



**ERNEST ORLANDO LAWRENCE  
BERKELEY NATIONAL LABORATORY**

**Site Environmental Report for 2002**

Volume 1

**Environment, Health, and Safety Division**

July 2003



## **DISCLAIMER**

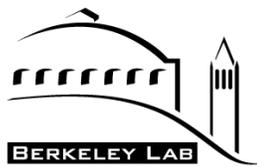
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# Site Environmental Report for 2002

Volume I

JULY 2003



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Ernest Orlando Lawrence Berkeley National Laboratory

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098



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## Preface

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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. The *Site Environmental Report for 2002* summarizes Berkeley Lab's compliance with environmental standards and requirements, characterizes environmental management efforts through surveillance and monitoring activities, and highlights significant programs and efforts for calendar year 2002. 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 a general overview of the Laboratory, the status of environmental programs, and summarized results from surveillance and monitoring activities. Volume II contains individual data results from the monitoring programs. This year, the *Site Environmental Report* was distributed on a CD in PDF format that includes Volume I, Volume II, and related documents. The report is also available on the Web at <http://www.lbl.gov/ehs/esg/>.

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 additionally reported using the more conventional (non-SI) system of measurements because this system is referenced by some current regulatory standards and is more familiar to some readers. The tables included at the end of the Glossary are intended to help readers understand the various prefixes used with SI units of measurement and convert these units from one system to the other.

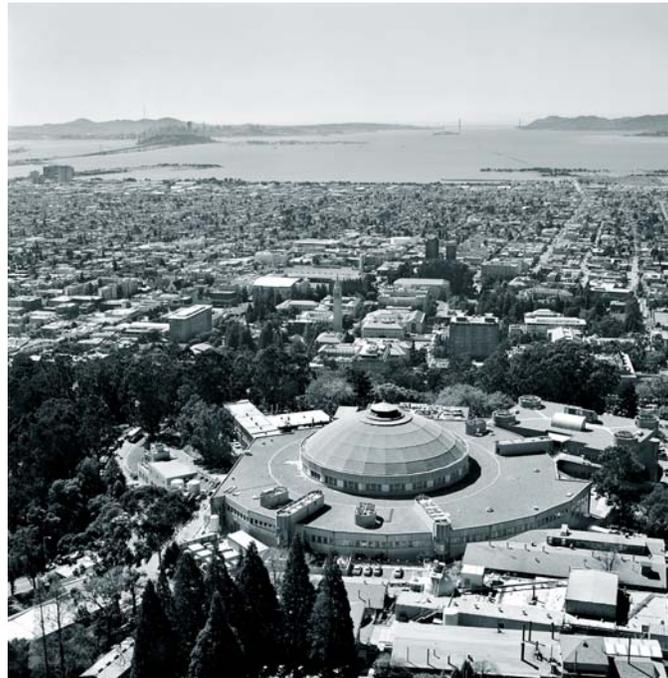
This report was prepared under the direction of Michael Ruggieri of the Environmental Services Group. The primary authors are Robert Fox, Iraj Javandel, Ginny Lackner, Michael Ruggieri, Patrick Thorson, and Linnea Wahl. Other key contributors include Steve Wyrick (Volume II), Netty Kahan (technical editing),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

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

Copies of the report are available from the Berkeley Lab Environmental Services home page (<http://www.lbl.gov/ehs/esg/>) or through Michael Ruggieri (telephone: 510-486-5440; e-mail: [mrruggieri@lbl.gov](mailto:mrruggieri@lbl.gov)).



# Executive Summary



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## 1.1 INTRODUCTION

The mission of Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is to continue the long tradition of outstanding research that has made it a premier national and international multiprogram laboratory. 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 United States Department of Energy (DOE) management system that involves five core functions: work planning, hazard and risk analysis, establishment of controls, work performance, 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.

This annual *Site Environmental Report* covers activities for calendar year (CY) 2002. Volume I summarizes environmental protection performance and environmental monitoring activities. Volume II contains individual analytical data that are summarized in the first volume. (Volume II is available on request; for details, see the Preface.) Data are presented in the report using the International System of Units measuring system, more commonly referred to as the metric system. For the convenience of readers, both volumes of this report can be accessed on the Web from the Berkeley Lab Environmental Services home page, which is located at <http://www.lbl.gov/ehs/esg/>. Readers are encouraged to comment on this report by completing either the survey card included with the distributed hard copy of the report or the survey form in the Web version of the report.

The format and content of this report satisfy the requirements of DOE Order 231.1, *Environment, Safety, and Health Reporting*,<sup>1</sup> and the operating contract between the University of California Office of the President (UCOP) and DOE.<sup>2</sup>

## 1.2 OPERATING PERMITS

At the end of CY 2002, Berkeley Lab held the following 48 environmental operating permits from various regulatory agencies:

- Air emission sources (33)
- Hazardous waste handling and treatment operations (2)
- Stormwater discharges (1)
- Underground storage tanks (8)
- Wastewater discharges (4)

For further discussion of these permits, see Chapter 3.

### 1.3 INSPECTIONS

Twenty-four inspections of Berkeley Lab's environmental programs occurred during CY 2002. One notice of violation (NOV) was issued in 2002 from an inspection in 2001 by the City of Berkeley pertaining to the *Hazardous Materials Business Plan*.<sup>3</sup> For more details on the NOV, see Section 3.3.3.

### 1.4 INCIDENT TRACKING

Berkeley Lab filed one report to DOE for a minor environmental incident reportable under its occurrence-reporting program. On February 6, 2002, an NOV was received from the City of Berkeley Toxics Management Division for a chemical inventory reporting deficiency that was identified during an inspection performed in December 2001. For more details on this incident, see Sections 3.3.3 and 3.4.3.1.2.

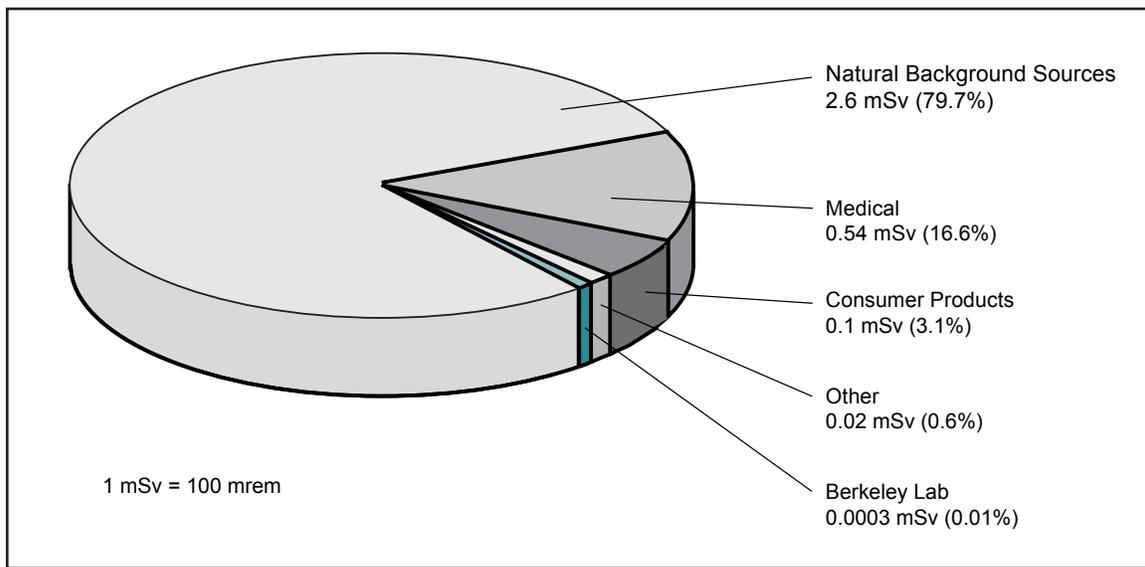
### 1.5 PERFORMANCE EVALUATION

Each year, UCOP and DOE perform an assessment of Berkeley Lab's environmental program, using measures developed jointly by Berkeley Lab, UCOP, and DOE.<sup>4</sup> In 2002, there were nine 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 2002

<b>Performance measure</b>	<b>UCOP rating</b>	<b>DOE rating</b>
Radiation protection of the public and the environment	Outstanding	Outstanding
Tracking of environmental incidents	Outstanding	Outstanding
Waste reduction and recycling	Excellent	Excellent
Integrated Safety Management Program	Outstanding	Outstanding
Waste management commitments	Outstanding	Outstanding
Program innovation in waste management and environmental restoration	Outstanding	Outstanding
Environmental restoration release site completions	Outstanding	Outstanding
Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
Cost variance for waste management activities	Outstanding	Outstanding

From both UCOP and DOE, Berkeley Lab received ratings of "outstanding" on all performance measures except the one for waste reduction and recycling, which received a rating of "excellent." For additional information on the performance review program, see Section 3.5.



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

## 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

Both radiological and nonradiological contaminants are monitored in the local environment.<sup>5</sup> Sections 1.6.1 and 1.6.2 briefly summarize environmental monitoring results from CY 2002.

### 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 2002, the measured neutron and gamma doses at Berkeley Lab were determined to be indistinguishable from background measurements. Therefore the net penetrating neutron and gamma doses to the public due to Laboratory activities were not measurable and the total potential dose to the public from Berkeley Lab activities was based solely on the measurement of dispersible radionuclides.

Dispersible radionuclide emission sources are regulated by the United States Environmental Protection Agency (US/EPA). US/EPA has set 0.1 millisieverts per year (mSv/yr) (10 millirem per year [mrem/yr])<sup>6</sup> 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. A person would have to reside full time at the Lawrence Hall of Science to receive the maximum dose from dispersible radionuclides. The estimated maximum potential dose from all airborne radionuclides released from the Laboratory site in CY 2002 was about 0.0003 mSv (0.03 mrem), with tritium accounting for about 46% of that amount. This is about 0.3% of the US/EPA dose limit for dispersible radionuclide emissions. See Figure 1-1.

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 2002 from dispersible radionuclide emissions was estimated at 0.003 person-Sv (0.3 person-rem). 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.

A one-year program of supplemental environmental tritium monitoring, which was begun in April 2001 for the US/EPA's reevaluation of the site for the National Priorities List (Superfund sites) and for response to community concerns, was completed in May 2002. The results from the supplemental monitoring were provided to the US/EPA in June 2002.

After reviewing the data, in July 2002 the US/EPA announced that the environmental sampling at the Lawrence Berkeley National Laboratory had indicated that tritium levels were well below federal health standards and that no further action was required under the Superfund program.<sup>7</sup> Furthermore, the US/EPA changed the site's Superfund status from "potentially eligible" for listing to "no further federal response." Summaries of the results for activities in 2002 are presented in Chapters 3, 4, and 5. A copy of the *Summary Report for Supplemental Tritium Monitoring*<sup>8</sup> can be found on the Web at <http://www.lbl.gov/ehs/taskforce/> and on the CD version of the *Site Environmental Report*.

### **1.6.2 Nonradiological Monitoring**

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

In compliance with the four wastewater discharge permits<sup>9</sup> issued to the Laboratory by the East Bay Municipal Utility District (EBMUD), Berkeley Lab samples for metals, chlorinated hydrocarbons, and other specified parameters in sanitary sewer discharges. All results were well within compliance limits this year. For details on the wastewater discharge sampling program, see Chapter 5.

Stormwater discharges at Berkeley Lab are regulated under a general permit<sup>10</sup> 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<sup>11</sup> 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 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, creeks, and lakes), see Chapter 5.

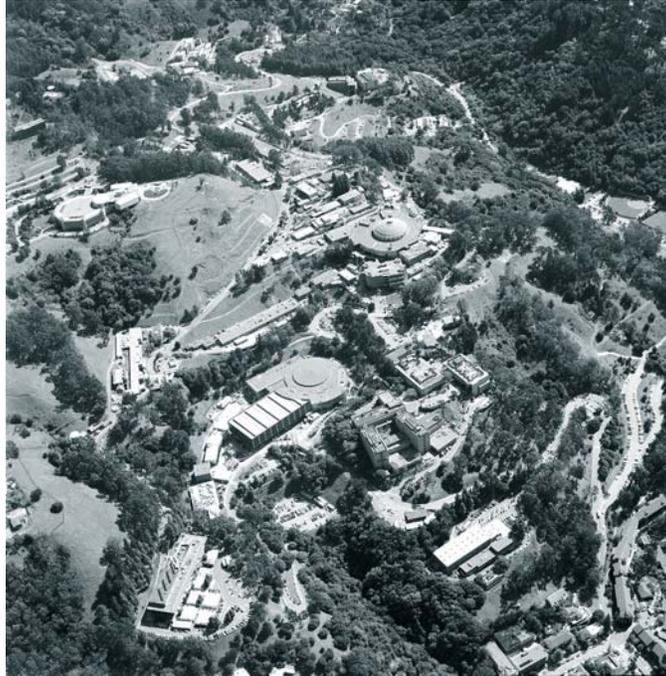
Extensive groundwater monitoring has been conducted by Berkeley Lab since the early 1990s, and ten groundwater plumes have been identified. These plumes are all on-site. The groundwater in the vicinity of the Laboratory is not used for public drinking water. Four types of contaminant plumes exist on-site:

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

The Laboratory continues to monitor these plumes and is developing 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 contaminants are reported to regulatory agencies quarterly, along with other program developments and planned activities. 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 samples collected near roadways or parking lots, and some metal concentrations in soil and sediment.<sup>12</sup> In all instances, measured levels of contaminants were within regulatory limits. The levels of oil and grease measured at Berkeley Lab are typical for an urban setting. The levels of metals are within the range (or only slightly above) established background values for the Berkeley Lab site.<sup>11</sup> However, Berkeley Lab will continue to monitor these locations. For more information on Berkeley Lab's impact on soil and sediment, see Chapter 7.

# Introduction



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## **2.1 HISTORY**

Lawrence Berkeley National Laboratory was founded by Ernest O. Lawrence in 1931. Recipient of the 1939 Nobel Prize in physics for his invention of the cyclotron (particle accelerator), Lawrence 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, materials science, medical imaging, and advanced electrical battery technologies. 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.

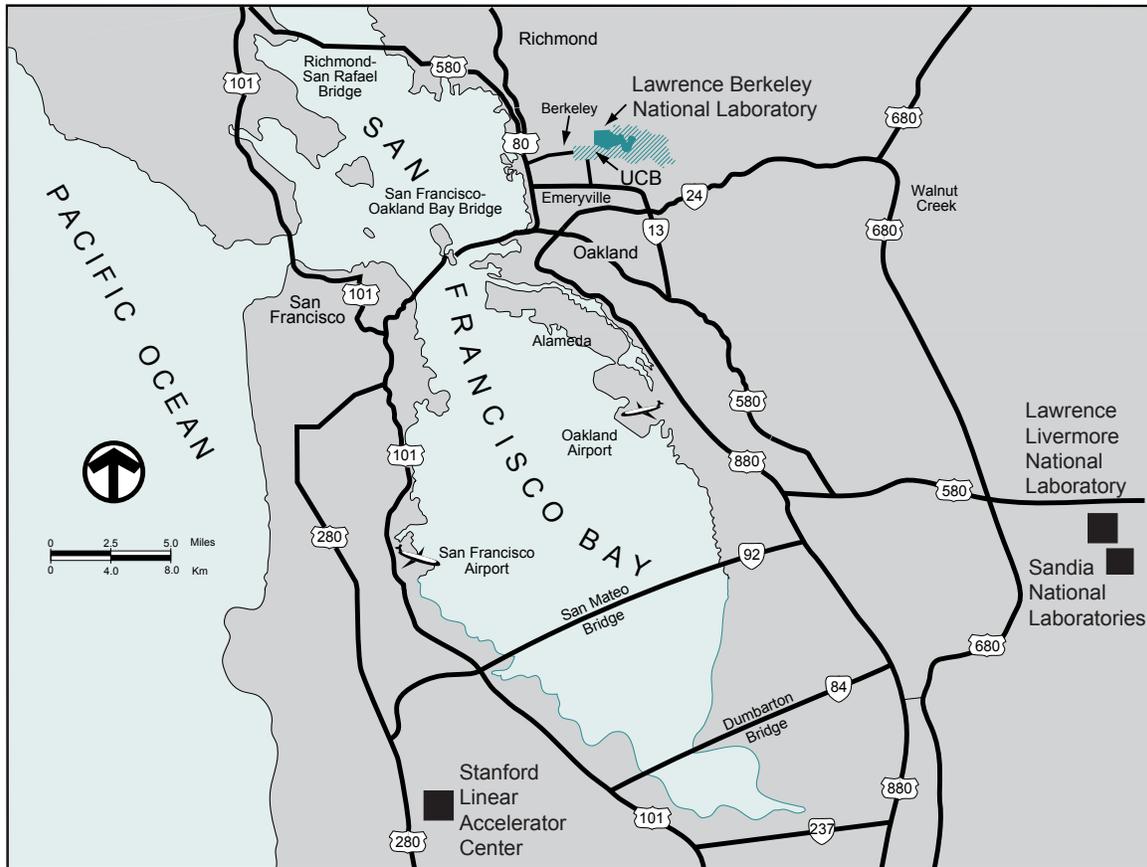
## **2.2 LABORATORY**

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 (3 miles) 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



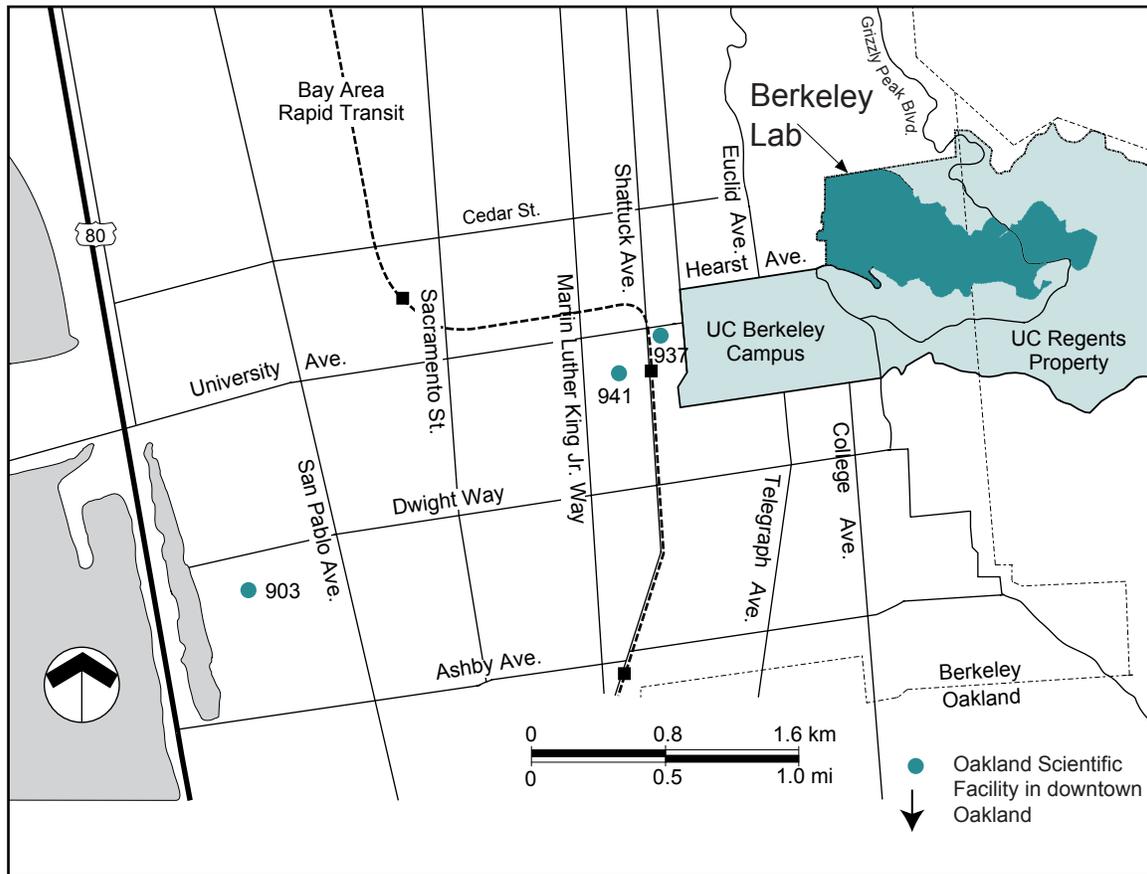
**Figure 2-1** San Francisco Bay Area Map

(which forms the eastern part of the site), with elevations ranging from 150 to 330 meters (500 to 1,100 feet) 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 399,484.<sup>1</sup>

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.

### 2.2.2 Population and Space Distribution

About 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



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

**Figure 2-2** Vicinity Map

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. About 300 of the Laboratory's scientists serve as faculty members at UC Berkeley and UC San Francisco.<sup>2</sup>

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.<sup>3</sup>

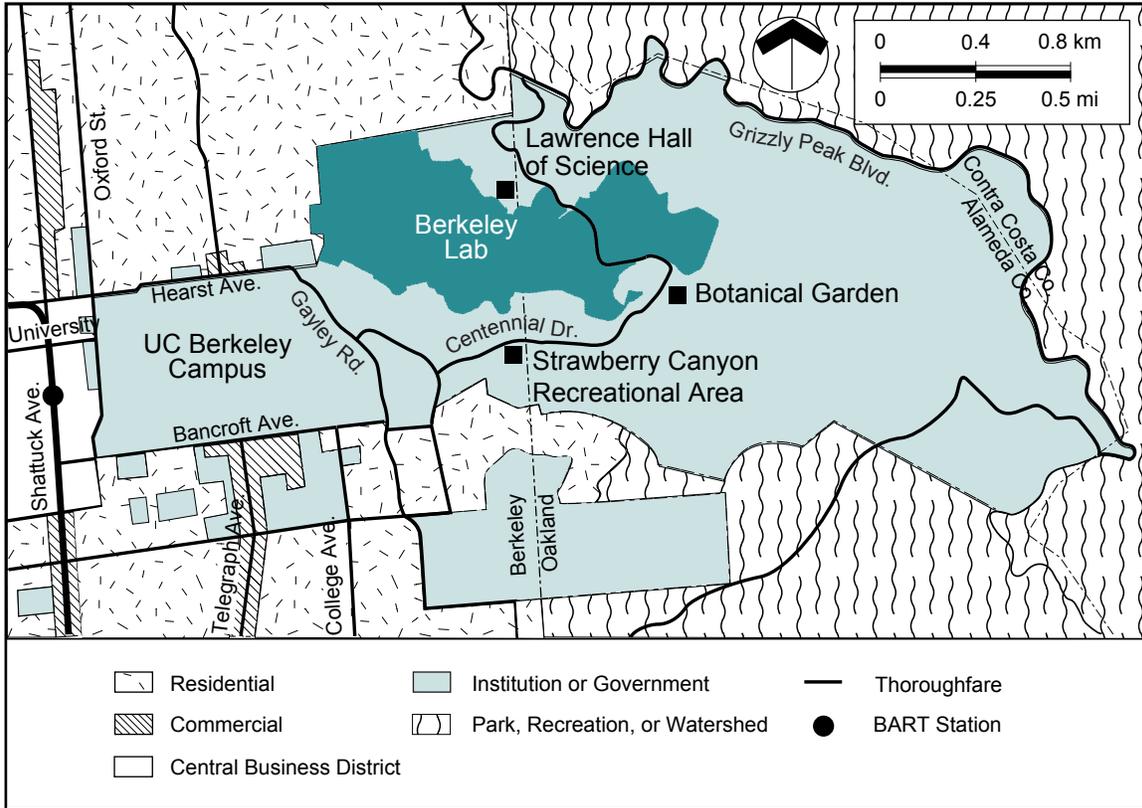


Figure 2-3 Adjacent Land Use

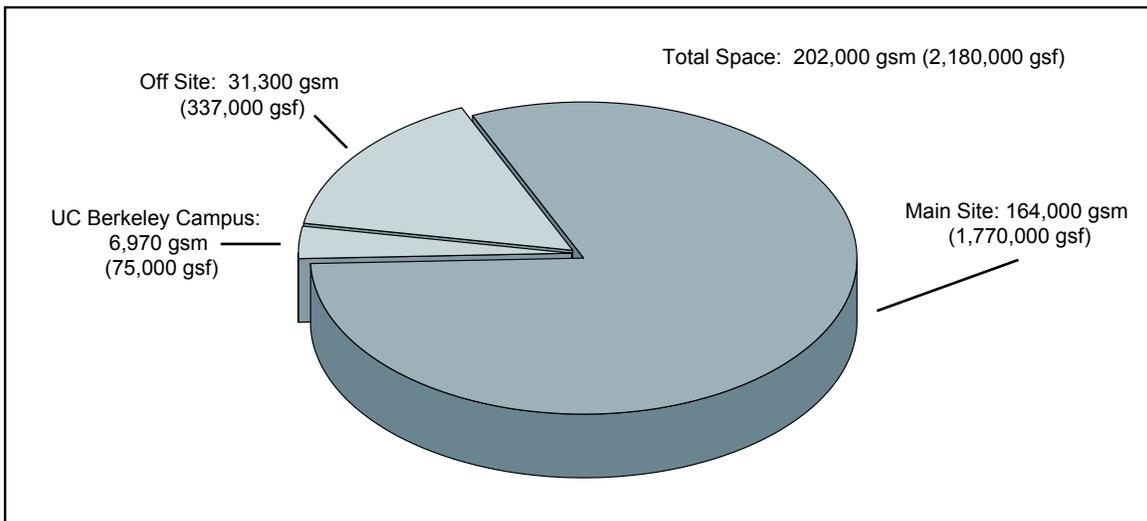


Figure 2-4 Space Distribution

### **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.

The water supply system is highly reliable for both domestic use and emergency purposes. This reliability is enhanced by separate connections to two EBMUD sources (Shasta and Berkeley View) 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 begun in 2002. All Laboratory water is supplied by gravity feed. The entire system has sufficient capacity to meet the flow-rate and duration requirements for fire protection.

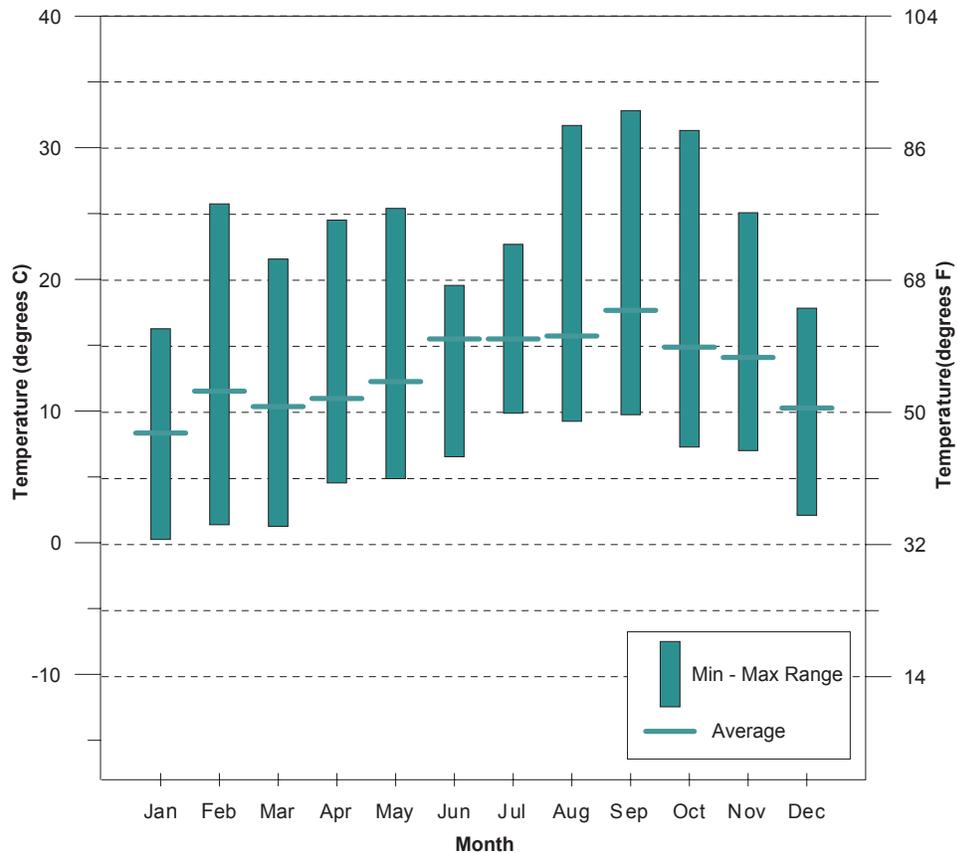
## **2.3 ENVIRONMENTAL SETTING**

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.

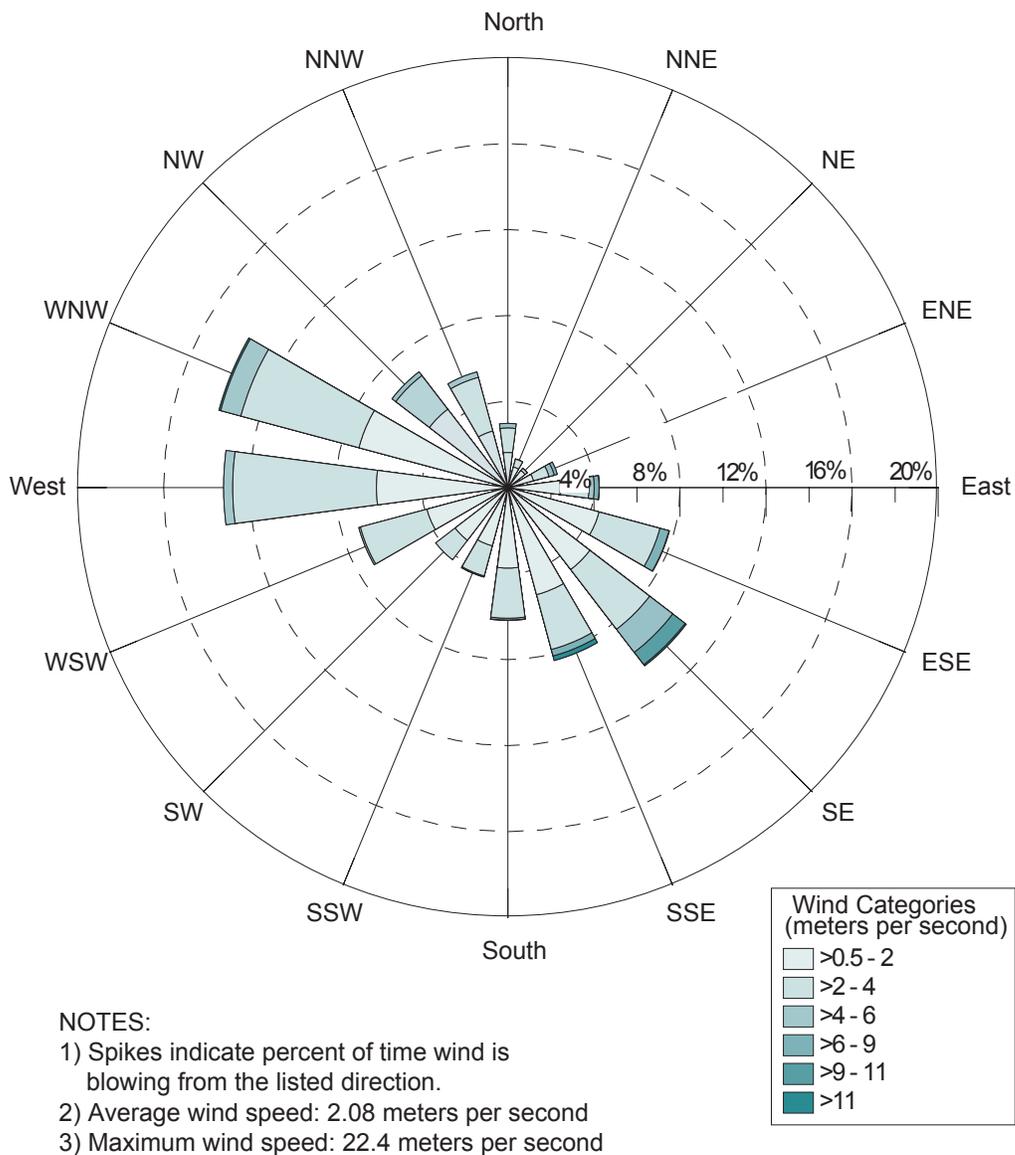
On-site wind patterns change little from one year to the next. The most prevalent wind pattern occurs during fair weather, with daytime westerly winds blowing off the bay, followed by lighter nighttime southeasterly winds originating in the East Bay hills. The other predominant wind pattern is associated 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 2002 monthly precipitation totals to the average since 1974.



**Figure 2-5** Temperature Summary by Month

### 2.3.2 Vegetation

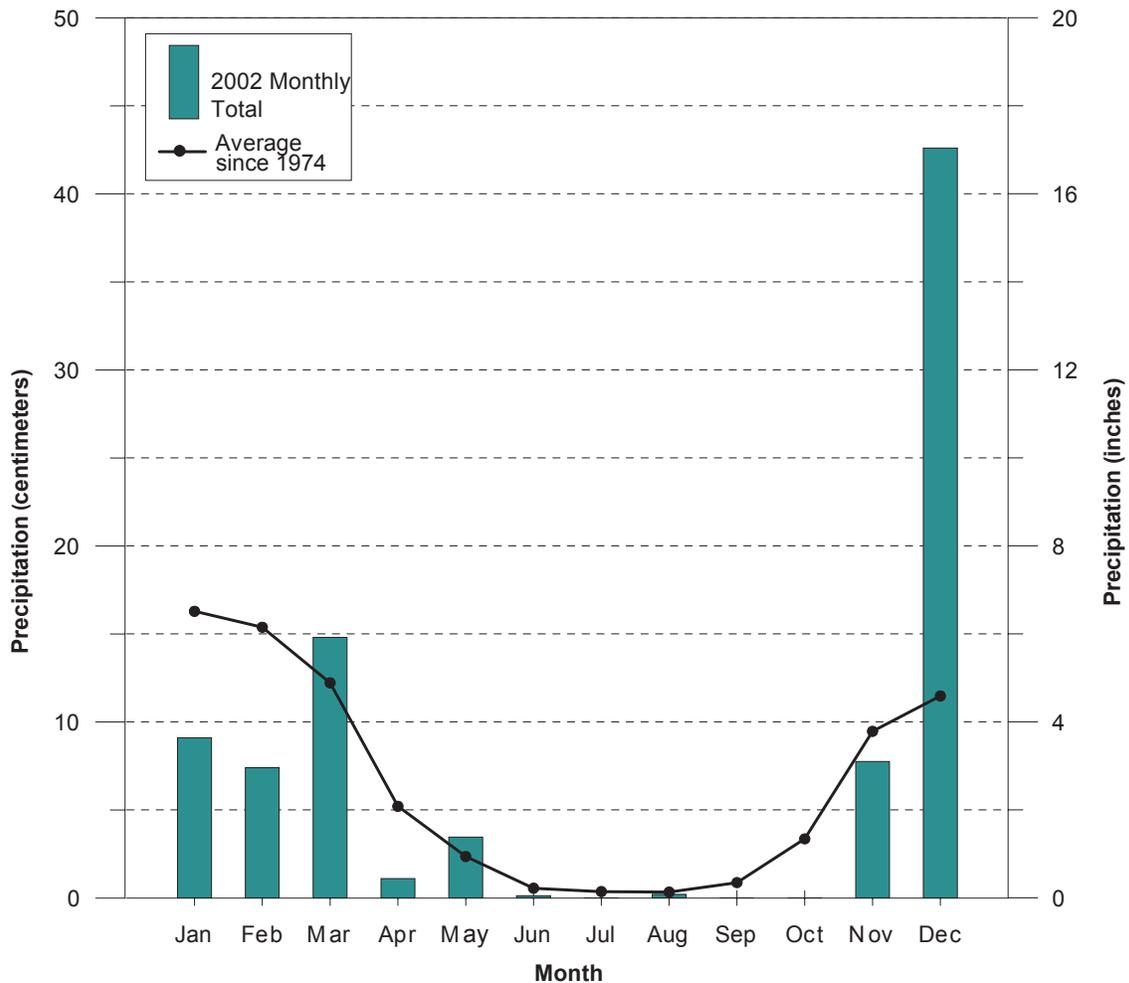
Vegetation on the Berkeley Lab site is a mixture of native plants, naturalized exotics, and ornamental species. The site was intensively grazed and farmed for approximately 150 years before the development of the Laboratory at this site in the late 1930s. The Laboratory's vegetation management program uses the natural succession of the native plant communities as a guide to coordinate vegetation in outlying areas and to link these areas to the vegetation assemblies beyond the Laboratory site. Berkeley Lab also works to maintain a wooded and savanna character in the area of 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 2-6** Annual Wind Patterns

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 has implemented a program that will allow Laboratory buildings to survive a wind-driven firestorm similar in intensity to that of 1991. As part of this program, Berkeley Lab has 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 or

thinning operations, erosion control measures have been installed where necessary and these areas have been seeded with native grasses and broadleaf herbs.



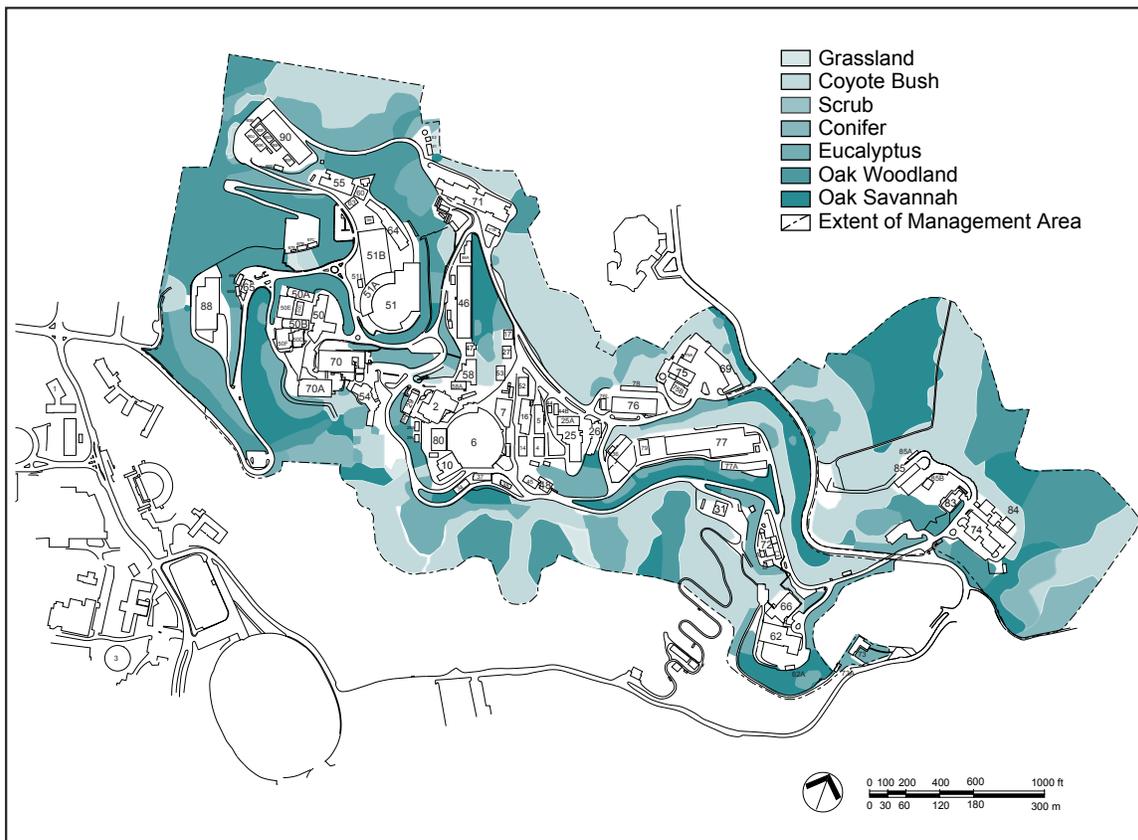
**Figure 2-7** Precipitation Summary by Month

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. The Laboratory's grass/herb lands, brushlands, and trees provide cover, food, and breeding sites for

wildlife that is typical of disturbed (e.g., previously grazed) areas with a Mediterranean climate located in midlatitude California. More than 120 species of birds, mammals, and reptiles/amphibians 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 as a critical habitat for the Alameda whip snake, which has been designated as “endangered” pursuant to the Endangered Species Act. However, no Alameda whip snake sightings have been reported on or in the vicinity of the Berkeley Lab site. The most abundant large mammal is the Columbian black-tailed deer.



**Figure 2-8** Vegetation Types

### 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) ( $3.3 \times 10^{-5}$  and  $3.3 \times 10^{-8}$  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 ( $3.3 \times 10^{-7}$  and  $3.3 \times 10^{-12}$  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 ( $3.3 \times 10^{-4}$  and  $3.3 \times 10^{-6}$  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 meters (98 feet) below the surface across the site.

## Environmental Program Summary



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### 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) 2002.

### 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.
2. *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.
3. *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.
4. *Work Performance.* Conduct that accomplishes the tasks in accordance with the established controls.
5. *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 2002 is shown in Figure 3-1.

The Environmental Services Group (ESG) oversees sitewide environmental compliance activities, provides technical assistance to Laboratory staff, and assesses 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.

### 3.3 PROGRAM SUMMARY

The following sections discuss environmental permits, audits, and inspections, and United States Department of Energy (DOE)-reportable environmental incidents at Berkeley Lab for CY 2002.

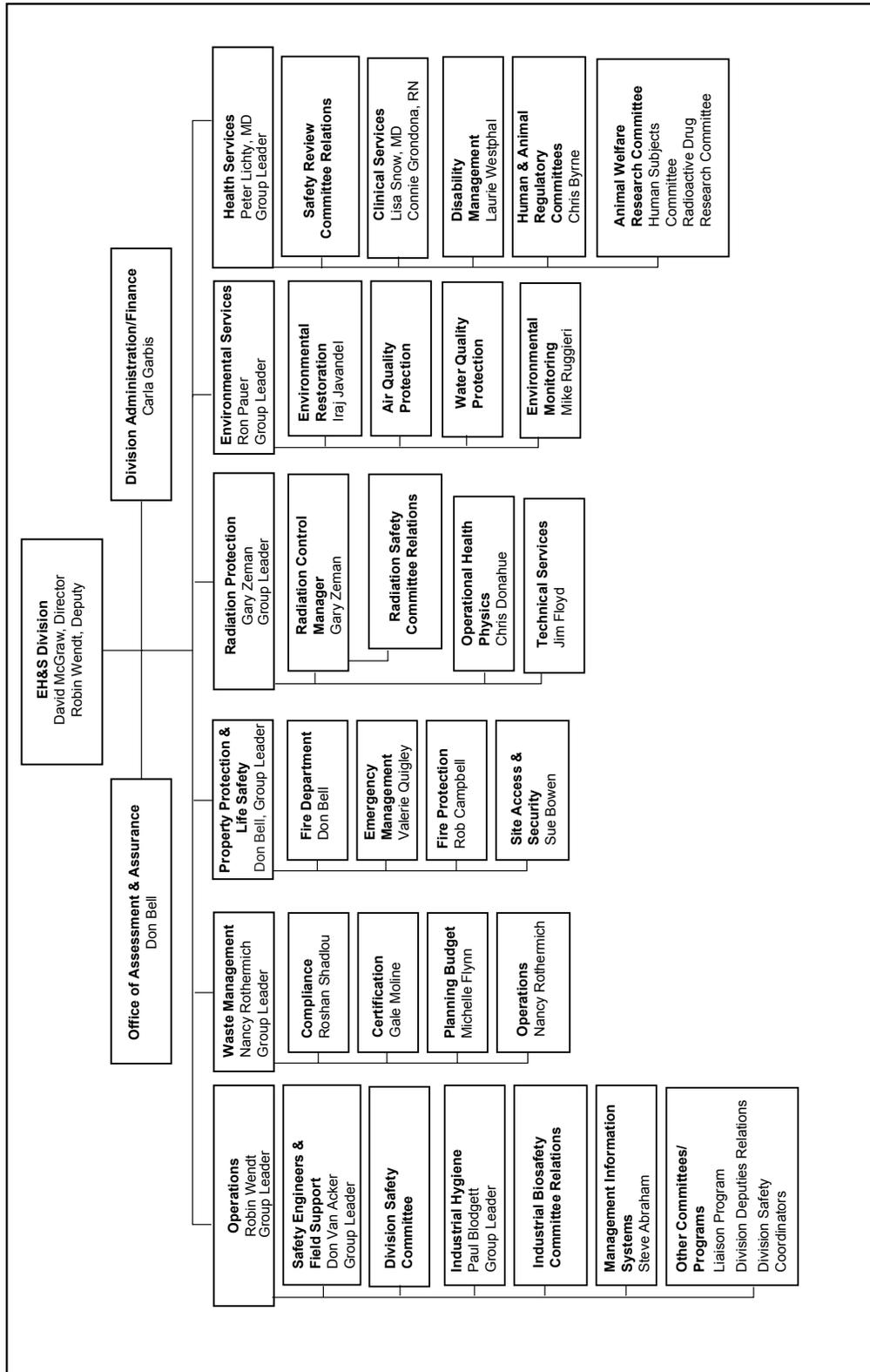


Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization

### 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.

### 3.3.2 Summary of Audits and Inspections

The agencies regulating the environmental programs at Berkeley Lab periodically inspect the Laboratory. Table 3-2 lists the inspections by these agencies that occurred at Berkeley Lab during

**Table 3-1** Environmental Permits Held by Berkeley Lab at the End of 2002

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD <sup>a</sup>	Various activities with emissions to air	33	Section 3.4.1.2
Hazardous waste	DTSC <sup>b</sup>	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 <sup>c</sup>	Sitewide stormwater discharges	1	Section 3.4.6.2
Underground storage tanks	City of Berkeley	Underground storage tanks containing petroleum products	8	Section 3.4.6.4
Wastewater	EBMUD <sup>d</sup>	Sitewide and operation-specific wastewater discharges to sanitary sewer	4	Section 3.4.6.1

<sup>a</sup> Bay Area Air Quality Management District

<sup>b</sup> Department of Toxic Substances Control

<sup>c</sup> State Water Resources Control Board

<sup>d</sup> East Bay Municipal Utility District

CY 2002. 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. Berkeley Lab received one notice of violation (NOV) in February 2002 from an inspection by the City of Berkeley in December 2001. See Section 3.3.3.

**Table 3-2** Environmental Audits, Inspections, and Appraisals in CY 2002

Organization	Inspection title	Start date	Length (days)	Violations
BAAQMD	Permitted air emission sources	April 9	1	0
City of Berkeley	Underground storage tanks	October 21	1	0
EBMUD	Wastewater monitoring inspections at Hearst and Strawberry outfalls	February 14	1	0
		May 13	1	0
		August 6	1	0
		December 11	1	0
	Wastewater monitoring inspections at B77 treatment unit	February 20	1	0
		September 3	1	0
	Inspection of motor pool at B76	August 16	1	0
Wastewater monitoring inspections at B25 treatment unit	January 11	1	0	
	July 16	1	0	
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry outfalls	January 15	1	0
		April 15	1	0
		July 8	1	0
		November 18	1	0
	EBMUD self-monitoring inspections at B77 treatment unit	January 15	1	0
		April 8	1	0
		November 18	1	0
	EBMUD self-monitoring inspections at B25 treatment unit	April 9	1	0
		November 18	1	0
	EBMUD self-monitoring inspections at groundwater treatment units	March 14	1	0
October 4		1	0	
DTSC	Inspection of Hazardous Waste Handling Facility	February 28	2	0
Central Contra Costa Sanitary District	General wastewater and stormwater operations inspection at Production Genome Facility (Walnut Creek)	December 16	1	0

Note: A Notice of Violation was received in 2002 from the City of Berkeley Toxics Management Division for a chemical inventory deficiency identified during 2001. See Section 3.3.3 for details.

### 3.3.3 Summary of DOE-Reportable Environmental Incidents

One environmental incident in 2002 was reportable under the DOE occurrence-reporting program,<sup>1</sup> which is used to track incidents across the DOE complex. On February 6, 2002, an NOV was received from the City of Berkeley Toxics Management Division (TMD) for a chemical inventory reporting deficiency that was identified during an inspection performed December 10–11, 2001. The NOV indicated that the chemical inventory submitted to the TMD was incorrect because the amount of sulfuric acid in Building 77, which was approximately 341 liters (L) (90 gallons [gal]), exceeded the 208 L (55 gal) threshold for chemical inventory reporting but was not reported. The NOV included a notice for Berkeley Lab to prepare a compliance plan within 30 days. On March 8, 2002, Berkeley Lab submitted a work plan to the TMD that described the corrective actions

responding to the NOV. All items listed in the plan have been completed within the specified schedule, and all future activities associated with the plan are on track.

### **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<sup>2</sup> 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, volatile air toxics)
- Ozone-depleting substances (e.g., chlorofluorocarbons or Freons)

The State of California's own air pollution control program<sup>3</sup> 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*),<sup>4</sup> as well as sections of DOE Orders 5400.1<sup>5</sup> and 5400.5.<sup>6</sup> Subpart H is part of the National Emission Standards for Hazardous Air Pollutants program (NESHAPs). The United States Environmental Protection Agency (US/EPA) administers NESHAPs, while DOE administers Orders 5400.1 and 5400.5.

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<sup>7</sup> guidance. The assessment 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 compliance status with an annual report to US/EPA, which is available on Berkeley Lab's ESG Web page at <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 non-NESHAPs air emission activities.

At the end of CY 2002, Berkeley Lab held operating permits from BAAQMD for 33 activities.<sup>8</sup> Two of these permitted activities were located at the Production Genomics Facility (PGF) 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. The number of permitted activities represents a significant jump from previous years and results from a rule change at BAAQMD that requires operating permits for previously exempt diesel-powered standby emergency generators. All 22 permits obtained during the year for the main site and the PGF were for such generators. 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.<sup>9</sup> For a list of active operating permits, see Table 3-3.

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](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)<sup>10</sup> was passed by Congress to regulate actual or threatened releases into the environment. 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.

After considering information available in 1991 about historic Laboratory activities, US/EPA determined that environmental risks were low and did not warrant a CERCLA-based investigation.

**Table 3-3** Air Emission Sources Permitted by BAAQMD at the End of 2002

BAAQMD category	Description	Building	Abatement type
Combustion equipment	Standby emergency generators	64,70	Catalytic converter
	Standby emergency generators	Various <sup>a</sup>	—
	Standby emergency generators	PGF <sup>b</sup>	—
Gasoline dispensing	Gasoline pumps	76	Vapor recovery
Surface coating and printing	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

<sup>a</sup> Generators located at Buildings 2, 37, 48, 50A, 50B, 55, 62, 64, 66, 70A, 72, 74, 75, 76 (3), 77, 84B, and 85.

<sup>b</sup> 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.

However, at the request of the Committee to Minimize Toxic Waste, a local citizens' group, US/EPA reevaluated the Berkeley Lab site in 1998 to determine whether the site is eligible for inclusion on the federal Superfund program list, also known as the National Priorities List (NPL).

In evaluating Berkeley Lab for possible inclusion on the NPL, US/EPA considered ambient-air data for tritium releases permitted under the Clean Air Act. US/EPA determined, based on CERCLA screening criteria, that the site was eligible for the NPL. US/EPA also determined, however, that existing data indicated that the low levels of tritium at Berkeley Lab are well below US/EPA clean air public health standards and do not indicate a need to add Berkeley Lab to the Superfund sites. To make a final listing decision, US/EPA requested additional sampling of the air, water, and soil in and around the Laboratory. Berkeley Lab responded to this request by preparing sampling plans for air, vegetation, soil and sediments, and surface water. The sampling plans were reviewed by US/EPA and approved by DOE in early 2001. Sampling began in April 2001 and was completed in May 2002.

The results from the supplemental monitoring were provided to the US/EPA in June 2002. After reviewing the data, the US/EPA announced in July 2002 that the environmental sampling at the Berkeley Lab had found tritium levels well below federal health standards and that no further action was required under the Superfund program.<sup>10</sup> Furthermore, the US/EPA changed the site's Superfund status from "potentially eligible" for listing to "no further federal response." A copy of the *Summary Report for Supplemental Tritium Monitoring* can be found on the Web at <http://www.lbl.gov/ehs/taskforce/> and on the CD version of this *Site Environmental Report*.

Berkeley Lab continues to investigate 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).<sup>12</sup> Because these areas of interest relate to groundwater protection, all monitoring efforts for the year are described in Chapter 6.

CERCLA also has implications for off-site incidents associated with Berkeley Lab's activities. Quicksilver Products, Inc., operated a mercury recycling facility in Brisbane, California, from 1988 to 1995. The California Department of Toxic Substances Control (DTSC) conducted an investigation and cleanup of the site and is now seeking recovery of its costs. In 1999, DTSC identified Berkeley Lab as one of the parties potentially responsible for these costs because the Laboratory once sent fluorescent/mercury lamps and mercury-contaminated debris to the Quicksilver site. In CY 2002, the Laboratory resolved its potential liability with DTSC as part of a settlement negotiated by the University of California (UC) for its campuses and its UC-operated DOE facilities in California.

### **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; the Federal Insecticide, Fungicide and Rodenticide Act; and the 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).<sup>13</sup> 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.<sup>14</sup> 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*)<sup>15</sup> DOE is required to evaluate its facilities such as Berkeley Lab 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 at its facilities.

Berkeley Lab determined that no chemical usage in CY 2002 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.

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 2002, a survey was performed on all 18 chemicals and chemical categories that had their reporting thresholds 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 well 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)<sup>16</sup> to the City of Berkeley each year, although federal sovereign immunity from such regulations has not been waived.

The 2002 HMBP included a list of all hazardous materials present in amounts exceeding the state's aggregate threshold quantities (i.e., 208 L [55 gal] 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.

On December 10 and 11, 2001, the TMD performed a routine facility inspection of the Berkeley Lab Hazardous Materials Management Program. Berkeley Lab responded to an NOV identified in this inspection by completing a work plan. All items listed in the plan have been completed within the specified schedule, and all future activities associated with the plan are on track.

**Table 3-4** Trends in Highest Quantities of EPCRA Toxic Release Inventory Reporting

Substance	1999 (kg)	2000 (kg)	2001 (kg)	2002 (kg)
Chlorofluorocarbons	44	246	260	164
Methanol	759	468	593	322
Nitric acid	709	746	861	778
1,1,1-Trichloroethane	44	21	2	<1

#### 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.<sup>17</sup>

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

Passed by Congress in 1972, the Federal Insecticide, Fungicide, and Rodenticide Act<sup>18</sup> 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)<sup>19</sup> 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) remain the sole substance 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 [ppm]). The remaining TSCA-PCB equipment items are four large low-voltage capacitors. These capacitors remain in use, containing an estimated 170 kg (375 lb) of regulated PCB dielectric fluid. Because of the small amounts of PCBs, the Laboratory is not required to prepare an annual PCB report for the US/EPA; however, Berkeley Lab maintains records of PCB usage.

A research project required the import of silicon tetrafluoride enriched with the stable isotope silicon-29. 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. The exemption was granted, and the material was imported.

### **3.4.4 Hazardous Waste (Resource Conservation and Recovery Act)**

The primary goal of the RCRA<sup>20</sup> 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.<sup>21</sup> 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 the 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 Hazardous Waste Handling Facility (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<sup>22</sup> was approved by DTSC on May 4, 1993, and is valid until May 2003. Berkeley Lab has submitted a timely permit-renewal application for operation of its HWHF and will continue operating under the current permit conditions until the new permit is 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 permit.

Berkeley Lab has an additional hazardous waste permit<sup>23</sup> 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"

**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

tier. The level of treatment determines which tier applies. The City of Berkeley requests renewal of this permit each year. In March 2002, the Laboratory submitted the 2002 FTU renewal package to the City of Berkeley.

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

- The *Annual Hazardous Waste Report*,<sup>24</sup> 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*,<sup>25</sup> 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 generated to meet a DTSC operating-permit requirement.

In October 1995, DTSC approved the Laboratory's Mixed Waste Site Treatment Plan,<sup>26</sup> 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<sup>27</sup> 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.

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.

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 and are subject to annual inspections. No outside agencies performed inspections in 2002.

#### **3.4.4.3 RCRA 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*, which details 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, Berkeley Lab 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* and *Phase II Progress Report*, and in the *Draft Final RCRA Facility Investigation Report*, submitted to DTSC on September 29, 2000. DTSC approved the *Draft Final RCRA Facility Investigation Report* on July 27, 2001. During the investigation phase, 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 quarterly meetings at which the status of performed and planned activities is discussed. The program also holds technical workshops with the agencies. The technical meetings give the agencies a detailed description of results from field investigations and facilitate agency involvement in planning future activities.

### 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*)<sup>28</sup> 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<sup>29</sup> 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 unfeasible or impracticable
- Manage hazardous waste in an environmentally safe manner and minimize present and future threats to health and the environment if it is unfeasible 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*,<sup>30</sup> and the *Hazardous Waste Management Report Summary*.<sup>31</sup> The last report was compiled in 1999 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<sup>32</sup> 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)<sup>33</sup> 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<sup>34</sup> 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 (a) the cities of Berkeley and Oakland for stormwater and (b) EBMUD for drinking-water supply and wastewater discharges.

#### **3.4.6.1 Wastewater**

The Laboratory has four wastewater discharge permits<sup>35</sup> 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
- Treatment unit discharge of rinse water from the metal finishing operations in Building 77

- Treatment unit discharge of groundwater from hydraugers and groundwater monitoring wells

Permits are renewed annually, except for the treated-groundwater permit, which has a two-year duration. 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 permit limits were exceeded. For more information regarding the results of the Laboratory's annual self-monitoring program, see Chapter 5.

EBMUD also inspects the Laboratory's sanitary sewer discharge activities without prior notice. The agency conducted inspections on eight separate occasions throughout the year. Table 3-2 lists these inspections. While most of the inspections are routine sample collections, on August 16 EBMUD performed a nonroutine inspection of the vehicle maintenance facility. No violations resulted from any inspections.

The wastewater discharge permits for Buildings 25 and 77 require that each facility maintain a Toxic Organics Management Plan (TOMP).<sup>36</sup> 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)<sup>37</sup> 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,<sup>38</sup> and the TOMP and ASPCP for Building 25 will also be combined to reduce duplication of information.

#### **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.<sup>39</sup> 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 *Stormwater Pollution Prevention Plan*<sup>40</sup> and a *Stormwater Monitoring Program*.<sup>41</sup> 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.<sup>42</sup> 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 2002.

### **3.4.6.3 Aboveground Storage Tanks**

Aboveground storage tanks (ASTs) also fall under the authority of the CWA.<sup>33</sup> The CWA and the state's Aboveground Petroleum Storage Act<sup>43</sup> outline the regulatory requirements for ASTs. Under the authority of the CWA, a Spill Prevention, Control, and Countermeasures (SPCC) Plan<sup>44</sup> 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 spills or leaks from petroleum-containing tanks. ASTs are provided with secondary containment or spill kits to capture any potential spills. Also, the Lab inspects ASTs periodically for corrosion, cracks, leaks, or other damage. The locations of ASTs are shown in Figure 3-2.

In 2002, Berkeley Lab installed one new engine generator with a fuel AST capacity of 1,600 L (430 gal) at Building 70. An existing 3,800 L (1,000 gal) AST at Building 70 was taken out of service when the new engine generator was installed. Another engine generator with a fuel capacity of 950 L (250 gal) was moved from Building 50 to Building 64.

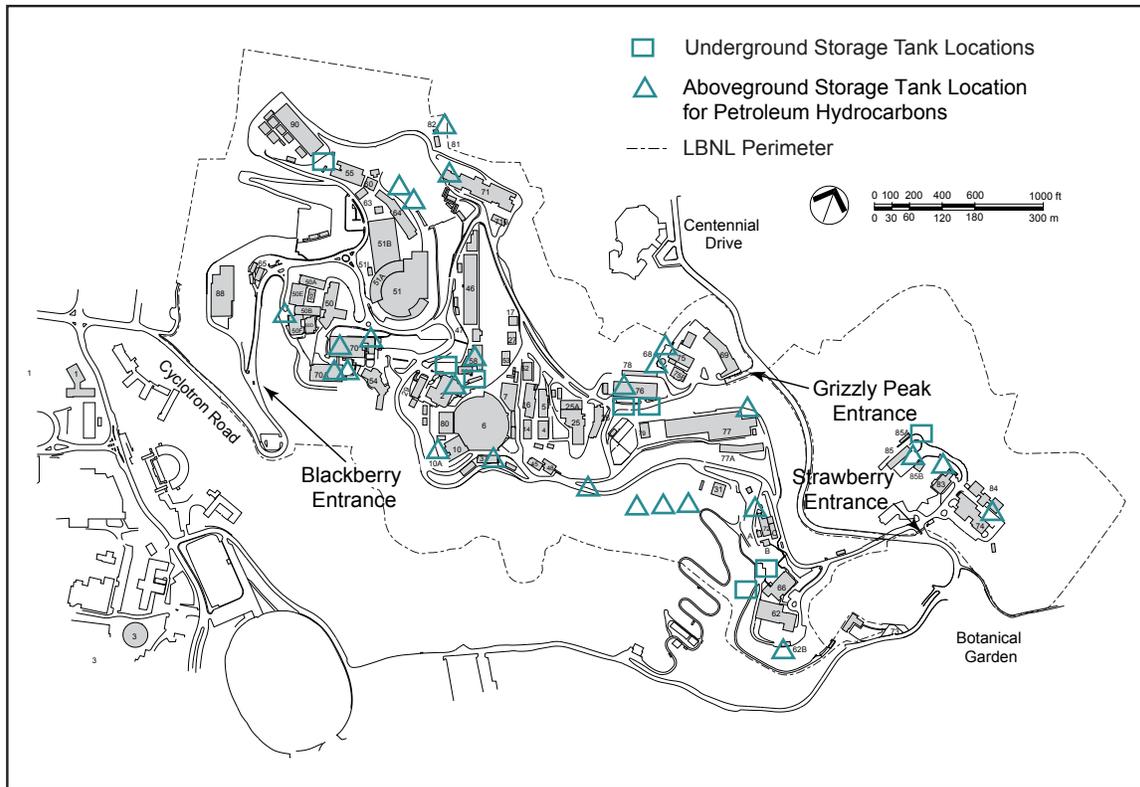
Nonpetroleum (i.e., chemical or hazardous) ASTs consist of FTU tanks, storage drums at Waste Accumulation Areas (WAA), and storage drums at product distribution areas. FTU tanks are inspected each operating day by operators of the FTU. WAAs are inspected weekly by EH&S staff. Product distribution areas, 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.<sup>45</sup> 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.<sup>46</sup> The City of Berkeley is the local administering agency for UST regulations that apply to Berkeley Lab.

At the end of 2002, eight permitted USTs remained at the Laboratory (see Table 3-6 and Figure 3-2). The tanks contain either diesel fuel or unleaded gasoline. The Laboratory has removed seven tanks since 1993 and properly closed each site.



**Figure 3-2** Aboveground and Underground Storage Tank Locations

On October 21, 2002, the City of Berkeley inspected all eight USTs and found no violations. Secondary containment was tested according to the requirements of Senate Bill 989 (2002) on October 15 and 18, 2002, for all eight USTs. All UST secondary containment systems met testing requirements except for two USTs located at Building 66. The Building 66 USTs are scheduled for removal in 2003.

### 3.4.7 Safe Drinking Water Act

The Safe Drinking Water Act<sup>47</sup> 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.

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

Registration tank ID number	LBNL building number	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
66-1	66	Diesel	15,200 (4,000)	Glasteel	1987
66-2	66	Diesel	7,600 (2,000)	Glasteel	1987
76-1	76	Unleaded gasoline	38,000 (10,000)	Glasteel	1990
76-2	76	Diesel	38,000 (10,000)	Glasteel	1990

To prevent damage to laboratory research involving such organisms, researchers have instituted measures to neutralize the chloramine in order 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. For waterline breaks and legally mandated testing and flushing of fire hydrants, the Facilities Division and Fire Department neutralize the chloramine before the water reaches a storm drain.

### 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 FY 2002.<sup>48</sup>

Berkeley Lab received performance ratings of "outstanding" from both DOE and UCOP for all environmental performance measures except for one measure, waste reduction and recycling, which received a rating of "excellent." For more information on environmental performance objectives, criteria, and measures, go to the Berkeley Lab's Office of Assessment and Assurance home page at <http://www.lbl.gov/ehs/oa/>.

**Table 3-7** Environmental Performance Measure Ratings for FY 2002

<b>Performance measure</b>	<b>UCOP rating</b>	<b>DOE rating</b>
Radiation protection of the public and the environment	Outstanding	Outstanding
Tracking of environmental incidents	Outstanding	Outstanding
Waste reduction and recycling	Excellent	Excellent
Integrated Safety Management Program	Outstanding	Outstanding
Waste management commitments	Outstanding	Outstanding
Program innovation in waste management and environmental restoration	Outstanding	Outstanding
Environmental restoration release site completions	Outstanding	Outstanding
Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
Cost variance for waste management activities	Outstanding	Outstanding

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# Air Quality



<b>4.1</b>	<b>BACKGROUND</b>	<b>4-2</b>
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#### 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)<sup>1</sup>
- DOE Order 5400.1 (*General Environmental Protection Program*)<sup>2</sup>
- DOE Order 5400.5 (*Radiation Protection of the Public and the Environment*)<sup>3</sup>

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*<sup>4</sup> 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 reported in this section of the report. 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 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 matter 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<sup>a</sup>

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

<sup>a</sup>For a complete list of radionuclides evaluated under NESHAPs regulations, see the *Radionuclide Air Emission Annual Report for 2002*, found on 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  $1.0 \times 10^{-3}$  millisieverts per year (mSv/yr) (0.1 millirem per year [mrem/yr]).<sup>1</sup> As mentioned in Section 3.4.1.1, Berkeley Lab uses a comprehensive strategy approved by the US/EPA to satisfy this requirement.<sup>5</sup> 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.* Limits on radionuclide inventories combined with emission estimates.

These assessment levels are assigned to each of six stack 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. At the end of the year 2002, all sources evaluated for NESHAPs compliance were considered “small sources” of emissions (Category II through V). One source, the former National Tritium Labeling Facility (NTLF), changed from Category I to Category III at the end of 2002 when the second phase of cleanup activities was completed. Most sources fall into Category V, which requires no monitoring. In 2002, there were 115 sources in this grouping that adhered to strict inventory limits specified in individual work authorizations. Twenty-nine sources were assessed as Category II or III, which require continuous sampling. Four of these locations have more rigorous real-time monitoring systems to estimate emissions, including the location of the former compliance Category I source (the Hillside Stack west of Building 75). 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 <sup>a</sup> (mSv/yr) <sup>b</sup>	Sampling/monitoring strategy
Noncompliant	AEDE $\geq$ 0.1	Reduce or relocate source term and reevaluate before authorization.
I	$0.1 > \text{AEDE} \geq 0.001$	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	$0.001 > \text{AEDE} \geq 0.0005$	Continuous sampling with weekly analysis.
III	$0.0005 > \text{AEDE} \geq 0.0001$	Continuous sampling with monthly analysis.
IV	$0.0001 > \text{AEDE} \geq 0.00001$	Sampled annually during project activity.
V	$0.00001 > \text{AEDE}$	No monitoring required. Inventory controlled by administrative methods (Radiation Work Authorization/Permit).

<sup>a</sup> Abbreviated as AEDE

<sup>b</sup> 1 mSv = 100 mrem

Stack exhaust samples collected during 2002 were analyzed for five radiological parameters: gross alpha, gross beta, carbon-14, iodine-125, and tritium. As in past years, tritium in the form of tritiated water vapor was the predominant radionuclide emitted from Berkeley Lab activities. For the entire Laboratory, tritium emissions measured for the year totaled  $2.90 \times 10^{11}$  becquerels (Bq) (7.85 curies [Ci]). Ninety-five percent of the tritium was emitted from the NTLF exhaust stacks. 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 CY 2002

Monitoring type	Method	Location
Continuous real-time	Real-time monitoring of $^3\text{H}$	Building 75 National Tritium Labeling Facility
	Real-time monitoring of $^{11}\text{C}$ , $^{13}\text{N}$ , and $^{15}\text{O}$	Building 88 accelerator exhaust
	Real-time monitoring of $^{11}\text{C}$ , $^{13}\text{N}$ , $^{15}\text{O}$ , and $^{18}\text{F}$	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	7 stacks
	Sampling with monthly analysis	16 stacks and 1 room
No monitoring	Inventory (administrative) control	115 rooms

**Table 4-4** Summary of Berkeley Lab Radiological Air Emissions<sup>a</sup>

Nuclide	Total (Bq/yr)	Percentage total
<sup>3</sup> H	$2.9 \times 10^{11}$	64.3%
<sup>18</sup> F	$1.5 \times 10^{11}$	33.6%
<sup>11</sup> C	$6.3 \times 10^9$	1.4%
<sup>14</sup> C	$2.6 \times 10^9$	0.6%
<sup>35</sup> S	$3.5 \times 10^8$	0.1%
<sup>125</sup> I	$3.6 \times 10^7$	< 0.1%
<sup>32</sup> P	$8.3 \times 10^6$	< 0.1%
<sup>123</sup> I	$2.4 \times 10^6$	< 0.1%
<sup>99m</sup> Tc	$1.4 \times 10^6$	< 0.1%
<sup>13</sup> N	$6.7 \times 10^5$	< 0.1%
All others	$1.3 \times 10^6$	< 0.1%
Total	$4.5 \times 10^{11}$	100.0%

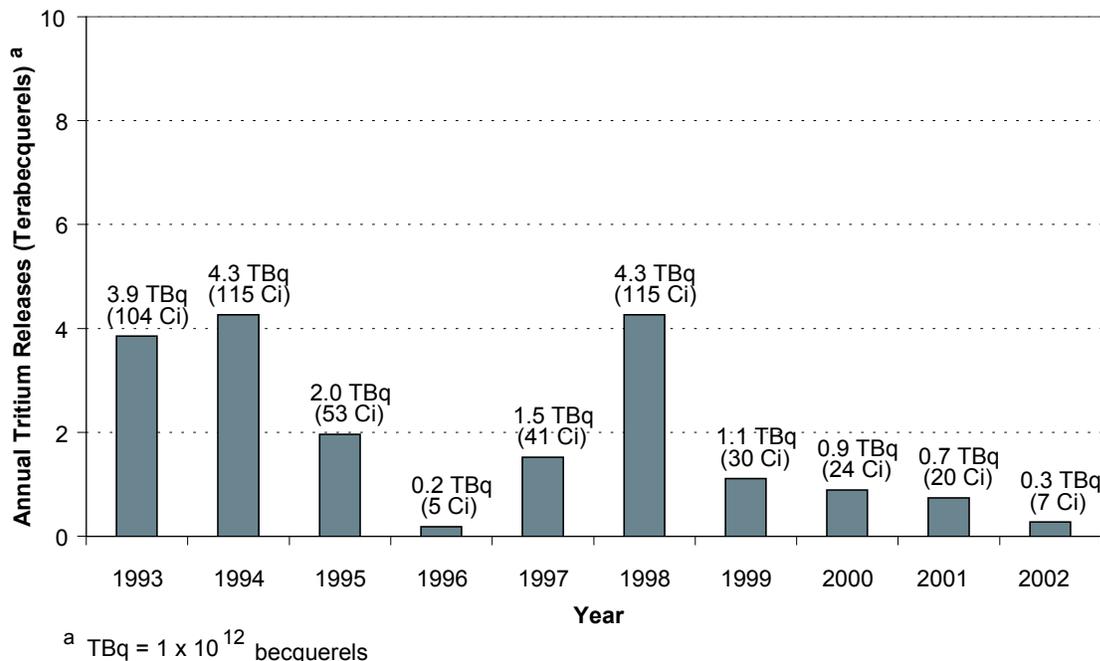
<sup>a</sup> For a complete list of radiological air emissions, see NESHAPs *Annual Radionuclide Air Emission Report* for 2002, found on Berkeley Lab's Environmental Services Group home page at <http://www.lbl.gov/ehs/esg/>.

Tritium emissions for the year 2002 continued to be well below regulatory levels of concern. The NTLF annual emission of  $2.75 \times 10^{11}$  Bq (7.42 Ci) was far below both the five- and ten-year averages for the facility. For information on trends in annual tritium releases from the NTLF, see Figure 4-1.

In addition to air emissions from exhaust systems, Berkeley Lab also collects and analyzes for tritium in rainwater that drains back down the Hillside Stack, associated with the former NTLF. In January and April 2002, during NTLF cleanup efforts, the average concentration of tritium in drain water was  $2.46 \times 10^5$  Bq/L ( $6.63 \times 10^6$  pCi/L) and the maximum was  $2.87 \times 10^5$  Bq/L ( $7.76 \times 10^6$  pCi/L). In December, after the second phase of NTLF cleanup efforts were complete, the concentration of tritium in drain water was only 13% of the earlier value:  $3.28 \times 10^4$  Bq/L ( $8.85 \times 10^5$  pCi/L) average and  $3.61 \times 10^4$  Bq/L ( $9.75 \times 10^5$  pCi/L) maximum. 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 was  $8.30 \times 10^6$  Bq ( $2.24 \times 10^{-4}$  Ci), which is 0.005% of East Bay Municipal Utility District's annual limit of  $1.9 \times 10^{11}$  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.

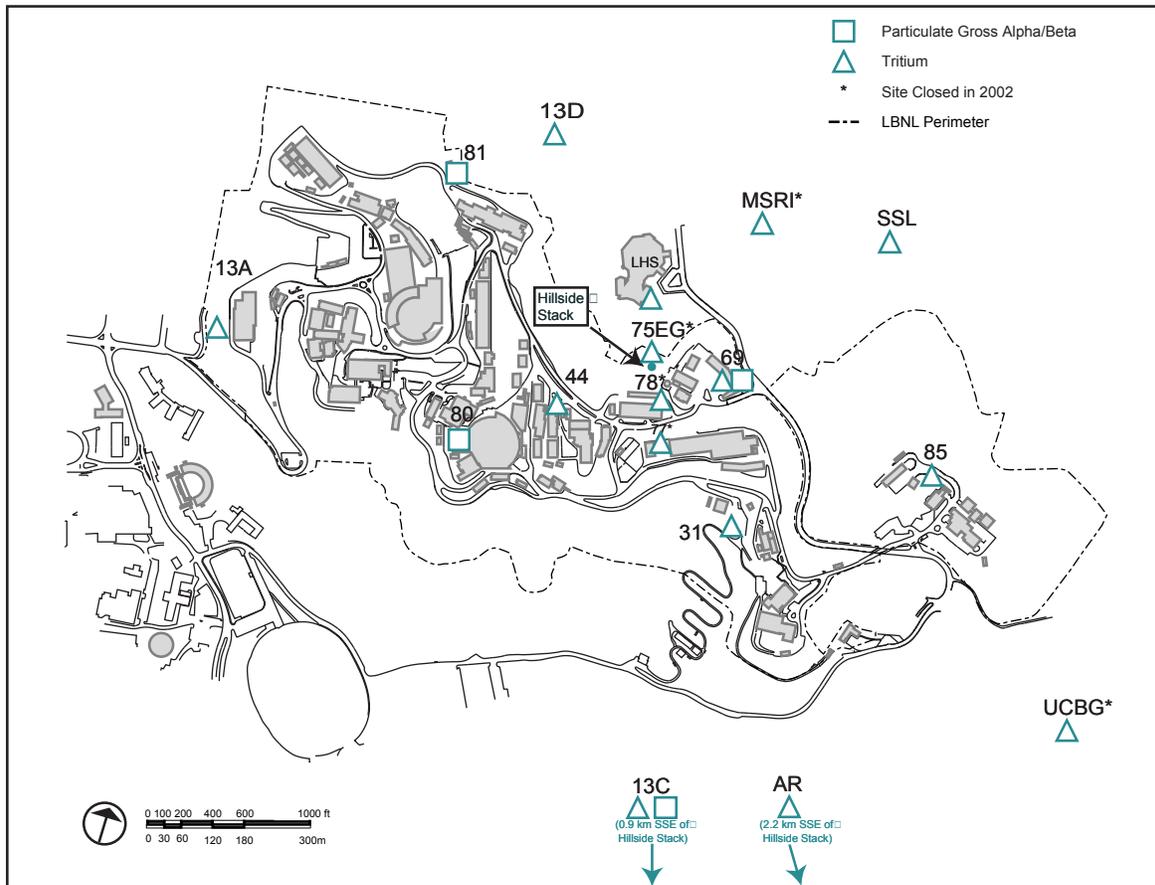


**Figure 4-1** Trends in Annual Tritium Releases from NTLF

#### 4.3.1 Tritium

Berkeley Lab began the calendar-year sampling for airborne tritium at 15 ambient-air monitoring sites as it continued with the supplemental sampling requested both by US/EPA—for that agency’s ongoing Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) evaluation—and by members of the Berkeley public. See Section 3.4.2 for background on the CERCLA evaluation. The ambient-air portion of the supplemental sampling program concluded in early May, at which time the Laboratory began scaling back the number of monitoring sites. At the end of the year, ten sites remained in the network. Several of the sites added for supplemental sampling remained operational while closure activities continued at the NTLF; and tritium waste remained stored at the Hazardous Waste Handling Facility waiting for proper off-site disposal. For a map showing the network, see Figure 4-2.

Of the 15 sampling sites that operated during 2002, 8 were on the main grounds of the facility, 6 were off-site on adjacent University of California property, and the final site was located at the East Bay Municipal Utility District’s Amato Reservoir (ENV-AR), located 2.2 kilometers (1.4 miles) south-southeast of the Berkeley Lab facility. Instrumentation at each site operates on the principle of continuously drawing outdoor air at a constant rate through sampling media (i.e., silica gel).



**Figure 4-2** Ambient-Air Monitoring Network Sampling Locations

Berkeley Lab replaces the sampling media monthly and submits the samples to a certified laboratory for analysis. As in past years, average and maximum tritium concentration values at all sites in the network were much less than 1% of the allowable DOE annual exposure standard for airborne tritium ( $3.7 \times 10^3 \text{ Bq/m}^3$  [ $1.0 \times 10^5 \text{ pCi/m}^3$ ]).<sup>3</sup> Consistent with stack emission results, which dropped by nearly two-thirds, standard statistical measures for each ambient-air site were all lower in 2002 than in the previous year. The site with the highest recorded concentration was the site closest to and downwind of the Hillside Stack, which served the former NTLF. The site, ENV-75EG, measured an average monthly concentration of  $1.07 \text{ Bq/m}^3$  ( $28.9 \text{ pCi/m}^3$ ), with the highest one-month reading of  $1.74 \text{ Bq/m}^3$  ( $47.0 \text{ pCi/m}^3$ ). Even this one-month maximum value was only 0.1% of the DOE annual standard and only about one-third of the previous year's highest value.

US/EPA-requested supplemental monitoring continued for the first four months of 2002, ending in early May. Monthly average and maximum concentrations were down, significantly in some cases, across the entire network from their 2001 supplemental monitoring counterparts. As expected, given its proximity to the Hillside Stack and prevalent wind patterns, ENV-75EG recorded both the highest

average and maximum of monthly sample results, though these summary values were roughly 50% of corresponding results for 2001. The downward trend across the network correlated with the drop in stack emissions from the NTLF after ongoing research activities ceased at the end of 2001. A complete summary of supplemental monitoring activities is found in a Berkeley Lab report from December 2002, *Summary Report for Supplemental Tritium Monitoring*.<sup>5</sup> This report is found at the Berkeley Lab Web page <http://www.lbl.gov/ehs/taskforce/>.

Results from other sites were significantly less than concentrations measured at ENV-75EG. Table 4-5 summarizes the network's airborne tritium concentrations for the year.

#### **4.3.2 Particulate Gross Alpha/Beta**

The ambient-air sampling network also includes stations with instrumentation designed to collect air particulate samples for measurement of gross alpha and gross beta levels. 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 4-6 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 extremely low, approaching or remaining 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.
- The results for each parameter change very 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.

In cooperation with the Laboratory's Low Background Facility, a facility capable of detecting radiation at extremely low levels, an evaluation of stack samples from Building 70 and 70A and ambient-air samples from all four particulate sampling stations in the network revealed naturally occurring levels of potassium-40 activity in the sampling media itself.<sup>6</sup> The level of potassium is very small, and the gross beta results include this activity. The Laboratory is investigating a method that would account for potassium-40 occurring in the sampling media.

**Table 4-5** Summary of Ambient-Air Tritium Sampling

Station ID	Number of samples	Mean (Bq/m <sup>3</sup> ) <sup>a</sup>	Mean as percentage of standard <sup>b</sup>	Median (Bq/m <sup>3</sup> )	Maximum (Bq/m <sup>3</sup> )
ENV-B13A	12	<0.11 <sup>c</sup>	—	<0.11 <sup>c</sup>	0.12
ENV-B13C	12	<0.12 <sup>c</sup>	—	<0.12 <sup>c</sup>	0.12
ENV-B13D	12	<0.10 <sup>c</sup>	—	<0.10 <sup>c</sup>	0.12
ENV-31	12	<0.17 <sup>c</sup>	—	<0.17 <sup>c</sup>	<0.17 <sup>c</sup>
ENV-44	12	0.15	0.004	<0.11 <sup>c</sup>	0.50
ENV-69	12	0.24	0.006	0.18	0.58
ENV-75EG	4	1.07	0.029	1.11	1.74
ENV-77	4	0.50	0.014	0.51	0.87
ENV-78	4	0.74	0.020	0.72	1.23
ENV-85	12	<0.09 <sup>c</sup>	—	<0.09 <sup>c</sup>	0.10
ENV-AR	12	<0.11 <sup>c</sup>	—	<0.11 <sup>c</sup>	0.57
ENV-LHS	12	0.24	0.006	0.28	0.41
ENV-MSRI	4	0.30	0.008	0.14	0.84
ENV-SSL	12	0.10	0.003	0.11	0.24
ENV-UCBG	4	0.09	0.002	<0.08 <sup>c</sup>	0.17

<sup>a</sup> 1 Bq = 27 pCi<sup>b</sup> Standard of comparison =  $3.7 \times 10^3$  Bq/m<sup>3</sup> (source: "Derived Concentration Guide" in DOE Order 5400.5)<sup>c</sup> Statistic was below the highest value for analytical sensitivity (minimum detectable amount) measured for this site.**Table 4-6** Summary of Gross Alpha and Gross Beta Ambient-Air Particulate Sampling Network Results

Analyte	Station ID	Number of samples	Mean (Bq/m <sup>3</sup> ) <sup>a</sup>	Median (Bq/m <sup>3</sup> )	Maximum (Bq/m <sup>3</sup> )
Alpha	ENV-B13C <sup>b</sup>	12	$<9.0 \times 10^{-5}$	$<9.0 \times 10^{-5}$	$1.1 \times 10^{-4}$
	ENV-69 <sup>b</sup>	12	$9.8 \times 10^{-5}$	$<9.0 \times 10^{-5}$	$2.2 \times 10^{-4}$
	ENV-80	12	$9.0 \times 10^{-5}$	$9.0 \times 10^{-5}$	$1.9 \times 10^{-4}$
	ENV-81 <sup>b</sup>	12	$<1.0 \times 10^{-4}$	$<1.0 \times 10^{-4}$	$1.8 \times 10^{-4}$
Beta	ENV-B13C	12	$5.2 \times 10^{-4}$	$4.3 \times 10^{-4}$	$1.1 \times 10^{-3}$
	ENV-69	12	$5.8 \times 10^{-4}$	$4.8 \times 10^{-4}$	$1.1 \times 10^{-3}$
	ENV-80	12	$6.2 \times 10^{-4}$	$5.7 \times 10^{-4}$	$1.1 \times 10^{-3}$
	ENV-81	12	$6.8 \times 10^{-4}$	$6.9 \times 10^{-4}$	$1.2 \times 10^{-3}$

<sup>a</sup> 1 Bq = 27 pCi<sup>b</sup> One or more summary statistic (mean, median, maximum) was below the highest value for analytical sensitivity (minimum detectable amount) for this site.



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## Surface Water and Wastewater



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## 5.1 SURFACE WATER PROGRAM

Lawrence Berkeley National Laboratory's surface water monitoring in calendar year (CY) 2002 included rainwater, creeks, lakes, and stormwater. The first three surface water types mentioned are monitored primarily for gross alpha, gross beta, and tritium, based on United States Department of Energy (DOE) orders<sup>1</sup> that prescribe monitoring for radioisotopes. Nonradiological monitoring of surface water is also performed 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<sup>2</sup> and includes monitoring for metals and other constituents. The monitoring programs for each type of surface water are described in detail in this chapter.

To place the Laboratory's surface water results in a familiar context, this chapter uses drinking-water standards as conservative reference points. In reality, drinking-water standards are not directly applicable to the surface water program (no such standards exist), because the water being monitored is not a source of public 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.<sup>3</sup> The United States Environmental Protection Agency (US/EPA) limit for tritium in drinking water is 740 Bq/L (20,000 pCi/L).<sup>4</sup>

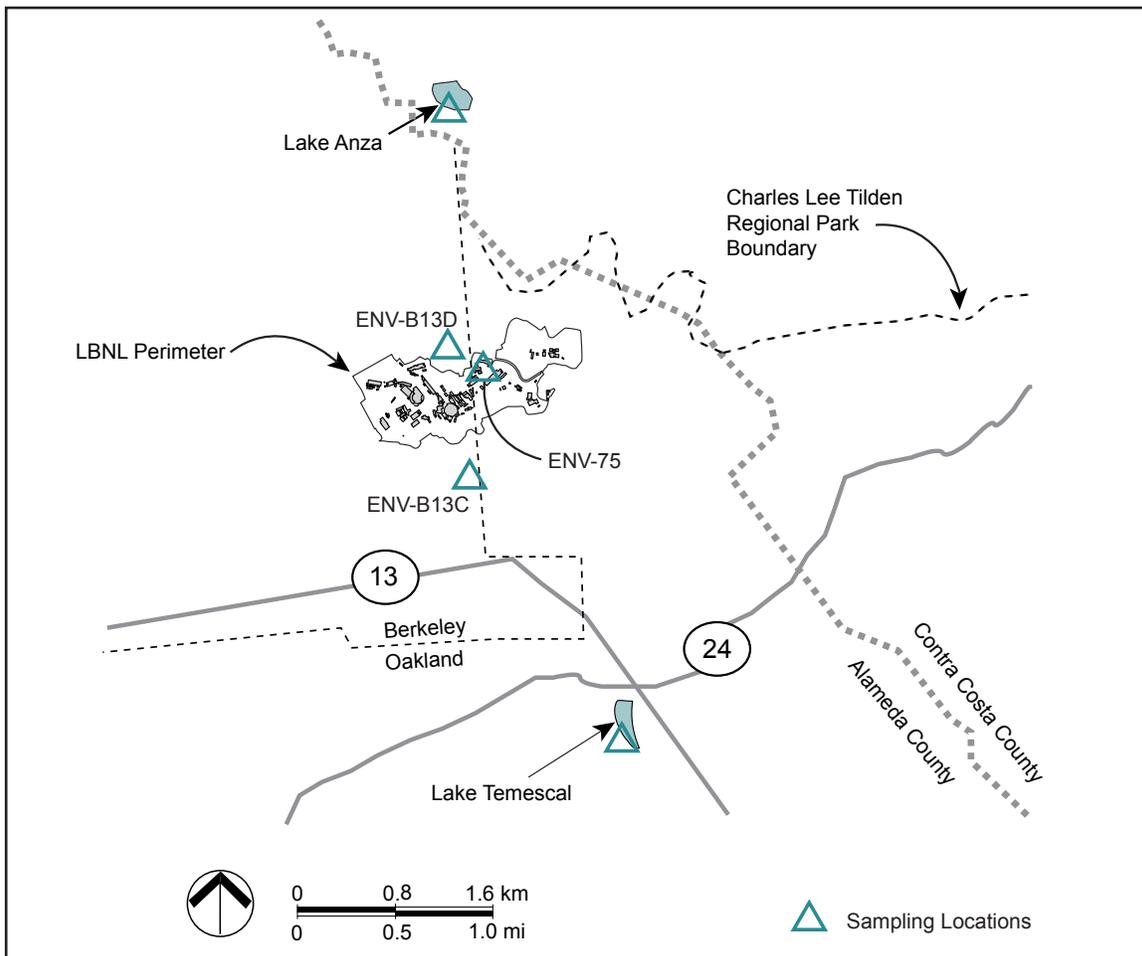
Surface water samples were analyzed by both commercial and in-house state-certified laboratories.

### 5.1.1 Rainwater

Through June, rainwater composite samples were collected monthly from three locations whenever rainfall occurred (see Figure 5-1). July, August, September, and October either were dry or had too little measurable rain, so no samples were collected for those months.

One location (ENV-75) is on-site near Building 75. Of the two off-site locations, one (ENV-B13C) is south of Berkeley Lab on Panoramic Hill, and one (ENV-B13D) is located northwest of the Lawrence Hall of Science (LHS). In August, the rainwater monitoring network was reduced to include just one station, ENV-75, as a result of the closure of the Lab's most significant source of radioactive air effluent, the National Tritium Label Facility (NTLF). Rainwater was collected at this station for the months of November and December.

Samples were analyzed for tritium and gross alpha and beta radiation. One sample at ENV-B13C showed an alpha level of 0.73 Bq/L (19.7 pCi/L). All other results for alpha and beta activity were below federal and state MCLs for drinking water, and most were below detection limits. Again, this water is not used for drinking purposes.

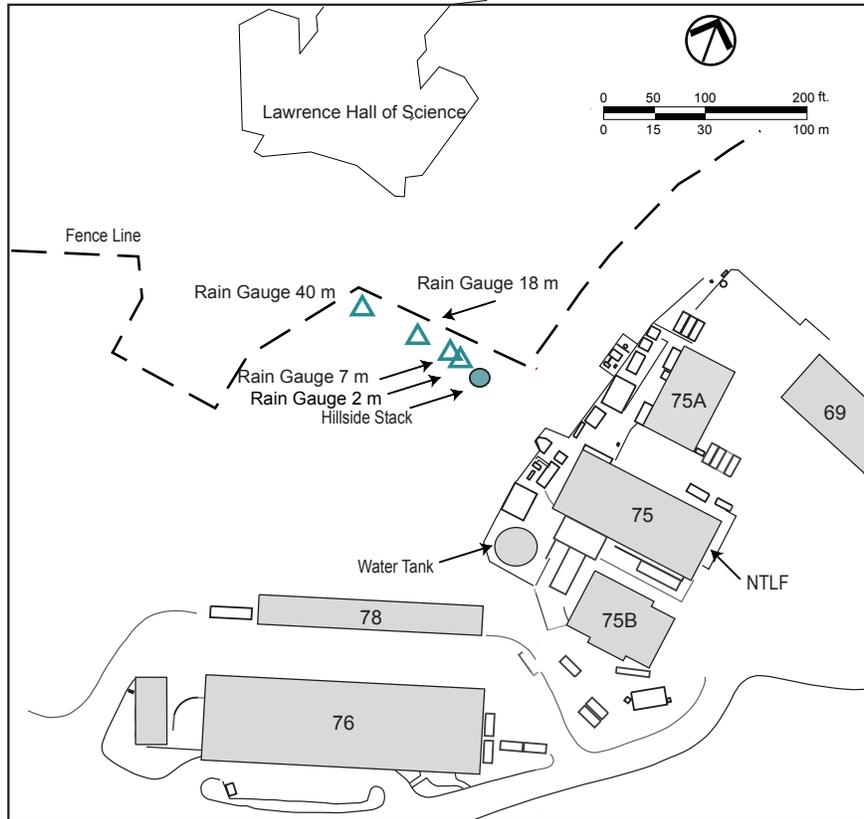


**Figure 5-1** Rainwater and Lake Sampling Locations

On-site, eight rainwater samples were collected at ENV-75, and tritium was detected in only four of the samples. The maximum tritium concentration was 16 Bq/L (440 pCi/L).

As in 2001, additional rainfall monitoring was conducted to address a community request to perform rainwater monitoring for tritium near the Building 75 hillside exhaust stack (Hillside Stack) in the eucalyptus grove between the NTLF and LHS. Accordingly, Berkeley Lab collected rainwater from five storms and during each storm sampled rain at 2 meters (m) (6.6 feet [ft]), 7 m (23 ft), 18 m (59 ft), and 40 m (130 ft) from the stack (see Figure 5-2).

Rainwater from the four monitoring gauges near the Hillside Stack was collected after major storms that provided enough water to analyze. Sampling intervals varied, but all were between one and two weeks. As expected, at this proximity to the stack, tritium was always detected. In general, tritium levels were highest for rain collected at the gauge seven meters from the stack, and then decreased with increasing distance from the stack; however, the maximum concentration was seen at the 18-meter site on February 15 (974 Bq/L [26,300 pCi/L]).

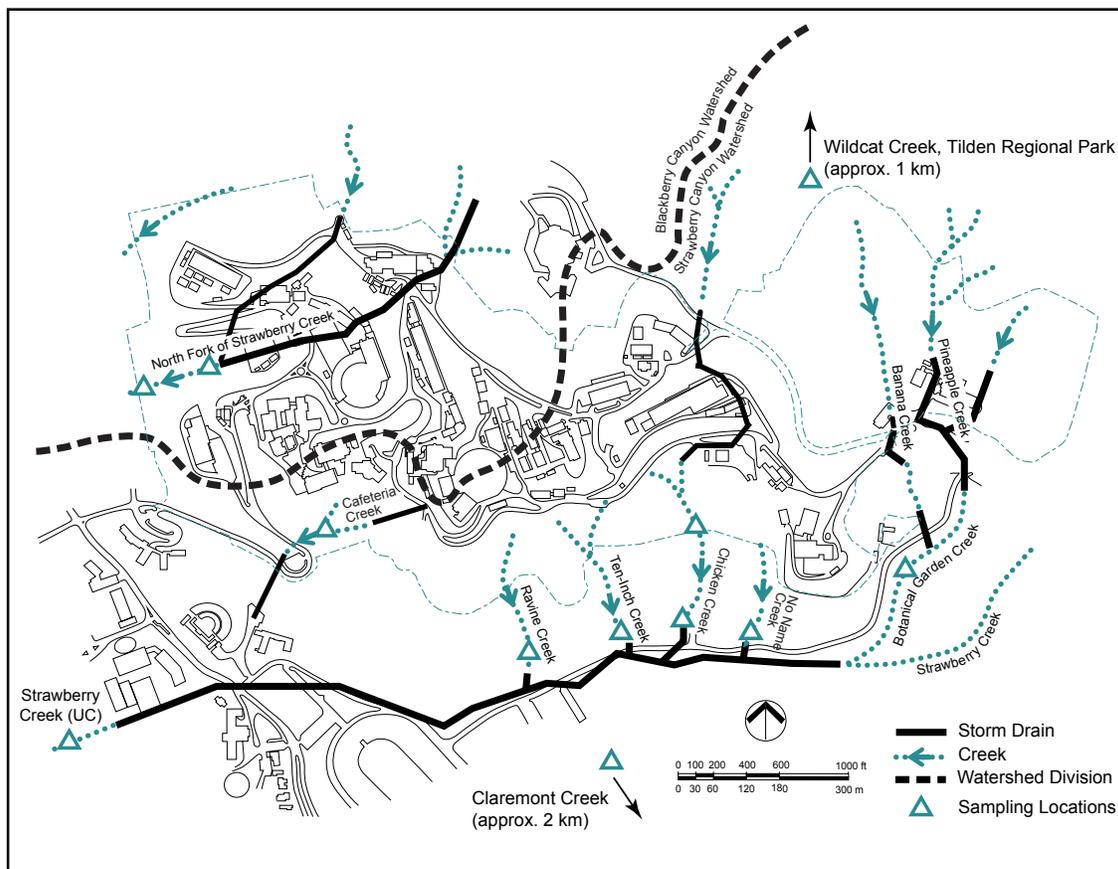


**Figure 5-2** Supplemental Rain Sampling Locations

Otherwise, maximal concentrations varied among storms and among sampling sites. The maximum levels cited above are well below the highest concentrations measured at the same locations in CY 2001 (35,500 Bq/L [960,000 pCi/L]). Due to the closure of the NTLF and the sharp decrease in ambient tritium levels, these special rainwater samplings have been discontinued.

### 5.1.2 Creeks

Given Berkeley Lab's location in the hills of the Strawberry Creek watershed, many streams and creeks at and near the site flow at varying intensities throughout the year. When creek flow occurs, a grab sample is collected and analyzed quarterly for alpha and beta activity and tritium. Creeks routinely sampled during CY 2002 were Chicken Creek, Claremont Creek, the North Fork of Strawberry Creek, Strawberry Creek (UC), and Wildcat Creek. In August, monitoring at the two off-site creeks (Claremont and Wildcat) was eliminated due to the closure of the NTLF. For creek sampling locations, see Figure 5-3. Neither alpha nor beta activity was detected at any sampling site.



**Figure 5-3** Creek Sampling Locations

A second set of creeks was also sampled once and analyzed for metals, volatile organic compounds, and tritium. These creeks (also shown in Figure 5-3) include Banana Creek, Pineapple Creek, Botanical Garden Creek, Cafeteria Creek, No Name Creek, Ravine Creek, and Ten-Inch Creek. No volatile organic compounds were detected at any location. Some metals were present, including arsenic, barium, copper, lead, vanadium, and zinc—most in low amounts within background levels. Except for zinc at Cafeteria Creek, no other San Francisco Bay Region Basin Plan (Basin Plan)<sup>5</sup> levels were exceeded. Note that these limits are not intended to be applied to creek water, but are given here for comparison purposes. See Section 5.1.4 for more information on these limits.

Additionally, sampling for tritium was carried out in accordance with the approved Tritium Sampling Plan for Surface Water, which was designed and approved to meet the request of the US/EPA for additional information on levels of tritium in certain media. Samples in this effort were taken at various points on Chicken Creek, the North Fork of Strawberry Creek, and Strawberry Creek (UC). An extra sampling also was collected at the request of a community member. The results for these special samplings are included in the analysis below, along with results from routine environmental sampling. A brief description of the program can be found in Section 3.4.2. Complete results for the Supplemental Monitoring Program are also available in the *Summary Report for Supplemental Tritium Monitoring*,<sup>6</sup> included on the CD on which this *Site*

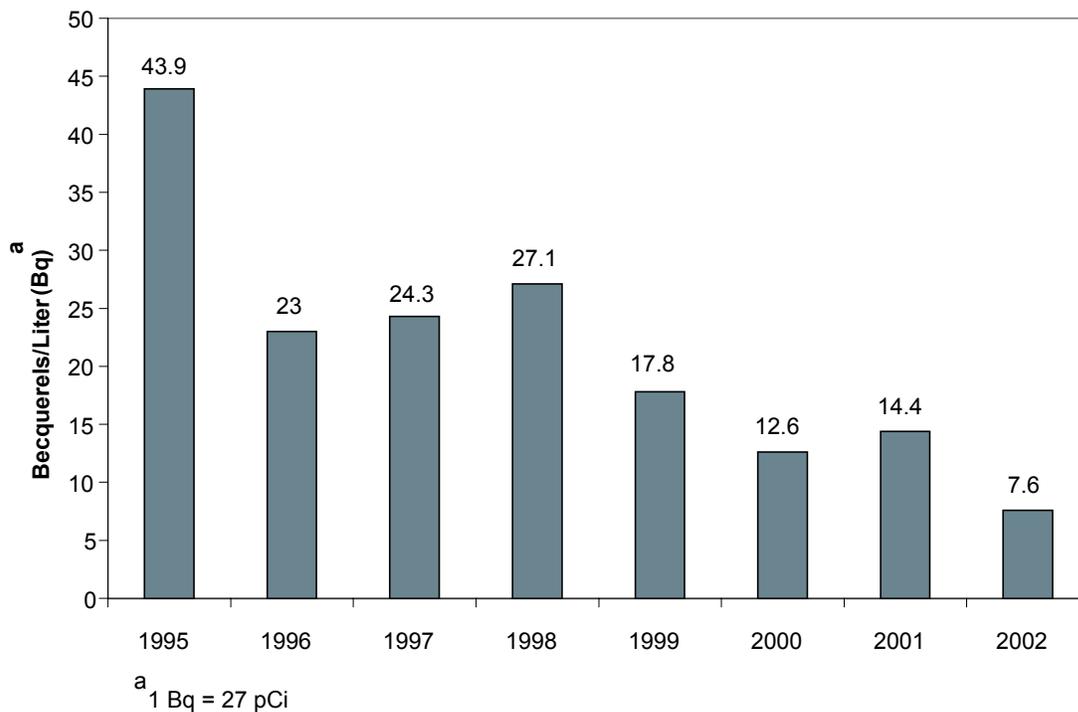
*Environmental Report* is found, and on the Web at <http://www.lbl.gov/ehs/taskforce/>, under Documents.

Tritium was generally not detected, except in Chicken Creek, and a few times at low levels in the North Fork of Strawberry Creek. The maximum level measured in CY 2002, which was in Chicken Creek, was 20 Bq/L (540 pCi/L), nearly two orders of magnitude below the drinking-water limit (although this water is not used as a public drinking-water source).

Chicken Creek is the only creek in which tritium has been found with any regularity. Figure 5-4 presents a comparison of the annual mean for tritium in Chicken Creek over the past eight years. From a high of 43.9 Bq/L (1,190 pCi/L) in 1995, average tritium levels decreased by nearly 50% in 1996 to 23 Bq/L (620 pCi/L) and remained near that level for 1997 and 1998. During the three years from 1999 to 2001, average tritium levels in Chicken Creek remained below the 1997/1998 levels, and in 2002 they dropped again by nearly 50% from 2001 levels.

### 5.1.3 Lakes

The annual lake sampling was performed once again at Lake Anza in Tilden Regional Park and at Lake Temescal in Oakland's Temescal Regional Park (see Figure 5-1). Samples from both lakes contained no gross alpha or beta activity or tritium above minimum detectable amounts. Since five years of sampling at these sites has produced no quantifiable levels of tritium and the NTLF closed in 2002, this program was eliminated and will not be continued in 2003.



**Figure 5-4** Annual Averages for Tritium in Chicken Creek (1995–2002)

### 5.1.4 Stormwater

Berkeley Lab lies within the Blackberry Canyon and Strawberry Canyon watersheds, which are part of the main Strawberry Creek watershed. There are two main creeks in these watersheds, 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 Strawberry Creek or its north fork, 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 must follow the General Permit for Stormwater Discharges Associated with Industrial Activities.<sup>2</sup> Permit holders must develop and maintain a *Storm Water Monitoring Plan* (SWMP)<sup>7</sup> and a *Storm Water Pollution Prevention Plan* (SWPPP).<sup>8</sup> 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 5-5.

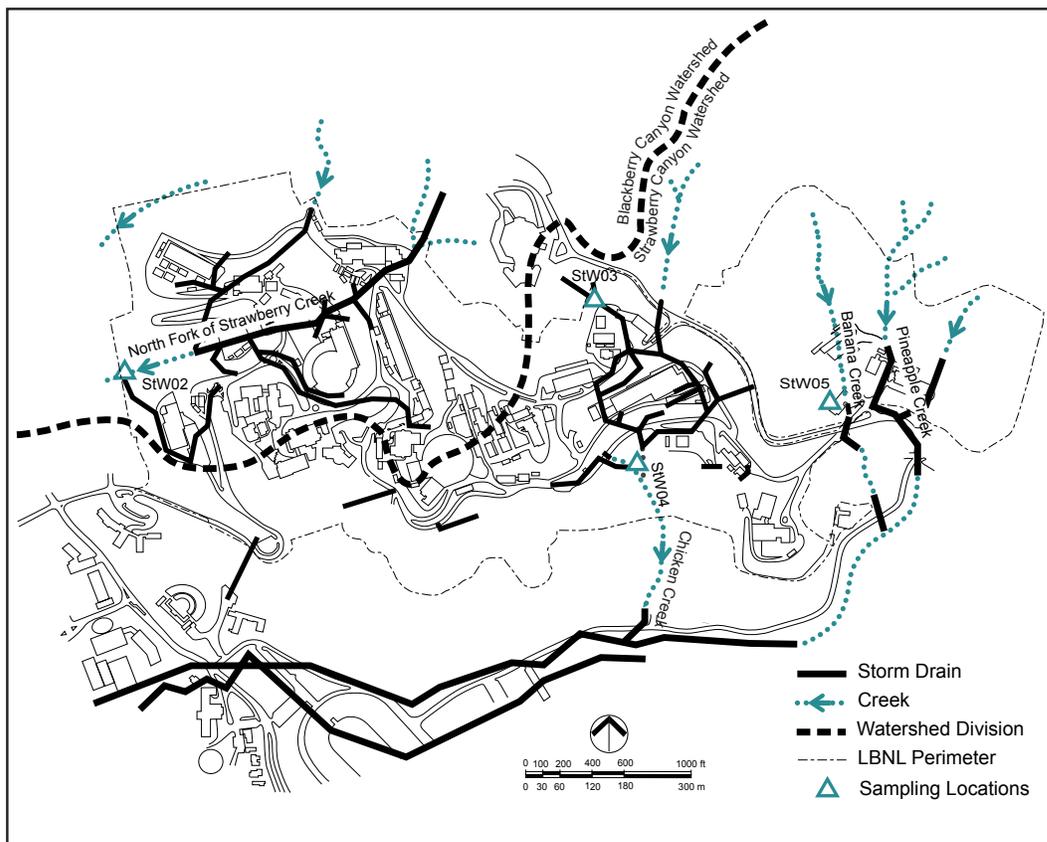


Figure 5-5 Stormwater Sampling Locations

Berkeley Lab's SWMP explains the rationale for sampling, sampling locations, and the kinds of radiological and nonradiological analyses to be performed. The SWMP was revised and updated for the stormwater year of 2001–2002 (i.e., for the latter half of 2001). Certain changes to the monitoring program resulted from an in-depth look at the results over the past several years, as provided for in the permit.

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.

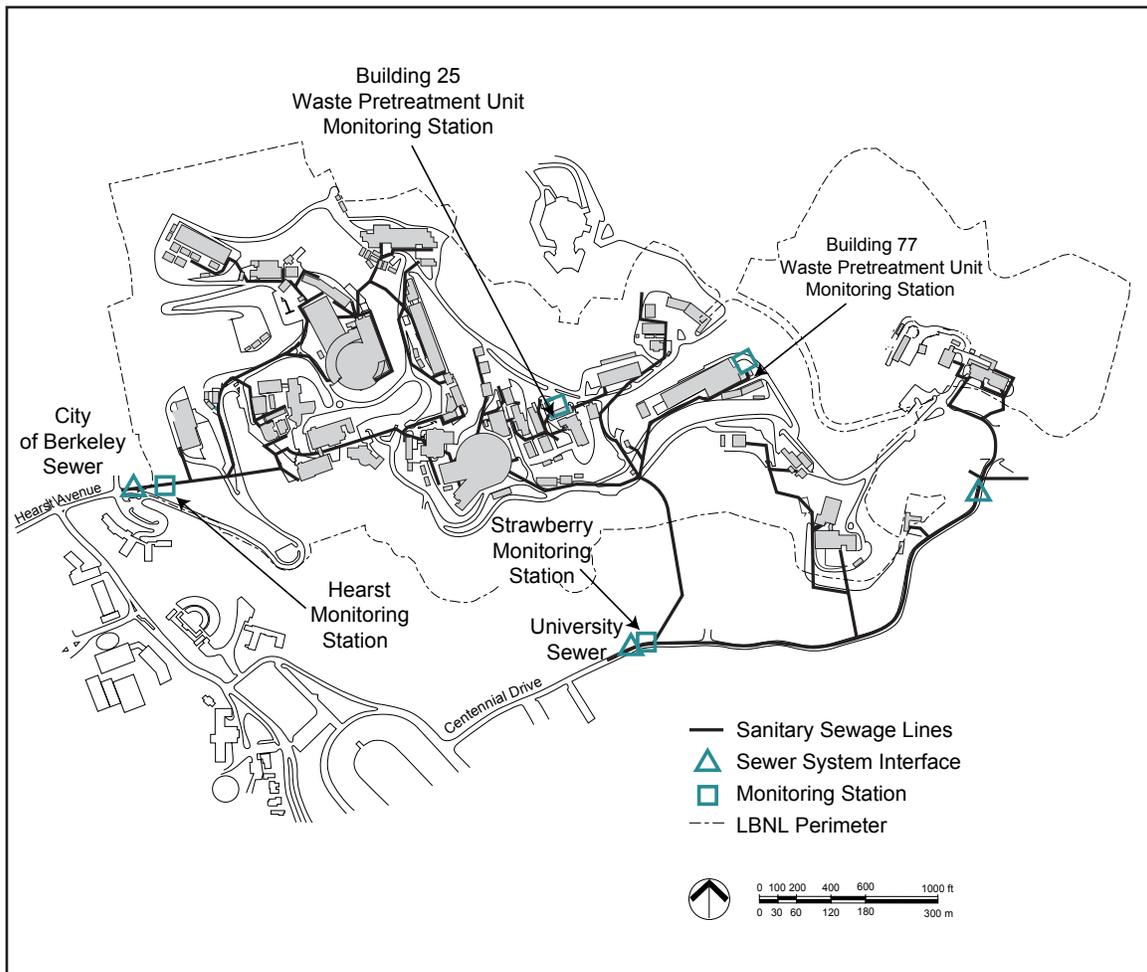
In CY 2002, the measured pH was always near neutral, and total petroleum hydrocarbons (diesel) were often seen in small quantities at most sampling points. Oil and grease were detected only once, in Chicken Creek, slightly above the detection limit. Specific conductance, usually a measure of the mineralization of water, generally was low and below the MCL for domestic drinking water. The measure for TSS also was usually very low, indicating clear water. 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, with only one sample at Chicken Creek somewhat elevated. Nutrients such as ammonia nitrogen and nitrate plus nitrite also were seen at all stations at low levels.

For the four metals for which the Lab now analyzes, most levels were generally below detection limits. Maximums were 3.2 milligrams per liter (mg/L) at Chicken Creek for aluminum, 4.8 mg/L at Chicken Creek for iron, and 51 mg/L in East Canyon for magnesium. Zinc was only seen once above detection level, in Chicken Creek. The General Permit does not contain specific discharge limits for metals. For comparison purposes, Table 4-3 of the Basin Plan<sup>5</sup> 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.

Routine stormwater samples are also analyzed for alpha and beta emitters and tritium. No alpha emitters were detected. Beta emitters were detected at low concentrations (similar to background levels of naturally occurring radioisotopes commonly found in stormwater) once at the Building 69 Storm Drain Manhole (StW03) and twice at Chicken Creek (StW04). The maximum tritium concentration in stormwater (20 Bq/L [540 pCi/L]) was measured in a Chicken Creek sample.

## 5.2 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 5-6).



**Figure 5-6** Sanitary Sewer System

- Hearst Station, located at the head of Hearst Avenue below 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 LHS, Space Sciences Laboratory, Mathematical Sciences Research Institute, Animal Research Facility, and Botanical Garden.

Self-monitoring of wastewater discharge 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.<sup>9</sup> EBMUD is the local Publicly Owned Treatment Works that regulates all industrial and sanitary discharges to its treatment facilities.

Berkeley Lab currently has 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 renews the site's wastewater discharge permits annually in September, except for the treated groundwater permit, which is granted for two years. In 2002 EBMUD extended the 2001–2002 permits (sitewide, Building 25, and Building 77) rather than issuing new ones.

As in previous years, the Laboratory's 2001–2002 sitewide permit required monitoring of wastewater discharges four times per year 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 results were below discharge limits.

### **5.2.1 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 guidance<sup>10</sup> and orders,<sup>1</sup> but it also ensures compliance with radiological limits given in the California Code of Regulations<sup>11</sup> cited by the EBMUD wastewater discharge permit. California regulations now incorporate by reference the applicable federal regulations<sup>12</sup> and associated discharge limits.

Analysis is performed by a state-certified commercial 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.

#### **5.2.1.1 Nonradiological Monitoring**

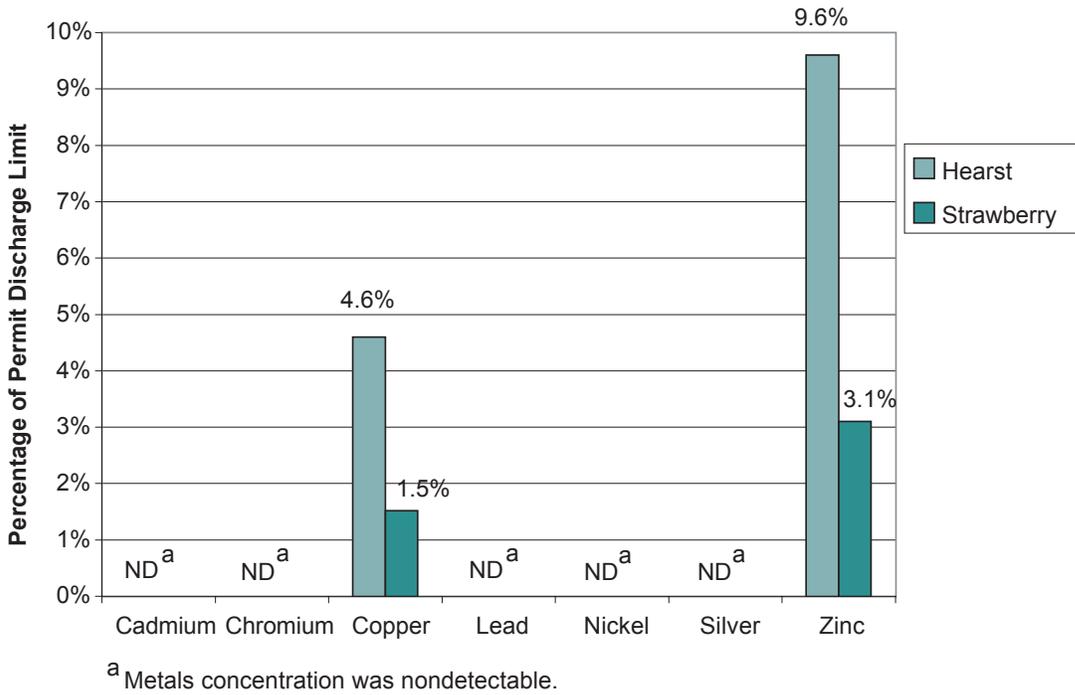
Four self-monitoring samples were taken from the Hearst and Strawberry outfalls during CY 2002. All results were well within discharge limits, as were all measurements made by EBMUD in its four independent samplings. Although analysis for metals was required for only one of the four samples, analysis was done twice, at the January and November samplings. With the exception of copper and zinc, small amounts of which were always seen in both outfalls, most metals were below detection limits in both the Hearst and Strawberry outfalls. Figure 5-7 shows the metal results as a percentage of permit discharge limits.

No chlorinated hydrocarbons were detected, except for chloroform, which is present in EBMUD supply water; occasionally very small amounts of bromodichloromethane were detected 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 year in its annual permit application, and these then become the permit limits.

#### **5.2.1.2 Radiological Monitoring**

The Hearst and Strawberry sewer outfalls are continuously sampled at half-hour intervals using automatic equipment. The composite samples were collected biweekly and submitted to a state-certified laboratory for analysis of gross alpha, gross beta, iodine-125, and tritium. During 2002, this program was modified and expanded to include analyses for phosphorus-32, sulfur-35, and carbon-14. Since September 2002, samples have been collected every four weeks. Split samples are analyzed periodically for additional quality control purposes.

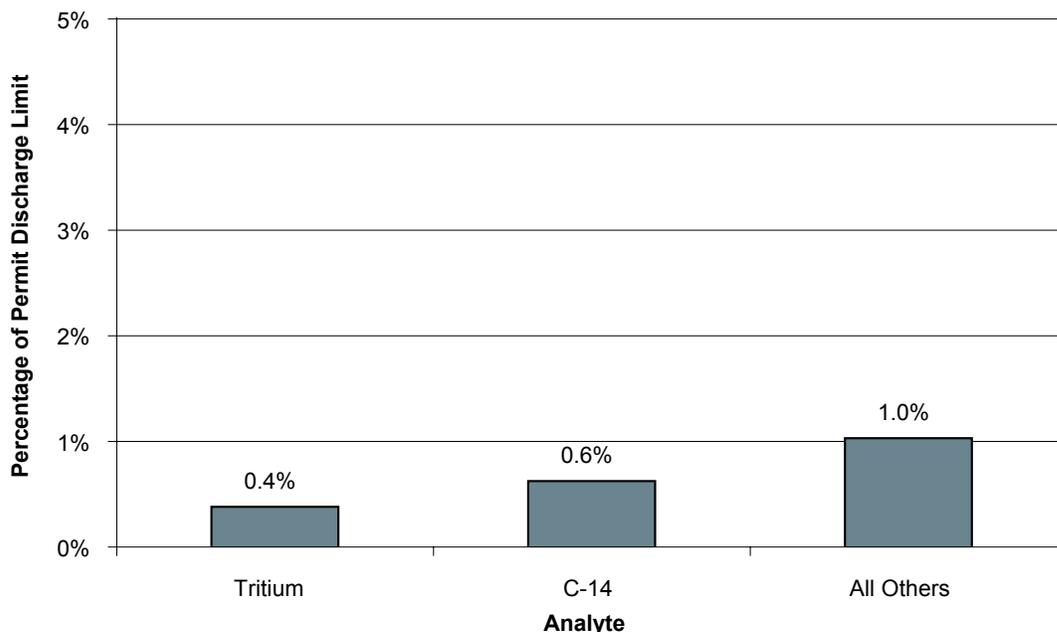
A special study was begun this year to determine whether there currently are low levels of plutonium in sewer effluent. Historical research activities may have accidentally deposited very small amounts of plutonium into the sewer system at Berkeley Lab. For this study, 12 samples were collected from the Hearst sewer outfall and analyzed for plutonium-238 and plutonium-239+240. The samples were analyzed using a sensitive technique performed by LLNL. The results from these analyses are near or below detection limits. This study will be continued in 2003 to further investigate whether Berkeley Lab's sewer effluent contains detectable levels of plutonium.



**Figure 5-7** Concentration of Metals in Sewer Water Samples as a Percentage of Permit Discharge Limit

The federal<sup>12</sup> and state<sup>11</sup> regulatory limits for radioisotopes are based on total amounts released per year. For tritium, this limit is  $1.9 \times 10^{11}$  Bq (5 Ci) per year, and for carbon-14 it is  $3.7 \times 10^{10}$  Bq (1 Ci) per year. The limit for all other radioisotopes is a combined  $3.7 \times 10^{10}$  Bq (1 Ci) per year. Radioisotopes discharged into Berkeley Lab’s sewer wastewater, expressed as a percentage of their permit limit, are summarized in Figure 5-8.

Alpha emitters, which can potentially come from transuranic and heavy-element research, were not detected at Hearst Monitoring Station and were only once measured slightly above detection limits at Strawberry Monitoring Station. Beta emitters, including iodine-125 from biomedical research, were usually detected in both sewers at low levels, with levels at Strawberry generally somewhat lower than those at Hearst. The maximum concentration of beta emitters (excluding iodine-125) for the year was 0.496 Bq/L (13.4 pCi/L) at Hearst Monitoring Station. For the individual isotopes, the highest iodine-125 concentration was 5.7 Bq/L (154 pCi/L), at Hearst Monitoring Station; sulfur-35 was seen once at a low level in both Hearst and Strawberry Monitoring Stations; and phosphorus-32 and carbon-14 were not detected in either sewer.



Note: Release calculations were normalized to 365 days. "All Others" consists of gross alpha and beta, I-125, P-32, and S-35.

**Figure 5-8** Radioisotopes Discharged to Sewers in 2002 as a Percentage of Permit Discharge Limit

With two exceptions, tritium levels were below the minimum detectable amount at Hearst Monitoring Station. At Strawberry Monitoring Station, tritium levels were above detection limits about half the time, with a maximum of 16 Bq/L (420 pCi/L). The total annual discharge of tritium in wastewater was  $7.03 \times 10^8$  Bq (0.019 Ci); for carbon-14 it was  $2.3 \times 10^8$  Bq ( $6.25 \times 10^{-3}$  Ci); and the total for other radioisotopes was  $3.7 \times 10^8$  Bq (0.010 Ci). The amount of tritium decreased from last year's level by more than 50%, while the total for other radioisotopes remained the same. All values, however, were well below allowable limits. For example, tritium was only 0.4% of the allowable federal and state limit, carbon-14 was 0.63% of its limit, and all other isotopes together were approximately 1% of their limit.

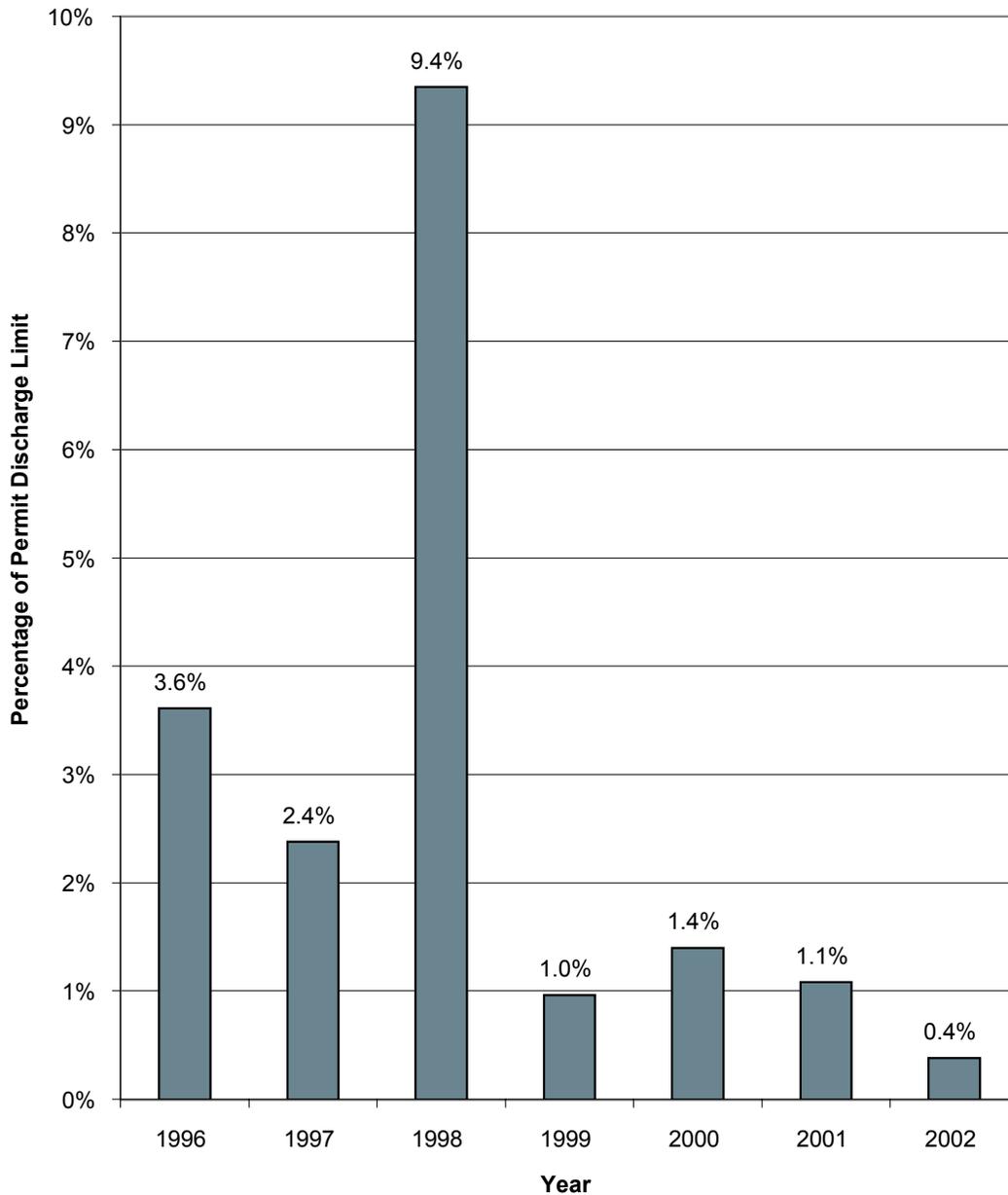
Figure 5-9 trends the total amount of tritium released to Berkeley Lab's sewers over the past seven years. Results were consistently under 10% of the permitted level, and in the past three years have trended downward to under 1%.

### 5.2.2 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

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—two self-monitorings and two efforts by EBMUD—yielded daily maximum and monthly average results well within EBMUD discharge limits.<sup>9</sup>



**Figure 5-9** Annual Releases of Tritium to Sewers (1996–2002) as a Percentage of Permit Discharge Limit

### **5.2.3 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 (three) and EBMUD (two) inspection samples were well within permitted limits.

### **5.2.4 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 double-filtered 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 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 volatile organic compounds. Most results were below detection limits.

Occasional low levels of some chlorinated hydrocarbons have been measured (parts per billion), which 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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# Groundwater



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## 6.1 BACKGROUND

This chapter reviews the groundwater monitoring program at Lawrence Berkeley National Laboratory, emphasizing the calendar year (CY) 2002 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,<sup>1</sup> 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 the United States Department of Energy (DOE). 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 quarterly to review results of the previous quarter's 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 a groundwater piezometric map indicating the hydraulic head distribution 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, groundwater flow directions show local deviations from the general trends presented on the piezometric map because of the subsurface geometry of geologic units. The velocity of the groundwater varies from approximately 0.001 meter per year (0.003 foot per year) to about 300 meters per year (990 feet per year).

### 6.2.3 Groundwater Quality

Groundwater samples from monitoring wells are tested for total dissolved solids (TDS), cations, and anions. During CY 2002, the TDS concentrations measured in groundwater monitoring wells ranged from 550 to 1,950 milligrams per liter.

## 6.3 GROUNDWATER MONITORING RESULTS

In CY 2002, one new monitoring well was installed and fourteen monitoring wells that were no longer needed were properly destroyed. This brings the total number of monitoring wells in the program to 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 2002. 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,<sup>2</sup> the number of monitoring wells in which the analyte was detected, and the ranges in concentrations detected (in microgram per liter [ $\mu\text{g/L}$ ]). Table 6-3 presents tritium results (in Becquerels per liter [ $\text{Bq/L}$ ]).

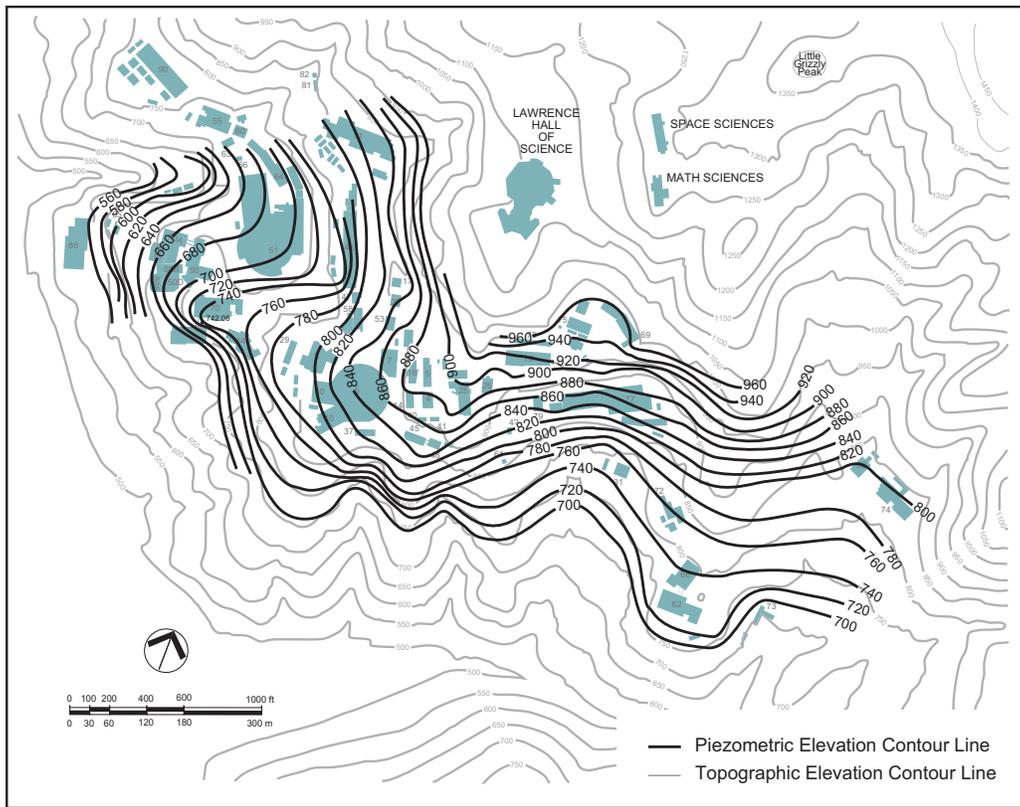


Figure 6-1 Groundwater Piezometric Map

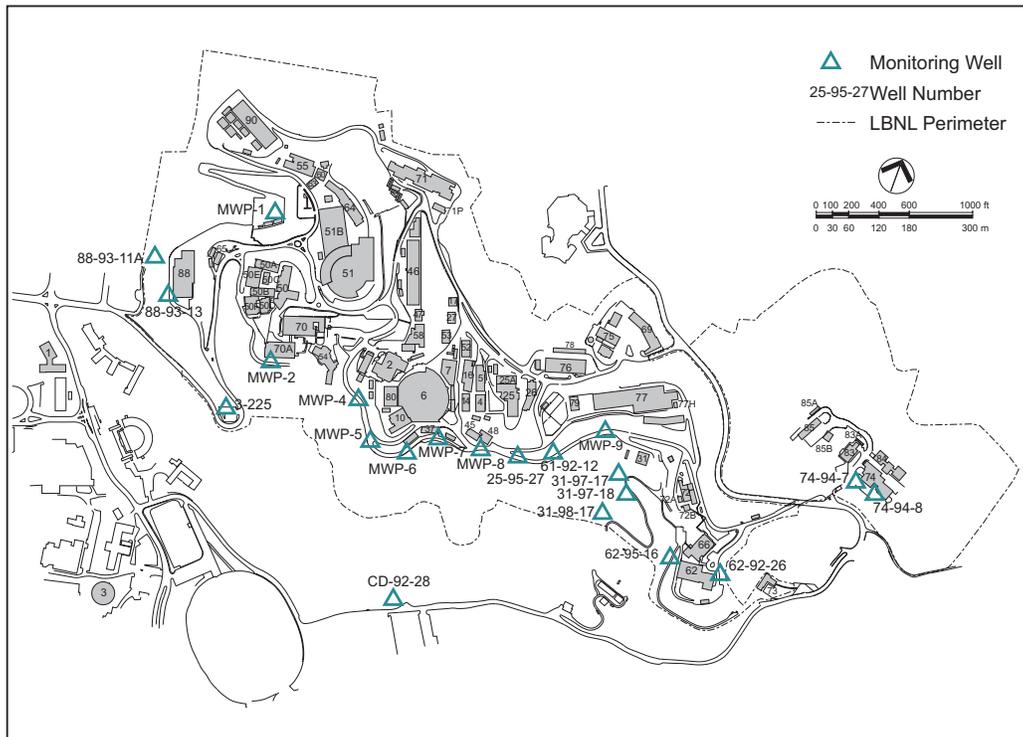


Figure 6-2 Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

**Table 6-1** Metals Detected<sup>a</sup> in Groundwater Samples from Monitoring Wells

Metal	Number of wells sampled	Number of samples	Number of wells in which analyte was detected	Range of concentrations (µg/L) <sup>b</sup>	Drinking-water standard (µg/L)
Antimony	55	68	2	2 – 4	6
Arsenic	69	82	46	2 – 68	10
Barium	55	68	51	10 – 1300	1000
Beryllium	55	68	0	—	4
Cadmium	54	67	2	0.2 – 0.4	5
Chromium	56	69	2	9.8 – 20	50
Cobalt	54	67	0	—	NS <sup>c</sup>
Copper	54	67	1	20	1000 <sup>d</sup>
Lead	55	68	0	—	15 <sup>e</sup>
Mercury	57	70	3	0.21 – 0.62	2
Molybdenum	63	76	17	64 – 840	NS <sup>c</sup>
Nickel	55	68	3	10	100
Selenium	59	72	7	3 – 72	50
Silver	54	67	2	10 – 20	100 <sup>d</sup>
Thallium	55	68	0	—	2
Vanadium	55	68	15	10 – 74	NS <sup>c</sup>
Zinc	54	67	19	10 – 72	5000 <sup>d</sup>

<sup>a</sup> Metals not detected in any samples are beryllium, cobalt, lead, and thallium

<sup>b</sup> Micrograms per liter

<sup>c</sup> NS = Not specified

<sup>d</sup> Secondary MCL

<sup>e</sup> Action Level

#### 6.4 GROUNDWATER CONTAMINATION PLUMES

Based on groundwater monitoring results, ten 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 37, 51/64, 51L, 71, and 76
- *Freon plume*: Building 71
- *Tritium plume*: Building 75/77
- *Petroleum hydrocarbon plumes*: Buildings 7 and 74

Groundwater contaminated with VOCs was also detected in three other areas of the site (Buildings 69, 75, and 77) in CY 2002. Based on current information, however, the extent of contamination in those areas is limited.

**Table 6-2** VOCs Detected in Groundwater Samples from Monitoring Wells<sup>a</sup>

Analytes detected	Number of wells in which analyte was detected	Range of concentrations (µg/L)	Drinking-water standard (µg/L)
<b>Aromatic or nonhalogenated hydrocarbons</b>			
Benzene	9	1 – 36.2	1
n-Butylbenzene	1	5.4	NS <sup>b</sup>
sec-Butylbenzene	2	4.4 – 9.4	NS <sup>b</sup>
p-Isopropyltoluene	1	11.5	NS <sup>b</sup>
Methyl tert-Butyl Ether	1	1.8	13
Naphthalene	1	38.6	NS <sup>b</sup>
n-Propylbenzene	1	2.7	NS <sup>b</sup>
1,2,3-Trichlorobenzene	2	5.7 – 52	NS <sup>b</sup>
1,2,4-Trichlorobenzene	1	1.1	70
1,2,4-Trimethylbenzene	4	1.1 – 9.4	NS <sup>b</sup>
1,3,5-Trimethylbenzene	5	1.1 – 8.7	NS <sup>b</sup>
<b>Halogenated hydrocarbons</b>			
Carbon Tetrachloride	21	1.2 – 1,790	0.5
Chloroform	24	3 – 99	100 <sup>c</sup>
1,2-Dibromo-3-chloropropane	1	6.3	NS <sup>b</sup>
1,1-Dichloroethane	29	0.55 – 608.9	5
1,1-Dichloroethene	36	1 – 230	6
cis-1,2-Dichloroethene	56	1 – 2,700	6
trans-1,2-Dichloroethene	10	1 – 27.6	10
Methylene Chloride	2	190	5
1,1,1,2-Tetrachloroethane	2	5.3 – 29	NS <sup>b</sup>
1,1,2,2-Tetrachloroethane	1	46.1	1
Tetrachloroethene	52	1 – 53,393	5
1,1,1-Trichloroethane	4	1.6 – 37.1	200
1,1,2-Trichloroethane	2	4.1 – 27.3	5
Trichloroethene	74	1.1 – 41,750	5
Freon 113-1,1,2-Trichlorotrifluoroethane	2	5.7 – 9.4	1,200
Vinyl Chloride	13	1.1 – 34.8	0.5

<sup>a</sup> 499 samples taken from 200 wells during the year

<sup>b</sup> NS = Not specified

<sup>c</sup> Standard is for total trihalomethanes.

**Table 6-3** Tritium Detected<sup>a</sup> in Groundwater Samples from Monitoring Wells

Well number	January–March (Bq/L) <sup>b</sup>	April–June (Bq/L)	July–September (Bq/L)	October–December (Bq/L)
6-92-17	NS <sup>c</sup>	8	NS	NS
31-97-17	62	NS	45	NS
69-97-21	35	NS	<11	NS
71-95-9	<11	<11	14	NS
71B-98-13	20	<11	<11	<11
71B-99-3R	20	18	<11	<11
75-92-23	71	NS	57	NS
75-97-5	941, 910 <sup>d</sup>	797, 840 <sup>d</sup>	951, 907 <sup>d</sup>	933, 862 <sup>d</sup>
75-97-7	44	NS	23	NS
75-98-14	145	138, 127 <sup>d</sup>	162	193
75-99-6	31	22, 49	57	34
75-99-7	259	230	267	257, 239 <sup>d</sup>
75B-92-24	80	NS	82	NS
76-93-6	24	NS	86	NS
76-93-7	33	<11	<11	NS
76-98-21	19	<11	<11	<11
77-94-6	339, 337 <sup>d</sup>	NS	223, 340 <sup>d</sup>	NS
77-97-9	455, 466 <sup>d</sup>	NS	311, 407 <sup>d</sup>	NS
77-97-11	49	NS	108	NS
78-97-20	96	NS	73	NS
MW76-1	21	NS	<11	NS
MW91-2	23	NS	<11	NS
MW91-4	27	NS	<11	NS
MW91-5	81	NS	66	NS
MW91-6	125	NS	67	NS

<sup>a</sup> 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])

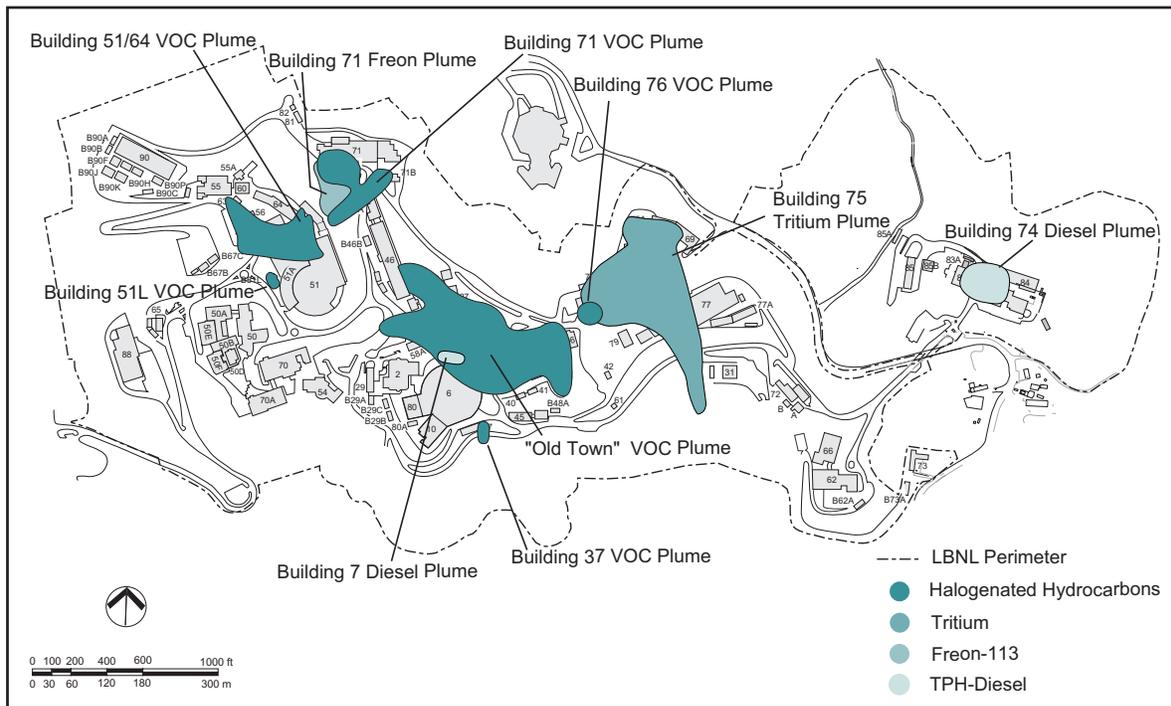
<sup>b</sup> Becquerels per liter

<sup>c</sup> NS = Not sampled

<sup>d</sup> Duplicate sample

#### 6.4.1 VOC 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), 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; carbon tetrachloride; and vinyl chloride; several of which are products of PCE and TCE degradation.



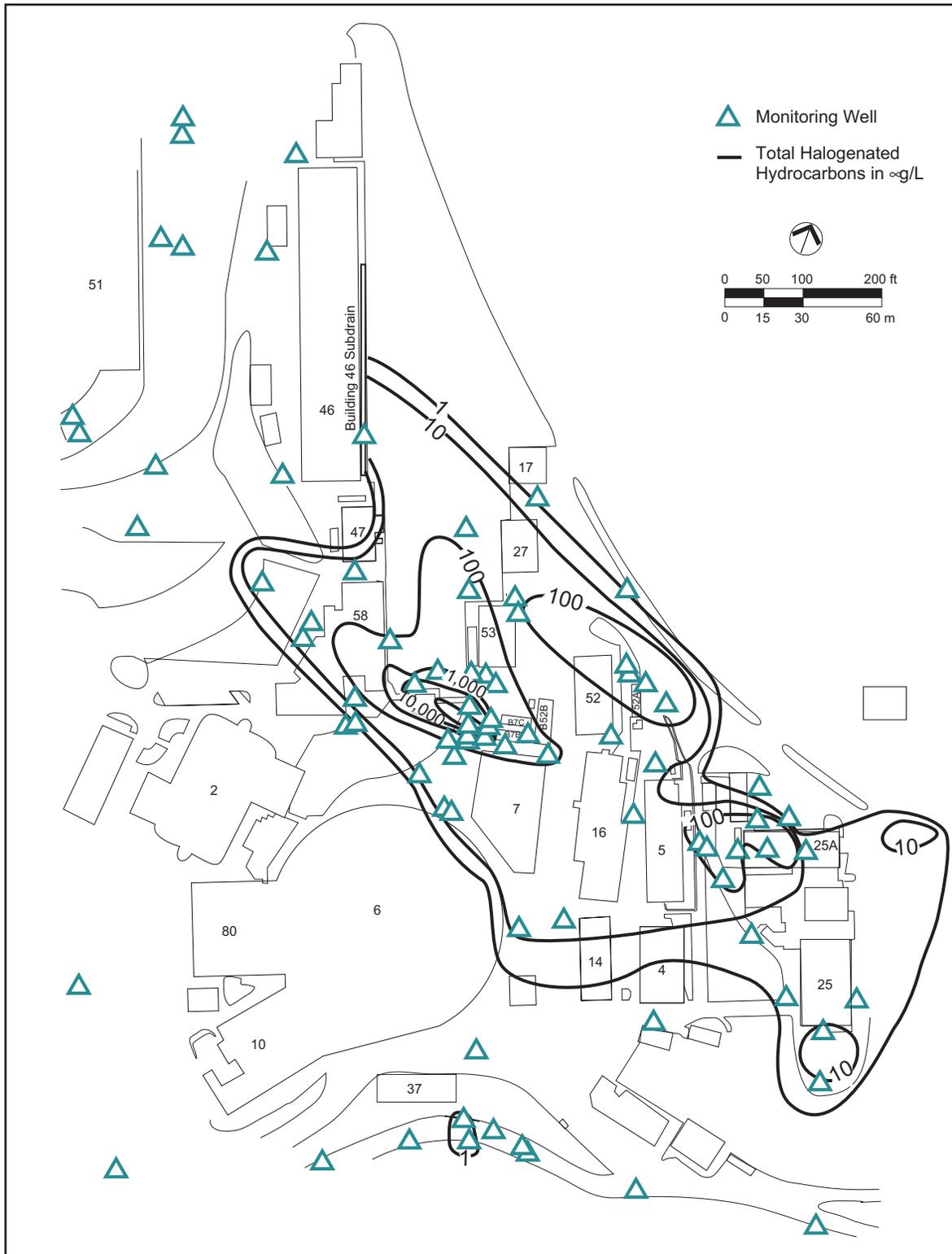
**Figure 6-3** Groundwater Contamination Plumes (October 2002)

The maximum concentration of total halogenated hydrocarbons detected in groundwater samples collected from Old Town VOC plume wells in CY 2002 was 107,654  $\mu\text{g/L}$ , which primarily consisted of PCE (49,207  $\mu\text{g/L}$ ) and TCE (55,828  $\mu\text{g/L}$ ). Figure 6-4 shows the areal extent of VOCs in groundwater in the Old Town area.

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.

Six 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.



**Figure 6-4** Groundwater Contamination (Total Halogenated Hydrocarbons in micrograms per liter [ $\mu\text{g/L}$ ]) in Old Town Area (September 2002)

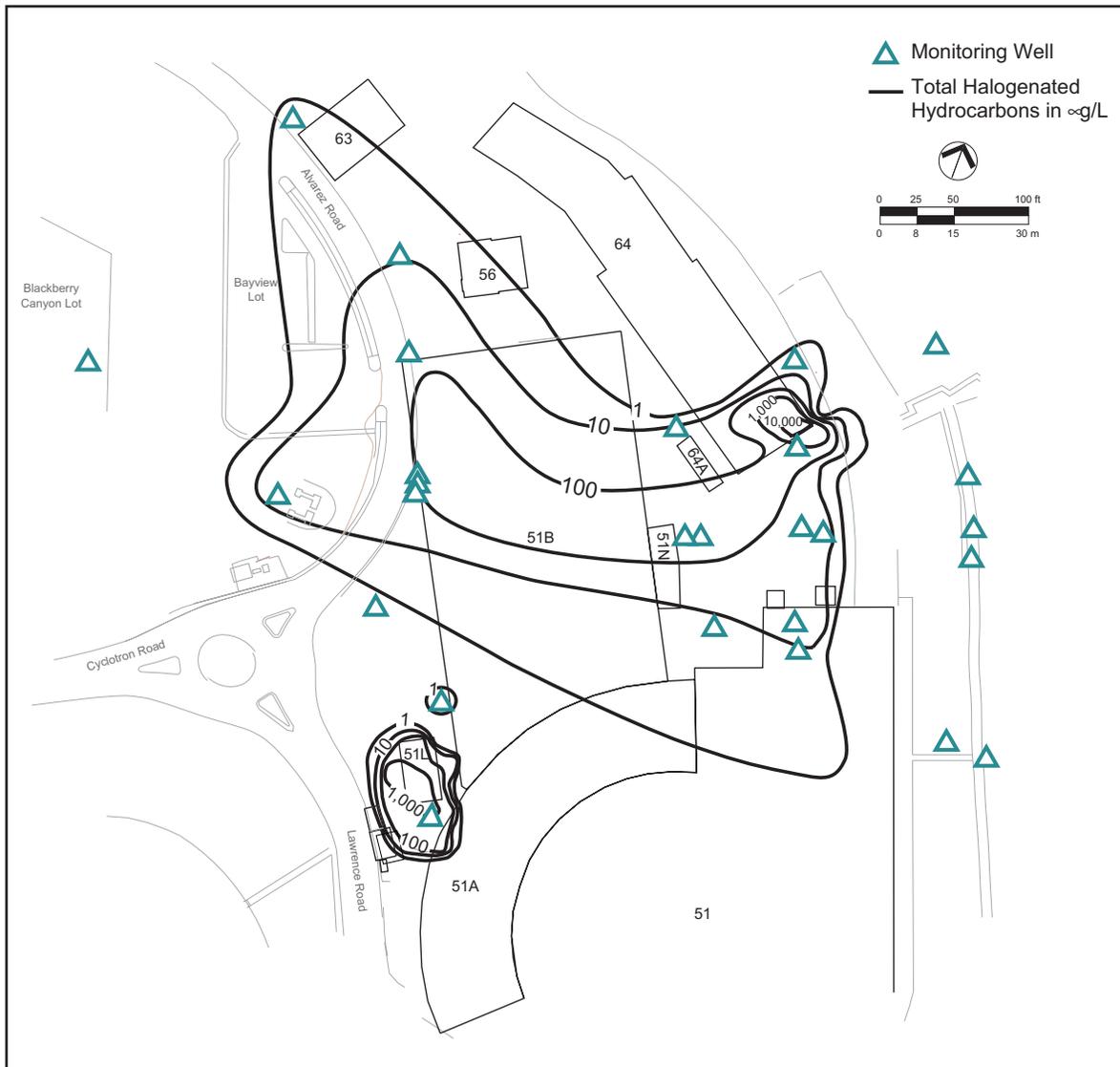
- A subdrain located east of Building 46 intercepts the northern lobe of the plume and prevents the discharge of contaminated groundwater to the storm drain.
- A groundwater collection trench was installed west of Building 58 to intercept the southern lobe of the plume and prevent its further migration.
- A groundwater collection trench was installed on the slope east of Building 58, in an area 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 1,1,1-TCA; 1,1-DCA; 1,1-DCE; PCE; TCE; and lower concentrations of other halogenated hydrocarbons. Halogenated hydrocarbons were detected in CY 2002 at a maximum total concentration of 21,877 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 2002 in samples collected from groundwater monitoring wells in the Building 51/64 area was 881 µg/L. The contaminants primarily consisted of 1,1-DCA (608 µg/L); 1,1-DCE (61 µg/L); TCE (106 µg/L); and PCE (66 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), east of Building 37 (Building 37 VOC plume), around and under 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 2002 was 1,351 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 as an interim corrective measure (see Section 6.5.1).

The Building 37 VOC plume is defined by the presence of trace amounts of halogenated hydrocarbons, primarily TCE in two monitoring wells southeast of Building 37. There has been a decreasing trend in VOC concentrations detected in these two wells since January 1994, when pumping and treating groundwater for plume management was initiated. The maximum concentration of halogenated hydrocarbons detected in wells monitoring the plume in CY 2002 was less than the drinking-water MCL.



**Figure 6-5** Groundwater Contamination (Total Halogenated Hydrocarbons in micrograms per liter [ $\mu\text{g/L}$ ]) at Building 51/64 VOC Plume (September 2002)

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 2002 was 1,693  $\mu\text{g/L}$ . The contaminants consisted primarily of cis-1,2-DCE (706  $\mu\text{g/L}$ ); trans-1,2-DCE (515  $\mu\text{g/L}$ ); and TCE (165  $\mu\text{g/L}$ ).

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 2002 was 25.8  $\mu\text{g/L}$ .

### 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 9.4 µg/L. 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, small amounts of tritium (less than 20 Bq/L [less than 540 pCi/L]) were detected in a few monitoring wells in the Building 71B area. The source of the tritium was the former National Tritium Labeling Facility (NTLF) at Building 75. The maximum concentration of tritium detected in monitoring wells in CY 2002 was 951 Bq/L (25,700 pCi/L), at monitoring well 75-97-5, which is above the drinking-water standard of 740 Bq/L (20,000 pCi/L).<sup>3</sup> 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 76 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 2002 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 2002. 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 one monitoring well in CY 2002 at a concentration of 1.8 µg/L. The California MCL for MTBE is 13 µg/L.

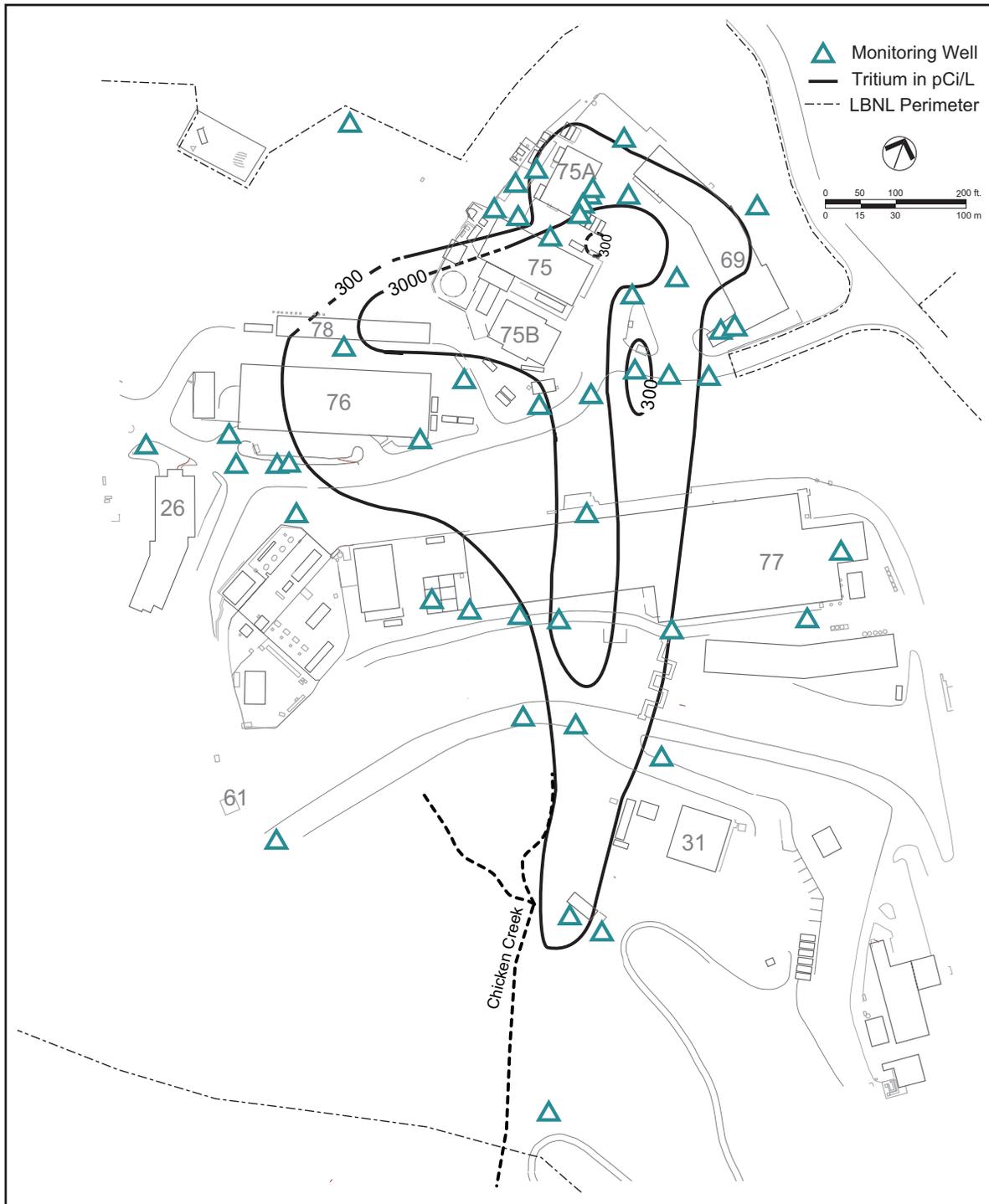
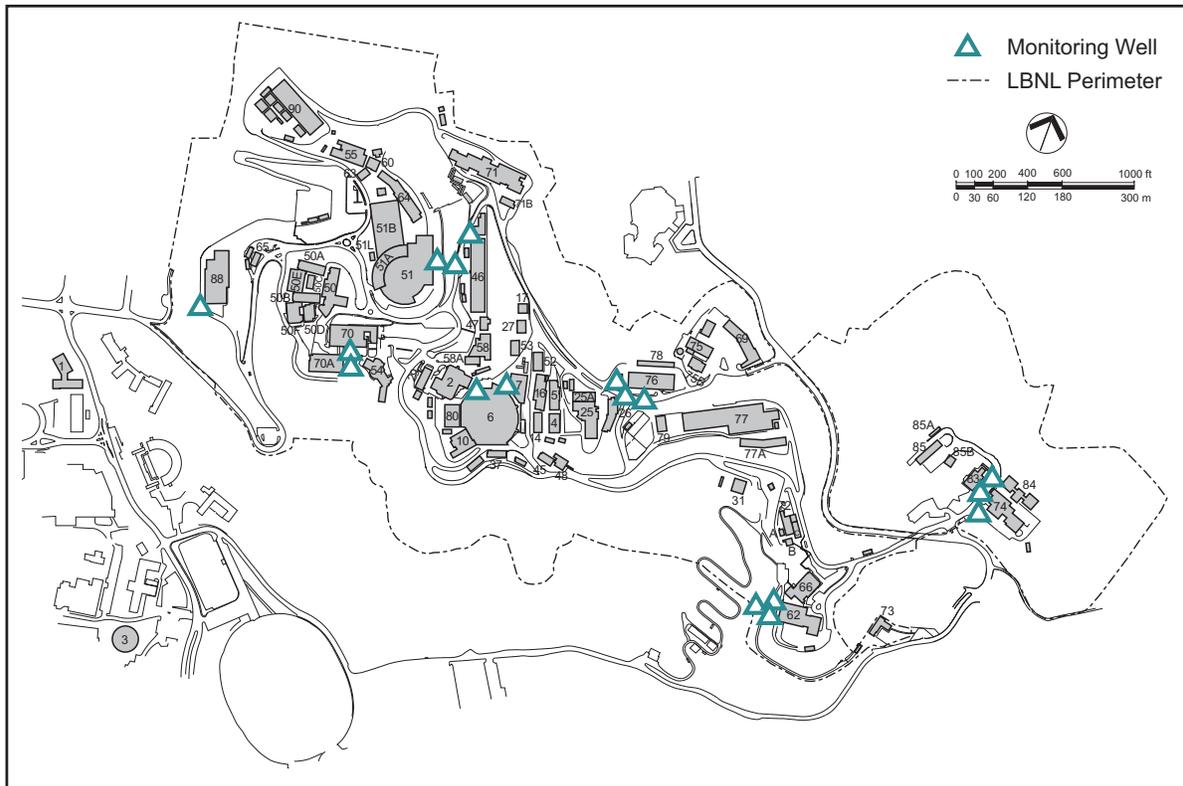


Figure 6-6 Groundwater Contamination (Tritium in picocuries per liter [pCi/L]) (October – December 2002)



**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 ( $\mu\text{g/L}$ )
Building 7E	Removed	Kerosene or Diesel	TPH-K <sup>a</sup> = 64,000 TPH-D <sup>b</sup> = 430
Building 46A <sup>c</sup>	Abandoned	Gasoline	NS <sup>d</sup>
Building 51 <sup>c</sup>	Removed	Diesel	NS <sup>d</sup>
Building 62 <sup>c</sup>	Removed	Diesel	ND <sup>e</sup>
Building 70A <sup>c</sup>	Removed	Diesel	ND <sup>e</sup>
Building 74 <sup>c</sup>	Removed	Diesel	TPH-D <sup>b</sup> = 130
Building 76 (Tank No. 1) <sup>c</sup>	Removed	Diesel	TPH-D <sup>b</sup> = 450
Building 76 (Tank No. 2) <sup>c</sup>	Removed	Gasoline	ND <sup>e</sup>
Building 88 <sup>c</sup>	Abandoned	Diesel	ND <sup>e</sup>

<sup>a</sup> TPH-K – TPH quantified as kerosene range hydrocarbons

<sup>b</sup> TPH-D = TPH quantified as diesel range hydrocarbons

<sup>c</sup> Approved No Further Action (NFA) status by the City of Berkeley

<sup>d</sup> NS = Not sampled

<sup>e</sup> ND = Not detected

## 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:

- Removing or controlling sources of contamination
- Preventing discharge of contaminated water to surface waters
- Eliminating potential pathways that could contaminate groundwater
- Preventing further migration of contaminated groundwater

### 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 5.2.4 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 2002.
- 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 2002.

#### 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. Eight 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,<sup>4</sup> or recirculated to flush contaminants from the subsurface.

Table 6-5 lists both the volume of contaminated groundwater treated by each system in CY 2002 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 2002 (liters) <sup>a</sup>	Total volume treated (liters)
Building 6 former underground storage tank	Building 6 Bioventing	873,033	4,022,002
Old Town VOC plume	Building 7 Trench	862,310	8,565,186
Old Town VOC plume	Building 25A	463,519	463,519
Building 37 VOC plume	Building 37	314,477	4,629,286
Old Town VOC plume	Building 46	4,338,034	38,242,300
Building 71 and Old Town VOC plumes and water collected from purging monitoring wells	Building 51 Firetrail <sup>b</sup>	3,359,373	49,217,294
Building 51 subdrain system and Building 51/64 VOC plume	Building 51 Sump	1,357,032	8,160,399
VOC-contaminated groundwater at Building 51L	Building 51L	585,377	752,958
<b>Total volume treated</b>		<b>12,153,154</b>	<b>114,052,943</b>

<sup>a</sup> 1 liter = 0.264 gallons

<sup>b</sup> B51 Hydrauger system is routed into the Building 51 Firetrail treatment system

## Soil and Sediment



7.1	BACKGROUND	7-2
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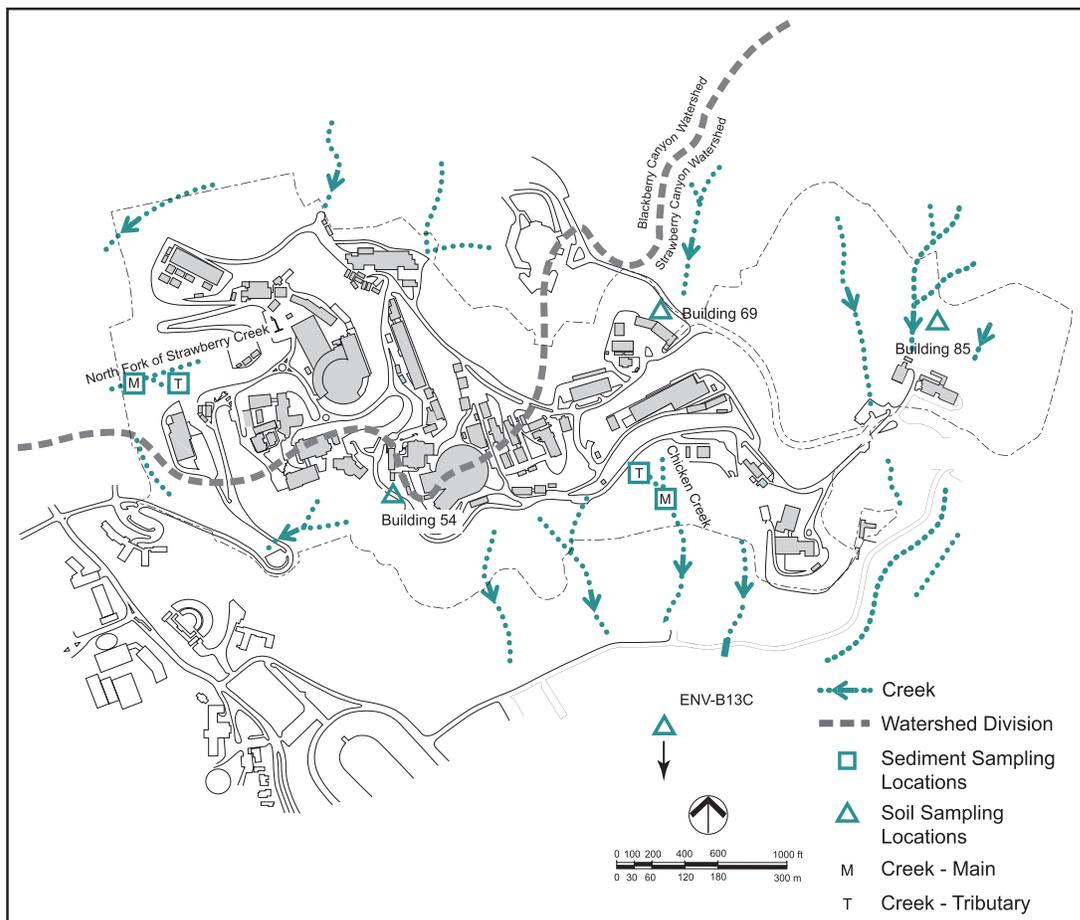
## 7.1 BACKGROUND

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.<sup>1</sup>

Berkeley Lab's *Environmental Monitoring Plan*<sup>2</sup> sets out the details of the soil and sediment program. In calendar year (CY) 2002, 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

**Table 7-1** Tritium Analysis Results in Soil and Sediment Samples<sup>a</sup>

<b>Sampling location</b>	<b>Matrix</b>	<b>Tritium (Bq/g)<sup>b</sup></b>
Building 54	Soil	< 0.006 <sup>c</sup>
Building 69	Soil	0.0063
Building 85	Soil	< 0.005 <sup>c</sup>
ENV-B13C	Soil	< 0.007 <sup>c</sup>
Chicken Creek—main	Sediment	0.0048
Chicken Creek—tributary	Sediment	< 0.005 <sup>c</sup>
North Fork Strawberry Creek—main	Sediment	0.005
North Fork Strawberry Creek— tributary	Sediment	0.0015

<sup>a</sup> One sample per location

<sup>b</sup> 1 Bq = 27 pCi

<sup>c</sup> Result below minimum detectable amount

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). Sediment samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, polychlorinated biphenyls (PCBs), petroleum hydrocarbons (diesel fuel and oil and grease), and pH.

### 7.3 SOIL AND SEDIMENT ANALYSIS RESULTS

All gross alpha and gross beta radiation and gamma-emitter results were similar to background levels of naturally occurring radioisotopes commonly found in soil and sediment. In CY 2002, the highest soil tritium concentration was 0.006 becquerel per gram (Bq/g) (0.2 picocurie per gram [pCi/g]) and the highest sediment tritium concentration was 0.005 Bq/g (0.1 pCi/g). Table 7-1 shows the tritium analysis results.

PCB results for sediment samples were all below or near practical quantification limits. Measurements for pH were within the normal range for soils and sediments. The maximum level of oil and grease (4,100 milligrams per kilograms [mg/kg]) was measured at the Chicken Creek tributary location. Oil and grease contamination is commonly associated with motorized vehicle use on roads and parking lots. Metal concentrations for soils and sediments were within or slightly above the established background values for the Berkeley Lab site.<sup>4</sup> This location will be sampled in future years to monitor any changes.

Table 7-2 shows sample analysis results for metals (where at least one result was above the limit of quantification) and oil and grease results.

#### **7.4 SUPPLEMENTAL SOIL AND SEDIMENT SAMPLING**

In 2001, soil and sediment at Berkeley Lab were sampled and analyzed for tritium in accordance with the approved *Soil, Surface Water and Sediment Sampling Plan for Tritium*, which was designed and approved to meet the request of the Environmental Sampling Task Force. This supplemental sampling is discussed in detail in the *Summary Report for Supplemental Tritium Monitoring*,<sup>5</sup> included on the CD on which this *Site Environmental Report* is found and on the Web at <http://www.lbl.gov/ehs/taskforce/>.

**Table 7-2** Metals and Oil/Grease Results in Soil and Sediment Samples<sup>a,d</sup>

Analyte	Sample location						Regulatory criteria (TTLC <sup>b</sup> )		
	Soil			Sediment					
	B54	B69	B85	ENV-B13C	Chicken Creek-Main	Chicken Creek-Tributary	N. Fork Strawberry Creek-Main	N. Fork Strawberry Creek-Tributary	
Antimony	2	2	<1 <sup>c</sup>	8.6	<1 <sup>c</sup>	<1 <sup>c</sup>	1	2	500
Arsenic	8.6	2	3	5.7	2	3.6	4.4	3.6	500
Barium	250	130	140	130	120	110	76	74	10,000
Cadmium	9.7	<1 <sup>c</sup>	<1 <sup>c</sup>	<1 <sup>c</sup>	<1 <sup>c</sup>	<1 <sup>c</sup>	<1 <sup>c</sup>	<1 <sup>c</sup>	100
Chromium	49	93	98	26	35	64	42	20	2,500
Cobalt	13	22	22	6.5	9.6	9	7.2	5.2	8,000
Copper	43	30	39	25	27	27	36	15	2,500
Lead	35	<10 <sup>c</sup>	17	64	14	23	27	<10 <sup>c</sup>	1,000
Mercury	0.13	<0.05 <sup>c</sup>	0.07	0.18	<0.05 <sup>c</sup>	0.084	0.095	0.33	20
Nickel	42	64	59	24	43	49	27	17	2,000
Vanadium	70	88	120	33	28	49	39	33	2,400
Zinc	150	64	69	83	190	210	190	99	5,000
Oil & grease	--	--	--	--	630	4,100	2,400	790	--

<sup>a</sup> One sample per location, all results in milligrams per kilograms

<sup>b</sup> Total Threshold Limit Concentration (22 California Code of Regulations 66261.24)<sup>3</sup>

<sup>c</sup> Result was below detection limit.

<sup>d</sup> Results for beryllium, molybdenum, silver, and thallium were all below practical quantification limits and are not reported in Table 7-2. These results, along with other non-TTLC metals (aluminum, boron, manganese, and iron), are included in Volume II.



## Vegetation and Foodstuffs



<b>8.1</b>	<b>BACKGROUND</b>	<b>8-2</b>
<b>8.2</b>	<b>TREE SAMPLING FOR LANDSCAPE MANAGEMENT</b>	<b>8-3</b>
<b>8.3</b>	<b>SUPPLEMENTAL TREE SAMPLING</b>	<b>8-5</b>

## 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

Berkeley Lab performs vegetation sampling 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.

United States Department of Energy (DOE) guidance<sup>1</sup> 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 well below the requirement for a minimal monitoring program. Nevertheless, Berkeley Lab's vegetation sampling program collects and analyzes samples at least every five years. For this sampling, tritium air emissions were identified as the only potentially significant contributor to these pathways.

Tritium emissions can be in the form of 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 are a mixture of tritiated water vapor and tritiated hydrogen gas; however, to provide a very conservative estimate of actual dose in modeling and dose calculations, 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.

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

## 8.2 TREE SAMPLING FOR LANDSCAPE MANAGEMENT

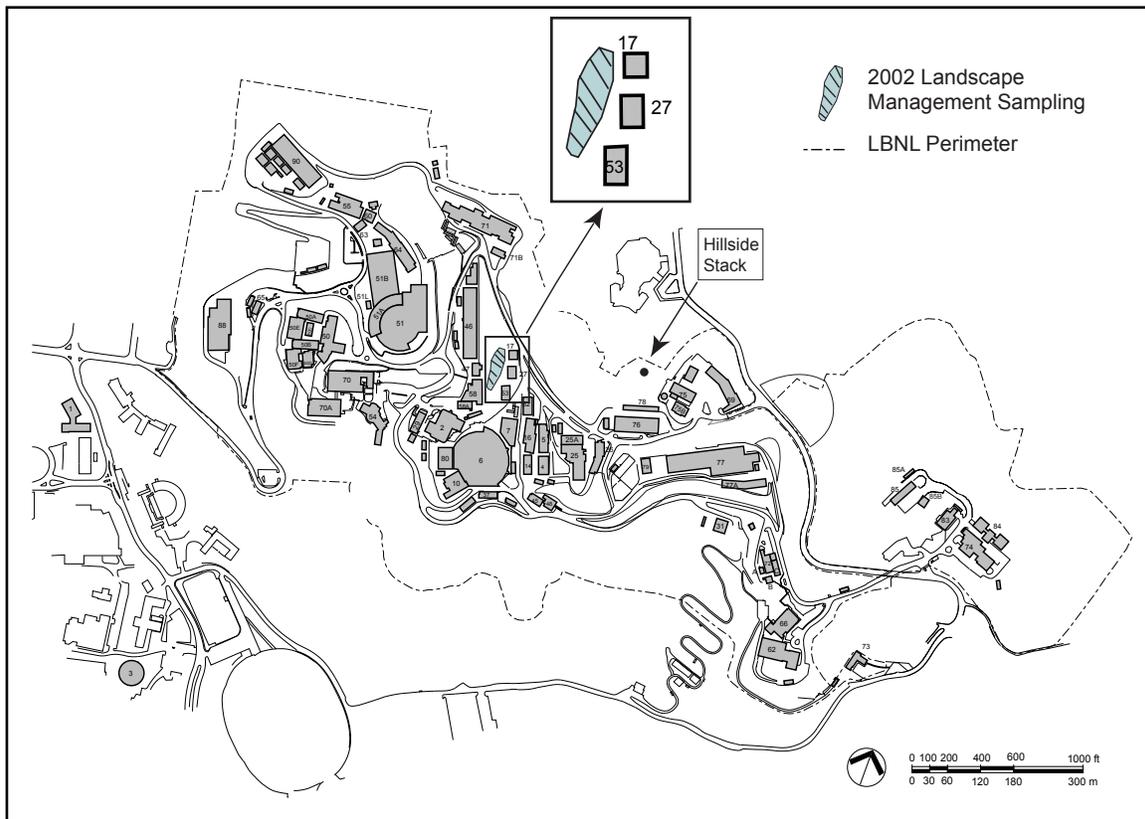
Berkeley Lab manages on-site trees and vegetation (and some immediately adjacent to the University of California) as part of a multiyear wildland-fire risk-management program and a maintenance program for a fire-safe landscape.<sup>3</sup>

Environmental tritium levels have been determined to be above regional background levels near the former National Tritium Labeling Facility (NTLF) in Building 75; they decrease with distance from the Building 75 Hillside Stack.<sup>4</sup> At a few hundred meters from the Hillside Stack, tissue-free water and organically bound tritium levels in tree wood are at or below the detection limits required by contract: less than 0.019 becquerel per gram (Bq/g) (0.5 picocurie per gram [pCi/g]) for tissue-free water tritium and 0.19 Bq/g (5 pCi/g) for organically bound tritium.

Before Berkeley Lab considers the removal and release of trees to the public, the trees are sampled and analyzed for tritium, using commercially available analytical methods. The tritium results are evaluated using a DOE-approved method, which is based on the fact that tritium in uncontaminated trees is so low that the analytical laboratory cannot detect it (i.e., tritium is less than the minimum detectable activity [MDA]). Thus the MDA is used as the background tritium level, and a representative group of trees with an average tritium level less than the average MDA is considered indistinguishable from background. If the average tritium level of the group of trees is greater than the average MDA, a statistical test (the paired t-test) is performed to determine whether the difference between the results and the MDAs is likely to have occurred by chance. A chance occurrence indicates that the tritium level of the trees does not significantly differ from the MDA (at the 95% confidence level), and so is determined to be indistinguishable from background. Only trees with tritium levels that are indistinguishable from background are released to the public.

In 2001, Berkeley Lab requested that DOE authorize a specific tritium level below which trees can be released to the public for unrestricted use. Such a level was chosen carefully to prevent harm to the public or the environment. For example, a national standard recommends that material with tritium levels below 111 Bq/g (3,000 pCi/g) can be released without restrictions.<sup>5</sup> This value has been shown to be protective of the public health and the environment. In 2002, DOE reviewed and commented on the Laboratory's request and a revised application was prepared. A decision by DOE is expected in 2003.

In 2002, Berkeley Lab marked and sampled several trees that were being considered for removal near Buildings 17 and 27 (see Figure 8-1). Tritium in trees at this distance from the NTLF, greater than 250 meters (m) (820 feet [ft]), was expected to be very low and indistinguishable from regional



**Figure 8-1** Vegetation Sampling Areas

background levels. Six trees near Buildings 17 and 27 were sampled using a documented procedure.<sup>6</sup> The procedure was designed to provide representative samples for characterizing tritium levels within the tree stands and to prevent sample cross-contamination. The samples were analyzed at a commercial laboratory for tissue-free water tritium (TFWT) and organically bound tritium (OBT).

Data are shown in Table 8-1. The mean TFWT result was 0.003 Bq/g (0.08 pCi/g) and the maximum result was 0.0043 Bq/g (0.12 pCi/g). For OBT analyses, the mean result was 0.076 Bq/g (2.045 pCi/g), and the maximum result was 0.23 Bq/g (6.3 pCi/g), which was the only result greater than the MDA. Data quality was assessed by analyzing field duplicates, laboratory control spikes, laboratory method blanks, and laboratory duplicates.

**Table 8-1** Results of Tree Sampling for Landscape Management

Tree sampled	Result		Minimum detectable activity (MDA)	
	Bq/g	pCi/g	Bq/g	pCi/g
Tissue-free water tritium (TFWT)				
1	0.0022	0.06	0.002	0.06
2	<b>0.0043<sup>a</sup></b>	<b>0.12<sup>a</sup></b>	0.003	0.07
3	0.0037	0.1	0.003	0.07
4	0.0029	0.079	0.002	0.06
5	<0.002	<0.06	0.002	0.06
6	0.003	0.082	0.003	0.07
Mean	0.003	0.081	0.0024	0.065
Organically bound tritium (OBT)				
1	<0.14	<4	0.14	4
2	<b>0.23<sup>a</sup></b>	<b>6.3<sup>a</sup></b>	0.11	3
3	<0.13	<4	0.13	4
4	<0.13	<4	0.13	4
5	<0.14	<4	0.14	4
6	<0.13	<4	0.13	4
Mean	0.076	2.045	0.142	3.833

<sup>a</sup> Maximum measured value

The results were assessed to determine whether they were distinguishable from regional background levels using the DOE-approved statistical method.<sup>7,8</sup> As expected, tritium levels in trees near Buildings 17 and 27 were indistinguishable from background. Based on this determination, several trees in the area were cut down and removed from Berkeley Lab property.

### 8.3 SUPPLEMENTAL TREE SAMPLING

In 2001, vegetation around the perimeter of Berkeley Lab was sampled for tritium in accordance with the approved *Vegetation Sampling Plan for Tritium*, which was designed and approved to meet the request of the Environmental Sampling Project Task Force. This supplemental sampling is discussed in detail in the *Summary Report for Supplemental Tritium Monitoring*,<sup>9</sup> included on the CD on which this *Site Environmental Report* is found, and on the Web at [www.lbl.gov/ehs/taskforce/](http://www.lbl.gov/ehs/taskforce/), under Documents.

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## Radiological Dose Assessment



<b>9.1</b>	<b>BACKGROUND</b>	<b>9-2</b>
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<b>9.5</b>	<b>DOSE TO ANIMALS AND PLANTS</b>	<b>9-8</b>

## 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 either type of dose (individual or population): 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 Système Internationale (SI) units used to express doses to humans are sieverts (Sv) or millisieverts (mSv); 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, programs at Berkeley Lab are managed 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) 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 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).

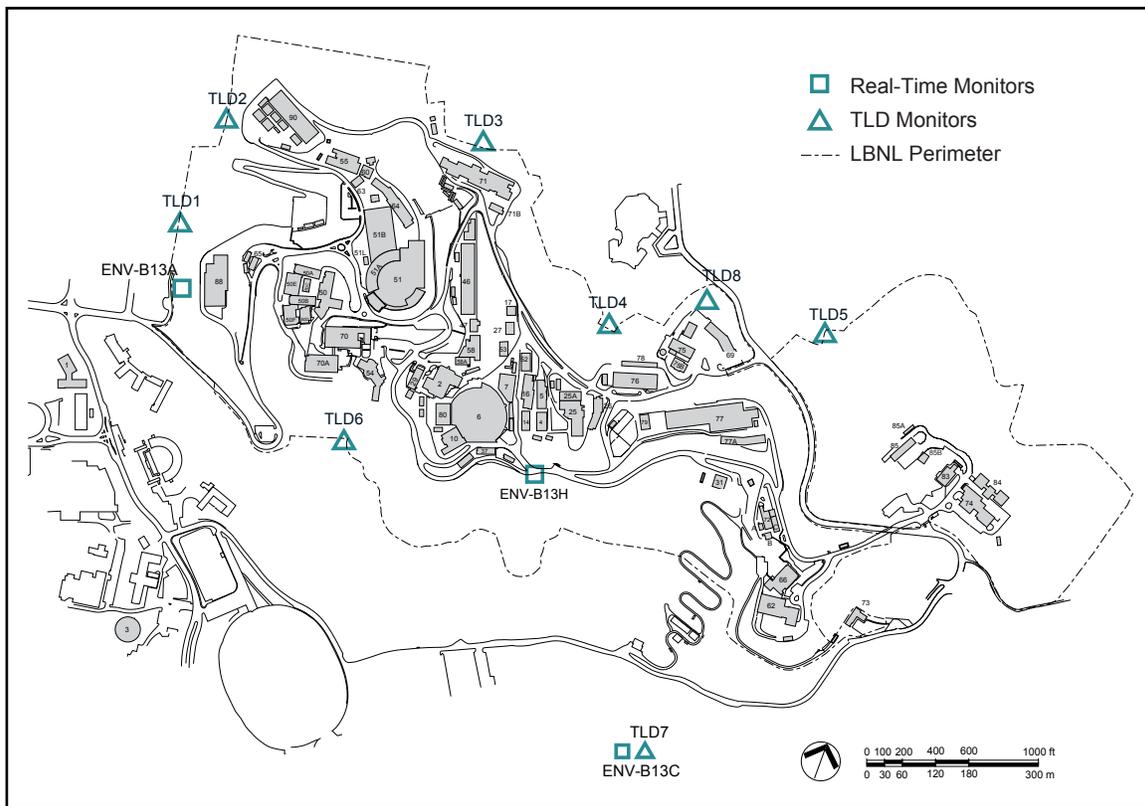
The Laboratory uses two methods to determine the environmental radiological impact from accelerator operations. One method consists of a network of three real-time environmental monitoring stations (ENV-B13A, ENV-B13C, and ENV-B13H) located around the perimeter of the site; these stations track instantaneous 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 gamma and neutron radiation. The annual doses to an individual from each form of penetrating radiation are derived from measurements at these 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. To better estimate these small net doses, this year a more accurate and robust calculation method was employed. The results for 2002 indicate that the net doses at ENV-13A and ENV-13H (representing doses due to Lab activities) were indistinguishable from the net doses at the remote location ENV-13C (representing the variability in natural background dose and detector performance).

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. One TLD was added in 2002 (TLD 8) at the site boundary near Building 75A. 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 2002 was 0.60 mSv (60 mrem), and the gamma radiation dose at the remote location (Panoramic) was 0.71 mSv (71 mrem). The average fence-line TLD dose measurement is lower than the remote background. The TLD results are consistent with the low-dose values measured by the real-time monitoring stations.



**Figure 9-1** Environmental Penetrating Radiation Monitoring Stations

### 9.2.2 Irradiator-Produced Penetrating Radiation

Used for radiobiological and radiophysics research, a single gamma irradiator with an 800-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 less than background levels (0.001 mSv/hr [0.1 mrem/hr]) at 1 meter (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).<sup>1</sup> Berkeley Lab satisfies this requirement with the use of CAP88-PC.<sup>2</sup>

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 14 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 2002 was 0.0003 mSv (0.03 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<sup>3</sup> 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 projected an annual population dose from all airborne radionuclides of 0.003 person-Sv (0.3 person-rem).

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

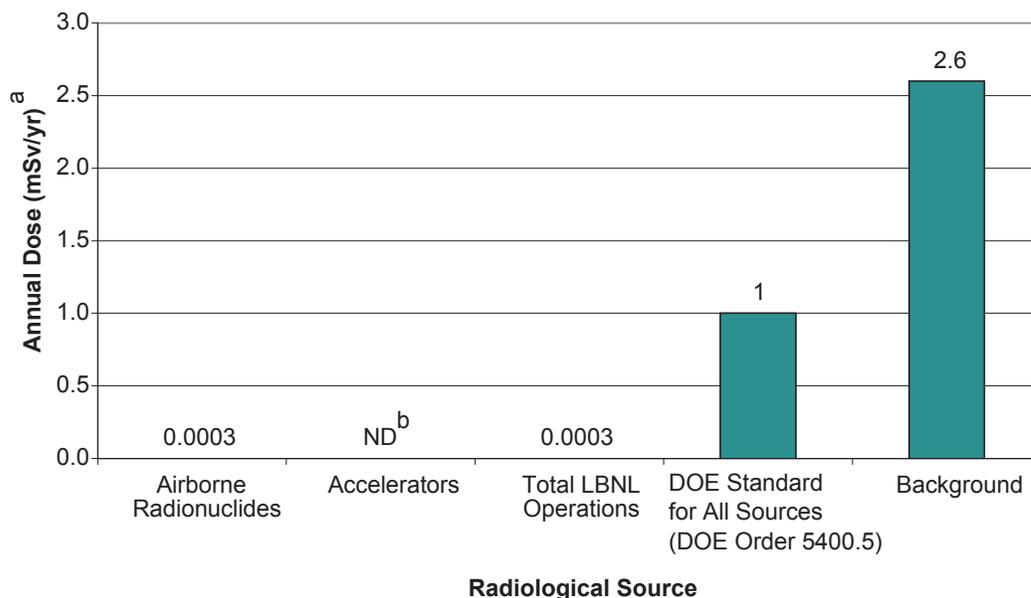
Building	Building description	Distance to MEI <sup>a</sup> (m)	Direction to MEI <sup>a</sup>	Dose to MEI (mSv/yr) <sup>b</sup>	Percent of MEI total dose
75	National Tritium Labeling Facility	110	NW	$1.3 \times 10^{-4}$	42.9%
55/56/64	Department of Nuclear Medicine and Functional Imaging	460	E	$1.0 \times 10^{-4}$	33.0%
85	New Hazardous Waste Handling Facility	570	WNW	$3.7 \times 10^{-5}$	12.2%
1	Donner Laboratory (UC Berkeley)	990	ENE	$1.9 \times 10^{-5}$	6.3%
74/83/84	Human Genome Facility/Life Sciences	690	WNW	$7.1 \times 10^{-6}$	2.3%
70/70A	Nuclear/Life Sciences	530	ENE	$4.9 \times 10^{-6}$	1.6%
75/75A/75S	Old Hazardous Waste Handling Facility/Storage Locker	150	NW	$2.7 \times 10^{-6}$	0.9%
88	88-Inch Cyclotron	690	ENE	$1.8 \times 10^{-6}$	0.6%
26/76	Radioanalytical Laboratory	250	N	$2.3 \times 10^{-7}$	0.1%
51B	Bevatron Facility	440	E	$3.6 \times 10^{-8}$	<0.1%
3	Calvin Lab (UC Berkeley)	1060	NE	$1.7 \times 10^{-9}$	<0.1%
6	Advanced Light Source Facility	370	NNE	$1.3 \times 10^{-10}$	<0.1%
72	Low-Background Counting Facility	500	NW	$8.7 \times 10^{-13}$	<0.1%
71	Accelerator and Fusion Research	310	ESE	$2.5 \times 10^{-17}$	<0.1%
<b>Total</b>				<b><math>3.0 \times 10^{-4}</math></b>	<b>100%</b>

<sup>a</sup> Distances and directions are relative to the maximally exposed individual to airborne emissions.

<sup>b</sup> 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. Because the greatest possible dose from direct radiation was indistinguishable from background radiation levels, the 2002 total dose from Berkeley Lab activities is due solely to exposure to airborne radionuclides by the MEI. As presented in Table 9-2 and Figure 9-2, the maximum effective dose equivalent from Berkeley Lab operations to an individual residing at the LHS in 2002 is about 0.0003 mSv (0.03 mrem) per year. This value is approximately 0.02% of the nominal background radiation<sup>4</sup> in the Bay Area and about 0.3% of the DOE annual limits.<sup>5</sup>



<sup>a</sup> 1 mSv/yr = 100 mrem/yr

<sup>b</sup> Nondetect: Dose from direct radiation was indistinguishable from natural background radiation levels.

**Figure 9-2** Comparison of Radiological Dose Impacts for 2002

As noted previously, the estimated dose to the population within 80 km (50 mi) of Berkeley Lab from airborne radionuclides was 0.003 person-Sv (0.3 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 0.00002% of the background level.

**Table 9-2** Comparison of Radiological Dose Impacts

Dose/standard/background	Dose from direct radiation	Dose from airborne radionuclides
Annual EDE <sup>a</sup>	Indistinguishable from background	0.0003 mSv/yr
Regulatory standard	1 mSv/yr (DOE)	0.10 mSv/yr (US/EPA)
Impact as percentage of standard	Not applicable	0.3%
Annual background	1 mSv/yr	1.6 mSv/yr
Impact as percentage of background	Indistinguishable from background	0.02%

<sup>a</sup> EDE = Effective dose equivalent

## 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).<sup>5</sup> 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).<sup>6</sup>

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.<sup>6</sup> 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 2002 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. Only <sup>3</sup>H exceeded background levels in a few samples, which were evaluated using the DOE standard 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 gray/day). In addition, they show that the Laboratory is well within international recommendations for limiting dose to other plants and animals.

## Quality Assurance



<b>10.1</b>	<b>OVERVIEW</b>	<b>10-2</b>
<b>10.2</b>	<b>SPLIT AND DUPLICATE RESULTS FOR ENVIRONMENTAL MONITORING</b>	<b>10-3</b>

## 10.1 OVERVIEW

Lawrence Berkeley National Laboratory's quality assurance policy is documented in the *Operating and Assurance Plan* (OAP).<sup>1</sup> 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*<sup>2</sup> and applicable United States Department of Energy (DOE)<sup>3</sup> and United States Environmental Protection Agency (US/EPA)<sup>4</sup> guidance. When special quality assurance (QA) 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<sup>5</sup> 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 2002, seven external analytical laboratories were available for use under a joint contract with Berkeley Lab and Lawrence Livermore National Laboratory (LLNL).

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 up to six areas at the external analytical laboratories for the type of services provided. These audited services include: (1) quality assurance 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 technical QA assessments performed by the Environmental Services Group and internal assessments conducted by 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.<sup>6</sup> 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.

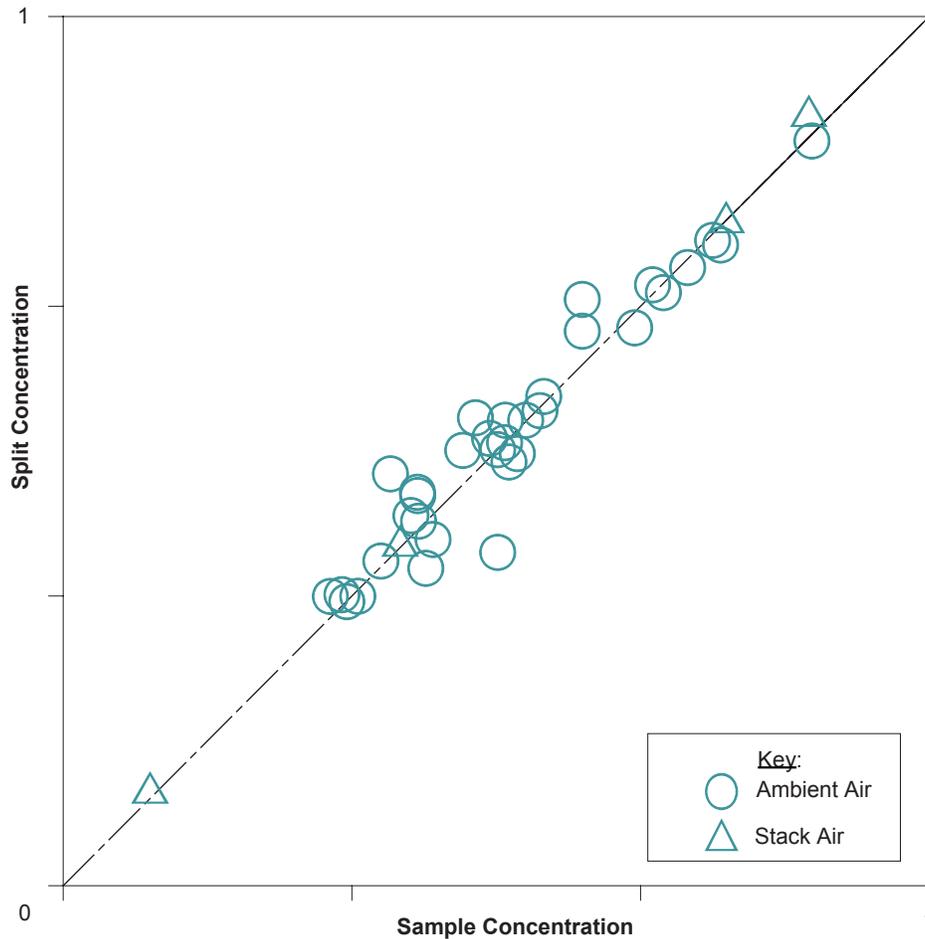
In addition, US/EPA conducts external audits of the NESHAPs monitoring program under 40 CFR 61, Subpart H. As discussed in Section 3.4.2, US/EPA had requested additional sampling of the air, water, and soil in and around the Laboratory to help determine whether to include Berkeley Lab on the Superfund List. A draft sampling and analysis plan for this US/EPA-requested sampling was developed in 1999. In 2000, DOE, US/EPA, and the Environmental Sampling Project Task Force reviewed the plan. In early 2001, DOE approved the plan, and sampling began. Sampling was completed in 2002. In July 2002, the EPA announced that environmental tritium levels at Berkeley Lab were well below federal health standards and it would not list Berkeley Lab on the federal National Priorities List. A copy of the *Summary Report for Supplemental Tritium Monitoring* can be found on the Web at <http://www.lbl.gov/ehs/taskforce/> and on the CD version of the *Site Environmental Report*.

## 10.2 SPLIT AND DUPLICATE RESULTS FOR ENVIRONMENTAL MONITORING

Berkeley Lab's environmental monitoring programs place considerable emphasis on collecting split and duplicate samples for quality assurance purposes. In 2002, 425 split and 30 duplicate samples were collected for analysis in ambient air, rainwater, sediment, soil, surface water, stack exhaust air, wastewater, and vegetation. These quality assurance samples were analyzed for a wide range of specific substances. In broad terms, the analytes include substances in the following three categories: radiological material, organic and toxic chemicals, and metals. Berkeley Lab uses the metrics of relative percent difference and relative error ratio to determine the validity of a sample and its corresponding quality assurance result. Relative percent difference is determined in all cases. Relative error ratio is applied only to radiological analyses.

For each media, approximately half or more of the quality assurance sample pair results were below analyte detection limits. The media with the greatest percentage of sample pairs below detection

limits was the wastewater program, where the percentage exceeded 94% (240 of the 255 pairs). Overall, 75% of the sample pairs from all media were below detection limits.



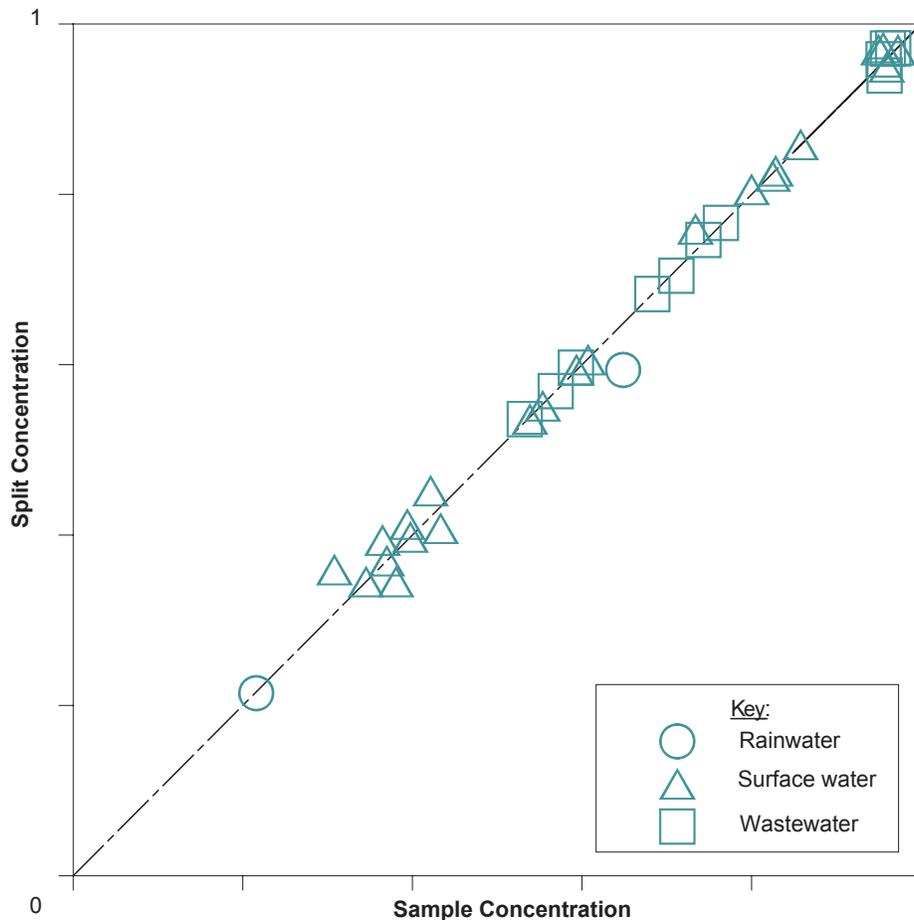
NOTE:

- 1) Sample and split concentrations are plotted on a logarithmic scale.
- 2) Concentrations are normalized to a scale of 0 to 1 for ease of plotting multiple media on one chart.
- 3) Plot contains 33 pairs of ambient air samples and 4 pairs of stack air samples.

**Figure 10-1** Comparison of Quality Assurance Samples for Air Sampling Programs

A total of 111 quality assurance sample-pair results were above detection limits, and they are plotted in Figures 10-1 through 10-3. These figures combine analyses for ambient and stack air (Figure 10-1); sediment, soil, and vegetation (Figure 10-2); and rainwater, surface water, and wastewater (Figure 10-3). The number of pairs plotted for individual sampling media is indicated in the notes in Figures 10-1 through 10-3. Actual concentrations are normalized to fall within the

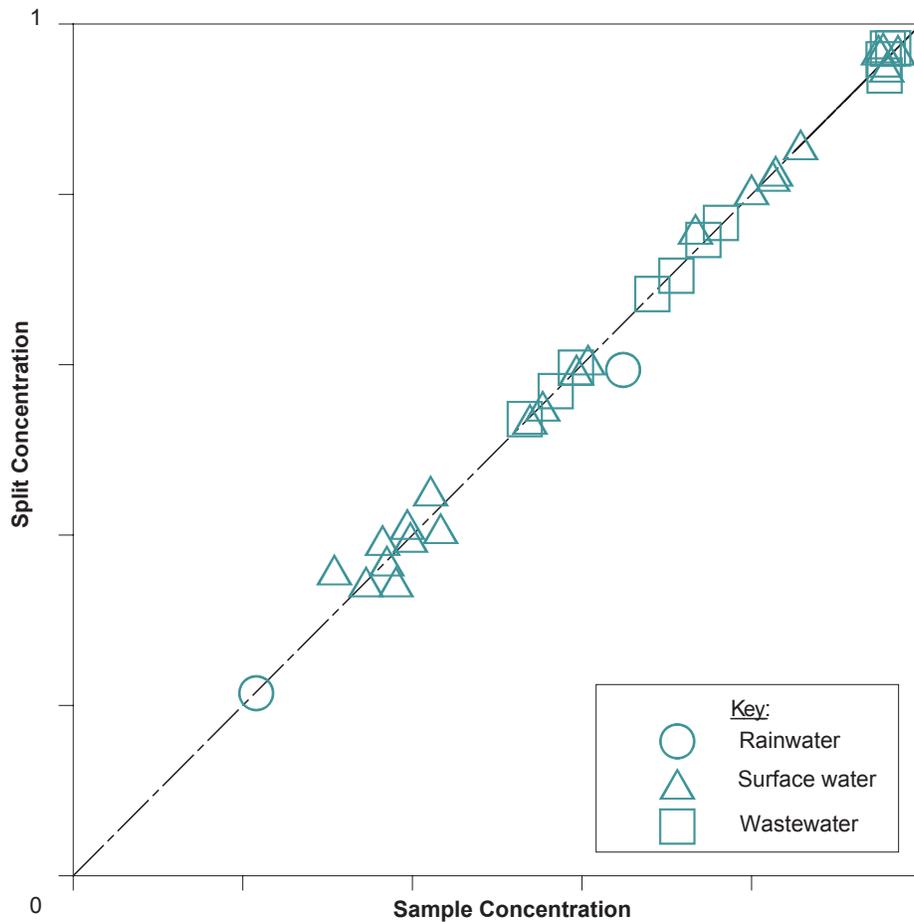
numeric range of zero to one. An ideal match of a quality assurance pair would fall on the diagonal line. All three charts show good agreement between split and duplicate sample pairs. Any pair that falls outside of Berkeley Lab's relative percent difference or relative error ratio criteria is investigated.



## NOTE:

- 1) Sample and split concentrations are plotted on a logarithmic scale.
- 2) Concentrations are normalized to a scale of 0 to 1 for ease of plotting multiple media on one chart.
- 3) Plot contains 2 pairs of rainwater samples, 22 pairs of surface water samples, and 15 pairs of wastewater samples.

**Figure 10-2** Comparison of Quality Assurance Sample Results for Sediment, Soil, and Vegetation Sampling Programs



## NOTE:

- 1) Sample and split concentrations are plotted on a logarithmic scale.
- 2) Concentrations are normalized to a scale of 0 to 1 for ease of plotting multiple media on one chart.
- 3) Plot contains 2 pairs of rainwater samples, 22 pairs of surface water samples, and 15 pairs of wastewater samples.

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

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## Acronyms and Abbreviations

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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, Ethylbenzene, and Xylene
Cal/EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	curie
COD	chemical oxygen demand
CUPA	Certified Unified Program Agency
CWA	Clean Water Act
CY	calendar year
DCA	dichloroethane
DCE	dichloroethylene
DOE	United States Department of Energy
DTSC	Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EDE	Effective Dose Equivalent
EH&S	Environment, Health, and Safety Division at Berkeley Lab
EMCAP	Environmental Management Consolidated Audit Program
EPCRA	Emergency Planning and Community Right-to-Know Act

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ESG	Environmental Services Group
FTU	fixed treatment unit
gsf	gross square feet
gsm	gross square meters
Gy	gray (measure of radiation in SI)
HEPA	high efficiency particulate air
HMBP	Hazardous Materials Business Plan
HWHF	Hazardous Waste Handling Facility
ISM	Integrated Safety Management
kg	kilogram
L	liter
LBNL	Lawrence Berkeley National Laboratory
LHS	Lawrence Hall of Science
LLNL	Lawrence Livermore National Laboratory
m	meter
MCL	maximum contaminant level
MDA	Minimum Detectable Amount
MEI	maximally exposed individual
mg	milligram
mrem	millirem
mSv	millisievert
MTBE	methyl tertiary butyl ether
ND	nondetectable
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOV	Notice of Violation
NPL	National Priorities List
NPDES	National Pollutant Discharge Elimination System
NTLF	National Tritium Labeling Facility
NQA	Nuclear Quality Assurance
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)
PGF	Production Genomics Facility
ppm	parts per million
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RER	Relative Error Ratio
RFI	RCRA Facility Investigation
RMPP	Risk Management and Prevention Plan
RPD	Relative Percent Difference
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
TMD	Toxics Management Division (City of Berkeley)
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
UHVCF	Ultra-High Vacuum Cleaning Facility
US/EPA	United States Environmental Protection Agency
UST	underground storage tank
UV	ultraviolet
VOC	Volatile Organic Compound
WAA	Waste Accumulation Area
Web	World Wide Web
WMG	Waste Management Group
yr	year

# Glossary

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**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  $2.22 \times 10^{12}$  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<sup>1</sup>**

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 ( $1 \times 0.12$ ).

**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.

**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 ( $^{40}\text{K}$ ), 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.

**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 greater than 7; and neutral solutions have a pH of 7.

**Piezometer**

Generally, a small-diameter, nonpumping well used to measure the elevation of the water table or potentiometric surface. The water table is an imaginary surface that represents the static pressure of groundwater and is defined by the level to which water will rise.

**Plume<sup>1</sup>**

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.

**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. The PQL is used in the reporting of nonradiological analytes and is typically set at 5 to 10 times the method detection limit.

**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  $2.58 \times 10^4$  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  $^{40}\text{K}$ ; the natural decay chains  $^{235}\text{U}$ ,  $^{233}\text{U}$ , or  $^{232}\text{Th}$ ; 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.

<sup>1</sup> 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].

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

<b>Prefix</b>	<b>Factor</b>	<b>Symbol</b>
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 <sup>a</sup>
deka	10 = $10^1$	da <sup>a</sup>
deci	0.1 = $10^{-1}$	d <sup>a</sup>
centi	0.01 = $10^{-2}$	c <sup>a</sup>
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

<sup>a</sup>Avoid where practical.

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

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

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