Site Environmental Report for 2001

Volume I

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Ernest Orlando Lawrence Berkeley National Laboratory

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Preface

Each year, Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) 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 2001 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 2001.

The report is separated into two volumes. Volume I contains a general overview of the Laboratory, the status of environmental programs, and summary results from surveillance and monitoring activities. Volume II contains the individual data results from monitoring programs. Although a printed version of Volume II is not part of the report's initial distribution, it is available on request (see below).

The report follows the Laboratory's policy of using the International System of Units (SI), or metric system of measurements. Whenever possible, results are also reported using the more conventional inch-pound system of measurements because this system is referenced by some current regulatory standards and may be 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 of programmatic information include Nancy Rothermich and Steve Wyrick. We also wish to thank Teresa Grossman, who provided word processing and illustration support to the Environmental Services Group.

This report was prepared through Berkeley Lab's Technical and Electronic Information Department. Julie McCullough and Cheryl Ventimiglia managed technical editing, design, and production of the report, assisted by Rich Albert and Teresa Duque (technical editing), Jean Wolslegel (composition), Flavio Robles, Jr. (illustration), 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 Michael Ruggieri (telephone: 510-486-5440; e-mail: mrruggieri@lbl.gov).

1

Executive Summary

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. In order to provide the highest degree of protection for the public and the environment, Berkeley Lab employs Integrated Safety Management (ISM). ISM is a comprehensive U.S. Department of Energy 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. 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 impact on public health and the environment.

This annual Site Environmental Report covers activities for calendar year (CY) 2001. Volume I summarizes environmental protection performance and environmental monitoring activities. Volume II contains individual analytical data 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 United States Department of Energy (DOE) Order 231.1, Environment, Safety and Health Reporting,[1] and the operating contract between the University of California Office of the President (UCOP) and DOE.[2]

1.2 OPERATING PERMITS

At the end of CY 2001, Berkeley Lab held 27 environmental operating permits from various regulatory agencies:

- Air emission sources (11),
- Hazardous waste handling and treatment operations (3),
- Stormwater discharges (1),
- Underground storage tanks (8), and
- Wastewater discharges (4).

For further discussion of these permits, see Chapter 3.

1.3 INSPECTIONS

Twenty-five inspections of Berkeley Lab's environmental programs occurred during CY 2001. Three notices of violation were issued by regulatory agencies. Two notices of violation resulted from an underground storage tank inspection by the City of Berkeley. The other notice of violation came from an inspection by the City of Berkeley of Hazardous Materials Business Plan activities. A summary of these inspections is provided in Table 3-2. For more details on the violations, see Sections 3.4.3.1.2 and 3.4.6.4.

The DOE Office of Environment, Safety and Health Oversight (EH-2) conducted an inspection of environmental monitoring programs at Berkeley Lab in July. The inspection found that the Berkeley Lab programs were effective for detecting and monitoring the release of contaminants to the environment and that they were in compliance with related DOE and federal regulations and requirements. No serious findings or issues were identified that required formal correction.

1.4 INCIDENT TRACKING

Berkeley Lab filed two reports to DOE for minor environmental incidents reportable under its occurrence reporting program. For a description of these incidents, see Sections 3.3.3 and 3.4.6.4.

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.[3] In 2001, 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 2001

Performance measure	UCOP rating	DOE rating
1) Radiation protection of the public and the environment	Excellent	Excellent
2) Tracking environmental incidents	Outstanding	Outstanding
3) Waste reduction and recycling	Outstanding	Outstanding
4) Integrated Safety Management Program	Outstanding	Outstanding
5) Waste management commitments	Outstanding	Outstanding
6) Program innovation in waste management and environmental restoration	Outstanding	Outstanding
7) Environmental restoration release site completions	Outstanding	Outstanding
8) Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
9) Cost variance for waste management activities	Outstanding	Outstanding

From both UCOP and DOE, Berkeley Lab received ratings of "outstanding" on performance measures 2–9, and "excellent" on performance measure 1. For additional information on the performance review program, see Section 3.5.

1.6 ENVIRONMENTAL MONITORING

Berkeley Lab's environmental monitoring program serves several purposes:

- To demonstrate that Laboratory activities operate within regulatory and DOE requirements;
- To provide a historical record of any Laboratory impacts on the environment; and
- To support environmental management decisions.

Both radiological and nonradiological contaminants are monitored in the local environment.[4] Below are brief summaries of environmental measurements taken in CY 2001.

1.6.1 Radiological Monitoring

A significant portion of the environmental monitoring program measures radiological impacts from Laboratory activities. The Laboratory monitors two types of radiation: (1) penetrating radiation from sources such as accelerators, and (2) dispersible radionuclides from a wide range of Laboratory research activities. Specially designed shielding is in place to reduce the release of penetrating radiation into the environment, and capture systems are used to 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. A person would have to reside full-time at a location near Berkeley Lab's 88-Inch Cyclotron to receive the maximum dose from both direct penetrating radiation and dispersible radionuclides. For CY 2001, this maximum annual dose to an individual was determined to be 0.004 millisievert (mSv) (0.4 millirem [mrem]), or only about 0.4% of the applicable DOE radiological standard of 1 mSv/yr (100 mrem/yr).[5] This estimate is also about 0.2% of the naturally occurring background radiation in the Bay Area. The estimate for background radiation in the Bay Area is 2.6 mSv/yr (260 mrem/yr).[6] Figure 1-1 shows that Berkeley Lab is a minor contributor to the dose received by a typical member of the public from all contributing sources of radiation (i.e., natural terrestrial background, medical, and consumer products). Berkeley Lab also estimates the cumulative dose impact (collective population dose) from its penetrating and dispersible radiological activities to the entire population found within an 80-kilometer (50-mile) radius of the Laboratory. This measure is the sum of all individual doses (i.e., ranging from a maximum of 0.004 mSv near the site boundary to essentially 0 mSv at an 80-kilometer distance) within the specified region. The collective population dose for CY 2001 was estimated at

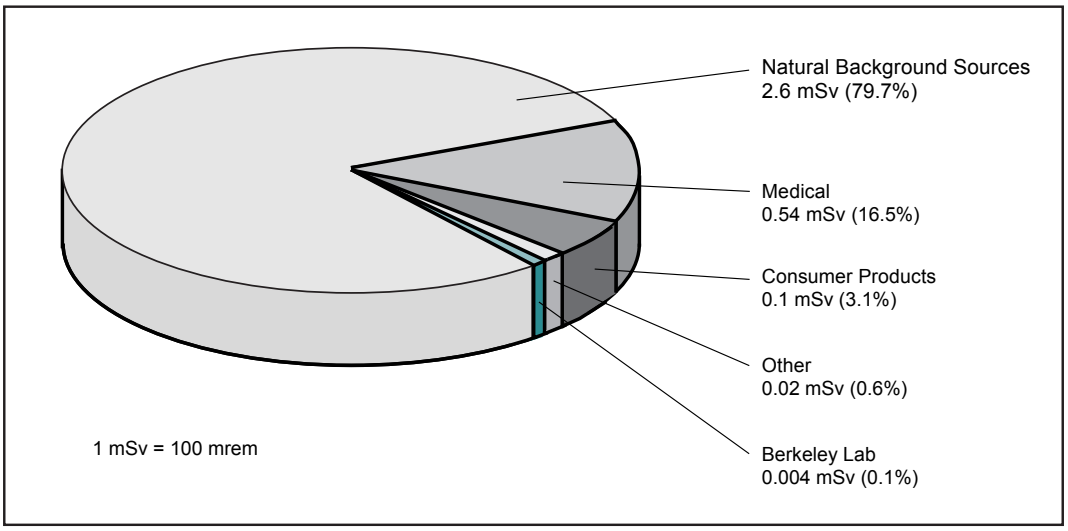


Figure 1-1 Typical Radiation Doses Received by the Public, Including Maximum Contribution from Berkeley Lab

0.009 person-Sv (0.9 person-rem), or about 0.00007% of the dose that the population within this region received from background radiation. 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.

Dispersible radionuclide emission sources are regulated by the United States Environmental Protection Agency (US/EPA). US/EPA has set 0.1 mSv/yr (10 mrem/yr)[7] as the maximum allowable dose to the public from all exposure pathways (e.g., inhalation, ingestion) 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 only. The estimated maximum potential dose from all airborne radionuclides released from the Laboratory site in CY 2001 was about 0.0006 mSv (0.06 mrem), with tritium accounting for about 75% of that amount. This dose is about 15% of Berkeley Lab's total maximum dose to the public for both penetrating radiation and dispersable radionuclides, and it is 0.6% of the US/EPA limit for dispersible radionuclide emissions.

A one-year program of supplemental environmental tritium monitoring was begun in April 2001 for the US/EPA's re-evaluation of the site for the National Priorities List (NPL) and for response to community concerns. The results from samples collected in CY 2001 confirm that tritium concentrations at Berkeley Lab are low and do not pose significant risks to human health or the environment. A summary of the results are included in Chapter 10.

1.6.2 Nonradiological Monitoring

Berkeley Lab's nonradiological monitoring program focuses primarily on water, soil, and sediment. In compliance with the four wastewater discharge permits[8] 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[9] issued by the State Water Resources Control Board. Stormwater discharges are treated differently from wastewater in that no specific discharge limits are cited in the permit. References in the permit to the Water Quality Control Plan (Basin Plan)[10] for the San Francisco Bay Basin are intended as guidelines rather than measures of compliance for stormwater discharges. Berkeley Lab analyzes stormwater samples for a wide set of potential contaminants, including pH, oil and grease, total suspended solids, and 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 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. There are four types of plume contaminants:

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

The Laboratory continues to characterize 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 for oil and grease samples collected near roadways or parking lots, and some metal concentrations that were slightly above normal background ranges. In all instances, measured levels of contaminants did not exceed any regulatory limits. The levels of oil and grease measured at Berkeley Lab are typical for an urban setting, and the levels of metals probably result from the presence of items such as pressure-treated wood and galvanized iron fences. However, Berkeley Lab will continue to monitor these locations. For more on Berkeley Lab's impact on soil and sediment, see Chapter 7.

2

Introduction

2.1 HISTORY

Berkeley Lab 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 directed at 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 other Berkeley Lab scientists.

The Laboratory supports work in such diverse fields as fundamental physics, energy conservation technology, materials science, structural biology, medical imaging, and advanced battery technologies.[1] 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 U.S. Department of Energy (DOE) mission concepts of exploring the complexity of energy and matter, advancing the science needed to attain abundant clean energy, understanding energy impacts on our living planet, and 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, also 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 479 hectares (1,183 acres) of land owned by the University of California. The Laboratory's 80-hectare (200-acre) main site is under long-term lease to DOE.

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

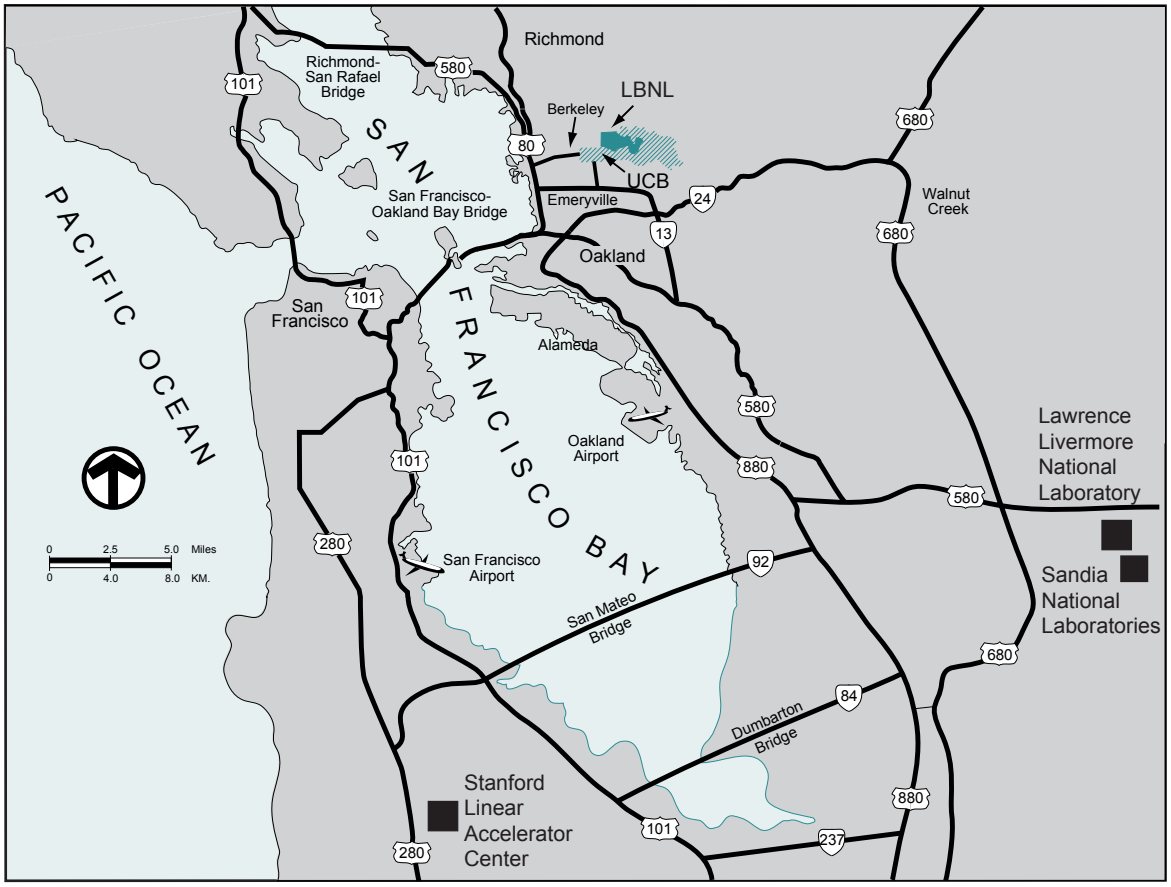


Figure 2-1 San Francisco Bay Area Map

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

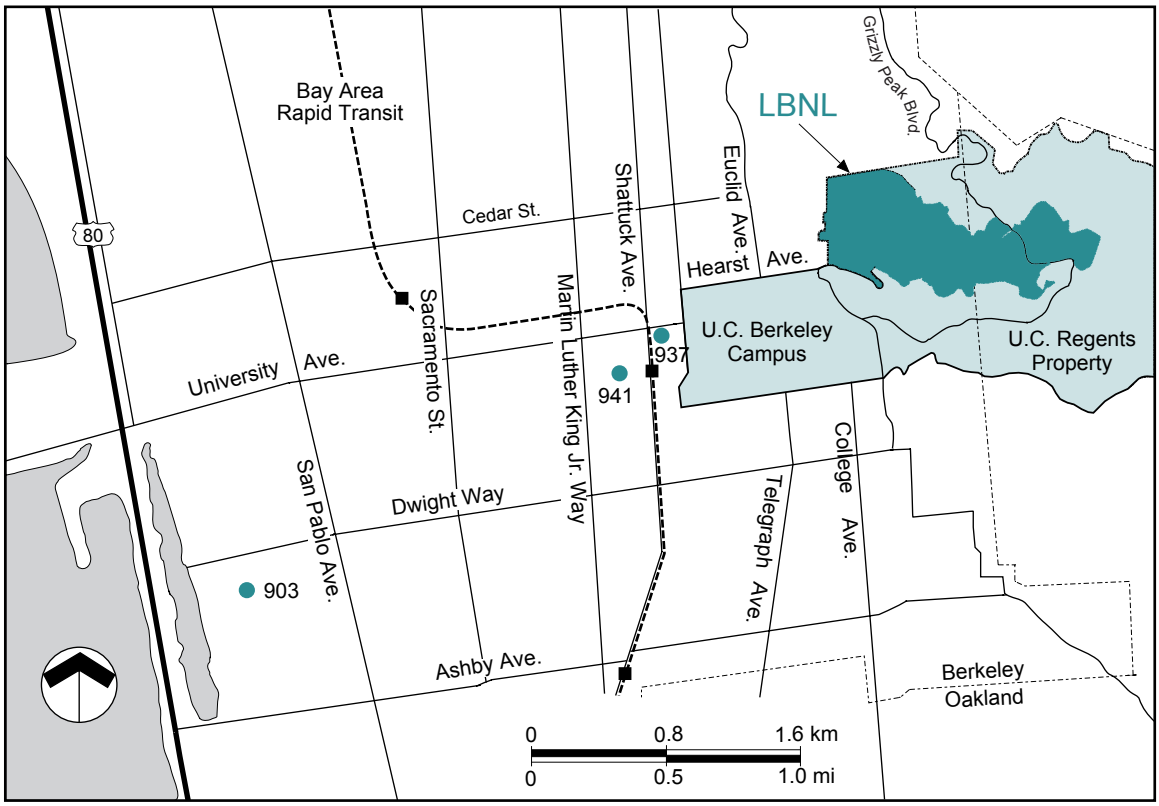


Figure 2-2 Vicinity Map

Berkeley Lab research and support activities are conducted in structures having a total area of 190,000 gross square meters (2.05 million gross square feet). Eighty-five percent of this space is on the main site, 4% is on the UC Berkeley campus (i.e., Donner and Calvin laboratories), and the remaining 11% is located in various other off-site buildings. Figure 2-4 shows the Berkeley Lab space distribution.

2.2.3 Water Supply

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

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 ensured by two separate connections to EBMUD's Shasta and Berkeley View sources

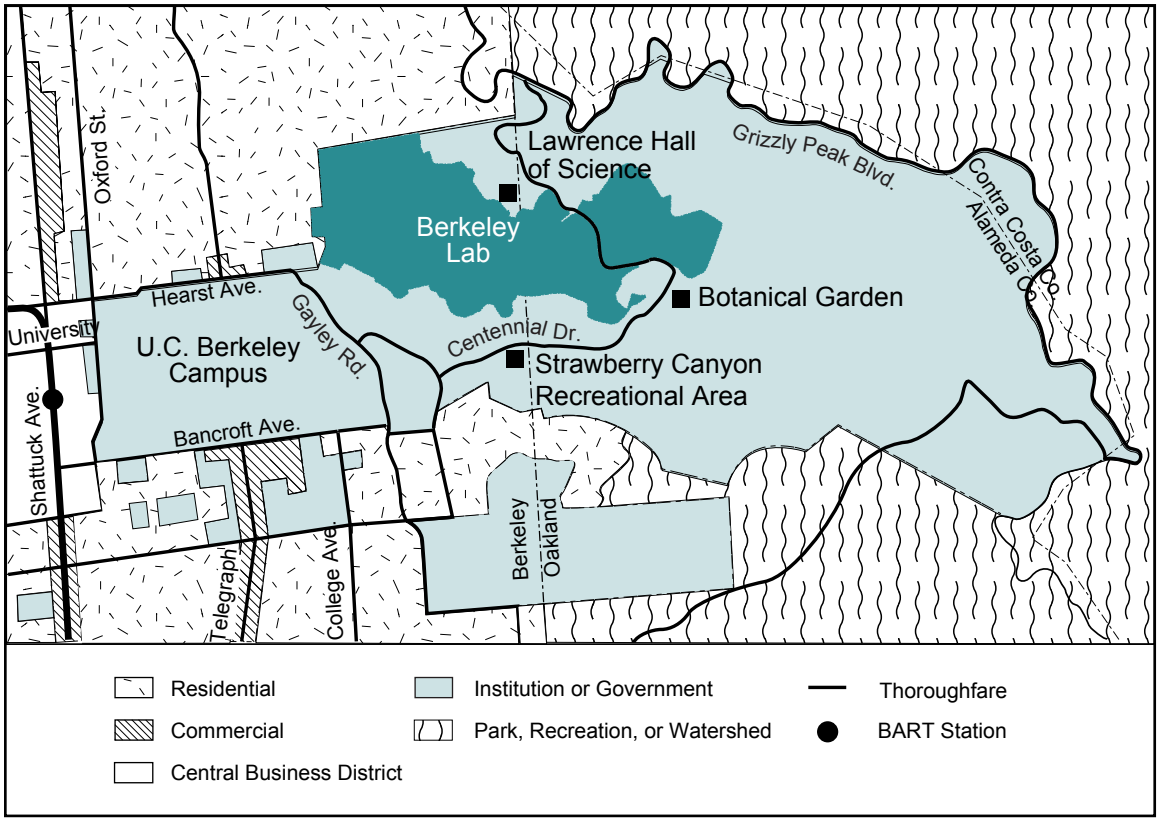


Figure 2-3 Adjacent Land Use

and two 760,000-liter (200,000-gallon) on-site storage tanks. 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.

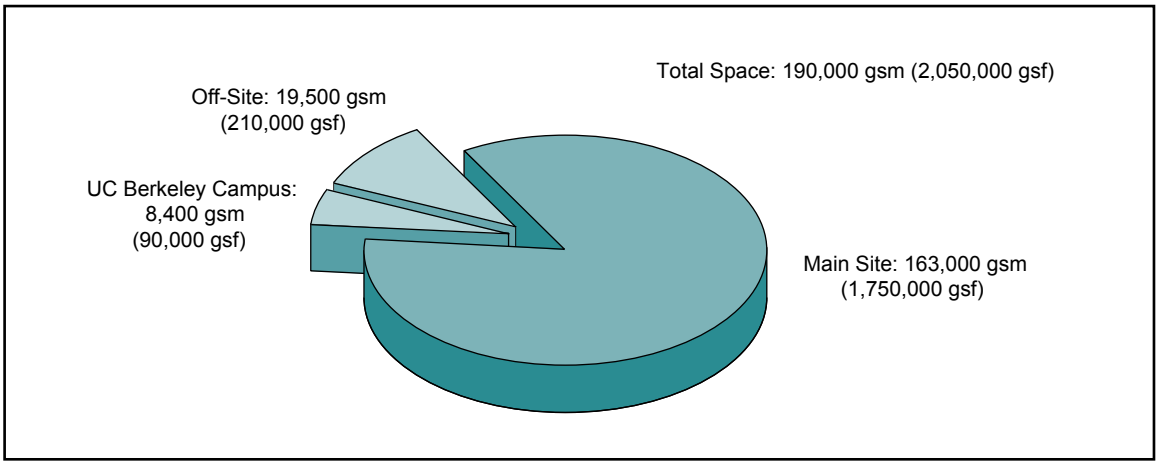


Figure 2-4 Space Distribution

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 site's relatively warm, wet winters and cool, dry summers. 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 (windrose), illustrates the frequency of the two predominant wind patterns. Precipitation data are provided in Figure 2-7, which compares 2001 monthly precipitation totals to the average since 1974.

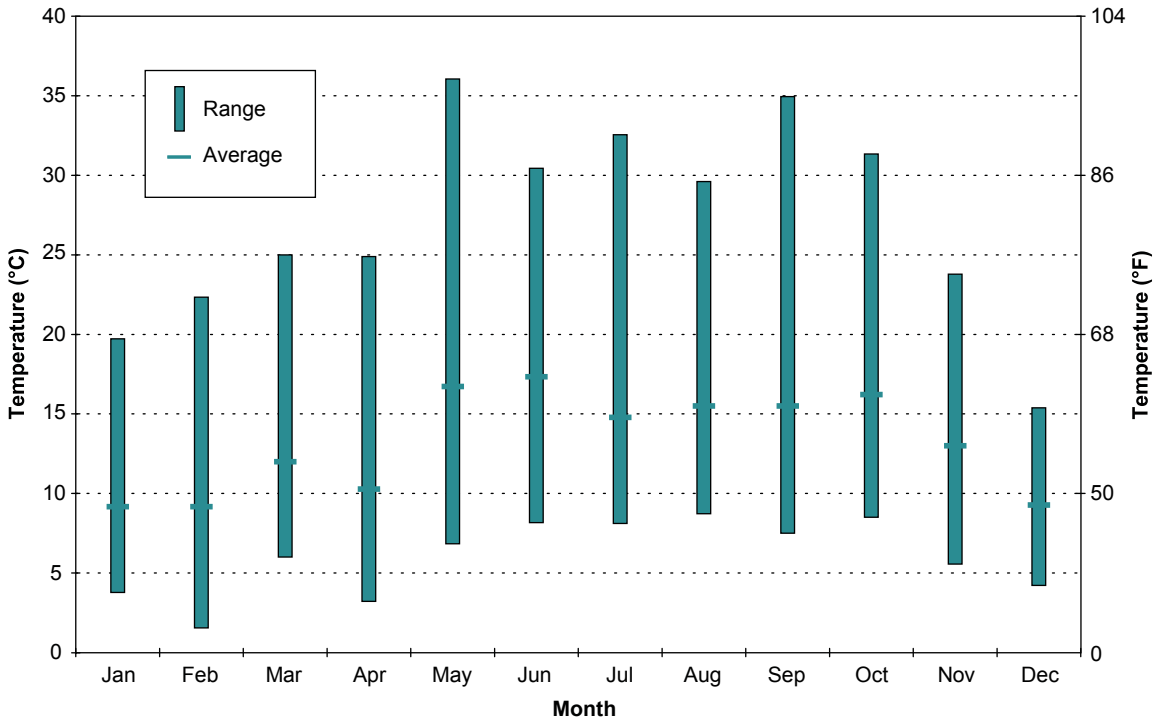


Figure 2-5 Temperature Summary by Month

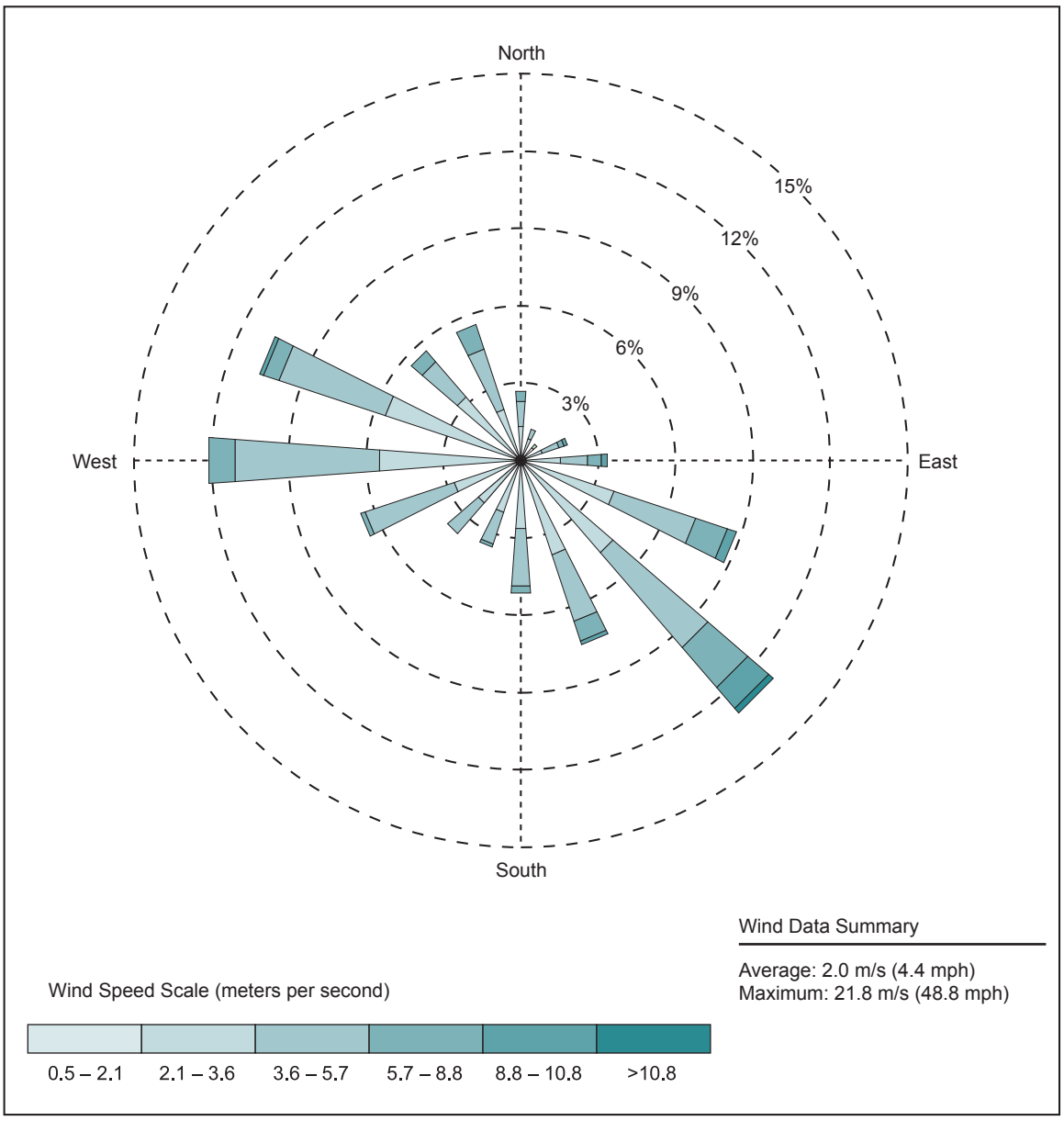


Figure 2-6 Annual Wind Patterns

2.3.2 Vegetation

Berkeley Lab's vegetation management program reinforces native and naturalized vegetation and avoids disruption of outlying natural habitats wherever possible. Because visual screening of the Laboratory is an important community objective, the Laboratory works to maintain and renew groves of both native and nonnative trees that are important to this screening effect. No rare, threatened, or endangered species of plants are present on the site. Figure 2-8 shows the vegetation types and locations on-site.

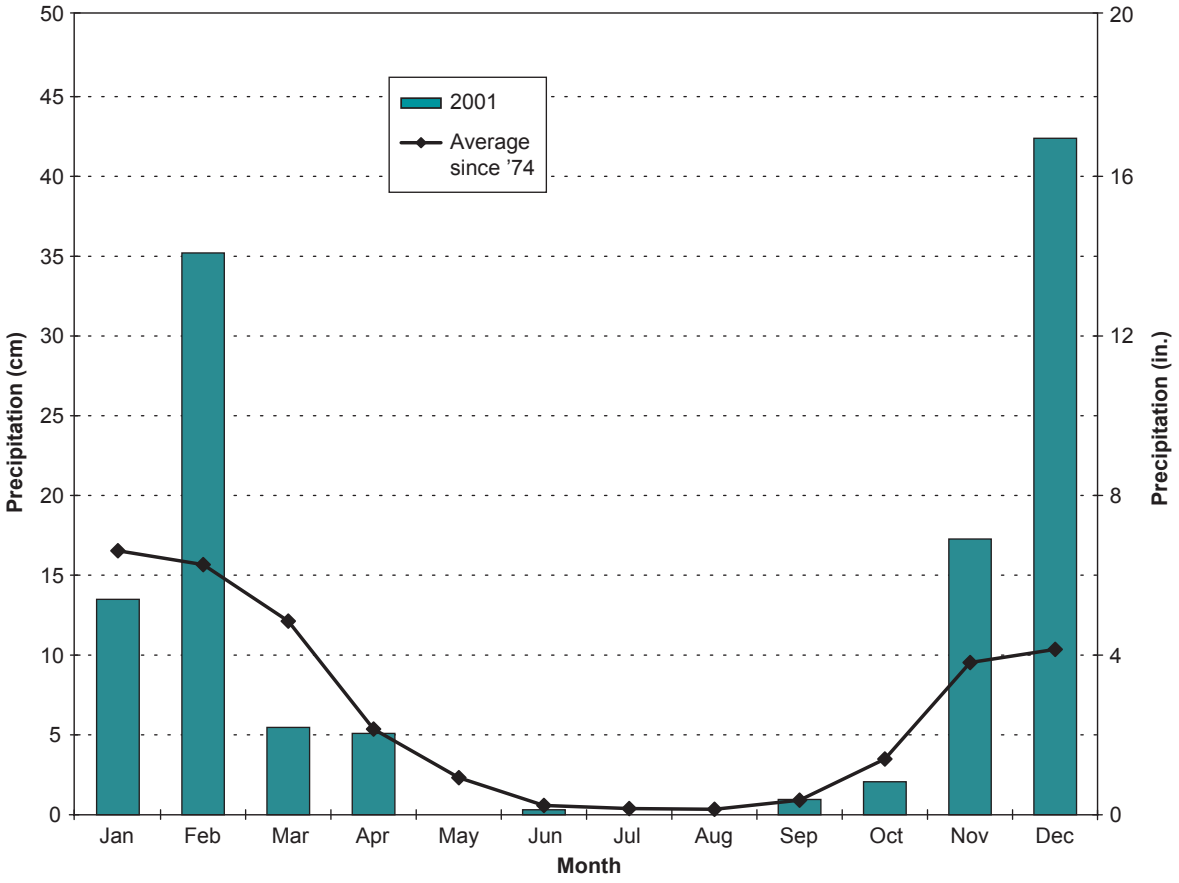


Figure 2-7 Precipitation Summary by Month

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 Diablo wind-driven firestorm similar in intensity to that of 1991. The Laboratory uses the national successional trends of existing vegetation to reduce fire risks. As part of this program, the Laboratory has effectively removed a number of invasive exotic plants from the site, including French broom, artichoke thistle, Cape ivy, and pampas grass. In addition, the Laboratory has removed and thinned eucalyptus stands across the site. After removal and thinning operations are completed, erosion-control measures are installed and these areas are seeded with native grasses and forbs.

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.

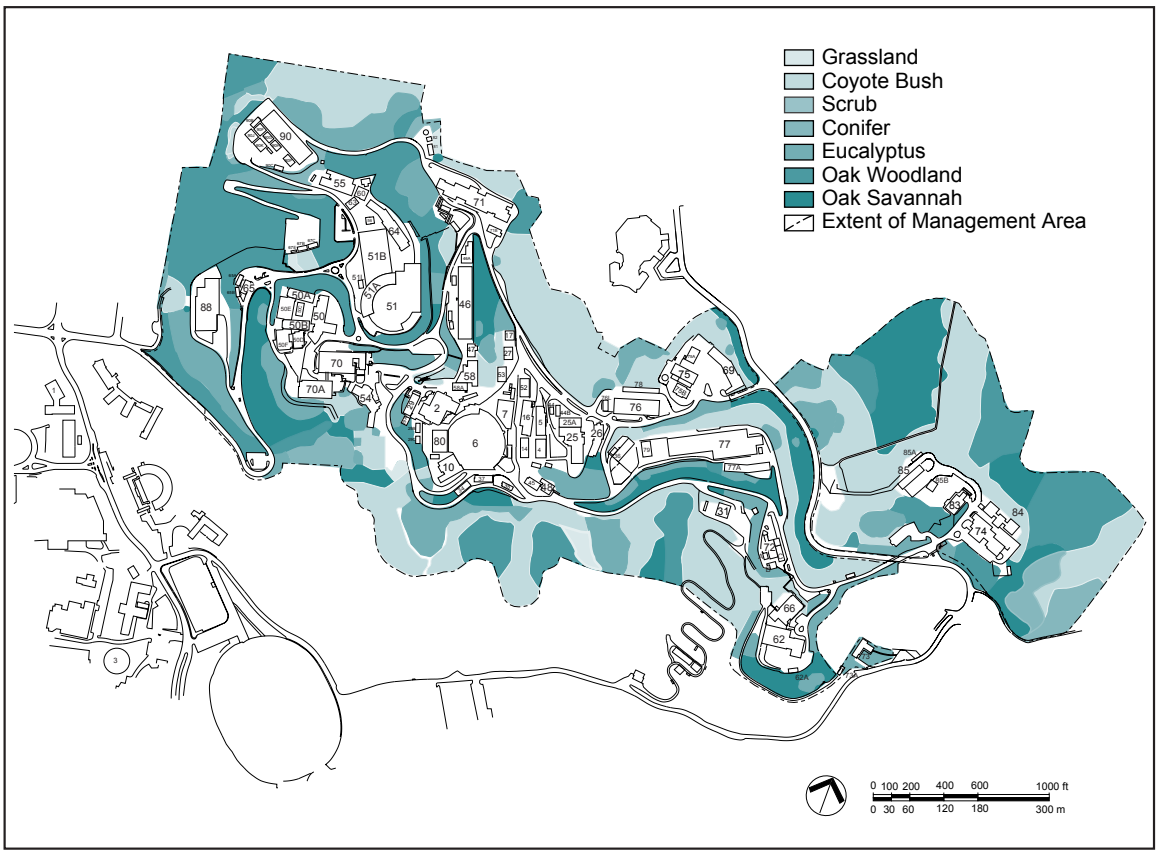


Figure 2-8 Vegetation Types

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. Berkeley Lab's grass/forb lands, brush lands, and trees provide cover, food, and breeding sites for wildlife typical of disturbed (e.g., previously grazed) areas with a Mediterranean climate located in midlatitude California. Over 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 U.S. 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 Berkeley Lab property. The most abundant large mammal is the Columbian black-tail deer. The Laboratory's tree stands offer nesting and cover sites for many resident and migratory species of birds.

2.3.4 Geology

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 claystones, 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. 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 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 at 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, landsliding, paleotopography, and tilting of the rock units underlying the site have created a complex geological structure.

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.

2.3.5 Hydrogeology

The hydrogeology at Berkeley Lab is complex. The ancient landslide deposits underlying the site generally consist of fractured volcanic rocks that readily allow groundwater movement, while the sedimentary rocks generally impede groundwater flow. The relationship between high-permeability landslide deposits and low-permeability sedimentary rocks is complex because of landsliding and the paleotopography. Additionally, coarse-grained strata in the sedimentary rocks may form confined aquifers at some locations.

Groundwater flow is a concern at the Laboratory because of its potential effect on slope stability, as well as on the 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, with moderately spaced open fractures that allow for groundwater movement. The hydraulic conductivity ranges between approximately 10^{-5} and 10^{-8} m/s (3.3×10^{-5} and 3.3×10^{-8} ft/s).
- The Orinda Formation consists primarily of fine-grained sediments with closed fractures. The hydraulic conductivity of the fined-grained sediments of this formation ranges between approximately 10^{-7} to 10^{-12} m/s (3.3×10^{-7} to 3.3×10^{-12} ft/s). The Orinda Formation typically has lower values of hydraulic conductivity than the underlying Great Valley Group or overlying Moraga Formation and therefore impedes the horizontal and vertical flow of groundwater.
- The volcanic rocks in the ancient landslide deposits constitute the main waterbearing unit at Berkeley Lab. The hydraulic conductivity within the Moraga Formation is relatively high, generally ranging between 10^{-4} and 10^{-6} m/s (3.3×10^{-4} and 3.3×10^{-6} ft/s). Although this rock material 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.

3

Environmental Program Summary

3.1 INTRODUCTION

This chapter provides an overview of Berkeley Lab'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) 2001.

3.2 OVERVIEW OF ENVIRONMENTAL RESPONSIBILITIES

In order 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 Berkeley Lab 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 the risks associated with any activity to acceptable levels. Acceptable levels are determined by responsible line management, but are always in conformance with all applicable laws.
4. *Work Performance*. Conducting the tasks to accomplish the activity 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 is responsible for administering environmental protection and compliance programs at Berkeley Lab. The organizational structure of EH&S as of CY 2001 is shown in Figure 3-1.

The Environmental Services Group (ESG) oversees site-wide 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 CY 2001 monitoring result summaries, see Chapters 4–11. The Waste Management Group (WMG) manages hazardous, medical, radioactive, and mixed (hazardous and radioactive) waste generated at the Laboratory. The Radiation Protection Group (RPG) 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 U.S. Department of Energy (DOE)-reportable environmental incidents at Berkeley Lab for CY 2001.

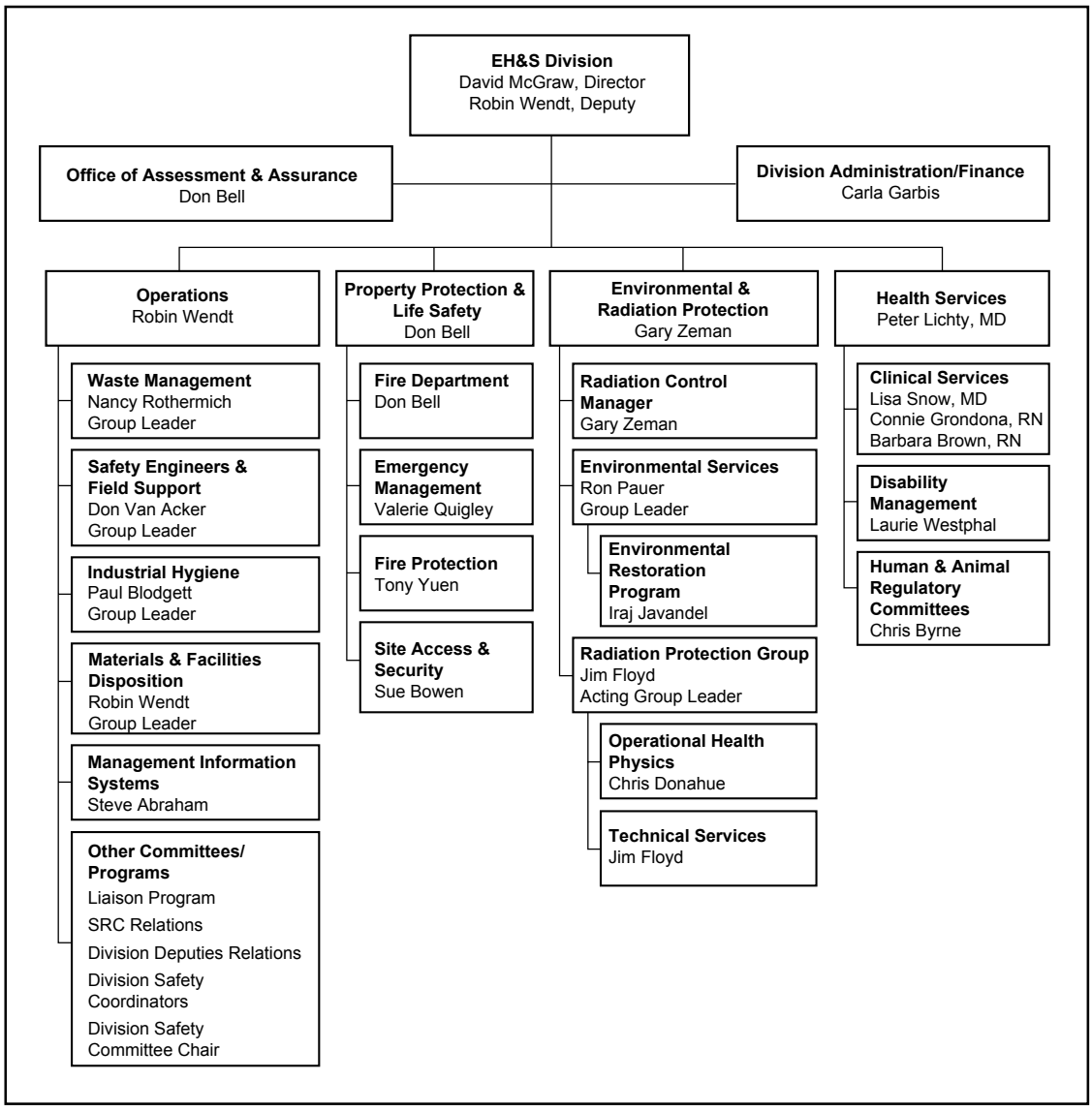


Figure 3-1 Berkeley Lab Environment, Health and Safety Division Organization

3.3.1 Summary of Environmental Permits

Certain Berkeley Lab activities require operating permits from environmental regulatory agencies. Table 3-1 summarizes, by area of environmental activity, the 27 active permits held by Berkeley Lab 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 2001

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD	Various activities with emissions to air	11	Section 3.4.1.2
Hazardous waste	DTSC	Hazardous Waste Handling Facility operations	2	Section 3.4.4.1
Hazardous waste	City of Berkeley	Fixed Treatment Units	1	Section 3.4.4.1
Stormwater	SWRCB	Site-wide 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	Site-wide and operation-specific wastewater discharges to sanitary sewer	4	Section 3.4.6.1

CY 2001. 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 three notices of violation from the two inspections by the City of Berkeley in November and December. See Sections 3.4.3.1.2 and 3.4.6.4 for details.

DOE's Office of Environment, Safety and Health Oversight (EH-2) conducted an inspection of environmental monitoring programs at Berkeley Lab July 9–19, 2001. The primary purpose of the inspection was to assess the accuracy and the adequacy of methods and programs for quantifying releases of contaminants to the environment and resulting impacts on the public and the environment. The inspection focused on radionuclide releases and monitoring, and it used DOE's integrated safety management program as a framework for the inspection. The inspection encompassed five areas: monitoring and migration of liquid effluents, direct radiation, radiological air emissions and resulting dose estimates, groundwater monitoring and protection, and line management oversight.

The DOE inspection found that the Berkeley Lab programs were effective for detecting and monitoring the release of contaminants to the environment and that they were in compliance with related DOE and federal regulations and requirements. No serious findings or issues were identified that required formal correction. The inspection did make six observations where Berkeley Lab could further enhance implementation of DOE environmental and radiological standards, and Berkeley Lab has addressed each of those observations. In addition, the inspection identified six positive attributes associated with the programs that it pointed out as being exemplary.

Table 3-2 Environmental Audits, Inspections, and Appraisals in CY 2001

Organization	Inspection title	Start date	Length (days)	Violations
City of Berkeley	Underground Storage Tanks	November 7	2	2
	Inspection of Hazardous Materials Business Plan, Fixed Treatment Units, and Hazardous Waste Generation Areas	December 10	1	1
EBMUD	Wastewater monitoring inspections at Hearst and Strawberry Outfalls	January 16 March 27 June 18 November 21	1 1 1 1	0 0 0 0
	Wastewater monitoring inspections at B77 Treatment Unit	May 21	1	0
	Inspection of motor pool at B76	April 2	1	0
	Wastewater monitoring inspections at B25 Treatment Unit	February 5 July 26	1 1	0 0
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry Outfalls	January 17 April 16 July 9 October 30	1 1 1 1	0 0 0 0
	EBMUD self-monitoring inspections at B77 Treatment Unit	January 11 April 9 October 22	1 1 1	0 0 0
	EBMUD self-monitoring inspections at B25 Treatment Unit	January 8 April 18 December 3	1 1 1	0 0 0
	EBMUD self-monitoring inspections at groundwater treatment units	April 9 October 5	1 1	0 0
DTSC	DTSC inspection of Hazardous Waste Handling Facility (HWHF)	January 17	3	0
Contra Costa County	Inspection of Hazardous Waste Generation Areas	December 13	1	0
DOE EH-24	Inspection of Environmental Monitoring and Surveillance programs	July 9	9	0

3.3.3 Summary of DOE Reportable Environmental Incidents

Two environmental incidents in 2001 were reportable under the DOE occurrence-reporting program.[1] (DOE's occurrence reporting program is designed to track incidents across the DOE complex.) The first was the discovery of a sump that drains the Building 75 hillside exhaust stack. The sump was not part of any routine maintenance or monitoring program, and it was found to contain water contaminated with tritium. This incident is described in greater detail below. The second was the result of an inspection by the City of Berkeley, whereby two violations were identified related to underground storage tank operation. No injuries, accidents, or damage resulted

from these incidents. Table 3-3 describes these two incidents and gives the sections of this report where they are discussed.

During the EH-24 inspection in July 2001, an outdoor sump (containing water) was found that drains the hillside exhaust stack of the National Tritium Labeling Facility (NTLF) behind Building 75. The sump was constructed of concrete, was approximately 440 liters (115 gallons) in volume, and was covered by a wooden decking. Berkeley Lab staff were not aware of the sump. Berkeley Lab analyzed the sump water and determined that it contained tritium at a concentration of 5.2×10^4 Bq/L (1.4×10^6 pCi/L). Because the sump water was not a source of drinking water, the concentration was not a health concern. The sump was approximately 80% full of water and the total tritium activity was about 0.5 millicurie. Although the sump water represented a very minor air emission source, Berkeley Lab assessed and reported this source as part of the Annual National Emission Standards for Hazardous Air Pollutants (NESHAPs) Report for CY 2001. In November 2001, the stack drain line was extended to an aboveground container for the controlled collection of water, and the previous sump was filled with cement.

No radionuclides were released when the sump was discovered; however, there is the potential that at some time in the past overflow or leakage from the sump may have contributed to soil or groundwater contamination. This area is currently under investigation by the Environmental Restoration Program for tritium contamination.

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[2] 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); and
- Ozone-depleting substances (e.g., chlorofluorocarbons or "freons").

The State of California's own air pollution control program[3] gives it additional powers to control sources of air emissions.

Table 3-3 Summary of Environmental Incidents During 2001

Incident Date	Report Number	Description	Section for more information
July 11	EHS-01-1	Sump discovery at Building 75	3.3.3
November 15	OPS-01-2	Notice of violation for Underground Storage Tanks	3.4.6.4

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),[4] as well as sections of DOE Orders 5400.1[5] and 5400.5.[6] Subpart H is part of the NESHAPs program. The U.S. 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 moderate- to high-hazard projects that may release radionuclides. This review includes a determination of the dose to the nearest off-site member of the public (the maximally exposed individual, or MEI) following NESHAPs regulations and DOE EH-0173T[7] guidance. The assessment takes a conservative or worst-case approach by assuming that no portion of the radionuclides projected to be released are collected by emission controls, even if such controls exist. Berkeley Lab's method for determining the appropriate level of sampling, monitoring, or 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 Environmental Services Group Web page at http://www.lbl.gov/ehs/esg/.

On September 14, 2001, the National Institutes of Health (NIH) and Berkeley Lab announced that NIH was withdrawing funding for the NTLF and that the NTLF would terminate operations in December 2001 after 19 years of service. In December the NTLF ceased operating, and the inventory of tritiated hydrogen (HT) gas used for labeling activities was removed and shipped to a DOE facility. Berkeley Lab has prepared a work plan for the clean closure of the facility, and cleanup activities are under way.

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. Mobile source emissions (e.g., motor vehicles) are the notable exception.

At the end of CY 2001, Berkeley Lab held operating permits from BAAQMD for ten activities, with an Authority to Construct approval for an eleventh activity.[8] (The operating permit will follow completion of construction.) 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.[9] For a list of active operating permits, see Table 3-4.

Regulations affecting the phaseout of ozone-depleting substances are largely administered at the federal level by US/EPA, although the City of Berkeley has its own ordinance on these materials. The Laboratory has made extensive progress in eliminating emissions of the Class I ozone-depleting substances from activities such as centrifugal chillers, refrigeration and freezer equipment, solvent cleaning systems, fire suppression operations, and research equipment. 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 (13,200 pounds). Currently, emissions are estimated at less than 10 kilograms (22 pounds) each year, a reduction of more than 99% from levels a decade earlier.

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)[10] 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 3-4 Air Emission Sources Permitted By BAAQMD at the End of 2001

BAAQMD category	BAAQMD source number	Description	Building	Abatement type
Combustion equipment	191	Standby emergency generator[a]	64	Catalytic converter
Gasoline dispensing	76	Gasoline pumps	76	Vapor recovery
Surface coating and printing	74	Paint spray booth	76	Liquid separator
	96	Paint spray booth	77	Dry filter
	147	Epoxy-mixing hood	53	—
Surface preparation and cleaning	97	Sandblast booth	77	Baghouse
	140	Vapor degreaser	52	Chiller
	188	Wipe-cleaning	Site-wide	—
Miscellaneous	189	Soil vapor extraction	7E	Activated carbon
	190	Soil vapor extraction	58	Activated carbon
	192	Soil vapor extraction	7	Activated carbon

[a] Authority to Construct approval obtained in 2001

At the request of the Committee to Minimize Toxic Waste (CMTW), 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 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 releases permitted under the Clean Air Act. US/EPA determined, based on CERCLA screening criteria, that the site is eligible for the NPL. US/EPA also determined, however, that existing data indicate 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 list. 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. For a summary of the supplemental monitoring performed in 2001, see Chapter 10.

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).[11] 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 it once sent fluorescent/mercury lamps and mercury-contaminated debris to the Quicksilver site. Berkeley Lab and other potentially responsible parties are negotiating allocation of the cleanup costs with DTSC.

3.4.3 Hazardous Materials

The following sections discuss programs related to the Emergency Planning and Community Right-to-Know Act, Toxic Release Inventory, 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

The Emergency Planning and Community Right-To-Know Act (EPCRA) was passed in 1986 as Title III of the Superfund Amendments and Reauthorization Act (SARA).[12] This 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.[13] 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

DOE facilities such as Berkeley Lab are required under Executive Order 13148 (Greening the Government Through Leadership in Environmental Management)[14] to evaluate the applicability of the Toxic Release Inventory (TRI) reporting requirements of EPCRA. TRI reporting consists of two steps: (1) determining usage and (2) submitting US/EPA Form R if threshold quantities are exceeded.

Berkeley Lab determined that no chemical usage during CY 2001 exceeded the TRI criterion of 4,536 kilograms (10,000 pounds) for a listed substance and that, therefore, preparation of a Form R was not necessary. Table 3-5 shows the highest usage levels of the chemicals from the Laboratory's assessment over the last several years, including several substances either recently removed from the TRI list by US/EPA or now listed by US/EPA for reasons of use or production not found at Berkeley Lab.

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)[15] to the City of Berkeley each year, although federal sovereign immunity from such regulations has not been waived.

The 2001 HMBP included a list of all hazardous materials present in amounts exceeding the state's aggregate threshold quantities (i.e., 208 liters [55 gallons] for liquids, 227 kilograms [500 pounds] for solids, and 5.7 cubic meters [200 cubic feet] for compressed gases) on a building basis. The plan included annotated floor plans and summary documentation on emergency plans, procedures, and training.

On December 10–11, 2001, the City of Berkeley Toxics Management Division (TMD) performed a routine facility inspection of the Berkeley Lab Hazardous Materials Management Program. TMD is

Table 3-5 Trends in Highest Quantities of EPCRA Toxic Release Inventory Reporting

Substance	1998 (kg)	1999 (kg)	2000 (kg)	2001 (kg)
Chlorofluorocarbons	143	44	246	260
Methanol	266	759	468	593
Nitric acid	707	709	746	861
1,1,1-Trichloroethane	69	44	21	2

the local Certified Unified Program Agency (CUPA) for Berkeley. Based on that inspection, on February 2, 2002, the City of Berkeley issued a written Notice of Violation (NOV) to Berkeley Lab. The NOV found the chemical inventory submitted to the City to be incorrect; specifically, a quantity of sulfuric acid was present in Building 77 that exceeded the 55-gallon threshold for chemical inventory reporting but was not reported. Berkeley Lab responded by completing a work plan to correct the deficiency within the required 30-day period.

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 an RMPP is not required for the site.[16]

3.4.3.2 Federal Insecticide, Fungicide, and Rodenticide Act

Passed by Congress in 1972, the Federal Insecticide, Fungicide, and Rodenticide Act[17] 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 Toxics Substances Control Act

The objective of the Toxic Substances Control Act (TSCA)[18] is to minimize the exposure of humans and the environment to chemicals found in manufacturing, processing, commercial distribution, or 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 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 inventoried TSCA-regulated PCB transformers (PCB concentrations greater than 500 ppm). The remaining TSCA-PCB equipment items are four large low-voltage capacitors. These capacitors are still in use, containing an estimated 170 kilograms (375 pounds) of regulated PCB dielectric fluid. Because of the small amounts of PCBs, the Laboratory is not required to prepare an annual PCB report for US/EPA; however, records of PCB usage are maintained.

3.4.4 Hazardous Waste (Resource Conservation and Recovery Act)

The primary goal of the Resource Conservation and Recovery Act of 1976 (RCRA)[19] 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[20] laws. 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 tier; however, the other three tiers have been delegated to the City of Berkeley for oversight. Listed in decreasing order of regulatory complexity, these tiers are:

- Full permit,
- Standardized permit,
- Permit-by-rule,
- Conditional authorization, and
- 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[21] was approved by DTSC on May 4, 1993, and is valid for ten years. The permit allows for storage and treatment of certain hazardous and mixed wastes at the HWHF. Allowed 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 medical, hazardous, radioactive, and mixed waste generated at the Laboratory off-site for disposal. 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 and then discharged in conformance with the EBMUD wastewater discharge permit.

Berkeley Lab has an additional hazardous waste permit[22] to operate five fixed treatment units (FTUs). The type and location of each unit are listed in Table 3-6. 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 3-6 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 separator	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 2001, the Laboratory submitted the 2001 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 for 2001,[23] 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 Waste Reduction Report,[24] 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 (STP),[25] 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 annually in October for the previous fiscal year.

3.4.4.2 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; and
- Development and implementation of plans to remediate contaminated areas.

The RCRA Facility Investigation (RFI) 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 whenever there was an imminent threat to human health or 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.

3.4.4.3 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[26] 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 12 buildings, including 3 off-site buildings. The Life Sciences programs are the primary generators of medical waste. Berkeley Lab does not treat any medical waste; treatment of medical waste is performed at off-site vendor facilities. Berkeley Lab ships medical waste off-site for treatment through incineration or steam sterilization.

Under the state's program, Berkeley Lab is considered a large-quantity generator because it generates more than 91 kilograms (200 pounds) of medical waste each month. All large-quantity generators, including Berkeley Lab, are required to register and are subject to annual inspections. There were no inspections from outside agencies in 2001. Berkeley Lab continues to dispute some of the findings from the last inspection in July 2000. The final status of the contested violations has not yet been resolved.

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)

Executive Order 13101 (Greening the Government through Waste Prevention, Recycling, and Federal Acquisition)[27] replaces 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:

- Paper and paper products,
- Vehicular products,
- Construction products,
- Transportation products,
- Park and recreation products,
- Landscaping products,
- Miscellaneous products, and
- 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 buyers 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 produced 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[28] in 1989. With an emphasis on minimizing waste and preventing pollution, the Act has the following goals:

- To reduce hazardous waste at its source;
- To encourage recycling wherever source reduction is not feasible or practicable;
- To manage hazardous waste in an environmentally safe manner and minimize present and future threats to health and the environment if it is not feasible to reduce or recycle; and
- To 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,[29] and the Hazardous Waste Management

Report Summary.[30] 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[31] 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 remain below the *de minimis* numbers identified in the Act and are not subject to its reporting requirements.

3.4.6 Water Quality (Clean Water Act)

The Clean Water Act (CWA)[32] regulates the discharge of pollutants to the waters of the United States from both point and nonpoint sources using various means, including development of pollutant discharge standards and limitations and a permit and licensing system to enforce these standards. California is authorized by US/EPA to administer the principal components of the federal water quality management program.

Additionally, the Porter-Cologne Water Quality Control Act[33] established a comprehensive statewide system for regulating water use in California. This 1969 Act provides for the three-tiered system that is still in use today: the State Water Resources Control Board (SWRCB), the nine RWQCBs, and local governments.

For Berkeley Lab, the regional authority is the San Francisco Bay RWQCB. The local authorities are (a) the cities of Berkeley and Oakland for stormwater and (b) EBMUD for drinking water supply and wastewater.

3.4.6.1 Wastewater

The Laboratory has four wastewater discharge permits[34] issued by EBMUD for the following activities:

- General site-wide wastewater discharge;
- Discharge from the treatment unit at the metal finishing operations in Building 25;
- Discharge from the treatment unit at the metal finishing operations in Building 77; and
- Site-wide discharge of treated 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. For 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 April 2, EBMUD inspected the vehicle maintenance facility. No violations resulted from any inspections.

The wastewater discharge permits for Buildings 25 and 77 require that the facility maintain a Toxic Organics Management Plan (TOMP).[35] 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)[36] is 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: site-wide 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[37] and will be combined for Building 25 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.[38] 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[39] and a Stormwater Monitoring Program.[40] Together, these documents represent the Laboratory's plan and procedures for identifying, monitoring, and reducing pollutants in its stormwater discharges. The Stormwater Monitoring Program was revised in December 2001.

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.[41] No regulatory concerns were raised by either agency regarding the annual report. For a summary of the stormwater monitoring results for CY 2001, 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 CY 2001.

3.4.6.3 Aboveground Storage Tanks

Aboveground storage tanks (ASTs) also fall under the authority of the Clean Water Act.[42] The Clean Water Act and the State's Aboveground Petroleum Storage Act[43] outline the regulatory requirement for this type of tank. Under the authority of the Clean Water Act, a Spill Prevention, Control, and Countermeasures (SPCC) plan[44] is required for petroleum-containing aboveground and

underground tanks. Berkeley Lab maintains an SPCC plan whose goal is to prevent and, if needed, mitigate potential spills or leaks from petroleum-containing tanks. ASTs are provided with secondary containment or spill kits to capture any potential spills. Also, ASTs are inspected periodically for corrosion, cracks, leaks, or other damage.

In November 2001, Berkeley Lab installed a new 6,000-gallon AST behind Building 64. This new AST supports a newly installed two-megawatt engine generator. Figure 3-2 shows the locations of the ASTs that contain petroleum products (e.g., gasoline and diesel fuel), excluding drum storage areas.

Nonpetroleum (i.e., chemical or hazardous) ASTs consist of FTU tanks, drum storage at Waste Accumulation Areas (WAA), and drum storage 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 during routine petroleum drum 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.[45] The

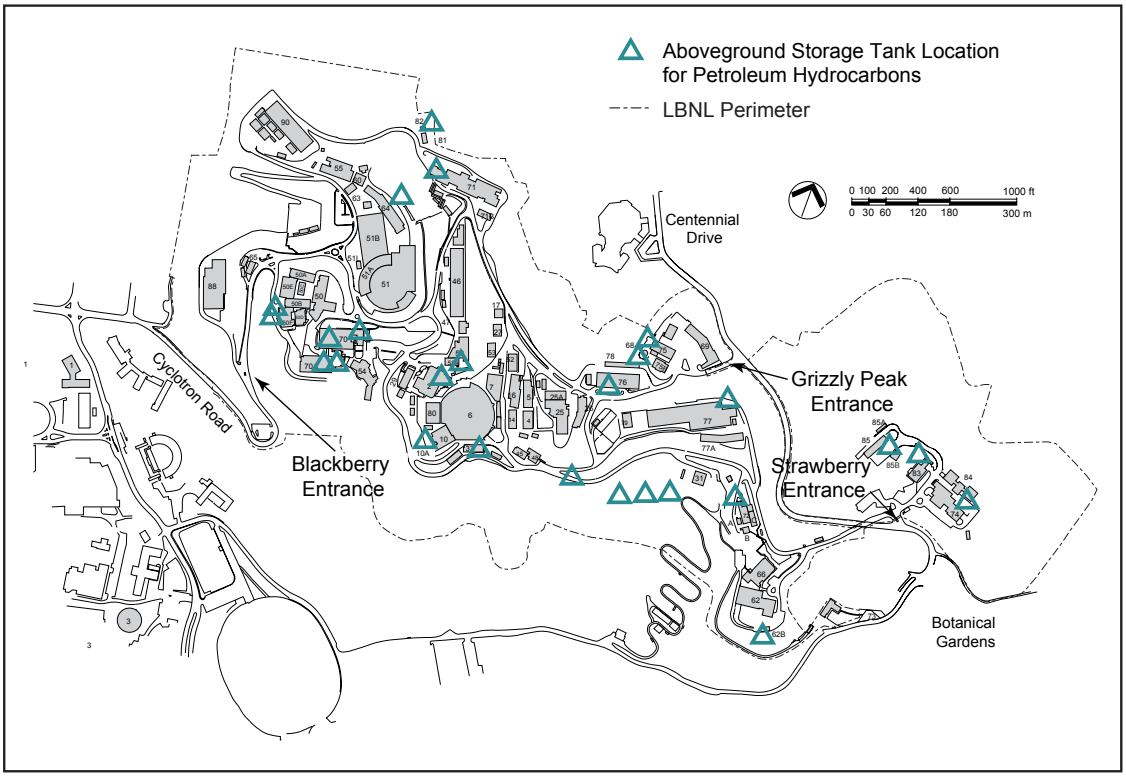


Figure 3-2 Aboveground Storage Tank Locations

state requirements for USTs containing hazardous materials include permitting, construction design, monitoring, record keeping, inspection, accidental releases, financial responsibility, and tank closure. The state's program satisfies the provisions of RCRA.[46] The City of Berkeley is the local administering agency for UST regulations that apply to Berkeley Lab.

At the end of 2001, eight permitted USTs remained at the Laboratory (see Table 3-7). The tanks contain either diesel fuel or unleaded gasoline. The Laboratory has removed seven tanks from the site since 1993.

On November 7 and 8, 2001, the City of Berkeley inspected all eight USTs. The City of Berkeley inspector found two minor violations and requested that repairs be made within sixty days. It was found that tank 55-1 did not have overfill protection. Also, the audible alarm for the leak monitor at Building 66 was found not to be operational. However, the alarm light and printout of the alarm status were both operational, and the system status is inspected daily. Repairs were completed in both areas by November 16, 2001 — within eight days. These two violations were entered into the DOE occurrence-reporting system used to track incidents.

3.4.7 Safe Drinking Water Act

The Safe Drinking Water Act[47] 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 drinking-water-supply distribution system 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 3-7 Underground Storage Tank Operating Permits from the City of Berkeley

Registration tank ID number	LBNL building number	Stored material	Capacity, 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
Double-walled steel 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 and Fire Departments have implemented methods of neutralizing chloramine in the water before it reaches a storm drain.

3.5 PROGRAM PERFORMANCE

Since 1994, Berkeley Lab, DOE, and Berkeley Lab's managing partner, the University of California Office of the President (UCOP), have used a system to measure the effectiveness of the Laboratory's environmental programs. These annual performance measures have been integrated directly into the operating contract for the site. Possible ratings include "unsatisfactory," "marginal," "good," "excellent," and "outstanding." Table 3-8 summarizes the UCOP and DOE ratings for each of the environmental performance measures for FY 2001.

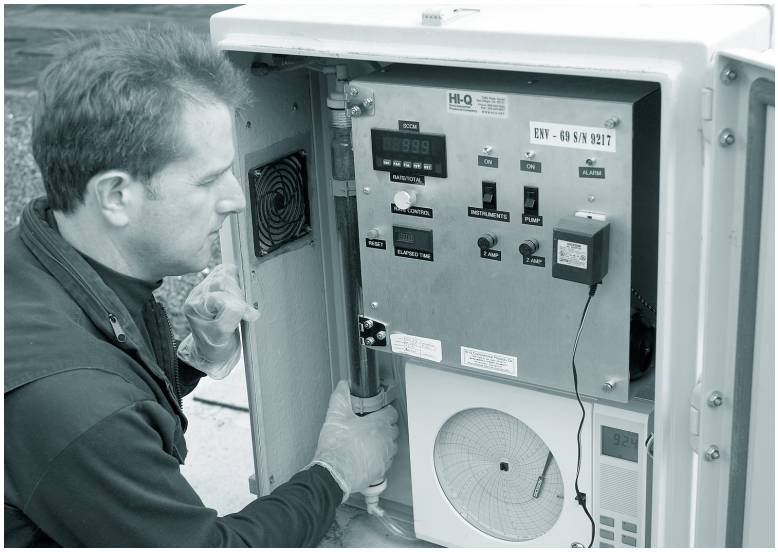
Berkeley Lab received outstanding performance ratings from both DOE and UCOP for all environmental performance measures except for one measure, which received an excellent rating. For more information on environmental performance objectives, criteria, and measures, go to Berkeley Lab's Office of Assessment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

Table 3-8 Environmental Performance Measure Ratings for FY 2001

Performance measure	UCOP rating	DOE rating
1) Radiation protection of the public and the environment	Excellent	Excellent
2) Tracking environmental incidents	Outstanding	Outstanding
3) Waste reduction and recycling	Outstanding	Outstanding
4) Integrated Safety Management Program	Outstanding	Outstanding
5) Waste management commitments	Outstanding	Outstanding
6) Program innovation in waste management and environmental restoration	Outstanding	Outstanding
7) Environmental restoration release site completions	Outstanding	Outstanding
8) Cost and schedule variance for environmental restoration activities	Outstanding	Outstanding
9) Cost variance for waste management activities	Outstanding	Outstanding

4

Air Quality



4.1 BACKGROUND

Berkeley Lab's air monitoring program is designed to meet the following requirements:

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

NESHAPs and DOE Order 5400.5 include monitoring requirements for radiological air emissions. DOE Order 5400.1 includes additional requirements for monitoring nonradiological air emissions.

Berkeley Lab's air quality monitoring program, as summarized in this report, measures only radiological emissions. Estimates of nonradiological air emissions generally use alternative methodologies (e.g., engineering calculations, record keeping, and dose/risk modeling) to satisfy regulatory requirements. The exceptions are a few Bay Area Air Quality Management District (BAAQMD)-permitted activities on-site that require periodic monitoring. The comprehensive Environmental Monitoring Plan[4] prepared by Berkeley Lab describes the basis and current scope of the air monitoring program at the Laboratory.

The air monitoring program consists of two separate 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 outdoor surroundings.

The number and placement of monitoring stations, as well as the parameters monitored and their frequency, are routinely reviewed to address changes in Laboratory operations or external requirements.

4.2 EXHAUST SYSTEM MONITORING RESULTS

Berkeley Lab uses various radionuclides in its radiochemical and biomedical research programs. In addition, radioactive materials are generated from the operations of charged-particle accelerators. Radionuclide releases through building exhaust systems are usually in the form of vapor or gas. Releases of solid particulate matter are the least common form, as high efficiency particulate air (HEPA) filtration is used to collect exhaust particulate.

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, fluorine-18, and argon-41.

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

Nuclide name (atomic number)	Symbol	Principal radiation types	Half-life
Carbon (6)	^{11}C ^{14}C	positron/gamma beta	20.5 minutes 5,730 years
Fluorine (9)	^{18}F	positron/gamma	109.7 minutes
Germanium (32)	^{71}Ge	gamma	11.4 days
Hydrogen/Tritium (1)	^{3}H	beta	12.3 years
Iodine (53)	^{123}I ^{125}I	gamma beta	13.1 days 60.14 days
Phosphorus (15)	^{32}P	beta	14.3 days
Sulfur (16)	^{35}S	beta	87.2 days
Technetium (43)	^{99m}Tc	gamma	6.0 hours

[a] For a complete list of radionuclides evaluated under NESHAPs regulations, see the Radionuclide Air Emission Annual Report for 2001, 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 1.0×10^{-3} millisieverts per year (mSv/yr) (0.1 mrem/yr).[1] As discussed in Section 3.4.1.1, Berkeley Lab uses a comprehensive strategy approved by the U.S. Environmental Protection Agency (US/EPA) to satisfy this requirement. This strategy involves three distinct levels of assessment:

- *Real-time monitoring*. Sophisticated monitoring systems that provide instant measurements.
- *Continuous sampling*. In-line instrumentation for collection of time-integrated air samples that undergo laboratory analysis following US/EPA protocols.
- *Administrative controls*. Strict administrative limits on radionuclide inventories combined with emission estimates.

These three assessment levels are applied to six stack source categories (see Table 4-2). The number and location of sources under the six compliance-assessment categories change in response to the research at Berkeley Lab. All but one source are considered "small sources" of emissions under NESHAPs. Most activities fall into Category V, which requires no monitoring. In calendar year (CY) 2001, there were 115 sources in this grouping that adhered to strict inventory limits specified in individual work authorizations. Twenty-three sources were assessed as Category II or III, which requires continuous sampling. Five locations have more rigorous real-time monitoring systems to estimate emissions, including the only compliance Category I source on-site (the hillside stack west of Building 75). Table 4-3 lists the source profile by category for the reporting year.

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

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

[a] AEDE

[b] 1mSv = 100 mrem

Collected stack exhaust samples were analyzed for five radiological parameters during CY 2001: 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. Tritium emissions for the entire Laboratory totaling 7.5×10^{11} becquerels (Bq) (20 curies [Ci]) were measured for the year, with nearly all tritium being emitted from the National Tritium Labeling Facility (NTLF) exhaust stacks. Table 4-4 provides the 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 2001

Monitoring type	Method	Location
Continuous Real-time	Real-time monitoring of ^{3}H	Bldg. 75 National Tritium Labeling Facility
	Real-time monitoring of ^{11}C, ^{13}N, and ^{15}O	Bldg. 88 accelerator exhaust
	Real-time monitoring of ^{11}C, ^{13}N, ^{15}O, and ^{18}F	Bldg. 56 Biomedical Isotope Facility accelerator exhaust (2 locations)
	Real-time monitoring of gross alpha	Bldg. 70A Heavy Element Research Laboratory
Continuous sampling	Sampling with weekly analysis	10 locations
	Sampling with monthly analysis	13 locations
No monitoring	Inventory (administrative) control	115 locations

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

Nuclide	Total (Bq/yr)	% Total
^{3}H	7.47×10^{11}	88.3%
^{18}F	8.15×10^{10}	9.6%
^{11}C	1.73×10^{10}	2.1%
^{71}Ge	3.02×10^{8}	<0.1%
^{14}C	3.12×10^{7}	< 0.1%
^{125}I	1.55×10^{7}	< 0.1%
^{123}I	9.25×10^{6}	< 0.1%
^{32}P	7.13×10^{6}	< 0.1%
^{35}S	6.26×10^{6}	< 0.1%
^{99m}Tc	1.30×10^{6}	< 0.1%
All others	1.38×10^{6}	< 0.1%
Total	8.47×10^{11}	100.0%

[a] For a complete list of radiological air emissions, see NESHAPs Annual Report for 2001, found on Berkeley Lab's Environmental Services home page at http://www.lbl.gov/ehs/esg.

Tritium emissions for CY 2001 continued to be below regulatory levels of concern, and the NTLF annual emission of 7.5×10^{11} Bq (20 Ci) was below both the five- and ten-year averages for the facility. In fact, the total annual emissions were about one-fourth of US/EPA's reportable quantity for a single release of tritium of 3.70×10^{12} Bq (100 Ci).[5] For information on trends in annual tritium releases from the NTLF, see Figure 4-1.

4.3 AMBIENT-AIR MONITORING RESULTS

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

4.3.1 Tritium

Berkeley Lab began the calendar-year sampling for airborne tritium at seven ambient monitoring sites. Eight new sites were added by May to provide supplemental sampling data requested by US/EPA for their ongoing Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) evaluation and by members of the Berkeley public. See Sections 3.4.2 and 10.1 for background on the CERCLA evaluation. See Section 10.2 for a summary of supplemental sampling ambient-air results for 2001. Under the expanded network, eight of the sites were on the main grounds of the facility, six were off-site on adjacent University of California property, and the

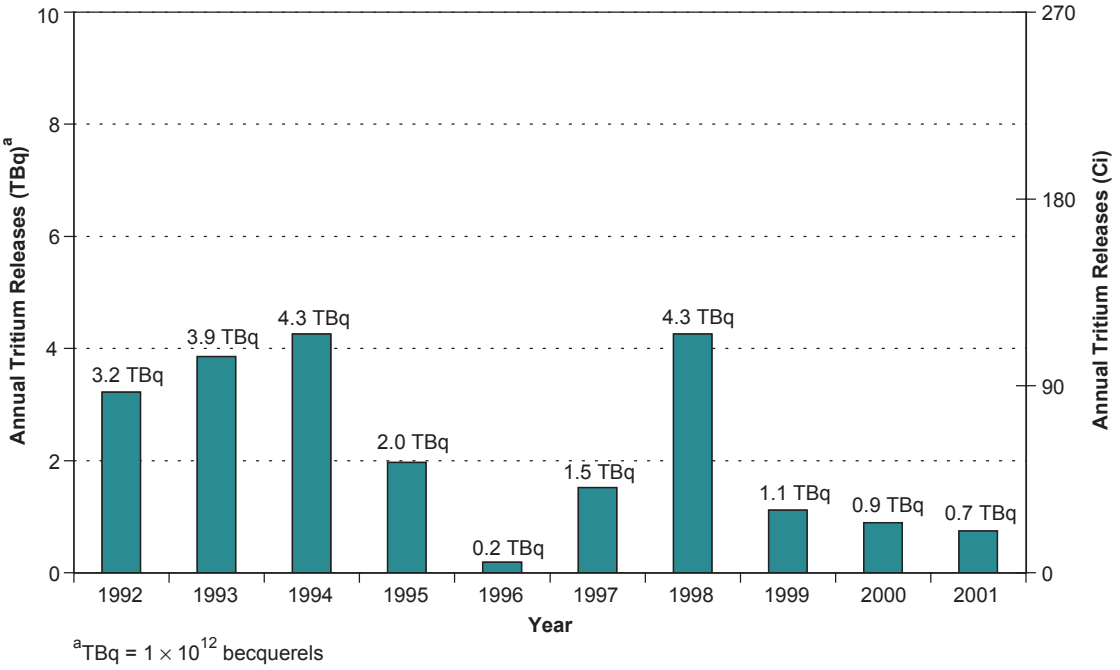


Figure 4-1 Trends in Annual Tritium Releases from NTLF

final sampling site was off-site at the East Bay Municipal Utility District's Amito Reservoir, located 2.2 kilometers (1.4 miles) from Berkeley Lab. For a map showing the network, see Figure 4-2. Instrumentation at each site continuously samples outdoor air. The sampling media are replaced and analyzed monthly.

As in past years, average and maximum tritium concentration values at all sites in the network are much less than 1% of the allowable DOE annual exposure standard for airborne tritium (3.7×10^3 Bq/m^3 [1×10^5 pCi/m^3]).[3] Results from all existing sites are well within the range of values measured at each site during the past five years. Results from the new sites provide added understanding of the impact from the NTLF, Berkeley Lab's main tritium operation. Data collected from the new sites fall well within the bounds established by the existing network and are consistent with predictions of dispersion patterns based on the Laboratory's emissions sources, local wind patterns, and the complex terrain of the site. As expected, the site with the highest recorded concentration was the site closest to the hillside stack serving the NTLF and downwind of this stack. The site, ENV-75EG, measured an average monthly concentration of 2.40 Bq/m^3 (64.8 pCi/m^3), with the highest one-month reading of 4.67 Bq/m^3 (126.0 pCi/m^3). Even this one-month maximum value was only one-tenth of 1% of the DOE annual standard referenced above. 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 designed to collect air particulate samples for measurement of gross alpha and gross beta levels. This network complements the exhaust-system

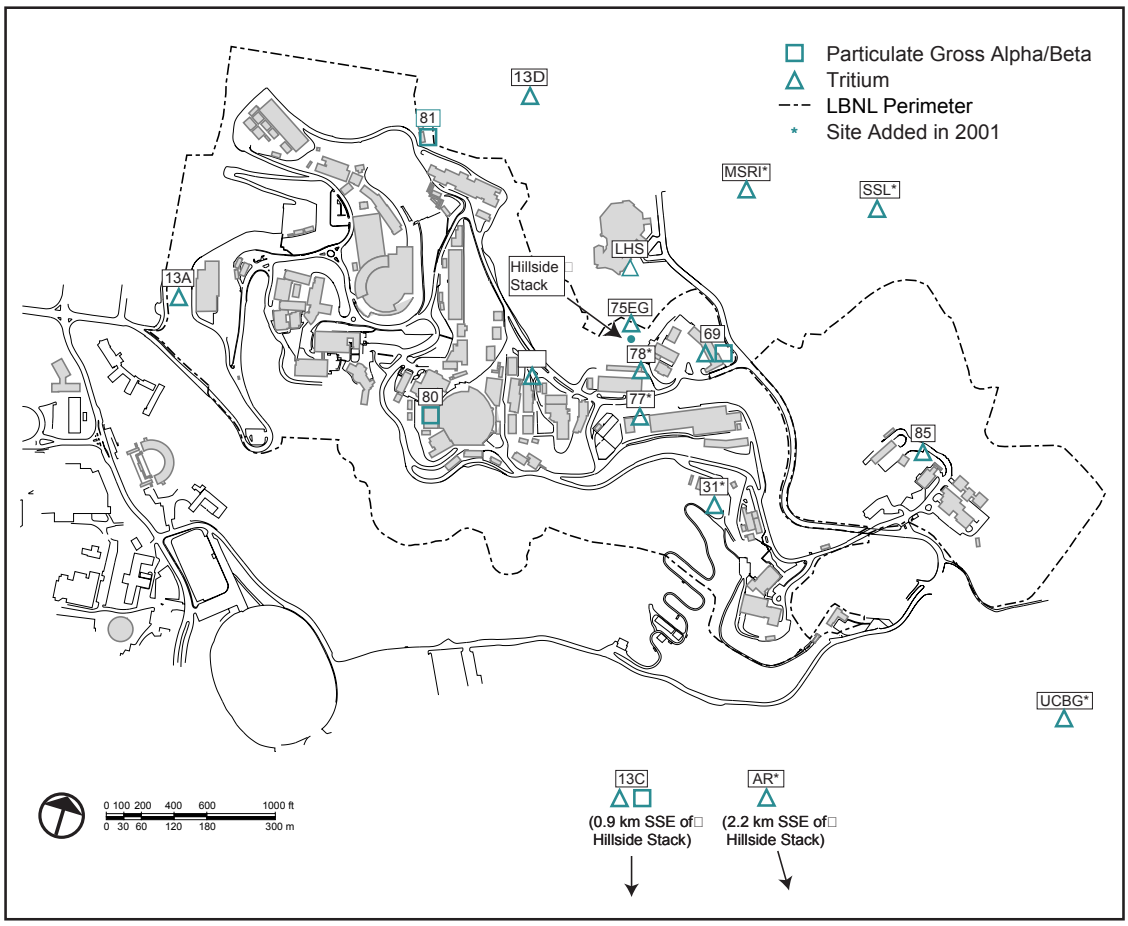


Figure 4-2 Ambient-Air Monitoring Network Sampling Locations

sampling program discussed earlier in this chapter. Unlike the airborne tritium network, the air particulate sampling stations remained unchanged (four monitoring sites): three sites on the main grounds of the Laboratory and a fourth at an off-site location, ENV-B13C. As with tritium sampling, the samplers draw air past collection media at a constant rate, with the media replaced monthly and samples analyzed by certified laboratories.

Table 4-6 summarizes gross alpha and beta results from routine sampling 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; and
- 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.

Table 4-5 Summary of Ambient-Air Tritium Sampling

Station ID	Number of samples	Mean (Bq/m^3)[a]	Mean as percentage of standard[b]	Median (Bq/m^3)	Maximum (Bq/m^3)
ENV-B13A	12	<0.18[c]	—	<0.18[c]	0.24
ENV-B13C	12	<0.18[c]	—	<0.18[c]	0.32
ENV-B13D	12	<0.19[c]	—	<0.19[c]	0.42
ENV-31	9	<0.19[c]	—	<0.19[c]	0.32
ENV-44	9	0.27	0.007	0.28	0.51
ENV-69	12	0.60	0.016	0.56	1.23
ENV-75EG	12	2.40	0.065	2.50	4.67
ENV-77	9	0.75	0.020	0.56	1.95
ENV-78	9	1.10	0.030	0.81	2.20
ENV-85	12	<0.19[c]	—	<0.19[c]	0.31
ENV-AR	8	0.27	0.007	0.18	0.88
ENV-LHS	12	1.05	0.028	1.00	2.27
ENV-MSRI	8	0.40	0.011	0.43	0.62
ENV-SSL	8	0.30	0.008	0.32	0.69
ENV-UCBG	8	<0.33[c]	—	<0.33[c]	<0.33[c]

[a] 1 Bq = 27 pCi
[b] Standard of comparison = 3.7×10^3 Bq/m^3 (source: Derived Concentration Guide in DOE Order 5400.5)
[c] 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^3)[a]	Median (Bq/m^3)	Maximum (Bq/m^3)
Alpha	ENV-B13C[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$
	ENV-69[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$
	ENV-80[b]	12	$<1.8 \times 10^{-4}$	$<1.8 \times 10^{-4}$	$<1.8 \times 10^{-4}$
	ENV-81	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	1.4×10^{-4}
Beta	ENV-B13C	12	4.8×10^{-4}	4.4×10^{-4}	7.8×10^{-4}
	ENV-69	12	4.6×10^{-4}	4.1×10^{-4}	8.0×10^{-4}
	ENV-80	12	5.2×10^{-4}	5.0×10^{-4}	8.0×10^{-4}
	ENV-81	12	5.2×10^{-4}	4.6×10^{-4}	8.8×10^{-4}

[a] 1 Bq = 27 pCi
[b] Mean, median, and maximum of the results were below the highest value for analytical sensitivity (minimum detectable amount) for this site.

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

	Sample Location								
	Soil				Sediment				
Analyte	B50	B69	B85	ENV-B13C	Chicken Creek–Main	Chicken Creek–Tributary	N. Fork Strawberry Creek–Main	N. Fork Strawberry Creek–Tributary	Regulatory criteria (TTLC[b])
Arsenic	8	3	3	8	2	2	3	3.6	500
Barium	210	120	140	150	100	310	76	77	10,000
Cadmium	2.6	1.2	1.1	<1[c]	<1[c]	<1[c]	<1[c]	<1[c]	100
Chromium	41	110	100	36	30	39	20	22	2,500
Cobalt	10	23	21	8.8	9.7	7.9	5.1	6.1	8,000
Copper	140	24	35	25	20	19	13	96	2,500
Lead	130	<10[c]	<10[c]	93	<10[c]	15	20	<10[c]	1,000
Mercury	0.27	<0.05[c]	0.058	0.12	<0.05[c]	<0.05[c]	0.19	0.13	20
Nickel	45	65	60	30	41	42	16	18	2,000
Vanadium	52	100	110	44	25	31	36	35	2,400
Zinc	170	66	57	220	99	86	110	140	5,000
Oil & grease	—	—	—	—	600	290	370	570	—

[a] One sample per location, all results in mg/kg
[b] Total Threshold Limit Concentration (22 California Code of Regulations 66261.24)[3]
[c] Result was below detection limit.
[d] Results for antimony, beryllium, molybdenum, selenium, silver, and thallium were all below practical quantification limits and are not reported in Table 7-1. These results, along with other non-TTLC metals (aluminum, boron, manganese, and iron), are included in Volume II.

5

Surface Water and Wastewater

5.1 SURFACE WATER PROGRAM

Berkeley Lab's surface water monitoring in calendar year (CY) 2001 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 U.S. Department of Energy (DOE) orders[1] that prescribe monitoring for radioisotopes. Nonradiological monitoring of surface water occurs as part of the Laboratory's ongoing efforts to characterize and manage its overall impact on the environment. Stormwater monitoring is performed under the California General Permit for Stormwater Discharges Associated with Industrial Activities[2] and includes monitoring for metals and other constituents. 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 cites drinking-water standards as a comparison. In actuality, the drinking-water standard is not a compliance standard for the surface water program (no such standard exists), and 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.[3] The U.S. Environmental Protection Agency (US/EPA) limit for tritium in drinking water is 740 Bq/L (20,000 pCi/L).[4]

Surface water samples were analyzed by both commercial and in-house state-certified laboratories. Individual results can be found in Volume II.

5.2 SURFACE WATER RESULTS

The following sections discuss the monitoring results from rainwater, creeks, lakes, and stormwater.

5.2.1 Rainwater

Rainwater composite samples were collected monthly from three locations whenever rainfall occurred (see Figure 5-1). May, June, July, August, and September were either dry or did not have enough 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.

Samples were analyzed for tritium and gross alpha and beta radiation. Figure 5-2 summarizes the levels of alpha and beta emitters and tritium measured in rainwater samples taken during CY 2001. Results for alpha and beta activity were all below federal and state MCLs for drinking water. Again, this water is not used for drinking purposes.

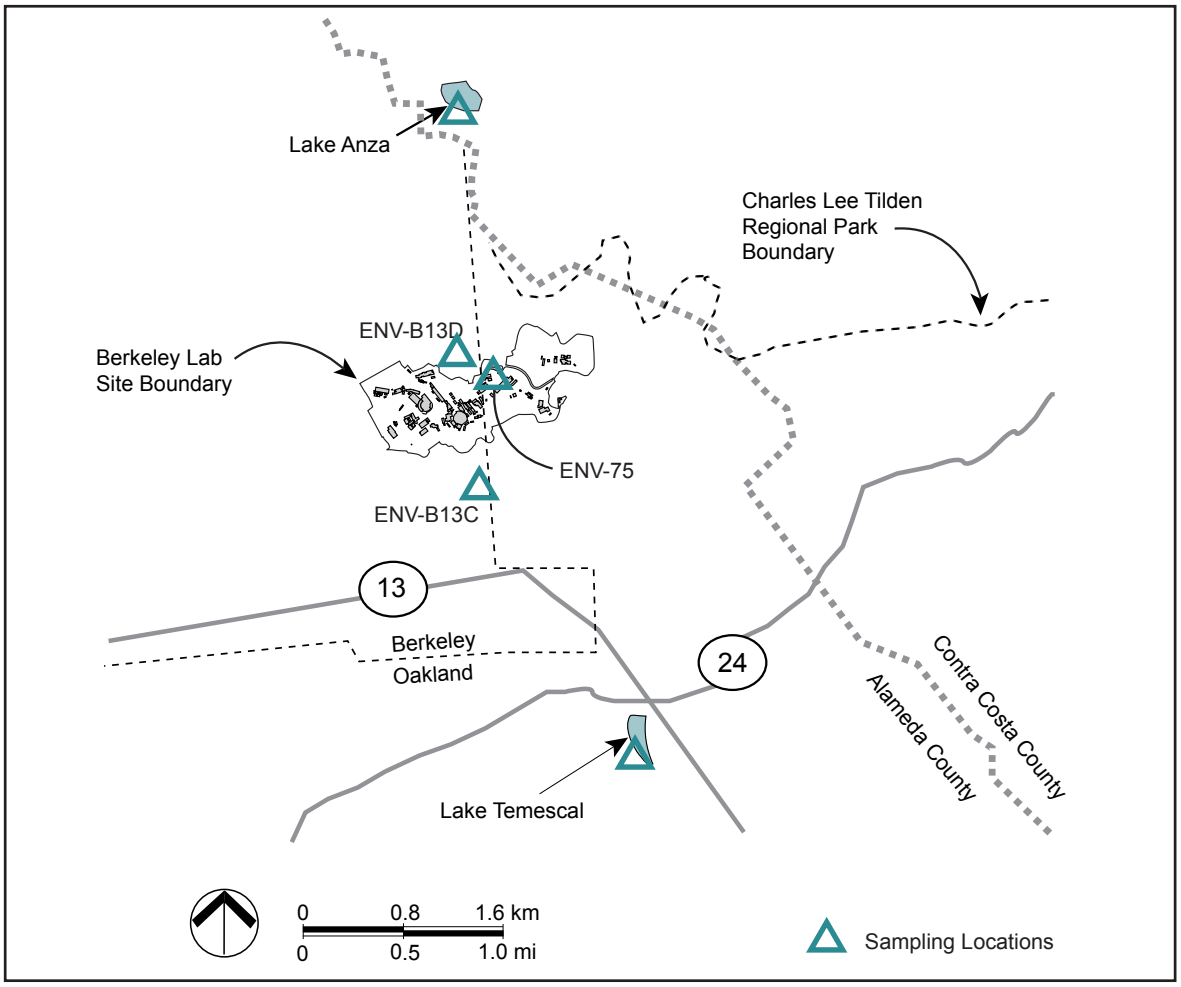
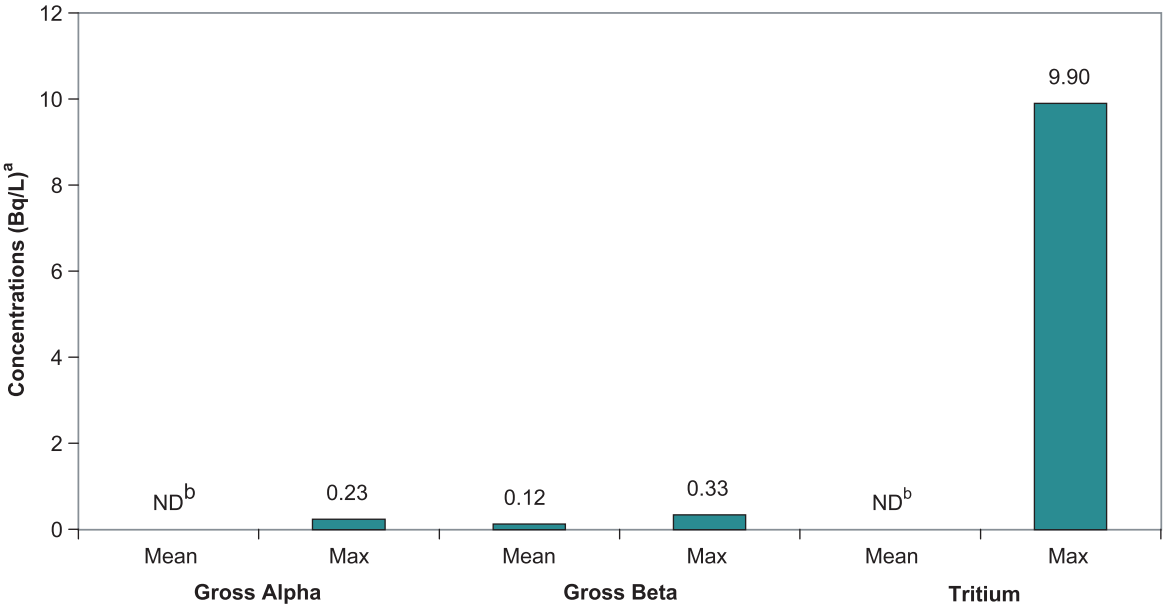


Figure 5-1 Rainwater and Lake Sampling Locations

On-site, routine rainwater monitoring detected tritium three times at ENV-75 (a maximum of 10 Bq/L [270 pCi/L]); tritium was detected only once off-site, at ENV-B13C.

This year, in addition to the routine rainfall monitoring, special rainfall monitoring was conducted. Based on community input, the City of Berkeley asked Berkeley Lab to perform extra rainwater monitoring for tritium in locations very close to the Building 75 exhaust stack and in the eucalyptus grove between the National Tritium Labeling Facility (NTLF) and the Lawrence Hall of Science (LHS). Accordingly, Berkeley Lab installed four rain gauges at two meters from the stack, seven meters from the stack, eighteen meters from the stack at an ambient air sampling station, and 40 meters from the stack at the fence gate between Berkeley Lab and LHS (see Figure 5-3).

Rainwater from the four special monitoring gauges was collected after every major storm that provided enough water to analyze. Intervals varied from one day in March to nearly a month toward



[a]1 Bq = 27 pCi
[b]Mean was less than the maximum MDA for the analyte (0.15 Bq/L for alpha and 7 Bq/L for tritium)

Figure 5-2 Rainwater Radiological Monitoring Results

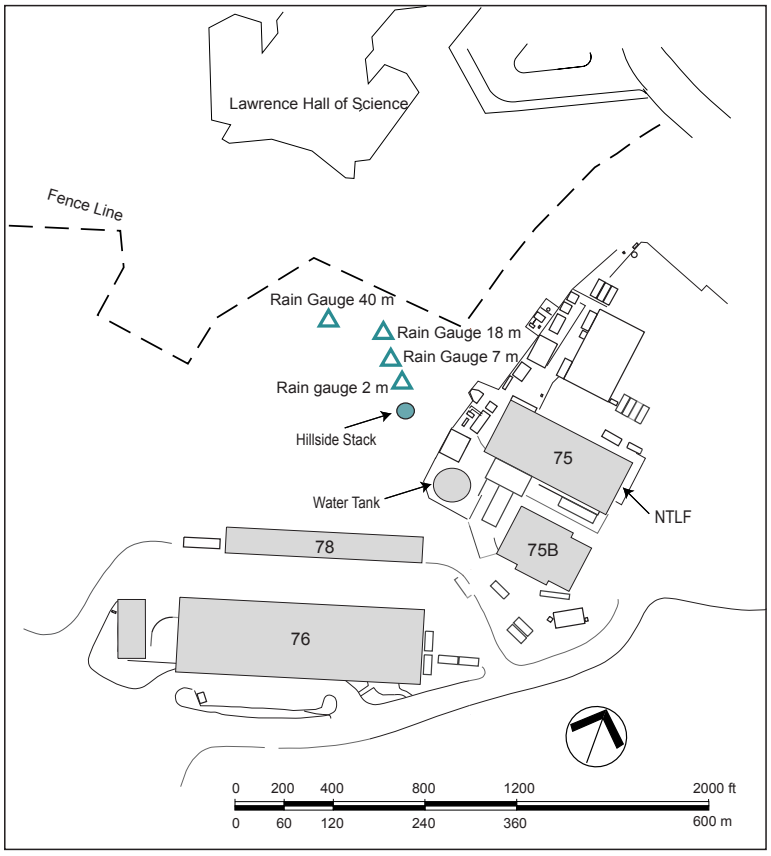


Figure 5-3 Supplemental Rain Sampling Locations

the end of the rainy season. As expected, tritium was always detected this close to the stack. 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. The highest concentrations were seen at all four locations for the March 2 collection, with a maximum of 35,500 Bq/L (960,000 pCi/L) at the seven-meter distance. This is nearly an order of magnitude higher than all other rainfall measurements. That sample was collected over approximately 24 hours between March 1 and 2, during which 0.48 inch of rain fell. This period of rainfall coincided with a small emission of 0.21 curie of tritium from the NTLF.

5.2.2 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 2001 were Chicken Creek, Claremont Creek, the North Fork of Strawberry Creek, Strawberry Creek (UC), and Wildcat Creek. For creek sampling locations, see Figure 5-4. Alpha activity was not detected at any sampling site, with the exception of a low amount at Chicken, Claremont, and the North Fork of Strawberry creeks during the August sampling, and in Claremont Creek in December. Beta activity was only detected in low concentrations in the August sampling in Chicken Creek, the North Fork of Strawberry, and Strawberry Creek (UC).

A second set of creeks was also sampled once and analyzed for metals, volatile organic compounds, and tritium. These creeks (also shown in Figure 5-4) 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, vanadium, selenium, and zinc — all in low amounts within background levels for this site and well below limits stipulated in the San Francisco Bay Region Basin Plan.[5] See Section 5.4 for more information.

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 US/EPA's request 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, Strawberry Creek (UC), and the Strawberry Creek outfall to the bay. The results for these special samplings are included in the analysis below and in the data in Volume II, along with results from routine environmental sampling. For more description of this additional monitoring, and a figure showing the sampling sites, see Chapter 10.

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 seen in CY 2001 was 32 Bq/L (2,240 pCi/L),

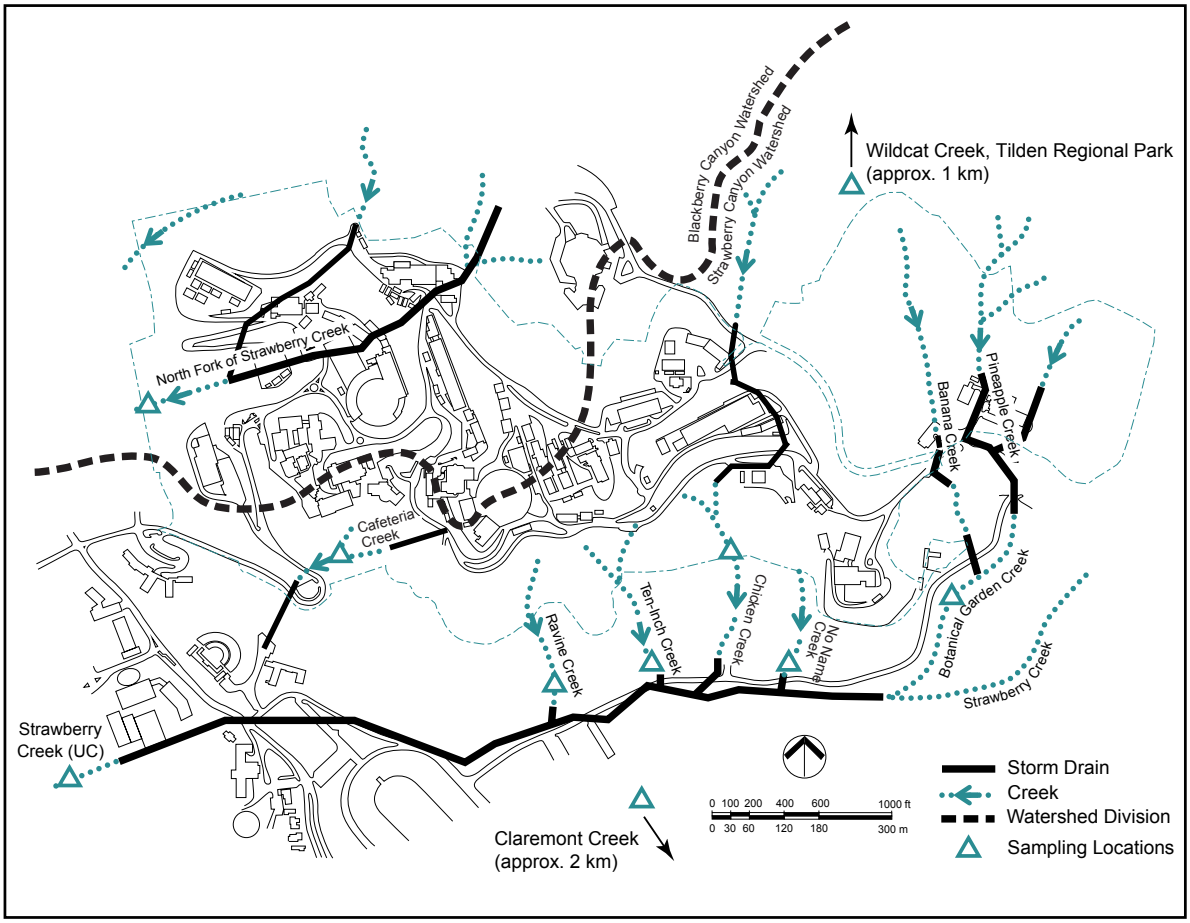


Figure 5-4 Creek Sampling Locations

nearly an order of magnitude below drinking-water levels, although this water is not used by the local water provider.

Chicken Creek is the only creek in which tritium has been found with any regularity. Figure 5-5 presents a comparison of the annual mean for tritium in Chicken Creek over the last seven 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 last three years, from 1999 to 2001, average tritium levels in Chicken Creek have remained below the 1997/1998 levels.

5.2.3 Lakes

Lake sampling is performed once each year 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.

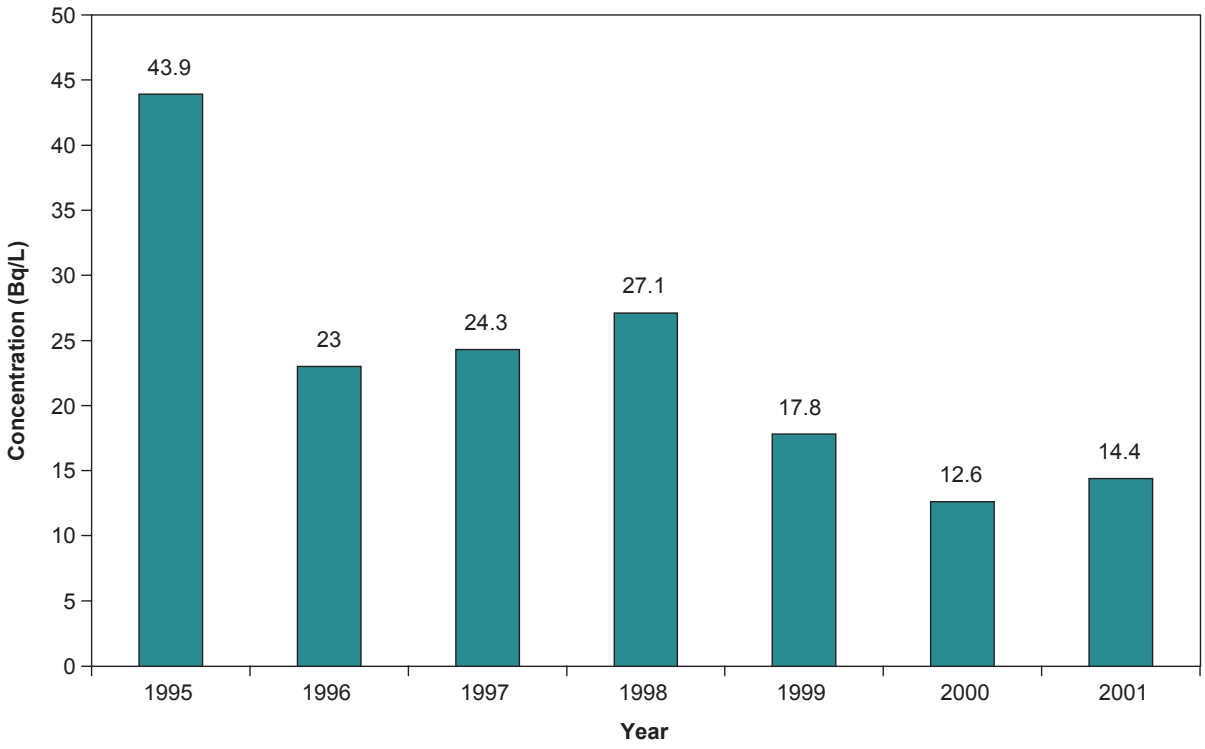


Figure 5-5 Annual Averages for Tritium in Chicken Creek (1995–2001)

5.2.4 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 UC Berkeley campus.

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

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 2001/02 (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.

Following a request from the City of Berkeley, Berkeley Lab had in the past committed to analyzing at least one sample per stormwater year (July 1 through June 30) for both total and dissolved metals as a comparison. For five years, dissolved-metals results were consistently lower than total metals and were generally not detected at all. Therefore, beginning with the 2001/02 stormwater year, Berkeley Lab will sample only for total metals, as required by the permit. Additionally, because many metals analyzed were not detected, the list of metals analyzed has been reduced to four (aluminum, iron, magnesium, and zinc). All others had not been detected in the last two years or more. Sampling points are shown in Figure 5-6.

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

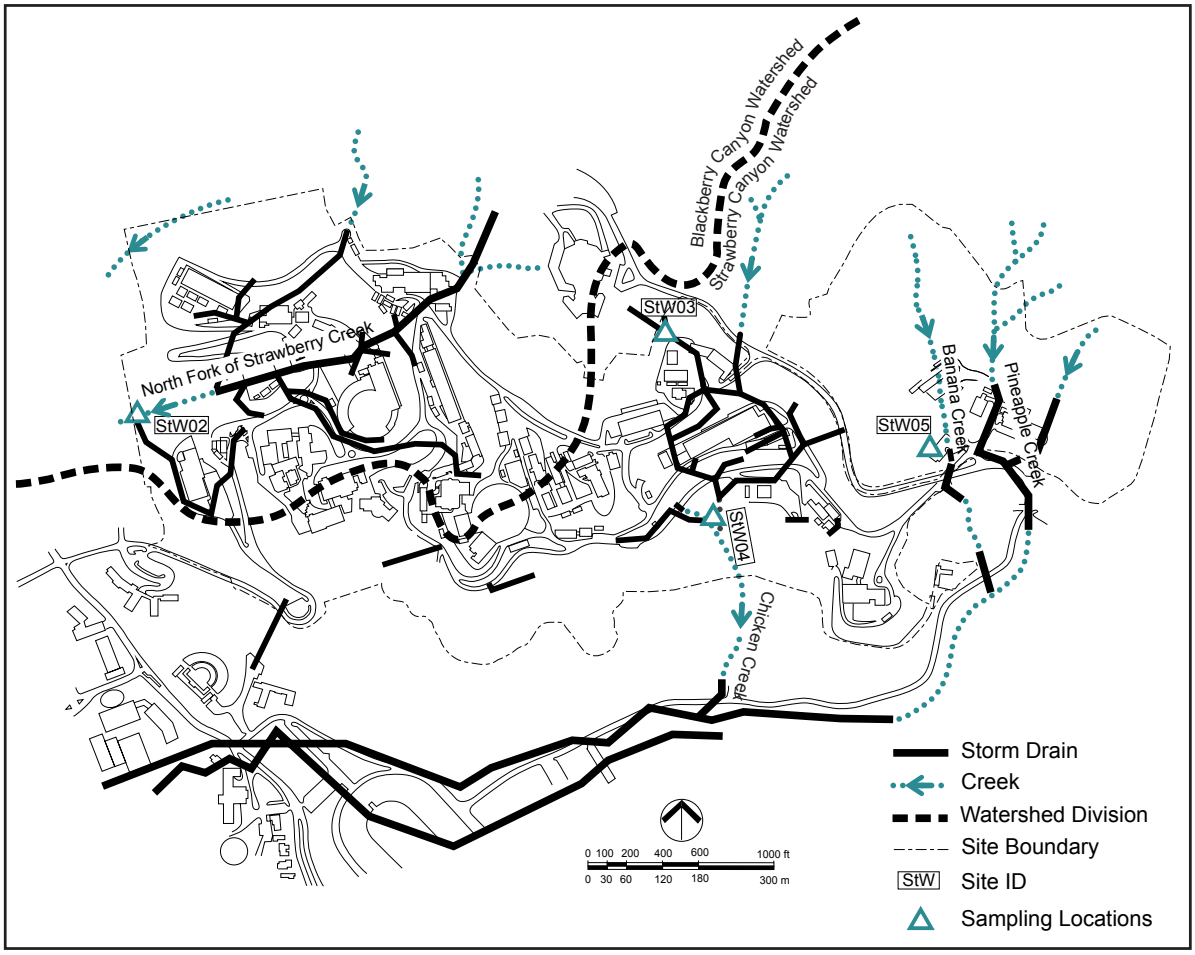


Figure 5-6 Stormwater Sampling Locations

facilities located above Berkeley Lab. This point was chosen as a basis of comparison, facilitating an investigation if contaminants were found. Another influent point, previously called StW01, at the Building 71 manhole, was deleted from the program during CY 2001 for safety reasons.

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, 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.
- Toxic chemicals and other pollutants that are likely to be present in stormwater discharge in significant quantities.

In CY 2001, the measured pH was always near neutral, and total petroleum hydrocarbons (diesel) were often seen in low quantities at most sampling points. Oil and grease was not detected. Specific conductance, usually a measure of the degree of mineralization of water, was generally low and within the range of domestic drinking water. The measure for total suspended solids (TSS) was also 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. COD results in stormwater discharge for the Laboratory were generally low. Nutrients such as ammonia, nitrate, and nitrite were also seen at all stations at low levels. Chicken Creek often exhibits higher levels of all these parameters than other sites.

Metal concentrations were generally below detection limits. Only aluminum, iron, magnesium, and zinc were above detection levels in the total-metals analyses. The General Permit does not contain specific discharge limits for metals. For comparison purposes, Table 4-3 of the Basin Plan[5] gives effluent limitations for selected toxic pollutants discharged to shallow surface waters applicable to point source discharges from Publicly Owned Treatment Works (such as the East Bay Municipal Utility District [EBMUD]) and industrial effluent.

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 (typical for natural background levels) once each at the Building 69 Storm Drain Manhole (StW03) and East Canyon (StW05), and at Chicken Creek (StW04). The maximum tritium concentration in stormwater (60.7 Bq/L [1,640 pCi/L]) was measured in a sample collected from the Building 69 Storm Drain Manhole (StW03), a location where stormwater runs onto the site. By comparison, the maximum tritium concentration at the corresponding stormwater discharge location was 16 Bq/L (430 pCi/L), measured in a sample collected from Chicken Creek (StW04).

5.3 WASTEWATER DISCHARGE PROGRAM

The Laboratory's sanitary sewer system is based on gravity flow and discharges through one of two monitoring stations, Hearst or Strawberry (see Figure 5-7).

- 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 just before the Laboratory's sanitary sewer system connects 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 located above the Laboratory and separate from the main UC Berkeley campus (Lawrence Hall of Science, Space Sciences Laboratory, Mathematical Sciences Research Institute, Animal Research Facility, and Botanical Garden).

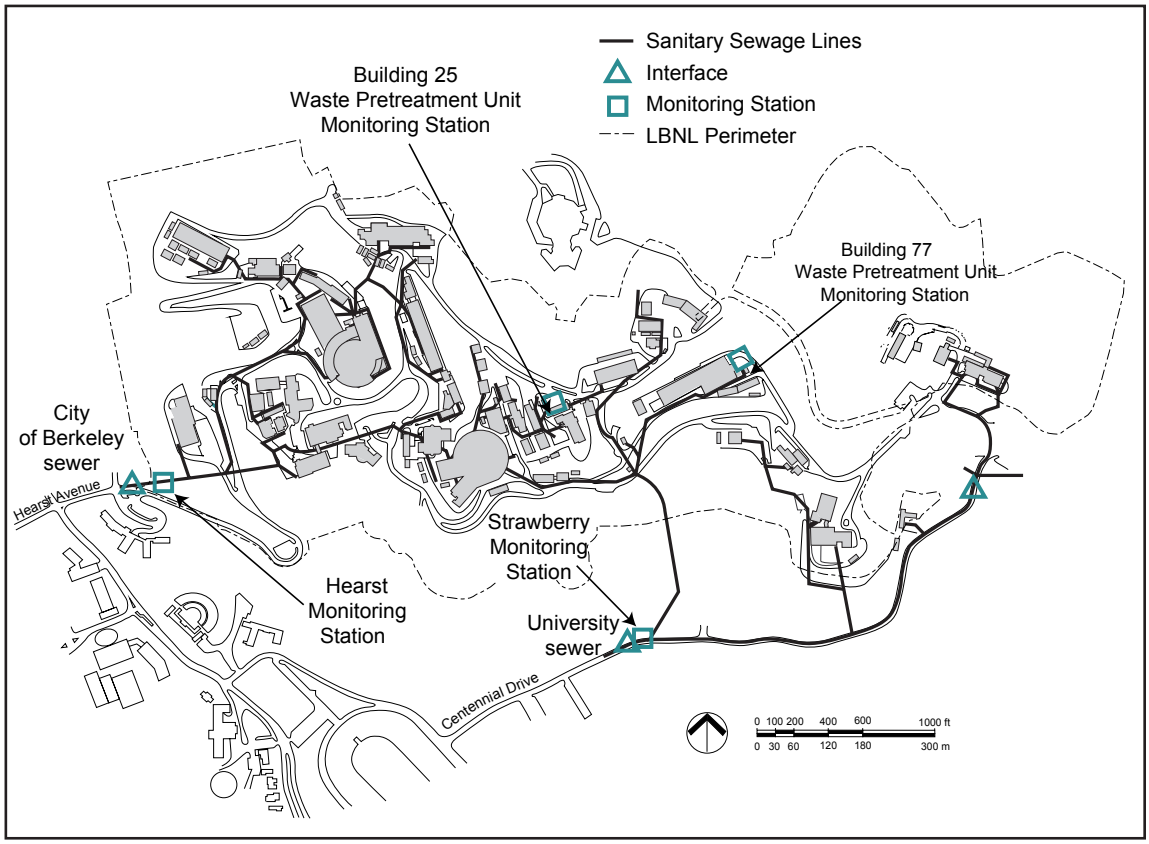


Figure 5-7 Sanitary Sewer System

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.[8]

Berkeley Lab currently has four wastewater discharge permits issued by EBMUD: one for general site-wide 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. EBMUD is the local Publicly Owned Treatment Works that regulates all industrial and sanitary discharges to its treatment facilities.

As in previous years, the Laboratory's 2001–2002 permit required monitoring of wastewater discharge four times per year and metals analysis once per year at times specified in the permit. EBMUD continues to perform unannounced monitoring four times per year. There were no changes in permit requirements, and all results were below discharge limits. Individual sampling results are presented in Volume II.

5.4 WASTEWATER RESULTS

The following sections discuss the radiological and nonradiological monitoring results from the Hearst and Strawberry sewer outfalls.

5.4.1 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. Site-wide samples are always analyzed for pH, total identifiable chlorinated hydrocarbons, total suspended solids, and chemical oxygen demand, with additional analyses for metals required once during the permit year.

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

5.4.1.1 Nonradiological Monitoring

Four nonradiological self-monitoring samples were taken from the Hearst and Strawberry outfalls during CY 2001. All results were well within discharge limits, as were all measurements made by

EBMUD in its independent samplings. Analysis for metals was required for only one of the four samples and was carried out at the October sampling. Most metals were not detected above detection limits in either the Hearst or Strawberry outfalls. Figure 5-8 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; in one sample very small amounts of bromodichloromethane, methylene chloride (in Hearst Sewer), and toluene (in Strawberry Sewer) were detected. According to the permit, the pH level must remain at no less than 5.5; all results were well above this value. Total suspended solids and chemical oxygen demand are measured to determine wastewater strength, which forms the basis for EBMUD's charges 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.

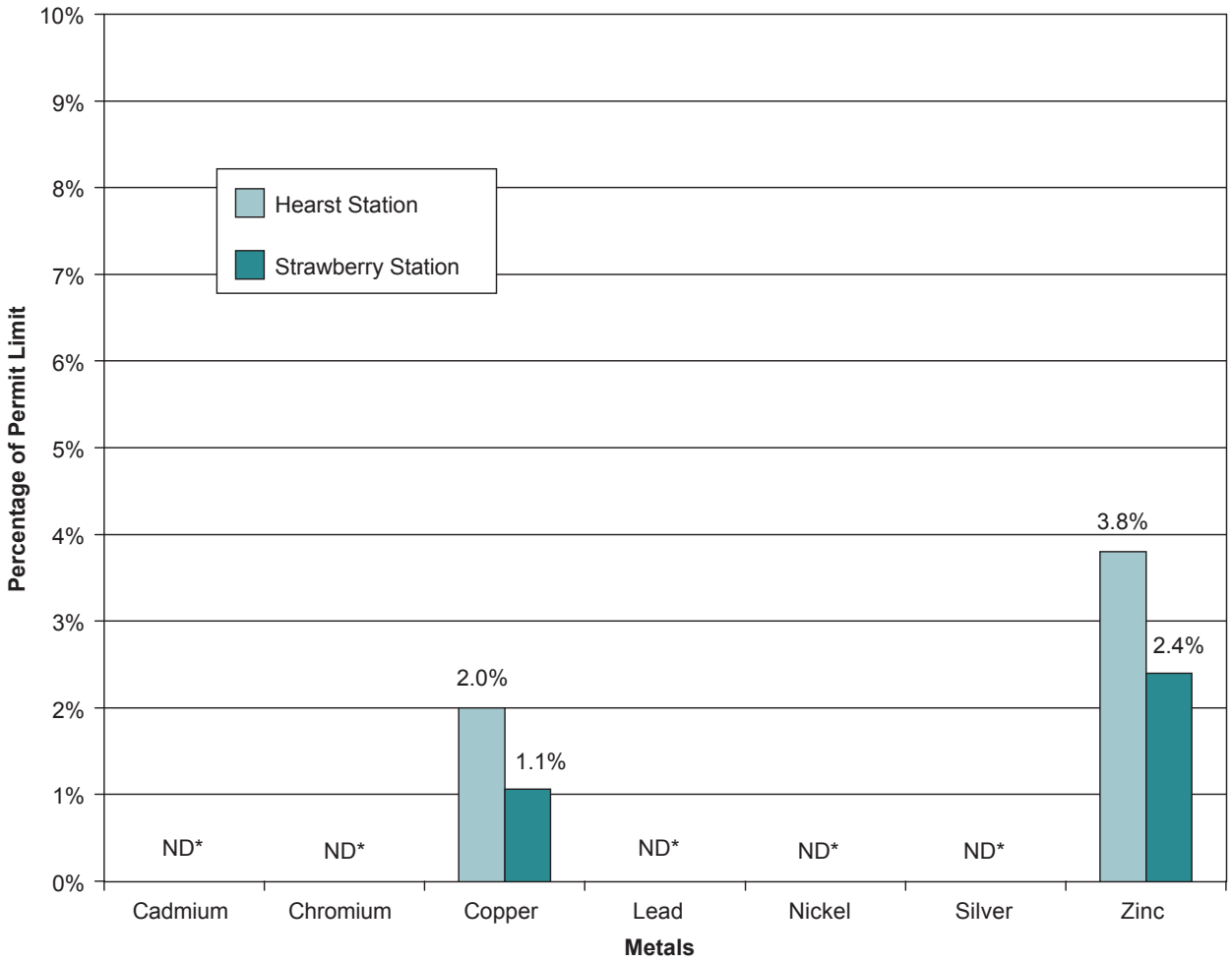


Figure 5-8 Concentration of Metals in Sewer Water Samples as a Percentage of Permit Limit

5.4.1.2 Radiological Monitoring

The Hearst and Strawberry sewer outfalls are sampled continuously by automatic equipment that collects samples at half-hour intervals. The composite samples are collected biweekly for subsequent analysis of gross alpha, gross beta, iodine-125, and tritium by a state-certified laboratory. Split samples were analyzed periodically for additional quality control purposes.

The federal[11] and state[10] regulatory limits are based on total amounts released per year. For tritium, this limit is 1.9×10^{11} Bq (5 Ci) per year, and for carbon-14 it is 3.7×10^{10} Bq (1 Ci) per year. The limit for all other radioisotopes is a combined 3.7×10^{10} Bq (1 Ci) per year. Radioisotopes discharged into Berkeley Lab's sewer wastewater, expressed as a percentage of their permit limit, are summarized in Figure 5-9.

Alpha emitters, which can potentially come from transuranic and heavy-element research, were detected just above detection limits three times at Hearst Station and three times at Strawberry

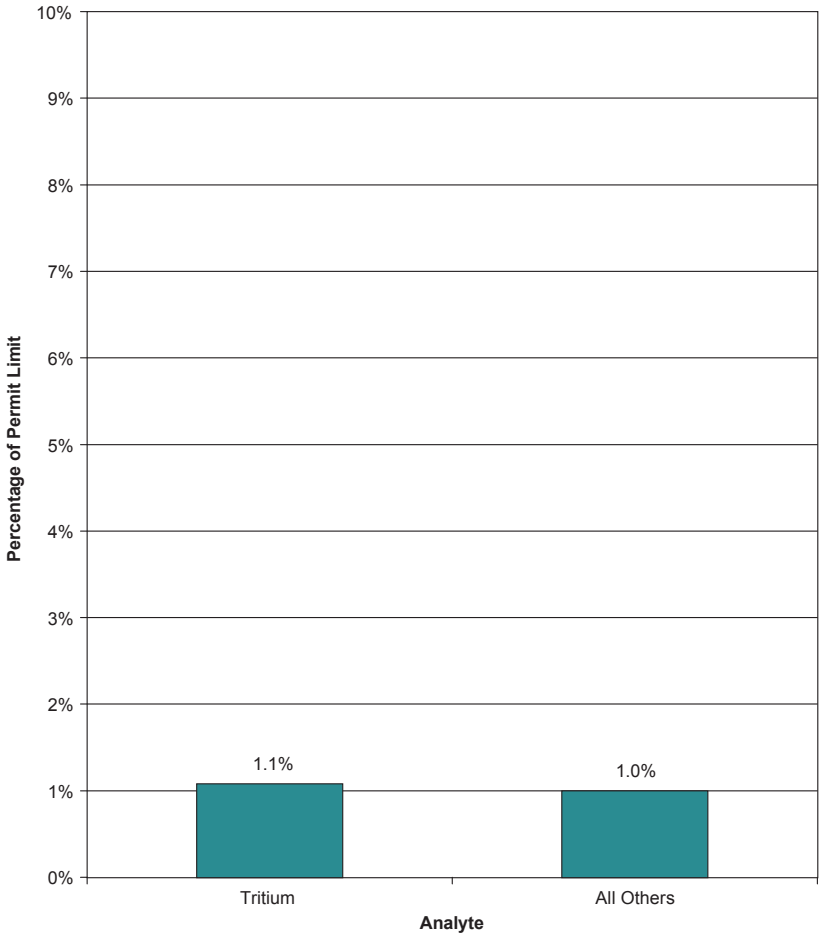


Figure 5-9 Radioisotopes Discharged to Sewers in 2001 as a Percentage of Permit Limit

Station. Beta emitters, including iodine-125 from biomedical research, were usually detected in both sewers at low levels, with levels at Strawberry generally being lower than those at Hearst. The maximum concentration of beta emitters (excluding iodine-125) for the year was 0.93 Bq/L (25.1 pCi/L), while the highest iodine-125 concentration was 6.48 Bq/L (175 pCi/L), both at Hearst Station.

With two exceptions, tritium levels were below the minimum detectable amount at Hearst Monitoring Station. Tritium levels were usually above detection limits at Strawberry Monitoring Station. The total annual discharge of tritium in wastewater was 2.0×10^9 Bq (0.054 Ci), and the total for other radioisotopes was 3.7×10^8 Bq (0.010 Ci). Ten percent of the tritium discharge was due to water in the NTLF hillside stack sump, referred to in Section 3.3.3. The amount of tritium decreased from last year's level, while the total for other radioisotopes increased. All values, however, were well below allowable limits. For example, tritium was only 1.1% of the allowable federal and state limit, and all other isotopes together were also approximately 1% of their limit.

Figure 5-10 trends the total amount of tritium released to Berkeley Lab's sewers over the last five years. Results are consistently under 10% of the permitted level.

5.4.2 Building 25 Photo Fabrication Shop Wastewater

The Photo Fabrication Shop in Building 25 manufactures electronic printed circuit boards and screen print nomenclature on panels to support the needs of Berkeley Lab research and operations. 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 — one self-monitoring and two efforts by EBMUD — yielded daily maximum and monthly average results well within EBMUD discharge limits.[8]

5.4.3 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 (60-gallon) per minute fixed treatment unit, designated FTU 006.

All self-monitoring (three) and EBMUD (two) inspection samples were well within permitted limits. There were no changes to the 2001–2002 permit.

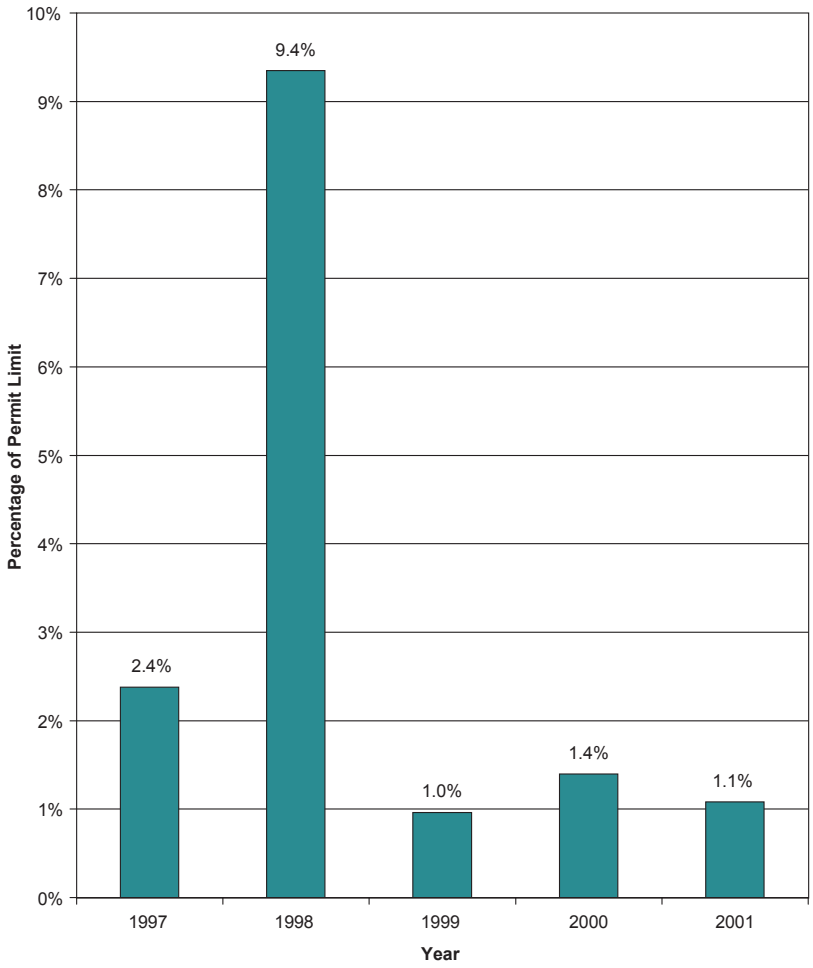


Figure 5-10 Annual Releases of Tritium to Sewers (1996–2001) as a Percentage of Permit Limit

5.4.4 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, plus well samplings and developments. All treated groundwater discharged under the permit is routed through the Hearst Sewer. One of the conditions for this discharge is a semiannual report on the volumes treated and discharged, and any contaminants found.

Tests using US/EPA-approved methodologies are run monthly on treated groundwater to determine levels of volatile organic compounds. Most results were below detection limits. Occasional low levels of certain chlorinated hydrocarbons have been measured (parts per billion), which do not

exceed allowable limits. As a precautionary measure, a sample is taken from between the two drums of carbon in each system to assist in determining when the first drum 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.

6

Groundwater

6.1 BACKGROUND

This chapter reviews the groundwater-monitoring program at Berkeley Lab, emphasizing the calendar year (CY) 2001 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 showing monitoring well locations and contaminant concentrations, and graphs showing changes in contaminant concentrations over time. These reports are available for public review at UC Berkeley's main library (Doe Library).

Berkeley Lab's groundwater monitoring program was started in 1991 to:

- Characterize the magnitude and extent of groundwater contamination;
- Evaluate the potential for future contaminant migration;
- Monitor groundwater quality near the site perimeter; and
- 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 also sampled for other potential contaminants.

Under the Resource Conservation and Recovery Act of 1976 (RCRA) Corrective Action Program,[1] the Laboratory identifies areas of soil and groundwater contamination that may have resulted from past releases of contaminants to the environment. It then determines the sources and extent of the contamination and develops and implements remediation plans.

Activities are coordinated closely with the regulatory oversight agencies, including the California/Environmental Protection Agency (Cal/EPA) Department of Toxic Substances Control, San Francisco Bay Regional Water Quality Control Board, City of Berkeley, and the U.S. 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 only included 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 shown 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 1.0 meter per day (3.3 feet per day).

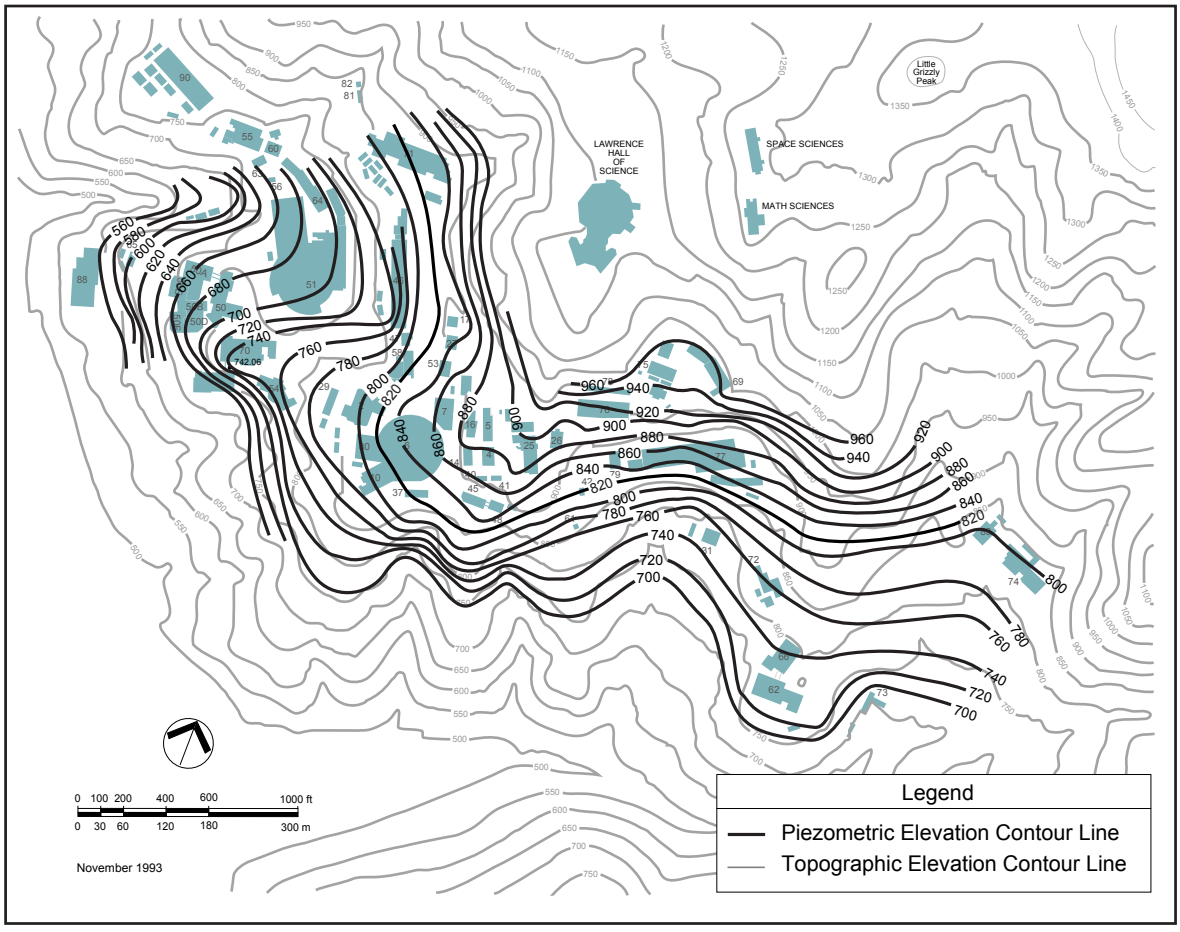


Figure 6-1 Groundwater Piezometric Map

6.2.3 Groundwater Quality

Groundwater samples from monitoring wells are tested for total dissolved solids (TDS), cations, and anions. During CY 2001, the TDS concentrations measured in groundwater monitoring wells ranged from 105 to 4,460 mg/L.

6.3 GROUNDWATER MONITORING RESULTS

In CY 2001, eight new monitoring wells were installed, bringing the total number of monitoring wells in the program to 198. 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 2001. 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 (the metal being tested for),[2] the number of monitoring wells in which the analyte was detected, and the ranges in concentrations detected. Table 6-3 presents tritium results.

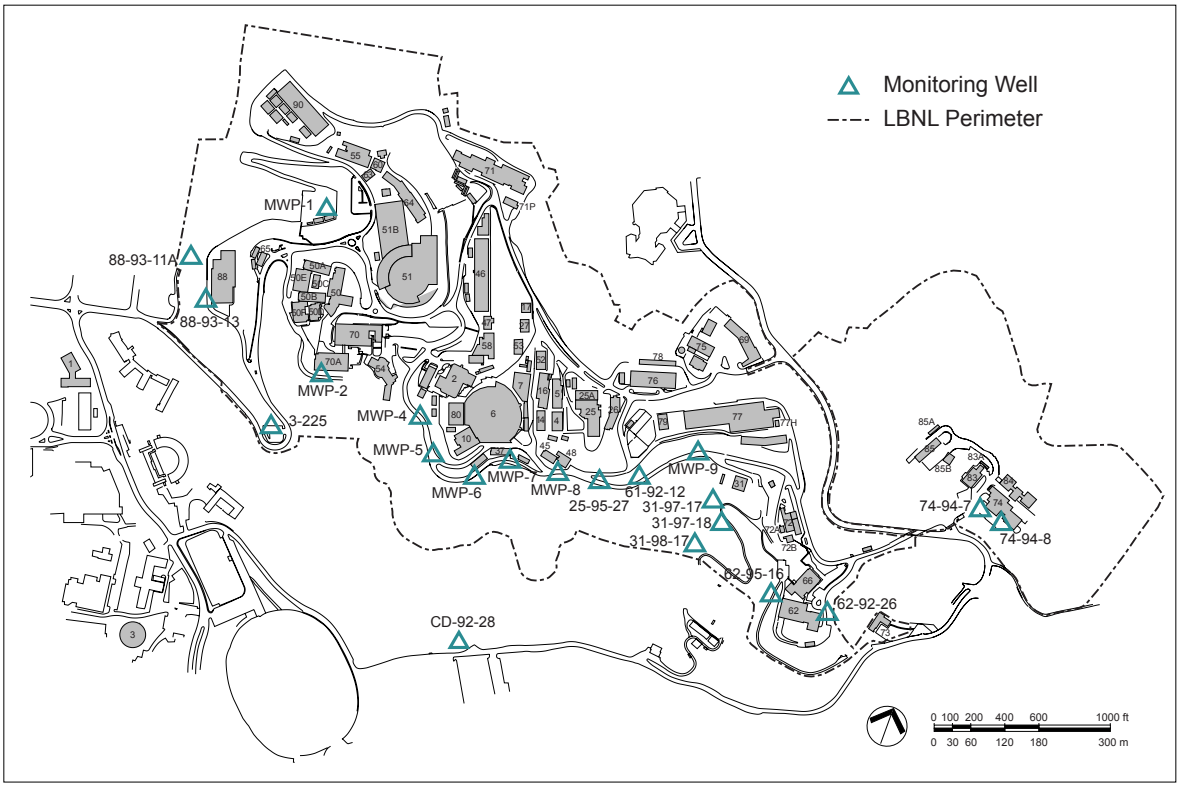


Figure 6-2 Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

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

Metal	Number of wells sampled	Number of samples	Number of wells analyte detected	Range of concentrations (μg/L)	Drinking water standard (μg/L)
Antimony	48	62	1	3	6
Arsenic	62	76	45	2–74	10
Barium	48	63	45	10–1000	1,000
Beryllium	49	63	—	—	4
Cadmium	48	62	—	—	5
Chromium	50	64	3	10–20	50
Cobalt	48	62	—	—	NS[b]
Copper	48	62	1	40	1,000[c]
Lead	49	63	—	—	15[d]
Mercury	49	65	2	0.78–1.5	2
Molybdenum	57	71	18	51–810	NS[b]
Nickel	49	63	—	—	100
Selenium	53	67	9	2–150	50
Silver	48	62	—	—	100[c]
Thallium	49	63	—	—	2
Vanadium	49	63	21	10–68	NS[b]
Zinc	48	62	13	12–64	5,000[c]

[a] Metals not detected in any samples are beryllium, cadmium, cobalt, lead, nickel, silver, and thallium.
[b] NS = Not specified
[c] Secondary MCL
[d] 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

Contamination was also detected in groundwater in other areas of the site in CY 2001. Based on current information, however, the extent of contamination in these areas is limited.

Table 6-2 VOCs Detected in Groundwater Samples from Monitoring Wells[a]

Analytes detected	Number of wells analyte detected	Range of Concentrations (μg/L)	Drinking water standard (μg/L)
Aromatic or Nonhalogenated Hydrocarbons			
Benzene	7	0.5–43.2	1
sec-Butylbenzene	1	1.1	NS[b]
1,3-Dichlorobenzene	2	0.51–1.2	NS[b]
1,4-Dichlorobenzene	3	0.52–1.3	5
Ethylbenzene	1	1.1–2.1	700
Hexachlorobutadiene	2	5.8–740	NS[b]
Methyl tert-Butyl Ether	1	0.5	13
p-Isopropyltoluene	2	0.63–1.4	NS[b]
Naphthalene	1	5.5	NS[b]
n-Propylbenzene	1	1.1	NS[b]
Toluene	3	0.7–3.9	150
1,2,4-Trimethylbenzene	1	1.1	NS[b]
Xylenes (total)	1	1.7	1,750
Halogenated Hydrocarbons			
Bromoform	3	0.79–5.5	100[c]
Bromomethane	1	2.2	NS[b]
Carbon Tetrachloride	24	1.3–1,948	0.5
Chloroform	30	0.96–93.1	100[c]
Dibromomethane	1	0.89–2.1	NS[b]
1,1-Dichloroethane	34	0.69–644	5
1,2-Dichloroethane	4	1.5–7.7	0.5
1,1-Dichloroethene	50	0.98–250	6
cis-1,2-Dichloroethene	53	1–3,740	6
trans-1,2-Dichloroethene	23	0.59–36.2	10
Methylene Chloride	4	0.71–2,100	5
1,1,1,2-Tetrachloroethane	5	3.8–35	NS[b]
1,1,2,2-Tetrachloroethane	2	1.1–7	1
Tetrachloroethene	61	1.1–54,653	5
1,1,1-Trichloroethane	11	1.1–92	200
1,1,2-Trichloroethane	4	0.63–69.6	5
Trichloroethene	80	1.1–40,126	5
Freon 11-Trichlorofluoromethane	1	2.1	NS[b]
Freon 113-1,1,2-Trichlorotrifluoroethane	5	0.61–17.3	1,200
Freon 123A-1,2-Dichlorotrifluoroethane	5	1.4–12.7	NS[b]
Vinyl Chloride	18	0.65–68.4	0.5

[a] 501 samples taken from 200 wells during the year
[b] NS=Not specified
[c] Standard is for total trihalomethanes

Table 6-3 Tritium Detected in Groundwater Samples from Monitoring Wells

Well number	January–March (Bq/L)[a]	April–June (Bq/L)	July–September (Bq/L)	October–December (Bq/L)
31-97-17	72	NS[b]	72	NS
46A-92-15	NS	<11	NS	20, 14[c]
52-94-10	NS	NS	NS	<11, 11
52-95-2B	NS	NS	15	15
69-97-21	20	NS	18	NS
71-95-9	<11	28	25	NS
71B-98-13	NS	16	NS	16, 9[c]
71B-99-3R	NS	24	NS	22, 21,[c] 17, 17[c]
75-92-23	136	NS	106	NS
75-97-5	1,022; 958[c]	844; 810[c]	1,031; 958[c]	957; 884[c]
75-97-7	51	NS	32	NS
75-98-14	264	199	186	157
75-99-7	289	279	255	241, 235[c]
75A-00-7	NS	<11	NS	14
75B-92-24	121	NS	147	NS
MW76-1	21	NS	18	NS
76-93-6	173	NS	84	NS
76-98-21	20	15	14	<11
76-98-22	15	19	20	<11
77-94-6	473	NS	354; 354[c]	NS
77-97-11	259	NS	220	NS
77-97-9	495	NS	NS	477; 444[c]
78-97-20	114	NS	126	NS
MW91-2	35	NS	27	NS
MW91-4	23	NS	26	NS
MW91-5	127	NS	63	NS
MW91-6	150	NS	119	NS

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

6.4.1 VOC Plumes

Covering the area of Buildings 4–7, 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 tetrachloroethylene (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.

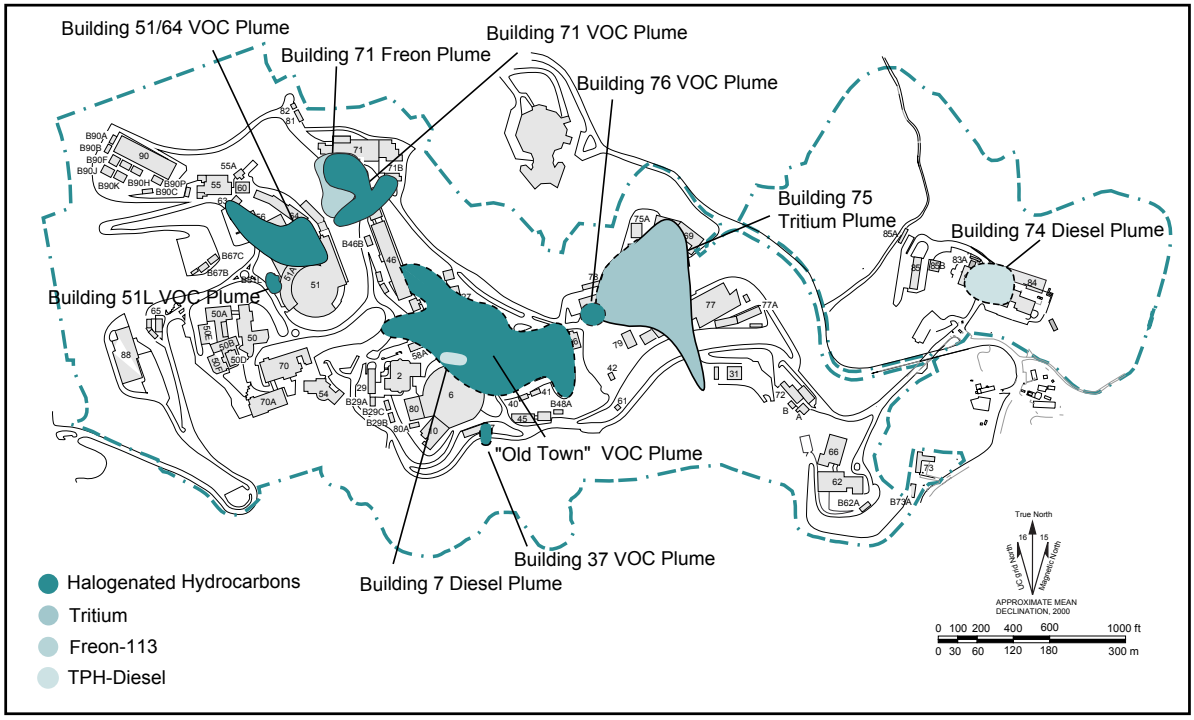


Figure 6-3 Groundwater Contamination Plumes (September 2001)

The maximum concentration of total halogenated hydrocarbons detected in groundwater samples collected from Old Town VOC plume wells in CY 2001 was 113,240 µg/L, which primarily consisted of PCE (62,000 µg/L), TCE (49,000 µg/L), and carbon tetrachloride (1,800 µg/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 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.

Five interim corrective measures have been instituted to manage the Old Town VOC plume (see Section 6.5):

- A groundwater collection trench was installed immediately downgradient from the former Building 7 sump to control the source of the groundwater contamination.

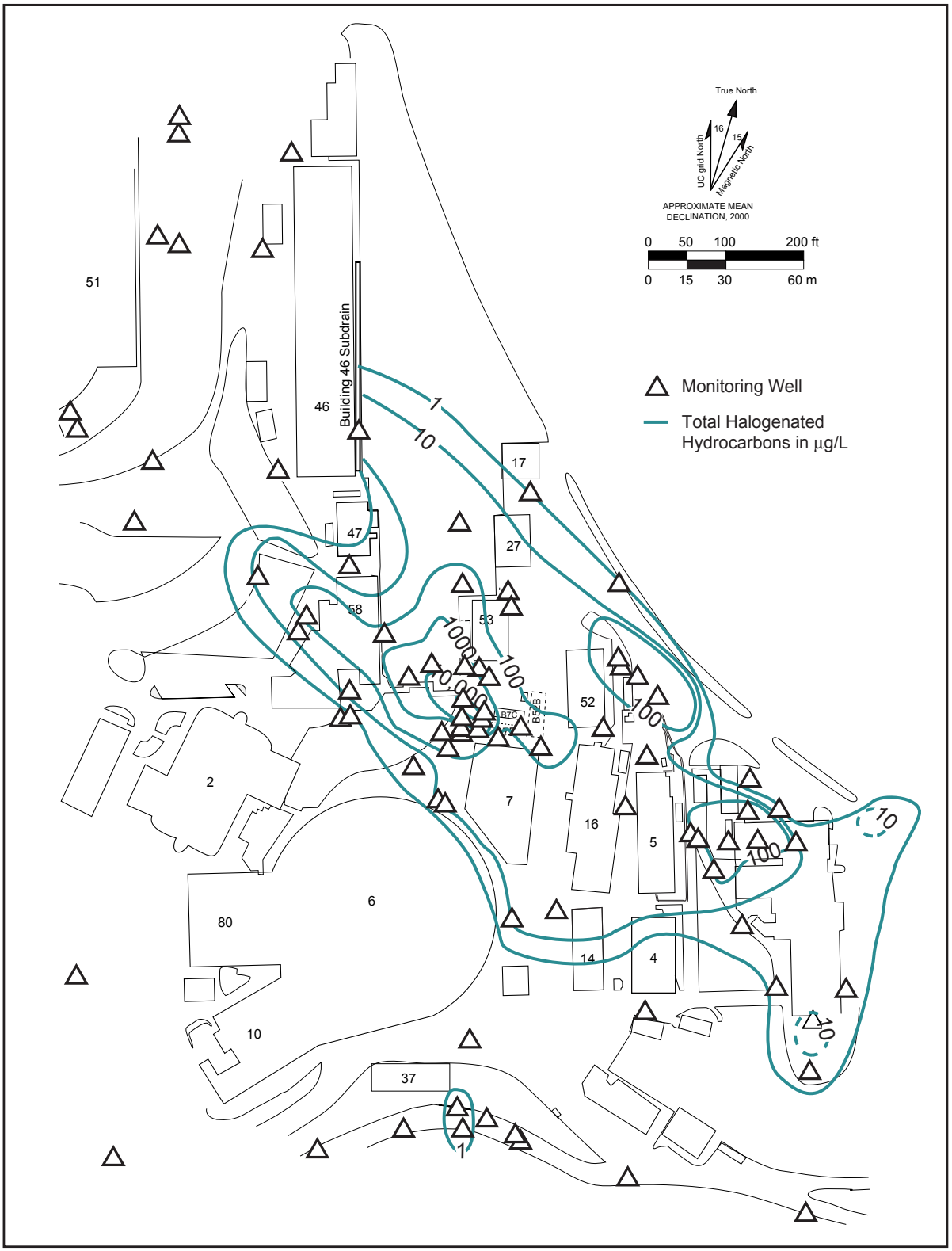


Figure 6-4 Groundwater Contamination (Total Halogenated Hydrocarbons in µg/L) in Old Town Area (September 2001)

- 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 2001 at a maximum total concentration of 22,080 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 2001 in samples collected from groundwater monitoring wells in the Building 51/64 area was 1,148 μg/L. The contaminants primarily consisted of 1,1-DCA (644 μg/L), 1,1-DCE (105 μg/L), TCE (187 μg/L), and PCE (114 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 as an interim corrective measure.

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, 1,1,1-TCA, and vinyl chloride. The maximum concentration of total halogenated hydrocarbons detected in wells monitoring the plume in 2001, 1,371 μg/L, was 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 in CY 2000 as an interim corrective measure.

The Building 37 VOC plume is defined by the presence of trace amounts of halogenated hydrocarbons, primarily TCE in monitoring wells MWP-7 and MW37-92-6. 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 2001 was less than the drinking water MCL.

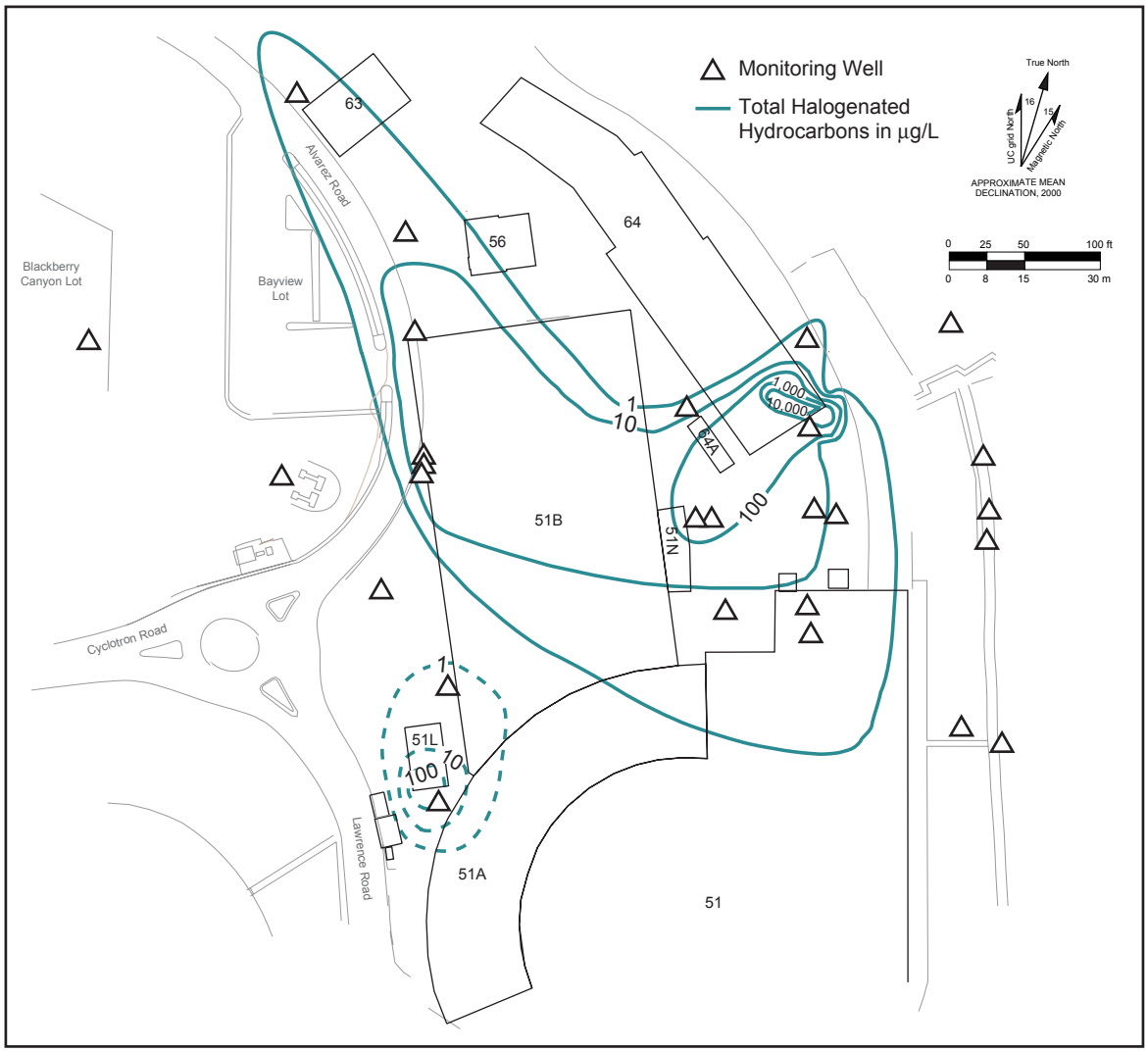


Figure 6-5 Groundwater Contamination (Total Halogenated Hydrocarbons in µg/L) at Building 51/64 VOC Plume (September 2001)

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. This is a recently identified plume. 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 2001 was 3,931 µg/L. The contaminants consisted primarily of cis-1,2-DCE (2,625 µg/L), trans-1,2-DCE (1,078 µg/L), and TCE (227 µg/L).

The Building 76 VOC plume is defined by the presence of TCE and cis-1,2-DCE. The maximum concentration of total halogenated hydrocarbons detected in wells monitoring the plume in CY 2001 was 19.8 µg/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 was most likely 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 20 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 (less than 30 becquerels per liter [Bq/L]) of tritium 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 2001 was 1,031 Bq/L (27,800 pCi/L), at monitoring well 75-97-958, which is above the drinking-water standard of 740 Bq/L (20,000 pCi/L).[3] 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 48 other monitoring wells, including 20 wells close to the Berkeley Lab property line, were analyzed for tritium. No tritium was detected in any of these samples above the reporting limit of 11 Bq/L (300 pCi/L).

6.4.4 Petroleum Hydrocarbon Plumes

Monitoring wells have been installed at or downgradient from two abandoned and seven 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 2001 are listed in Table 6-4.

Petroleum hydrocarbon plumes are located 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 2001. 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 2001 at a concentration of 0.5 μg/L. The California MCL for MTBE is 13 μg/L.

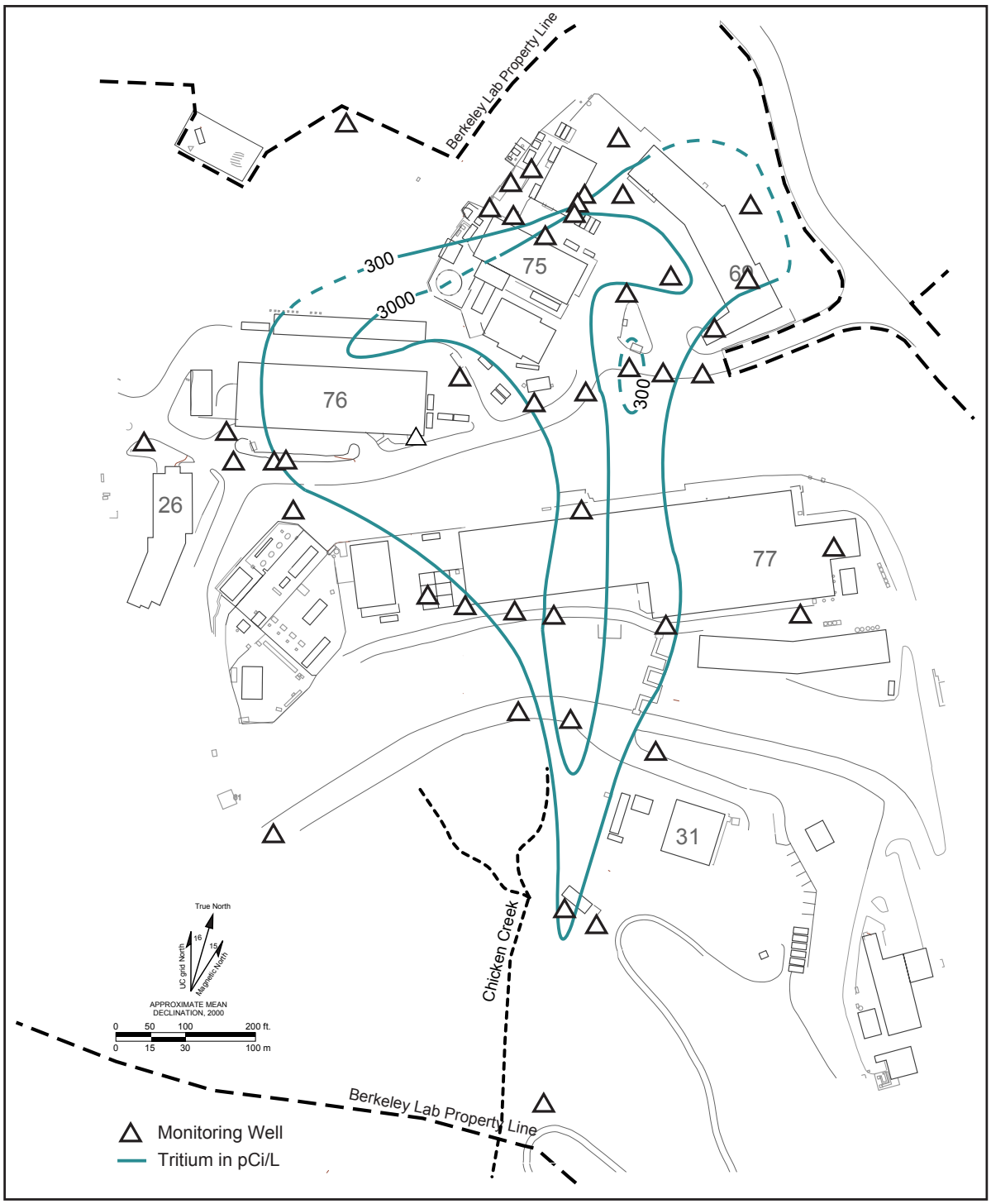


Figure 6-6 Groundwater Contamination (Tritium in pCi/L), October to December 2001

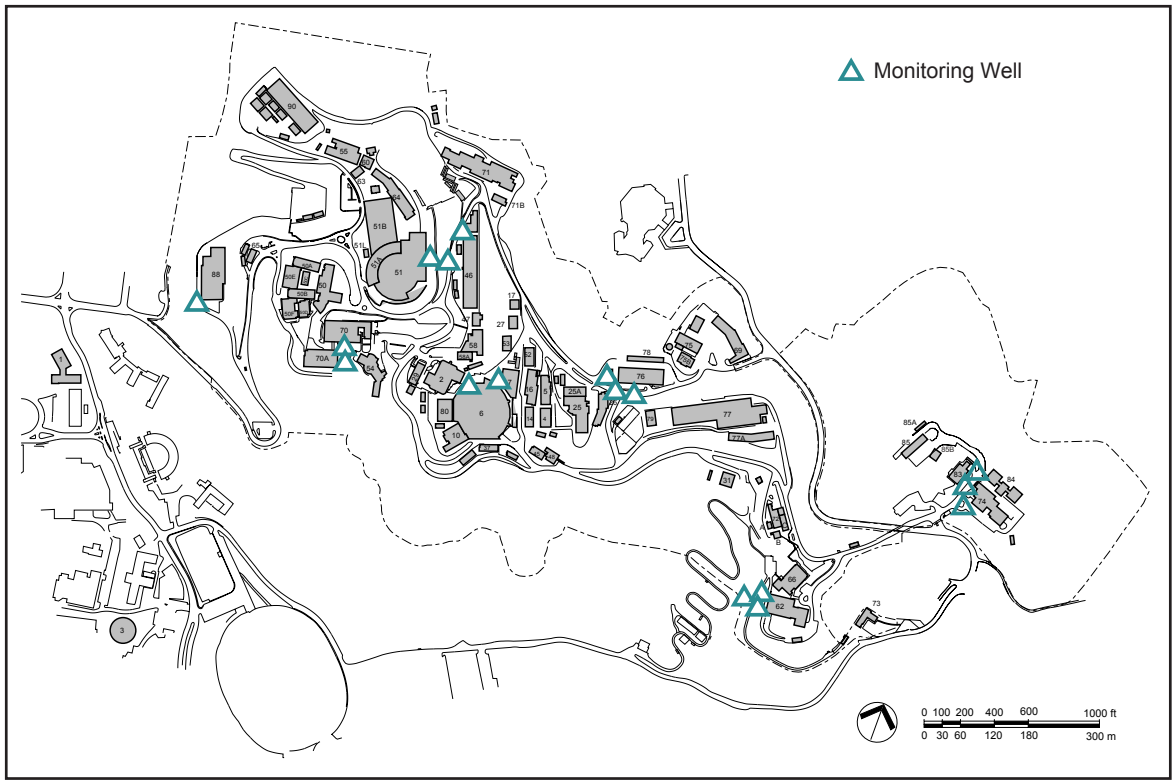


Figure 6-7 Approximate Locations of Monitoring Wells Associated with Underground Storage Tanks

Table 6-4 Total Petroleum Hydrocarbon Concentrations in Former UST Sites

UST location	Status	Present or previous contents	Maximum concentration (µg/L)
Building 51[a]	Removed	Diesel	NS[e]
Building 70A[a]	Removed	Diesel	ND[b]
Building 62[a]	Removed	Diesel	TPH-D[c] = 50
Building 74[a]	Removed	Diesel	TPH-D[c] = 250
Building 76[a]	Removed	Diesel	TPH-D[c] = 350
Building 76[a]	Removed	Gasoline	ND[b]
Building 7E	Removed	Kerosene	TPH-K[d] = 1,800
		Diesel	TPH-D[c] = 1,200
Building 88[a]	Abandoned	Diesel	ND[b]
Building 46A[a]	Abandoned	Gasoline	NS[e]

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

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 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; and
- 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 at the Laboratory, including the following in CY 2001:

- Approximately 35 cubic meters (48 cubic yards) of VOC-contaminated soil were excavated from the source area of the Old Town VOC plume east of Building 52A.
- Highly contaminated soil and groundwater near the source location (the former Building 7 sump) are a continuing source of contamination for the Old Town plume. To control the source of contamination, the Laboratory constructed a groundwater collection trench immediately downgradient from the former sump location in 1996. Contaminated groundwater is extracted from the collection trench and treated. The treatment system removed approximately 3.5 kg of VOCs (consisting primarily of PCE, TCE, and carbon tetrachloride) from the groundwater in CY 2001.
- Approximately 50 cubic meters (68 cubic yards) of polychlorinated biphenyl (PCB)/tritium–contaminated soil were removed from the B75J pad.

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 the hydrauger effluent when the water is contaminated with VOCs. See Sections 5.4.3 and 6.5.4 for more information on discharge from this system.

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 2001.
- 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 2001.

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. Seven 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 (EBMUD),[4] or recirculated to flush contaminants from the subsurface.

Table 6-5 lists both the volume of contaminated groundwater treated by each system in CY 2001 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 CY 2001 (liters)[a]	Total volume treated (liters)
Building 37 VOC plume	Building 37	295,767	4,314,809
Old Town VOC plume	Building 46	3,666,280	33,904,266
Building 71 and Old Town VOC plume and water collected from purging monitoring wells	Building 51 Fire Trail[b]	3,126,879	45,857,921
Building 51 subdrain system and Building 51/64 VOC plume	Building 51 Sump	1,092,256	6,803,367
VOC-contaminated groundwater at Building 51L	Building 51L	85,609	167,581
Old Town VOC plume	Building 7 Trench	504,226	7,702,876
Building 6 former underground storage tank	Building 6 Bioventing	648,174	3,148,969
Total volume treated		9,419,191	101,899,789

[a] 1 liter = 0.264 gallons
[b] B51 hydrauger system is routed into the Building 51 fire trail system and is included in that total.

7

Soil and Sediment

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.[1] 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.

Details on Berkeley Lab's soil and sediment program are included in its Environmental Monitoring Plan.[2] In calendar year (CY) 2001, 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).

Locations were chosen to coincide with 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, gross beta, and gamma-emitter results were similar to background levels of

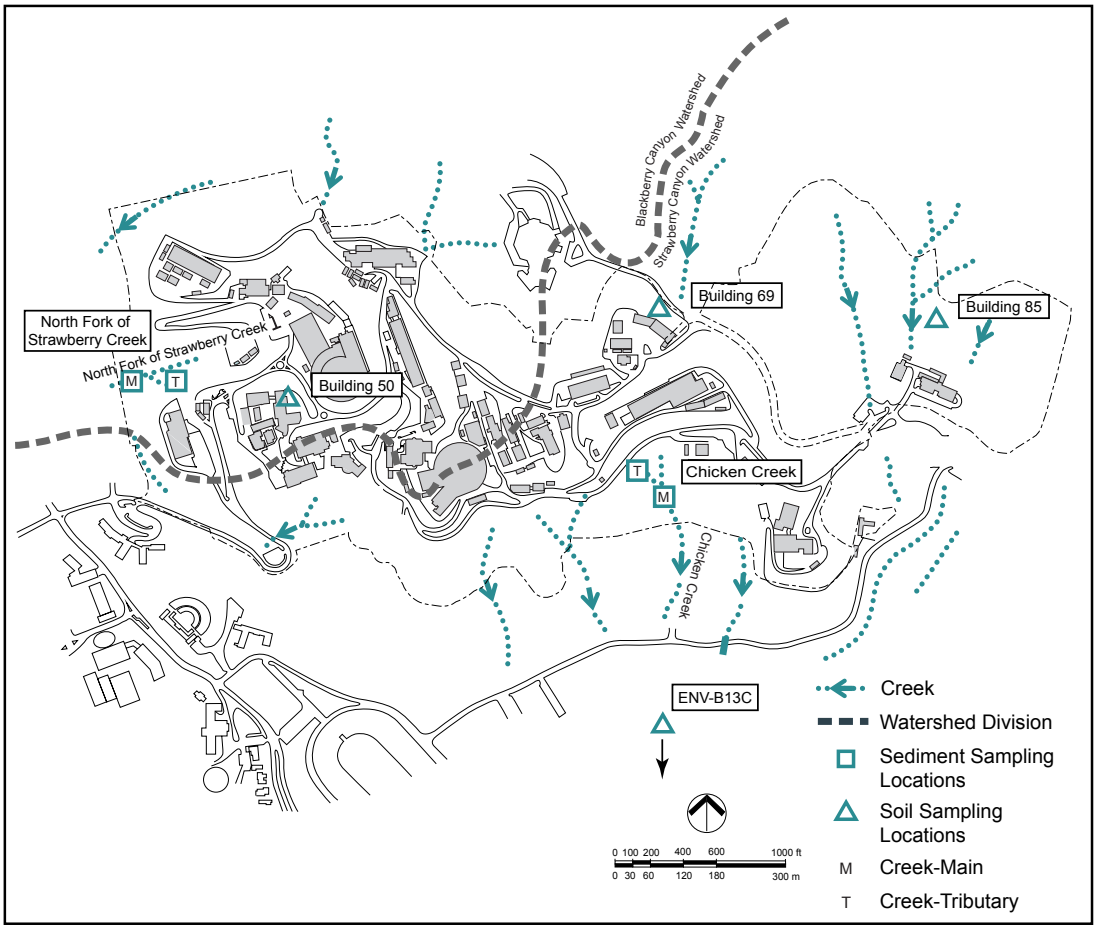


Figure 7-1 Soil and Sediment Sampling Sites

naturally occurring radioisotopes commonly found in soil and sediment. In CY 2001, none of the soil or sediment samples contained detectable levels of tritium.

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 (600 mg/kg) was measured at the Chicken Creek main location. Oil and grease contamination is commonly associated with motorized vehicle use on roads and parking lots. This location will be sampled in future years to monitor any changes.

Table 7-1 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 CY 2001, 238 soil and 50 sediment samples were collected at Berkeley Lab and analyzed for tritium in response to a request by the Environmental Sampling Project Task Force. This supplemental sampling is discussed in detail in Chapter 10. The results from this supplemental monitoring provide information on the surface area and horizontal distribution of tritium in shallow soil and on surficial creek sediment. The data obtained from samples collected in CY 2001 are consistent with historical data collected by the routine Environmental Monitoring Program and the ongoing RCRA Corrective Actions Program.

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

	Sample Location								
	Soil				Sediment				
Analyte	B50	B69	B85	ENV-B13C	Chicken Creek—Main	Chicken Creek—Tributary	N. Fork Strawberry Creek—Main	N. Fork Strawberry Creek—Tributary	Regulatory criteria (TTLC[b])
Arsenic	8	3	3	8	2	2	3	3.6	500
Barium	210	120	140	150	100	310	76	77	10,000
Cadmium	2.6	1.2	1.1	<1[c]	<1[c]	<1[c]	<1[c]	<1[c]	100
Chromium	41	110	100	36	30	39	20	22	2,500
Cobalt	10	23	21	8.8	9.7	7.9	5.1	6.1	8,000
Copper	140	24	35	25	20	19	13	96	2,500
Lead	130	<10[c]	<10[c]	93	<10[c]	15	20	<10[c]	1,000
Mercury	0.27	<0.05[c]	0.058	0.12	<0.05[c]	<0.05[c]	0.19	0.13	20
Nickel	45	65	60	30	41	42	16	18	2,000
Vanadium	52	100	110	44	25	31	36	35	2,400
Zinc	170	66	57	220	99	86	110	140	5,000
Oil & grease	—	—	—	—	600	290	370	570	—

[a] One sample per location, all results in mg/kg
[b] Total Threshold Limit Concentration (22 California Code of Regulations 66261.24)[3]
[c] Result was below detection limit.
[d] Results for antimony, beryllium, molybdenum, selenium, silver, and thallium were all below practical quantification limits and are not reported in Table 7-1. These results, along with other non-TTLC metals (aluminum, boron, manganese, and iron), are included in Volume II.

8

Vegetation and Foodstuffs

8.1 BACKGROUND

Sampling 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 Berkeley Lab activities and to calculate potential human doses 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 → exchange to surface water body → aquatic species → human; and
- Airborne emissions → surface or groundwater → vegetable crop → human.

Routine sampling of vegetation and foodstuffs is not required under any applicable environmental regulations. Berkeley Lab undertakes voluntary sampling efforts 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. Dose assessments performed using very cautious assumptions indicate extremely low potential impacts.

U.S. Department of Energy (DOE) guidance[1] indicates that when the annual effective dose equivalent for the consumption of vegetation and foodstuffs is between 0.001 millisievert (mSv) (0.1 millirem [mrem]) and 0.01 mSv (1 mrem), only a minimal vegetation and foodstuff surveillance program is required. Using conservative assumptions, Berkeley Lab's maximum individual dose attributable to the consumption of locally grown vegetation and foodstuffs was well below the requirement for a minimal monitoring program. 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. Nevertheless, in modeling and dose calculations, the Laboratory assumes that 100% of the emissions are tritiated water vapor to provide a very conservative estimate of actual dose.

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.[2] The objective of this portion 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 task-management program and its maintenance program for a fire-safe landscape.[3]

Environmental tritium levels have been determined to be above regional background levels near the National Tritium Labeling Facility (NTLF); they decrease with distance from the NTLF stack.[4] At about 200 meters from the NTLF stack, tissue-free water and organically bound tritium levels in tree wood are below detection limits (nominally 0.019 becquerel per gram [Bq/g], or 0.5 picocurie [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 method approved by DOE, and only trees with tritium levels that are indistinguishable from background are released to the public.

In calendar year (CY) 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 must be chosen carefully, so that there will be no expected harm to the public or the environment. For example, a national standard recommends that material with tritium levels less than 111 Bq/g (3,000 pCi/g) can be released without restrictions.[5] This value has been shown to be protective of the public health and the environment. DOE is considering Berkeley Lab's request.

In CY 2001, Berkeley Lab marked and sampled several trees near Building 76 that were being considered for removal (see Figure 8-1). Trees at this distance from the NTLF, within 200 m, were expected to have low but detectable levels of tritium. Eucalyptus trees near Building 76 were sampled using a systematic and documented procedure.[6] 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 and organically bound tritium.

As expected, the tritium results from about half of the trees sampled were very low but detectable, and therefore none of the trees were cut down or released for unrestricted use. Thirteen samples were below the analytical detection limits: nominal minimum detectable activities for tissue-free water tritium were 0.019 Bq/g (0.5 pCi/g) and for organically bound tritium were 0.19 Bq/g (5 pCi/g). Trees in this area were not cut down or removed from Berkeley Lab property.

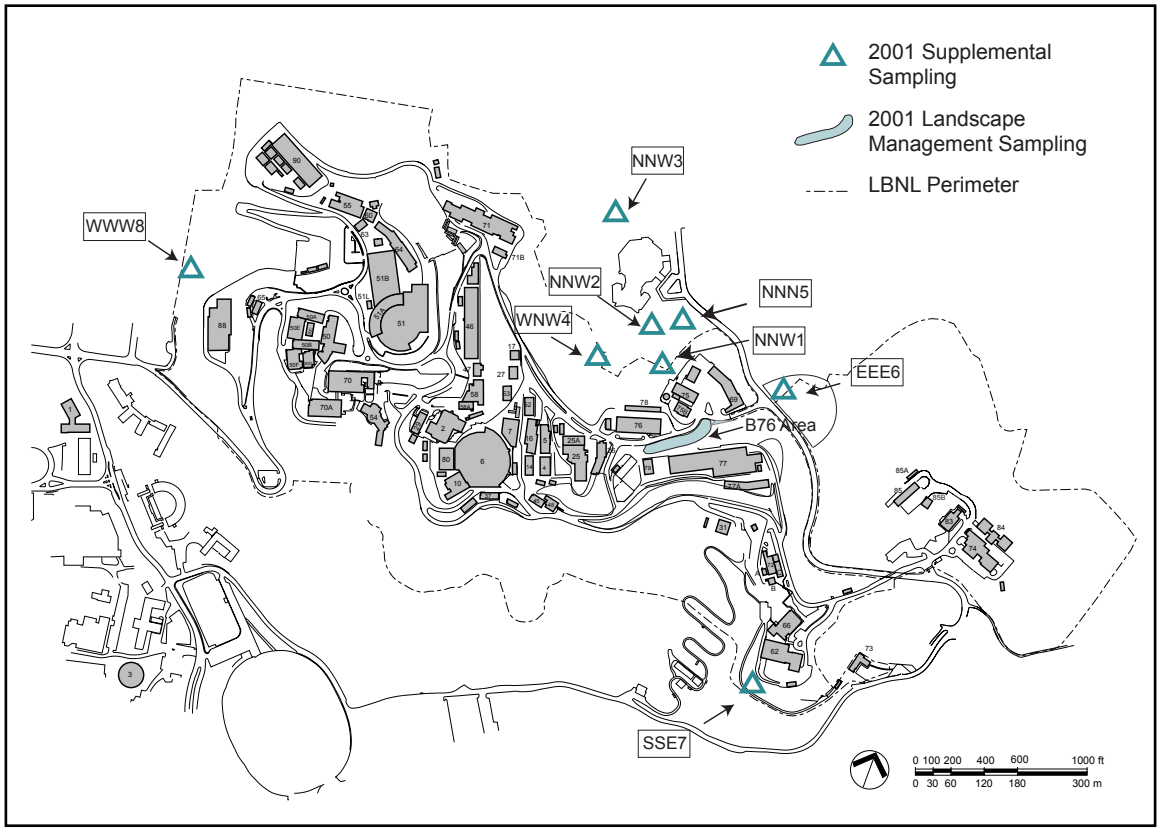


Figure 8-1 Vegetation Sampling Areas

The results from the sampling and analyses conducted in CY 2001 confirm what has been measured and reported previously: trees within 200 meters of the NTLF's exhaust stack have detectable tritium concentrations, and tritium concentrations in vegetation decrease with distance from the stack.

8.3 SUPPLEMENTAL TREE SAMPLING

In CY 2001, vegetation around the perimeter of Berkeley Lab was sampled in response to a request by the Environmental Sampling Project Task Force. This supplemental sampling is discussed in detail in Chapter 10 and is summarized below.

Sampling locations are shown in Figure 8-1. Samples of tree wood, leaves, duff (plant litter beneath the tree), and transpired water were collected in dry and wet seasons. Samples were analyzed for tissue-free water tritium and organically bound tritium.

Results of sampling support the conclusion that tritium concentrations in vegetation decrease with distance from the stack. Results also support the conclusion of a 1997 risk assessment indicating that there is no potential for adverse impact from the vegetation as a result of Berkeley Lab tritium activities.

9

Radiological Dose Assessment

9.1 BACKGROUND

This chapter presents the estimated dose results from Berkeley Lab's penetrating radiation and airborne radionuclide monitoring programs. The doses projected from each monitoring program are presented separately before being evaluated cumulatively 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. Factors affecting either type of dose (individual or population) include the type of radiation, distance from the activity, complexity of terrain, meteorological conditions, emission levels, food production and consumption patterns, and length of exposure.

To minimize radiological impacts to the environment and the public, environmental 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 moderate- to high-hazard activities 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 1 millirem (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. Accelerators produce both gamma and neutron forms of radiation when operational. Irradiators are primarily limited to gamma radiation.

Historically, U.S. Department of Energy (DOE) facilities have reported "fence-post doses," which are measured or computed values reflecting 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 (Building 6), Biomedical Isotope Facility (Building 56), and 88-Inch Cyclotron (Building 88).

Berkeley Lab 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 site's perimeter; 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. For these doses, see Table 9-1.

The second method uses passive detectors known as thermoluminescent detectors (TLDs). Figure 9-1 also shows the locations of Berkeley Lab's TLD sites.

Currently, six TLDs (TLDs 1–6) are near the site boundary, and one (TLD 7) is positioned at the remote location ENV-B13C. TLDs are used to measure gross gamma radiation, and they do not

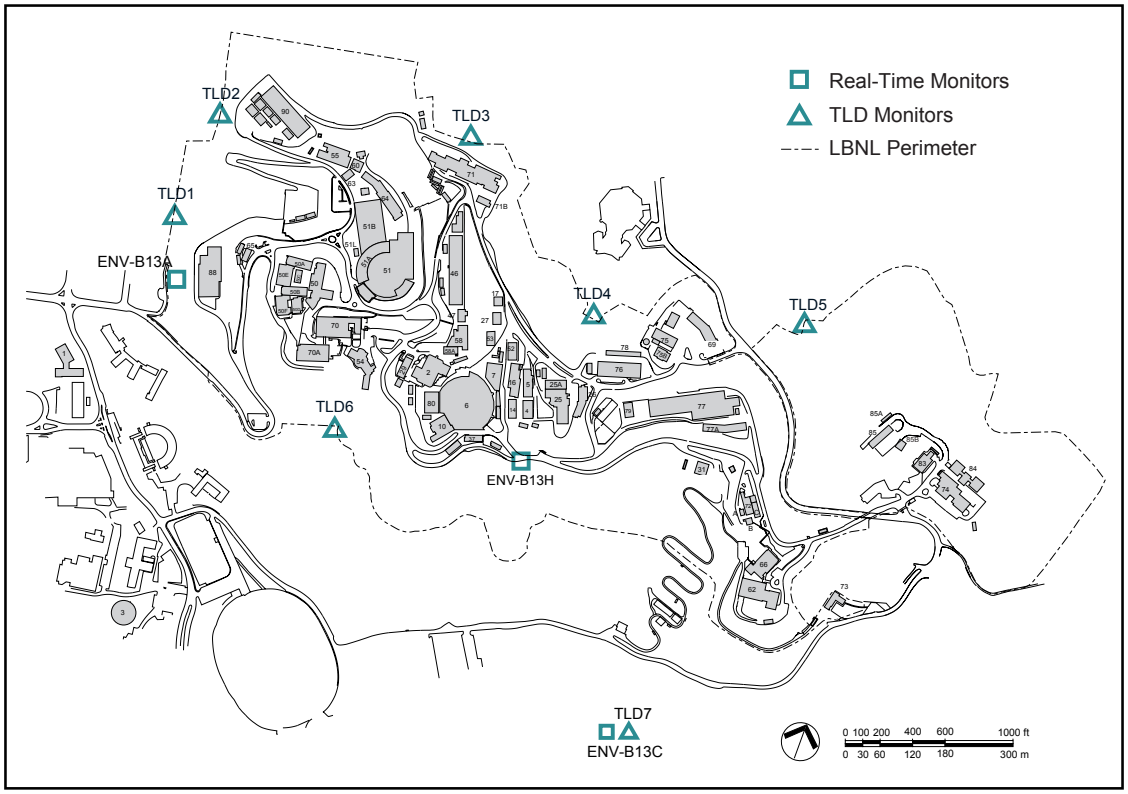


Figure 9-1 Environmental Penetrating Radiation Monitoring Stations

Table 9-1 Annual Penetrating Radiation Dose at Site Perimeter Resulting from Accelerators

Monitoring station	Net gamma dose (mSv/yr)[a]	Net neutron dose (mSv/yr)	Total dose[b] (mSv/yr)
ENV-B13A (Bldg. 88)	0.0006	0.0027	0.0033
ENV-B13C (Panoramic)	0.0003	0.0009	0.0012
ENV-B13H (ALS)	0.0006	0.004	0.0045

[a] 1 mSv = 100 mrem
[b] Standard of comparison is DOE limit of 1 mSv/yr.

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 measurement are to record and compare the gross penetrating radiation exposures (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 (CY) 2001 was 0.65 millisievert (mSv) (65 mrem), and the gamma radiation dose at the remote location (Panoramic) was 0.72 mSv (72 mrem). The average fence-line TLD dose measurement is lower than and indistinguishable from the remote background. The TLD results are consistent with the low-dose values measured by the real-time monitoring stations.

Dose results from the network represent the potential impact to an individual situated at a particular monitoring location. The predicted dose to the surrounding population is estimated through a site-specific model.[1] Although no regulatory standard exists for population dose values, Berkeley Lab uses United States Census[2] data, extending outward to a distance of 80 kilometers (50 miles) from a facility, for this population model. In the Laboratory's model, the population dose due to gamma and neutron radiation is derived from the maximum measured dose at the perimeter as measured by the real-time monitoring systems, primarily at station ENV-B13A. The predicted population dose to the approximately 5 million people within 80 kilometers (50 miles) of Berkeley Lab in CY 2001 was estimated at 0.0036 person-Sv (0.36 person-rem).

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 a massive, interlocked, reinforced-concrete-covered structure built as part of Building 74. The irradiator was out of operation for the first several months of CY 2001; it was returned to service in July. Routine surveys performed when the irradiator was in operation confirmed that no area exceeded 0.001 mSv/hr (0.1 mrem/hr) at 1 m from the outside walls or ceiling of the labyrinth. The Building 74 irradiator is about 80 m (260 ft) from the site's perimeter fence, about 150 m (500 ft) from the nearest public institution (the UC Berkeley Botanical Garden), and more than 700 m (2,300 ft) from the nearest residence. The projected annual dose to any member of the public is less than 0.002 mSv/yr (0.2 mrem/yr) at the perimeter fence,

less than 0.0004 mSv/yr (0.04 mrem/yr) at the Botanical Garden, and less than 0.00002 mSv/yr (0.002 mrem/yr) at the nearest residence.

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 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 radionuclide inputs 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 U.S. Environmental Protection Agency.[3] Berkeley Lab satisfies this requirement with the use of CAP88-PC.[4]

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 not one 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 network for the dispersion-modeling module of CAP88-PC.

Berkeley Lab performed 15 individual CAP88-PC modeling runs to predict the impact from groupings of the Laboratory’s release points. Table 9-2 lists the attributes of these groupings.

Table 9-2 Summary of Dose Assessment at Location of Maximally Exposed Individual (MEI) from Airborne Emissions

Building	Building description	Distance to MEI[a] (m)	Direction to MEI[a]	Dose to MEI (mSv/yr)[b]	Percent of MEI total dose
75	National Tritium Labeling Facility	110	NW	4.2×10^{-4}	75.1%
55/56/64	Center for Functional Imaging/BIF/Life Sciences	440	E	9.1×10^{-5}	16.3%
1	Donner Laboratory (UC Berkeley)	980	ENE	3.4×10^{-5}	6.0%
75A/75S	Old Hazardous Waste Handling Facility/Storage Locker	150	NW	4.9×10^{-6}	0.9%
85	New Hazardous Waste Handling Facility	550	WNW	3.8×10^{-6}	0.7%
88	88-Inch Cyclotron	670	ENE	2.7×10^{-6}	0.5%
70/70A	Nuclear/Life Sciences	510	NE	1.9×10^{-6}	0.3%
74/83/84	Human Genome Facility/Life Sciences	730	WNW	3.4×10^{-7}	<0.1%
3	Calvin Lab (UC Berkeley)	1,070	NE	2.3×10^{-9}	<0.1%
6	Advanced Light Source	370	NE	1.0×10^{-7}	<0.1%
26/76	Radioanalytical Laboratory	240	N	2.2×10^{-7}	<0.1%
71	Heavy Ion Linear Accelerator/Instrument Calibration	220	E	2.3×10^{-9}	<0.1%
72	Low-Background Counting Facility	540	NW	3.1×10^{-15}	<0.1%
75U	Storage Container	130	NW	2.3×10^{-10}	<0.1%
75 Sump	Sump	130	NW	2.1×10^{-7}	<0.1%
			Total	**5.5×10^{-4}**	**100%**

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

Details of these groupings and modeling runs are included in the Laboratory's annual NESHAPs report. After the complete set of modeling runs, the location of the maximally exposed individual (MEI) to airborne emissions was determined to be at the Lawrence Hall of Science. The source groupings listed in Table 9-2 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 Lawrence Hall of Science) to airborne radionuclides for CY 2001 was less than 0.001 mSv (0.1 mrem).

In CY 2001, an audit by DOE EH-24 personnel found that a small, concrete-lined sump near the exhaust stack of the National Tritium Labeling Facility was open to the weather. The sump had collected rainwater and water that had drained from the exhaust stack. Tritium was measured in the sump water at 5.2×10^4 becquerels (Bq)/L (1.4×10^6 pCi/L).

The dose to a person at the Lawrence Hall of Science from evaporation of the sump water was estimated, using CAP88-PC, at less than 3×10^{-7} mSv/yr (3×10^{-5} mrem/yr). This represents a

small fraction — about 0.04% — of the total dose to the MEI (a person residing at the Lawrence Hall of Science) from Berkeley Lab's airborne emissions, and an even smaller fraction, about 0.0002%, of the U.S. Environmental Protection Agency's (US/EPA) standard for airborne radionuclide emissions, 0.1 mSv/yr (10 mrem/yr).

As with penetrating radiation, the dose from airborne radionuclides to the surrounding population is estimated for a region that extends from the site for 80 kilometers (50 miles). 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 United States Census data 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 0.005 person-Sv (0.5 person-rem).

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. Furthermore, this total impact is an overly conservative estimate. It is the sum of the greatest possible dose from direct radiation and the greatest possible dose from airborne radionuclides received by the maximally exposed individual to total radioactivity. A person would have to reside full time at a location near the 88-Inch Cyclotron to receive the maximum dose from both direct penetrating radiation and dispersible radionuclides. As presented in Table 9-3 and Figure 9-2, the maximum effective dose equivalent to an individual residing near the 88-Inch Cyclotron from both direct penetrating radiation and dispersible radionuclides in CY 2001 is about 0.004 mSv (0.4 mrem) per year. This value is approximately 0.2% of the nominal background radiation[5] in the Bay Area and about 0.4% of the DOE annual limits.[6]

Table 9-3 Summary of Radiological Dose Impacts to a Person Residing Near the 88-Inch Cyclotron

	Dose from direct radiation	Dose from airborne radionuclides	Dose from total radioactivity (direct and airborne)
Annual EDE[a]	0.0033 mSv/yr[b]	0.0003 mSv/yr	0.004 mSv/yr
Standard of comparison	1 mSv/yr (DOE)	0.10 mSv/yr (US/EPA)	1 mSv/yr (DOE)
Impact as % of standard	0.3%	0.3%	0.4%
Annual background	1 mSv/yr	1.6 mSv/yr	2.6 mSv/yr
Impact as % of background	0.3%	0.02%	0.2%

[a] EDE = Effective Dose Equivalent
[b] 1 mSv = 100 mrem

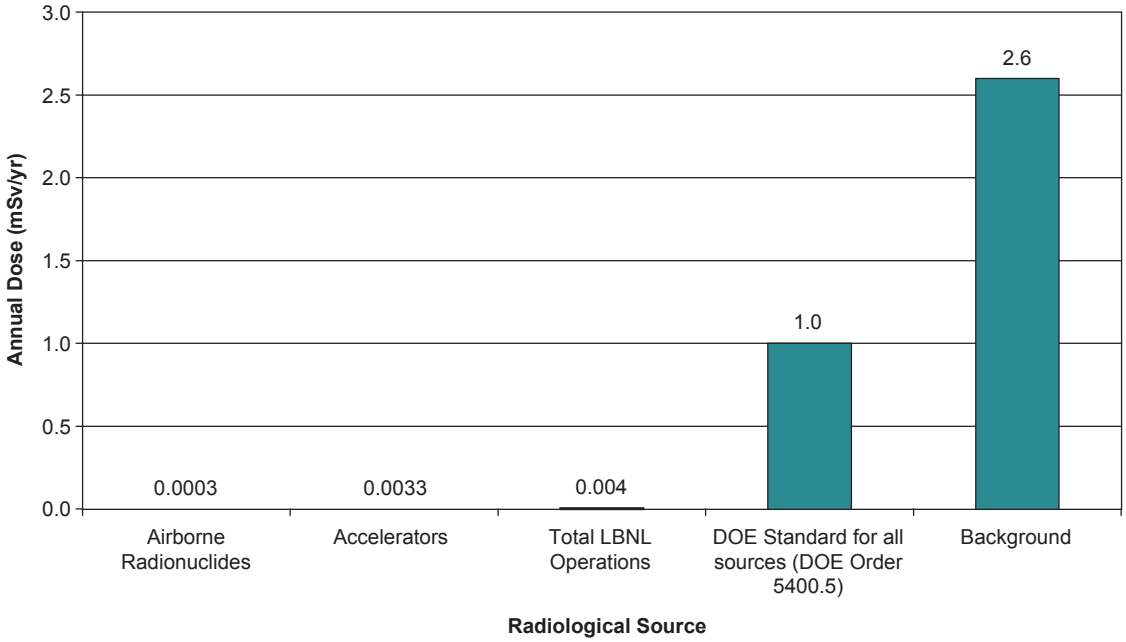


Figure 9-2 Comparison of Radiological Dose Impacts

The estimated dose to the population within 80 kilometers of Berkeley Lab from these same activities was 0.009 person-Sv (0.9 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 0.00007% of the background level.

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 gray/day).[6] In addition, international recommendations suggest that doses to terrestrial animals should be limited to less than 0.1 rad/day (0.001 gray/day), and doses to terrestrial plants should not exceed 1 rad/day (0.01 gray/day).[7]

To assist sites in demonstrating compliance with these limits, DOE issued an interim technical standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, in June 2000.[7] Along with other institutions in the DOE complex, Berkeley Lab was asked to review and comment on the proposed standard. As part of the review, results of environmental monitoring at Berkeley Lab were compared to the standard biota concentration guides. Results of this preliminary assessment show that concentrations of radionuclides in environmental media at Berkeley Lab are orders of magnitude less than those listed in the DOE guide. This indicates that animals and plants are protected at levels well below the recommended dose limits. The proposed screening tool will be used in the future to perform biota dose evaluations as required by DOE guidance. The final version of the technical standard is expected in 2002.

10

Supplemental Monitoring

10.1 INTRODUCTION

In 1991, the United States Environmental Protection Agency (US/EPA) initially evaluated Berkeley Lab under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)[1] for possible inclusion on the federal Superfund List. US/EPA determined at that time that Berkeley Lab did not qualify as a Superfund site. In 1997, the Committee to Minimize Toxic Waste (CMTW), a Berkeley-based organization, formally requested that US/EPA review additional data regarding tritium contamination and re-evaluate Berkeley Lab for possible listing as a Superfund site. In evaluating Berkeley Lab, US/EPA considered data submitted by CMTW and the United States Department of Energy (DOE). US/EPA issued a preliminary Superfund Evaluation Report in July 1998, with a finding that Berkeley Lab is potentially eligible for the National Priorities List because of the tritium levels in ambient air that were reported by Berkeley Lab. US/EPA has recognized, however, that although the tritium levels in air sometimes exceeded Superfund screening criteria, they have been well below its National Emissions Standards for Hazardous Air Pollutants (NESHAPs).[2]

In the July 1998 report, US/EPA stated that while the operation of the National Tritium Labeling Facility (NTLF) resulted in detectable but small levels of tritium in nearby soil, groundwater, and surface water, the data do not show tritium concentrations in sufficient quantities to necessitate action for remediation. Nevertheless, US/EPA requested supplemental sampling to support a final decision.

In September 1998, US/EPA requested that the supplemental samples of soil, surface water, sediment, and ambient air be collected consistent with US/EPA Superfund guidance, and that Berkeley Lab consider input from local stakeholders. These sample data would be used by US/EPA to determine the nature and extent of present tritium contamination in the environment surrounding Berkeley Lab, and would enable US/EPA to make a final decision as to whether or not Berkeley Lab is eligible to be listed on the National Priorities List.

In response to US/EPA's request, Berkeley Lab prepared a draft Tritium Sampling and Analysis Plan. To ensure that sufficient information was generated, Berkeley Lab proposed to take samples in a variety of environmental media. Because the primary exposure pathway is air, the sampling plan presented a methodology for acquiring additional ambient air samples. To assure that potential secondary exposure pathways are considered, US/EPA recommended that samples be taken in soil, sediments, and surface water. To address public concern over tritium levels in vegetation, Berkeley Lab also collected samples of vegetation and plant-transpired water.

In order to enhance stakeholder involvement in the development and implementation of the Tritium Sampling and Analysis Plan, Berkeley Lab established the Environmental Sampling Project Task Force, consisting of 24 community stakeholder groups. The members of this Task Force were requested to review the sampling plan in detail, making comments to DOE and US/EPA for their

consideration in revising or augmenting this sampling program. They were also to review and comment on the sampling results.

The Task Force met throughout 2000 and the beginning of 2001. Based on members' comments and community input, the Tritium Sampling and Analysis Plan was revised and resubmitted to US/EPA and DOE in January and February of 2001 for concurrence and approval. US/EPA concurred with the Plan, and DOE approved the Plan in 2001. Sampling began in April 2001.

The next four sections of this chapter discuss the collection and analysis of supplemental samples for ambient air, soil and sediment, water, and vegetation collected in calendar year (CY) 2001.

10.2 AMBIENT AIR

The ambient air supplemental monitoring began in May 2001 and continued for one year. To prepare for this phase, Berkeley Lab expanded its air-monitoring network from seven to fifteen sites, with the primary purpose of gathering representative data to satisfy US/EPA guidance under CERCLA. A second reason for the expansion was to address a recommendation from the City of Berkeley that the Laboratory provide monitoring coverage in compass directions downwind of the NTLF, where the wind seldom blows. The fifteen sites effectively covered all sixteen compass directions, with most of the new sites located at distances from the NTLF where detectable levels of tritium would likely be present even from small accidental releases. Nearly all of the sites were located within 1 kilometer (0.6 mile) of the NTLF. The station furthest from the Laboratory, ENV-AR, is located more than 2.2 kilometers (1.4 miles) south-southeast of the NTLF at the East Bay Municipal District's (EBMUD's) Amito Reservoir. This site was selected as a regional background site because of its distance from the source of the tritium emissions under review and because it is outside the predominant downwind patterns from the NTLF, while being located at a similar elevation with similar meteorological conditions (e.g., temperature, humidity, precipitation). Figure 10-1 depicts the locations of all stations in the network.

Sample monitoring and collection procedures followed those used in the routine sampling program (see Chapter 4). Data from all stations in the network are made available to US/EPA for use in its ongoing evaluation. Along with a greater number of sample points that come from a larger network, Berkeley Lab increased the number of quality assurance split samples. Discussion of this quality assurance program and results from split analyses are included in Section 11.2 of the quality assurance chapter. In the remainder of this section, data results from the first eight months, or 67% of the supplemental ambient air sampling period, are summarized, excluding the results from split analysis samples.

As with the routine air-monitoring program (see Chapter 4), all average and maximum tritium concentration values from the supplemental monitoring period were well below 1% of the allowable DOE annual exposure standard for airborne tritium (3.7×10^3 becquerels [Bq]/m^3 [1.0×10^5 pCi/m^3]).[3] At stations that existed before the network's expansion, average tritium concentrations

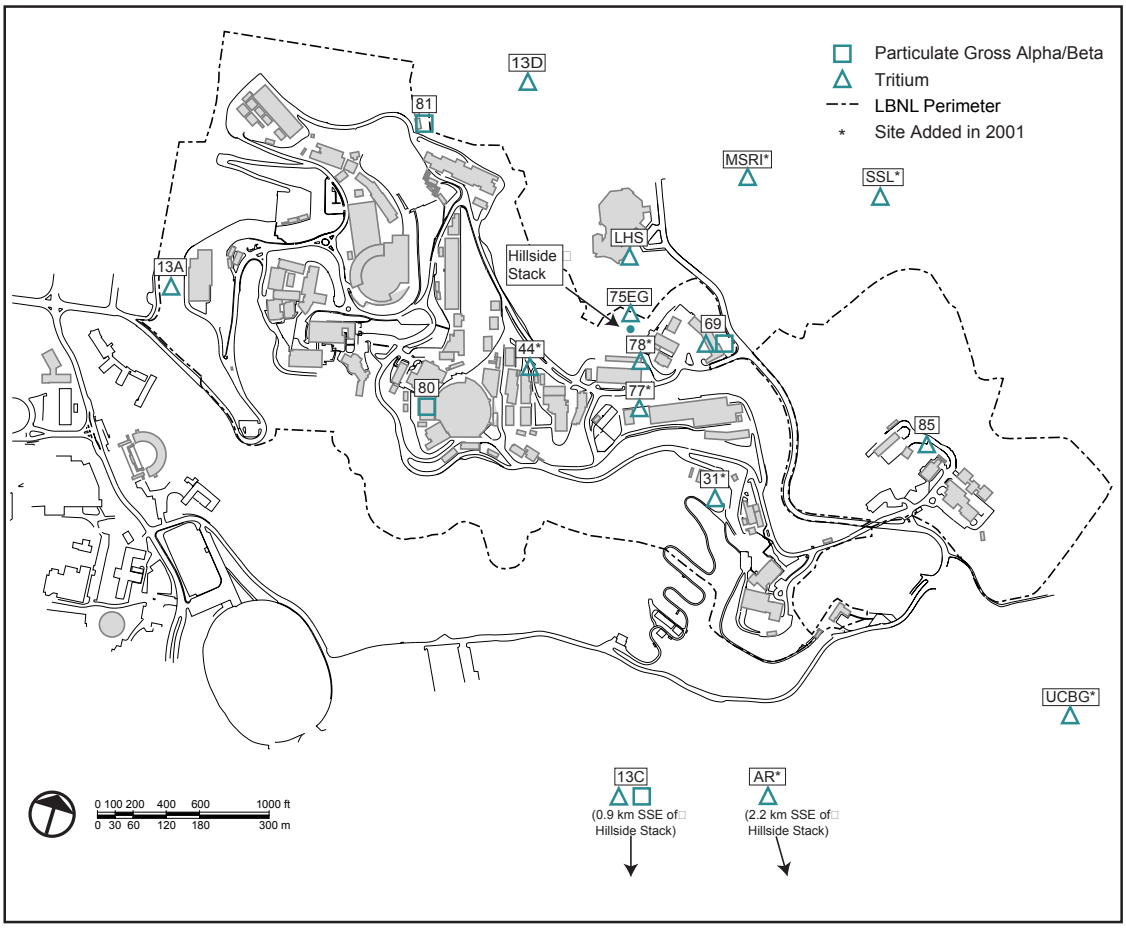


Figure 10-1 Ambient Air–Monitoring Network Sampling Locations

during the supplemental monitoring period were generally below those measured during the first four months of the year. This decrease correlated with a similar decrease in emissions from the NTLF operations. Statistical summaries for the supplemental monitoring period are provided in Table 10-1.

The greatest ambient tritium concentrations were measured at stations nearest the hillside stack. Concentrations decreased rapidly with distance from the stack. At a distance of 500 meters (1,650 feet) from the stack, the air tritium concentrations were frequently nondetectable. The observed spatial distribution of results is predominantly determined by prevailing wind patterns, although the influence of the complex terrain is noticeable in the vicinity of the hillside stack. This is best reflected by comparing stations ENV-78 and ENV-69. Both stations are located within the small bowl-shaped region that includes the NTLF and the hillside stack. Though not directly within the predominant downwind direction of the hillside stack, ENV-78 reported the higher mean, median, and maximum values of the two sites.

Table 10-1 Summary of Supplemental Ambient Tritium Sampling

Station ID	Number of samples	Mean (Bq/m^3)[a]	Mean as percentage of standard[b]	Median (Bq/m^3)	Maximum (Bq/m^3)
ENV-B13A	8	< 0.18[c]	—	< 0.18[c]	0.24
ENV-B13C	8	< 0.18[c]	—	< 0.18[c]	0.32
ENV-B13D	8	<0.19[c]	—	<0.19[c]	0.42
ENV-31	8	<0.19[c]	—	<0.19[c]	0.32
ENV-44	8	0.24	0.006	0.25	0.51
ENV-69	8	0.52	0.014	0.48	0.88
ENV-75EG	8	2.08	0.056	1.92	3.34
ENV-77	8	0.68	0.018	0.51	1.95
ENV-78	8	1.01	0.027	0.80	2.20
ENV-85	8	<0.19[c]	—	<0.19[c]	0.31
ENV-AR	8	0.27	0.007	<0.18	0.88
ENV-LHS	8	0.90	0.024	0.94	1.30
ENV-MSRI	8	0.40	0.011	0.43	0.62
ENV-SSL	8	0.30	0.008	0.32	0.69
ENV-UCBG	8	<0.33[c]	—	<0.33[c]	<0.33[c]

[a] 1 Bq = 27 pCi
[b] Standard of comparison = 3.7×10^3 Bq/m^3 (source: Derived Concentration Guide in DOE Order 5400.5)
[c] Statistic was below the highest value for analytical sensitivity (minimum detectable amount) measured for this site.

10.3 SOIL

Soil samples were collected from 64 locations up to a maximum distance of approximately 600 meters (2,000 feet) from the NTLF hillside stack. The locations were selected to provide sample coverage in a radial pattern around the stack. Two additional locations (SSNTLF-01-65 and SSNTLF-01-66), situated approximately 1.6 kilometers (1 mile) northeast of the NTLF, were sampled to represent background soil conditions. The soil samples were collected from early April to early May 2001. Figures 10-2, 10-3, and 10-4 identify the soil sampling locations. Samples were collected at two depths at each location, from 0.15 to 0.30 meter (0.5 to 1 foot), and from 0.45 to 0.60 meter (1.5 to 2 feet) below ground surface. A total of 238 samples were analyzed, including split and duplicate samples.

The surface material (e.g., grass, leaves) was removed prior to sampling to ensure that nonsoil material was excluded from the soil sample. Samples were then collected using a soil drive sampler loaded with a 6-inch-long brass liner. Single-point (discrete) samples were collected at all locations. In addition, composite soil samples were collected from seven locations to address concerns expressed by the City of Berkeley. Samples from all locations were analyzed for tritiated water (HTO). In addition, samples from five locations where soil tritium levels were historically highest were analyzed for total tritium (HTO plus organically bound tritium [OBT]). Duplicate samples were collected at approximately 20% of the locations. Split samples were collected at

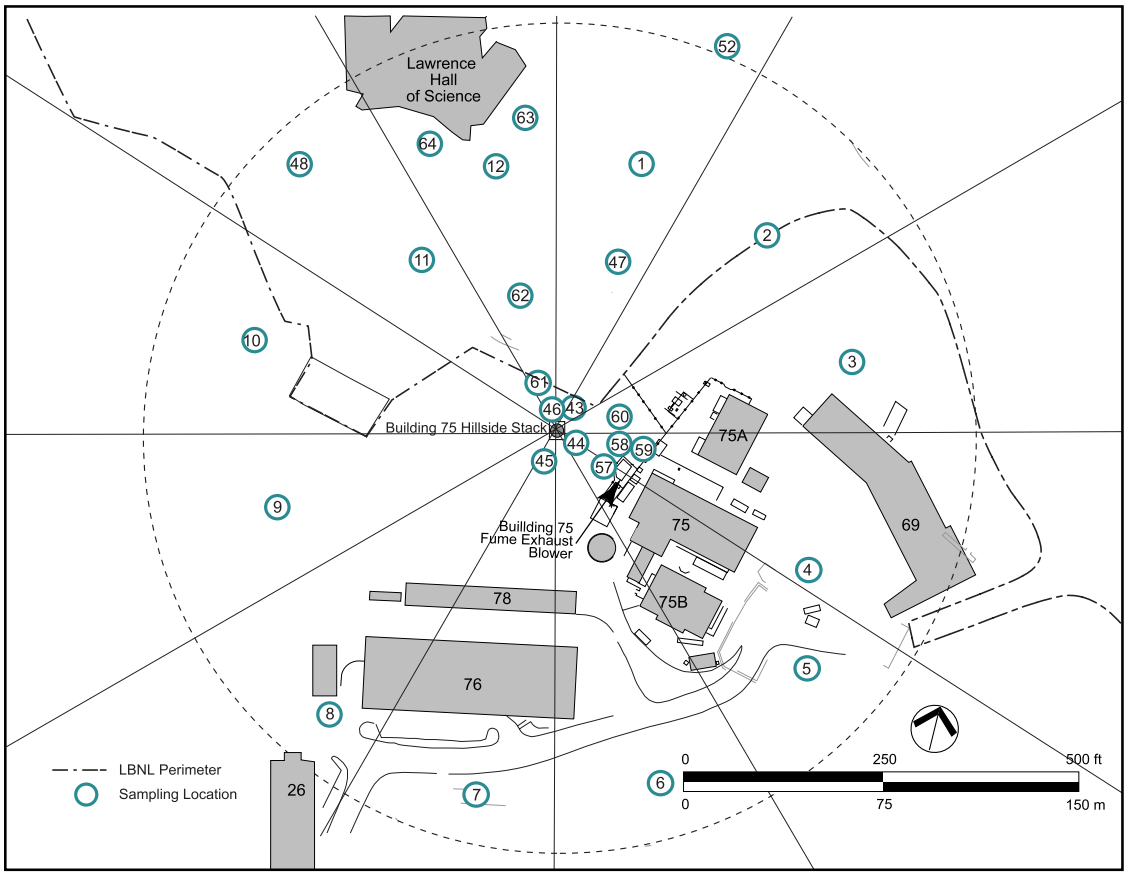


Figure 10-2 Supplemental Soil Sample Locations Near the NTLF Hillside Stack

approximately 15% of the locations and sent to both US/EPA and a third analytical laboratory for analysis. The reporting limits were 0.007 Bq/g (0.2 pCi/g) for HTO and 0.2 Bq/g (5 pCi/g) for total tritium.

Tritium was detected at 21 of the 66 sampling locations, all within 150 meters (500 feet) of the Building 75 hillside stack. The five locations with concentrations greater than 0.037 Bq/g (1 pCi/g) were within approximately 60 meters (200 feet) of the Building 75 hillside stack, with maximum concentrations of 0.37 Bq/g (10 pCi/g) HTO and 1.53 Bq/g (41.4 pCi/g) total tritium detected at location SSNTLF-01-43, immediately adjacent to the stack. Total tritium was not detected at any other location.

The soil sampling data indicate that the maximum concentrations of tritium in soils are found in the areas adjacent to or near the NTLF hillside stack, with concentrations decreasing to levels below the reporting limit (0.007 Bq/g [0.2 pCi/g]) at distances greater than 150 meters (500 feet) from the stack. These findings are consistent with historical sampling results, and consistent with the ambient air monitoring data that indicate highest concentrations nearest the source.

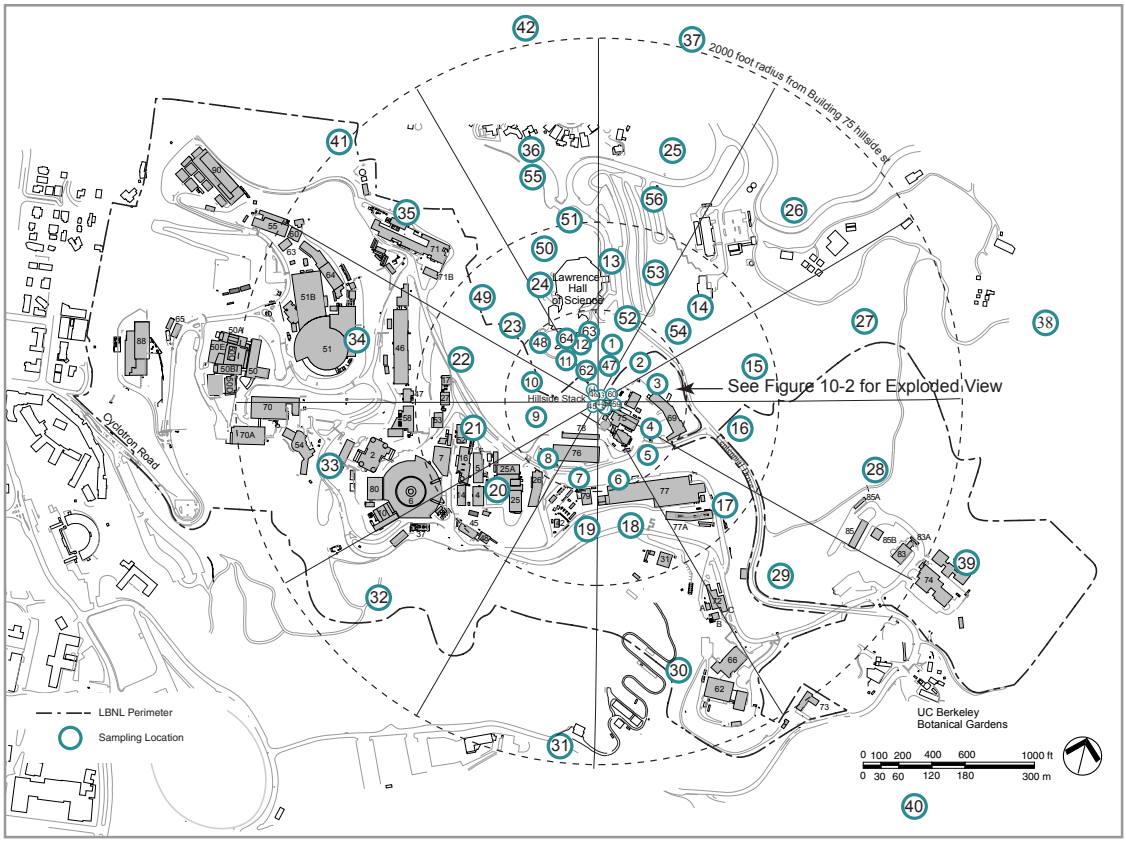


Figure 10-3 Supplemental Soil Sample Locations on and around Berkeley Lab

10.4 SEDIMENT

Sediment samples were collected from seven creeks where they flow off-site from Berkeley Lab (Figure 10-5), from Strawberry Creek on the University of California (UC) at Berkeley campus, and at the outfall of Strawberry Creek to San Francisco Bay. In addition, background sediment samples were collected from Lake Anza and Lake Temescal, about 2.4 kilometers (1.5 miles) north and south, respectively, of Berkeley Lab (Figure 10-6). Samples were collected in April 2001 to represent rainy-season conditions, and again at the end of August or the beginning of September to represent dry-season conditions. A total of 50 samples were analyzed, including split and duplicate samples.

Samples were collected from the creek bed by first removing organic debris from the surface and then scooping the sediment into a brass tube or glass jar. All samples were analyzed for HTO; twelve samples were also analyzed for total tritium. Duplicate samples were collected at approximately 20% of the sampling locations. Split samples were collected at approximately 10% of the sampling locations and sent to US/EPA and a third analytical laboratory for analysis. The detection limits were 0.007 Bq/g (0.2 pCi/g) for HTO and 0.2 Bq/g (5 pCi/g) for total tritium.

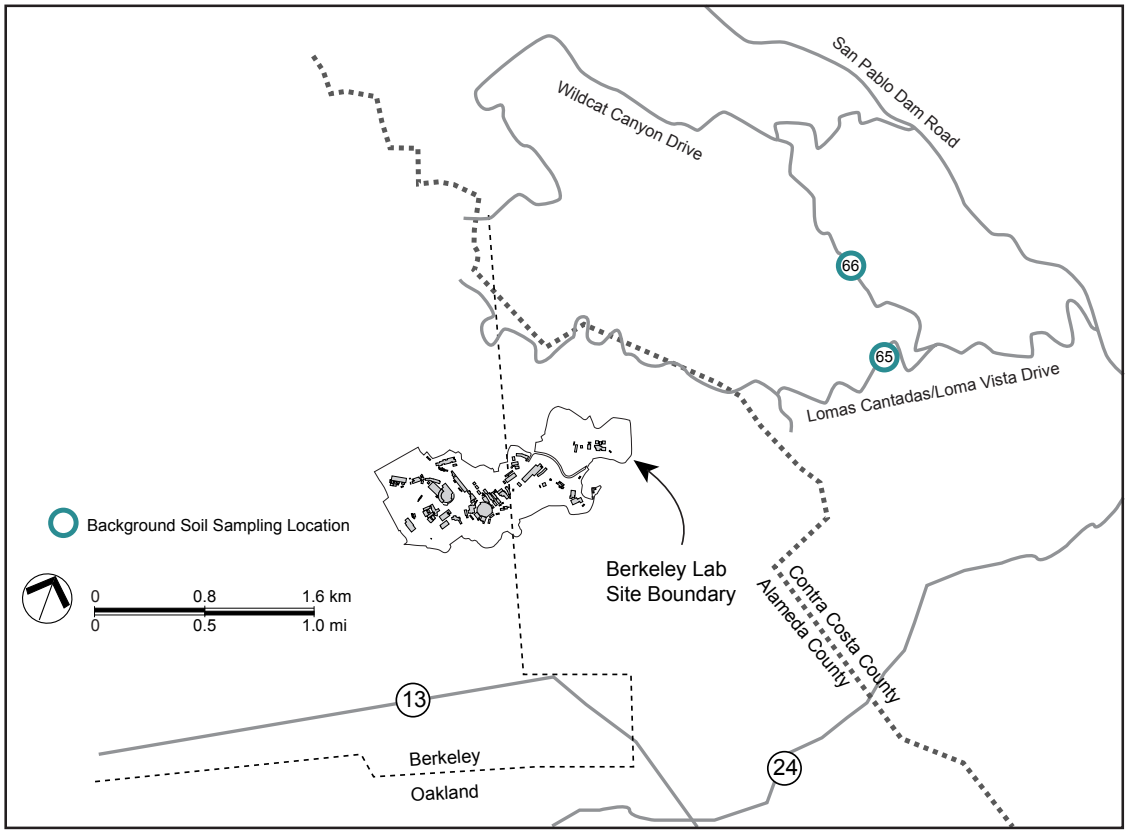


Figure 10-4 Supplemental Soil Sample Background Locations

Tritium was detected in only a single sample, the April sample from Banana Creek. The value was at the detection limit of 0.007 Bq/g (0.2 pCi/g). Tritium was not detected in the corresponding duplicate sample, indicating that the reported detection is questionable. Tritium was not detected in the sediment samples collected at either of the background sampling locations, at Strawberry Creek on the UC Berkeley campus, or at the outfall of Strawberry Creek to San Francisco Bay.

10.5 SURFACE WATER

Surface water samples were collected from the same locations as sediment samples (Figure 10-5). Samples were collected in April 2001, and then monthly from August to December. Monthly sampling continued through April 2002. In addition, background surface water samples were collected from Lake Anza and Lake Temescal in April and at the beginning of September (Figure 10-6). The August creek samples and September background samples were collected to represent dry season conditions, and the remaining samples were collected to represent rainy season conditions.

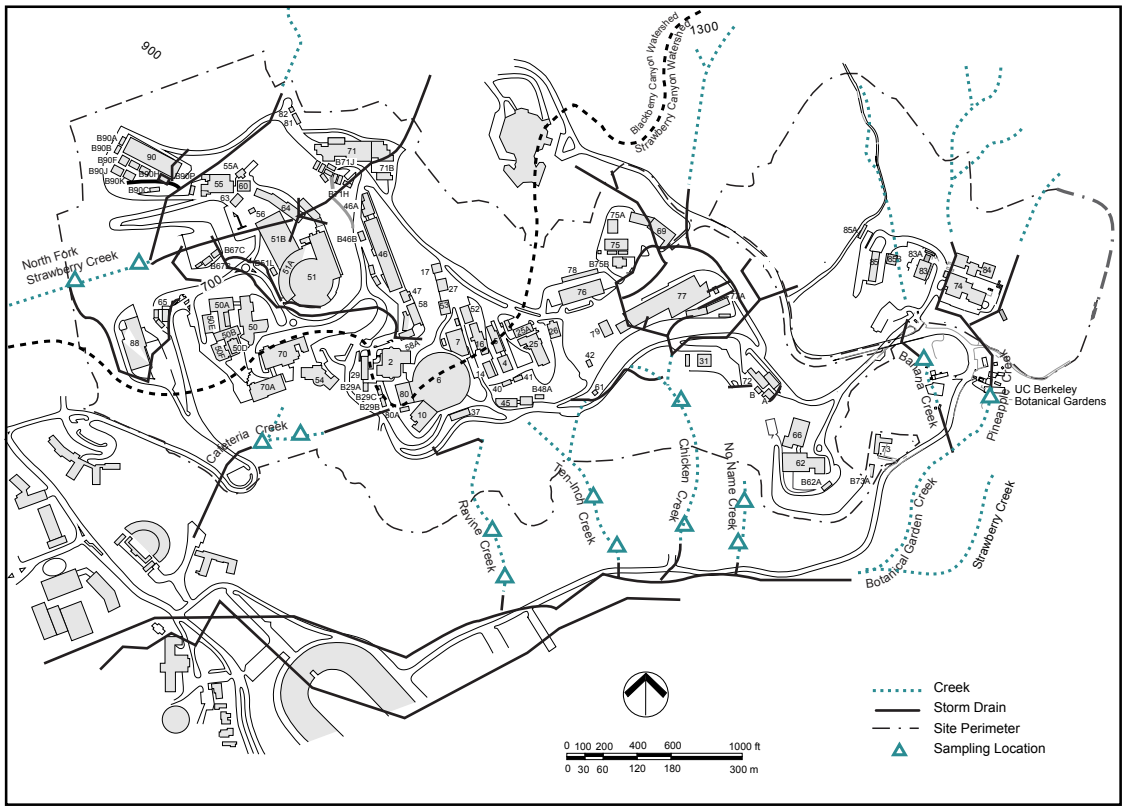


Figure 10-5 Supplemental Surface Water and Sediment Sample Locations on and near the Berkeley Lab Site

Samples were collected by scooping up water in glass jars. Duplicate samples were collected at approximately 20% of the sampling locations. A total of 95 samples were analyzed for HTO, including split and duplicate samples. Split samples were collected at approximately 10% of the sampling locations and sent to US/EPA and a third analytical laboratory for analysis. The detection limit was 7 Bq/L (200 pCi/L).

Tritium was detected in most of the surface water samples collected from upper and lower Chicken Creek, and in three of the four samples collected from North Fork Strawberry Creek in October and November. Concentrations ranged from 8.5 to 21.0 Bq/L (230 to 560 pCi/L) in Chicken Creek and 7.8 to 10.0 Bq/L (210 to 270 pCi/L) in North Fork Strawberry Creek. These findings are consistent with historical sampling results, where tritium has been consistently detected in Chicken Creek, and occasionally in North Fork Strawberry Creek, with the maximum concentrations detected during the highest periods of rainfall. Tritium was not detected at any other surface water sampling location, including the background locations, Strawberry Creek on the UC Berkeley campus, and the outfall of Strawberry Creek to San Francisco Bay.

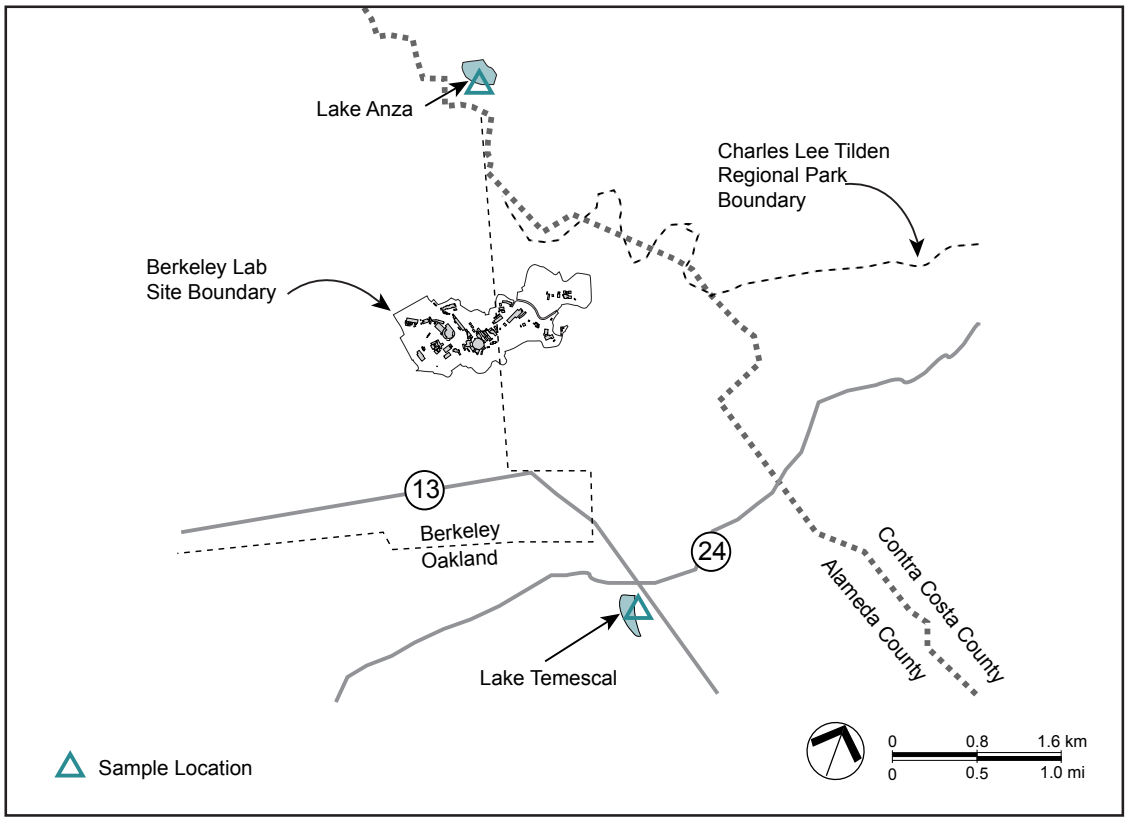


Figure 10-6 Supplemental Surface Water and Sediment Sample Background Locations

10.6 VEGETATION

In CY 2001, vegetation around the perimeter of the Berkeley Lab site was sampled with the following objectives, which are stated in the Tritium Sampling and Analysis Plan:

- Characterize tritium in trees near the NTLF's exhaust stack and the Lawrence Hall of Science, and
- Compare sample results with computer-modeled values to determine if there is a potential for adverse impact from vegetation as a result of Berkeley Lab tritium activities.

Samples were collected from trees at eight locations near the Berkeley Lab boundary (Figure 10-7) and at two distant background locations in Tilden and Chabot Regional Parks. Wood, leaf, duff (plant litter beneath the tree), and transpired water samples were collected during the dry season (September 2001) and the wet season (November–December 2001).

Samples were analyzed for tissue-free water tritium and organically bound tritium (OBT). The minimum level of tritium that the analytical laboratory could detect was 0.02 Bq/g (0.5 pCi/g) of tissue-free water tritium and 0.2 Bq/g (5 pCi/g) of OBT. The minimum level of tritium that the

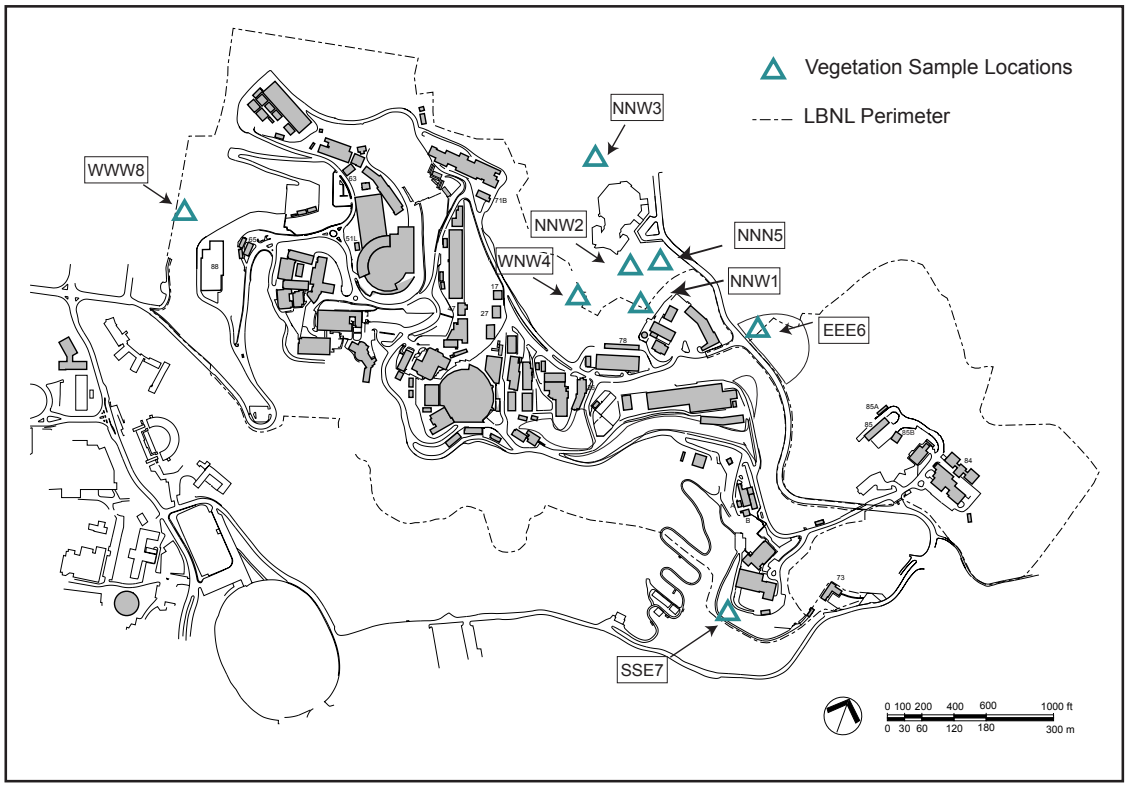


Figure 10-7 Supplemental Vegetation Sampling Locations

analytical laboratory could detect in transpired water was 7 Bq/L (200 pCi/L). The tissue-free water tritium and OBT results for wood, leaf, and duff samples are summarized in Figures 10-8 and 10-9.

10.6.1 Wood

As shown in previous sampling, tritium was not detected in the wood of trees at 200 meters or more from the NTLF's hillside exhaust stack.[4] In trees within 200 meters of the stack, tissue-free water tritium was detected in wood at levels ranging from 0.02 to 0.36 Bq/g (0.6 to 10 pCi/g). The average result is 0.2 Bq/g (5.0 pCi/g). OBT was detected in wood from only one tree within 200 meters of the stack, at a level (0.2 Bq/g [5 pCi/g]) very near the limit of detection. In all other trees, OBT was less than the detection limit.

10.6.2 Leaf

Tritium was not detected in the leaves of trees at 300 meters or more from the hillside exhaust stack. In trees within 300 meters of the stack, tissue-free water tritium results ranged from less than 0.02 Bq/g (0.5 pCi/g) (not detected) to 0.34 Bq/g (9.2 pCi/g). The average result

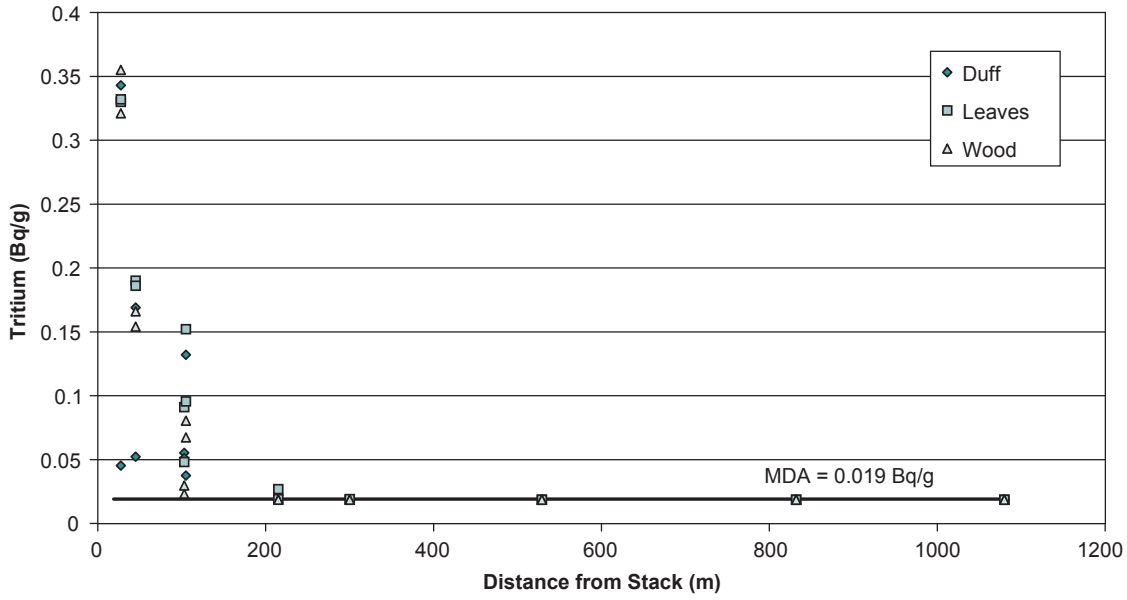


Figure 10-8 Tissue-Free Water Tritium Results with Distance from the NTLF Hillside Stack

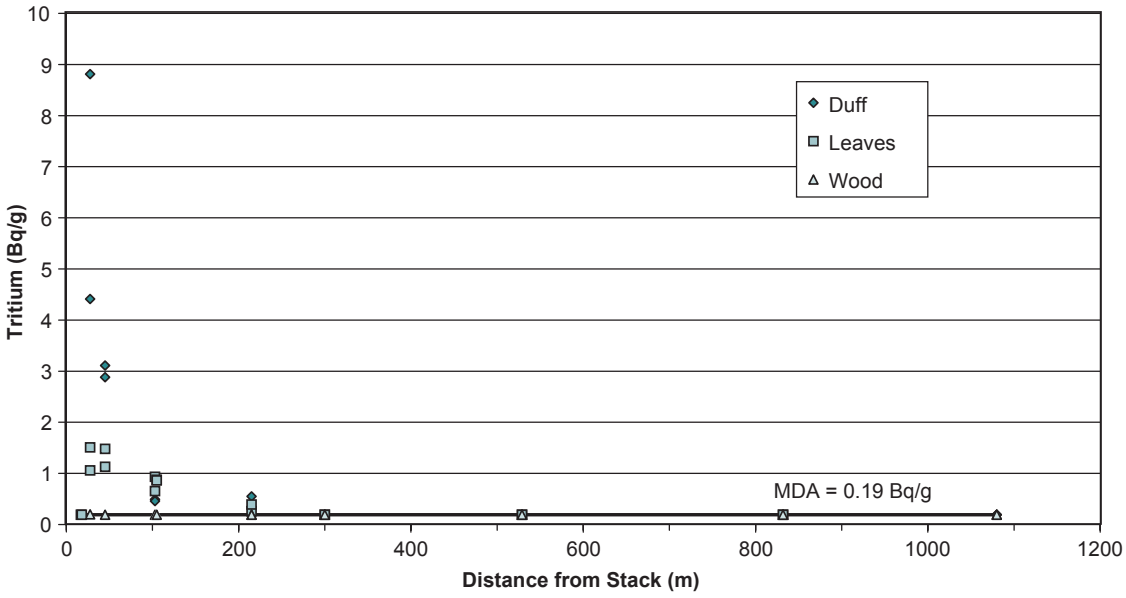


Figure 10-9 Organically Bound Tritium Results with Distance from the NTLF Hillside Stack

is 0.18 Bq/g (4.8 pCi/g). OBT was measured in leaves from trees within 300 meters of the stack at levels ranging from 0.26 to 1.8 Bq/g (7.1 to 48.8 pCi/g). The average result is 1.1 Bq/g (28.4 pCi/g).

10.6.3 Duff

As with leaves, tritium was not detected in duff beneath trees at 300 meters or more from the hillside exhaust stack. In duff within 300 meters of the stack, tissue-free water tritium was detected at levels ranging from less than 0.019 Bq/g (0.5 pCi/g) (not detected) to 0.34 Bq/g (9.3 pCi/g). The average result is 0.11 Bq/g (3.0 pCi/g). OBT was measured in duff beneath trees within 300 meters of the stack at levels ranging from 0.35 to 10.8 Bq/g (9.4 to 292 pCi/g). The average result is 3.2 Bq/g (87.5 pCi/g).

10.6.4 Transpired Water

Transpired water was collected at three locations near the NTLF's exhaust stack and at two distant background locations, Tilden and Chabot Regional Parks. No tritium was detected in transpired water collected at the background locations. In samples collected within 300 meters of the stack, tritium in transpired water ranged from 14 to 504 Bq/L (384 to 13,600 pCi/L). As with other sampled media, tritium levels decreased with increasing distance from the stack (Figure 10-10).

10.6.5 Conclusions from Vegetation Results

The first objective of sampling, to characterize tritium in trees near the NTLF's exhaust stack and the Lawrence Hall of Science, was accomplished by determining that, as shown in previous sampling, tritium levels in vegetation decrease with distance from the NTLF hillside exhaust stack.

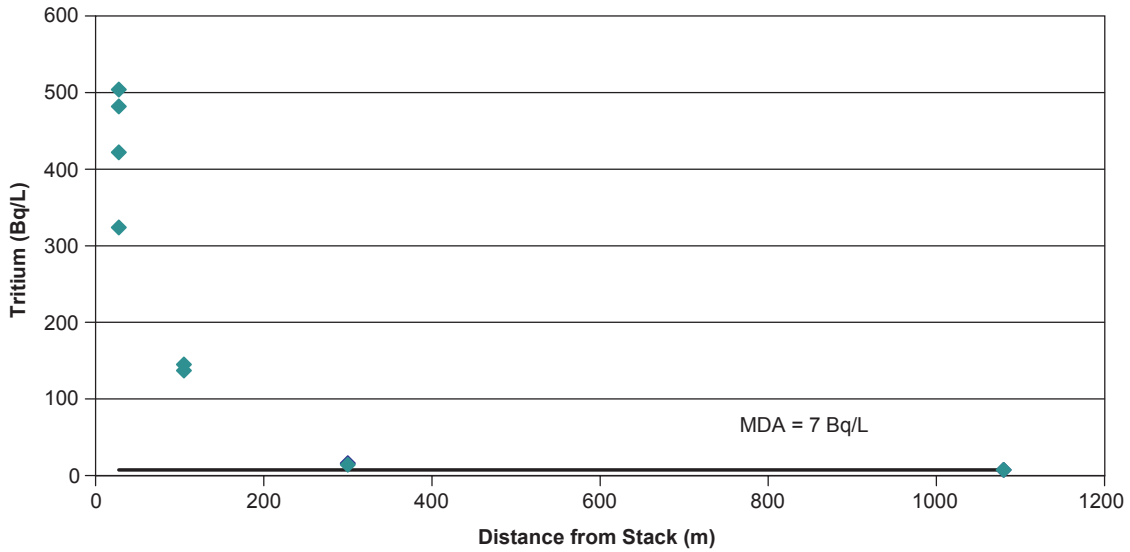


Figure 10-10 Tritium in Transpired Water with Distance from the NTLF Hillside Stack

The second objective of sampling, to determine if there is a potential for adverse impact from vegetation as a result of Berkeley Lab tritium activities, is addressed by comparing sample results with computer-modeled values. For this comparison, a risk assessment can be used that was performed in 1997 in response to the community's concern about risk from tritium released at Berkeley Lab.[5]

Appendix F of the risk assessment (page F-2) assumed that near the NTLF hillside exhaust stack, in the area where vegetation samples were collected in 2001, the level of tissue-free water tritium in vegetation is 1,350 Bq/L (36,500 pCi/L). This value is equivalent to about 1 Bq (27 pCi) of tritium in each gram of vegetation. This value is more than 2.5 times greater than the maximum value of tissue-free water tritium in wood, leaves, and duff sampled in 2001 (about 0.4 Bq/g [10 pCi/g]). (The risk assessment did not consider OBT to be a factor in determining risk.) Thus, the risk assessment overestimates the risk from tritium in vegetation.

10.7 SUMMARY

The results obtained from the supplemental environmental sampling confirm previous sampling reported by Berkeley Lab: environmental tritium concentrations are above background levels near the NTLF hillside stack, and they decrease rapidly (to background levels) with distance. Furthermore, the results demonstrate that the tritium concentrations at Berkeley Lab are low and do not pose significant risks to human health or the environment. These results are corroborated by the results of previous risk assessments and public health evaluations. In addition, the results also are consistent with National Emission Standard for Hazardous Air Pollutants requirements.

The supplemental monitoring was completed in May 2002, and when the results are validated, they will be reviewed by US/EPA for determining if Berkeley Lab should be placed on the National Priority List.

11

Quality Assurance

11.1 OVERVIEW

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

In addition to the OAP, the monitoring and sampling activities and results presented in this report were conducted in accordance with Berkeley Lab's Environmental Monitoring Plan[2] and applicable U.S. Department of Energy (DOE)[3] and U.S. Environmental Protection Agency (US/EPA)[4] 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 (QAPP) is developed and implemented.

On-site and off-site (contract) analytical laboratories are used to analyze samples for the environmental monitoring program. Both types of laboratories must meet demanding QA/QC specifications and certifications[5] that were established to define, monitor, and document laboratory performance. The QA/QC data provided by these laboratories are incorporated into Berkeley Lab's data quality-assessment processes. For calendar year (CY) 2001, seven off-site contract 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.

DOE's Environmental Management Consolidated Audit Program (EMCAP) audits off-site contract analytical laboratories annually. A DOE representative who has Nuclear Quality Assurance (NQA)-1 lead auditor training leads 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 off-site contract analytical laboratory locations. Any deficiencies found in the audit are followed by corrective actions.

A joint performance-evaluation committee, composed of members from Berkeley Lab and LLNL, evaluates off-site laboratory performance using performance evaluation samples. Radiological performance-evaluation samples were sent to the off-site contract analytical laboratories for analysis. The joint Berkeley Lab–LLNL performance evaluation committee uses the results of the

performance evaluation samples to identify and monitor trends in performance, and to solicit corrective action responses for unacceptable results.

To verify that environmental monitoring activities are adequate and effective, internal and external oversight is performed as required on specific environmental monitoring programs. Internal oversight activities consist of technical QA assessments performed by the Environmental Services Group and internal independent assessments conducted by the Berkeley Lab Office of Assessment and Assurance.

DOE's external oversight of Berkeley Lab programs is performed through the Operational Awareness Program.[6] Operational awareness activities include field orientation, meetings, audits, workshops, document and information system reviews, and day-to-day communications. DOE criteria for performance evaluation include (a) federal, state, and local regulations with general applicability to DOE facilities and (b) applicable DOE requirements.

In addition, US/EPA conducts external audits of the NESHAPs monitoring program under 40 CFR 61, Subpart H. US/EPA has also performed tritium analyses on Berkeley Lab ambient-air split samples; results from those analyses are discussed in Section 11.2. As discussed in Section 10.1, US/EPA has 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.

11.2 QUALITY CONTROL RESULTS FOR MONITORING TRITIUM IN AMBIENT AIR

11.2.1 Ambient-Air Sample and Split Results

Berkeley Lab routinely analyzes split samples from its ambient-air tritium-monitoring program to determine the precision and reproducibility of its monitoring results. Split analyses were performed each month. In late 1997, US/EPA also began analyzing split samples from two of the network's sites: ENV-LHS and ENV-13D (see Figure 11-1). The samples shared with US/EPA are analyzed at its National Air and Radiation Environmental Laboratory (NAREL) facility. In 2000, Berkeley Lab added Lawrence Livermore National Laboratory's Chemistry and Material Science's Environmental Services (CES) as another quality assurance laboratory for its program. With the expanded ambient-air network, the number of intra- and interlaboratory comparisons increased in CY 2001. Figure 11-1 shows a plot of these paired results. The horizontal line shown in the figure represents agreement between split sample results.

For CY 2001, there were 65 interlaboratory and 22 intralaboratory result pairs. NAREL analyzed 34 of the interlaboratory split samples, while CES analyzed the remaining 31. Berkeley Lab measures the results for each pair of split samples by calculating the relative error ratio (RER) and the relative

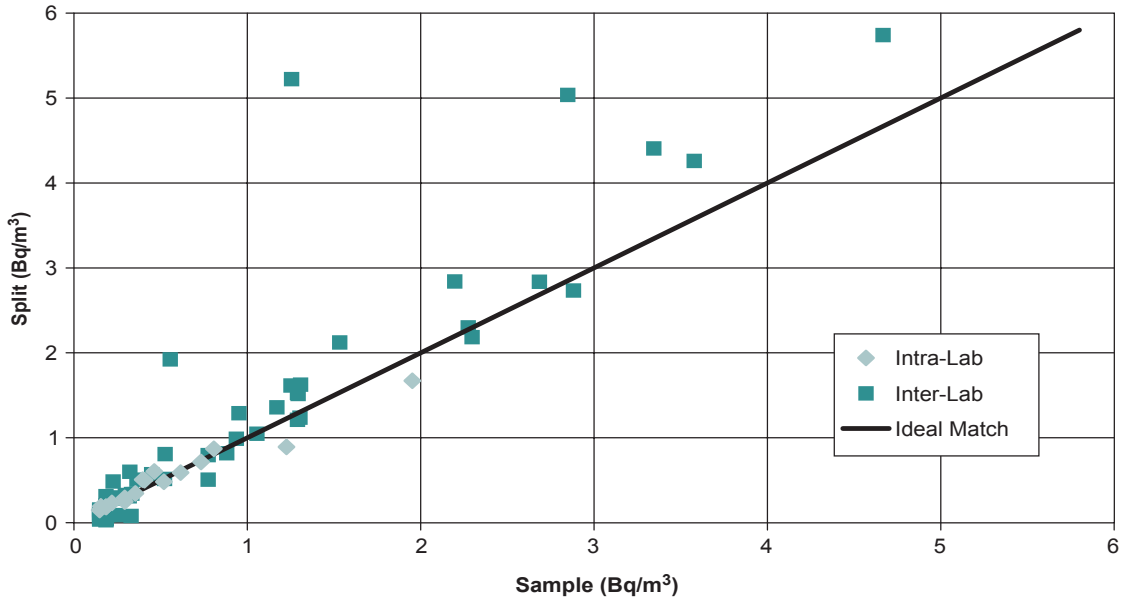


Figure 11-1 Comparison of Split Results for Tritiated Water in Ambient Air

percent difference (RPD). The RER is defined as the difference between the two results divided by the sum of the reported sample analytical errors. The RPD is defined as the difference between the two results divided by their average. When pair data are outside of those limits, an investigation is made into the cause of these differences. Because of potential differences in analytical procedures and equipment, it is typical for these metrics to be smaller for split samples analyzed by the same laboratory than for pairs analyzed by different laboratories. That indeed was the case this past year. The average RER and RPD for the intralaboratory samples were 0.40% and 13%, respectively, with no split sample pairs exceeding both criteria. The average RER and RPD for the interlaboratory samples were 0.79% and 18%, respectively, with only one of the sixty-five split sample pairs falling outside both criteria. That one sample pair included tritium results at or below commercial analytical detection limits. Overall, the split sample results showed excellent agreement.

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Acronyms and Abbreviations

AEDE	Annual Effective Dose Equivalent
ALARA	As low as reasonably achievable
ALS	Advanced Light Source
ANSI	American National Standards Institute
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
CES	Chemistry and Material Sciences, Environmental Services/LBNL
CFR	Code of Federal Regulations
Ci	Curie
CMTW	Committee to Minimize Toxic Waste
COD	Chemical Oxygen Demand
CODF	Chemical Oxygen Demand, Filtered
CUPA	Certified Unified Program Agency
CWA	Clean Water Act
CY	Calendar Year
DCA	Dichloroethane
DCE	Dichloroethene
DHS	Department of Health Services (State of California)
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
ERPG	Environmental and Radiation Protection Group
ESG	Environmental Services Group
FTU	Fixed Treatment Unit
FY	Fiscal Year
gsf	gross square feet
gsm	gross square meters
Gy	gray (measure of radiation in SI)
HEPA	High Efficiency Particulate Air
HMBP	Hazardous Materials Business Plan
HPS	Health Physics Society
HT	Tritiated hydrogen
HWHF	Hazardous Waste Handling Facility
ISM	Integrated Safety Management
ICM	Interim Corrective Measure
kg	kilogram
L	liter
LBNL	Lawrence Berkeley National Laboratory
LHS	Lawrence Hall of Science
LLNL	Lawrence Livermore National Laboratory
m	meter
mL	milliliter
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Amount
MEI	Maximally Exposed Individual
mg	milligram
mrem	millirem
mSv	millisievert

MTBE	Methyl Tertiary Butyl Ether
NAREL	National Air and Radiation Environmental Laboratory
ND	Nondetectable
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NIH	National Institutes of Health
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
PCB	Polychlorinated Biphenyl
PCE	Perchloroethylene (Tetrachloroethylene)
pCi	Picocurie (one trillionth of a curie)
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAML	Radiation Analytical Measurements Laboratory
RCRA	Resource Conservation and Recovery Act
RER	Relative Error Ratio
RFI	RCRA Facility Investigation
RMPP	Risk Management and Prevention Plan
RPD	Relative Percent Difference
RPG	Radiation Protection Group
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
SI	Systéme Internationale or International System of Units (the metric system)
SPCC	Spill Prevention, Control and Countermeasures
STP	Site Treatment Plan
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 Organic 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
WMG	Waste Management Group
yr	year

Glossary

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

Air particulates
Airborne particles that include dust, dirt, and other pollutants that occur as particles, and any pollutants that may be 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, identical to the helium nucleus, comprising two protons and two neutrons that are 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 saturated layer of rock or soil below the ground surface that can supply usable quantities of groundwater to wells and springs. Aquifers can be a source of 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)
Unit of radioactive decay equal to one disintegration per second (SI unit).

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) or person-rem (conventional).

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

Controlled area
Any laboratory area with controlled access 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 the natural background radiation.

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

De minimis
A level that is considered to be insignificant and not needing to be addressed or controlled.

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) or rad (conventional).

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

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

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 hypothetical 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 an 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) or person-rem (conventional). 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."

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) or rem (conventional).

Effluent
A liquid waste discharged to the environment.

Emission
A release of air to the environment containing 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) or roentgen (conventional).

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 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}K), a naturally occurring radionuclide, is a major source of internal radiation in living organisms.

Millirem
A common unit for reporting radiation dose. A 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-sv
See definition of Collective Effective Dose Equivalent.

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

Piezometer
Generally, a small-diameter, 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 head of groundwater and is defined by the level to which water will rise.

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

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/roentgen).

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

Radiation
Electromagnetic energy in the form of waves or particles.

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

Radiological
Arising from radiation or radioactive materials.

Radionuclide
An unstable nuclide. *See* nuclide and radioactivity.

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

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

Remediation
See Environmental remediation.

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

Sievert
A unit of radiation dose equivalent. The sievert is the SI unit equivalent to the rem. 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).

Terrestrial
Pertaining to or deriving from the earth.

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

Thermoluminescent dosimeter
A type of dosimeter. After being exposed to radiation, the material in the dosimeter (lithium fluoride) luminesces on being heated. The amount of light that the material emits is proportional to the amount of radiation (dose) to which it was exposed. *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 beyond 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 partially saturated or unsaturated region of the ground above the water table that does not yield water to wells.

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

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

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

[a]Avoid where practical.

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

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

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