were taken from the Hearst and Strawberry outfalls during CY 2003. All results were well within discharge limits, as were all measurements made by EBMUD in its four independent samplings. Some metals were below detection limits in both the Hearst and Strawberry outfalls; however, small amounts of chromium, copper, silver, and zinc were measured in both outfalls. Figure 5-5 shows the metal results as a percentage of permit discharge limits.

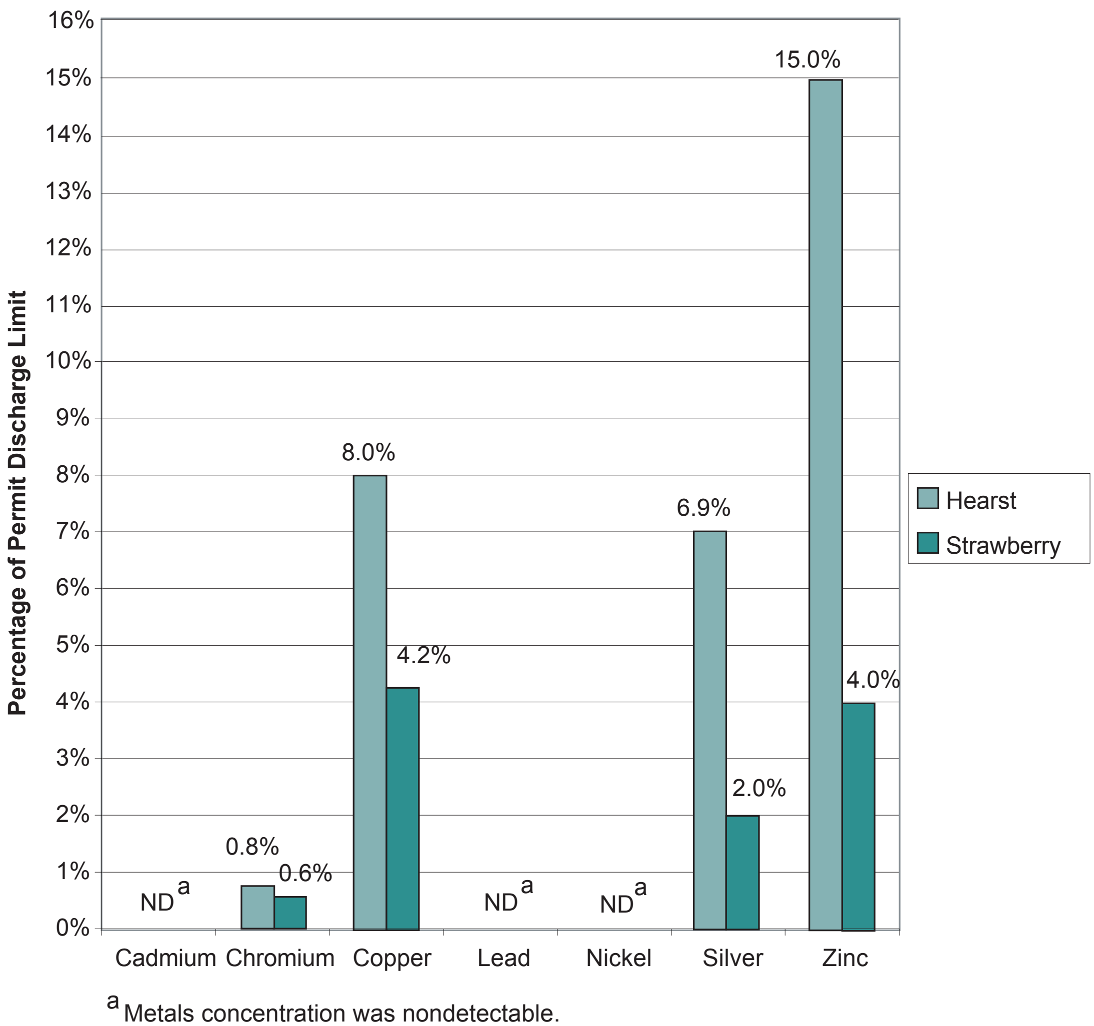


Figure 5-5 Concentration of Metals in Sewer Water Samples as a Percentage of Permit Discharge Limit

No chlorinated hydrocarbons were detected, except for chloroform, which is present in EBMUD supply water, and very small amounts of 1,2-dichloroethane and benzene (in Strawberry) and toluene (in both sewers). According to the permit, the pH level must remain at least as high as 5.5; all results were well above this value. TSS and COD are measured to determine wastewater strength, which forms the basis for the costs charged by EBMUD to the Laboratory for wastewater treatment. On the basis of past years' monitoring results, Berkeley Lab projects the average and maximum wastewater strength for the coming period in its permit application, and these then become the permit guidelines. TSS and COD in CY 2003 were consistently higher in Hearst than in Strawberry outfalls.

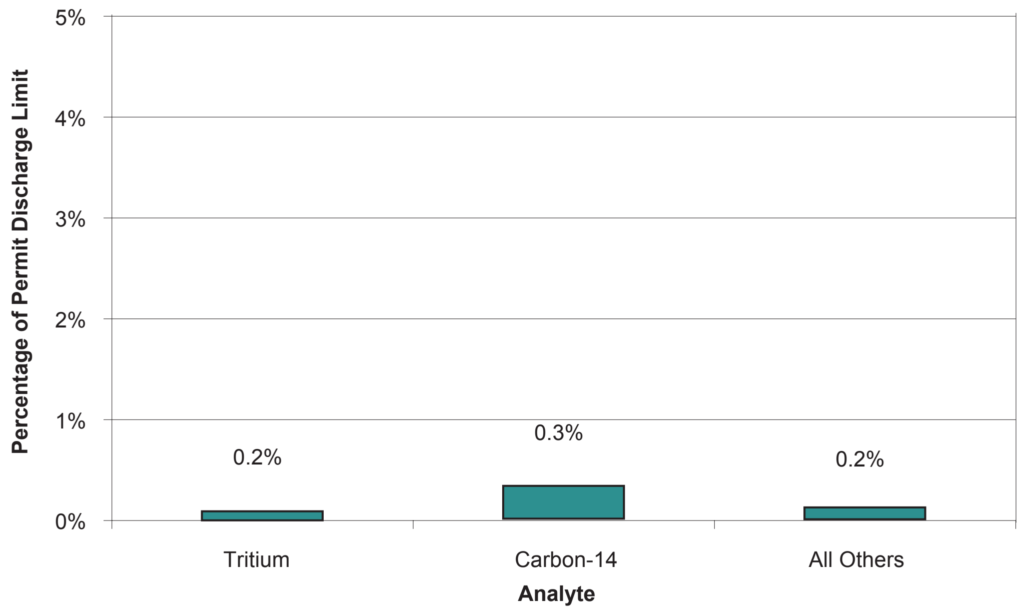
5.3.1.2 Radiological Monitoring

The Hearst and Strawberry sewer outfalls are continuously sampled at half-hour intervals using automatic equipment. The composite samples are collected every four weeks and submitted to a state-certified laboratory for analysis of gross alpha radiation, gross beta radiation, iodine-125, tritium, phosphorus-32, sulfur-35, and carbon-14. Split samples are analyzed periodically for additional quality control purposes.

A special study was completed this year to determine the levels of plutonium in sewer effluent. It was hypothesized that past research activities might have accidentally deposited small amounts of plutonium into the sewer system at Berkeley Lab. For this study, five samples were collected from both Hearst and Strawberry sewer outfalls and analyzed for plutonium-238 and plutonium-239+240. The results from these analyses were near or below detection limits. Since over the course of two years no conclusive evidence of plutonium in Berkeley Lab sewers has been seen, this special study has been terminated.

The federal[11] and state[10] regulatory limits for radioisotopes are based on total amounts released per year. For tritium, this limit is 1.9×10^{11} Bq (5 curies [Ci]) per year, and for carbon-14 it is 3.7×10^{10} Bq (1 Ci) per year. The limit for all other radioisotopes is a combined 3.7×10^{10} Bq (1 Ci) per year. Radioisotopes discharged into Berkeley Lab's sewer wastewater, expressed as a percentage of their permit discharge limit, are summarized in Figure 5-6.

Alpha emitters, which can potentially come from transuranic and heavy-element research, were not detected at either Hearst or Strawberry monitoring stations. Gross beta emitters were usually detected in both sewers at low levels, with levels at Strawberry generally lower than those at Hearst. The maximum concentration of gross beta emitters for the year was 0.4 Bq/L (11 pCi/L) at Hearst Monitoring Station. The other individual isotopes—iodine-125, sulfur-35, and phosphorus-32—were not detected at either sewer outfall.



Note: "All Others" consists of gross alpha and beta, iodine-125, phosphorus-32, and sulfur-35.

Figure 5-6 Radioisotopes Discharged to Sewers in 2003 as a Percentage of Permit Discharge Limit

With one exception of a sample just at detection level, tritium levels were below the minimum detectable amount at Hearst Monitoring Station. At Strawberry Monitoring Station, tritium levels were above detection limits only twice, with a maximum of 21 Bq/L (580 pCi/L). The total annual discharge of tritium in wastewater was 3.56×10^8 Bq (0.01 Ci); for carbon-14 it was 1.08×10^8 Bq (0.003 Ci); and the total for other radioisotopes was 8.04×10^7 Bq (0.002 Ci). The amount of tritium decreased from last year's level by 50%, while the total for other radioisotopes decreased by 80%. All values, however, were well below allowable limits. For example, tritium was only 0.2% of the allowable federal and state limit, carbon-14 was 0.3% of its limit, and all other isotopes together were approximately 0.2% of their limit.

Figure 5-7 trends the total amount of tritium released to Berkeley Lab's sewers over the past eight years. Results were consistently under 10% of the permitted level, and in the past three years have trended downward to nearly zero.

5.3.2 Building 25 Photo Fabrication Shop Wastewater

The Photo Fabrication Shop in Building 25 manufactures electronic circuit boards and screen-print nomenclature on panels, and the shop performs chemical milling, to support the needs of Berkeley Lab research and activities. Wastewater containing metals and acids from these operations is routed

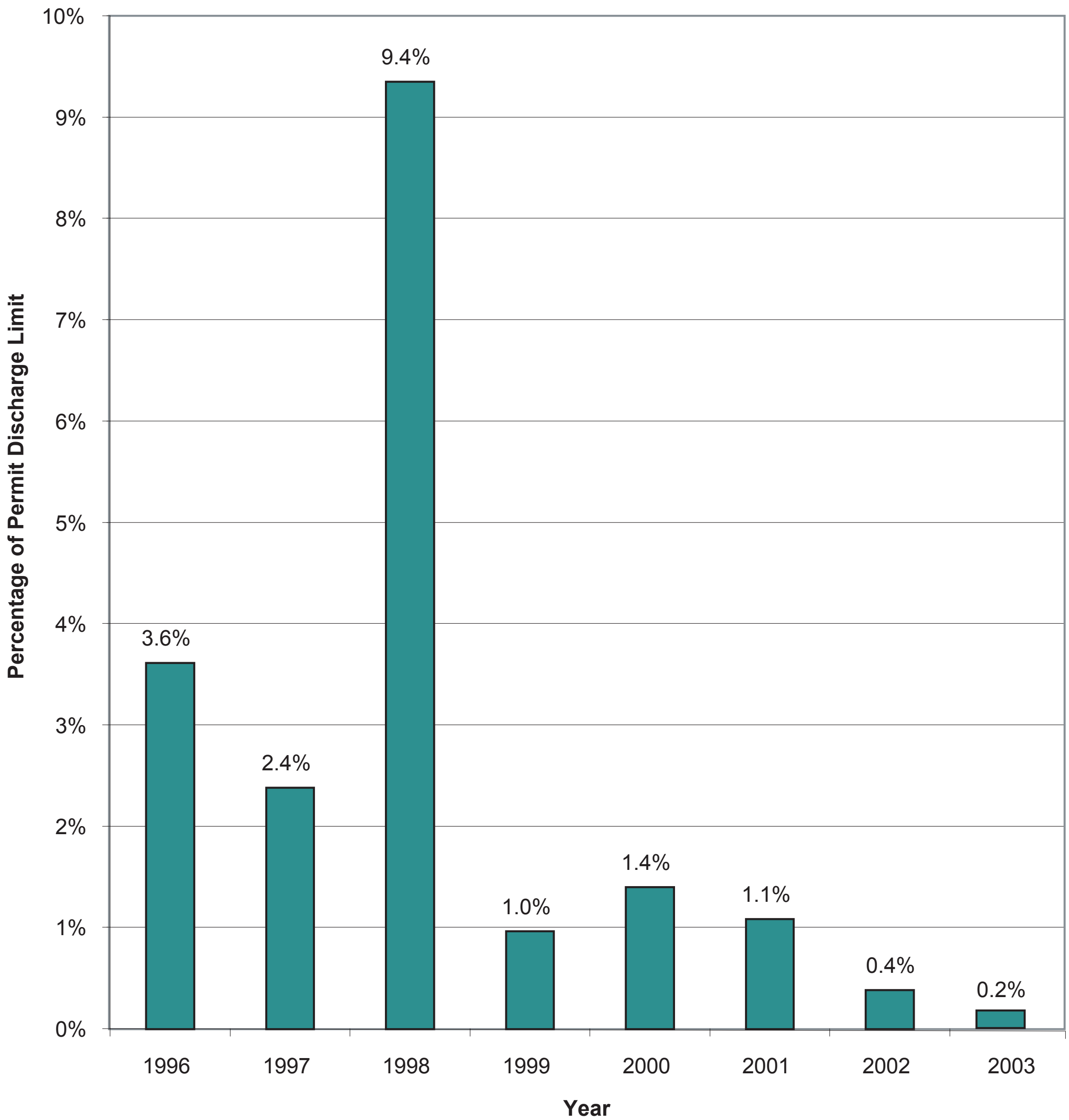


Figure 5-7 Annual Releases of Tritium to Sewers (1996–2003) as a Percentage of Permit Discharge Limit

to a fixed treatment unit (FTU) before discharge to the sanitary sewer. The Building 25 FTU treats wastewater in batch mode.

All sampling performed by Berkeley Lab and EBMUD—one self-monitoring and two efforts by EBMUD—yielded daily maximum and monthly average results well within EBMUD discharge limits.[8]

5.3.3 Building 77 Ultra-High Vacuum Cleaning Facility Wastewater

The Ultra-High Vacuum Cleaning Facility (UHVCF) at Building 77 cleans various types of metal parts used in research and support operations at Berkeley Lab. Cleaning operations include passivating, acid and alkaline cleaning, and ultrasonic cleaning. Acid and alkaline rinsewaters containing metals from UHVCF operations are routed to a nearby 227-liter-per-minute (60-gallon-per-minute) FTU.

All self-monitoring (two) and EBMUD (one) inspection samples were well within permitted limits.

As noted previously, in 2003 EBMUD combined the permits for Buildings 77 and 25 into one. Berkeley Lab now samples at both facilities once per year for pH and metals. Instead of monitoring for chlorinated hydrocarbons, the Laboratory now submits a *Total Toxic Organics Compliance Report* twice per year, certifying that Buildings 25 and 77 are implementing the applicable solvent management plan and that no dumping of concentrated toxic organics into wastewaters has occurred.

5.3.4 Treated Hydrauger and Extraction Well Discharge

Since 1993, EBMUD has permitted Berkeley Lab to discharge treated groundwater to the sanitary sewer. The treatment process consists of passing the contaminated groundwater through a two-stage carbon adsorption system.

The EBMUD permit allows for discharge of treated groundwater from certain hydrauger (subsurface drain) treatment systems and extraction wells, and also from well sampling and development activities. All treated groundwater discharged under the permit is routed through the Hearst Sewer. One of the conditions for this discharge is the submission of a semiannual report that provides information on the volumes treated and discharged as well as any contaminants found.

Tests using US/EPA-approved methodologies are performed monthly on treated groundwater to determine levels of VOCs. Most results were below detection limits.

Occasional low levels of some chlorinated hydrocarbons have been measured (parts per billion) that do not exceed allowable limits. As a precautionary measure, a sample is collected from the outflow of the first drum of carbon in each system to assist in determining when it should be changed out. This prevents contaminated groundwater from being discharged to the sanitary sewer.

For further discussion of groundwater monitoring and treatment, see Chapter 6.

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6

Groundwater

Collection of a gas sample from a soil vapor extraction system near Building 7

6.1 BACKGROUND

This chapter reviews the groundwater monitoring program at Lawrence Berkeley National Laboratory, emphasizing the calendar year (CY) 2003 results. Additional details on the program can be obtained from Environmental Restoration Program quarterly progress reports, which contain all the groundwater monitoring data, site maps that show monitoring well locations and contaminant concentrations, and graphs that show changes in contaminant concentrations over time. These reports are available for public review at the City of Berkeley main public library.

Berkeley Lab's groundwater monitoring program began in 1991 to serve the following purposes:

- Characterize the magnitude and extent of groundwater contamination
- Evaluate the potential for future contaminant migration
- Monitor groundwater quality near the site perimeter
- Monitor groundwater quality near existing and removed hazardous materials or hazardous waste storage units, including underground storage tanks

The Laboratory has installed an extensive system of wells to monitor groundwater quality. Four categories of contaminants are monitored under the program: volatile organic compounds (VOCs), hydrocarbons, metals, and tritium. Selected wells are sampled for additional potential contaminants.

Under the Resource Conservation and Recovery Act of 1976 (RCRA) Corrective Action Program,[1] the Laboratory identified areas of soil and groundwater contamination that may have resulted from past releases of contaminants to the environment. It then determined the sources and extent of the contamination. After conducting a risk assessment, the Laboratory identified areas that require corrective action.

Activities are coordinated closely with the regulatory oversight agencies, including the California Environmental Protection Agency Department of Toxic Substances Control, San Francisco Bay Regional Water Quality Control Board, City of Berkeley, and United States Department of Energy. These agencies review and comment on the work plans prepared for all activities. Berkeley Lab submits quarterly progress reports to these agencies and meets with them frequently to review results of various activities.

Maximum contaminant levels (MCLs) for drinking water are included in this chapter for contaminants with established limits. Groundwater at Berkeley Lab is not used for human consumption, and the use of MCLs is included only as a reference.

6.2 HYDROGEOLOGIC CHARACTERIZATION

The following sections discuss the hydrologic units, groundwater flow, and groundwater quality.

6.2.1 Hydrogeologic Units

Moraga Formation volcanic rocks, Orinda Formation sediments, and Great Valley Group sediments constitute the principal bedrock units underlying the site. The structural geology and physical characteristics of these three units are the principal hydrogeologic factors controlling the movement of groundwater and groundwater contaminants at the Laboratory.

6.2.2 Groundwater Flow

Depth to water is measured monthly in site monitoring wells. The depth to groundwater ranges from approximately 0 to 30 meters (0 to 98 feet). Figure 6-1 shows groundwater elevations at Berkeley Lab, based on water levels measured in wells. This map shows that the groundwater surface generally mirrors the surface topography.

In the western part of Berkeley Lab, groundwater generally flows toward the west; over the rest of the Laboratory, groundwater generally flows toward the south. In some areas, due to the subsurface geometry of geologic units, groundwater flow directions show local deviations from the general trends presented on the piezometric map. The velocity of the groundwater varies from approximately 0.001 meter per year (m/yr) (0.003 foot per year [ft/yr]) to about 300 m/yr (990 ft/yr).

6.2.3 Groundwater Quality

Groundwater samples from monitoring wells are tested for total dissolved solids (TDS), cations, and anions. The TDS concentrations measured in groundwater monitoring wells at the Lab ranged from 406 to 2,180 milligrams per liter.

6.3 GROUNDWATER MONITORING RESULTS

The total number of monitoring wells in the program is 185. Twenty monitoring wells are located close to the site boundary, and one well is located downgradient from the Laboratory (see Figure 6-2).

Tables 6-1, 6-2, and 6-3 summarize groundwater monitoring results for CY 2003. Tables 6-1 and 6-2 summarize the metal results and VOC results, respectively. The tables show the drinking-water standard (MCL) for the analyte,[2,3] the number of monitoring wells in which the analyte was detected, and the ranges in concentrations detected (in micrograms per liter [µg/L]). Table 6-3 presents tritium results (in becquerels per liter [Bq/L]).

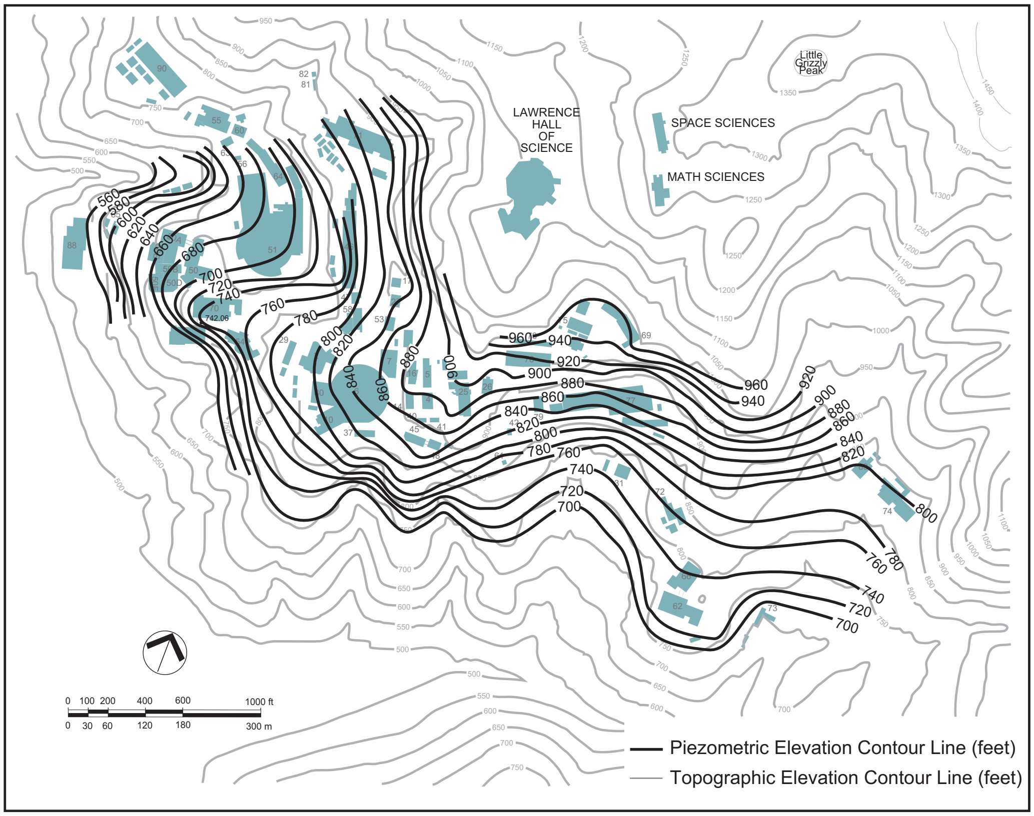


Figure 6-1 Groundwater Piezometric Map

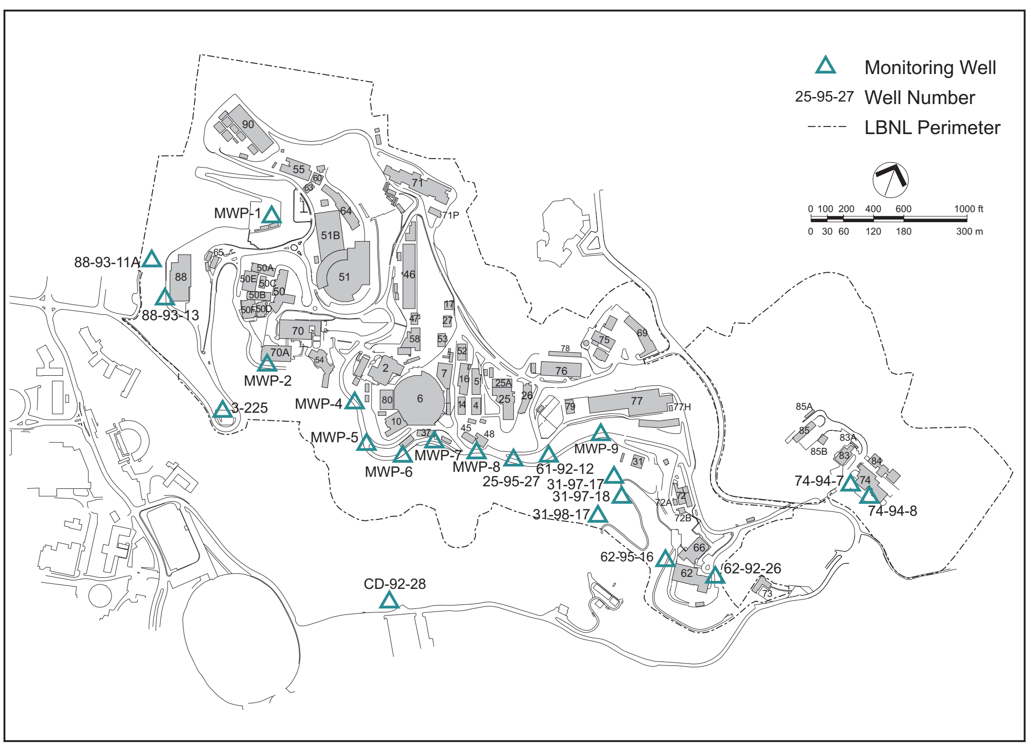


Figure 6-2 Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

Table 6-1 Metals Detected in Groundwater Samples from Monitoring Wells[a]

Metal	Number of wells sampled	Number of samples	Number of wells in which analyte was detected	Range of concentrations (µg/L)[b]	Drinking-water standard (MCL) (µg/L)
Antimony	24	29	0	—	6
Arsenic	38	43	15	2–61	50
Barium	26	31	22	13–810	1000
Beryllium	23	28	0	—	4
Cadmium	23	28	3	0.3–0.4	5
Chromium	26	31	1	100	50
Hexavalent chromium	1	1	0	—	50[c]
Cobalt	23	28	1	130	NS[d]
Copper	23	28	0	—	1000[e]
Lead	23	28	0	—	15[f]
Mercury	25	30	0	—	2
Molybdenum	35	40	6	72–870	NS
Nickel	24	29	1	690	100
Selenium	26	31	3	3–60	50
Silver	23	28	0	—	100[e]
Thallium	23	28	0	—	2
Vanadium	23	28	10	12–360	NS
Zinc	23	28	9	11–120	5000[e]

[a] Metals not detected in any samples are antimony, beryllium, hexavalent chromium, copper, lead, mercury, silver, and thallium.
[b] Micrograms per liter
[c] Drinking water standard is for total chromium
[d] NS = Not specified
[e] Secondary MCL (guidelines for cosmetic or aesthetic effects)
[f] Action Level: the level at which the water system must take action. EPA is requiring water systems to control the corrosiveness of their water if the level of lead at home taps exceeds an Action Level.

6.4 GROUNDWATER CONTAMINATION PLUMES

Based on groundwater monitoring results, nine principal groundwater contamination plumes have been identified on-site. The plumes are listed below, and the locations are shown in Figure 6-3:

- *VOC plumes:* Old Town and Buildings 51/64, 51L, 71, and 76
- *Freon plume:* Building 71
- *Tritium plume:* Building 75/77
- *Petroleum hydrocarbon (diesel) plumes:* Buildings 7 and 74

Groundwater contaminated with VOCs also was detected in three other areas of the site (Buildings 69, 75, and 77) in CY 2003. Based on current information, however, the extent of contamination in those areas is limited.

Table 6-2 Volatile Organic Compounds Detected in Groundwater Samples from Monitoring Wells[a]

Analytes detected	Number of wells in which analyte was detected	Range of concentrations (µg/L)	Drinking-water standard (MCL) (µg/L)
Aromatic or nonhalogenated hydrocarbons			
Benzene	6	0.53–67.2	1
n-butylbenzene	3	1.6–16.2	NS [b]
sec-butylbenzene	1	1.4	NS
tert-butylbenzene	1	1.6	NS
1,2-dichlorobenzene	1	0.6	600
1,4-dichlorobenzene	4	0.5–2.6	5
p-isopropyltoluene	1	1.3	NS
Methyl tert-butyl ether	2	0.54–1.7	13
Naphthalene	3	2.3–22.4	NS
Toluene	4	1.2–6.6	150
1,2,4-trimethylbenzene	4	1.2–2.8	NS
1,3,5-trimethylbenzene	4	1.3–2.0	NS
Xylenes (total)	1	3.2	1,750
Halogenated hydrocarbons			
Bromodichloromethane	1	1	100 [c]
Bromoform	2	3.7–14	100 [c]
Carbon tetrachloride	23	0.58–2,500	0.5
Chloroform	31	0.58–65	100 [c]
1,1-dichloroethane	30	0.7–400	5
1,2-dichloroethane	5	0.82–6.6	0.5
1,1-dichloroethene	39	0.55–320	6
cis-1,2-dichloroethene	57	0.57–720	6
trans-1,2-dichloroethene	19	0.65–25	10
Freon 114-1,2-dichlorotetrafluoroethane	1	5.2	NS
Methylene chloride	3	6–1,600	5
1,1,1,2-tetrachloroethane	5	1.7–72	NS
Tetrachloroethene	69	0.51–64,000	5
1,1,1-trichloroethane	6	0.52–14.7	200
1,1,2-trichloroethane	3	1–14	5
Trichloroethene	81	0.54–45,400	5
Freon 11-trichlorofluoromethane	1	0.52	150
Freon 113-1,1,2-trichlorotrifluoroethane	4	0.85–8.6	1,200
Vinyl chloride	21	0.59–51.7	0.5

[a] 561 samples taken from 179 wells during the year
[b] NS = Not specified
[c] Standard is for total trihalomethanes.

Table 6-3 Tritium Detected in Groundwater Samples from Monitoring Wells[a] (in Bq/L[b])

Well number	January–March	April–June	July–September	October–December
31-97-17	82	NS[c]	65	NS
69-97-21	23	NS	NS	NS
71-95-9	16	<11	<11	<11
75-92-23	68	NS	64	NS
75-97-5	1018; 892[d]	872; 836[d]	831; 792[d]	808; 766[d]
75-97-7	28	NS	NS	NS
75-98-14	158	172	280	216; 201[d]
75-99-6	53	65	69	60
75-99-7	268	262; 250[d]	264	301; 263[d]
75B-92-24	47	NS	75	NS
76-93-6	86	NS	168	NS
77-94-6	414	NS	294; 328[d]	NS
77-97-9	409	NS	379; 361[d]	NS
77-97-11	225	NS	193; 189[d]	NS
78-97-20	75	NS	68	NS
MW91-2	19	NS	24	NS
MW91-4	43	NS	<11	NS
MW91-5	54	NS	48	NS
MW91-6	115	NS	89	NS

[a] For comparison, the drinking water standard determined by California Department of Health Services is 740 becquerels per liter (Bq/L) (20,000 picocuries per liter [pCi/L]).
[b] Becquerels per liter
[c] NS = Not sampled
[d] Duplicate sample

6.4.1 Volatile Organic Compound Plumes

Covering the area of Buildings 4, 5, 6, 7, 14, 16, 25, 27, 52, 53, and 58, and the slope west of Building 53, the Old Town VOC plume is the most extensive plume at Berkeley Lab. This plume is defined by the presence of perchloroethylene (PCE), trichloroethylene (TCE), carbon tetrachloride, and lower concentrations of other halogenated hydrocarbons, including 1,1-dichloroethylene (1,1-DCE); cis-1,2-DCE; 1,1-dichloroethane (1,1-DCA); 1,2-DCA; 1,1,1-trichloroethane (1,1,1-TCA); 1,1,2-TCA; and vinyl chloride; several of which are products of PCE and TCE degradation.

The maximum concentration of total halogenated hydrocarbons detected in groundwater samples collected from Old Town VOC plume wells in CY 2003 was 108,286 µg/L, which primarily consisted of PCE (60,200 µg/L) and TCE (45,400 µg/L). Figure 6-4 shows the areal extent of VOCs in groundwater in the Old Town area.

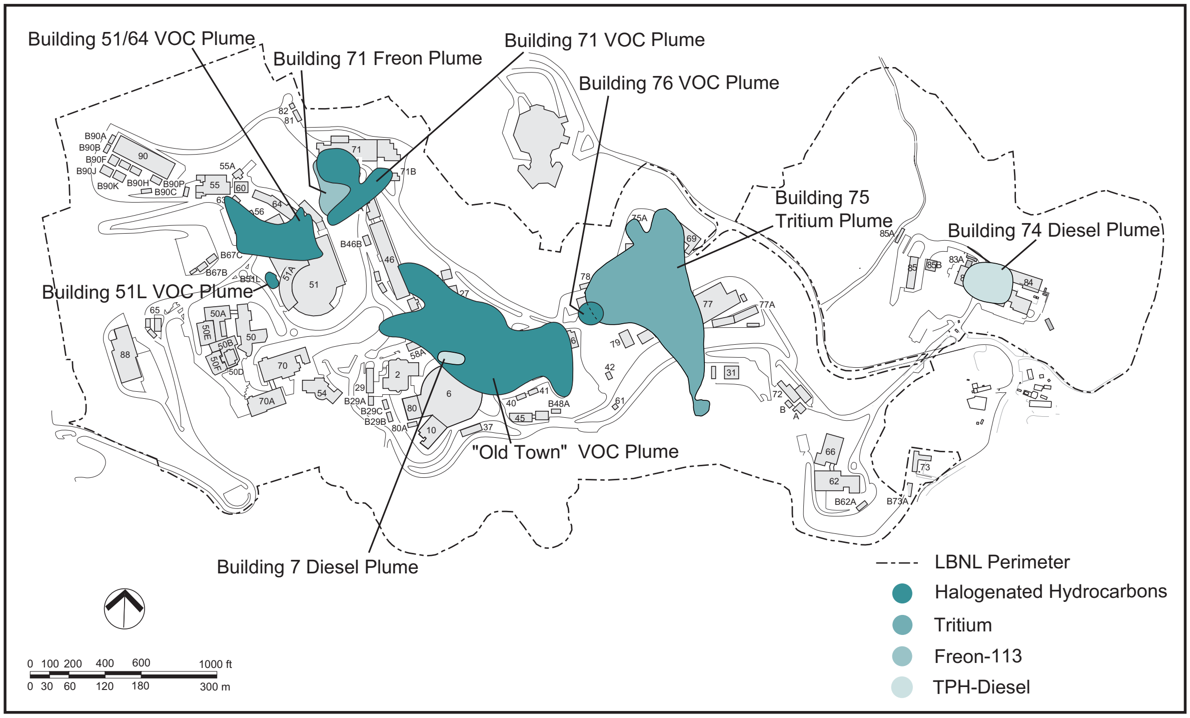


Figure 6-3 Groundwater Contamination Plumes (September 2003)

The presence of the maximum VOC concentrations north of Building 7 suggests that the primary source of the Old Town VOC plume was an abandoned sump located between Buildings 7 and 7B. The sump was discovered and its contents removed in 1992. The sump itself was removed in 1995 after underground utility lines that crossed the sump were relocated. Other less significant source areas for groundwater contamination are indicated by relatively high concentrations of halogenated hydrocarbons detected in groundwater samples from monitoring wells west of Building 16, east of Building 52, and west of Building 25A. The contaminated groundwater from these sources flows westward, where it intermixes with the main Old Town plume.

The following interim corrective measures have been instituted to manage the Old Town VOC plume:

- A groundwater collection trench was installed immediately downgradient from the former Building 7 sump to control the source of the groundwater contamination.
- A groundwater collection trench was installed west of Building 25A to control the source of groundwater contamination in this area.
- A subdrain located east of Building 46 was installed to intercept the northern lobe of the plume and to prevent the discharge of contaminated groundwater to the storm drain.
- A groundwater collection trench was installed west of Building 58 to intercept the southern lobe of the plume and prevent its further migration.

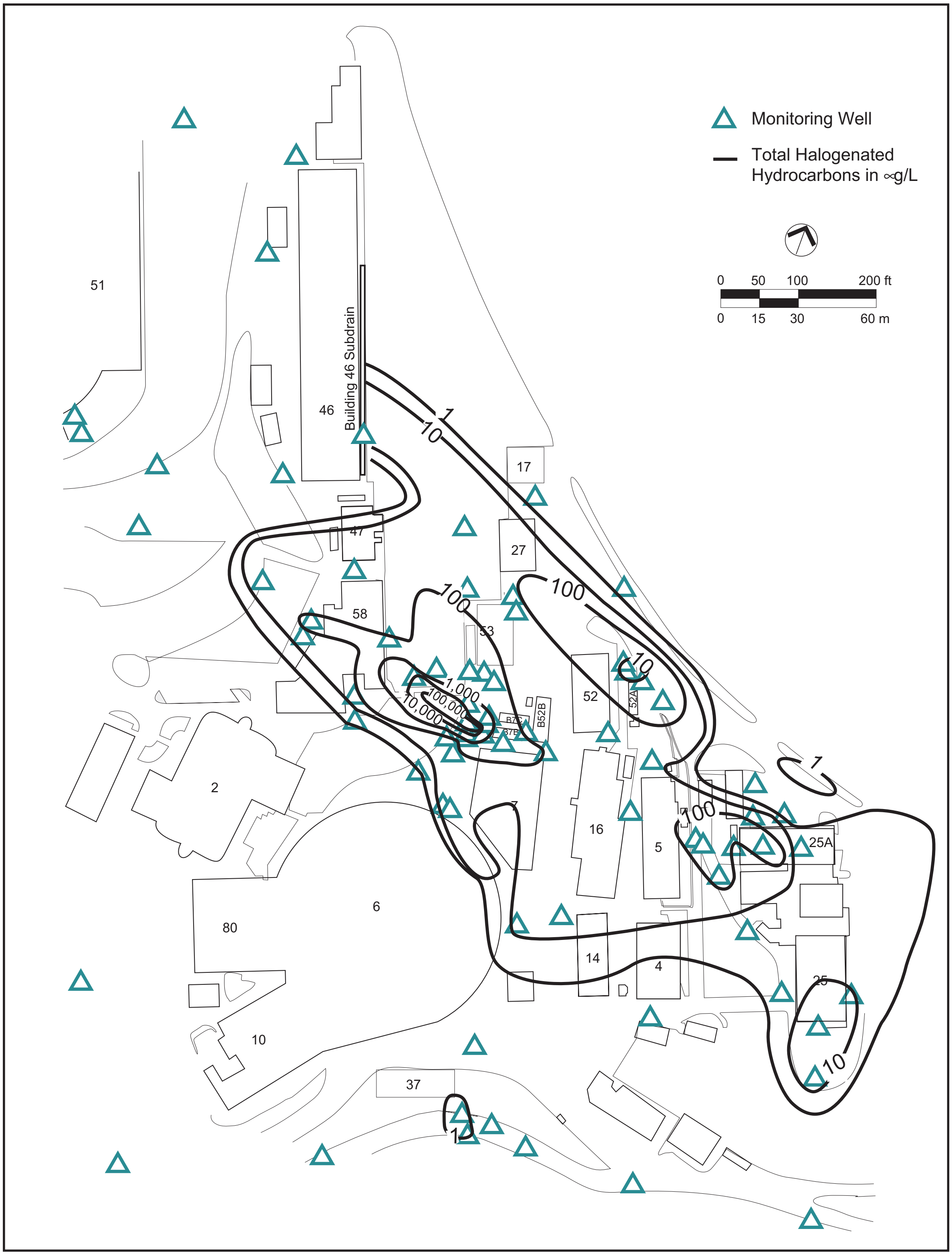


Figure 6-4 Groundwater Contamination (Total Halogenated Hydrocarbons in Micrograms per Liter [μg/L]) in Old Town Area (September 2003)

- Two groundwater collection trenches were installed east of Building 58, in areas where high VOC concentrations had been detected in soil gas and groundwater.
- Contaminated soil believed to be the source of groundwater contamination east of Building 52A was removed.

A second plume of VOC-contaminated groundwater, the Building 51/64 VOC plume, extends from the southeast corner of Building 64, under Buildings 64 and 51B. This plume is defined by the presence of 1,1-DCA; 1,1-DCE; PCE; TCE; and lower concentrations of other halogenated hydrocarbons. Halogenated hydrocarbons were detected in CY 2003 at a maximum total concentration of 20,292 μg/L in a water sample from a temporary sampling point close to the previously removed source area of the plume. The maximum concentration of total halogenated hydrocarbons detected in CY 2003 in samples collected from groundwater monitoring wells in the Building 51/64 area was 755 μg/L. The contaminants primarily consisted of 1,1-DCA (377 μg/L); 1,1-DCE (88 μg/L); TCE (120 μg/L); and PCE (143 μg/L). Figure 6-5 shows the areal extent of VOCs in groundwater in the Building 51/64 area. In 2000, highly contaminated soil was excavated from the source area of the plume as an interim corrective measure (see Section 6.5.1).

Other VOC plumes have been identified south of Building 71 (Building 71 VOC plume), around and under former Building 51L (Building 51L VOC plume), and south of Building 76 (Building 76 VOC plume). These plumes cover less area than the Old Town plume, and fewer contaminants have been detected.

The Building 71 VOC plume is defined by the presence of halogenated hydrocarbons, predominantly PCE; TCE; cis-1,2-DCE; 1,1-DCA; and vinyl chloride. The maximum concentration of total halogenated hydrocarbons detected in wells monitoring the plume in 2003 was 1,580 μg/L, detected in a monitoring well installed south of Building 71B, close to the source of the plume. Contaminated groundwater from the plume is discharged continuously through five subhorizontal drains (hydraugers). Effluent from these hydraugers is collected and treated before being released under permit to the sanitary sewer. Highly contaminated soil was excavated from the source area of the plume in CY 2000 and CY 2003 as interim corrective measures (see Section 6.5.1).

The Building 51L VOC plume is defined by the presence of TCE; cis-1,2-DCE; trans-1,2-DCE; and smaller amounts of other degradation byproducts. The horizontal and vertical extent of this plume was identified in CY 2001. The maximum concentration of total halogenated hydrocarbons detected in a temporary sampling point in CY 2003 was 2,591 μg/L. The contaminants consisted primarily of cis-1,2-DCE (1,100 μg/L); trans-1,2-DCE (457 μg/L); TCE (551 μg/L); and vinyl chloride (132 μg/L).

The Building 76 VOC plume is defined by the presence of TCE and cis-1,2-DCE. The maximum concentration of total halogenated hydrocarbons detected in wells monitoring the plume in CY 2003 was 24.4 μg/L.

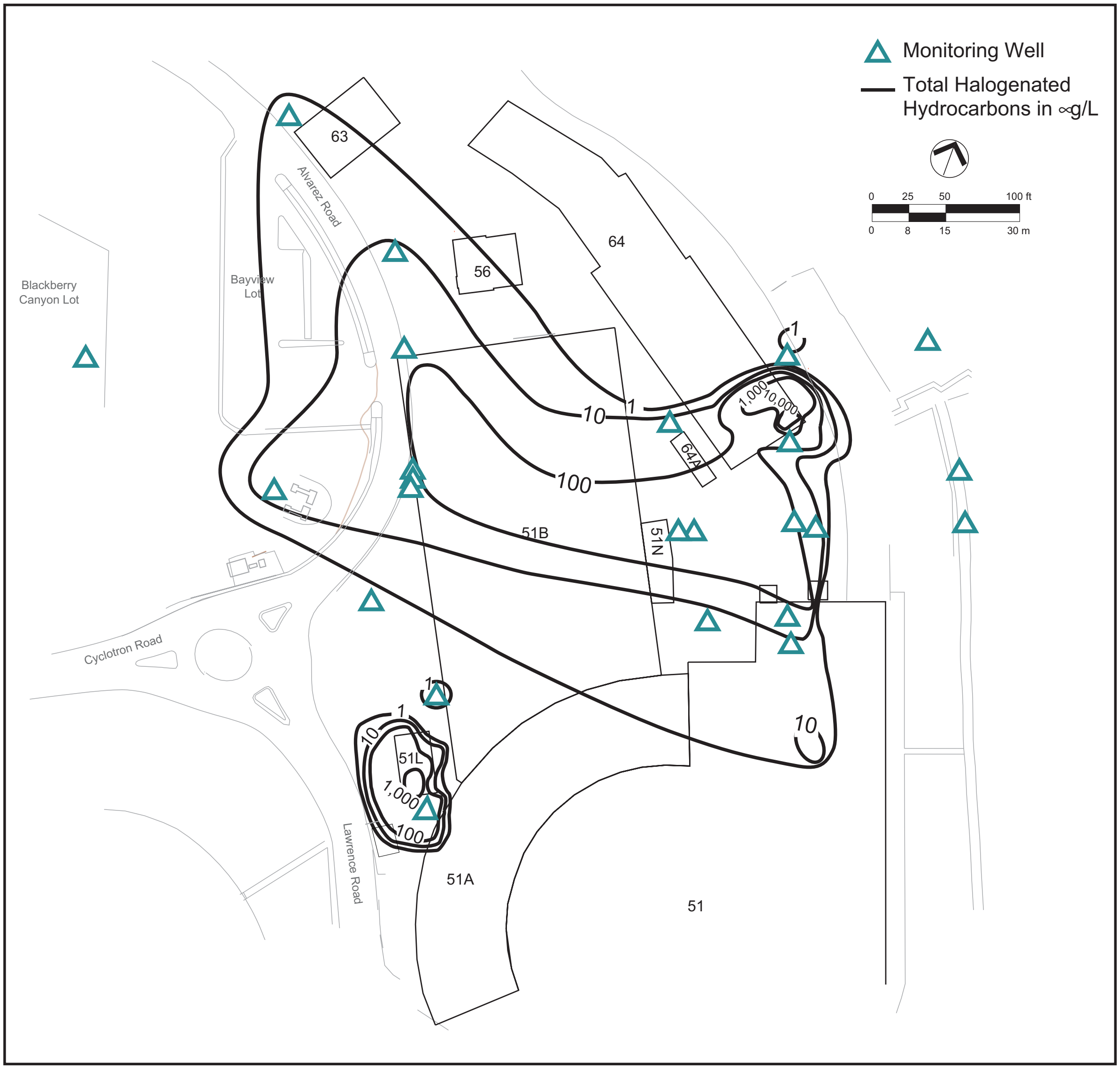


Figure 6-5 Groundwater Contamination (Total Halogenated Hydrocarbons in Micrograms per Liter [µg/L]) at Building 51/64 VOC Plume (September 2003)

6.4.2 Freon Plume

High concentrations of Freon-113 were detected in groundwater south of Building 71 in 1993 and 1994. The source of Freon-113 most likely was past spills from the Linear Accelerator Cooling Unit located in Building 71. The cooling unit is no longer in operation. Concentrations of Freon-113 have decreased from 8,984 µg/L in 1994 to approximately 8.6 µg/L in 2003. The MCL for Freon-113 is 1,200 µg/L. Contaminated groundwater from the plume is continuously discharged through two hydraugers. Effluent from these hydraugers is collected and treated before being released under permit to the sanitary sewer.

6.4.3 Tritium Plume

The tritium plume covers the areas of Buildings 31, 75, 76, 77, and 78. In addition, a small amount of tritium, 16 Bq/L (432 picocuries per liter [pCi/L]) was detected in a monitoring well in the Building 71B area. The source of the tritium was the former National Tritium Labeling Facility at Building 75. The maximum concentration of tritium detected in monitoring wells in CY 2003 was 1,018 Bq/L (27,505 pCi/L), at monitoring well 75-97-5, which is above the drinking-water standard of 740 Bq/L (20,000 pCi/L).[2] Tritium has been detected above the drinking-water standard in only one monitoring well. Figure 6-6 shows groundwater tritium concentration contours in the Building 75/77 area. The area of tritium-contaminated groundwater extends southward from Building 75 toward Chicken Creek, in the direction of groundwater flow. In addition to the wells listed in Table 6-3, water samples from 51 other monitoring wells, including 20 wells close to the Berkeley Lab property line, were analyzed for tritium. No tritium above the reporting limit of 11 Bq/L (300 pCi/L) was detected in any of these samples.

6.4.4 Petroleum Hydrocarbon Plumes

Monitoring wells have been installed at or downgradient from two abandoned and five removed underground fuel storage tanks (USTs). Figure 6-7 shows the approximate locations of these wells. The maximum concentrations of total petroleum hydrocarbons (TPH) detected at these sites in CY 2003 are listed in Table 6-4.

Petroleum hydrocarbon plumes are located in three areas: north of Building 6, near Building 74, and south of Building 76. No BTEX components (i.e., benzene, toluene, ethyl benzene, xylenes) were detected above drinking-water MCL at UST sites in CY 2003. A dual-phase (groundwater and soil vapor) extraction and treatment system has been installed at the location of the Building 7E former UST as an interim corrective measure.

Methyl tertiary butyl ether (MTBE) was detected in two monitoring wells in CY 2003 at a maximum concentration of 1.7 μg/L. The California MCL for MTBE is 13 μg/L.

6.5 INTERIM CORRECTIVE MEASURES

Interim corrective measures are used to remediate contaminated media or prevent movement of contamination, where the presence or movement of contamination poses a potential threat to human health or the environment. Throughout the RCRA Corrective Action Process, Berkeley Lab has conducted the following interim corrective measures in consultation with regulatory agencies:

- Removed or controlled sources of contamination
- Prevented discharge of contaminated water to surface waters
- Eliminated potential pathways that could contaminate groundwater
- Prevented further migration of contaminated groundwater

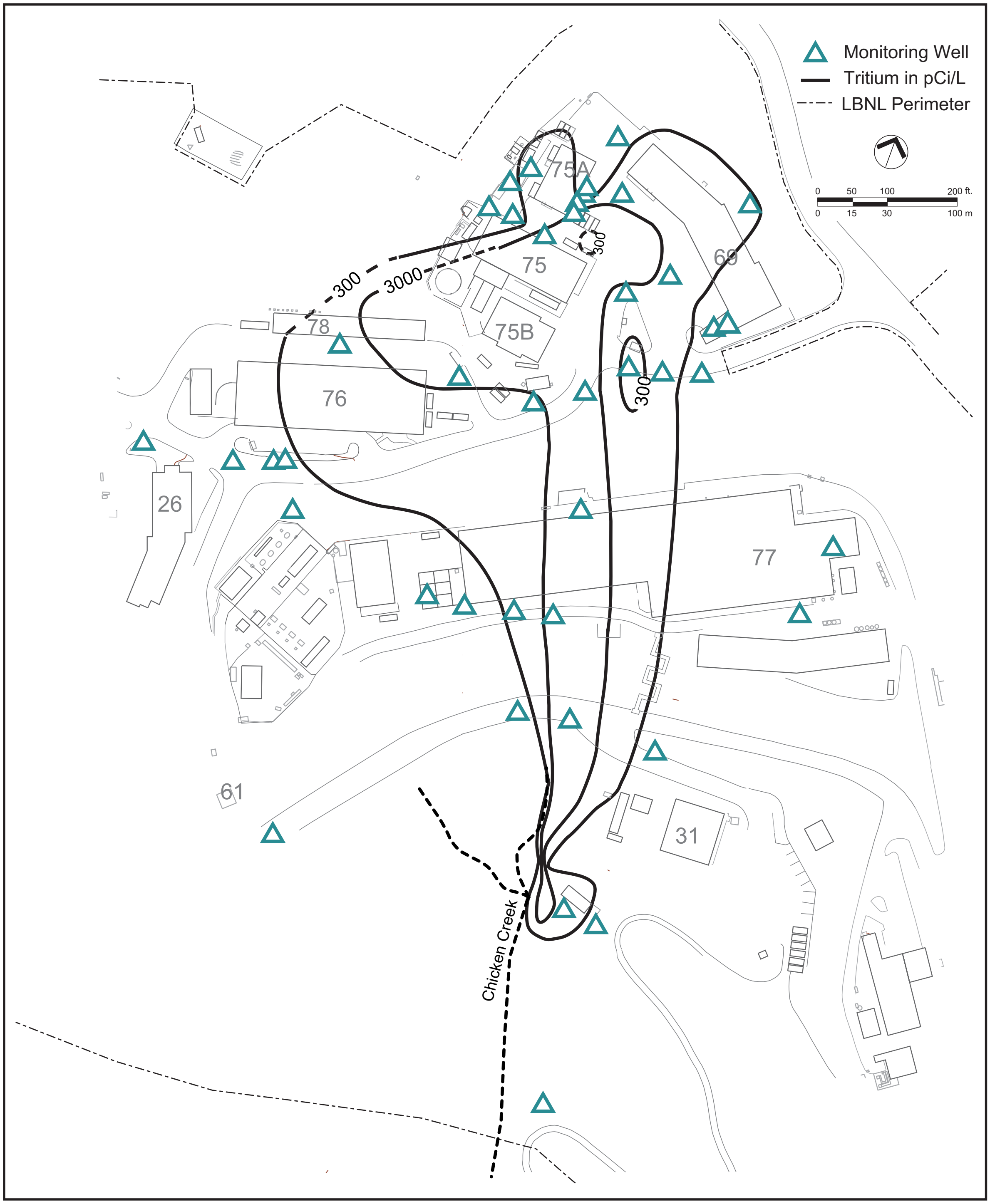


Figure 6-6 Groundwater Contamination (Tritium in Picocuries per Liter [pCi/L] (September 2003)

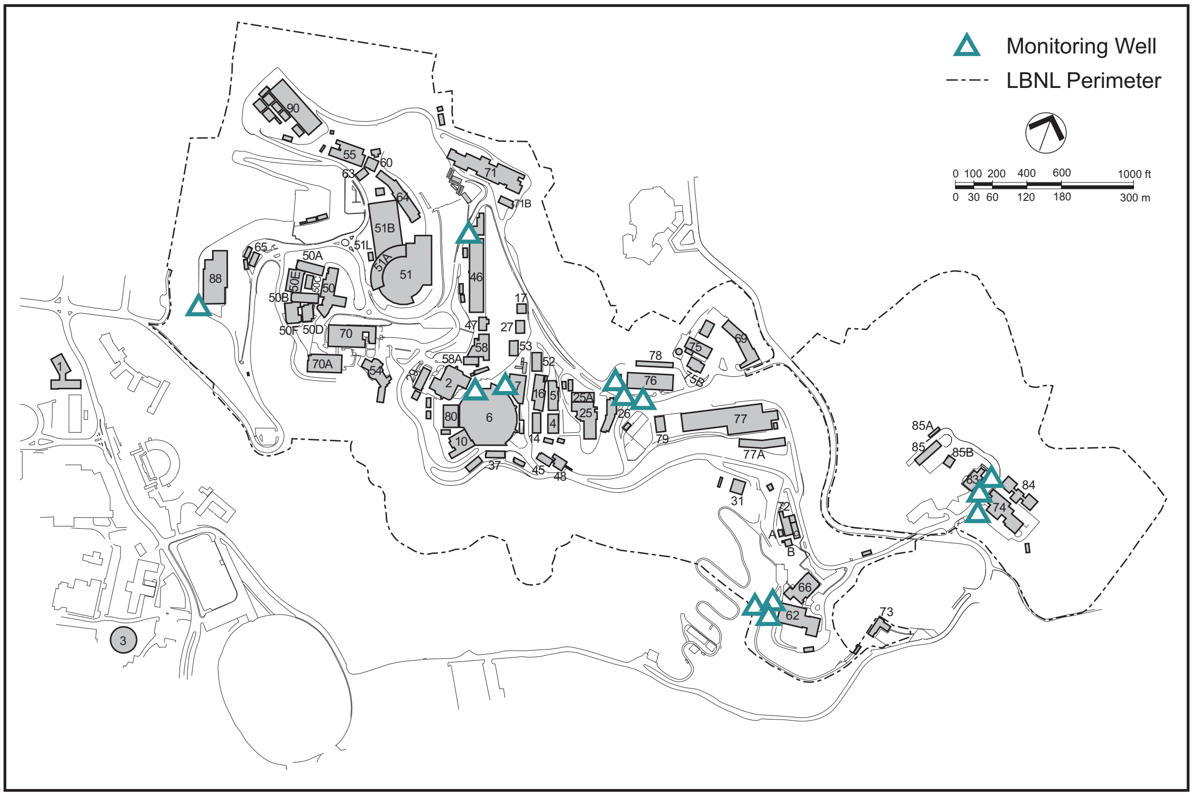


Figure 6-7 Approximate Locations of Monitoring Wells Associated with Underground Storage Tanks

Table 6-4 Total Petroleum Hydrocarbon Concentrations in Former Underground Storage Tank Sites

UST Location	Status	Present or previous contents	Maximum concentration (µg/L)
Building 7E	Removed	Kerosene or Diesel	TPH-K[a] = 1,500 TPH-D[b] = 540
Building 62[c]	Removed	Diesel	TPH-D = 52
Building 74[c]	Removed	Diesel	TPH-D = 220
Building 76 (Tank No. 1)[c]	Removed	Diesel	TPH-D = 230
Building 76 (Tank No. 2)[c]	Removed	Gasoline	ND[d]
Building 88[c]	Abandoned	Diesel	ND

[a] TPH-K = TPH quantified as kerosene range hydrocarbons
[b] TPH-D = TPH quantified as diesel range hydrocarbons
[c] Approved No Further Action (NFA) status by the City of Berkeley
[d] ND = Not detected

6.5.1 Source Removal or Control

The need for interim corrective measures is evaluated if (1) the contaminant concentrations pose a potential threat to human health or the environment or (2) leaching of contaminants from soil may affect groundwater. Several sources of contamination have been removed. The following is a list of such actions:

- Removed approximately 35 cubic meters of VOC-contaminated soil from the source area of the Building 52A plume
- Removed highly contaminated soil from the source location of the Old Town plume
- Removed most of the VOC-contaminated soil from the source area of Building 71B plume
- Removed most of the VOC-contaminated soil from the source area of Building 51/64 plume
- Removed more than 100 cubic meters of soil contaminated with polychlorinated biphenyl and tritium from the Building 75A area

6.5.2 Preventing Discharge of Contamination to Surface Waters

Slope stability is a concern at Berkeley Lab because of the geology and topography of the site. Free-flowing hydraugers were installed in the past to dewater and stabilize areas of potential landslides. Effluent from these hydraugers generally enters the creeks. Some of the hydraugers intercept contaminated groundwater. To prevent the discharge of contaminated groundwater to the creeks, Berkeley Lab installed a system to collect and treat hydrauger effluent that is contaminated with VOCs. See Sections 5.3.4 and 6.5.4 for more information on discharge from this system. Additionally, effluent from a subdrain east of Building 46, which is contaminated with VOCs, is collected and treated.

6.5.3 Preventing Further Migration of Contaminated Groundwater

Berkeley Lab is capturing and treating contaminated groundwater using collection trenches and subdrains as interim corrective measures to control groundwater plumes that could migrate off-site or contaminate surface water.

- In 1998, a groundwater collection trench was constructed on the slope west of Building 53 in the Old Town plume core area. A dual-phase groundwater and soil vapor extraction and treatment system was installed to remove contaminants from the soil and groundwater. Operation of the system continued in CY 2003.
- In 1998, a groundwater extraction and treatment system was installed west of Building 58 at the downgradient edge of the Old Town plume. Operation of the system continued in CY 2003.
- In 2002, a groundwater extraction and treatment system was installed west of Building 25A to control migration of contaminated groundwater in this area. Operation of the system continued in CY 2003.

6.5.4 Treatment Systems

As described above, Berkeley Lab is using collection trenches and subdrains to control groundwater plumes that could migrate off-site or contaminate surface water. Nine granular-activated carbon treatment systems have been installed. The treated water is recycled for industrial use on-site, released to the sanitary sewer in accordance with Berkeley Lab's treated groundwater discharge permit from the East Bay Municipal Utility District,[4] or recirculated to flush contaminants from the subsurface.

Table 6-5 lists both the volume of contaminated groundwater treated by each system in CY 2003 and the total volume treated since the treatment systems were first placed in operation.

Table 6-5 Treatment of Contaminated Groundwater

Source of contamination	Treatment system	Volume of water treated in 2003 (liters)[a]	Total volume treated (liters)
Building 6 former underground storage tank	Building 6 Bioventing	1,618,462	5,640,464
Old Town VOC plume	Building 7 Trench	7,557,389	16,122,575
Old Town VOC plume	Building 25A	771,572	1,235,091
Old Town VOC plume	Building 37	250,597	4,879,883
Old Town VOC plume	Building 46	6,145,398	44,387,698
Building 71 and Old Town VOC plumes and water collected from purging monitoring wells	Building 51 Firetrail[b]	4,711,367	53,928,661
Building 51 subdrain system and Building 51/64 VOC plume	Building 51 Sump	1,266,790	9,427,190
VOC-contaminated groundwater at Building 51L	Building 51L	764,010	1,516,967
Building 51/64 VOC plume	Building 64	18,342	18,342
Total volume treated		23,103,927	137,156,871

[a] 1 liter = 0.264 gallons
[b] B51 Hydrauger system is routed into the Building 51 Firetrail treatment system and is included in that total.

7

Soil and Sediment

Collection of a soil sample

7.1 BACKGROUND

The analysis of soil and sediment as part of a routine environmental monitoring program can provide information regarding past releases to air or water. Berkeley Lab performs annual soil and sediment sampling to determine long-term accumulation trends and baseline profiles. No specific regulatory requirements exist for routinely assessing these media, although contamination discovered by sampling must be handled according to federal and state hazardous waste regulations.[1]

Berkeley Lab's *Environmental Monitoring Plan*[2] sets out the details of the soil and sediment program. In calendar year (CY) 2003, sampling was performed in October before the rainy season. All individual sampling results are presented in Volume II.

7.2 SOIL AND SEDIMENT SAMPLING

Soil samples from the top 2 to 5 centimeters (1 to 2 inches) of surface soils were collected from three locations around the site and one off-site environmental monitoring station (see Figure 7-1).

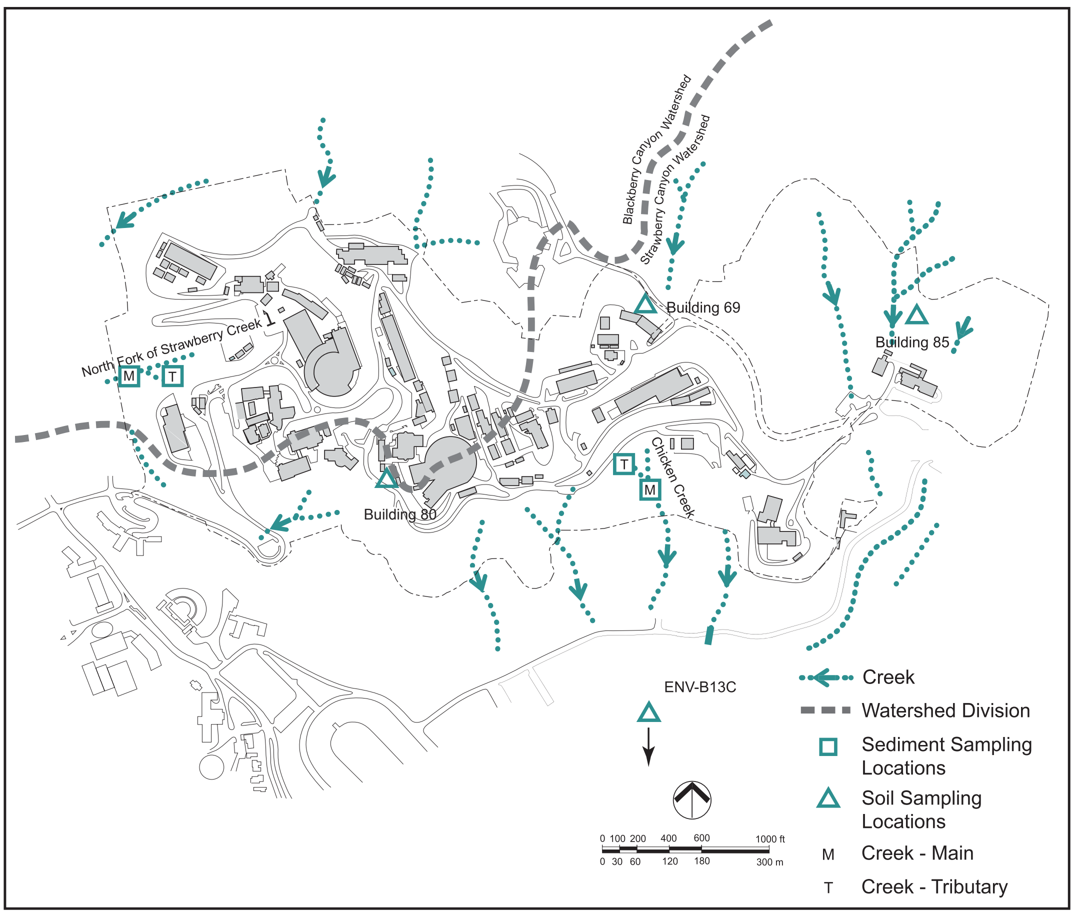


Figure 7-1 Soil and Sediment Sampling Sites

When possible, locations were chosen to coincide with the locations of ambient-air sampling stations. Samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, moisture content, and pH.

Sediment samples were collected during the same period from main and tributary creek beds of the North Fork of Strawberry Creek and Chicken Creek (see Figure 7-1). The samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, polychlorinated biphenyls (PCBs), petroleum hydrocarbons (diesel fuel and oil/grease), moisture content, and pH.

7.3 SOIL AND SEDIMENT ANALYSIS RESULTS

In CY 2003, the gross alpha and beta radiation and gamma emitter results were similar to background levels of naturally occurring radioisotopes commonly found in soil and sediment. All soil and sediment tritium concentrations were below the detection limit (0.2 picocurie per gram).

All PCB results for sediment samples were below practical quantification limits. Measurements of pH were within the normal range for soils and sediments.

The maximum concentrations of oil/grease and diesel fuel were measured in the sediment sample from the Chicken Creek tributary location at 10,000 milligrams per kilograms (mg/kg) and 340 mg/kg, respectively. Sediment samples from the Chicken Creek location historically have contained comparable concentrations of oil/grease. In January 2004, a second sample was collected at the same location, and the concentrations of oil/grease and diesel fuel were 3,100 mg/kg and 170 mg/kg, respectively. For comparison, in CY 2002, the concentrations of oil/grease and diesel fuel in the sediment sample from Chicken Creek tributary were measured at 4,100 mg/kg and 48 mg/kg, respectively. These forms of contamination are commonly associated with local motorized vehicle use on roads and parking lots that drain to creeks. This location will be sampled in future years to monitor any changes in oil/grease and diesel fuel concentrations.

All except one of the metal concentrations measured in the soil and sediment samples were at or near the established background values for the Berkeley Lab site. The soil sample collected at the Building 80 location contained a mercury concentration of 0.98 mg/kg, which is slightly above the upper-level background value for mercury (0.60 mg/kg) in soil at Berkeley Lab.[4] To confirm this result, in January 2004 a second sample was collected at the same site and analyzed. The mercury concentration in the second sample was 0.56 mg/kg. Additional samples will be collected at this site in CY 2004 to determine the areal extent of these mercury levels in the soil.

Table 7-1 shows sample analysis results for metals, oil/grease, and diesel fuel where at least one result was above the practical quantification limit.

Table 7-1 Metals and Oil/Grease Results in Soil and Sediment Samples[a,d]

	Sample location								
	Soil				Sediment				
Analyte	B69	B80	B85	ENV-B13C	Chicken Creek Main	Chicken Creek-Tributary	N. Fork Strawberry Creek-Main	N. Fork Strawberry Creek-Tributary	Regulatory criteria (TTLC[b])
Arsenic	2	6.9	3	9	3	5.6	4	5	500
Barium	100	220	150	170	92	120	67	90	10,000
Beryllium	<1[c]	1	<1[c]	<1[c]	<1[c]	<1[c]	<1[c]	<1[c]	75
Chromium	84	74	110	41	70	55	26	27	2,500
Cobalt	22	15	25	10	13	11	14	6.6	8,000
Copper	21	41	40	28	27	30	17	19	2,500
Lead	<10[c]	130	21	39	21	29	27	13	1,000
Mercury	<0.05[c]	0.98	0.17	0.094	<0.05[c]	0.068	0.095	0.053	20
Nickel	50	66	65	35	64	47	27	20	2,000
Vanadium	83	70	130	51	28	49	39	33	2,400
Zinc	61	100	74	91	130	120	110	140	5,000
Diesel fuel	--	--	--	--	<20[c]	340	<10[c]	51	--
Oil & grease	--	--	--	--	230	10,000	510	680	--

[a] One sample per location, all results in milligrams per kilograms
[b] Total Threshold Limit Concentration (22 California Code of Regulations 66261.24)[3]
[c] Result was below detection limit.
[d] Results for antimony, cadmium, molybdenum, selenium, silver, and thallium were all below practical quantification limits and are not reported in this table.These results, along with other non-TTLC metals (aluminum, boron, manganese, and iron), are included in Volume II.

8

Vegetation and Foodstuffs

Sampling of transpired water from a Eucalyptus tree

8.1 BACKGROUND

Sampling and analysis of vegetation and foodstuffs can provide information regarding the presence, transport, and distribution of radioactive emissions in the environment. This information can be used to detect and evaluate changes in environmental radioactivity resulting from Lawrence Berkeley National Laboratory activities and to calculate potential human doses that would occur from consuming vegetation and foodstuffs. Possible pathways or routes for ingesting radionuclides include the following:

- Liquid effluent → marine species → human
- Airborne emissions → vegetable crop → human
- Airborne emissions → forage crop → meat (milk) animal → human
- Airborne emissions → surface water body → aquatic species → human
- Airborne emissions → surface water or groundwater → vegetable crop → human

For vegetation sampling, tritium air emissions have been identified as the only potentially significant contributor to these pathways.

Tritium emissions occur either as tritiated water vapor or tritiated hydrogen gas. The relative dose from an exposure to tritiated hydrogen gas is much less than that from an equal exposure to tritiated water. Laboratory tritium emissions primarily are tritiated water vapor, so the Laboratory assumes that 100% of the emissions are tritiated water vapor.

Tritiated water vapor released into the environment mixes and exchanges readily with atmospheric water (e.g., precipitation, fog, vapor) and with other sources of environmental water (e.g., plant water, surface water, soil water). Within plants, tritium exists as either tissue-free water tritium or organically bound tritium (OBT).

Berkeley Lab performs routine vegetation sampling (see data in Volume II) to better understand the integrated impact of its operations on all media in the surrounding environment and to verify its overall dose-assessment program. This assessment program, presented in Chapter 9, includes vegetation and foodstuffs as one of the contributing pathways in determining the overall impact from Berkeley Lab's airborne radionuclides. The dose assessments, which have been performed using conservative assumptions, indicate extremely low potential impacts.

Berkeley Lab also performs tree sampling for landscape management. Only trees with tritium levels indistinguishable from background are removed and released to the public. In 2003, no sampling for landscape management was necessary.

8.2 ROUTINE VEGETATION SAMPLING

United States Department of Energy guidance[1] indicates that when the annual effective dose equivalent for the consumption of vegetation and foodstuffs is between 0.001 millisievert (mSv) (0.1 millirem [mrem]) and 0.01 mSv (1 mrem), only a minimal vegetation and foodstuff surveillance program is required. Even when conservative assumptions are used, Berkeley Lab's maximum individual dose attributable to the consumption of locally grown vegetation and foodstuffs is below 0.001 mSv (0.1 mrem), and therefore even a minimal monitoring program is not required. Nevertheless, Berkeley Lab's vegetation sampling program collects and analyzes samples at least every five years.

The Laboratory's *Environmental Monitoring Plan*[2] outlines the current vegetation sampling program. The objective of the program is to better understand the distribution of tritium in local vegetation.

In 2003, as part of the routine vegetation sampling program, Berkeley Lab collected transpired water samples from three trees that had been previously sampled in September 2001 and January 2002.[3] The purpose of sampling was to determine if tritium levels in water transpired by eucalyptus trees had changed after the closure of the National Tritium Labeling Facility (NTLF).

Berkeley Lab collected transpired water from three trees: NNW1 at 27.5 meters (m) north-northwest of the Hillside Stack (which vents the former NTLF); NNW2 at 105 m north-northwest of the stack, and NEE10 (in Tilden Park), which served as a background location, 1.1 kilometer northeast of the stack (see Figure 8-1). Details of these locations and the trees sampled are available in the report on previous vegetation sampling.[3] The sampling team worked in accordance with Environmental Services Group procedures.[4]

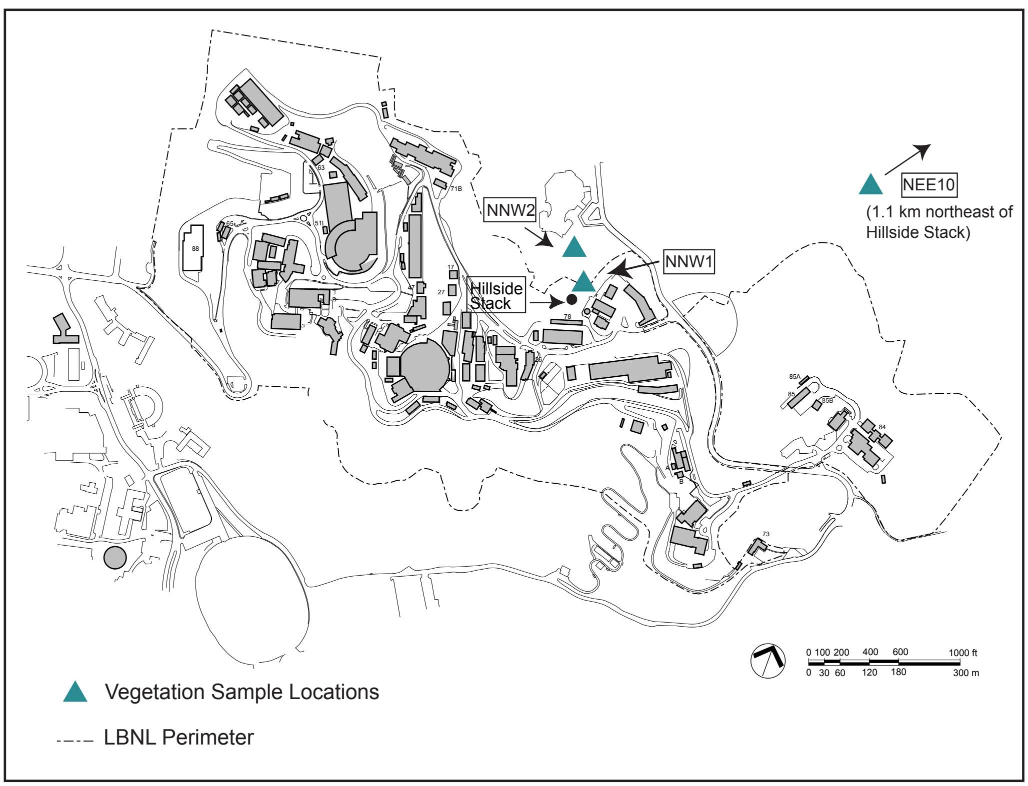


Figure 8-1 2003 Transpired Water Sampling Locations

The samples were analyzed for tritium by an off-site (external) analytical laboratory certified by the California Department of Health Services. Results are shown in Table 8-1 and discussed below.

As expected, tritium in the background sample (NEE10) was less than the minimum level that the analytical laboratory could detect. Tritium in the other two trees was measurable. At NNW1, the tree closest to the former NTLF's Hillside Stack, tritium levels did not change appreciably from the last-measured value in January 2002; and both the September 2003 and January 2002 values were about 65–75% of the September 2001 value. In September 2003, at NNW2, the tree farther from the stack, tritium levels decreased to about 35% the values measured in September 2001 and January 2002.

The results of quality control (QC) samples indicate that the quality of the sample collection and analysis are acceptable.

- The results of the split sample compare well. The relative error ratio of the two samples is 0.27, which is much less than the acceptable limit of 1. The relative percent difference between the two samples is 5.6%, which also is much less than the acceptable limit of 20%.
- The QC analyses performed by the external analytical laboratory were also acceptable. The blank was less than the minimum detectable limit; the duplicates had a relative error ratio of 0.09, which is much less than the acceptable limit of 1; and both spikes were well within the acceptable control limits of 80–120%, with 92% recovery of the matrix spike and 99% recovery of the laboratory control spike.

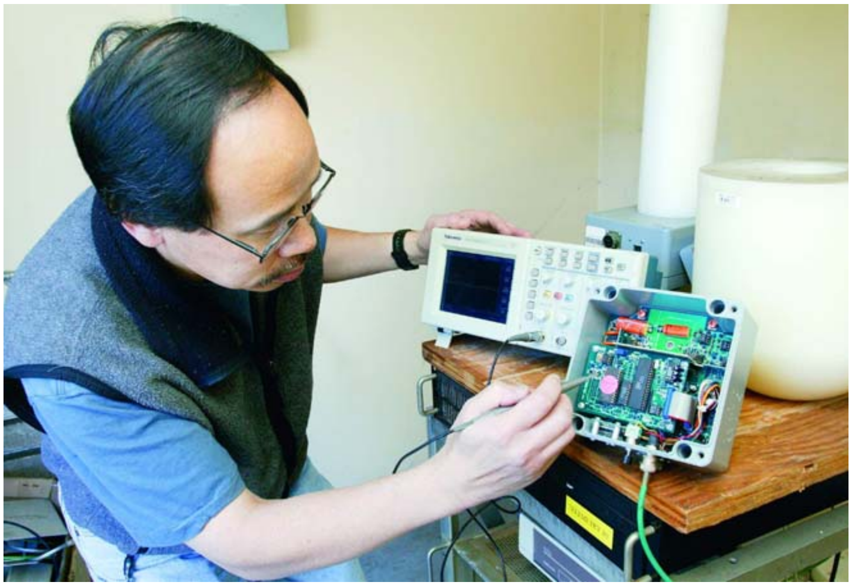
Results of transpired water sampling are inconclusive as to whether tritium levels in water transpired by eucalyptus trees have changed after the closure of the NTLF. In one tree, tritium levels in transpired water have decreased dramatically, but in the other, there was no appreciable change from the January 2002 results.

Table 8-1 Comparison of Recent Results of Transpired Water Sampling

Sample description	Tritium in transpired water (becquerels per liter [Bq/L])		
	September 2001	January 2002	September 2003
NNW1 sample	504	324	350
NNW1 duplicate	481	356	330
NNW2 sample	137	145	49
NNW2 duplicate	137	139	Not collected
NEE10 sample	<7	<7	<6

9

Radiological Dose Assessment



Checking real-time gamma and neutron detector systems

9.1 BACKGROUND

This chapter presents the estimated dose results from Lawrence Berkeley National Laboratory's penetrating radiation and airborne radionuclide monitoring programs. The doses projected from each monitoring program are presented separately before they are cumulatively evaluated to summarize the overall impact of the Laboratory's radiological activities on members of the public. Additionally, the radiological impact of Berkeley Lab's operations on local plants and animals is discussed.

Earlier chapters refer to monitoring and sampling results in terms of concentrations of a substance. An exposure over a period of time is referred to as "dose." An important measure for evaluating the impact of any radiological program, dose can be estimated for individuals as well as for populations. The following factors affect both individual dose and population dose: the type of radiation, distance from the activity, complexity of terrain, meteorological conditions, emission levels, food production and consumption patterns, and length of exposure. The International System of Units (SI) uses sieverts (Sv) or millisieverts (mSv) to express doses to humans; the common units are rem or millirem (mrem). Doses to animals and other nonhuman biota are expressed in the SI units of grays (Gy) and the common units of rad.

To minimize radiological impacts to the environment and the public, Berkeley Lab manages its programs so that radioactive emissions and external exposures are as low as reasonably achievable (ALARA). The Berkeley Lab Environmental ALARA Program ensures that a screening (qualitative) review is performed on activities that could result in a dose to the public or the environment. Potential doses from activities that may generate airborne radionuclides are estimated through the National Emission Standards for Hazardous Air Pollutants (NESHAPs)[1] process (discussed in Section 4.2). If the potential for a public dose is greater than 0.01 mSv (1 mrem) to an individual or 10 person-rem (see Glossary) to a population, an in-depth quantitative review is performed.

9.2 PENETRATING RADIATION MONITORING RESULTS

Radiation-producing machines (e.g., accelerators, x-ray machines, irradiators) and various radionuclides are used at Berkeley Lab for high-energy particle studies and biomedical research. Penetrating radiation is primarily associated with accelerator and irradiator operations at the Laboratory. When operational, accelerators produce both gamma and neutron forms of radiation. Irradiators are primarily limited to gamma radiation production.

Historically, United States Department of Energy (DOE) facilities have reported "fence-post doses": measured or computed values that reflect the exposures to an individual assumed to be living 100% of the time at the perimeter or fence line of the facility. This chapter provides both maximum fence-post dose estimates and the more realistic estimates of exposures to workplaces or residences of Berkeley Lab's nearest neighbors.

9.2.1 Accelerator-Produced Penetrating Radiation

Berkeley Lab operates radiation-detection equipment at environmental monitoring stations near the site's research accelerators, which include the Advanced Light Source Facility (Building 6), Biomedical Isotope Facility (Building 56), and 88-Inch Cyclotron (Building 88).

The Laboratory uses two methods to determine the environmental radiological impact from accelerator operations:

One method consists of a network of three real-time environmental monitoring stations (ENV-B13A, ENV-B13C, and ENV-B13H) located around the perimeter of the site; these stations track instantaneous gamma and neutron radiation impacts. Figure 9-1 shows the location of these stations. Each real-time station contains sensitive gamma and neutron pulse counters, which continuously detect and record direct radiation doses. The annual doses to an individual member of the public from each form of penetrating radiation are derived from measurements at these stations.

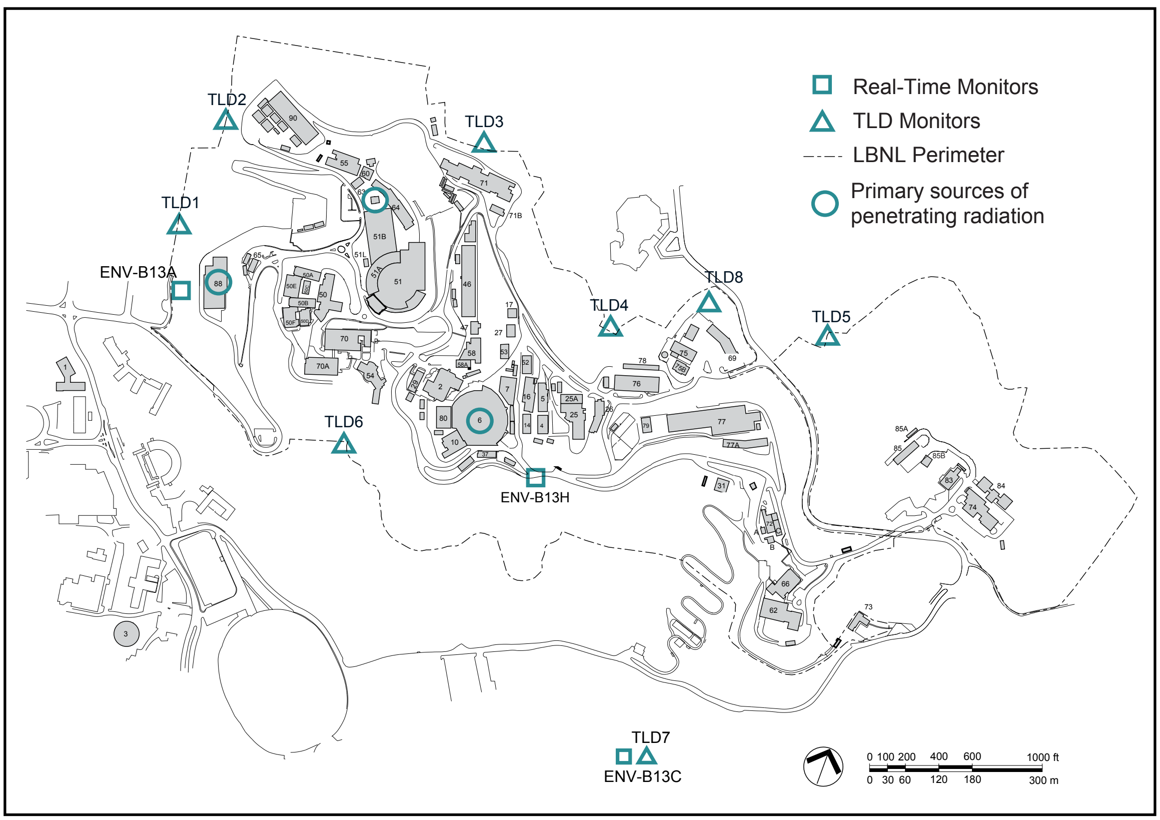


Figure 9-1 Environmental Penetrating Radiation Monitoring Stations

During past years, direct gamma and neutron radiation doses to the public from Laboratory activities (net doses) have trended downward and are not easily discernible from the natural background levels. This reduction in net dose is mostly due to improvements in shielding and changes in operational procedures at the Building 88 accelerator. The results for 2003 indicate that the maximum dose to a member of the public from direct radiation was 0.002 mSv (0.2 mrem) for a person residing near the 88-inch Cyclotron.

The second method uses passive detectors known as thermoluminescent dosimeters (TLDs). Figure 9-1 also shows the locations of Berkeley Lab's TLD sites. Currently, seven TLDs (TLDs 1 through 6 and 8) are near the site boundary, and one (TLD 7) is positioned at the remote location ENV-B13C. TLDs are used to measure gross gamma radiation, and they do not exclude background radiation. In addition, results from TLDs provide an average dose over time that must be determined by analysis rather than real-time instrumentation.

The objectives of the TLD program are to record and compare the gross penetrating radiation exposures (from Berkeley Lab operations and background) to ensure that public radiation exposure is kept well below allowable regulatory limits. The mean fence-line gamma radiation dose recorded by these TLDs for calendar year 2003 was indistinguishable from the remote background dose measured at ENV-B13C. The TLD results are consistent with the low-dose values measured by the real-time monitoring stations.

9.2.2 Irradiator-Produced Penetrating Radiation

Used for radiobiological and radiophysics research, a gamma irradiator with a 440-curie cobalt-60 source is housed at Berkeley Lab in Building 74; the irradiator is in a massive interlocked structure that is covered with reinforced concrete. Routine surveys performed when the irradiator was in operation confirmed that gamma radiation doses were indistinguishable from background levels (0.001 mSv per hour [0.1 mrem per hour]) at 1 meter (m) (3.3 feet) from the outside walls or ceiling of the labyrinth.

Berkeley Lab also uses other, smaller, well-shielded gamma irradiators, which pose considerably less potential for environmental impact than the Building 74 irradiator. This class of smaller irradiators does not measurably increase the dose to the public.

9.3 DISPERSIBLE AIRBORNE RADIONUCLIDE RESULTS

"Dose due to dispersible contaminants" represents the time-weighted exposure to a concentration of a substance, whether the concentration is inhaled in air, ingested in drink or food, or absorbed through skin contact with soil or other environmental media. Dispersible radionuclides that affect the environmental surroundings of Berkeley Lab—and consequently the projected dose from Laboratory activities—originate as emissions from building exhaust points generally located on rooftops. Once emitted, these radionuclides may affect any of several environmental media: air, water, soil, plants, and animals. Each of these media represents a possible pathway of exposure affecting human dose.

Determining the dose to an individual and the population is accomplished using multipathway dispersion models. The primary radionuclides used for this modeling are the airborne emissions presented in Chapter 4. The NESHAPs regulation requires that any facility that releases airborne radionuclides must assess the impact of such releases using a computer program approved by the United States Environmental Protection Agency (US/EPA).[1] Berkeley Lab satisfies this requirement with the use of CAP88-PC.[2]

CAP88-PC is both a dispersion and dose-assessment predictive model. It computes the cumulative dose from all significant exposure pathways, such as inhalation, ingestion, and skin absorption. The methods and parameters used to calculate the dose are very conservative, taking an approach that reports dose calculations as “worst case” doses to the population exposed. For example, the model assumes that some portion of the food consumed by the individual was grown within the assessed area, that the individual resided at this location (i.e., a single, specific point) continuously throughout the year, and that all the radioactivity released was of the most hazardous form. Consequently, this worst-case dose is an upper-bound estimate, and one not likely to be received by anyone.

In addition to the emissions information, dose-assessment modeling requires the meteorological parameters of wind speed, wind direction, and atmospheric stability. Berkeley Lab uses on-site data from its local meteorological station for the dispersion-modeling module of CAP88-PC.

Berkeley Lab performed individual CAP88-PC modeling runs to predict the impact from groupings of the Laboratory’s release points. Table 9-1 lists the attributes of these groupings.

Details of these groupings and modeling runs are included in the Laboratory’s annual NESHAPs report. After the modeling runs were completed, the location of the maximally exposed individual (MEI) to airborne emissions was determined to be at the Lawrence Hall of Science (LHS). The source groupings listed in Table 9-1 give the orientation of their release points relative to the location of the MEI to airborne emissions (distance and direction). The combined dose to the MEI (a person residing at the LHS) to airborne radionuclides for 2003 was 0.0001 mSv (0.01 mrem).

The dose from airborne radionuclides to the surrounding population is estimated for a region that extends from the site for 80 kilometers (km) (50 miles [mi]). This region is divided into 208 sectors (i.e., 13 increasingly smaller circles, each divided into 16 equally spaced sectors). CAP88-PC is used to estimate the average dose to each sector for each radionuclide used at the Laboratory. Combining this dose with the most recent (2001) population data[3] for each sector gives a population dose to that sector. The total population dose represents the summation of the population doses from all sectors. This approach estimated an annual population dose from all airborne radionuclides of 0.002 person-Sv (0.2 person-rem).

Table 9-1 Summary of Dose Assessment at Location of Maximally Exposed Individual (MEI) from Airborne Emissions

Building	Building description	Distance to MEI[a] (m)	Direction to MEI[a]	Dose to MEI (mSv/yr)[b]	Percent of MEI total dose
55/56/64	Department of Nuclear Medicine and Functional Imaging	460	E	7.7×10^{-5}	81.1%
70/70A	Nuclear/Life Sciences	530	ENE	9.3×10^{-6}	9.8%
85	Hazardous Waste Handling Facility	570	WNW	4.0×10^{-6}	4.2%
75/75A	Former National Tritium Labeling Facility and Storage	110	NW	2.7×10^{-6}	2.6%
88	88-Inch Cyclotron	690	ENE	1.6×10^{-6}	1.7%
74/83/84	Human Genome Facility/Life Sciences	690	WNW	3.7×10^{-7}	0.4%
1	Donner Laboratory (UC Berkeley)	990	ENE	2.1×10^{-7}	0.2%
26/76	Radioanalytical Laboratory	250	N	8.6×10^{-9}	<0.1%
3	Calvin Lab (UC Berkeley)	1060	NE	3.8×10^{-9}	<0.1%
6/16	Advanced Light Source/Accelerator and Fusion Research	370	NNE	1.3×10^{-10}	<0.1%
72	Low-Background Counting Facility	500	NW	3.3×10^{-14}	<0.1%
71	Accelerator and Fusion Research	310	ESE	2.4×10^{-17}	<0.1%
			Total	**9.5×10^{-5}**	**100%**

[a] Distances and directions are relative to the maximally exposed individual to airborne emissions.
[b] 1 mSv = 100 mrem

9.4 TOTAL DOSE TO THE PUBLIC

The total radiological impact to the public from accelerator operations and airborne radionuclides is well below applicable standards and nominal background radiation levels. The 2003 total dose to the MEI from Berkeley Lab activities is mainly due to exposure to direct radiation. As presented in Table 9-2 and Figure 9-2, the maximum effective dose equivalent from Berkeley Lab operations to an individual residing near the 88-inch Cyclotron in 2003 is about 0.002 mSv (0.2 mrem) per year. This value is approximately 0.08% of the nominal background radiation[4] in the Bay Area and about 0.2% of the DOE annual limits.[5]

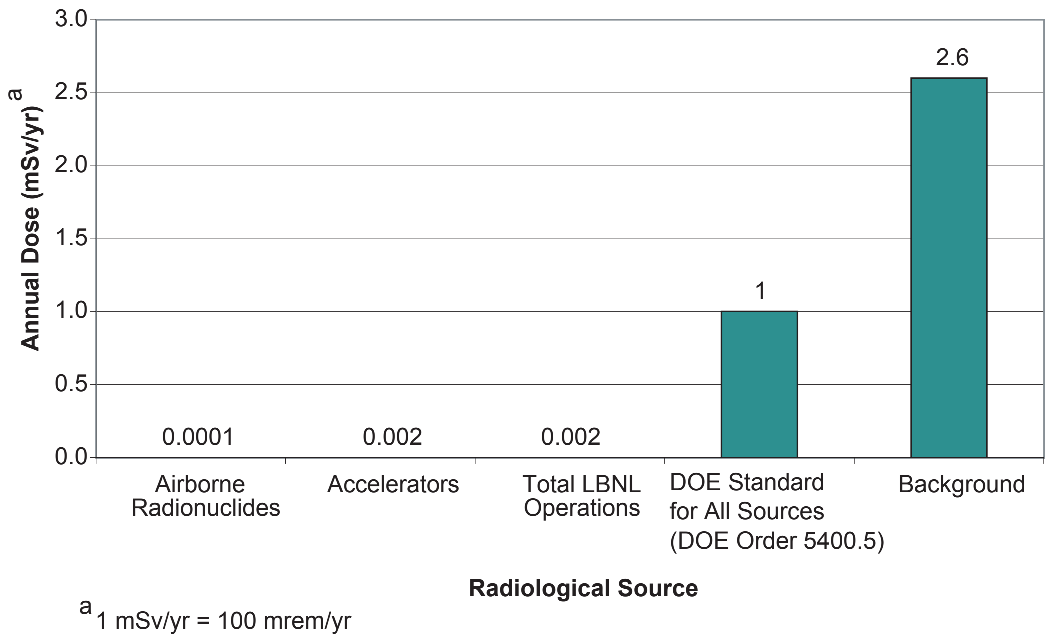


Figure 9-2 Comparison of Radiological Dose Impacts for 2003

As noted previously, the estimated dose to the population within 80 km (50 mi) of Berkeley Lab from airborne radionuclides emitted by laboratory operations was 0.002 person-Sv (0.2 person-rem) for the same period. From natural background sources alone, this same population receives an estimated dose of 13,000 person-Sv (1,300,000 person-rem). The dose to the population from Berkeley Lab is less than 0.00002% of the background level.

Table 9-2 Comparison of Radiological Dose Impacts

	Dose from direct radiation	Dose from airborne radionuclides
Annual effective dose equivalent to the MEI[a]	0.002 mSv[b]/yr	0.0001 mSv/yr
Regulatory standard	1 mSv/yr (DOE[c])	0.10 mSv/yr (US/EPA[d])
Dose to MEI as percentage of standard	0.2%	0.1%
Annual background	1 mSv/yr	1.6 mSv/yr
Dose to MEI as percentage of background	0.2%	0.004%

[a] MEI = maximally exposed individual
[b] 1 mSv = 100 mrem
[c] DOE = United States Department of Energy
[d] US/EPA = United States Environmental Protection Agency

9.5 DOSE TO ANIMALS AND PLANTS

As discussed in Section 8.1, liquid and airborne emissions may have pathways to animals and plants in addition to their pathways to humans. DOE requires that aquatic organisms be protected by limiting their radiation doses to 1 rad/day (0.01 Gy/day).[5] In addition, international recommendations suggest that doses to terrestrial animals should be limited to less than 0.1 rad/day (0.001 Gy/day), and doses to terrestrial plants should not exceed 1 rad/day (0.01 Gy/day).[6]

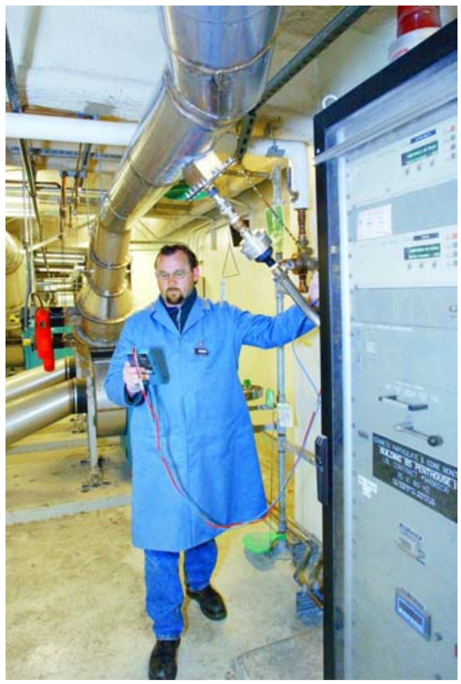
To assist sites in demonstrating compliance with these limits, DOE approved a technical standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, in August 2002.[6] Berkeley Lab applied the standard to evaluate aquatic and terrestrial plants and animals across the Laboratory's site.

Several sources of exposure were considered, including animal ingestion of vegetation, water, and soil; animal inhalation of soil; plant uptake of water; and external exposure of all receptors to radionuclides in water, soil, and sediment. Creek water, soil, and sediment samples were collected in 2003 and analyzed for several radionuclides, including gross alpha- and beta-emitting radionuclides. Gamma-emitting radionuclides were also analyzed to confirm that only background radionuclides (radionuclides from natural sources or global fallout) were present.

Most of these radionuclides were measured at levels less than natural background levels. In creek water, only tritium exceeded background levels in a few samples. In soil and sediment, radionuclide levels were similar to, and within the error range of, background levels. Thus, only tritium was evaluated using the DOE general screening process. Both terrestrial and aquatic systems passed the general screening process. These results confirm that Berkeley Lab is in compliance with DOE requirements to limit radiation doses to aquatic organisms to 1 rad/day (0.01 Gy/day). In addition, they show that the Laboratory is well within international recommendations for limiting dose to other plants and animals.

10

Quality Assurance



Calibration of stack air-flow meters

10.1 OVERVIEW

Lawrence Berkeley National Laboratory's quality assurance (QA) policy is documented in the *Operating and Assurance Plan* (OAP).[1] The OAP consists of a set of operating principles used to support internal organizations in achieving consistent, safe, and high-quality performance in their work activities. OAP principles are applied to individual programs through a graded approach, with consideration given to factors such as environmental, health, and safety consequences.

In addition to the OAP, the monitoring and sampling activities and results presented in this report were conducted in accordance with Berkeley Lab's *Environmental Monitoring Plan*[2] and applicable United States Department of Energy (DOE)[3] and United States Environmental Protection Agency[4] guidance. When special quality assurance and quality control (QC) requirements are necessary for environmental monitoring (such as the National Emission Standards for Hazardous Air Pollutants [NESHAPs] stack monitoring program), a Quality Assurance Project Plan is developed and implemented.

On-site and off-site (external) analytical laboratories analyze samples for the environmental monitoring program. Both types of laboratories must meet demanding QA/QC specifications and certifications[5] that were established to define, monitor, and document laboratory performance. The QA/QC data provided by these laboratories are incorporated into Berkeley Lab's data quality–assessment processes. For calendar year 2003, eight external analytical laboratories were available for use under a joint contract with Berkeley Lab and Lawrence Livermore National Laboratory.

Each set of data (batch) received from the analytical laboratory is systematically evaluated and compared to established data-quality objectives before the results can be authenticated and accepted into the environmental monitoring database. Categories of data-quality objectives include accuracy, precision, representativeness, comparability, and completeness. When possible, quantitative criteria are used to define and assess data quality.

The DOE Environmental Management Consolidated Audit Program (EMCAP) annually audits all external analytical laboratories, including those working with Berkeley Lab. A member of DOE or a DOE contractor representative, trained as a Nuclear Quality Assurance (NQA-1) lead auditor, heads the EMCAP audit team. Other team members come from across the DOE complex and add a wealth of experience. Typically, Berkeley Lab sends one representative to participate in EMCAP audits of Berkeley Lab's external analytical laboratory locations. The team audits each of the following six areas that pertain to the services provided by the particular external analytical laboratory: (1) QA management systems and general laboratory practices, (2) organic analyses, (3) inorganic and wet chemistry analyses, (4) radiochemical analyses, (5) laboratory information management systems and electronic deliverables, and (6) hazardous and radioactive material management. Also included in the lab audits is a review of the external analytical laboratory's performance in proficiency testing required by the California Environmental Laboratory Accreditation Program. Any deficiencies identified in the audit are followed by corrective actions.

To verify that environmental monitoring activities are adequate and effective, internal and external oversight is performed as required. Internal oversight activities consist of assessments performed by the Environmental Services Group and the Berkeley Lab Office of Assessment and Assurance. An assessment was performed on the NESHAPs Monitoring Program report by an independent consultant.

External oversight of Berkeley Lab programs is performed through the DOE Operational Awareness Program.[6] Operational awareness activities are ongoing and include field orientation, meetings, audits, workshops, document and information system reviews, and day-to-day communications. DOE criteria for performance evaluation include (1) federal, state, and local regulations with general applicability to DOE facilities and (2) applicable DOE requirements. This program enables DOE to directly oversee Berkeley Lab programs and assess performance.

10.2 PROFILE OF ENVIRONMENTAL MONITORING SAMPLES AND RESULTS

Berkeley Lab's environmental monitoring programs are comprehensive and extensive. In 2003, nearly 1,950 individual air, sediment, soil, vegetation, and water samples were collected (includes results from 60 samples collected by the Environmental Restoration Program). More than 4,200 analytical results were generated from these samples. The stack exhaust air monitoring program collected the vast majority (74%) of the samples obtained, as reflected by Figure 10-1. The combination of the stack and ambient-air monitoring programs accounts for nearly 85% of all samples collected.

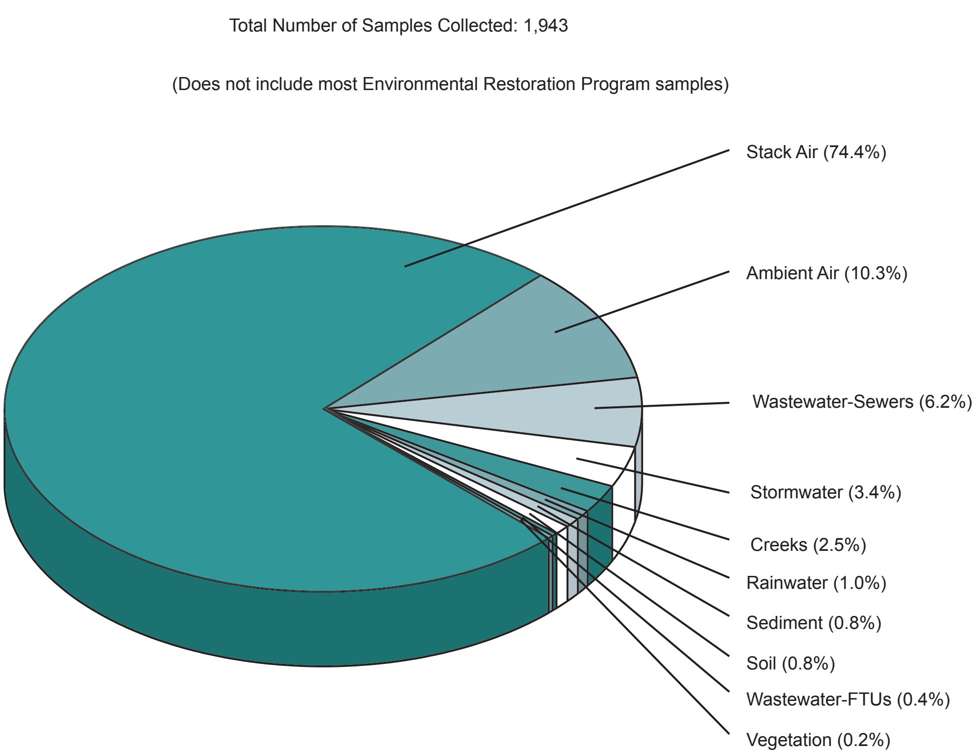


Figure 10-1 Quantity of Samples Collected per Program

The quantity of analytical results for each program is shown in Figure 10-2. The stack exhaust air monitoring program generated nearly 50% of the total program results. The combination of the stack and ambient-air monitoring programs accounts for nearly 55% of all results. The various water monitoring programs require a larger number of analytical tests per sample than air monitoring programs do. For instance, the creek monitoring program accounts for 2.5% of the total samples collected but it generates 19% of the total monitoring program results.

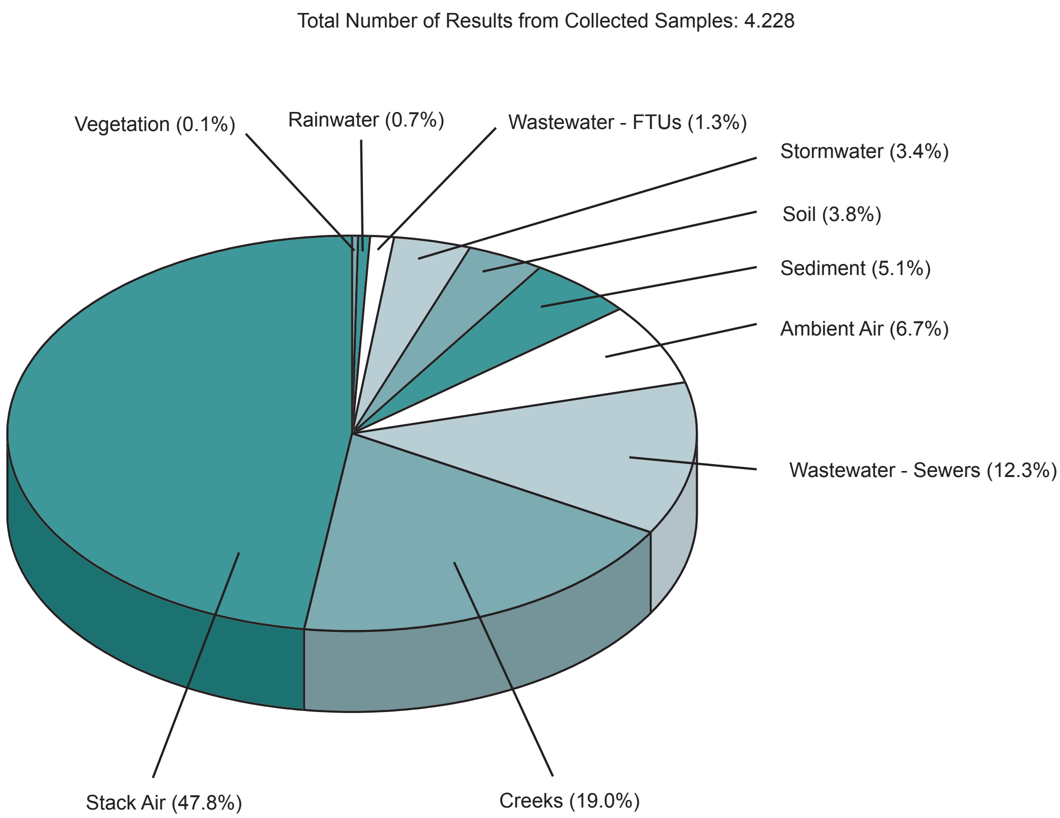


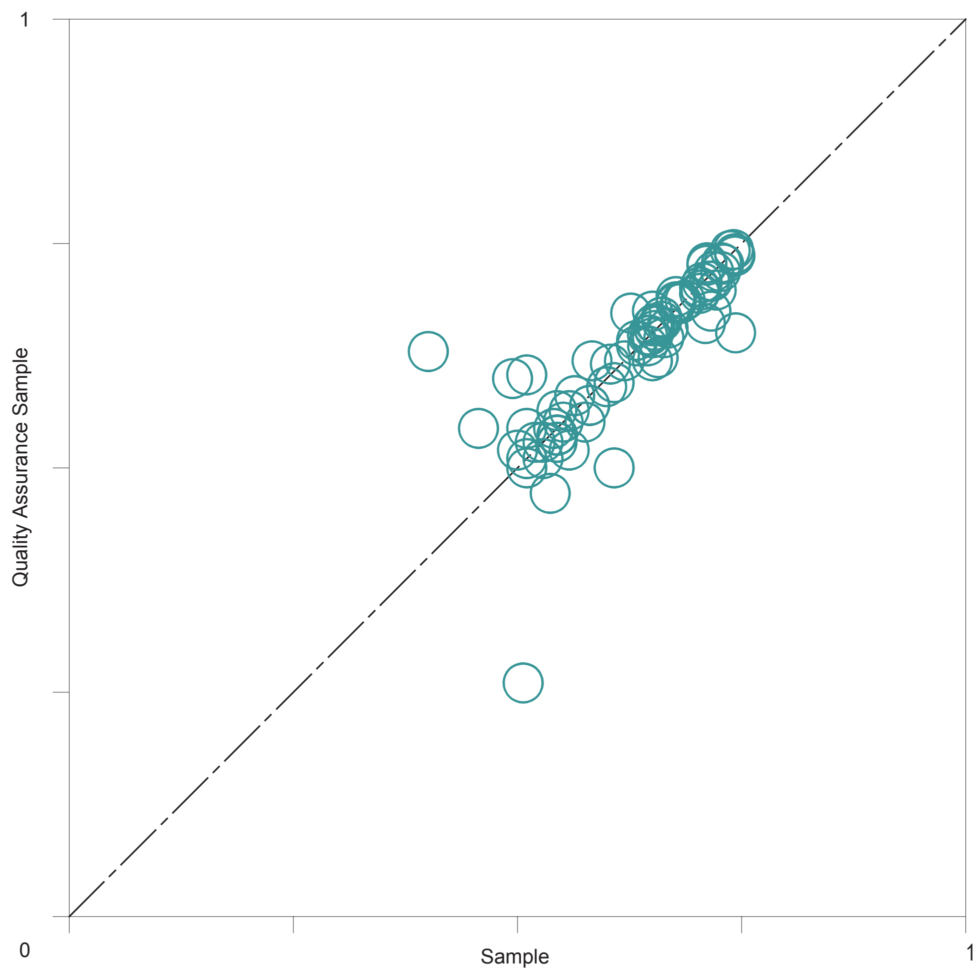
Figure 10-2 Quantity of Analytical Results per Program

10.3 SPLIT AND DUPLICATE RESULTS FROM ENVIRONMENTAL MONITORING

Berkeley Lab routinely collects split and duplicate samples for QA purposes. In 2003, 143 split and 75 duplicate samples of ambient air, rainwater, sediment, soil, surface water, stack exhaust air, wastewater, and vegetation were collected and analyzed. The results from these analyses provide information regarding the precision of the monitoring results. Berkeley Lab uses the metrics of relative percent difference and relative error ratio to determine whether the sample and its corresponding QA result are within control limits. Relative percent difference is determined in all cases. Relative error ratio is applied only to radiological analyses. When QA pair results are outside of control limits, an investigation is performed to determine the cause for the discrepancy.

Berkeley Lab's small impact on the environment from emissions is reflected by the large number of sampling results that are below detection limits. When one or both results from a QA sample pair (sample/split or sample/duplicate) are below analyte detection limits, a comparison of the results is not useful. Similar to the previous year, most (64%) of the sample pairs from all media were below detection limits. The media with the greatest percentage of sample pairs below detection limits was again the wastewater program: The percentage exceeded 80% (56 of the 69 pairs).

QA sample pairs with results above detection limits are shown in Figure 10-3. Seventy-eight of the 218 QA sample-pair results collected in all media are plotted on a logarithmic scale. The actual QA sample-pair concentrations have been converted so that all values are within the numeric range of zero to one. The diagonal line reflects an ideal distribution of QA pair results that are in perfect agreement. The chart shows excellent agreement overall between split and duplicate sample pairs. The few samples that are not near the diagonal line generally are duplicate samples, which tend to have greater differences in results than split samples.



NOTE:
1) Seventy-eight quality assurance sample pairs are plotted on a logarithmic scale.
2) Concentrations are normalized and unitless to a scale of 0 to 1 for ease of plotting multiple media on one chart.
3) The diagonal line represents the idential match.

Figure 10-3 Comparison of Quality Assurance Samples for Sampling Programs

Quality assurance sampling is integral to the philosophy of Berkeley Lab's environmental monitoring programs. Berkeley Lab will continue to assess and present the quality of environmental monitoring results in future reports.

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Acronyms and Abbreviations

AEDE	annual effective dose equivalent
ALARA	as low as reasonably achievable
ASPCP	Accidental Spill Prevention and Containment Plan
AST	aboveground storage tank
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Water Quality Control Plan
Berkeley Lab	Ernest Orlando Lawrence Berkeley National Laboratory
Bq	becquerel
BTEX	benzene, toluene, ethyl benzene, and xylene
CEQA	California Environmental Quality Act of 1970
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	curie
CMS	Corrective Measure Study
COD	chemical oxygen demand
CWA	Clean Water Act
CY	calendar year
DCA	dichloroethane
DCE	dichloroethylene
DHS	Department of Health Services
DOE	United States Department of Energy
DTSC	Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EH&S	Environment, Health, and Safety Division at Berkeley Lab
EMCAP	Environmental Management Consolidated Audit Program
EMS	environmental management system

EPCRA	Emergency Planning and Community Right-to-Know Act
ERP	Environmental Restoration Program
ESG	Environmental Services Group
FTU	fixed treatment unit
FY	fiscal year
gsf	gross square feet
gsm	gross square meters
Gy	gray (measure of radiation in SI)
HMBP	Hazardous Materials Business Plan
HWHF	Hazardous Waste Handling Facility
ISM	Integrated Safety Management
ISO	International Organization for Standardization
kg	kilogram
km	kilometer
L	liter
LBNL	Lawrence Berkeley National Laboratory
LHS	Lawrence Hall of Science
LLNL	Lawrence Livermore National Laboratory
m	meter
m^3	cubic meter
MCL	maximum contaminant level
MEI	maximally exposed individual
mg	milligram
mi	mile(s)
mrem	millirem
mSv	millisievert
MTBE	methyl tertiary butyl ether
ND	not detected
NEPA	National Environmental Policy Act of 1969
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOI	Notice of Intent
NOV	Notice of Violation
NQA	Nuclear Quality Assurance

NTLF	National Tritium Labeling Facility
OAP	Operating and Assurance Plan
OBT	organically bound tritium
PBT	persistence, bioaccumulation, and toxicity
PCB	polychlorinated biphenyl
PCE	perchloroethylene (tetrachloroethylene)
pCi	picocurie (one trillionth of a curie)
PDF	Portable Document Format
PGF	Production Genomics Facility
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RMPP	Risk Management and Prevention Plan
RWQCB	Regional Water Quality Control Board
s	second
SARA	Superfund Amendments and Reauthorization Act
SI	Système Internationale or International System of Units (the metric system)
SPCC	Spill Prevention, Control and Countermeasures
Sv	sievert
SWMP	Storm Water Monitoring Program
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TBq	terabecquerel (one-trillion becquerels)
TCA	trichloroethane
TCE	trichloroethylene
TDS	total dissolved solids
TFWT	tissue-free water tritium
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOMP	Toxic Organics Management Plan
TPH	total petroleum hydrocarbons
TRI	Toxic Release Inventory

TSCA	Toxic Substances Control Act
TSS	total suspended solids
UC	University of California
UCOP	University of California Office of the President
μg	microgram(s)
UHVCF	Ultra-High Vacuum Cleaning Facility
US/EPA	United States Environmental Protection Agency
USF&WS	United States Fish and Wildlife Service
UST	underground storage tank
UV	ultraviolet
VOC	volatile organic compound
WAA	Waste Accumulation Area
Web	World Wide Web
yr	year

Glossary

Accuracy
The degree of agreement between a measurement and the true value of the quantity measured.

Air particulates
Airborne particles that include dust, dirt, and other pollutants occurring as particles, as well as any pollutants associated with or carried on the dust or dirt.

Aliquot
An exact fractional portion of a sample taken for analysis.

Alpha particle
A charged particle comprised of two protons and two neutrons, which is emitted during decay of certain radioactive atoms. Alpha particles are stopped by several centimeters of air or a sheet of paper.

Ambient air
The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It does not include the air next to emission sources.

Aquifer
A subsurface saturated layer of rock or soil that can supply usable quantities of groundwater to wells and springs. Aquifers can provide water for domestic, agricultural, and industrial uses.

Background radiation
Ionizing radiation from sources other than LBNL. Background may include cosmic radiation; external radiation from naturally occurring radioactivity in the earth (terrestrial radiation), air, and water; internal radiation from naturally occurring radioactive elements in the human body; and radiation from medical diagnostic procedures.

Becquerel (Bq)
SI unit of radioactive decay equal to one disintegration per second.

Beta particle
A charged particle, identical to the electron, that is emitted during decay of certain radioactive atoms. Most beta particles are stopped by less than 0.6 centimeter of aluminum.

Categorical process
An industrial process governed by federal regulation(s) of wastewater discharges.

Collective effective dose equivalent
The sum of the effective dose equivalents of all individuals in an exposed population within a certain radius, usually 80 kilometers, for NESHAPs compliance. This value is expressed in units of person-sievert (SI unit) or person-rem (conventional unit).

Contaminant
Any hazardous or radioactive material present in an environmental medium such as air, water, or vegetation.

Controlled area
Any laboratory area with access controlled to protect individuals from exposure to radiation and radioactive materials.

Cosmic radiation
High-energy particulate and electromagnetic radiation that originates outside the earth's atmosphere. Cosmic radiation is part of natural background radiation.

Curie

Unit of radioactive decay equal to 2.22×10^{12} disintegrations per minute (conventional units).

De minimis

A level that is considered to be insignificant and does not need to be addressed or controlled.

Detection limit[1]

The lowest concentration of an analyte that can reliably be distinguished from a zero concentration.

Discharge

A release of a liquid into an area not controlled by LBNL.

Dose

The quantity of radiation energy absorbed during a given period of time.

Dose, absorbed

The energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the gray (SI unit) or rad (conventional unit).

Dose, effective

The hypothetical whole-body dose that would give a risk of cancer mortality and/or serious genetic disorder equal to a given exposure that may be limited to just a few organs. The effective dose equivalent is equal to the sum of individual organ doses, each weighted by degree of risk that the organ dose carries. For example, a 1-millisievert dose to the lung, which has a weighting factor of 0.12, gives an effective dose that is equivalent to 0.12 millisievert (1×0.12).

Dose equivalent

A term used in radiation protection that expresses all types of radiation (alpha, beta, and so on) on a common scale for calculating the effective absorbed dose. It is the product of the absorbed dose and certain modifying factors. The unit of dose equivalent is the sievert (SI unit) or rem (conventional unit).

Dose, maximum boundary

The greatest dose commitment, considering all potential routes of exposure, from a facility's operation to a hypothetical individual who is in an uncontrolled area where the highest dose rate occurs. It assumes that the individual is present 100% of the time (full occupancy), and it does not take into account shielding by obstacles such as buildings or hillsides.

Dose, maximum individual

The greatest dose commitment, considering all potential routes of exposure, from a facility's operation to a hypothetical individual at or outside the LBNL boundary where the highest dose rate occurs. It takes into account shielding and occupancy factors that would apply to a real individual.

Dose, population

The sum of the radiation doses to individuals of a population. It is expressed in units of person-sievert (SI unit) or person-rem (conventional unit). For example, if 1,000 people each received a radiation dose of 1 sievert, their population dose would be 1,000 person-sievert.

Dosimeter

A portable detection device for measuring the total accumulated exposure to ionizing radiation. *See also* Thermoluminescent dosimeter.

Downgradient

Commonly used to describe the flow of groundwater from higher to lower concentration. Analogous to "downstream."

Duplicate sample

A sample that is equivalent to a routine sample and is analyzed to evaluate sampling or analytical precision.

Effective dose equivalent
Abbreviated EDE, it is the sum of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The EDE includes the committed EDE from internal deposition of radionuclides and the EDE due to penetrating radiation from sources external to the body. EDE is expressed in units of sievert (SI unit) or rem (conventional unit).

Effluent
A liquid waste discharged to the environment.

Emission
A release of air to the environment that contains gaseous or particulate matter having one or more contaminants.

Environmental remediation
The process of improving a contaminated area to a noncontaminated or safe condition.

Exposure
A measure of the ionization produced in air by x-ray or gamma radiation. The unit of exposure is the coulomb per kilogram (SI unit) or roentgen (conventional unit).

External radiation
Radiation originating from a source outside the body.

Gamma radiation
Short-wavelength electromagnetic radiation of nuclear origin that has no mass or charge. Because of its short wavelength (high energy), gamma radiation can cause ionization. Other electromagnetic radiation, such as microwaves, visible light, and radio waves, have longer wavelengths (lower energy) and cannot cause ionization.

Groundwater
A subsurface body of water in a zone of saturated soil sediments.

Gray
The gray is the International System (SI) unit for absorbed dose, which is the energy absorbed per unit mass from any kind of ionizing radiation in any kind of matter. One gray is an absorbed radiation dose of one joule per kilogram.

Half-Life, radioactive
The time required for the activity of a radioactive substance to decrease to half its value by inherent radioactive decay. After two half-lives, one-fourth of the original activity remains ($1/2 \times 1/2$); after three half-lives, one-eighth of the original activity remains ($1/2 \times 1/2 \times 1/2$); and so on.

Hazardous waste
Waste exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). Because of its concentration, quantity, or physical or chemical characteristics, it may (1) cause or significantly contribute to an increase in mortality rates or cases of serious irreversible illness or (2) pose a substantial present or potential threat to human health or the environment when improperly treated, stored, transported, disposed of, or handled.

Hydrauger
A subhorizontal drain used to extract ground-water for slope stability purposes.

Internal radiation
Radiation from a source within the body as a result of deposition of radionuclides in body tissues by processes such as ingestion, inhalation, or implantation. Potassium (^{40}K), a naturally occurring radionuclide, is a major

source of internal radiation in living organisms.

Millirem
A common unit for reporting radiation dose. One millirem is one thousandth (10^{-3}) of a rem. *See* Rem.

Nuclide
A species of atom characterized by what constitutes the nucleus, which 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 able to exist for a measurable length of time.

Organic compound
A chemical whose primary constituents are carbon and hydrogen.

Part B Permit
The second, narrative section submitted by generators in the RCRA permitting process. It details the procedures followed at a facility to protect human health and the environment.

Perched
Separated from another water-bearing stratum by an impermeable layer.

Person-rem
See definition of Collective effective dose equivalent.

Person-sievert
See definition of Collective effective dose equivalent.

pH
A measure of hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH less than 7; basic solutions have a pH greater than 7; and neutral solutions have a pH of 7.

Piezometer
Generally, a small-diameter well primarily used to measure the elevation of the water table.

Plume[1]
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Pollutant
Any hazardous or radioactive material present in an environmental medium such as air, water, or vegetation.

Positron[2]
A particle that is equal in mass to the electron but opposite in charge. A positively charged beta particle.

Practical Quantification Limit (PQL)
The lowest amount of a matrix analyte that can be reliably and consistently measured within specified limits of precision and accuracy.

Precision
The degree of agreement between measurements of the same quantity.

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

Priority pollutants
A set of organic and inorganic chemicals identified by US/EPA as indicators of environmental contamination.

Rad
A unit of absorbed dose from ionizing radiation (0.877 rad per roentgen).

Radiation protection standard
Limits on radiation exposure regarded as necessary for protection of public health. These standards are based on acceptable levels of risk to individuals.

Radiation
Electromagnetic energy in the form of waves or particles.

Radioactivity
The property or characteristic of a nucleus of an atom to spontaneously disintegrate, accompanied by the emission of energy in the form of radiation.

Radiological
Arising from radiation or radioactive materials.

Radionuclide
An unstable nuclide. *See* Nuclide and Radioactivity.

Recharge zone
An area of the ground in which surface water migrates to the groundwater.

Rem
Acronym for "roentgen equivalent man." A unit of ionizing radiation, equal to the amount of radiation needed to produce the same biological effect to humans as 1 rad of high-voltage x rays. It is the product of the absorbed dose, quality factor, distribution factor, and other necessary modifying factors. It describes the effectiveness of various types of radiation in producing biological effects.

Remediation
See Environmental remediation.

Roentgen
A unit of radiation exposure that expresses exposure in terms of the amount of ionization produced by X or gamma rays in a volume of air. One roentgen is 2.58×10^{4} coulombs per kilogram of air.

Sievert
A unit of radiation dose equivalent. The sievert is the SI unit equivalent to the rem (conventional unit). It is the product of the absorbed dose, quality factor, distribution factor, and other necessary modifying factors. It describes the effectiveness of various types of radiation to produce biological effects. One sievert equals 100 rem.

Source
Any operation or equipment that produces, discharges, and/or emits pollutants (e.g., pipe, ditch, well, or stack).

Split Sample
A single well-mixed sample that is divided into parts for analysis and comparison of results.

Terrestrial
Pertaining to or deriving from the earth.

Terrestrial radiation
Radiation emitted by naturally occurring radionuclides, such as ^{40}K; the natural decay chains ^{235}U, ^{233}U, or ^{232}Th; or cosmic-ray induced radionuclides in the soil.

Thermoluminescent dosimeter
A type of dosimeter. After being exposed to radiation, the material in the dosimeter (lithium fluoride) luminesces on being heated. The amount of light that the material emits is proportional to the amount of radiation absorbed (dose). *See also* Dosimeter.

Tritium
A radionuclide of hydrogen with a half-life of 12.3 years. The very low energy of its radioactive decay makes it one of the least hazardous radionuclides.

Uncontrolled area

An area outside the boundaries of a controlled area. *See* Controlled area.

Upgradient

Opposite of the direction of groundwater flow from a designated area of interest. Analogous to "upstream."

Vadose zone

The region above the water table that is partially saturated or unsaturated and does not yield water to wells.

Wind rose

Meteorological diagram that depicts the distribution of wind direction over a period of time.

[1] Definition from Agency for Toxic Substances and Disease Registry, ATSDR Glossary of Terms (April 4, 2003). http://www.atsdr.cdc.gov/glossary/html [May 22, 2003].

[2] Definition from Bernard Shlein, Lester A. Slaback, Jr., and Brian Kent Birdy, editors, *Handbook of Health Physics and Radiological Health* (Lippincott Williams and Wilkins, 1998).

Table G-1 Prefixes Used with SI (Metric) Units

Prefix	Factor	Symbol
exa	1,000,000,000,000,000,000 = 10^{18}	E
peta	1,000,000,000,000,000 = 10^{15}	P
tera	1,000,000,000,000 = 10^{12}	T
giga	1,000,000,000 = 10^{9}	G
mega	1,000,000 = 10^{6}	M
kilo	1,000 = 10^{3}	k
hecto	100 = 10^{2}	h[a]
deka	10 = 10^{1}	da[a]
deci	0.1 = 10^{-1}	d[a]
centi	0.01 = 10^{-2}	c[a]
milli	0.001 = 10^{-3}	m
micro	0.000001 = 10^{-6}	μ
nano	0.000000001 = 10^{-9}	n
pico	0.000000000001 = 10^{-12}	p
femto	0.000000000000001 = 10^{-15}	f
atto	0.000000000000000001 = 10^{-18}	a

[a]Avoid where practical.

Table G-2 Conversion Factors for Selected SI (Metric) Units

To convert SI unit	To U.S. conventional unit	Multiply by
Area		
square centimeters	square inches	0.155
square meters	square feet	10.764
square kilometers	square miles	0.3861
hectares	acres	2.471
Concentration		
micrograms per gram	parts per million	1
milligrams per liter	parts per million	1
Length		
centimeters	inches	0.3937
meters	feet	3.281
kilometers	miles	0.6214
Mass		
grams	ounces	0.03527
kilograms	pounds	2.2046
kilograms	ton	0.00110
Pressure		
pounds per square foot	pascal	0.000145
Radiation		
becquerel	curie	2.7×10^{-11}
becquerel	picocurie	27.0
gray	rad	100
sievert	rem	100
coulomb per kilogram	roentgen	3,876
Temperature		
degrees Celsius	degrees Fahrenheit	1.8, then add 32
Velocity		
meters per second	miles per hour	2.237
Volume		
cubic meters	cubic feet	35.315
liters	gallons	0.2642

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