Site Environmental Report for 2000

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 2000 is intended to summarize Berkeley Lab's compliance with environmental standards and requirements, characterize environmental management efforts through surveillance and monitoring activities, and highlight significant programs and efforts for calendar year 2000.

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. Each chapter in Volume I begins with an outline of the sections that follow, including any tables or figures found in the chapter. Readers should use section numbers (e.g., §1.5) as navigational tools to find topics of interest in either the printed or the electronic version of the report. 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. Robert Fox, Iraj Javandel, Ginny Lackner, Michael Ruggieri, Patrick Thorson, and Linnea Wahl are the primary authors of the report. Other key contributors of programmatic information include David Baskin, 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 managed technical editing, design, and production of the report, assisted by Theresa Duque (technical editing), Jean Wolslegel (composition), and Flavio Robles, Jr. (illustration).

Copies of the report are available from the Berkeley Lab Environmental Services home page (http://www.lbl.gov/ehs/epg/html/env_protection.htm) or Michael Ruggieri (telephone: (510) 486-5440; e-mail: mrruggieri@lbl.gov).

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Executive Summary

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§1.1 I. 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 Department of Energy management system that involves five core functions that are applied at all levels of the Laboratory (work planning, hazard and risk analysis, establishment of controls, work performance, and feedback and improvement). 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.

Published annually, this Site Environmental Report covers activities for calendar year (CY) 2000. 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 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 Protection home page, which is located at http://www.lbl.gov/ehs/epg/html/env_protection.htm. Readers are encouraged to comment on this report by completing (a) the survey card included with the distributed hard copy or (b) the survey form in the Web version of this 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 II. ENVIRONMENTAL PERMITS, INSPECTIONS, INCIDENT TRACKING, AND PERFORMANCE EVALUATION

Berkeley Lab's environmental program involves operating permits, inspections, incident tracking, performance evaluation, and environmental monitoring. The first four items are summarized in §§1.3–1.6. Environmental monitoring is summarized in §§1.7–1.9.

§1.3 A. Permits

At the end of 2000, Berkeley Lab held 23 environmental operating permits from various regulatory agencies:

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

For further discussion of these permits, see Chapter 3.

§1.4 B. Inspections

Twenty-four inspections of Berkeley Lab's environmental programs occurred during calendar year 2000. Nineteen violations were issued by regulatory agencies and all of them resulted from one inspection by the California Department of Health Services (DHS) of the Medical Waste Program in July. The DHS described these violations as "minor or housekeeping issues." A summary of the inspections is provided in Table 3-2. For more details on the DHS inspection of the Medical Waste Program, see §3.19.

§1.5 C. Incident Tracking

There were no environmental incidents at Berkeley Lab reportable to DOE under its occurrence-reporting program.

§1.6 D. 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 2000, there were nine environmental performance measures:

Table 1-1 Environmental Performance Measure Ratings for 2000

Performance measure	UCOP rating	DOE rating
1) Radiation protection of the public and the environment	Excellent	Excellent
2) Tracking environmental incidents	Marginal	Marginal
3) Waste reduction and recycling	Outstanding	Outstanding
4) Integrated Safety Management Program	Outstanding	Excellent
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 UCOP, Berkeley Lab received ratings of "outstanding" on performance measures 3–9, "excellent" on performance measure 1, and "marginal" on performance measure 2. From DOE, Berkeley Lab received ratings of "outstanding" on performance measures 3 and 5–9, "excellent" on performance measures 1 and 4, and "marginal" on performance measure 2. Both DOE and UCOP gave Berkeley Lab a "marginal" rating for performance measure 2 ("tracking environmental incidents") because of 19 minor violations cited by DHS during its July inspection of Berkeley Lab's Medical Waste Program. For additional information on the DHS inspection of the Medical Waste Program, see §3.19. For additional information on the performance review program, see §3.29.

§1.7 III. 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 measured changes in 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 2000.

§1.8 A. 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 blocks are in place to reduce the release of penetrating radiation into the environment, and capture systems are used to minimize releases of dispersable 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. For CY 2000, this maximum annual dose to an individual was determined to be 0.003 millisieverts (mSv) (0.3 millirem [mrem]) or only about 0.3% of the applicable DOE radiological standard of 1 mSv/yr (100 mrem/yr).[5] This estimate is also about 0.1% 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 0.003 mSv near the site boundary to essentially 0 mSv at an 80-kilometer distance) within the specified region. The collective population dose for 2000 was estimated at 0.008 person-Sv (0.8 person-rem) or about 0.00006% of the dose that the population within this region received from background radiation. No regulatory standard exists for this measure. For further

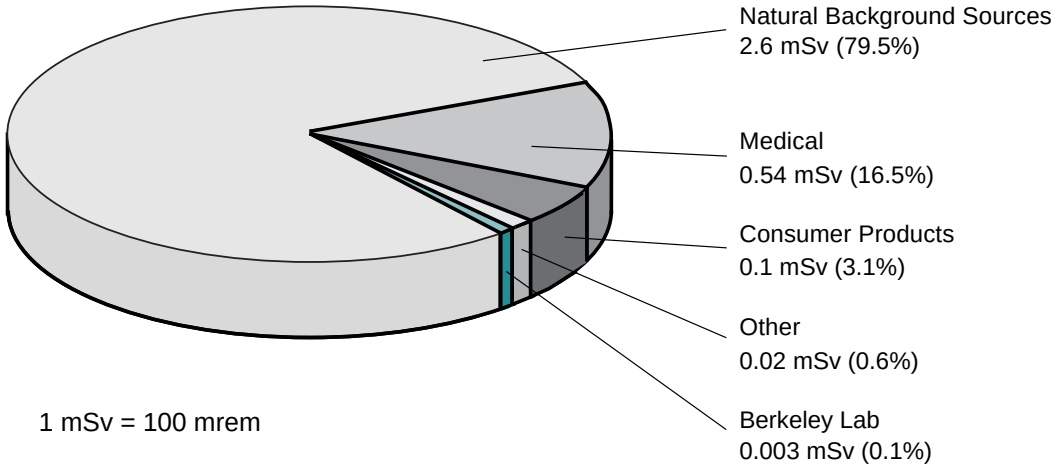

Figure 1-1 Typical Radiation Doses Received by Public, Including Maximum Contribution from Berkeley Lab

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. The estimated maximum potential dose from all airborne radionuclides released from the Laboratory site in 2000 was about 0.001 mSv (0.1 mrem), with tritium accounting for about 64% of that amount. This dose is about 30% of Berkeley Lab's total maximum dose to the public for both penetrating radiation and dispersable radionuclides.

§1.9 B. 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 nine 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 (five plumes);
- Petroleum hydrocarbon (two plumes);
- Freon (one plume); and
- Tritium (one plume).

The Laboratory has nearly completed characterizing 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 exception was for oil and grease samples collected near roadway 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 are probably because of 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.

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§2.1 I. HISTORY

Berkeley Lab was founded by Ernest O. Lawrence in 1931 on the Berkeley campus of the University of California. 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 DOE mission concepts of exploring the complexity of energy and matter, advancing the science for 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 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 their 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 both locally and nationally.

II. LABORATORY

§2.2 A. 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.

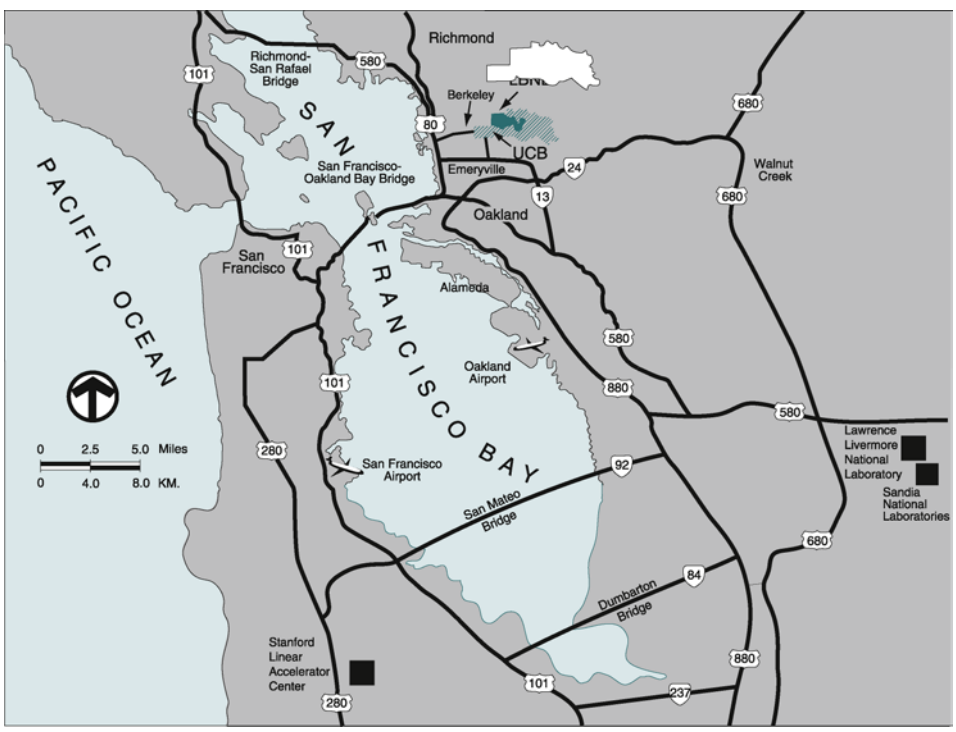

Figure 2-1 San Francisco Bay Area Map

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 Oakland at 399,484.

Adjacent land use consists of residential, institutional, and recreation areas. See Figure 2-3. The area to the south and east, which is University land, is maintained largely in a natural state and includes UC Berkeley's recreational facilities and Botanical Garden. Northeast of the Laboratory are the University's Lawrence Hall of Science, Space Sciences Institute, 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 multiunit dwellings, student residence halls, and private homes. The area to the west of Berkeley Lab is highly urbanized.

§2.3 B. 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 and Washington, D.C. About 300 of the Laboratory's scientists serve as faculty members at UC Berkeley and UC San Francisco.

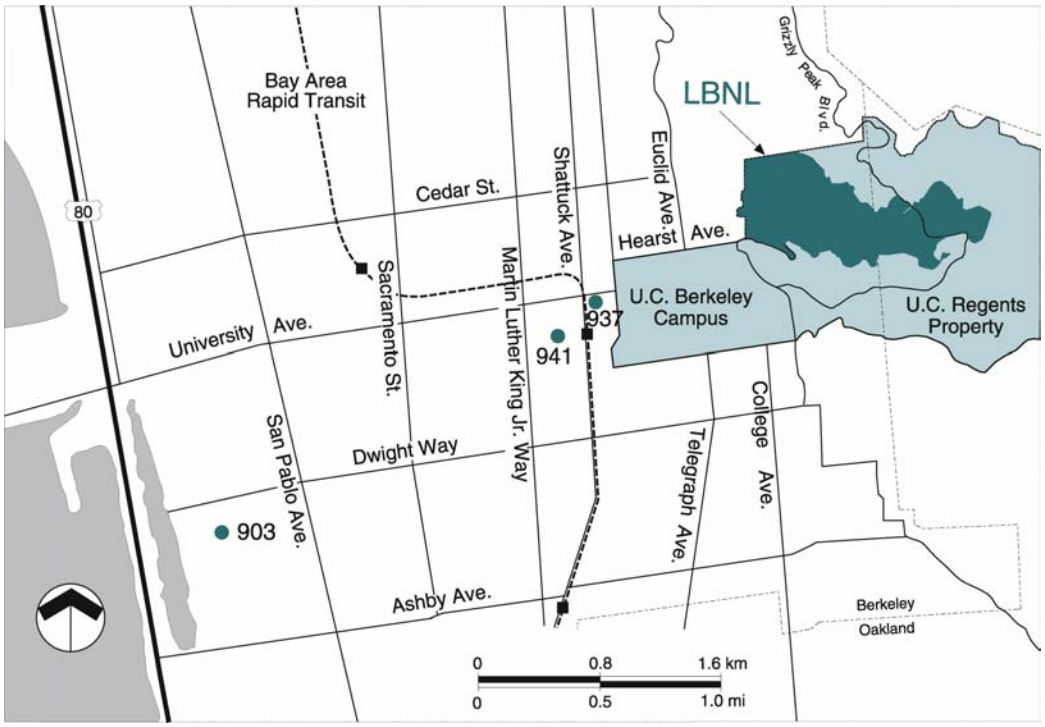

Figure 2-2 Vicinity Map

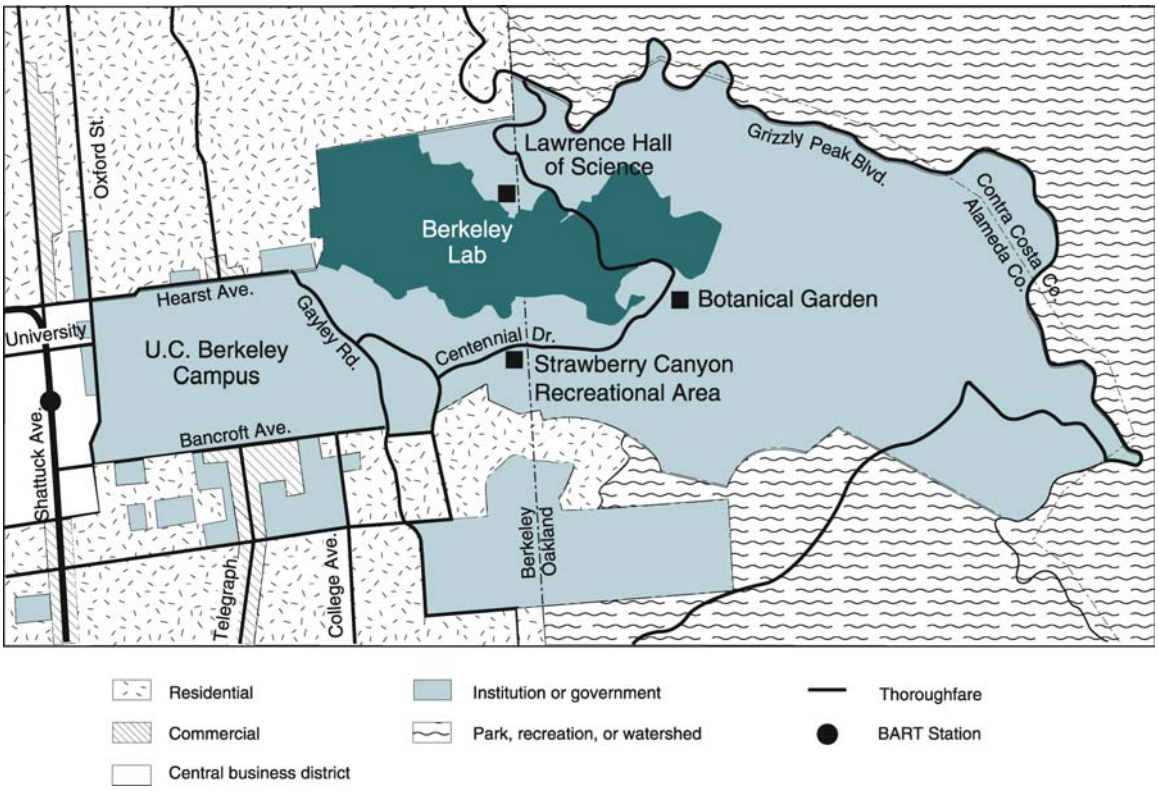

Figure 2-3 Adjacent Land Use

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% are located in various other off-site buildings. Figure 2-4 shows the Berkeley Lab space distribution.

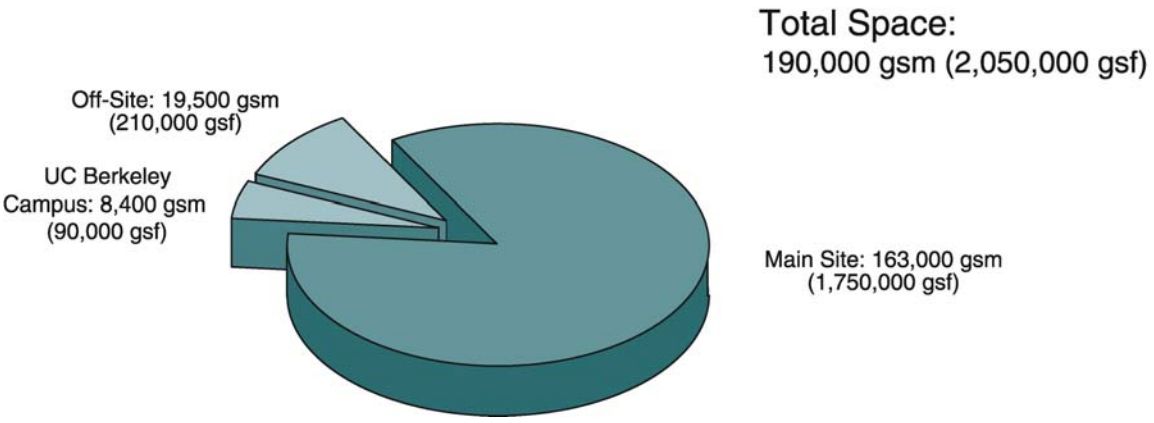

Figure 2-4 Space Distribution

§2.4 C. 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. In the spring of 1998, EBMUD converted from chlorine to chloramine as a disinfection agent throughout its supply area. The use of chloramine enables EBMUD drinking water to meet more stringent Safe Drinking Water Act standards for disinfection byproducts.

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 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.

III. ENVIRONMENTAL SETTING

§2.5 A. Meteorology

The climate of the site is a temperate one, influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west and the ridgeline to the east that stretches along 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.

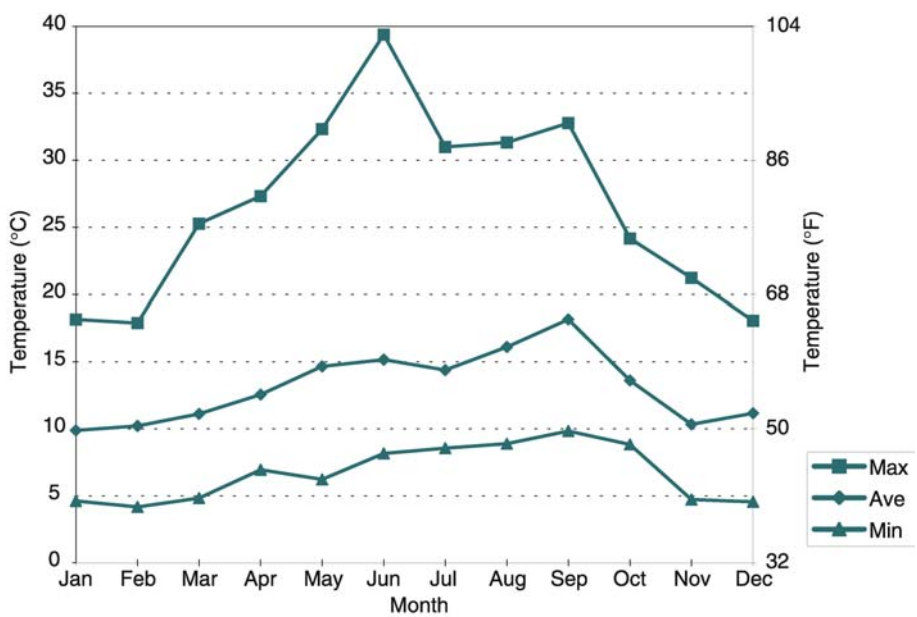

Figure 2-5 Temperature Summary by Month

On-site wind patterns change little from one year to the next. The most prevalent wind pattern occurs during fair weather, with daytime westerly winds blowing off the Bay, followed by lighter nighttime southeasterly winds originating in the East Bay hills. The other predominant wind pattern is associated with storm systems passing through the region, which usually occurs 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. A graphical summary of the annual wind patterns (windrose), Figure 2-6 illustrates the frequency of the two predominant wind patterns. Precipitation data are provided in Figure 2-7, which compares 2000 monthly precipitation totals to the average since 1974.

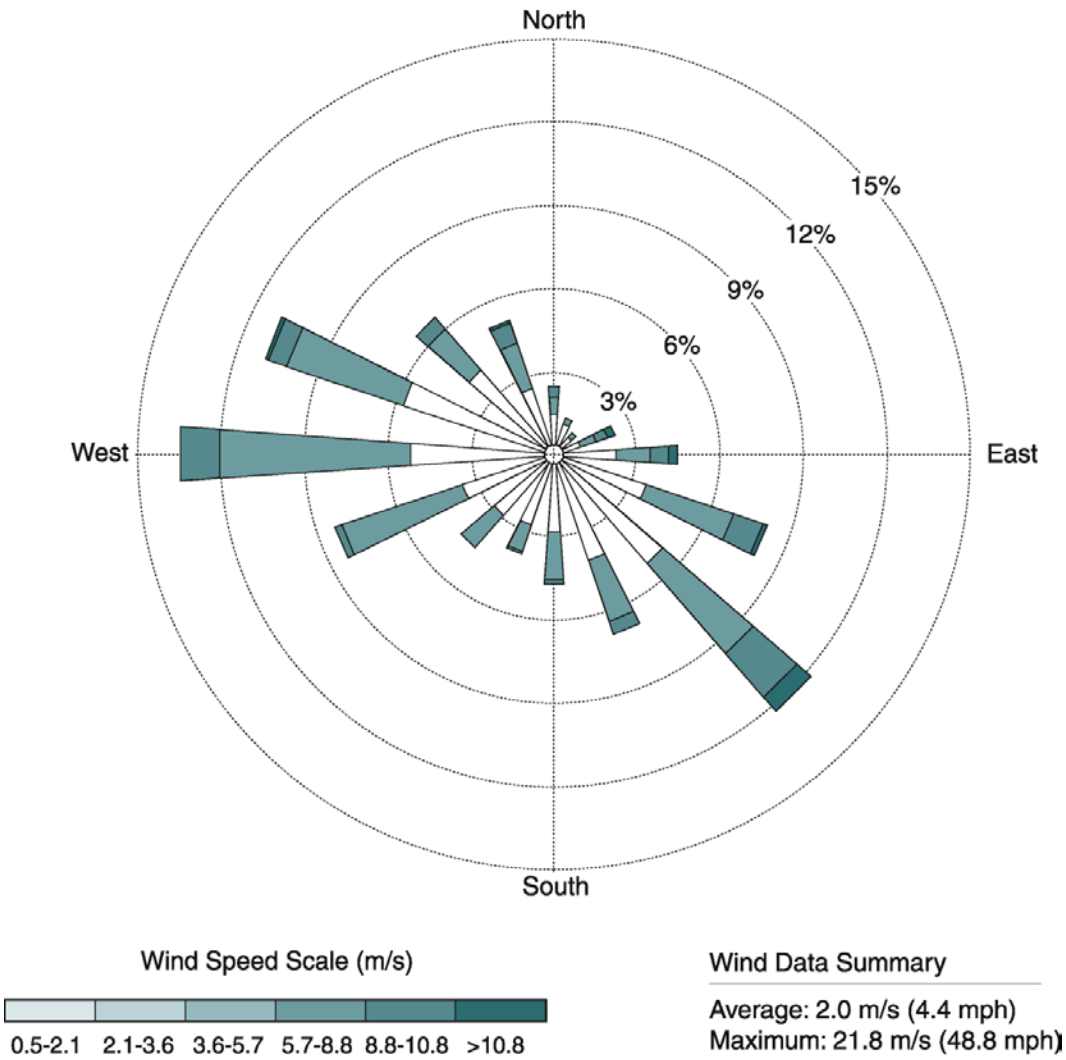

Figure 2-6 Annual Wind Patterns

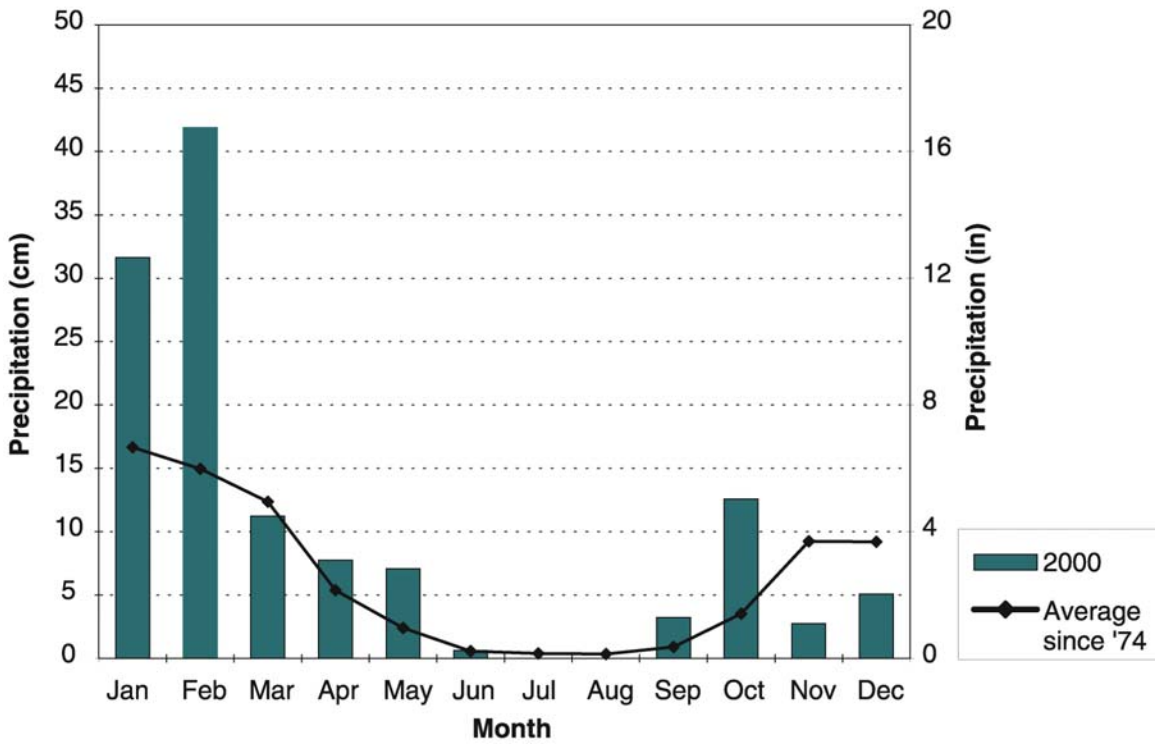

Figure 2-7 Precipitation Summary by Month

§2.6 B. Vegetation

In its maintenance and landscaping efforts, Berkeley Lab's vegetation management program reinforces native 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.

Berkeley Lab updated and intensified its fire management efforts after the October 1991 fire in the Berkeley/Oakland Hills to the south. The Laboratory uses the natural successional trends of existing vegetation to reduce fire risks.

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

§2.7 C. 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 grasses and brushlands provide cover, food, and breeding sites

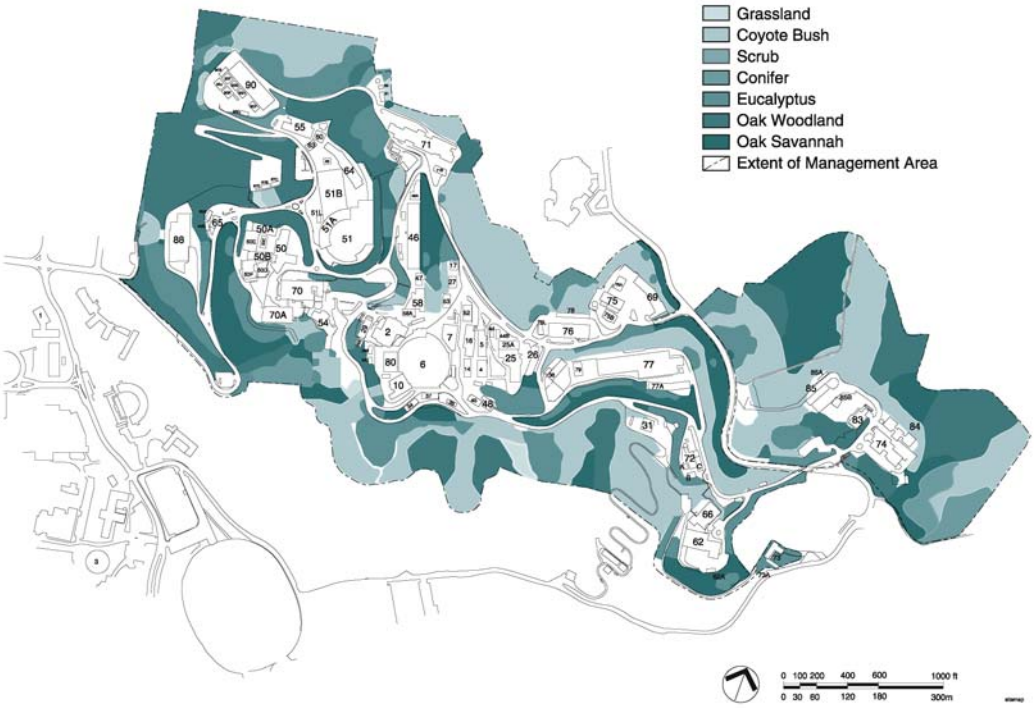

Figure 2-8 Vegetation Types

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 whipsnake, which has been designated as "endangered" pursuant to the Endangered Species Act. However, no Alameda whipsnake sitings have been reported on Berkeley Lab property. The most abundant large mammal is the Columbian blacktail deer. The Laboratory's tree stands offer nesting and cover sites for many resident and migratory species of birds.

§2.8 D. 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.

§2.9 E. 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 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} meters per second (3.3×10^{-5} and 3.3×10^{-8} feet per second).
- 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} meters per second (3.3×10^{-7} to 3.3×10^{-12} feet per second). 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}

meters per second (3.3×10^{-4} and 3.3×10^{-6} feet per second). 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

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C. Hazardous Materials

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a. Toxic Release Inventory **§3.11**

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

b. Hazardous Materials Business Plan **§3.12**

c. Risk Management and Prevention Plan **§3.13**

2. Federal Insecticide, Fungicide, and Rodenticide Act **§3.14**

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§3.1 I. 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 2000.

§3.2 II. OVERVIEW OF ENVIRONMENTAL RESPONSIBILITIES

In order to provide the highest degree of protection for the public and the environment, Berkeley Lab applies Integrated Safety Management (ISM). The application of ISM 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 Division (EH&S) is responsible for administering environmental protection and compliance programs at Berkeley Lab. The organizational structure of EH&S for 2000 is shown in Figure 3-1.

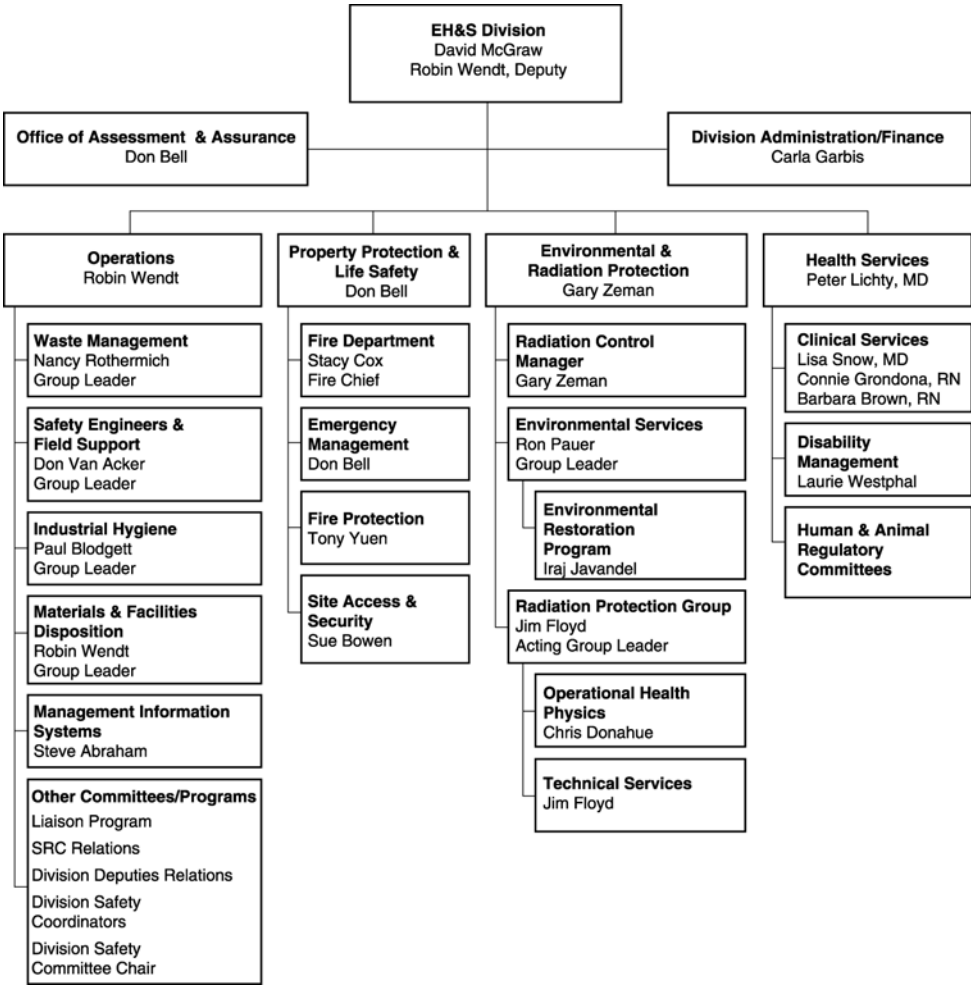


Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization

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 2000 monitoring result summaries, see Chapters 4–10. 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 the safe use of radiation sources at Berkeley Lab, including both machine sources (e.g., accelerators) and radioisotopes.

III. PROGRAM SUMMARY

§3.3 A. 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 active permits held by Berkeley Lab at the end of the year.

§3.4 B. 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 2000. 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

Table 3-1 Environmental Permits Held by Berkeley Lab at End of 2000

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD	Various activities with emissions to air	8	§3.8
Hazardous waste	DTSC	Hazardous Waste Handling Facility operations and hazardous waste treatment units	2	§3.17
Stormwater	SWRCB	Site-wide stormwater discharges	1	§3.25
Underground storage tank	City of Berkeley	Underground storage tanks containing petroleum products	8	§3.27
Wastewater	EBMUD	Site-wide and operation-specific wastewater discharges to sanitary sewer	4	§3.24

Table 3-2 Environmental Audits, Inspections, and Appraisals in 2000

Organization	Inspection title	Start date	Length (days)	Violations
EBMUD	Wastewater monitoring inspections at Hearst and Strawberry Outfalls	January 3	1	0
		February 16	1	0
		April 3	1	0
		July 6	1	0
		July 19	1	0
		November 30	1	0
	Wastewater monitoring inspections at B77 Treatment Unit	January 19	1	0
		April 7	1	0
		July 7	1	0
		November 22	1	0
	Inspection of motor pool at B76, FTUs at B70A and B2	July 10	1	0
	Wastewater monitoring inspections at B25 Treatment Unit	January 10	1	0
		May 4	1	0
LBNL	EBMUD self-monitoring inspections at Hearst and Strawberry Outfalls	February 7	1	0
		April 3	1	0
		July 12	1	0
		October 9	1	0
	EBMUD self-monitoring inspections at B77 Treatment Unit	January 10	1	0
		April 11	1	0
		July 10	1	0
		October 23	1	0
	EBMUD self-monitoring inspections at B25 Treatment Unit	April 4	1	0
DTSC	DTSC Inspection of Hazardous Waste Handling Facility (HWHF)	May 25	2	0
DHS	DHS Inspection of medical waste generation sites	July 27	1	19*

*Minor or housekeeping issues.

violations. Berkeley Lab received 19 violations from these 24 inspections, with all of the violations occurring from a State of California Department of Health Services (DHS) inspection of medical waste generation sites on July 27, 2000. See §3.19.

§3.5 C. Summary of DOE Reportable Environmental Incidents

There were no environmental incidents in 2000 reportable under the DOE occurrence-reporting program.[1]

IV. PROGRAM REVIEW

§3.6 A. 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.

Berkeley Lab divides its air quality protection and compliance activities into two categories: radiological (see §3.7) and nonradiological (see §3.8).

§3.7 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 National Emission Standards for Hazardous Air Pollutants (NESHAPs) program. 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 all projects that may release radionuclides. This review includes a determination of the dose to the nearest off-site member of the public 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 methodology for determining the appropriate level of sampling, monitoring, or administrative controls necessary to maintain compliance with NESHAPs has been approved by US/EPA and is summarized in Table 4-2. See §4.2. Results of the emissions-sampling and monitoring program are also presented throughout Chapter 4. The Laboratory documents its NESHAPs compliance status with an annual report to EPA, which is available on Berkeley Lab's Environmental Services Group home page at http://www.lbl.gov/ehs/epg/html/env_protection.htm.

§3.8 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 activities are the notable exception.

At the end of 2000, Berkeley Lab held operating permits from BAAQMD for eight activities.[8] 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 3-3.

§3.9 B. 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 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. 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 of 2001 and is scheduled to be completed in 2002.

Table 3-3 BAAQMD Permitted Air Emission Sources Active at End of 2000

BAAQMD category	BAAQMD source number	Description	Building	Abatement type
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
	188	Wipe-cleaning	Site-wide	—
Miscellaneous	189	Soil vapor extraction	7	Activated carbon
	190	Soil vapor extraction	58	Activated carbon

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 Substance 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.

C. Hazardous Materials

§3.10 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 §§3.11–3.13.

§3.11 a. Toxic Release Inventory

DOE facilities such as Berkeley Lab are required under Executive Order 12856 (Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements)[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 2000 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 3-4 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.

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

Substance	1997 (kg)	1998 (kg)	1999 (kg)	2000 (kg)
Chlorofluorocarbons	185[b]	143	44[d]	246
Isopropyl alcohol	493[c]	—[c]	—[c]	—[c]
Methanol	260	266	759[d]	468
Nitric acid	727	707	709[d]	746
1,1,1-Trichloroethane	1,521	69	44[d]	21

[a] Substance no longer required by US/EPA under this program.
[b] Amount includes only 6 kilograms of Class I ozone-depleting substance released; remainder is considered Class II.
[c] Substance not reportable, because use at Berkeley Lab does not meet recently updated TRI use or production criteria for listing.
[d] Quantities reported in the Site Environmental Report for 1999 were incorrectly high due to a calculational error.

§3.12 b. 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 2000 HMBP included a list of all hazardous materials present on-site 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). The plan included annotated floor plans and summary documentation on emergency plans, procedures, and training.

§3.13 c. 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 hazardous substances above the threshold quantities, and therefore a RMPP is not required for the site.[16]

§3.14 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.

§3.15 3. Toxic 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 is primarily large low- and high-voltage capacitors. Four of these capacitors are still in use, containing an estimated 170 kilograms (375 pounds) of regulated PCB dielectric fluid. Figure 3-2 shows the trends in reducing regulated PCB transformers and capacitors at the site. Because of the small amounts of PCBs, the Laboratory is not required to prepare an annual PCB report for US/EPA.

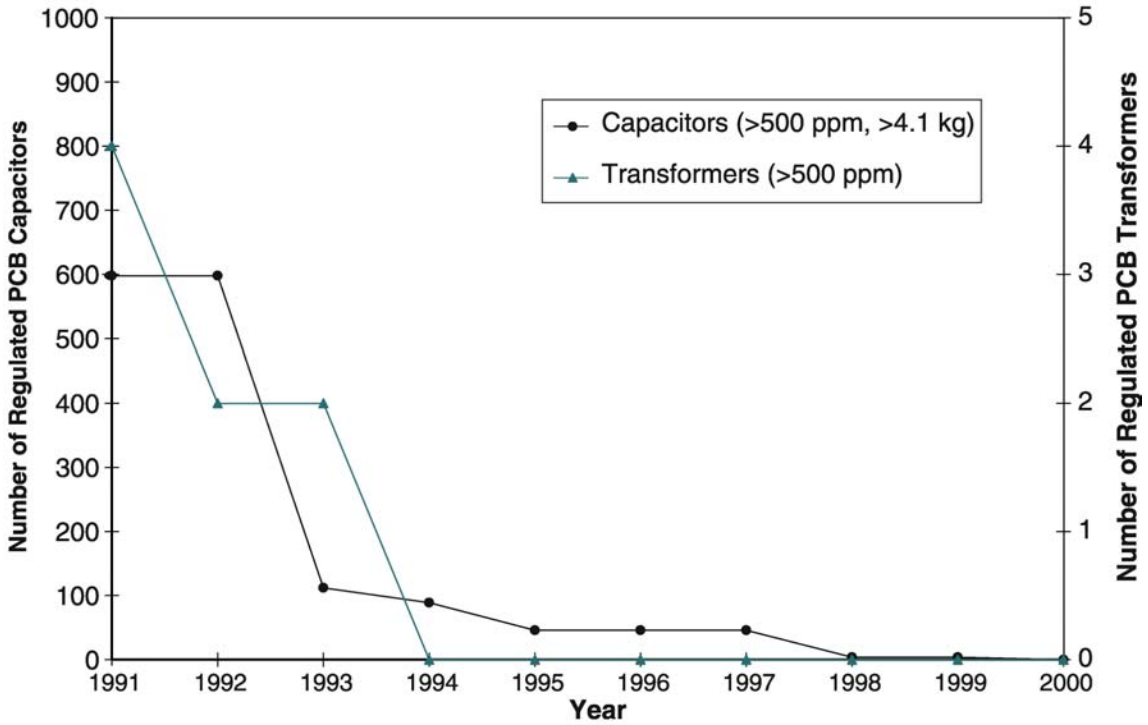


Figure 3-2 Trends in Eliminating Regulated PCBs

§3.16 D. 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.

§3.17 1. Hazardous Waste

In California, the Department of Toxic Substances Control (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. 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 including neutralization, consolidation, solidification, 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 sanitary sewer permit. In 2000, approximately 820 liters of this waste were discharged to the sanitary sewer.

A permit modification request filed by Berkeley Lab in January 1996 was approved in 1999. DTSC issued its final permit decision and approved the request to modify the HWHF Part B permit on May 20, 1999, starting a 30-day public appeal period. The public appealed the permit decision and requested a review of the permit modification approval. On November 16, 2000, DTSC denied the public appeal and the permit modifications became effective. The modifications allowed certain changes in waste streams, storage designations, treatment methods, and training requirements.

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 3-5. These

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

FTU	Building	Description of treatment	Permit tier
002	25	Metals precipitation and acid neutralization	Permit-by-rule
003	76	Oil/water 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

treatment units operate independently of the HWHF. Three of these FTUs are authorized to operate under the "conditional authorization" tier, while the remaining two are authorized to operate under the "permit-by-rule" tier. The level of treatment determines which tier applies. DTSC requests renewal of this permit each year. In March 2000, the Laboratory submitted the 2000 FTU renewal package to DTSC and the City of Berkeley. Beginning in 2000, the City of Berkeley began to oversee all tiered permitting renewals.

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

- The Annual Hazardous Waste Report for 2000,[23] prepared for DTSC, contains generator and transport information for all hazardous waste (including the hazardous waste portion of mixed waste) activities 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 that is more than one year old were generated to meet a DTSC operating permit requirement.
- Quarterly mixed waste management reports were generated in accordance with a May 1996 DTSC consent order to summarize all efforts to use commercial mixed waste disposal facilities. The approved modified permit supercedes the consent order. Under the approved permit the quarterly mixed waste management reports are no longer required. The last report was submitted to DTSC in November 2000.

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.

DOE's occurrence-reporting program is designed to track incidents at DOE facilities around the country. The program ranks incidents on a graded scale, using a rigid set of criteria. There were no waste-related occurrence reports in 2000.

§3.18 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 §3.9. 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 workplans for detailed site investigations. Subsequent to each of these submittals, Berkeley Lab carried out the investigations described in the workplans 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, which was submitted to DTSC on September 29, 2000. 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 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.

§3.19 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 three off-site buildings. The Life Sciences programs, including the Human Genome project, 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. In July, the Department of Health Services (DHS) conducted an inspection of Berkeley Lab and identified 19 violations of the Medical Waste Management Act. These violations were described by DHS as "minor or housekeeping issues." Berkeley Lab contested approximately half of the findings and submitted technical information to DHS that demonstrated why those findings should be dropped. The final status of the contested violations has not yet been resolved. Corrective actions for uncontested violations were completed within one month of the inspection. Furthermore, to improve the overall Medical Waste Program, Berkeley Lab is conducting more frequent internal inspections of waste generator areas and is providing more guidance to waste generators on housekeeping issues.

E. Pollution Prevention and Waste Minimization

§3.20 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 precursor, Executive Order 13101 seeks to integrate recycled materials into the procurement and acquisition process.[34] 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 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. In 2000, 46% of all Berkeley Lab purchases of paper and paper products and 47% of all nonpaper office products met this standard.

§3.21 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 three 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.

§3.22 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.

F. Water Quality

§3.23 1. 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 such 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 state-wide 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 Regional Water Quality Control Boards (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.

§3.24 a. 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 environmental 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 13 separate occasions throughout the year. Table 3-2 (see §3.4) contains these dates. While most of the inspections are routine sample collections, on July 10, EBMUD inspected the vehicle maintenance facility and some areas that require an ASPCP (see below). 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. The ASPCP for photo-processing units was revised and updated in October of 2000.

§3.25 b. 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 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 detailed discussion of stormwater results for 2000, see §5.6.

The City of Berkeley has the authority to inspect Berkeley Lab's stormwater program. No inspections of this program took place in 2000.

§3.26 c. 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 a 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 June 2000, Berkeley Lab submitted a "Storage Statement for Aboveground Petroleum Storage Tanks" to the State Water Resources Control Board. The statement included the total petroleum aboveground-stage tank capacity at Berkeley Lab. The total consists of 18,371 gallons of petroleum-containing ASTs and 1,320 gallons of petroleum-containing 55-gallon drums. Figure 3-3 shows the locations of the ASTs that contain petroleum products (e.g., gasoline and diesel fuel), excluding drum storage areas.

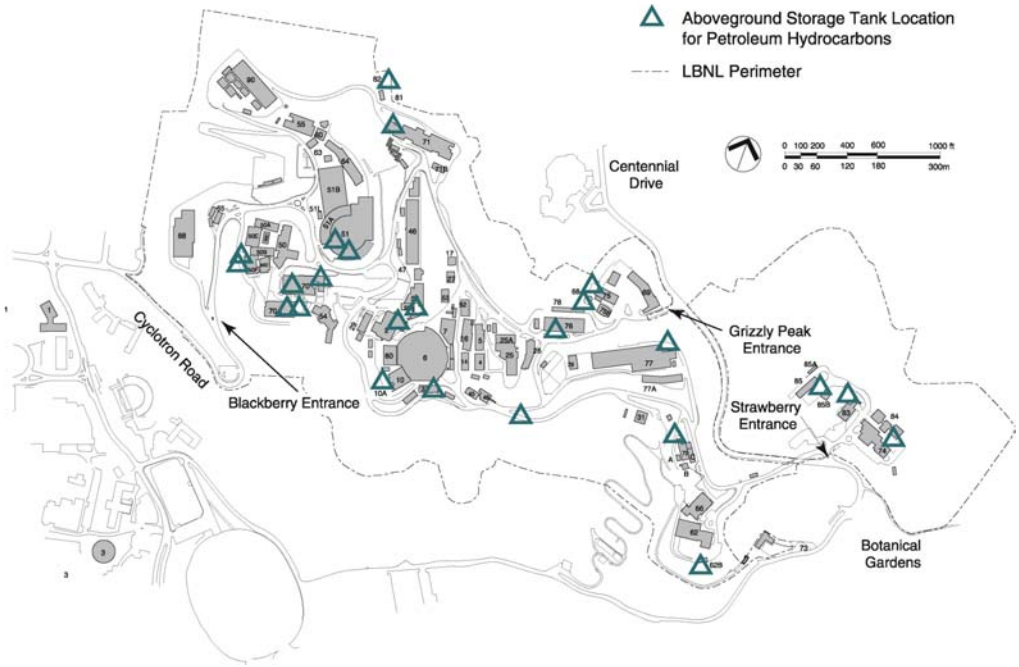


Figure 3-3 Aboveground Storage Tank Locations

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 non-petroleum drums, are inspected during routine petroleum drum inspections.

§3.27 d. 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 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 2000, eight permitted USTs remained at the Laboratory. See Table 3-6. The tanks contain either diesel fuel or unleaded gasoline. All tanks are double-walled and meet regulatory standards for construction, monitoring, leak containment, and design of operating tanks. The Laboratory has removed a total of seven tanks from the site since 1993.

Table 3-6 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

§3.28 2. 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. 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 water line 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.

§3.29 V. PROGRAM PERFORMANCE

Since 1994, Berkeley Lab, DOE, and Berkeley Lab's managing partner, the University of California Office of the President (UCOP), have utilized 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 3-7 summarizes the UCOP and DOE ratings for each of the environmental performance measures for FY 2000.

Berkeley Lab received either an excellent or outstanding performance rating from both DOE and UCOP for all performance measures except "tracking environmental incidents." Both DOE and UCOP gave Berkeley Lab a "marginal" rating for tracking environmental incidents due to the 19 minor violations that resulted from a single DHS inspection of the Medical Waste Program at Berkeley Lab in July. For more details on the violations, see Section 3.19. Berkeley Lab did not receive any violations from the other 23 environmental audits, inspections, and appraisals in 2000. The marginal rating was determined by applying a weighted score to each of the violations according to their severity and magnitude and then adding up the scores. The score sum was then compared to the preset gradients for this performance measure. The result fell short of the expectation for a "good" rating and the performance was categorized as "marginal." 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 3-7 Environmental Performance Measure Ratings for 2000

Performance measure	UCOP rating	DOE rating
1) Radiation protection of the public and the environment	Excellent	Excellent
2) Tracking environmental incidents	Marginal	Marginal
3) Waste reduction and recycling	Outstanding	Outstanding
4) Integrated Safety Management Program	Outstanding	Excellent
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

I. BACKGROUND **§4.1**
II. EXHAUST SYSTEM SAMPLING RESULTS **§4.2**
Table 4-1: Most Significant Radionuclides Used
Table 4-2: US/EPA-Approved NESHAPs Compliance Strategy
Table 4-3: NESHAPs Building Exhaust Sampling and Monitoring Profile in 2000
Table 4-4: Summary of Radiological Air Emissions
Figure 4-1: Trends in Annual Tritium Releases from NTLF
III. AMBIENT AIR MONITORING RESULTS
A. Tritium **§4.3**
Figure 4-2: Ambient Air Monitoring Network Sampling Locations
Table 4-5: Summary of Ambient Tritium Sampling
B. Gross Alpha/Beta **§4.4**
Table 4-6: Summary of Gross Alpha and Beta Ambient Air Particulate Sampling Network Results

§4.1 I. BACKGROUND

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

- 40 CFR Part 61, Subpart H (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, and DOE Order 5400.1 includes additional requirements for monitoring nonradiological air emissions.

Under present requirements, Berkeley Lab's air quality program measures only radiological components. Estimates of nonradiological air emissions use alternative methodologies (e.g., engineering calculations, record keeping, and dose/risk modeling) to satisfy regulatory requirements. The comprehensive Environmental Monitoring Plan[4] 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. Emissions monitoring measures contaminants in building exhaust systems (e.g., stacks). Ambient air surveillance measures contaminants in the outdoor environment.

Ambient air surveillance results alone cannot distinguish between Berkeley Lab, non-Berkeley Lab, and natural background emission sources. When combined with exhaust emissions monitoring results and local meteorological information, however, ambient air surveillance results can sufficiently characterize the environmental impact of Laboratory activities. The number and placement of monitoring stations, as well as the parameters monitored and their frequency, are routinely reviewed to account for changes in Laboratory operations or external requirements.

§4.2 II. EXHAUST SYSTEM SAMPLING 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 from on-site building exhaust systems are usually in the form of vapor or gas. Releases as solid particulate matter are the least common form, because 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*

Nuclide name (atomic number)	Symbol	Principal radiation types	Half-life
Carbon (6)	^{11}C	positron/gamma	20.5 minutes
	^{14}C	beta	5,730 years
Fluorine (9)	^{18}F	positron/gamma	109.7 minutes
Hydrogen/Tritium (1)	^{3}H	beta	12.28 years
Iodine (53)	^{123}I	gamma	13.1 days
	^{125}I	beta	60.14 days
	^{131}I	gamma	8.04 days
Nitrogen (7)	^{13}N	positron/gamma	9.97 minutes
Oxygen (8)	^{14}O	positron/gamma	71 seconds
	^{15}O	positron/gamma	122 seconds

*For a complete list of radionuclides evaluated under NESHAPs regulations, see Radionuclide Air Emission Annual Report for 2000, found on Berkeley Lab's Environmental Services Group home page at http://www.lbl.gov/ehs/epg/html/env_protection.htm.

The NESHAPs regulations require source measurement if the potential dose, or exposure over time, from emissions exceeds 1.0×10^{-3} mSv/yr (0.1 mrem/yr).[1] As discussed in §3.7, Berkeley Lab uses a comprehensive tiered strategy approved by US/EPA to satisfy this requirement. See Table 4-2. 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.

The number and location of sources under the six 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 compliance assessment Category V, which requires no monitoring. In 2000, there were 92 sources in this group that adhered to strict inventory limits specified in individual work authorizations. Twenty-five locations were continuously sampled. Four locations have more rigorous real-time monitoring systems to estimate emissions, including the only compliance Category I source on-site (the hillside stack at Building 75). Table 4-3 lists the breakdown of source assessment 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

Table 4-3 NESHAPs Building Exhaust Sampling and Monitoring Profile in 2000

Monitoring type	Method	Location
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)
Continuous	Sampling with weekly analysis	14 locations
	Sampling with monthly analysis	11 locations
No monitoring	Inventory (administrative) control	92 locations

The stack monitoring program analyzed exhaust emissions for five radiological parameters during 2000: 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 9.0×10^{11} Bq (24 Ci) were measured during the year, with nearly all tritium being emitted from the National Tritium Labeling Facility's (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 4-4 Summary of Radiological Air Emissions*

Nuclide	Total (Bq/yr)	% Total
H-3	$8.97 \times 10^{+11}$	96.4%
C-11	$1.78 \times 10^{+10}$	1.9%
F-18	$1.26 \times 10^{+10}$	1.4%
N-13	$3.11 \times 10^{+9}$	0.3%
O-15	$2.22 \times 10^{+8}$	< 0.1%
I-125	$7.77 \times 10^{+7}$	< 0.1%
C-14	$4.41 \times 10^{+7}$	< 0.1%
All others	$2.06 \times 10^{+7}$	< 0.1%
Total	$9.30 \times 10^{+11}$	100.0%

*For a complete list of radiological air emissions, see NESHAPs Annual Report for 2000, found on Berkeley Lab's Environmental Services home page at http://www.lbl.gov/ehs/epg/html/env_protection.htm.

Tritium emissions for the calendar year 2000 continued to be below regulatory levels of concern. The NTLF annual emission of 9.0×10^{11} Bq (24 Ci) was below both the five- and ten-year averages for that facility. In fact, the total annual emissions were about one-fourth of US/EPA's reportable quantity for a singular 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.

III. AMBIENT AIR MONITORING RESULTS

§4.3 A. Tritium

Berkeley Lab sampled for airborne tritium at seven ambient monitoring sites during the year. Four of the sites were on the main grounds of the facility and the remaining three were off-site, as seen in Figure 4-2. Instrumentation at each site continuously samples outdoor air. The sampling media are replaced and analyzed monthly. All sites were chosen based on emission source locations, local wind patterns, and proximity to off-site residential areas and facilities.

One site in the network, station ENV-75EG, was added in January of the reporting year to determine tritium levels within the eucalyptus grove surrounding the hillside stack. Since this site is new, comparison of its results to other sites is limited at this point. However, one observation noted is that airborne concentrations consistently drop off by a factor of about three between this station, which is about 20 meters from the hillside stack, and station ENV-LHS, which is about 110 meters from the stack in the same downwind direction.

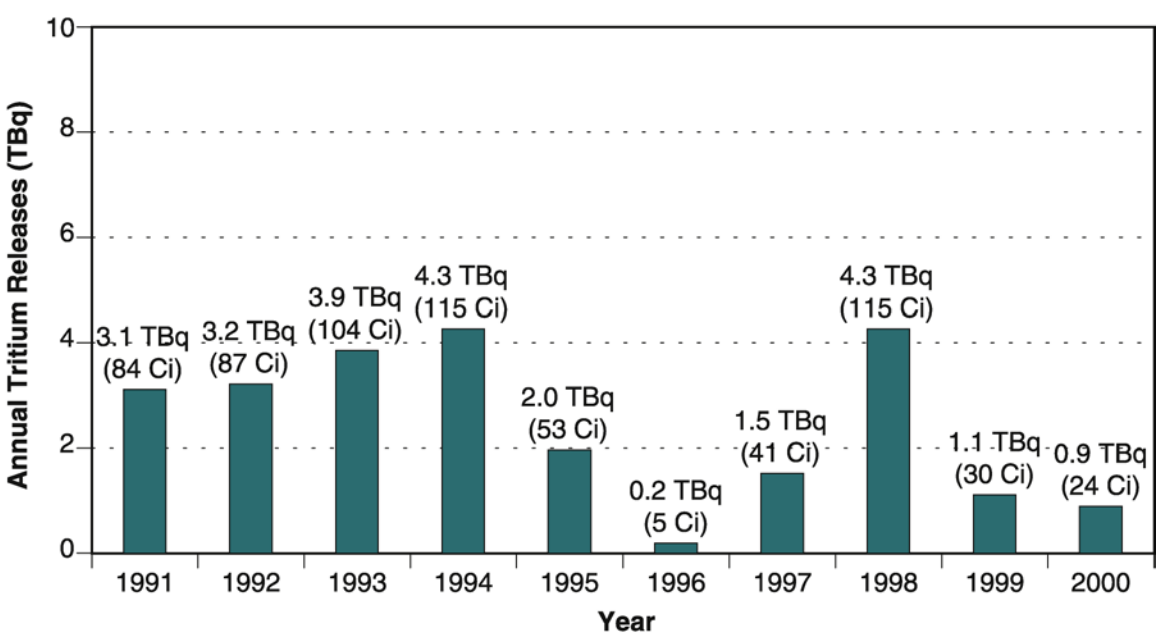


Figure 4-1 Trends in Annual Tritium Releases from NTLF

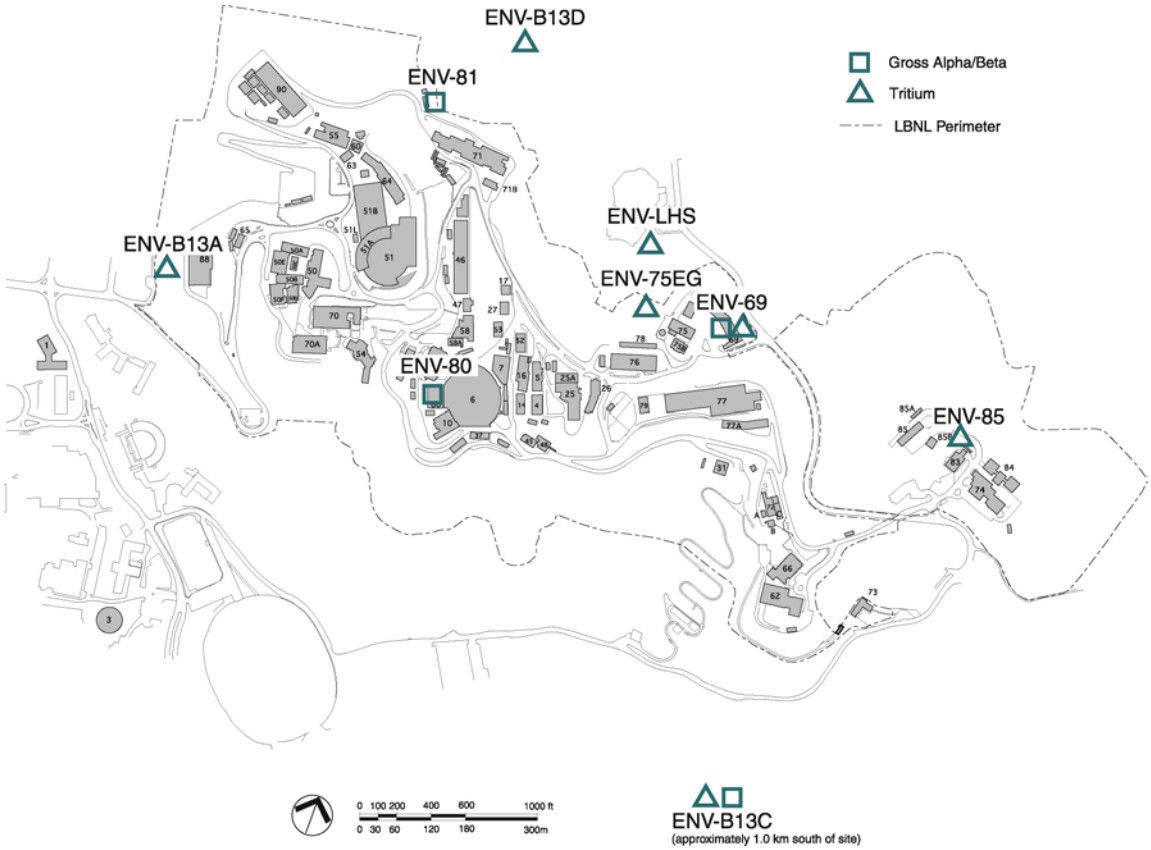


Figure 4-2 Ambient Air Monitoring Network Sampling Locations

Average and maximum tritium concentration values are much less than 1% of the allowable DOE annual exposure standard for tritium in air (3.7×10^3 Bq/m^3).[6] Results across the network are comparable to the previous year and well below levels measured as recently as 1995. For example, discounting the new site, the sampling station with the highest annual average concentration for the reporting year was station ENV-LHS at 0.70 Bq/m^3 (19 pCi/m^3). The highest annual average concentration for 1995, measured at station ENV-69, was considerably larger: 24 Bq/m^3 (650 pCi/m^3). Both sites are located at similar distances from the main source of tritium and downwind of the stack in different, although predominant, wind directions observed at the Laboratory. Table 4-5 summarizes the network's atmospheric tritium concentrations for the year.

§4.4 B. Gross Alpha/Beta

The ambient air sampling network also includes stations designed to sample air particulate emissions for measurement of gross alpha and gross beta levels. This network complements the exhaust system sampling program discussed in §4.1. The network consists of 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 4-5 Summary of 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	12	< 0.26[c]	—	< 0.26[c]	<0.26[c]
ENV-B13C	11	< 0.26[c]	—	< 0.26[c]	< 0.26[c]
ENV-B13D	12	<0.26[c]	—	< 0.26[c]	<0.26[c]
ENV-69	12	0.45	0.01	0.41	0.77
ENV-75EG	11	2.16	0.06	1.93	5.07
ENV-85	12	<0.26[c]	—	<0.26[c]	<0.26[c]
ENV-LHS	12	0.70	0.02	0.56	1.81

[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 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 over 1.0 kilometer (0.6 mile) south 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 4-6 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	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	1.6×10^{-4}
	ENV-69[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	2.4×10^{-4}
	ENV-80[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	2.0×10^{-4}
	ENV-81[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	2.5×10^{-4}
Beta	ENV-B13C	12	5.6×10^{-4}	4.1×10^{-4}	1.5×10^{-3}
	ENV-69	12	5.2×10^{-4}	4.3×10^{-4}	1.3×10^{-3}
	ENV-80	12	5.5×10^{-4}	4.1×10^{-4}	1.5×10^{-3}
	ENV-81	12	5.9×10^{-4}	4.2×10^{-4}	1.4×10^{-3}

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

5

Surface Water and Wastewater

I. SURFACE WATER PROGRAM **§5.1**

II. SURFACE WATER RESULTS

A. Rainwater **§5.2**

Figure 5-1: Rainwater and Lake Sampling Locations

Figure 5-2: Rainwater Radiological Monitoring Results

B. Creeks **§5.3**

Figure 5-3: Creek Sampling Locations

Figure 5-4: Annual Averages for Tritium in Chicken Creek (1995–2000)

C. Lakes **§5.4**

D. Stormwater **§5.5**

Figure 5-5: Stormwater Sampling Locations

III. WASTEWATER DISCHARGE PROGRAM **§5.6**

Figure 5-6: Sanitary Sewer System

IV. WASTEWATER RESULTS

A. Hearst and Strawberry Sewer Outfalls **§5.7**

1. Nonradiological Monitoring **§5.8**

Figure 5-7: Concentration of Metals in Hearst and Strawberry Sewer Water Samples as a Percentage of Permit Limit

2. Radiological Monitoring **§5.9**

Figure 5-8: Radioisotopes Discharged to Sewers in 2000 as a Percentage of Permit Limit

Figure 5-9: Annual Releases of Tritium to Sewers (1996–2000) as a Percentage of Permit Limit

B. Building 25 Photo Fabrication Shop Wastewater **§5.10**

C. Building 77 Ultra-High Vacuum Cleaning Facility Wastewater **§5.11**

D. Treated Hydrauger and Extraction Well Discharge **§5.12**

§5.1 I. SURFACE WATER PROGRAM

Berkeley Lab's surface water monitoring in 2000 consisted of rainwater, creeks, lakes, and stormwater. The first three surface water types mentioned are monitored primarily for gross alpha, gross beta, and tritium, based on DOE Orders[1] that prescribe monitoring for radioisotopes. Nonradiological sampling 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 further described in this chapter.

The limited hydrauger monitoring that had previously been performed by the Environmental Services Group was incorporated into the groundwater characterization efforts of the Environmental Restoration Group. For further information on groundwater monitoring, please see Chapter 6.

To place the Laboratory's results in a familiar context, this chapter cites drinking water standards as a comparison for results from certain sampling programs. 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 Bq/L (15 pCi/L) and 1.9 Bq/L (50 pCi/L), respectively.[3] The Environmental Protection Agency 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.

II. SURFACE WATER RESULTS

§5.2 A. Rainwater

Monthly rainwater composite samples are collected throughout the year from three locations, when rainfall occurs. See Figure 5-1. July, August, and September were dry months, so no samples were collected for those months; one sample was collected for May and the first half of June.

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 2000. 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.

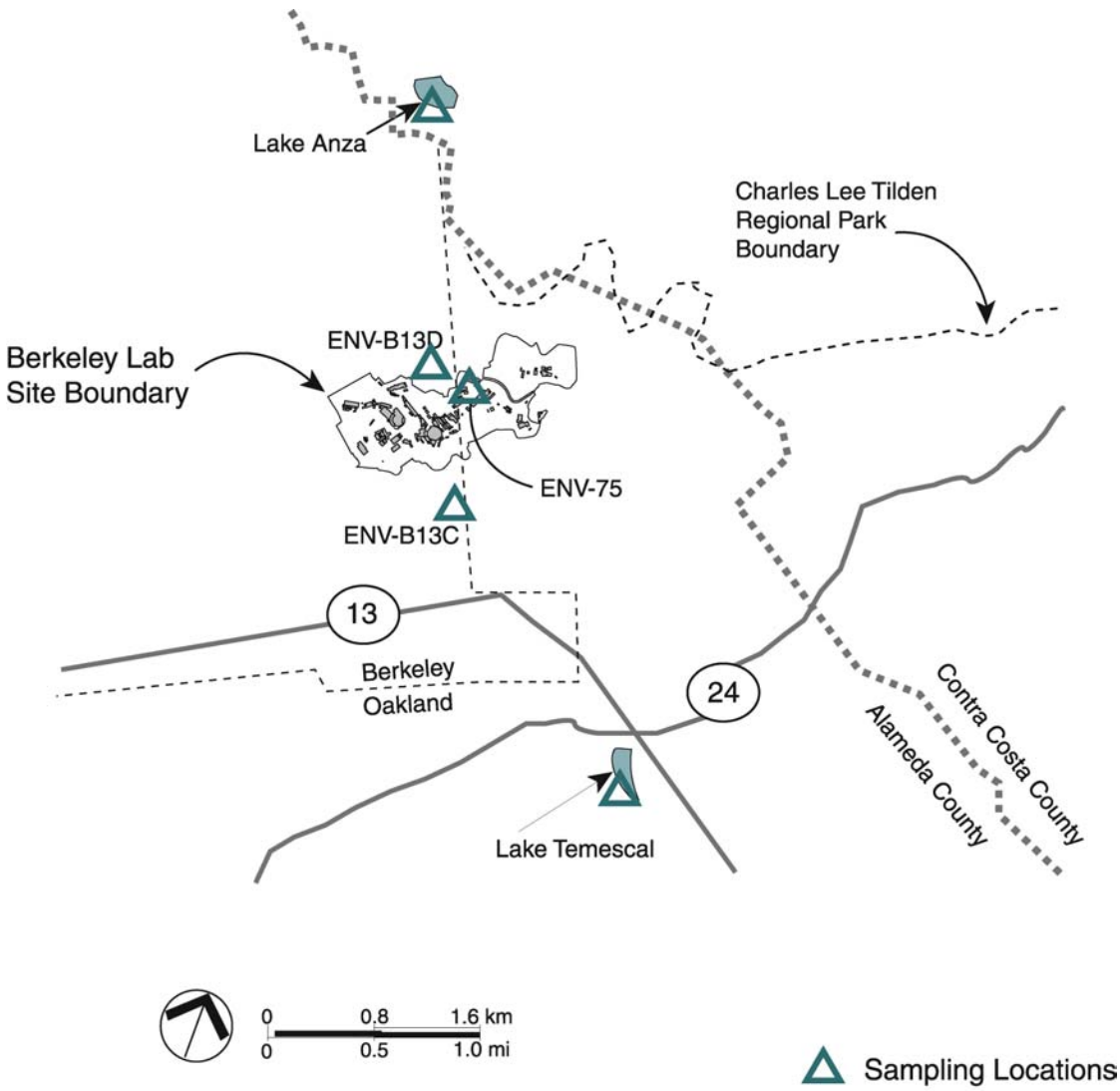
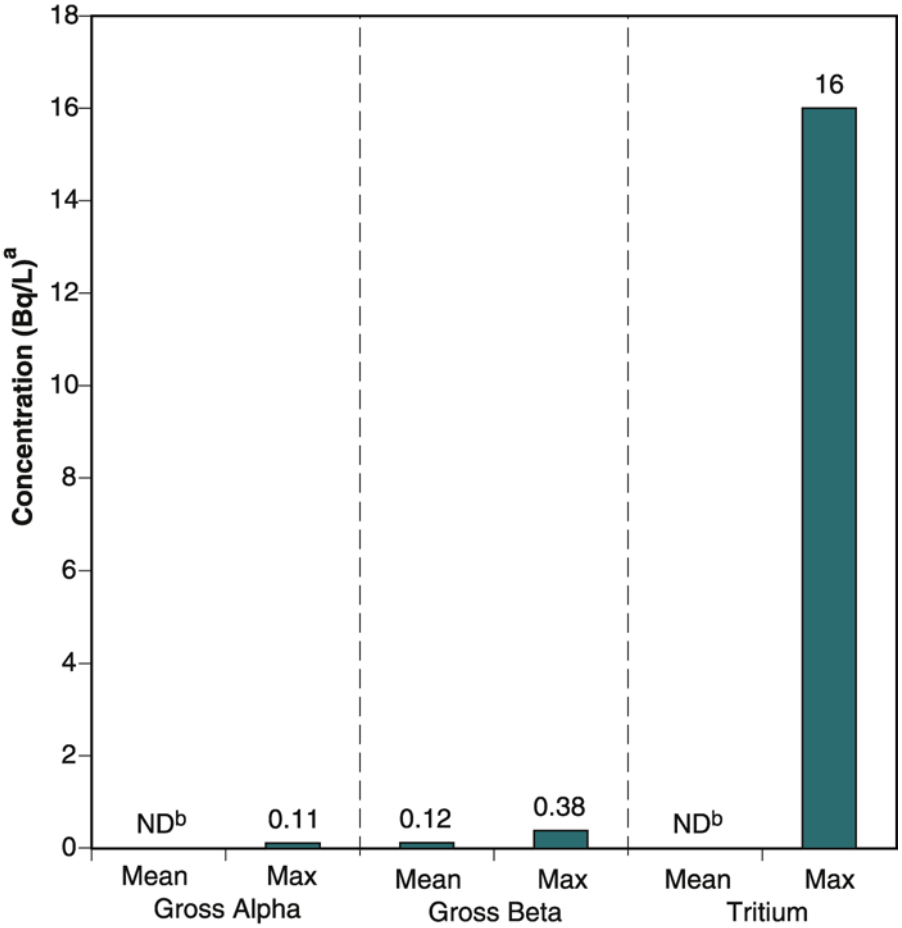


Figure 5-1 Rainwater and Lake Sampling Locations

Tritium was not detected in rainwater collected at the off-site locations. On-site, tritium in rainwater was detected only twice at ENV-75, with the maximum in January (16 Bq/L or 432 pCi/L). For comparison, this maximum tritium level represents approximately 2.2% of the US/EPA drinking water limit.

§5.3 B. 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



[a]1 Bq = 27 pCi

[b]Mean was less than the highest minimum detectable amount for the analyte (0.15 Bq/L for alpha and 7 Bq/L for tritium).

Figure 5-2 Rainwater Radiological Monitoring Results

beta activity and tritium. Creeks routinely sampled during 2000 were Chicken Creek, Claremont Creek, the North Fork of Strawberry Creek, Strawberry Creek (UC), and Wildcat Creek. For creek sampling locations, see Figure 5-3.

A second set of creeks was sampled once and analyzed for tritium, metals, and volatile organic compounds. These creeks (also shown in Figure 5-3) include Botanical Garden Creek, Cafeteria Creek, No Name Creek, Ravine Creek, and Ten-Inch Creek. No volatile organic compounds were detected at all. Some metals were present, including barium, chromium, copper, molybdenum, nickel, selenium, vanadium, and zinc—all in low amounts that are within background levels for this site and are well below limits stipulated in the San Francisco Region Basin Plan. See §5.5.

No alpha activity was detected at any sampling site, with the exception of a low amount at Chicken Creek during the March sampling. No beta activity was seen in any creek except one low amount in Strawberry Creek (UC). Tritium was generally not detected, except in Chicken Creek, where it was sometimes seen at low levels, and once in the North Fork of Strawberry Creek.

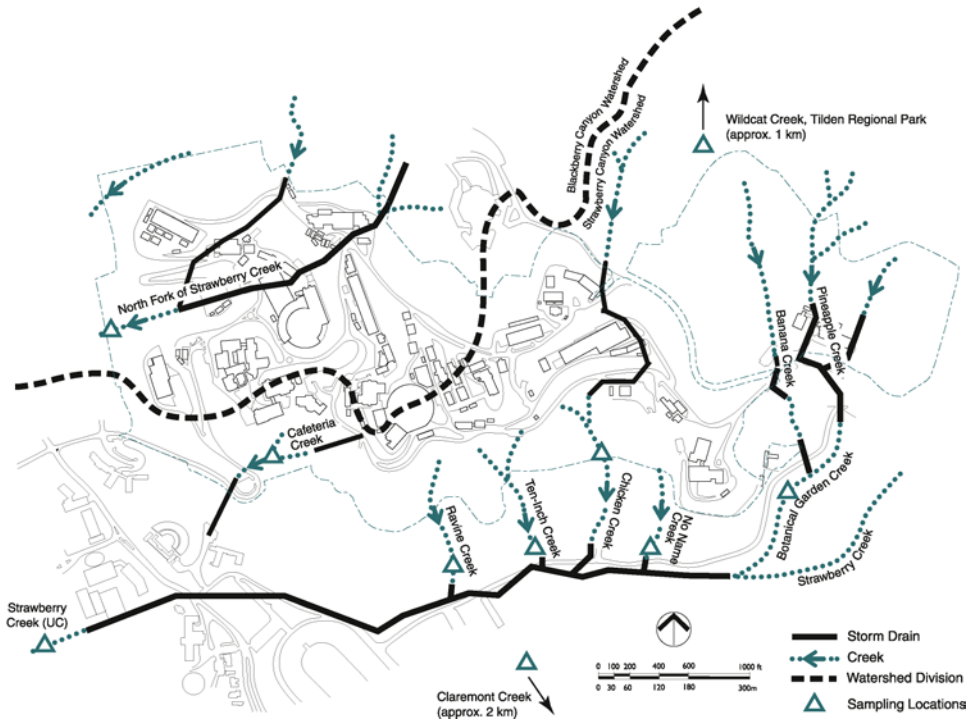


Figure 5-3 Creek Sampling Locations

Chicken Creek is the only creek in which tritium has been found with any regularity. Figure 5-4 presents a comparison of the annual mean for tritium in Chicken Creek over the last five 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 have remained near that level for the 1996–2000 period. The annual average for 2000, 12.6 Bq/L (340 pCi/L), represents a new low.

§5.4 C. 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.

§5.5 E. Stormwater

Berkeley Lab lies within the Blackberry Canyon and Strawberry Canyon watersheds. 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.

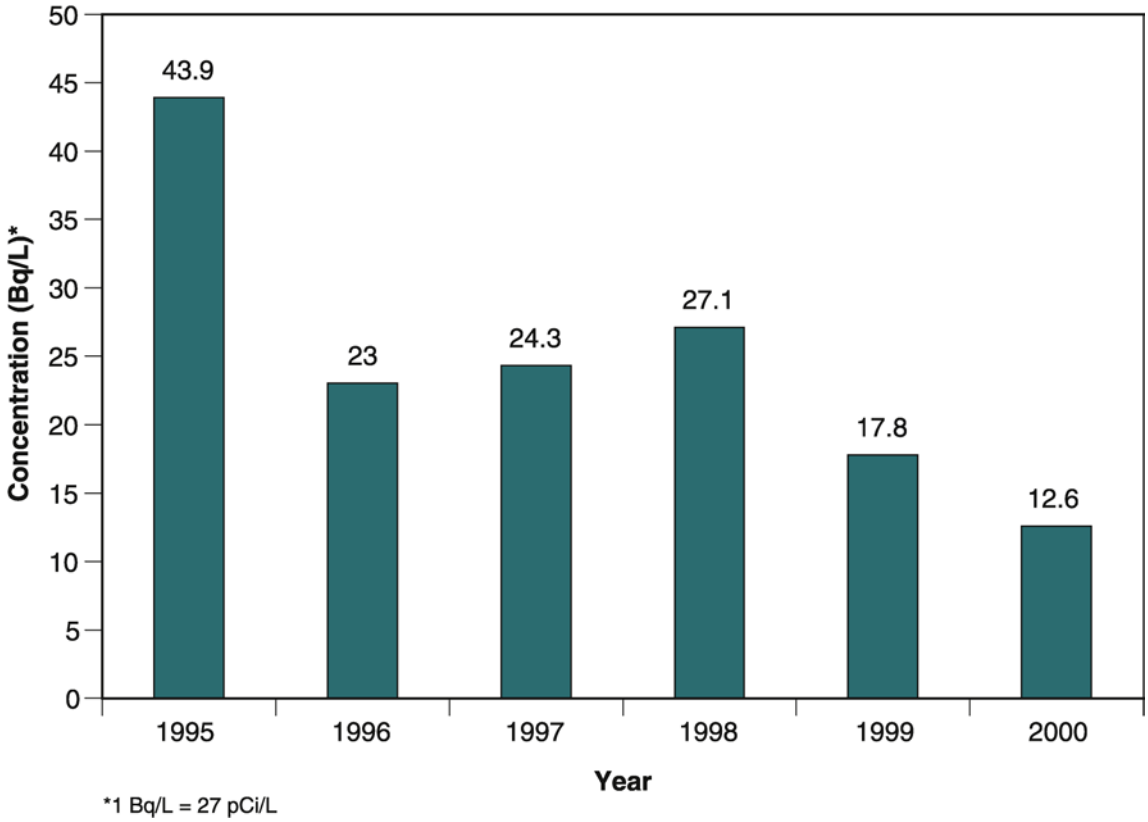


Figure 5-4 Annual Averages for Tritium in Chicken Creek (1995–2000)

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)[5] and a Storm Water Pollution Prevention Plan (SWPPP).[6] These are the guiding documents for the Laboratory's compliance with stormwater regulations. For further discussion of this compliance program, see §3.25.

Berkeley Lab's SWMP explains the rationale for sampling, sampling locations, and the kinds of radiological and nonradiological analyses to be performed. For metals, the permit requires analysis for total metals. Following a request from the City of Berkeley, however, Berkeley Lab has committed to analyzing at least one sample per stormwater year for both total and dissolved metals as a comparison. Dissolved metals are consistently lower than total metals. Sampling points are shown in Figure 5-5.

Two of the monitoring points, StW01 (Building 71-Storm Drain Manhole) and StW03 (Building 69-Storm Drain Manhole), are influent points, where stormwater comes

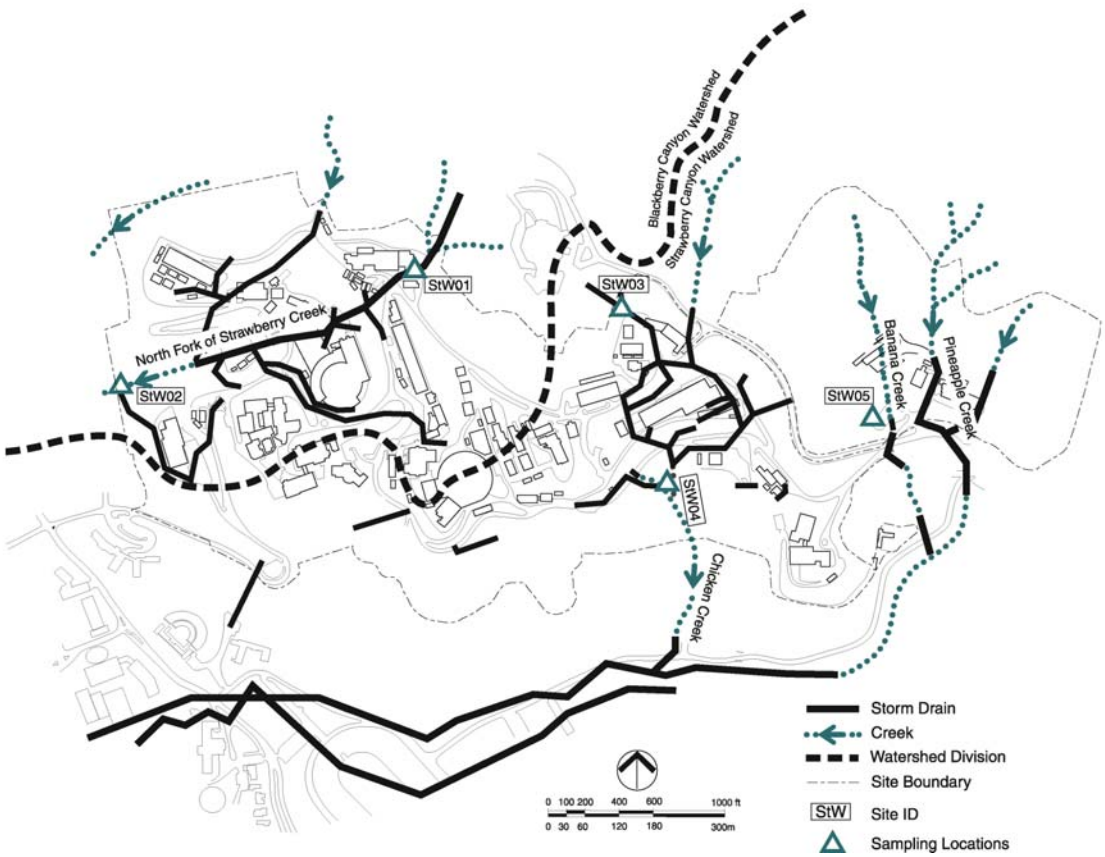


Figure 5-5 Stormwater Sampling Locations

onto the site from residential areas, roads, and UC Berkeley campus facilities located above Berkeley Lab. These points were chosen as a basis of comparison, facilitating an investigation if contaminants were found.

Under the terms of the General Permit, sampling must take place at least twice each "stormwater year" (July 1 through June 30) under specific conditions. Monitoring also includes visual observation of one storm per month and quarterly observation of authorized and unauthorized nonstormwater 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 2000, the measured pH was always near neutral, and total petroleum hydrocarbons (diesel) and oil and grease were often seen in low quantities at most sampling points. 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, filtered (CODF), is a measure that can be correlated to the amount of organic matter in the water. CODF 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.

Metal concentrations were generally below detection limits. Only aluminum, iron, thallium, and manganese were occasionally seen 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[7] gives effluent limitations for selected toxic pollutants discharged to shallow surface waters applicable to point source discharges from Publicly Owned Treatment Works (like 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 in very low concentrations at Building 69-Storm Drain Manhole (StW03) and once at Building 71-Storm Drain Manhole (StW01). All tritium values were low or nondetectable, with a maximum of 76.3 Bq/L (2,060 pCi/L) at Building 69 Storm Drain Manhole (StW03). The influent point at Building 69 consistently has the highest values for tritium in stormwater. The tritium value for the corresponding effluent point, Chicken Creek or StW04, was about one-third that level, at 28.7 Bq/L (775 pCi/L).

§5.6 III. WASTEWATER DISCHARGE PROGRAM

The Laboratory's sanitary sewer system is based on gravity flow and discharges through one of two monitoring stations, Hearst or Strawberry (see Figure 5-6):

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

Self-monitoring of wastewater discharge within Berkeley Lab also occurs at Buildings 25 and 77 and at groundwater treatment units (see Table 6-5), according to the terms of their respective EBMUD permits.[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

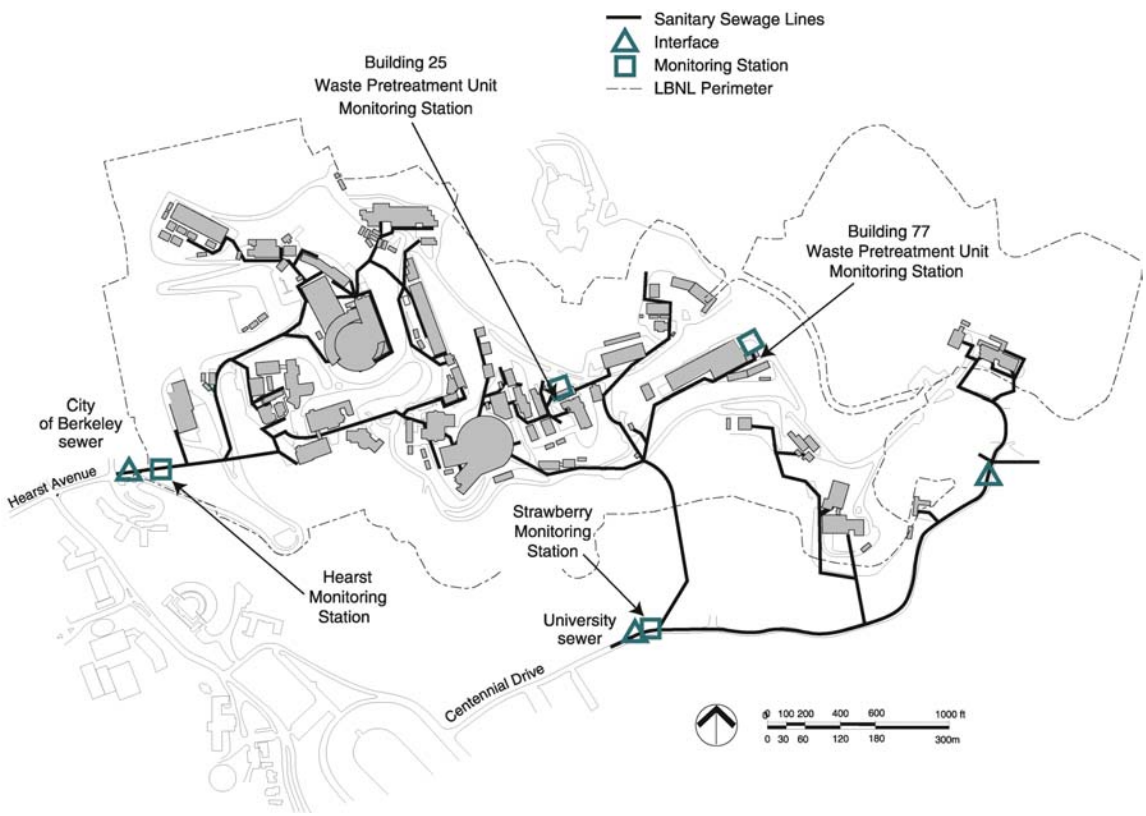


Figure 5-6 Sanitary Sewer System

for the treated groundwater permit, which is granted for two years. EBMUD is the local Publicly Owned Treatment Works that regulates all industrial discharges to its treatment facilities.

As in previous years, the Laboratory's 2000–2001 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.

IV. WASTEWATER RESULTS

§5.7 A. Hearst and Strawberry Sewer Outfalls

Sanitary sewer discharge monitoring is divided into two major 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.[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.

§5.8 1. Nonradiological Monitoring

Four nonradiological self-monitoring samples were taken from the Hearst and Strawberry outfalls during 2000. 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 Hearst or Strawberry outfalls. Figure 5-7 shows the metal results as a percentage of permit discharge limits.

No chlorinated hydrocarbons were detected, except for chloroform, which is present in EBMUD supply water, and one-time very small amounts of bromodichloromethane (in Strawberry Sewer) and naphthalene (in Hearst Sewer). According to the permit, the pH level must remain at no less than 5.5; all results were well above this. 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.

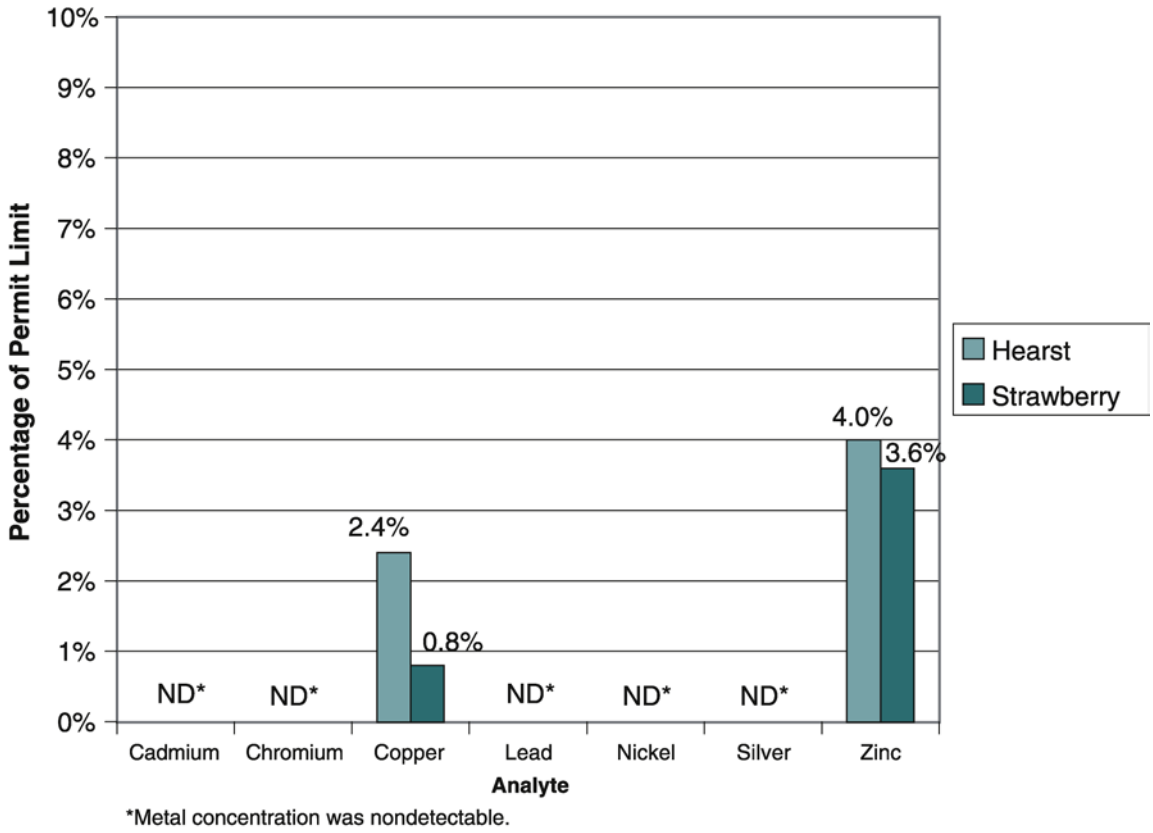


Figure 5-7 Concentration of Metals in Hearst and Strawberry Sewer Water Samples as a Percentage of Permit Limit

Starting with the 1997–1998 permit, Berkeley Lab is estimating the average and maximum wastewater strength for the coming year in its permit application, and these then become the permit limits.

§5.9 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 periodically analyzed by a third laboratory 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. The limit for all other radioisotopes is a combined 3.7×10^{10} Bq (1 Ci) per year. Radioisotopes discharged in Berkeley Lab's sewer wastewater, expressed as a percentage of their permit limit, are summarized in Figure 5-8.

Alpha emitters, which can potentially come from transuranic and heavy-element research, were not detected at Hearst Station and were only once detected at low levels at Strawberry Station. Beta emitters, including iodine-125 from biomedical research, were usually detected in both sewers at low levels, generally with less at Strawberry than at Hearst. The maximum concentration of beta emitters for the year was 0.95 Bq/L (25.7 pCi/L), while the highest iodine-125 concentration was 6.56 Bq/L (177 pCi/L), both at Hearst Station. For a complete set of the individual results, see the data tables in Volume II.

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 2.59×10^{9} Bq (0.069 Ci), and the total for other radioisotopes was 3.02×10^{8} Bq (0.008 Ci). The amount of tritium increased very slightly over last year's level, while the total for other radioisotopes decreased. All values, however, were well below allowable limits. For example, tritium was only 1.4% of the allowable federal and state limit, and all other isotopes together were also approximately 0.8% of their limit.

Figure 5-9 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.

§5.10 B. 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 other hazardous materials 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.

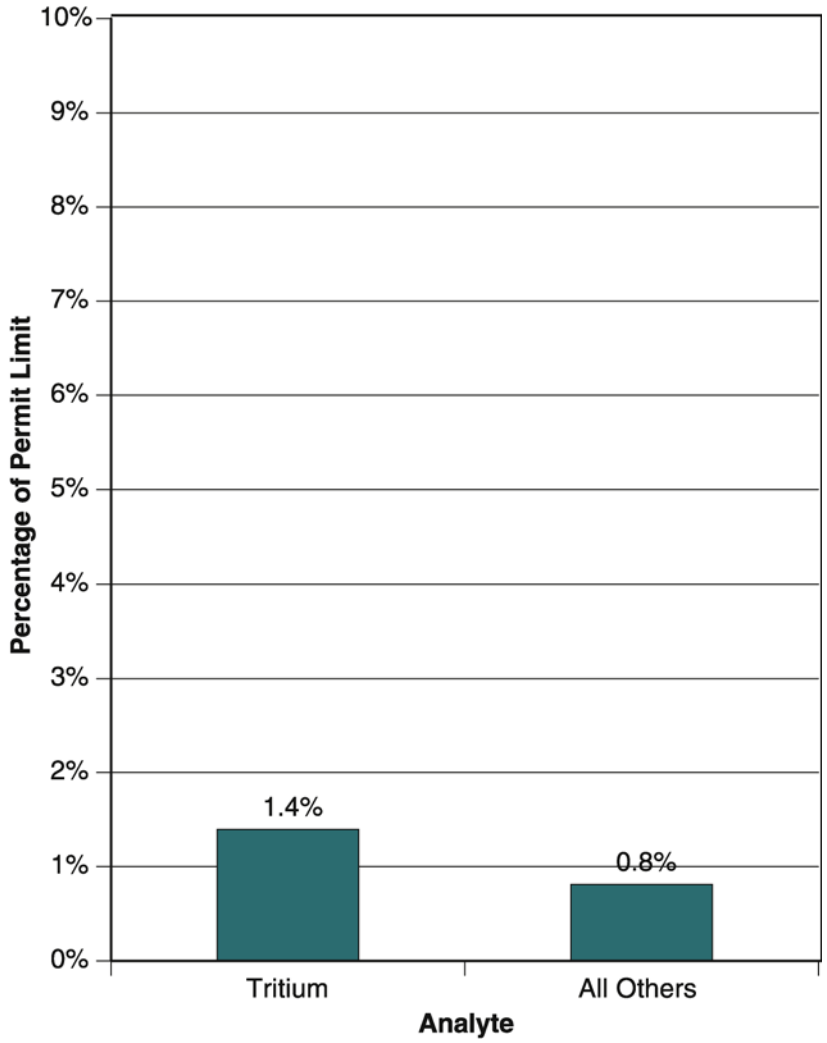


Figure 5-8 Radioisotopes Discharged to Sewers in 2000 as a Percentage of Permit Limit

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]

§5.11 C. 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. During 2000, new pipes with secondary containment were installed between the facility in Building 77 and the treatment unit across the street; to contain the pipes, the Laboratory

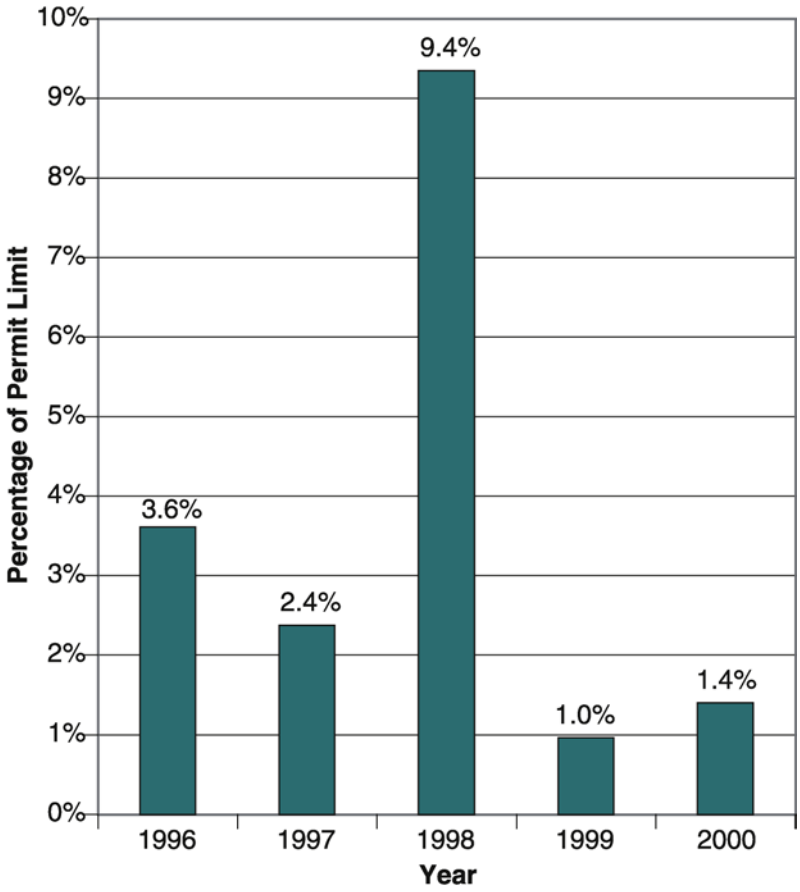


Figure 5-9 Annual Releases of Tritium to Sewers (1996–2000) as a Percentage of Permit Limit

also dug a new trench that conforms to regulations for pipes transporting hazardous waste. No ground leaks were found during removal of the old piping.

All self-monitoring and EBMUD inspection samples (four each) were well within permitted limits. For the 2000–2001 permit, received in September 2000, EBMUD reduced the number of UHVCF self-monitoring events to three and the number of times it would sample to two.

§5.12 D. 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 drains) 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 have been "nondetect." Occasional detections of certain chlorinated hydrocarbons have been extremely low (parts per billion) and 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

I. BACKGROUND **§6.1**

II. HYDROGEOLOGIC CHARACTERIZATION

A. Hydrogeologic Units **§6.2**

B. Groundwater Flow **§6.3**

Figure 6-1: Groundwater Piezometric Map

C. Groundwater Quality **§6.4**

III. GROUNDWATER MONITORING RESULTS **§6.5**

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

Table 6-1: Metals Detected in Groundwater Samples from Monitoring Wells

Table 6-2: VOCs Detected in Groundwater Samples from Monitoring Wells

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

IV. GROUNDWATER CONTAMINATION PLUMES **§6.6**

Figure 6-3: Groundwater Contamination Plumes (September 2000)

A. VOC Plumes **§6.7**

Figure 6-4: Groundwater Contamination (Total Halogenated Hydrocarbons in μg/L) in Old Town Area (September 2000)

Figure 6-5: Groundwater Contamination (Total Halogenated Hydrocarbons in μg/L) at Building 51/64 VOC Plume (September 2000)

B. Freon Plume **§6.8**

C. Tritium Plume **§6.9**

Figure 6-6: Groundwater Contamination (Tritium in pCi/L), October to December 2000

D. Petroleum Hydrocarbon Plumes **§6.10**

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

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

V. INTERIM CORRECTIVE MEASURES **§6.11**

A. Source Removal or Control **§6.12**

B. Preventing Discharge of Contamination to Surface Waters **§6.13**

C. Preventing Further Migration of Contaminated Groundwater **§6.14**

D. Treatment Systems **§6.15**

Table 6-5: Treatment of Contaminated Groundwater

§6.1 I. BACKGROUND

This chapter reviews the groundwater monitoring program at Berkeley Lab, emphasizing the 2000 results. Additional details on the program can be obtained in the 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 the UC Berkeley 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 closely coordinated with the regulatory oversight agencies, including the Cal/EPA Department of Toxic Substances Control, San Francisco Bay Regional Water Quality Control Board, City of Berkeley, and 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.

II. HYDROGEOLOGIC CHARACTERIZATION

§6.2 A. Hydrogeologic Units

Moraga Formation volcanic rocks, Orinda Formation sediments, and Great Valley Group sediments constitute the principle 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.

§6.3 B. 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). A groundwater piezometric map indicating the hydraulic head distribution at Berkeley Lab, based on water levels measured in wells, is given in Figure 6-1. This map indicates 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 meters per year (0.003 feet per year) to about 1.0 meters per day (3.3 feet per day).

§6.4 C. Groundwater Quality

Groundwater samples from monitoring wells are tested for total dissolved solids (TDS), cations, and anions. During 2000, the TDS concentrations measured in groundwater monitoring wells range from 105 to 4,460 mg/L.

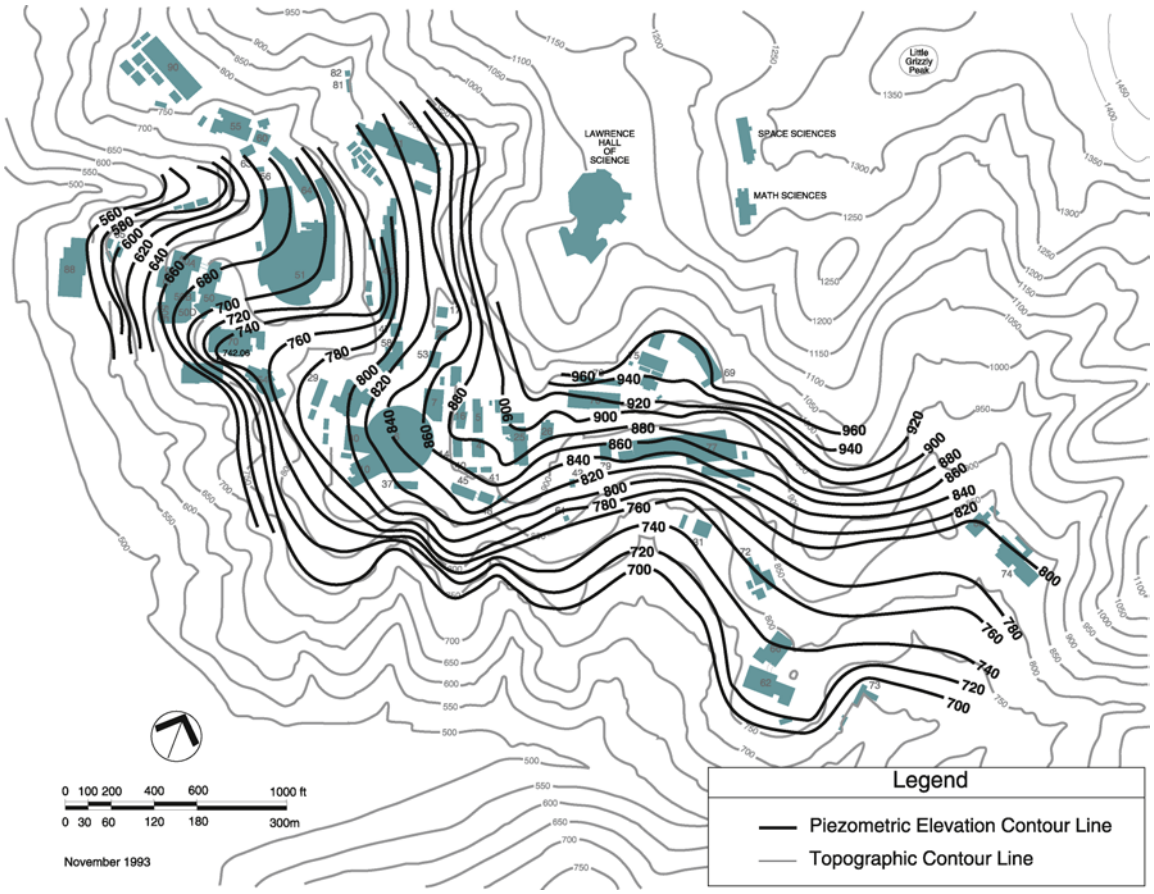


Figure 6-1 Groundwater Piezometric Map

§6.5 III. GROUNDWATER MONITORING RESULTS

In 2000, nine new monitoring wells were installed, and four were destroyed as part of interim corrective measures (ICMs), bringing the total number of monitoring wells in the program to 190. 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 2000. Tables 6-1 and 6-2 summarize the metal results and VOC results, respectively. The tables show the drinking water standard (maximum contaminant level or MCL) for the analyte,[2] the number of monitoring wells sampled, the number of monitoring wells in which the analyte was detected, and the ranges in concentrations detected. Table 6-3 presents tritium results.

§6.6 IV. GROUNDWATER CONTAMINATION PLUMES

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

- *VOC plumes:* Old Town and Buildings 37, 51/64, 71, and 76.
- *Freon plume:* Building 71.
- *Tritium plume:* Building 75/77.
- *Petroleum hydrocarbon plumes:* Buildings 7 and 74.

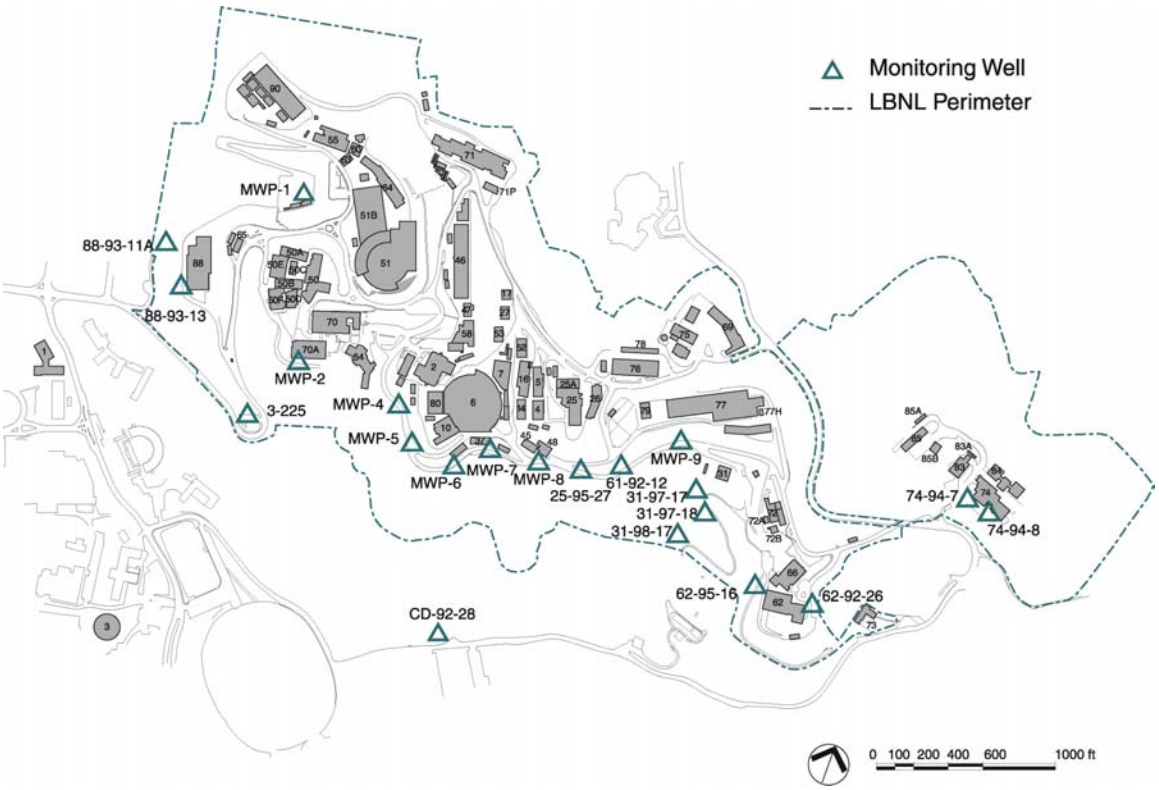


Figure 6-2 Approximate Locations of Monitoring Wells Closest to Berkeley Lab Property Line

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	49	61	2	1–4.1	6
Arsenic	66	78	60	2.2–103	50
Barium	50	62	36	3.5–980	1000
Beryllium	50	62	0		4
Cadmium	49	61	0		5
Chromium	51	63	15	3.1–20	50
Hexavalent Chromium	3	3	0		
Cobalt	50	61	0		NS[b]
Copper	49	61	24	1.3–110	1000[c]
Lead	50	62	0		15[d]
Mercury	52	64	1	4	2
Molybdenum	57	70	33	34.9–958	NS[b]
Nickel	50	62	11	1.2–74	100
Selenium	54	66	23	2–130	50
Silver	49	61	0		100[c]
Thallium	49	61	0		2
Vanadium	50	62	33	1.4–161	NS[b]
Zinc	49	61	12	5.5–42	5000[c]

[a] Metals not detected in any samples are beryllium, cadmium, hexavalent chromium, silver, and thallium.
[b] NS = Not specified
[c] Secondary MCL
[d] Action level

Contamination was also detected in groundwater in other areas of the site in 2000. Based on current information, however, the extent of contamination in these areas is limited.

§6.7 A. 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.

The maximum concentration of total halogenated hydrocarbons detected in groundwater samples collected from Old Town VOC plume wells in 2000 was 143,680 μg/L, which primarily consisted of PCE (72,800 μg/L), TCE (68,000 μg/L), and carbon tetrachloride (2,880 μg/L). Figure 6-4 shows the areal extent of VOCs in groundwater in the Old Town area.

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	4	0.56–10.5	1
Methyl Tertiary Butyl Ether	3	0.53–1.5	13
n-Butylbenzene	1	1.4	NS[b]
sec-Butylbenzene	1	1.0	NS[b]
p-Isopropyltoluene	1	1.5	NS[b]
Naphthalene	1	21.3	NS[b]
1,4-Dichlorobenzene	1	1.1–1.3	NS[b]
Toluene	4	0.74–9.2	150
Halogenated Hydrocarbons			
Bromoform	2	2–4.5	100[c]
Carbon Tetrachloride	25	1–2,880	0.5
Chloroethane	1	12	NS[b]
Chloroform	28	3–84.7	100[c]
Chloromethane	2	2–8.4	NS[b]
Dibromomethane	1	0.7	NS[b]
1,2-Dichlorotrifluoroethane (Freon-123A)	5	1.4–8.4	NS[b]
1,1-Dichloroethane	33	0.58–15,000	5
1,2-Dichloroethane	6	1.5–113	0.5
1,1-Dichloroethylene	40	0.57–4,840	6
cis-1,2-Dichloroethylene	53	0.5–3,300	6
trans-1,2-Dichloroethylene	15	1.1–53.9	10
2,2-Dichloropropane	1	29.7	NS[b]
Methylene Chloride	4	3.8–342	5
1,1,1,2-Tetrachloroethane	5	4.3–41.9	NS[b]
1,1,2,2-Tetrachloroethane	2	1.6–10	1
1,2,3-Trichloropropane	1	15	NS[b]
Tetrachloroethylene	68	1 – 72,800	5
1,1,1-Trichloroethane	32	1–110,000	200
1,1,2-Trichloroethane	9	0.66–282	5
Trichloroethylene	81	0.63–68,000	5
1,1,2-Trichlorotrifluoroethane (Freon 113	3	2.5–15.6	1,200
Vinyl Chloride	16	0.95–103.5	0.5

[a]488 samples taken from 187 wells during the year
[b]NS: Not Specified
[c]Standard is for total trihalomethanes

Table 6-3 Tritium Detected[a,b] in Groundwater Samples from Monitoring Wells

Well number	January–March (Bq/L)[c]	April–June (Bq/L)	July–September (Bq/L)	October–December (Bq/L)
31-97-17	52	NS[c]	51	NS
69-97-21	20	NS	24	NS
71-95-9	NS	NS	17,21	NS
75-92-23	141	NS	70,75[d]	NS
75-97-5	1001	687,907[d]	987, 1066[d]	968, 1010[d]
75-97-7	48	NS	34	NS
75-98-14	95	74,108[d]	93	125
75-99-7	236	187,263[d]	223,216[d]	207, 219[d]
75B-92-24	85	NS	115	NS
76-93-6	22	NS	42	NS
77-94-6	489	NS	326	NS
77-97-11	223	NS	188	NS
77-97-9	488	NS	374	NS
78-97-20	113	NS	94	NS
MW76-1	21	NS	20	NS
MW91-2	27	NS	22	NS
MW91-4	50	NS	30	NS
MW91-5	148	NS	84	NS
MW91-6	121	NS	117	NS

[a] Wells without detectable results in all quarters of sampling include 46A-92-15, 71-93-1, MW91-3, 69A-92-22, 75-96-20, 75-97-6, 69-97-8, 75-98-15, 75-99-4, 76-92-25, 76-93-7, 76-98-21, MW91-1, MWP-9, MWP-10, 77-92-10, 61-92-12, 77-93-8, 77-94-5, 31-97-18, 31-98-17, 88-93-11A, MWP-2, OW3-225, MWP-8, 52-94-10, 52-95-2B, 74-94-7, 74-94-8, 62-92-26, 62-92-27, MWP-4, MWP-5, MWP-6, MWP-7, 37-92-6, 37-92-18, 37-92-18A, 37-93-5, 37-94-9, MWP-1, and CD-92-28.
[b] For comparison, the drinking water standard determined by California Department of Health Services is 740 Bq/L (20,000 pCi/L).
[c] NS: Not sampled
[d] Duplicate sample

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.

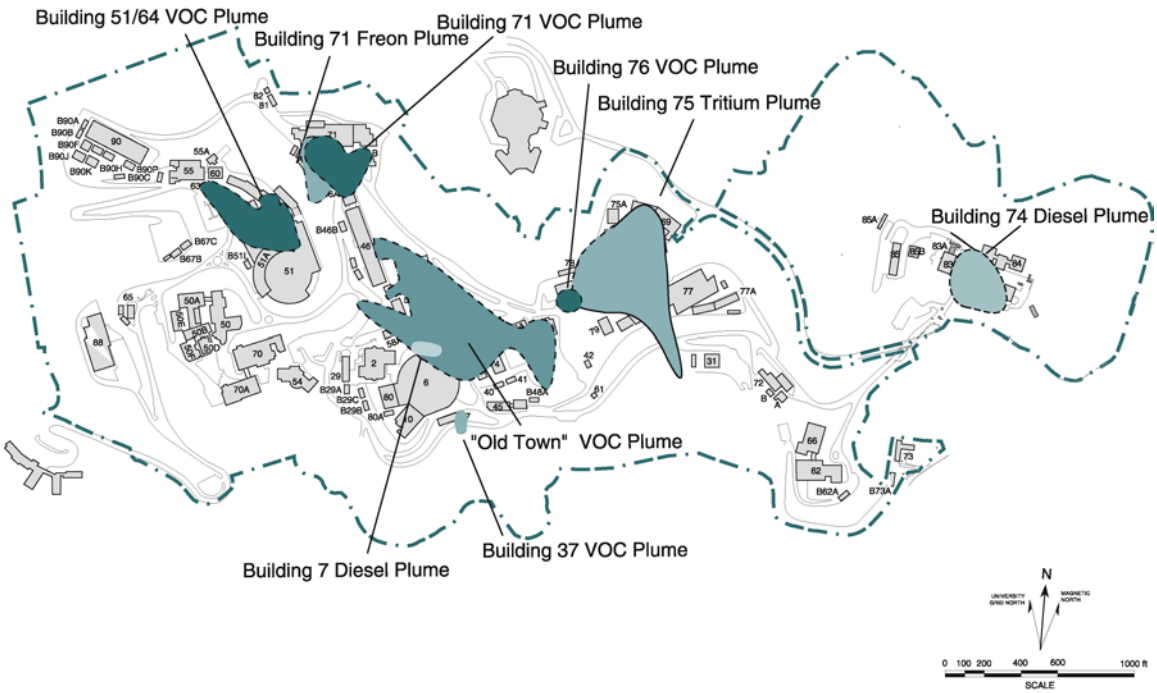


Figure 6-3 Groundwater Contamination Plumes (September 2000)

Four interim corrective measures have been instituted to manage the Old Town VOC plume (see §6.13):

- A groundwater collection trench was installed immediately downgradient from the former Building 7 sump to control the source of the groundwater contamination;
- A subdrain located east of Building 46 intercepts the northern lobe of the plume and prevents the discharge of contaminated groundwater to the stormdrain;
- A groundwater collection trench was installed west of Building 58 to intercept the southern lobe of the plume and prevent its further migration; and
- 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.

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 2000 at a maximum total concentration of 346,500 μg/L in a water sample from a temporary sampling point in the source area of the plume. The maximum concentration of total halogenated hydrocarbons detected in 2000 in samples collected from groundwater monitoring wells in the Building 51/64 area was 134,560 μg/L. The contaminants primarily consisted of 1,1,1-TCA (110,000 μg/L) and 1,1-DCA (9,400 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 (see §6.13).

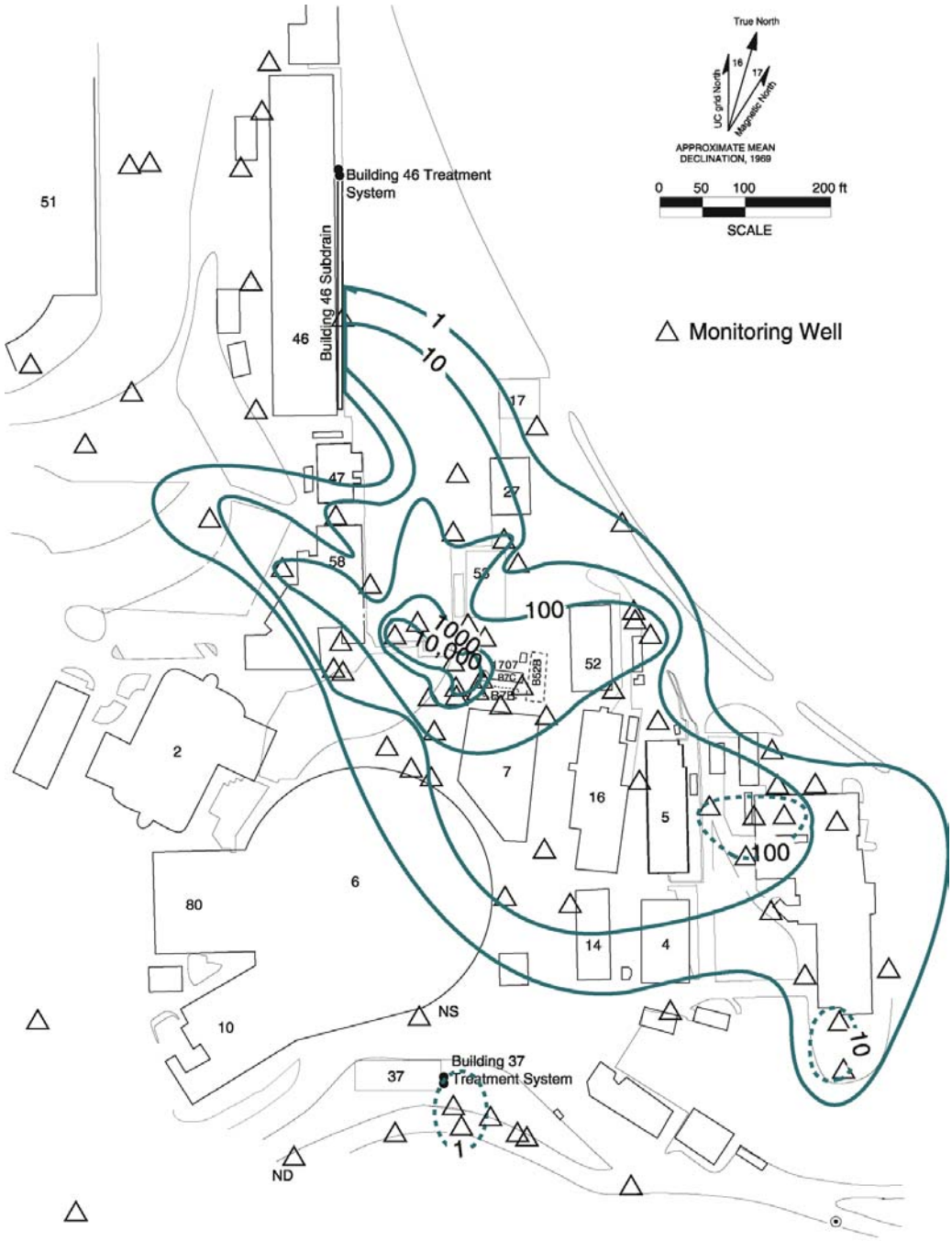


Figure 6-4 **Groundwater Contamination (Total Halogenated Hydrocarbons in μg/L) in Old Town Area (September 2000)**

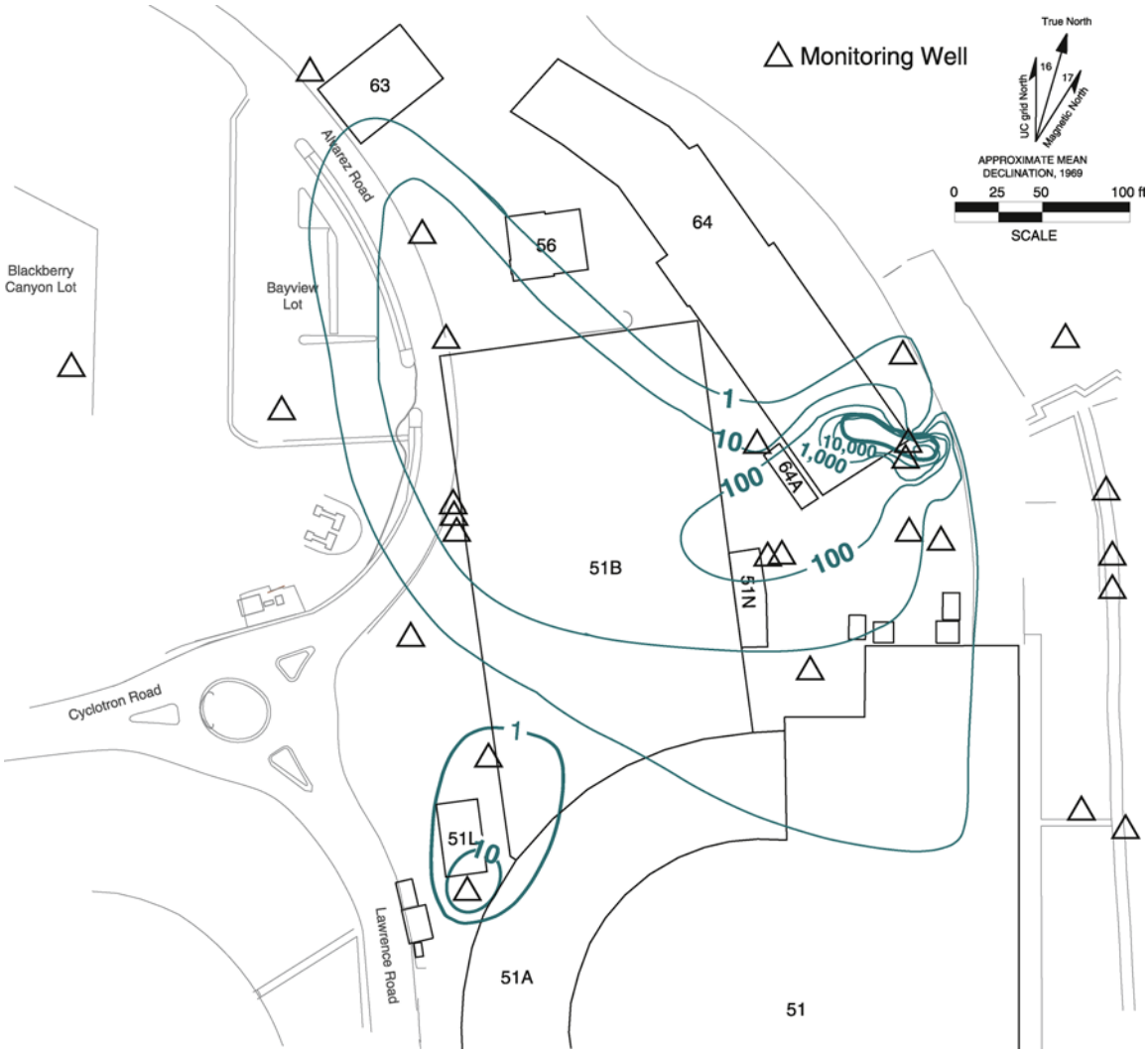


Figure 6-5 Groundwater Contamination (Total Halogenated Hydrocarbons in µg/L) at Building 51/64 VOC Plume (September 2000)

Other VOC plumes have been identified south of Building 71 (Building 71 VOC plume), east of Building 37 (Building 37 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 2000, 1,088 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 2000 as an interim corrective measure (see §6.13).

The Building 37 VOC plume is defined by the presence of halogenated hydrocarbons, primarily PCE and 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 groundwater for plume management was initiated. The maximum concentration of total halogenated hydrocarbons detected in wells monitoring the plume in 2000 was 7.2 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 2000 was 24 μg/L.

§6.8 B. 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 operational. 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.

§6.9 C. Tritium Plume

The tritium plume covers the areas of Buildings 31, 75, 76, 77, and 78. The source of the tritium is the National Tritium Labeling Facility at Building 75. The maximum concentration of tritium detected in monitoring wells in 2000 was 1,066 Bq/L (28,800 pCi/L), 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.

§6.10 D. 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 2000 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 at UST sites in 2000. 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 three monitoring wells in 2000 at a concentration of 1.5 μg/L. The California MCL for MTBE is 13 μg/L.

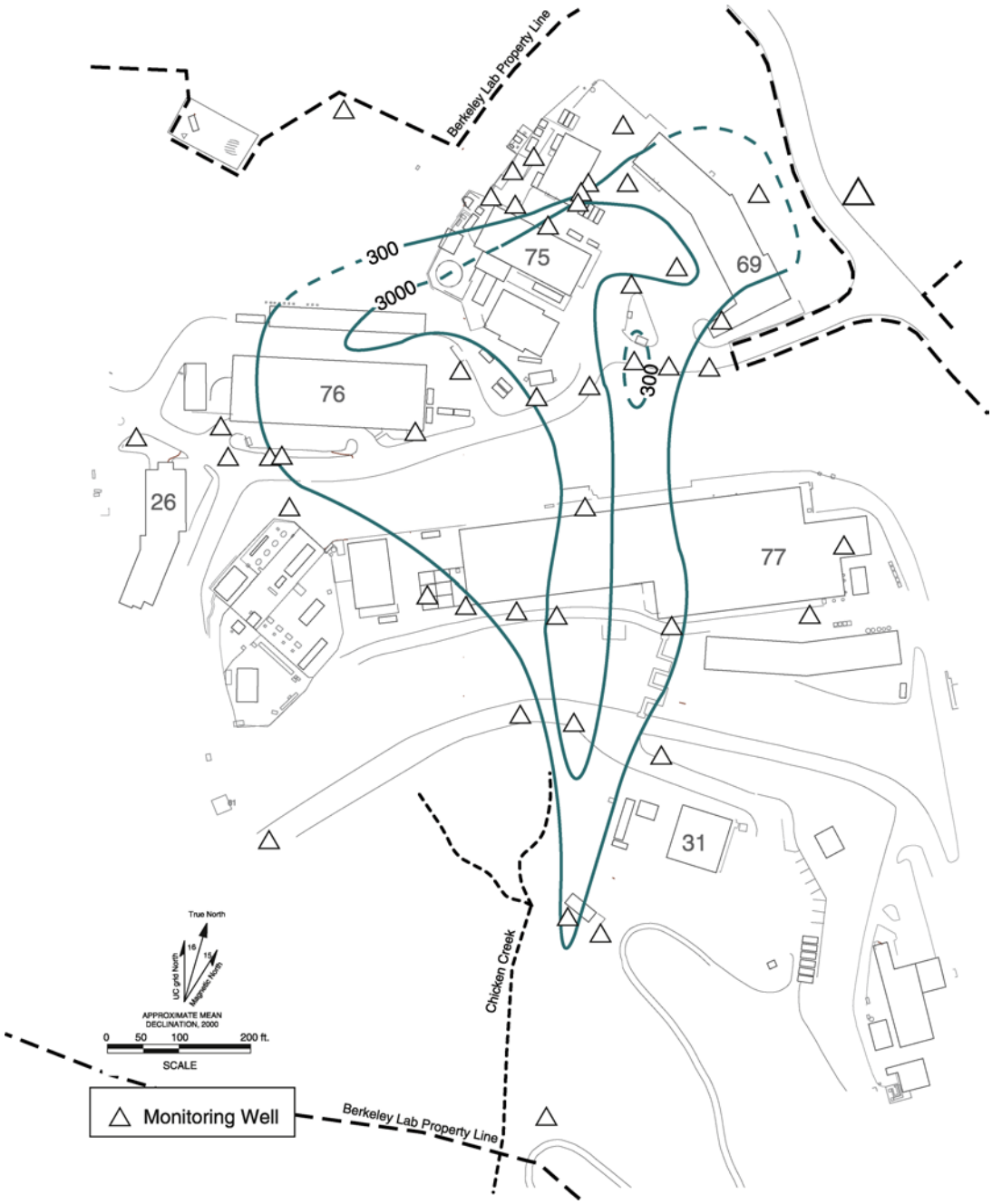


Figure 6-6 Groundwater Contamination (Tritium in pCi/L), October to December 2000

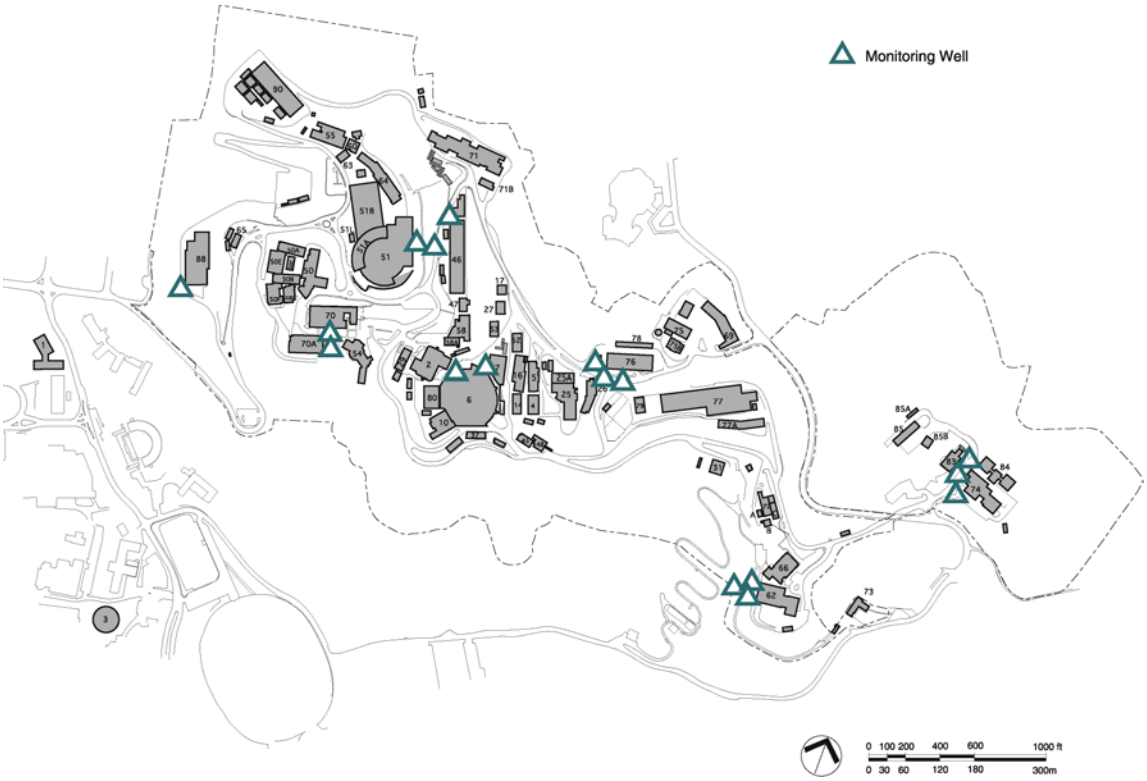


Figure 6-7 Approximate Locations of Monitoring Wells Associated with Underground Storage Tanks

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[f]
Building 70A[a]	Removed	Diesel	TPH-D[c] = 72
Building 62[a]	Removed	Diesel	TPH-D[c] = 140
Building 74[a]	Removed	Diesel	TPH-D[c] = 140
Building 76[a]	Removed	Diesel	TPH-D[c] = 610
Building 76[a]	Removed	Gasoline	TPH-G[d] = 63
Building 7E	Removed	Kerosene	TPH-K[e] = 4100
Building 88[a]	Abandoned	Diesel	ND[b]
Building 46A[a]	Abandoned	Gasoline	NS[f]

[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-G = TPH quantified as gasoline range hydrocarbons
[e] TPH-K = TPH quantified as kerosene range hydrocarbons
[f] NS = Not sampled

§6.11 V. 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;
- Stopping discharge of contaminated water to surface waters;
- Eliminating potential pathways that could contaminate groundwater; and
- Preventing further migration of contaminated groundwater.

§6.12 A. 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 2000:

- Approximately 54 cubic meters (70 cubic yards) of VOC-contaminated soil were excavated from the source area of the Building 71 VOC plume south of Building 71B.
- Approximately 138 cubic meters (180 cubic yards) of VOC-contaminated soil were excavated from the source area of the Building 51/64 VOC plume at the southeast corner of Building 64.
- 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 10 kg of VOCs (consisting primarily of PCE, TCE, and carbon tetrachloride) from the groundwater in 2000.
- A dual phase (groundwater and soil vapor) extraction and treatment system was installed at the location of the Building 7E former UST in 1998 to remove contaminants from the soil and groundwater. Operation of the system continued in 2000.

§6.13 B. 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.

§6.14 C. Preventing Further Migration of Contaminated Groundwater

Berkeley Lab is capturing and treating contaminated groundwater using extraction wells 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 2000.
- 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 2000.

§6.15 D. Treatment Systems

As described above, Berkeley Lab is using extraction wells 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 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 2000 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 2000 (liters)[a]	Total volume treated (liters)
Building 37 VOC plume	Building 37	408,810	4,019,042
Old Town VOC plume	Building 46	4,258,310	30,237,987
Building 71 VOC plume and water collected from purging monitoring wells	Building 51 firetrail	4,845,557	6,839,154
VOC contaminated hydrauger effluent[b]	Building 51 hydraugers	160,283	35,891,887
Building 51 subdrain system	Building 51 sump	1,307,313	5,711,111
	Building 51L	81,972	81,972
Old Town VOC plume	Building 7 trench	1,750,483	7,198,650
Building 6 former underground storage tank	Building 6 bioventing	1,137,597	2,500,795
Total volume treated		13,950,325	92,480,598

[a] 1 liter = 0.264 gallons

[b] B51 hydrauger system was routed into the Building 51 firetrail system as of February 2000, and is included in the B51 firetrail total.

7

Soil and Sediment

I. BACKGROUND **§7.1**
II. SOIL AND SEDIMENT SAMPLING **§7.2**
Figure 7-1: Soil and Sediment Sampling Sites
III. SOIL AND SEDIMENT ANALYSIS RESULTS **§7.3**
Table 7-1: Tritium Results in Soil and Sediment Samples
Table 7-2: Metals and Oil/Grease Results in Soil and Sediment Samples

§7.1 I. 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. DOE guidance recommends—and Berkeley Lab performs—annual soil and sediment sampling to determine long-term accumulation trends and baseline profiles.[1] No other 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 2000, sampling was performed in October before the rainy season. All individual sampling results are presented in Volume II.

§7.2 II. 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.

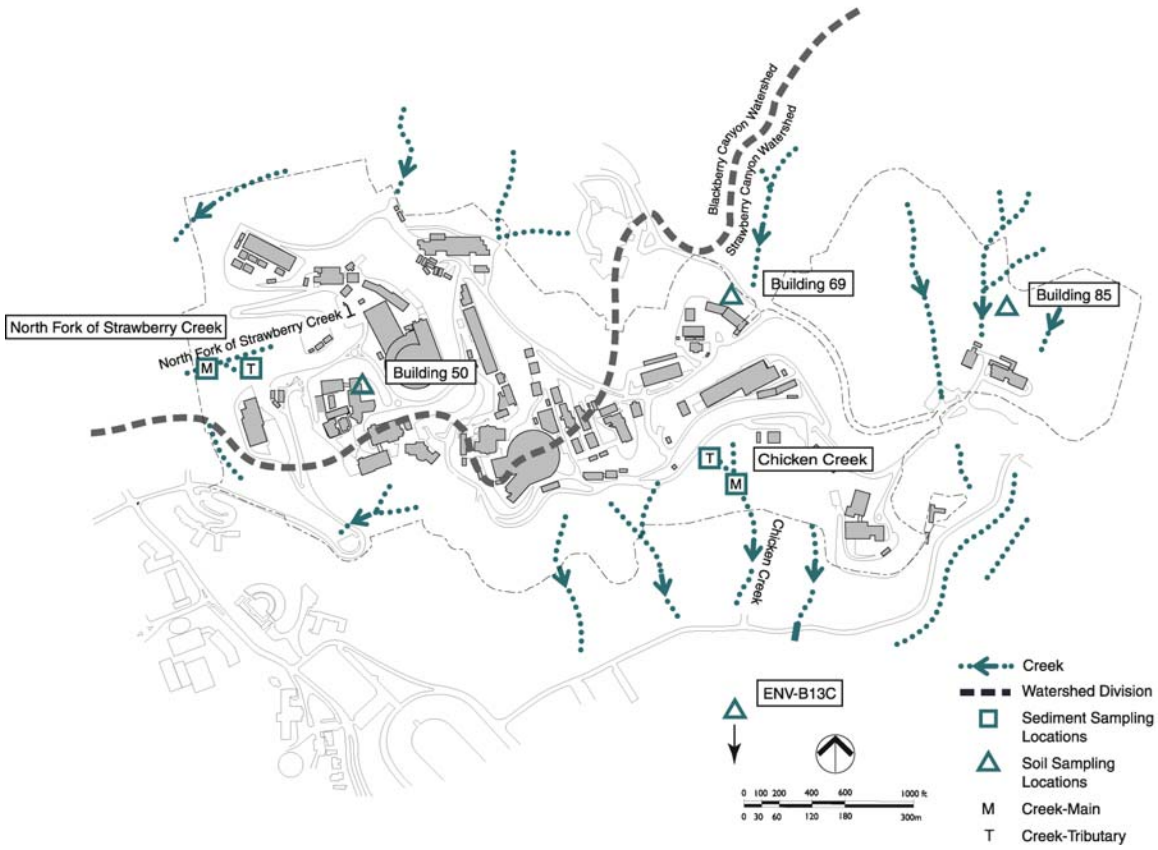


Figure 7-1 Soil and Sediment Sampling Sites

§7.3 III. SOIL AND SEDIMENT ANALYSIS RESULTS

All gross alpha, gross beta, and gamma-emitter results were similar to background levels of naturally occurring radioisotopes commonly found in soil and sediment. Tritium levels measured were comparable to results reported for these locations in previous years. In 2000, only one of the eight samples contained detectable levels of tritium. The maximum tritium level in soil was 0.011 Bq/g (0.30 pCi/g) of soil near Building 69. None of the sediment samples contained detectable levels of tritium. Table 7-1 summarizes the soil and sediment analysis results for tritium.

Berkeley Lab is currently conducting a corrective action program under the Resource Conservation and Recovery Act of 1976 (RCRA) to investigate soil and groundwater tritium contamination near the National Tritium Labeling Facility. For a summary of the RCRA investigation, see §3.18. For groundwater monitoring results, see §6.11.

Most of the results for metals analyses were within normal levels for soil and sediment, and all were well below regulatory levels.[3] Soil concentrations of some metals were slightly higher than normal background levels at the Building 50 sampling location (copper, lead, and zinc), and at the ENV-B13C sampling location (lead and zinc). In addition, sediment concentrations of copper and zinc were also slightly elevated

Table 7-1 Tritium Results in Soil and Sediment Samples[a]

Sampling location	Matrix	Tritium (Bq/g)[b]
Building 50	Soil	<0.007[c]
Building 69	Soil	0.0110
Building 85	Soil	<0.007[c]
ENV-B13C	Soil	<0.007[c]
Chicken Creek—Main	Sediment	<0.007[c]
Chicken Creek—Tributary	Sediment	0.007[c]
North Fork Strawberry Creek—Main	Sediment	0.007[c]
North Fork Strawberry Creek—Tributary	Sediment	<0.007[c]

[a] One sample per location
[b] 1 Bq = 27 pCi
[c] Result below minimum detectable amount

at the Chicken Creek Tributary sampling location. These levels may be caused by the proximity of galvanized iron (containing zinc) and pressurized wood fencing (containing copper sulfate). These locations will continue to be routinely monitored.

PCB results for sediment samples were near or below practical quantification limits. Measurements for pH were within the normal range for soils and sediments. The maximum level of oil and grease (750 mg/kg) was measured at the Chicken Creek Main location. Oil and grease contamination is commonly associated with motorized vehicles on roads and parking lots. This location will be sampled in future years to monitor any changes.

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

Table 7-2 Metals and Oil/Grease Results in Soil and Sediment Samples[a,d]

	Sample Location								
	Soil				Sediment				
Analyte	*B50 mg/kg*	*B69 mg/kg*	*B85 mg/kg*	*ENV-B13C mg/kg*	*Chicken Creek–Main mg/kg*	*Chicken Creek–Tributary mg/kg*	*N. Fork Strawberry Creek–Main mg/kg*	*N. Fork Strawberry Creek–Tributary mg/kg*	*Regulatory criteria (TTLC[b]) mg/kg*
Antimony	<0.5[c]	<0.5[c]	<0.5[c]	1	<0.5[c]	0.6	0.6	<0.5[c]	500
Arsenic	6.9	2	2	5.3	3	<2[c]	4	4	500
Barium	220	110	140	140	140	120	83	87	10,000
Chromium	44	96	100	33	49	67	29	29	2,500
Cobalt	12	21	22	<10[c]	<10[c]	<20[c]	<10[c]	<10[c]	8,000
Copper	180	24	35	26	21	110	29	14	2,500
Lead	130	<20[c]	23	170	<20[c]	<50[c]	23	<20[c]	1,000
Mercury	0.062	<0.05[c]	<0.05[c]	<0.05[c]	<0.05[c]	0.14	0.19	0.46	20
Nickel	49	59	59	31	38	81	24	23	2,000
Vanadium	59	93	120	42	30	47	37	43	2,400
Zinc	190	67	68	400	87	300	200	170	5,000
Oil & grease	—	—	—	—	750	60	41	93	—

[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 beryllium, cadmium, molybdenum, selenium, silver, and thallium were all below practical quantification limits and are not reported in Table 7-2. These results, along with other non-TTLC metals (aluminum, boron, manganese, and iron), are included in Volume II.

8

Vegetation and Foodstuffs

I. BACKGROUND **§8.1**

II. TREE SAMPLING **§8.2**

Figure 8-1: Vegetation Sampling Areas

III. RESULTS **§8.3**

§8.1 I. 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.

Department of Energy (DOE) guidance indicates that when the annual effective dose equivalent for the consumption of vegetation and foodstuffs is between 0.001 mSv (0.1 mrem) and 0.01 mSv (1 mrem), only a minimal vegetation and foodstuff surveillance program is required.[1] 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 an overestimate 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 (TFWT) or organically bound tritium (OBT).

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 II. TREE SAMPLING

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] In the future, Berkeley Lab is considering thinning nonnative tree stands around Buildings 75, 76, and 77 (Figure 8-1).

Environmental tritium levels have been determined to be above regional background levels near the National Tritium Labeling Facility (NTLF) and decrease with distance from the facility stack.[4] At about 200 meters from the NTLF stack, TFWT and OBT levels in vegetation are nearly indistinguishable from regional background levels.

The national standard, Surface and Volume Radioactivity Standards for Clearance (ANSI/HPS N13.12-1999), recommends that material with tritium levels less than 111 Bq/g (3,000 pCi/g) can be released without restrictions.[5] Until DOE authorizes specific release limits for vegetation on the Berkeley Lab site, however, the Laboratory has decided not to release vegetation with detectable tritium concentrations. In 2000, Berkeley Lab submitted an application for the authorization of release limits for tritium in vegetation to the Department of Energy.

In 2000, Berkeley Lab marked and sampled several trees near Building 77 that were being considered for removal. Trees at this distance from the NTLF were expected to have very low levels of tritium. Eucalyptus and pine trees near Building 77 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 TFWT and OBT.

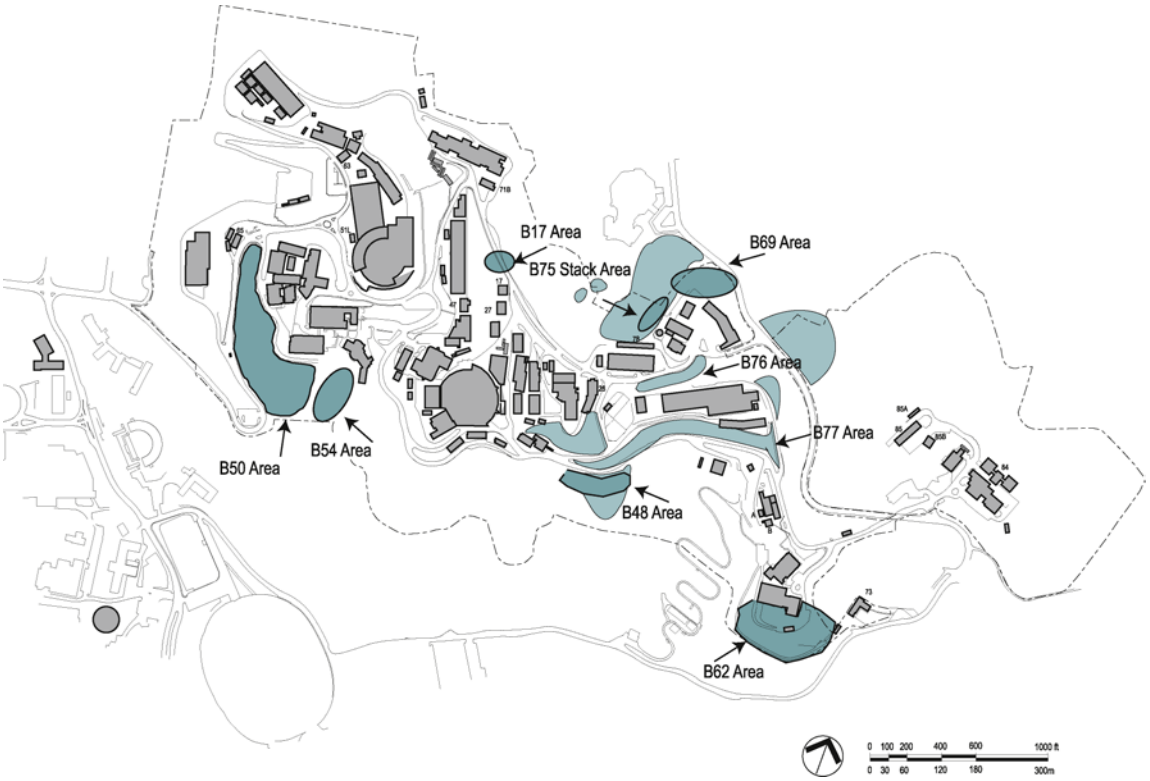


Figure 8-1 Vegetation Sampling Areas

§8.3 III. RESULTS

As expected, the tritium results from the vegetation samples were very low. All except one sample were below the analytical detection limits: nominal minimum detectable activities for TFWT were 0.019 Bq/g (0.5 pCi/g) and for OBT were 0.19 Bq/g (5 pCi/g). All trees in the areas where results were below analytical detection limits were taken down and chipped or removed from Berkeley Lab property.

One TFWT sample result was greater than the analytical detection limit: 0.04 Bq/g (1.08 pCi/g). This sample was taken from a tree near the deck south of Building 77, which had been sampled previously in 1998 and was found to have detectable tritium levels. Trees in this area were not removed.

The results from the sampling and analyses conducted in 2000 confirm what has been previously measured and reported: tritium concentrations in vegetation decrease with distance from the stack.

9

Radiological Dose Assessment

I. BACKGROUND **§9.1**
II. PENETRATING RADIATION MONITORING RESULTS **§9.2**
A. Accelerator-Produced Penetrating Radiation **§9.3**
Figure 9-1: Environmental Penetrating Radiation Monitoring Stations
Table 9-1: Annual Penetrating Radiation Dose at Site Perimeter Resulting from Accelerators
B. Irradiator-Produced Penetrating Radiation **§9.4**
III. DISPERSIBLE AIRBORNE RADIONUCLIDE RESULTS **§9.5**
Table 9-2: Summary of Dose Assessment at Location of Maximally Exposed Individual (MEI) from Airborne Emissions
IV. TOTAL DOSE TO THE PUBLIC **§9.6**
Table 9-3: Summary of Radiological Dose Impacts
Figure 9-2: Comparison of Radiological Dose Impacts
V. DOSE TO ANIMALS AND PLANTS **§9.7**

§9.1 I. 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 given separately before being evaluated cumulatively to summarize the overall impact of the Laboratory's radiological activities on members of the public. Finally, efforts to assess the radiological impact of Berkeley Lab's operations on local plants and animals are 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 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 quantitative review is performed on any activity with a potential for a public dose greater than 1 mrem to an individual or 10 person-rem to a population. Activities with potential for lower doses are reviewed qualitatively through the NESHAPs assessment-tiered strategy, discussed in Section 4.2.

§9.2 II. 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, 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.

§9.3 A. 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 located around the site's perimeter that track instantaneous gamma and neutron radiation impacts. Figure 9-1 shows the location of these stations (i.e., ENV-B13A, ENV-B13C, and ENV-B13H). 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 this 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 shows the locations of TLD sites. Based on a review of historical data, Berkeley Lab reduced the number of TLDs from 27 to 11 in

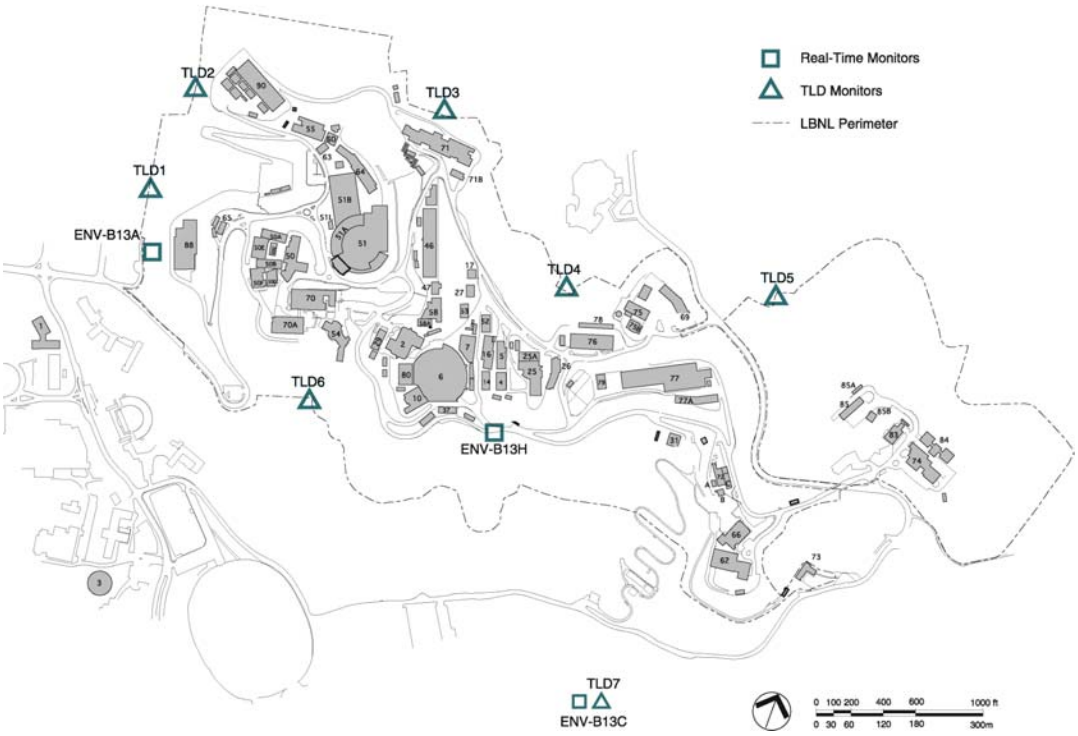


Figure 9-1 Environmental Penetrating Radiation Monitoring Stations

1999. Four TLDs located at off-site facilities (Building 903 Warehouse and Building 934) were discontinued in 2000 because the facilities no longer contained radioactive material. Currently, seven of these TLDs are located near the site boundary.

TLDs are used to measure only gamma radiation, and they cannot exclude background radiation. In addition, results from TLDs provide an average dose over time that must be determined by analytical technique rather than real-time instrumentation.

The objectives of the TLD measurement are to record the gross penetrating radiation exposures (from background and Berkeley Lab operations) and to ensure that public radiation exposure is kept well below allowable regulatory limits. The

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)	< 0.001	0.002	0.003
ENV-B13C (Panoramic)	< 0.001	< 0.001	< 0.002
ENV-B13H (ALS)	< 0.001	< 0.001	< 0.002

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

average gamma radiation dose recorded by these TLDs for 2000 is about 0.66 mSv (66 mrem). Because the measured gamma radiation value is near the typical background dose for natural gamma radiation in California (0.72 mSv [72 mrem]),[1] 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.[2] Although no regulatory standard exists for population dose values, Berkeley Lab follows the industry convention of using United States Census[3] data, extending outward to a distance of 80 kilometers (50 miles) from a facility, in creating 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 2000 was estimated at 2×10^{-3} person-Sv (2×10^{-1} person-rem).

During preparation of this report, an error was discovered in the collective doses reported for 1998 and 1999. In those years, the predicted population doses from gamma and neutron radiation were reported incorrectly because of an error in converting from millirem to microrem. This error was not made previous to 1998. For 1998, the dose was reported as 4.34×10^{-4} person Sv (4.34×10^{-2} person-rem); the correct dose is 4.34×10^{-3} person Sv ($4.34 \text{ x } 10^{-1}$ person-rem). For 1999, the dose was reported as 2.17×10^{-4} person Sv (2.17×10^{-2} person-rem); the correct dose is 2.17×10^{-3} person Sv (2.17×10^{-1} person-rem). The impact of these dose increases is negligible when compared to doses from background radiation sources (see §9.6).

§9.4 B. Irradiator-Produced Penetrating Radiation

Used for radiobiological and radiophysics research, a single gamma irradiator with a 1,000-curie cobalt-60 source is housed at Berkeley Lab in a massive, interlocked and reinforced-concrete-covered structure built as part of Building 74. Routine surveys performed when the irradiator was in operation confirmed that no area exceeded 0.001 mSv/hr (0.1 mrem/hr) at 1 meter from the outside walls or ceiling of the labyrinth. The Building 74 irradiator is about 80 meters (260 feet) from the site's perimeter fence and more than 700 meters (2,300 feet) 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 and less than 2×10^{-5} mSv/yr (0.002 mrem/yr) at the nearest residence.

Berkeley Lab also uses other smaller, well-shielded gamma irradiators, which pose considerably less environmental impact than the Building 74 irradiator. This class of smaller irradiators does not increase the dose level for the maximally exposed individual (MEI).

§9.5 III. 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 National Emission Standards for Hazardous Air Pollutants (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.[4] Berkeley Lab satisfies this requirement with the use of CAP88-PC.[5]

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 13 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. Details on these groupings and modeling runs are included in the Laboratory's annual NESHAPs report. The location of the MEI from airborne emissions was determined from the complete set of modeling runs. The source groupings listed in Table 9-2 give the orientation of their release points relative to the location of the MEI (distance and direction). The combined dose to the MEI from airborne radionuclides for 2000 was less than 0.001 mSv (0.1 mrem).

As with penetrating radiation, the dose from airborne radionuclides to the surrounding population is estimated for a region that extends out 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

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

Building	Building description	Distance to MEI[a] (meters)	Direction to MEI[a]	Dose at MEI (mSv/yr)[b]	Percent of MEI dose
75	National Tritium Labeling Facility	110	NW	5.7×10^{-4}	64.4%
55/56	Research Medicine/BIF	490	E	2.0×10^{-4}	22.6%
1	Donner Laboratory (UC Berkeley)	980	ENE	1.0×10^{-4}	11.3%
71/72	HILAC/NCEM	220	E	4.5×10^{-6}	0.5%
85	New Hazardous Waste Handling Facility	550	WNW	3.8×10^{-6}	0.4%
88	88-Inch Cyclotron	670	ENE	3.3×10^{-6}	0.4%
70/70A	Nuclear/Life Sciences	510	NE	2.1×10^{-6}	0.2%
75A/75	Old Hazardous Waste Handling Facility	150	NW	5.0×10^{-7}	<0.1%
3	Calvin Lab (UC Berkeley)	1,070	NE	3.8×10^{-9}	<0.1%
74/83/84	Buildings 74/83/84 Research Medicine	730	WNW	3.1×10^{-7}	<0.1%
2/6	Advanced Material Laboratory/ALS	370	NE	2.6×10^{-7}	<0.1%
26/76	RAML/Counting Laboratory	240	N	1.2×10^{-7}	<0.1%
75C	EHS Calibration Sources	150	NW	0.0	0%
			Total	**8.9×10^{-4}**	**100%**

[a] Distances and directions are relative to the cumulative MEI from all contributing sources.
[b] 1 mSv = 100 mrem

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 0.006 person-Sv (0.6 person-rem).

§9.6 IV. 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. Furthermore, this total impact is an overly conservative estimate. It is the sum of the greatest possible dose from direct radiation (received by a person who lives near the 88-Inch Accelerator) and the greatest possible dose from airborne radionuclides (received by a person who works at the Lawrence Hall of Science). As presented in Table 9-3 and Figure 9-2, the maximum effective dose equivalent

Table 9-3 Summary of Radiological Dose Impacts

	Maximally exposed individual (direct radiation)	Maximally exposed individual (airborne nuclides)	Maximally exposed individual (direct and airborne)
Annual EDE[a]	0.002 mSv/yr[b]	0.001 mSv/yr	0.003 mSv/yr
MEI location	Residence (110 meters west of Bldg. 88)	Workplace (110 meters northwest of Bldg. 75 at Lawrence Hall of Science)	Residence (110 meters west of Bldg. 88) and Workplace (110 meters northwest of Bldg. 75 at Lawrence Hall of Science)
Standard of comparison	1 mSv/yr (DOE)	0.10 mSv/yr (US/EPA)	1 mSv/yr (DOE)
Impact as % of standard	0.2%	1%	0.3%
Annual background	1 mSv/yr	1.6 mSv/yr	2.6 mSv/yr
Impact as % of background	0.2%	0.1%	0.1%

[a] EDE = Effective Dose Equivalent

[b] 1 mSv = 100 mrem

to an individual from all Berkeley Lab operations in 2000 is about 0.003 mSv (0.3 mrem) per year. This value is approximately 0.1% of the nominal background radiation[6] in the Bay Area and less than 0.3% of the DOE annual limits.[7]

The estimated dose to the population within 80 kilometers of Berkeley Lab from these same activities was 0.008 person-Sv (0.8 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 Laboratory's population dose is 0.00006% of the background level.

Because the 1998 and 1999 predicted population doses from gamma and neutron radiation were reported incorrectly (because of an error in converting millirem to microrem; see §9.3), the total combined population dose was also incorrect. This error was not made in previous years. For 1998, the total combined population dose was reported as 2.56×10^{-2} person Sv (2.56 person-rem); the correct dose is 2.95×10^{-2} person Sv (2.95 person-rem). For 1999, the dose was reported as 7.4×10^{-3} person Sv (7.4×10^{-1} person-rem); the correct dose is 9.2×10^{-3} person Sv (9.2×10^{-1} person-rem). The impact of these dose increases is negligible when compared to the dose from natural background sources: 0.0002% of background in 1998 and 0.00007% of background in 1999.

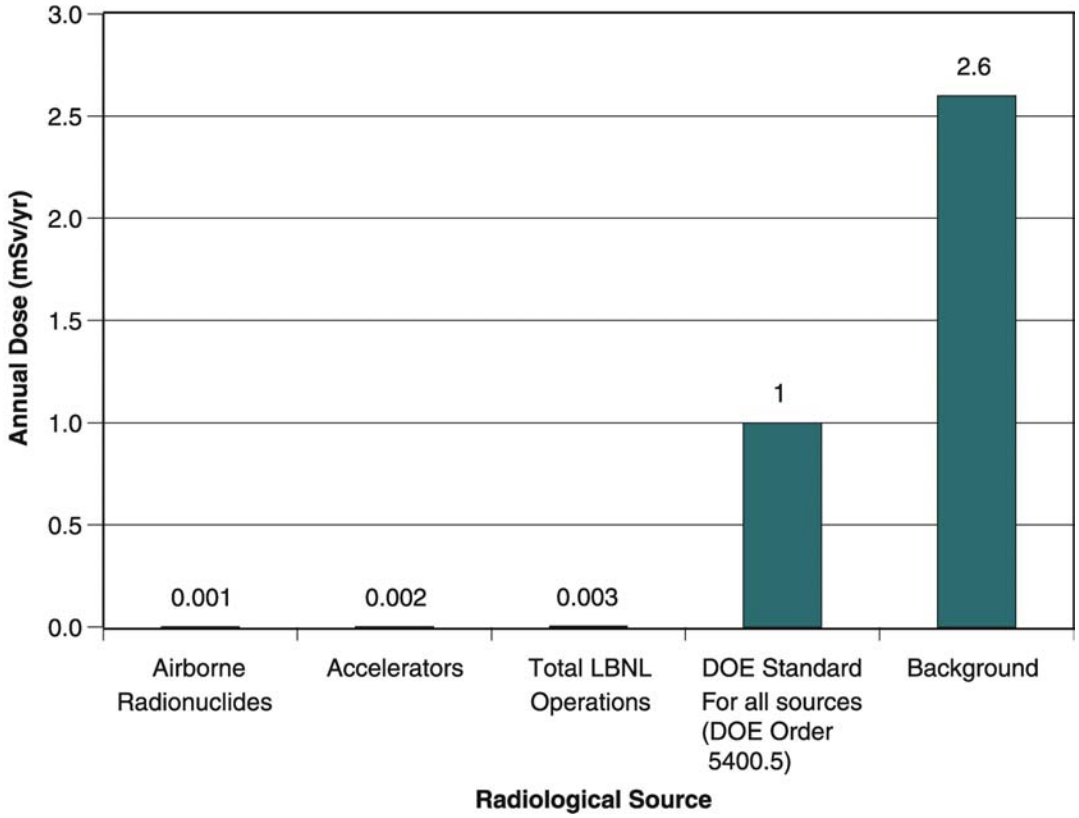


Figure 9-2 Comparison of Radiological Dose Impacts

§9.7 IV. 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. The Department of Energy requires that aquatic organisms be protected by limiting their radiation doses to 1 rad/day (0.01 Gy/day).[8] In addition, international recommendations suggest that doses to terrestrial animals should be limited to less than 0.1 rad/day (0.001 Gy/day) and doses to terrestrial plants should not exceed 1 rad/day (0.01 Gy/day).[7]

To assist DOE 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.[8] 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.

10
Quality Assurance

I. OVERVIEW **§10.1**

II. QUALITY CONTROL RESULTS FOR MONITORING TRITIUM IN AMBIENT AIR

A. Water Vapor Sampling Results **§10.2**

Figure 10-1: Comparison of Water Vapor Collected on Silica Gel vs. Available Water Vapor in Air

B. Ambient Air Sample and Split Results **§10.3**

Figure 10-2: Comparison of Sample and Split Results for Tritiated Water in Ambient Air

§10.1 I. 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 DOE[3] and 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) laboratories are utilized 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.

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.

Off-site laboratories are audited annually by DOE's Environmental Management Consolidated Audit Program (EMCAP). A DOE representative who has 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 locations. Any deficiencies found in the audit are followed by corrective actions.

A joint performance-evaluation committee, composed of members from Berkeley Lab (LBNL) and Lawrence Livermore National Laboratory (LLNL), evaluates off-site laboratory performance using performance evaluation samples. Both radiological and nonradiological performance evaluation samples are sent to the off-site laboratories for analysis. The joint LBNL/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 §10.2. As discussed in §3.9, 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, the plan was reviewed by DOE, US/EPA, and the Environmental Sampling Project Task Force. In early 2001, DOE approved the plan and sampling began. Sampling is scheduled to be completed in 2002.

II. QUALITY CONTROL RESULTS FOR MONITORING TRITIUM IN AMBIENT AIR

§10.2 A. Water Vapor Sampling Results

Berkeley Lab collects atmospheric water vapor on silica gel columns to measure the concentration of tritiated water in air. To verify the sampling efficiency for the collection of water vapor from ambient air, Berkeley Lab compares the mass of water vapor extracted from an individual field sample with the mass of water vapor available in the atmosphere for the sampling period. The amount of water collected on each silica gel

sample was determined during laboratory analysis. The amount of water vapor in the air available for collection (absolute humidity) was calculated, based on temperature and dew-point data obtained at the on-site meteorological tower. The calculated absolute humidity (grams/cubic meter) was averaged over the monthly tritium-sampling period.

The total mass of water vapor available for collection is determined by multiplying the average absolute humidity by the total volumetric flow through the sampler. Figure 10-1 compares the mass of water vapor collected with the mass of water vapor available.

The figure shows that the mass of water vapor collected from the air is nearly equal to the mass of water vapor available in the atmosphere. The observed small differences between those two values can be accounted for by the uncertainties associated with sampling instrumentation, micrometeorological spatial variations, and sample analysis. Furthermore, the data clearly indicate that the water vapor collection efficiency is consistently high across periods of varying weather conditions (rainfall, temperature, and humidity). The results for the year were consistent with the results reported for 1999.

§10.3 B. Ambient Air Sample and Split Results

Berkeley Lab routinely analyzes split samples from its ambient air tritium-monitoring program as a way to determine the precision and reproducibility of its monitoring results. A split analysis is performed at a different sampling site each month. In addition, in late 1997, US/EPA began analyzing split samples from two of the network's six sites: ENV-LHS at the Lawrence Hall of Science and ENV-13D at about 450 meters northwest of the National Tritium Labeling Facility hillside stack. The samples shared with US/EPA are analyzed at its National Air and Radiation Environmental Laboratory (NAREL) facility and provide an interlaboratory comparison of results. In 2000, Berkeley Lab added Lawrence Livermore National Laboratory's Chemistry and Material Science's Environmental Services (CES) as another quality assurance resource for its program.

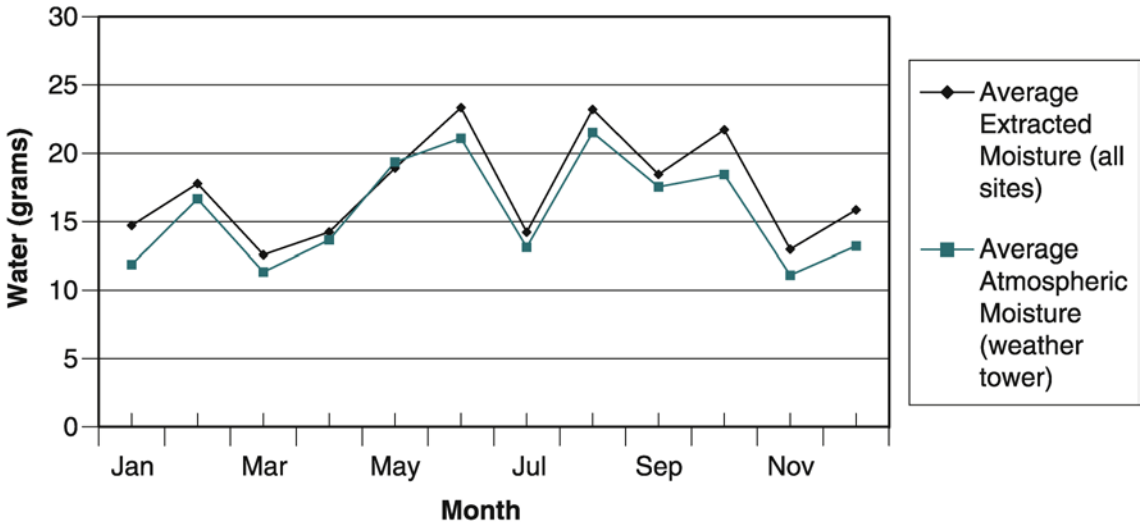


Figure 10-1 Comparison of Water Vapor Collected on Silica Gel vs. Available Water Vapor in Air

Berkeley Lab's split samples, which are sent to its contract analytical laboratory, provide an intralaboratory comparison with the sample result. Figure 10-2 shows a plot of the sample- and split-result pairs for both inter- and intralaboratory comparisons.

For 2000, there were 36 interlaboratory and 12 intralaboratory result pairs. NAREL analyzed 24 of the interlaboratory split samples, while CES analyzed the remaining 12. The average difference between all 48 sample- and split-result pairs was 0.3%. The average difference for the interlaboratory result pairs was slightly higher at 1.7%. In both situations, the results from Berkeley Lab's contract analytical laboratory were the higher of the two. These comparisons are nearly identical to the results from the previous year.

Figure 10-2 shows how the sample- and split-result pairs lie relative to a line that represents perfect agreement between sample and split.

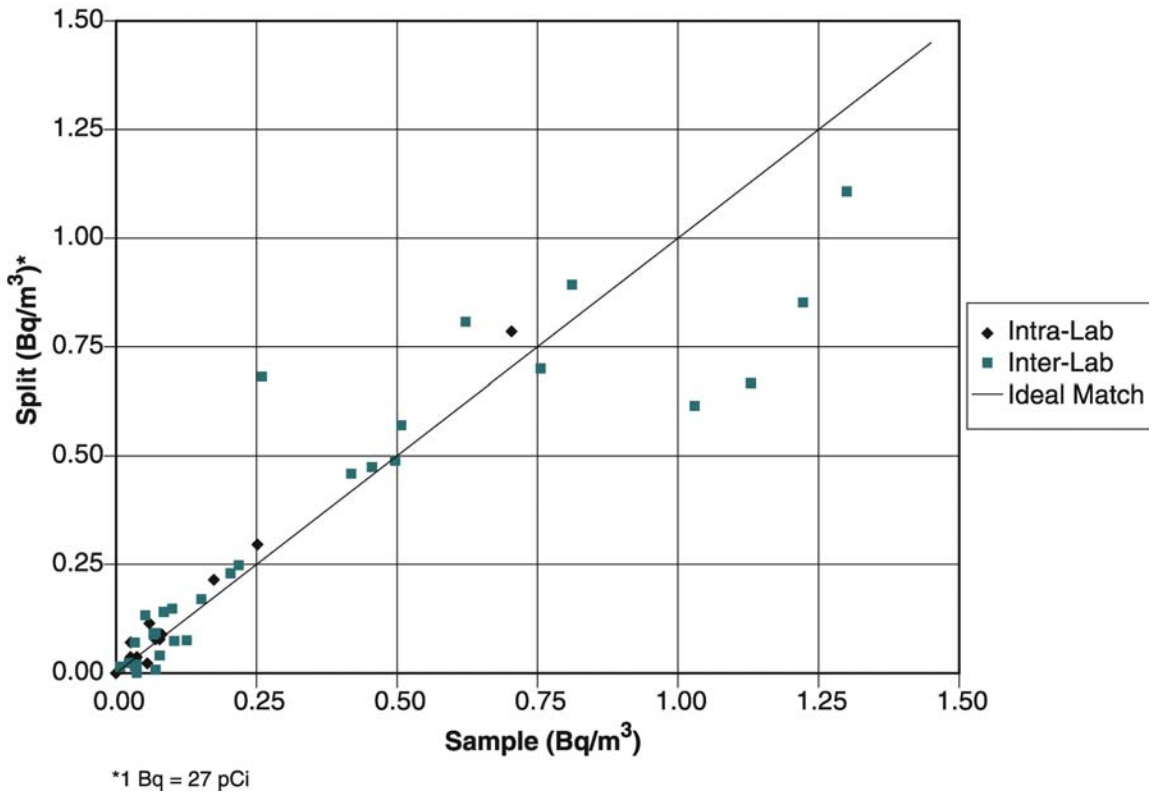


Figure 10-2 Comparison of Sample and Split Results for Tritiated Water in Ambient Air

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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 ground water 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 centimeters 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 minimus

A level of rise that is considered to be insignificant and not needing to be 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 and 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.

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 × 1/2); after three half-lives, one-eighth of the original activity remains (1/2 × 1/2 × 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, 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*
deka	10 = 10^{1}	da*
deci	0.1 = 10^{-1}	d*
centi	0.01 = 10^{-2}	c*
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

*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

Acronyms and Abbreviations

AEDE	Annual Effective Dose Equivalent
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 & Material Sciences, Environmental Services/LBNL
CFR	Code of Federal Regulations
Ci	Curie
CMTW	Committee to Minimize Toxic Waste
CODF	Chemical Oxygen Demand, Filtered
CWA	Clean Water Act
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

EMCAP	Environmental Management Consolidated Audit Program
EPCRA	Emergency Planning and Community Right To Know Act
ERG	Environmental Radiation Group
ESG	Environmental Services Group
FTU	Fixed Treatment Unit
FY	Fiscal Year
gsf	gross square feet
gsm	gross square meters
HEPA	High Efficiency Particulate Air
HMBP	Hazardous Materials Business Plan
HPS	Health Physics Society
HWHF	Hazardous Waste Handling Facility
ISM	Integrated Safety Management
ICM	Interim Corrective Measure
kg	kilogram
L	Liter
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
m	meter
ml	milliter
MCL	Maximum Contamination Level
MDA	Minimum Detectable Amount
MEI	Maximally Exposed Individual
mg	milligram
mrem	millirem
mSv	millisievert
MTBE	Methyl Tertiary Butyl Ether
NAREL	National Air & Radiation Environmental Laboratory
ND	Nondetectable
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NPL	National Priorities List
NPDES	National Pollutant Discharge Elimination System
NTLF	National Tritium Labeling Facility

OAP	Operating and Assurance Program
OBT	Organically Bound Tritium
PCB	Polychlorinated Biphenyl
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
RFI	RCRA Facility Investigation
RMPP	Risk Management and Prevention Plan
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
TFTW	Tissue Free Tritiated Water
TFWT	Tissue-Free Water Tritium
TLD	Thermoluminescent Dosimeter
TOC	Total Organic Carbon
TOMP	Toxic Organic Management Plan
TPH	Total Petroleum Hydrocarbons
TRI	Toxic Release Inventory
TSCA	Toxic Substance 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
VOC	Volatile Organic Compound
WAA	Waste Accumulation Area
WMG	Waste Management Group
yr	year

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