Site Environmental Report for 1999

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 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 1999 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 1999.

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 Protection Group. Iraj Javandel, Ginny Lackner, Michael Ruggieri, Patrick Thorson, and Henry Tran are the primary authors of the report. Other key contributors of programmatic information include David Baskin, Robert Fox, Nancy Rothermich, and Steve Wyrick.

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Copies of the report are available from the Berkeley Lab Environmental Protection 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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§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. 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 non-radiological activities are thoroughly monitored to assess their potential impact on the environment.

Published annually, this Site Environmental Report covers activities for calendar year 1999. Volume I summarizes environmental protection performance and environmental monitoring activities. Volume II contains all original analytical data used to summarize the environmental monitoring results 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 (UC) 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 1999, Berkeley Lab managed 23 operations that were subject to 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

Nineteen inspections of Berkeley Lab's environmental programs occurred during 1999, with no reports of violations issued from these inspections by regulatory agencies. For a summary of these inspections, see Table 3-2.

§1.5 C. Incident Tracking

Berkeley Lab filed one report with DOE for a minor environmental incident in 1999 that was reportable to DOE under its occurrence-reporting program. For further discussion of this incident, see §3.17.

§1.6 D. Performance Evaluation

Each year, UC and DOE perform an assessment of Berkeley Lab's environmental program, using measures developed jointly by Berkeley Lab, UC, and DOE.³ In 1999, there were nine environmental performance measures:

1. Radiation protection of the public and the environment;
2. Tracking environmental incidents;
3. Waste reduction and recycling;

4. Integrated Safety Management program;
5. Waste management commitments;
6. Program innovation in waste management and environmental restoration;
7. Environmental restoration release site completions;
8. Cost and schedule variance for environmental restoration activities; and
9. Cost variance for waste management activities.

From both UC and DOE, Berkeley Lab received ratings of “outstanding” on performance measures 3–6 and 8 and ratings of “excellent” on performance measures 1–2, 7, and 9. 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 from 1999.

§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 dispersible radionuclides to the atmosphere.

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 1999, 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 dominant source of radiation in the Bay Area, which is naturally occurring background radiation. 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 ranks as 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

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

individual doses (i.e., ranging from a maximum of 0.003 mSv near the site boundary to a minimum of 0 mSv at an 80-kilometer distance) within the specified region. The collective population dose for 1999 was estimated at 0.0074 person-Sv (0.74 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 discussion of the estimated dose impacts to the neighboring community from both direct and dispersible radiation, see Chapter 9.

Dispersible radionuclide 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. The estimated maximum potential dose from all airborne radionuclides released from the site in 1999 was less than 0.001 mSv (0.1 mrem), with tritium accounting for about 83% of that amount. This dose is about 30% of Berkeley Lab's total maximum dose to the public for both penetrating radiation and dispersible 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 permits⁸ 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 for permit-required sample analyses 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 permit⁹ 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, lakes, and hydraugers), 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 current 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. The levels of oil and grease measured at Berkeley Lab are typical for an urban setting. 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. 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. 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 200 to 330 meters (650 to 1,000 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 108,000 and Oakland at 396,000.

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 1,900 guests each year, who use its unique scientific facilities for varying lengths of time. Approximately 750 of these guests work on-site at any one 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 186,000 gross square meters (2-million gross square feet). Eighty-four percent of this space is on the main site, 6% is on the UC Berkeley campus (i.e., Donner and Calvin laboratories), and the remaining 10% is located in various other off-site buildings. There are 80 permanent buildings and 107 trailers and temporary buildings on the main site. 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 before being 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 spring 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 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 is provided in Figure 2-7, which compares 1999 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 nonnative trees that are important to this screening effect. No rare, threatened, or endangered species of plants are present on the site. See Figure 2-8.

Berkeley Lab updated and intensified its fire management efforts after the October 1991 fire in the Berkeley/Oakland Hills to the south. The Laboratory used 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 for wildlife typical of disturbed (e.g., previously grazed) areas with a Mediterranean

Figure 2-8 Vegetation Types

climate located in mid-latitude California. Over 120 species of birds, mammals, and reptiles/amphibians—none of which is rare, threatened, or endangered—exist on the site. 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

Berkeley Lab is underlain by sedimentary and volcanic rocks between the Hayward Fault and the Wildcat Fault. 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.

Landsliding, paleotopography, interbedding, faulting, and tilting of the sedimentary and volcanic rocks underlying the site have created a complex geological structure. Three geologic formations underlie the majority of the site:

- The western and southern parts are underlain by moderately to well-consolidated upper Cretaceous marine sediments belonging to the Great Valley Group.
- 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.

- The volcanic upper Miocene Moraga Formation underlies most of the higher elevations of the Laboratory as well as much of the area around the Advanced Light Source. The Moraga Formation consists of basalt and andesite, agglomerates, and pyroclastic tuffs.

The Miocene Claremont Formation and San Pablo Group are two additional geologic formations found on-site, but they underlie only the far easternmost area. The Claremont Formation consists of chert and shale. The San Pablo Group consists of marine sandstones.

Weathered detritus from the rock formations underlying the site has accumulated as soil deposits. These deposits are generally two to several meters thick throughout the site. Because of the hilly terrain, grading and filling have been necessary to provide suitable building sites. Consequently, cuts up to tens of meters deep have been made, and fills up to tens of meters thick have been placed.

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

Hydrogeology at Berkeley Lab is complex. Year-round springs, annual surface seeps, and variable water levels in observation wells indicate discontinuous and localized aquifers. These conditions are caused by a number of factors. The various rock units underlying the site have different permeabilities. Volcanic rocks are typically fractured, readily allowing groundwater to flow, while sedimentary rocks consist of interbedded very low permeability claystones and siltstones and include moderate-permeability sandstones. Orinda Formation sandstones are discontinuous and probably exist primarily as channel fillings in the claystones and siltstones. The relationship between high-permeability volcanic rocks and low-permeability sedimentary rocks is complex because of landsliding and paleotopography.

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 how fast groundwater can move through a medium such as volcanic rock. Hydraulic conductivity in the three major geologic formations is as follows:

- Although the Great Valley Group consists primarily of low-permeability rock material, its moderately spaced open fractures allow for groundwater movement. The hydraulic conductivity ranges between approximately 10^{-5} and 10^{-7} meters per second (3.3×10^{-5} and 3.3×10^{-7} feet per second).
- The Orinda Formation has a smaller hydraulic conductivity, generally ranging between 10^{-7} to 10^{-9} meters per second (3.3×10^{-7} to 3.3×10^{-9} feet per second), because it generally consists of low-permeability siltstone, which has closed fractures due to its low strength. Because the Orinda Formation usually underlies the Moraga Formation, it forms a relatively impermeable boundary for groundwater flow.

- 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). The rocks of this formation constitute the main water-bearing unit at Berkeley Lab. Although this rock material has low permeability, groundwater flows readily through the numerous fractures, which are open because of the rock's high strength. The presence of low-permeability interbeds of fine-grained sediments, 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 complex geology at the Laboratory results in water-table depths that vary from 0 to 30 meters (98 feet) below the surface across the site.

Environmental Program Summary

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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 1999.

§3.2 II. OVERVIEW OF ENVIRONMENTAL RESPONSIBILITIES

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 1999 is shown in Figure 3-1.

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

The Environmental Protection Group (EPG) 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 1999 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 the active permits held by Berkeley Lab at the end of the year by area of environmental activity.

Table 3-1 Environmental Permits Held by Berkeley Lab at End of 1999

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD	Various activities with atmospheric emissions	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	§3.26
Underground storage tank	City of Berkeley	Underground storage tanks containing petroleum products	8	§3.20
Wastewater	EBMUD	Site-wide and operation-specific wastewater discharges to sanitary sewer	4	§3.25

§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 1999. The list includes self-monitoring inspections conducted by Berkeley Lab, as required by East Bay Municipal Utility District (EBMUD) wastewater discharge permits, because these activities expose the Laboratory to potential regulatory violations. Berkeley Lab received no violations from these 19 inspections. See §3.17.

§3.5 C. Summary of Reportable Environmental Incidents

Berkeley Lab filed one report with DOE for a minor environmental incident in 1999 that was reportable under the DOE occurrence-reporting program.¹ No injuries, accidents, or damage resulted from this incident. Table 3-3 identifies this incident and the section in this report that describes the incident.

IV. PROGRAM REVIEW

§3.6 A. Air Quality (Clean Air Act)

The Clean Air Act² 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”).

Table 3-2 Environmental Audits, Inspections, and Appraisals in 1999

Organization	Inspection title	Start date	Length (days)	Violations
EBMUD	Wastewater monitoring inspections at Hearst and Strawberry Outfalls	January 12	3	0
		March 11	1	0
		June 1	1	0
	Wastewater monitoring inspections at B77 Treatment Unit	March 4	1	0
		April 28	1	0
		July 15	1	0
	Inspection of motor pool at B76, FTUs at B77 and B25, and Hazardous Waste Handling Facility	November 10	1	0
	Wastewater monitoring inspections at B25 Treatment Unit	April 22	1	0
	EBMUD self-monitoring inspections at Hearst and Strawberry Outfalls	February 8	1	0
		April 5	1	0
		July 12	1	0
		November 9	1	0
LBNL	EBMUD self-monitoring inspections at B77 Treatment Unit	January 12	1	0
		April 15	1	0
		July 12	1	0
		November 1	1	0
	EBMUD self-monitoring inspections at B25 Treatment Unit	April 15	1	0
		December 8	1	0
	Annual inspection of permitted air emission sources	November 3	1	0
BAAQMD	Annual inspection of permitted air emission sources	November 3	1	0

The State of California's own air pollution control program³ 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 Facilities⁴)

Table 3-3 Summary of Environmental Incidents During 1999

Incident date	Report number	Description	Section for more information
May 6	OAK-LBL-EHS-1999-0003	Mischaracterization of waste oil for recycling	§3.17

as well as DOE Orders 5400.1⁵ 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-0173T⁷ guidance. The assessment takes a conservative or worst-case approach by assuming that no portion of the release is 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 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 Protection 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 1999, Berkeley Lab had eight activities holding BAAQMD operating permits.⁸ The annual inspection of these sources by BAAQMD took place on November 3, and there were no findings from this visit. Operating permits are renewed annually, at which time BAAQMD also requests information required by the state's Air Toxics "Hot Spots" Information and Assessment Act of 1987.⁹ For a list of active operating permits, see Table 3-4.

Table 3-4 BAAQMD Permitted Air Emission Sources Active at End of 1999

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

§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, 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, EPA considered data submitted by CMTW and additional data provided by DOE. EPA determined, based on CERCLA screening criteria, that the site is eligible for the NPL. EPA also determined, however, that existing data indicate that low levels of tritium at Berkeley Lab are well below 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, 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 sediment, and surface water. Sampling is scheduled to begin in 2000 and to be completed the following year.

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. In 1999, two incidents developed:

- *Quicksilver site in Brisbane, California.* Quicksilver Products, Inc., operated as a mercury recycler at this location from 1988 through 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 possible allocation of the cleanup costs with DTSC.
- *Pilot Petroleum/Gibson Environmental Facility in Redwood City, California.* This facility, which treated and disposed of oily water wastes, was operated from 1989 through 1995 on property leased from the Port of Redwood City. After the operators of the facility declared bankruptcy in 1995, DTSC notified the Port that, as owner of the site, it must assume responsibility for closing the facility. The Port brought suit, seeking recovery under CERCLA of its costs to investigate and

remedy contamination at the site. Berkeley Lab was not named as a defendant in the suit, but the Laboratory answered interrogatories and requests for admission and document production.

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 1999 exceeded the TRI criterion of 4,536 kilograms (10,000 pounds) for a listed substance and that, therefore, preparation of a Form R was not necessary. Table 3-5 shows the highest usage levels of the chemicals from the Laboratory's assessment over the last several years, including several substances either recently removed from the TRI list by EPA or now listed by EPA for reasons of use or production not found at Berkeley Lab.

§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 1999 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

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

Substance	1996 (kg)	1997 (kg)	1998 (kg)	1999 (kg)
Acetone	285 ^a	— ^a	— ^a	— ^a
Chlorofluorocarbons	120	185 ^b	143	97
Hydrochloric acid	468	— ^c	— ^c	— ^c
Isopropyl alcohol	294	493 ^c	— ^c	— ^c
Methanol	158	260	266	1674
Nitric acid	1,030	727	707	1563
Sulfuric acid	1,161 ^a	— ^c	— ^c	— ^c
1,1,1-Trichloroethane	1,023	1,521	69	97

^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.

40 CFR Part 355. Berkeley Lab does not have any operations that contain hazardous substances above the threshold quantities, and therefore no RMPP is 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 Act¹⁷ 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 concentration 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 low amounts of PCBs, the Laboratory is not required to prepare an annual PCB report for EPA.

§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 waste²⁰ laws. The state program includes both permitting and enforcement elements. The state's permitting program for hazardous

Figure 3-2 Trends in Eliminating Regulated PCBs

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 a RCRA Part B permit. The current permit for the HWHF²¹ was approved by DTSC on May 4, 1993, and is valid for ten years. The permit allows for storage and simple treatment of certain hazardous and mixed wastes at the HWHF. Simple treatment includes 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 are stored until the radioactivity is undetectable and then discharged in conformance with the EBMUD sanitary sewer permit. In 1999, approximately 110 gallons of this waste were discharged to the sanitary sewer.

A permit modification request filed by Berkeley Lab in January 1996 remains under consideration by DTSC. Described in earlier site environmental reports, this request asked for certain changes in waste streams, storage designations, treatment methods, training, and sampling. A May 1996 consent order by DTSC allows the Laboratory to continue HWHF operations under a revised set of permit conditions until DTSC makes a determination. 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 modifications did not become effective in June, because an appeal was submitted and is being evaluated by DTSC.

Berkeley Lab has an additional hazardous waste permit²² to operate five fixed treatment units (FTUs). The type and location of each unit are listed in Table 3-6. These treatment units operate independently of the HWHF. Three of these FTUs are authorized to operate under the "conditional authorization" tier, while the remaining two are authorized to operate under the "permit-by-rule" tier. The level of treatment determines

Table 3-6 Fixed Treatment Units Subject to State's Tiered Permitting

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

which tier applies. DTSC requests renewal of this permit each year. In March 1999, the Laboratory submitted the 1999 FTU renewal package to DTSC and the City of Berkeley. Beginning in 2000, the City of Berkeley will oversee all future tiered permitting renewals.

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

- The Biennial Hazardous Waste Report for 1999,²³ 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 the previously described May 1996 DTSC consent order to summarize all efforts to use commercial mixed waste disposal facilities.

In late 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. See Table 3-3. In May, Berkeley Lab was notified by an off-site disposal facility that PCB contamination was found in oil destined for recycling. The contamination was verified by a third party contractor using a split sample and by a Berkeley Lab contract laboratory. The PCB-contaminated oil was diverted from recycling to incineration at a TSCA-permitted treatment facility. As a result of this incident, the WMG has incorporated routine analytical testing of all oil destined for recycling.

§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 to 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,²⁶ which details environmental investigations necessary to characterize the site, was submitted to DTSC in October 1992. Now into the final phase of the RFI, Berkeley Lab submitted seven RFI Work Plan Addenda²⁷ in 1999 before installing new groundwater monitoring wells, investigating areas of soil contamination, or evaluating potential source areas for groundwater contamination. In addition to these addenda, the Laboratory submitted two work plans²⁸ in 1999 for the implementation of Interim Corrective Measures (ICMs), including removal of contaminated soil.

In February 1997, Berkeley Lab submitted a Draft Final RCRA Facility Investigation Report²⁹ to the regulatory agencies overseeing the investigation (i.e., DTSC, the Regional Water Quality Control Board (RWQCB), and the City of Berkeley). The report documents RFI activities through September 1996. A report addendum that will include subsequent RFI activities (through completion of the RFI) is planned for submittal to these regulatory agencies in mid-2000.

Finally, Berkeley Lab's environmental restoration program submitted four quarterly progress reports³⁰ to DTSC in 1999 in accordance with RCRA Part B Permit requirements. These reports detail project activities conducted during each three-month period and activities planned for upcoming periods.

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), "sharps" waste (e.g., needles), and other waste 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 Act³¹ 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 four 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. The majority of the waste is treated via steam sterilization before disposal at a landfill.

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. The Laboratory completed its annual registration renewal in November.

§3.20 4. Underground Storage Tanks

In the early 1980s, California addressed the problem of groundwater contamination from leaking underground storage tanks (USTs) through a rigorous regulatory and remediation program.³² 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.³³ The City of Berkeley is the local administering agency for UST regulations that apply to Berkeley Lab.

At the end of 1999, eight permitted USTs remained at the Laboratory. See Table 3-7. 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.

E. Pollution Prevention and Waste Minimization

§3.21 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) replaces Executive Order 12873 (Federal Acquisition, Recycling, and Waste Prevention). Like its precursor, Executive Order

Table 3-7 **Underground Storage Tank Operating Permits from 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

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; 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.

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 reasonable cost and are compatible with the Laboratory's operating needs. Since 1999, Berkeley Lab has required that all toner cartridges be purchased as remanufactured toner cartridges.

§3.22 2. Hazardous Waste Source Reduction and Management Review Act

The California State Legislature passed the Hazardous Waste Source Reduction and Management Review Act³⁵ 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.

Berkeley Lab prepares a two-part report for compliance with this Act: the Source Reduction Evaluation Review Plan and Plan Summary³⁶ and the Hazardous Waste Management Report Summary.³⁷

§3.23 3. Pollution Prevention Act of 1990

The Pollution Prevention Act of 1990³⁸ 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

§3.24 1. Clean Water Act

The Clean Water Act (CWA)³⁹ 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 Act⁴⁰ 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.

§3.25 a. Wastewater

The Laboratory has four wastewater discharge permits⁴¹ 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 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 seven separate occasions throughout the year. Table 3-2 (see §3.4) contains these dates. 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).⁴² 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)⁴³ 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 combined⁴⁴ and will be combined for Building 25 to reduce duplication of information.

§3.26 b. Stormwater

Berkeley Lab's stormwater releases are permitted under the California-wide General Permit for Stormwater Discharges Associated With Industrial Activity.⁴⁵ 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 Plan⁴⁶ and a Stormwater Monitoring Program.⁴⁷ 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.⁴⁸ No regulatory concerns were raised by either agency regarding the annual report. For detailed discussion of stormwater results for 1999, 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 1999.

§3.27 c. Aboveground Storage Tanks

Aboveground storage tanks (ASTs) also fall under the authority of the Clean Water Act.⁴⁹ The Clean Water Act and the state's Aboveground Petroleum Storage Act⁵⁰ outline the regulatory requirements for this type of tank. 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 contain petroleum and nonpetroleum drums. Both types of drums are inspected during routine petroleum drum inspections.

ASTs are provided with secondary containment or spill kits to capture any potential spills. No ASTs were identified during the year that needed new or upgraded secondary containment. Figure 3-3 shows the locations of the ASTs that contain petroleum hydrocarbon products excluding drum storage areas.

§3.28 2. Safe Drinking Water Act

The Safe Drinking Water Act⁵¹ 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.

Figure 3-3 Aboveground Storage Tank Locations

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 3-8 summarizes the UCOP and DOE ratings for each of the environmental performance measures for FY 1999.

Table 3-8 Environmental Performance Measure Ratings for 1999

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

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

Table 4-4: Summary of Radiological Air Emissions Released

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: Gross Alpha and Beta Sampling Results from
Ambient Air Monitoring Network

§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 authorize monitoring requirements for radiological air emissions, while DOE Order 5400.1 includes additional requirements for 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 Plan⁴ 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. Emission monitoring measures airborne contaminants in building exhaust systems (e.g., stacks). Ambient air surveillance measures air 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 in solid form as particulate matter are the least common form.

Table 4-1 contains the names and decay characteristics of the most significant radionuclides used at Berkeley Lab. Radioactive gases produced by accelerator operations are mainly short-lived radionuclides, such as carbon-11, nitrogen-13, oxygen-15, and argon-41.

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

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	5730 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 1999, found on Berkeley Environmental Protection home page at http://www.lbl.gov/ehs/epg/html/env_protection.htm.

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

The number and location of sources under each assessment category change in response to the research at Berkeley Lab. All but one source are considered “small sources” of emissions under NESHAPs. A large majority fall into compliance assessment Category V, which requires no monitoring. The 96 sources in this group adhere to strict inventory limits specified in individual work authorizations. Twenty locations use continuous sampling, including the only compliance Category I source on-site (the tritium stack at Building 75). Three locations have more rigorous real-time monitoring systems to estimate emissions with radionuclide half-lives that are less than 100 hours. Table 4-3 lists the breakdown of source assessment by category for the reporting year.

The stack monitoring program analyzed emission samples for five radiological parameters in 1999: 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 totaling 1.15×10^{12} Bq (31.2 Ci) were measured during the year, with nearly all tritium emitted from the National Tritium Labeling Facility’s (NTLF) exhaust stacks. Table 4-4 provides the list

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

Compliance category	Annual effective dose equivalent* (mSv/yr)	Sampling/monitoring strategy
Noncompliant	AEDE > 0.1	Reduce or relocate source term and reevaluate before authorization.
I	$0.1 > \text{AEDE} > 0.001$	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	$0.001 > \text{AEDE} > 0.0005$	Continuous sampling with weekly analysis.
III	$0.0005 > \text{AEDE} > 0.0001$	Continuous sampling with monthly analysis.
IV	$0.0001 > \text{AEDE} > 0.00001$	Sampled annually during project activity.
V	$0.00001 > \text{AEDE}$	No monitoring required. Inventory controlled by administrative methods (Radiation Work Authorization/Permit).

*AEDE

Table 4-3 NESHAPs Building Exhaust Sampling and Monitoring Profile

Monitoring type	Method	Location
Real-time	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	8 locations
	Sampling with monthly analysis	12 locations
No monitoring	Inventory (administrative) control	96 locations

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.

Tritium emissions for 1999 continue to be below regulatory levels of concern. The NTLF annual emission of 1.11×10^{12} Bq (30 Ci) was below both the five- and ten-year averages for that facility. In fact, the total annual emissions were less than one-third 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 NTLF, see Figure 4-1.

Table 4-4 Summary of Radiological Air Emissions Released*

Nuclide	Total (Bq/yr)	% Total
H-3	1.15×10^{12}	90.2%
F-18	9.9×10^{10}	7.8%
C-11	2.22×10^{10}	1.7%
N-13	3.11×10^9	0.3%
O-15	2.22×10^8	0.0%
C-14	3.85×10^7	0.0%
I-125	1.21×10^7	0.0%
All others	3.15×10^5	0.0%
Total	1.28×10^{12}	100.0%

*For a complete list of radiological air emissions, see NESHAPs Annual Report for 1999, found on Berkeley Lab's Environmental Protection home page at http://www.lbl.gov/ehs/epg/html/env_protection.htm.

Figure 4-1 Trends in Annual Tritium Releases from NTLF

III. AMBIENT AIR MONITORING RESULTS

§4.3 A. Tritium

Berkeley Lab determined levels of airborne tritium in the environment in 1999 at six monitoring sites. Three of the locations were on-site and three were off-site, as seen in Figure 4-2. The sites were chosen based on emission source locations, local wind patterns, and proximity to off-site residential areas and facilities. Equipment at each site continuously samples outdoor air. The sampling media are replaced and analyzed monthly.

Table 4-5 summarizes the network's atmospheric tritium concentrations for the year. Average and maximum concentration values are far below 1% of the allowable DOE annual exposure standard for tritium in air.⁶ The most recent ambient air results for the network are down from the previous year and well below levels measured as recently as 1995. For example, the annual average concentration at the highest reporting station for 1999, ENV-LHS, was 0.66 Bq/m³ (16 pCi/m³). The highest annual average concentration for 1995, measured at adjacent sampling location ENV-69, was almost 40 times as large: 24 Bq/m³ (650 pCi/m³). Both sites are located near the main source of tritium at the Laboratory and comparable distances from the point of tritium release.

§4.4 B. Gross Alpha/Beta

The ambient air sampling network also included stations designed to sample air particulate for measuring gross alpha and gross beta levels. This network complements

Figure 4-2 Ambient Air Monitoring Network Sampling Locations

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	< 0.19 ^c	—	< 0.19 ^c	< 0.19 ^c
ENV-B13C	12	< 0.19 ^c	—	< 0.19 ^c	< 0.19 ^c
ENV-B13D	12	< 0.41 ^c	—	< 0.41 ^c	< 0.41 ^c
ENV-69	12	0.44	0.01	0.28	0.94
ENV-85	12	< 0.19 ^c	—	< 0.19 ^c	< 0.19 ^c
ENV-LHS	12	0.66	0.02	0.64	1.08

^a 1 Bq = 27 pCi

^b Standard of comparison = 3.7×10^3 Bq/m³ (source: DOE Order 5400.5)

^c Statistic was below the highest value for analytical sensitivity (minimum detectable amount) measured for this site.

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 site at the monitoring program's most remote station, 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.

A fifth station was added briefly to detect any sign of radioactive contamination from a nuclear accident in Japan at the end of September. Sampling equipment set up for this investigation was identical to that found elsewhere in the network. In this case, sampling media were replaced and analyzed daily. No sign of a radioactive plume was detected in any of the five samples collected during the period when the plume was predicted to reach the west coast of North America.

Table 4-6 summarizes gross alpha and beta results from routine sampling activities in 1999. 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 Gross Alpha and Beta Sampling Results from Ambient Air Monitoring Network

Analyte	Station ID	Number of samples	Mean (Bq/m ³) ^a	Median (Bq/m ³)	Maximum (Bq/m ³)
Alpha	ENV-B13C ^b	11	$<1.5 \times 10^{-4}$	$<1.5 \times 10^{-4}$	2.3×10^{-4}
	ENV-69 ^b	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	1.6×10^{-4}
	ENV-80 ^b	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	2.2×10^{-4}
	ENV-81 ^b	11	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	2.0×10^{-4}
Beta	ENV-B13C	11	6.5×10^{-4}	5.2×10^{-4}	1.3×10^{-3}
	ENV-69	12	6.3×10^{-4}	5.4×10^{-4}	1.2×10^{-3}
	ENV-80	12	6.1×10^{-4}	5.3×10^{-4}	1.1×10^{-3}
	ENV-81	11	5.5×10^{-4}	5.2×10^{-4}	9.8×10^{-4}

^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.

Surface Water and Wastewater

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§5.1 I. SURFACE WATER PROGRAM

Berkeley Lab's surface water monitoring includes rainwater, creeks, lakes, hydraugers, and stormwater. The first four surface water types are monitored primarily for gross alpha, gross beta, and tritium, based on DOE orders¹ 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 Activities² and includes monitoring for metals and other constituents. The monitoring programs for each type of surface water are further described in this chapter.

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 tritium concentration limit for drinking water is 740 Bq/L (20,000 pCi/L).⁴

Surface water samples were analyzed in 1999 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 when rainfall occurs. In 1999, April, May, June, July, August, September, and October were dry months, so no samples were collected for those months.

Samples collected throughout the year came from three locations. See Figure 5-1. 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, beta, and tritium seen in rainwater samples taken during 1999. Results for alpha and beta activity were all below federal and state MCLs for drinking water.

Tritium was not detected in rainwater collected at the off-site locations. On-site, tritium in rainwater was measured only twice at ENV-75, with the maximum in December (14 Bq/L or 378 pCi/L). For comparison, the maximum tritium level in rainwater represents approximately 1.9% of the US/EPA drinking water limit.

Figure 5-1 Rainwater and Lake Sampling Locations

§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 course of the year. When creek flow occurs, a grab sample is collected and analyzed quarterly for alpha and beta activity and tritium. Creeks routinely sampled during 1999 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 arsenic, barium, chromium, copper, molybdenum, nickel, selenium, vanadium, and

^a 1 Bq = 27 pCi

^b Mean was less than the highest minimum detectable amount for the analyte at this site (0.11 Bq/L for alpha and 7 Bq/L for tritium).

Figure 5-2 Rainwater Radiological Monitoring Results

zinc—all in low amounts that are within background levels for this site and are well below Basin Plan limits. See §5.6.

No alpha activity was detected at any sampling site, with the exception of a low amount at Chicken Creek during the December sampling. Small amounts of beta activity were occasionally seen in all creeks except Wildcat Creek. Tritium was generally not detected, except in Chicken Creek, where it was seen at low levels. A summary of tritium results above detection limits for creek sampling in 1999 is shown in Figure 5-4.

Chicken Creek is the only creek in which tritium has been found with any regularity. Figure 5-5 presents a comparison of the annual mean for tritium over the last five years in Chicken Creek. From a high of 43.9 Bq/L (1,190 pCi/L) in 1995, levels dropped by nearly half in 1996 to 23 Bq/L (620 pCi/L) and have remained reasonably consistent since then. The annual average for 1999, 17.8 Bq/L (481 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. In 1999, samples from both lakes did not contain gross alpha or beta activity or tritium above minimum detectable amounts.

Figure 5-3 Creek Sampling Locations

^a 1 Bq = 27 pCi

^b Mean was less than the highest minimum detectable amount for the analyte at this site (6–11 Bq/L).

Figure 5-4 Creek Tritium Monitoring Results

Figure 5-5 Annual Averages for Tritium in Chicken Creek (1995–1999)

§5.5 D. Hydraulers

Because of its steep hillsides, Berkeley Lab uses hydraulers to manage soil stability. Hydraulers are perforated pipes inserted into a hillside to improve drainage of groundwater. Figure 5-6 shows the locations of monitored hydraulers. Summary tritium data for hydraulers are displayed in Figure 5-7.

Four hydrauger sites (HYG77-0101, HYG77-02XX, HYGCC1, and HYGCC2) were routinely monitored in 1999 for alpha, beta, and tritium. HYG77-0104 has been deleted from the program because of lack of flow. HYG77-02XX is a manifold of several hydraulers (HYG77-0204 through HYG77-0207) and is sampled at the common discharge point. Hydraulers prefixed with HYG77 are located behind Building 77, while those prefixed with HYGCC are located near Chicken Creek, further to the south and further down the hillside.

Because hydrauger flow depends on several factors (including rainfall), it can vary considerably. No flow or very low flow prevents samples from being taken. At the hydraulers that could be sampled, no alpha or beta activity was detected. Tritium was detected only in the samples collected from the HYG77 hydraulers. The highest level measured was 341 Bq/L (9,207 pCi/L) for a sample collected at HYG77-0101—a decrease from last year's maximum of 504 Bq/L (13,608 pCi/L).

§5.6 E. Stormwater

Berkeley Lab lies within the Blackberry Canyon and Strawberry Canyon watersheds. There are two main creeks in the watershed, Strawberry Creek and the North Fork of

Figure 5-6 Hydrauger Sampling Locations

Strawberry Creek, plus several small tributaries that generally do not flow all year long. See Figure 5-8.

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.

^a 1 Bq = 27 pCi

^b Mean and/or maximum was less than the highest minimum detectable amount (11 Bq/L).

Figure 5-7 Hydrauger Tritium Monitoring Results

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.⁵ Permit holders must develop and maintain a Storm Water Monitoring Plan (SWMP)⁶ and a Storm Water Pollution Prevention Plan (SWPPP).⁷ These are the guiding documents for the Laboratory's compliance with stormwater regulations. For further discussion of this compliance program, see §§3.24 and 3.26.

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 5-8.

Two of the monitoring points, StW01 and StW03, are influent points, where stormwater comes 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 and to aid in an investigation if contaminants are 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.

Figure 5-8 Stormwater Sampling Locations

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

Note that in calendar year 1999, stormwater monitoring was performed three times due to rainfall patterns during the 1998–1999 stormwater year, which caused monitoring to occur only once in calendar year 1998.

In 1999, pH was always near neutral, and total petroleum hydrocarbons (diesel) and oil and grease (both tests for gas or oil) were often seen in very low quantities at all sampling points. Specific conductance, usually a measure of the degree of mineralization of water, was 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 as nitrogen and nitrate plus nitrite were also seen at all stations at low levels.

Metals results were generally in the “nondetect” range. 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 Plan⁸ 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 was sometimes detected in miniscule amounts at all locations except 71-Storm Drain Manhole. All tritium values were low or nondetect, with a maximum of 79.3 Bq/L (2,141 pCi/L) at Building 69 Influent (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 half that level at 40 Bq/L (1,080 pCi/L).

§5.7 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 5-9):

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

Figure 5-9 Sanitary Sewer System

University-owned piping and then into the City of Berkeley system. Because of the design of the network, 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., Lawrence Hall of Science, Space Sciences Laboratory, Mathematical Sciences Research Institute, Animal Research Facility, and the Botanical Garden).

Self-monitoring of wastewater discharge within Berkeley Lab also occurs at Buildings 25 and 77 and at groundwater treatment units (see Table 6-6), according to the terms of their respective EBMUD permits.⁹

Berkeley Lab currently has four wastewater discharge permits issued by EBMUD: one for general site-wide discharges, two for the metal finishing operations found in Buildings 25 and 77, and one for the discharge of treated groundwater from hydraugers. EBMUD renews the site's wastewater discharge permits annually in September, except for the treated groundwater permit, which is granted for two years. EBMUD is the local Publicly Owned Treatment Works that regulates all industrial discharges to its treatment facilities.

As in previous years, the Laboratory's 1999–2000 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, although EBMUD returned to a stated limit of 0.5 mg/L for total identifiable chlorinated hydrocarbons and dropped the limit of 0.1 mg/L for methylene chloride alone. All sampling results are presented in Volume II.

IV. WASTEWATER RESULTS

§5.8 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 to Berkeley Lab 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 guidance¹⁰ and orders,¹¹ but it also ensures compliance with the radiological limits given in the California Code of Regulations.¹² California regulations now incorporate by reference the applicable federal regulations¹³ 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.

§5.9 1. Nonradiological Monitoring

Four nonradiological self-monitoring samples were taken from the Hearst and Strawberry outfalls during 1999. 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 November sampling. Most metals were not detected above detection limits in either Hearst or Strawberry outfalls. Figure 5-10 shows the metals results for the 1999 sampling as a percentage of permit discharge limits.

No chlorinated hydrocarbons were found at all, except for chloroform, which is present in EBMUD supply water, and a one-time small amount of methylene chloride in Hearst Sewer. According to the permit, the pH level must remain at no less than 5.5; all results for 1999 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. Starting with the 1997-1998 permit, Berkeley Lab is expected to estimate the average and maximum wastewater strength for the coming year in its permit application, and these then become the permit limits. The estimates for 1999 met EBMUD's standard.

Figure 5-10 Concentration of Metals in Hearst and Strawberry Sewer Water Samples as a Percentage of Permit Limit

§5.10 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. Some split samples were occasionally analyzed by a third laboratory for additional quality control purposes.

The federal¹³ and state¹² regulatory limits are based on total amounts released per year. For tritium, this limit is 1.9×10^{11} Bq (5 curies) per year. The limit for all other radioisotopes is a combined 3.7×10^{10} Bq (1 curie) per year. Radioisotopes discharged in Berkeley Lab's sewer wastewater for 1999, expressed as a percentage of their permit limit, are summarized in Figure 5-11.

Alpha emitters, which can potentially come from transuranic and heavy-element research, were seen at Hearst Station twice at very low levels and not at all 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 0.9 Bq/L (24.3 pCi/L), while the highest I-125 concentration was 5.04 Bq/L (136 pCi/L), both at Hearst Station. For a complete set of the individual results, see the data tables in Volume II.

Figure 5-11 Radioisotopes Discharged to Sewers in 1999 as a Percentage of Permit Limit

With one exception, tritium levels were below the minimum detectable amount at Hearst Monitoring Station. Tritium levels were above detection limits at Strawberry Monitoring Station. The total annual discharge of tritium in wastewater was 1.78×10^9 Bq (0.048 Ci), and the total for other radioisotopes was 4.2×10^8 Bq (0.011 Ci). The amount of tritium was below last year's level by an order of magnitude, while the total for other radioisotopes remained about the same. All values, however, were well below allowable limits. For example, tritium was only 1% of the allowable federal and state limit, and all other isotopes together were also approximately 1% of their limit.

Figure 5-12 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, varying from about 1% to 9%.

§5.11 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.

All sampling performed by Berkeley Lab and EBMUD during two monitoring efforts each yielded daily maximum and monthly average results well within EBMUD discharge limits.⁹

Figure 5-12 Annual Releases of Tritium to Sewers (1995–1999) as a Percentage of Permit Limit

§5.12 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. During 1999, four overflow rinse tanks were converted to electronically controlled spray rinse tanks—a practice now in general use in metal finishing operations. This step is likely to save a considerable amount of water as well as to reduce both the use of chemicals and the amount of sludge generated as waste.

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. A task force investigating 1998 permit exceedances at this unit recommended modification of the unit by its manufacturer, training for operators, and use of an up-to-date manual. These corrective actions were taken, and all self-monitoring and EBMUD inspection samples taken during 1999 were well within permitted limits.

§5.13 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 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 “non-detect.” 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.

Groundwater

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II. HYDROGEOLOGIC CHARACTERIZATION

A. Hydrogeologic Units §6.2

B. Groundwater Flow §6.3

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III. GROUNDWATER MONITORING RESULTS §6.5

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A. VOC Plumes §6.7

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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 1999 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 Groundwater Protection Management Program Plan¹ established the program to accomplish these objectives by providing a framework for preventing future groundwater contamination and for remediating existing contamination at the site. 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,² 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.

Results in this chapter are compared against drinking water standards. Such a comparison should be interpreted with caution because the groundwater at the Berkeley Lab site is not used for human consumption.

II. HYDROGEOLOGIC CHARACTERIZATION

§6.2 A. Hydrogeologic Units

Moraga Formation volcanic rocks, Orinda Formation sediments, and Great Valley Group sediments constitute the major rock units at 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. Two additional units, the Claremont Formation and the San Pablo Group, have a limited presence in the easternmost area of the Laboratory.

§6.3 B. Groundwater Flow

Depth to water is measured monthly in all 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 direction of groundwater flow generally follows the topography.

In the western part of Berkeley Lab, groundwater generally flows toward the west; in 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 and the contrasting hydrogeologic properties across geologic contacts. The velocity of the groundwater varies from approximately 0.001 meters per year (0.003 feet per year) to about 10 meters per day (33 feet per day).

Figure 6-1 Groundwater Piezometric Map

§6.4 C. Groundwater Quality

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

§6.5 III. GROUNDWATER MONITORING RESULTS

In 1999, eight new monitoring wells were installed, bringing the total in the program to 182 wells. 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 1999. Tables 6-1 and 6-2 summarize the metals results and VOC results, respectively. The tables show the drinking water standard (maximum contaminant level or MCL) for the analyte,³ 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.

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	69	91	9	1–2.5	6
Arsenic	84	106	70	1.6–60.5	50
Barium	67	89	67	5.7–927	1000
Beryllium	67	89	0		4
Cadmium	67	89	0		5
Chromium	70	92	53	1–35.5	50
Hexavalent Chromium	1	1	0		
Cobalt	67	89	24	1–31.3	NS ^b
Copper	67	89	49	1–26	1000 ^c
Lead	67	89	6	1.2–2.1	15 ^d
Mercury	69	91	1	0.27	2
Molybdenum	75	97	68	1–430	NS ^b
Nickel	68	90	56	1–18.2	100
Selenium	68	90	17	2.1–93	50
Silver	67	89	0		100 ^c
Thallium	67	89	0		2
Vanadium	68	90	57	1–65.4	NS ^b
Zinc	67	89	33	5.1–60.3	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

§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.

Contamination was also detected in groundwater in other areas of the site in 1999. 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 58A and the slope west of Building 53, the Old Town VOC plume is the most extensive plume at Berkeley

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	2	0.83–36.2	1
Methyl tert-butyl ether	1	1.3	NS ^b
sec-Butylbenzene	1	3.7	NS ^b
p-Isopropyltoluene	2	0.93–5	NS ^b
1,4-Dichlorobenzene	1	0.51–0.89	NS ^b
Toluene	5	0.54–4.9	150
Xylenes, total	1	2.4	1,750
Halogenated hydrocarbons			
Bromoform	1	2	NS ^b
Carbon tetrachloride	20	0.79–1,800	0.5
Chloroform	49	0.78–149	100
Dibromochloromethane	1	0.58	NS ^b
Dichlorodifluoromethane (freon 12)	1	0.6	NS ^b
Dichlorotrifluoroethane (freon 123)	2	1.9–3.5	NS ^b
1,2-Dichlorotrifluoroethane (freon-123A)	7	1.1–3.2	NS ^b
1,1-Dichloroethane	33	0.5–16,900	5
1,2-Dichloroethane	3	0.5–45	0.5
1,1-Dichloroethene	44	0.55–8,680	6
cis-1,2-Dichloroethene	59	0.52–1,200	6
trans-1,2-Dichloroethene	13	0.57–36.9	10
Methylene chloride	5	1.6–210	5
1,1,1,2-Tetrachloroethane	2	18–85	NS ^b
Tetrachloroethene	56	0.65–38,300	5
1,1,1-Trichloroethane	18	0.54–86,400	200
1,1,2-Trichloroethane	4	0.61–8.2	5
Trichloroethene	80	1–45,000	5
Trichlorofluoromethane (freon 11)	1	2.4	150
1,1,2-Trichlorotrifluoroethane (freon 113)	3	1.1–20.7	1,200
Vinyl chloride	12	1.3–58.1	0.5

^a 451 samples taken from 180 wells during the year^b NS = Not specified

Lab. This plume is defined by the presence of tetrachloroethene (PCE), trichloroethene (TCE), and lower concentrations of other halogenated hydrocarbons, including 1,1-dichloroethene (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.

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)
MW91-4	31	NS ^d	34	NS
MW91-5	94	NS	82	162
MW91-6	138	NS	118	NS
75-92-23	202	NS	141	NS
75B-92-24	135	NS	188	NS
75-97-5	1166, 982 ^e	925	914, 970 ^f	989, 907 ^e
75-97-7	52	29	NS	NS
69-97-21	24	30	NS	NS
75-98-14	NS	166	162, 152 ^e	113
75-99-7	NS	NS	NS	198, 160 ^e
MW76-1	<11	NS	20	NS
76-93-6	180	NS	163	NS
78-97-20	109	134	NS	NS
76-98-22	<11, 5 ^e	<11	<11	<11
MW91-2	18	NS	24	29
77-94-6	441	394	NS	NS
77-97-9	432	448	NS	NS
77-97-11	229	228	NS	NS
31-97-17	64	45	NS	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 1 Bq = 27 pCi

^d NS = Not sampled

^e Duplicate sample

^f Split sample

The maximum concentration of total halogenated hydrocarbons detected in 1999 in groundwater samples collected from wells monitoring the Old Town VOC plume was 85,590 µg/L, which primarily consisted of PCE (38,000 µg/L), TCE (45,000 µg/L), and carbon tetrachloride (1,800 µg/L). Figure 6-4 shows the areal extent of VOCs in groundwater in the Old Town area.

The presence of the maximum VOC concentrations north of Building 7 suggests that the primary source of the Old Town VOC plume was apparently 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

Figure 6-3 Groundwater Contamination Plumes (September 1999)

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.

Four interim corrective measures (ICMs) 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 1999 at a maximum total concentration of 349,890 $\mu\text{g/L}$ 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 1999 in samples collected from groundwater monitoring wells in the Building 51/64 area was 110,652 $\mu\text{g/L}$. The

**Figure 6-4 Groundwater Contamination (Total Halogenated Hydrocarbons in µg/L)
in Old Town Area (September 1999)**

contaminants primarily consisted of 1,1,1-TCA (86,400 $\mu\text{g/L}$) and 1,1-DCA (8,720 $\mu\text{g/L}$). Figure 6-5 shows the areal extent of VOCs in groundwater in the Building 51/64 area.

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 1999, 536 $\mu\text{g/L}$, 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.

Figure 6-5 Groundwater Contamination (Total Halogenated Hydrocarbons in $\mu\text{g/L}$) at Building 51/64 VOC Plume (September 1999)

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 1999 was 8.8 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 1999 was 16 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 in 1999. 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 1999 was 1,166 Bq/L (31,503 pCi/L), which is above the drinking water standard of 740 Bq/L (20,000 pCi/L).⁴ Tritium has been detected above the drinking water standard in only one monitoring well.

§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 6-6 shows the approximate locations of these wells. The maximum concentrations of total petroleum hydrocarbons (TPH) detected at these sites in 1999 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 1999. A dual phase (groundwater and soil vapor) extraction and treatment system has been installed at the location of the Building 7E former UST as an interim corrective measure.

Methyl tertiary butyl ether (MTBE) was detected in one monitoring well in 1999 at a concentration of 1.3 µg/L. The US/EPA Drinking Water Advisory for MTBE is 20 to 40 µg/L.

Figure 6-6 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	NS ^f
Building 62 ^a	Removed	Diesel	TPH-D ^c = 570
Building 74 ^a	Removed	Diesel	TPH-D ^c = 170
Building 76 ^a	Removed	Diesel	TPH-D ^c = 540
Building 76 ^a	Removed	Gasoline	TPH-G ^d = 160
Building 7E ^a	Removed	Kerosene	TPH-K ^e = 2,000
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 1999:

- Approximately 30 cubic meters (40 cubic yards) of PCB-contaminated soil were excavated from the basement of the Building 51 Motor Generator Room.
- 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 9 kg of VOCs (consisting primarily of PCE, TCE, and carbon tetrachloride) from the groundwater in 1999.
- A dual phase (groundwater and soil vapor) extraction and treatment system was installed at the location of the Building 7E former UST to remove contaminants from the soil and groundwater. Approximately 54 kg of contaminant mass was removed by the vapor extraction system in 1999.

§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

As interim corrective measures to control groundwater plumes that could migrate off-site or contaminate surface water, Berkeley Lab is capturing and treating contaminated groundwater using extraction wells and subdrains. In addition, two groundwater collection trenches were constructed to prevent further migration of the Old Town plume. The first trench was installed west of Building 53 and the second at the base of the slope west of Building 58.

§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,⁵ or recirculated to flush contaminants from the subsurface.

Table 6-5 lists both the volume of contaminated groundwater treated by each system in 1999 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 1999 (liters)*	Total volume treated (liters)
Building 37 VOC plume	Building 37	325,722	3,610,231
Old Town VOC plume	Building 46	3,889,322	25,979,676
Building 71 VOC plume and water collected from purging monitoring wells	Building 51 firetrail	1,100,898	1,993,597
VOC-contaminated hydrauger effluent	Building 51 hydraugers	3,334,729	35,731,604
Building 51 subdrain system	Building 51 sump	1,156,768	4,403,798
Old Town VOC plume	Building 7 trench	1,935,464	5,448,167
Building 6 former underground storage tank	Building 6 bioventing	963,165	1,363,198
Total volume treated		12,706,067	78,530,272

*1 liter = 0.264 gallons

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 any 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 1999, sampling was performed in October before the rainy season. All sampling results are presented in Volume II.

§7.2 II. SOIL AND SEDIMENT SAMPLING

In 1999, 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 1999, only three of the eight samples contained detectable levels of tritium. The maximum tritium level in soil was 0.0094 becquerels per gram (Bq/g) (0.25 pCi/g) of soil near Building 69. The maximum tritium level in sediment was 0.0091 Bq/g (0.25 pCi/g) at the North Fork Strawberry Creek–Main location. 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 copper and zinc were slightly higher than normal background levels at Building 50 (244 mg/kg copper) and ENV-B13C (362 mg/kg). These slightly elevated levels may be due to the

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	0.0094
Building 85	Soil	<0.007 ^c
ENV-B13C	Soil	<0.007 ^c
Chicken Creek–Main	Sediment	<0.007 ^c
Chicken Creek–Tributary	Sediment	0.0075
North Fork Strawberry Creek–Main	Sediment	0.0091
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

proximity of galvanized iron (containing zinc) and pressurized wood fencing (containing copper sulfate) at these two locations.

PCB results for sediment samples were below practical quantification limits. Measurements for pH were within the normal range for soils and sediments. The maximum level of oil and grease (2,400 mg/kg) was measured at the Strawberry Creek–Tributary 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
Arsenic	6.8	<2 ^c	3	5.8	2.7	3.4	3.1	4.7	500
Barium	208	128	146	143	154	138	87	86	10,000
Beryllium	<1 ^c	<1 ^c	<1 ^c	<1 ^c	0.6	<0.5 ^c	<0.5 ^c	<0.5 ^c	75
Cadmium	2.4	<1 ^c	<1 ^c	<1 ^c	<0.5 ^c	<0.5 ^c	<0.5 ^c	0.7	100
Chromium	39	98	94	34	32	82	21	32	2,500
Cobalt	8.7	22	21	7.4	7.5	7.5	6.4	6.6	8,000
Copper	244	26	40	26	27	29	16	61	2,500
Lead	150	9	12	189	18	14	12	40	1,000
Nickel	47	63	64	29	37	44	19	25	2,000
Vanadium	55	108	125	41	30	40	38	38	2,400
Zinc	181	61	63	362	90	139	101	197	5,000
Oil & grease	—	—	—	—	430	680	820	2,400	—

^a One sample per location, all results in mg/kg^b Total Threshold Limit Concentration (22 California Code of Regulations 66261.24)³^c Result was below detection limit.^d Results for antimony, mercury, 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.

Vegetation and Foodstuffs

I. BACKGROUND §8.1

II. TREE SAMPLING §8.2

Figure 8-1: Areas Sampled in 1998–1999

III. RESULTS §8.3

Figure 8-2: Vegetation Tritium Concentration vs. Distance from NTLF

Table 8-1: Maximum Tritium Concentration Measured in Wood or Vegetation Materials

§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:

- 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.

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. Nevertheless, in modeling and dose calculations, the Laboratory conservatively assumes that 100% of the emissions are tritiated water vapor to provide a safe overestimate of actual dose.

Tritiated water vapor released to 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 Plan² outlines the current vegetation sampling program. 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 multi-year 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. See Figure 8-1.

Environmental tritium levels have been determined to be above regional background levels near the National Tritium Labeling Facility (NTLF) and to decrease with distance from the facility stack.⁴ A sampling and analysis plan was developed and implemented in 1998 to characterize tritium concentrations within tree stands that might be thinned in the future,⁵ and the results were reported in the Site Environmental Report for 1998. In 1999, a follow-on sampling and analysis plan was prepared and implemented to confirm vegetation tritium levels measured in 1998 and to investigate tritium levels at other

Figure 8-1 Areas Sampled in 1998–1999

locations at Berkeley Lab. Figure 8-1 shows the areas at Berkeley Lab that were sampled in 1998 and 1999. Tree selection and sampling were designed to (a) provide representative samples for characterizing tritium levels within the tree stands, (b) prevent sample cross-contamination, and (c) estimate field sampling variability.

In 1999, wood chip, leaf, and duff were collected from several locations within the Laboratory site. See Figure 8-1. Duff consists of tree litter and other decomposing vegetation material that lies on the ground under a tree canopy. Eucalyptus and pine trees were sampled using a systematic and documented procedure. The samples were analyzed at a commercial laboratory for TFWT and OBT.

§8.3 III. RESULTS

Tritium results from the vegetation samples collected in 1999 confirm the distribution patterns measured in 1998: concentrations of tritium in vegetation greater than the analytical detection limits occur only within a radius of 200 meters from the NTLF. Figure 8-2 shows all vegetation tritium results from both 1998 and 1999 as a function of distance from the NTLF stack. A detailed listing of tritium results obtained in 1999 is included in Volume II. Background levels for tritium in wood, leaf, and duff were established in 1998 from samples collected at Chabot Regional Park that were all below or near the analytical detection limits.

The maximum tritium concentrations (TFWT and OBT) found in each vegetation media (for both 1998 and 1999 results) and their distance from the NTLF are listed in Table 8-1. All the maximum tritium values occurred in samples located close to the NTLF stack and can be compared with recently published guidance in ANSI/HPS

Figure 8-2 Vegetation Tritium Concentration vs. Distance from NTLF

Table 8-1 Maximum Tritium Concentration Measured in Wood or Vegetation Materials

Type of vegetation material	Distance from NTLF stack (meters)	Maximum tritium concentration measured (Bq/g*)	Percent of ANSI/HPS N13.12 standard
Duff	20	47.4 (OBT)	42%
	5	3.89 (TFWT)	4%
Leaf	4	309 (OBT)	280%
	4	21.0 (TFWT)	19%
Wood	4	2.44 (OBT)	3%
	4	1.82 (TFWT)	2%

*All values are based on the actual sample weight (wet sample), so the total tritium concentration in a vegetation sample could be found by adding TFWT and OBT concentrations together. 1 Bq = 27 pCi.

N13.12–1999 (Surface and Volume Radioactivity Standards).⁶ These standards recommend an unrestricted tritium release limit of 111 Bq/g (3000 pCi/g) of vegetation for derived screening levels. In comparison, the average tritium concentration within a 200-meter radius from the NTLF stack is approximately 3.70 Bq/g (100 pCi/g). Using this average, the total tritium inventory within 200 meters of the NTLF stack is estimated to be less than 0.037 TBq (1 Ci) in the surrounding environment.

The results from the samplings and analyses conducted in 1998 and 1999 confirm what has been previously measured and reported: tritium concentrations in vegetation are elevated above regional background levels near the NTLF main stack and decrease with distance from the stack. At about 200 meters from the NTLF stack, TFWT and OBT levels in vegetation are nearly indistinguishable from regional background levels. This tritium characterization data will be utilized in preparing an application for the authorization of release limits for tritium in vegetation, which will be submitted to DOE for approval.

Routine sampling of vegetation and foodstuffs at Berkeley Lab 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 of Berkeley Lab's airborne radionuclides. Dose assessments using very conservative assumptions indicate extremely low impacts.

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)
- IV. COMBINED DOSE ASSESSMENT §9.6
 - Table 9-3: Summary of Radiological Dose Impacts
 - Figure 9-2: Comparison of Radiological Dose Impacts

§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 at the end of the chapter to summarize the overall impact of the Laboratory's radiological activities on the surrounding region.

Earlier chapters refer to monitoring and sampling results in terms of concentrations of a substance. The health effect of exposure to a concentration 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.

§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 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 the instantaneous gamma and neutron radiation impacts. Figure 9-1 shows the location of these stations (i.e., ENV-B13A, ENV-B13C, and ENV-B13H) in relation to the accelerators. 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). Based on a review of historical data, Berkeley Lab reduced the number of TLDs from 27 to 11 in 1999. Seven of these TLDs are located near the site boundary, and four others surround two off-site facilities (Building 903 Warehouse and Building 934). TLDs measure only gamma radiation; they are not sufficiently sensitive to detect environmental levels of neutron radiation. Additionally, because they cannot exclude background gamma radiation from their results, they provide time-average dose results that must be determined by analytical technique rather than real-time instrumentation. Figure 9-1 shows the locations of TLD sites near the main facility.

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 average gamma radiation recorded by these TLDs for 1999 is about 0.53 mSv

Figure 9-1 Environmental Penetrating Radiation Monitoring Stations

(53 mrem). Because this value is near the typical background dose for natural gamma radiation in California (0.72 mSv (72 mrem)),¹ the TLD results confirm 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 Census³ 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, primarily

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/year.

at station ENV-B13A. The predicted population dose to the approximately 5-million people within 80 kilometers (50 miles) of Berkeley Lab was estimated at 2.17×10^{-4} person-Sv (2.17×10^{-2} person-rem).

§9.4 B. Irradiator-Produced Penetrating Radiation

Used for radiobiological and radiochemical research, a single gamma irradiator with a 1400 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 0.01 mSv/hr (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 0.01 mSv/yr (1.0 mrem/yr) at the perimeter fence and less than 2×10^{-4} mSv/yr (0.02 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 cumulative dose level, because the maximally exposed individual (MEI) locations for each of the small irradiator activities are significantly different. See §9.6.

§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), the governing regulations for dispersible radionuclides, require that any facility that releases airborne radionuclides must assess the impact of such releases using a computer program approved by the Environmental Protection Agency.⁴ Berkeley Lab satisfies this requirement with the use of CAP88-PC.

CAP88-PC is both a dispersion and dose-assessment predictive model supplied and approved by US/EPA. 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 the most hazardous form. Consequently, this worst-case dose is an upper-bound estimate and not one likely to be received by anyone.

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

Berkeley Lab performed 15 individual CAP88-PC modeling runs to predict the impact from groupings of the Laboratory’s release points. Table 9-2 lists the attributes of these groupings. Details on these groupings and modeling runs are included in the Laboratory’s annual NESHAPs report. The location of the maximally exposed individual was determined from the complete set of modeling runs. The

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

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	6.7×10^{-4}	83.0%
55/56	Research Medicine/BIF	490	E	8.2×10^{-5}	10.2%
85	New Hazardous Waste Handling Facility	730	WNW	1.0×10^{-5}	1.3%
75A/75	Old Hazardous Waste Handling Facility	150	NW	5.8×10^{-6}	0.7%
88	88-Inch Cyclotron	670	ENE	3.8×10^{-6}	0.5%
70/70A	Nuclear / Life Sciences	510	NE	2.3×10^{-6}	0.3%
74/83	Buildings 74/83 Research Medicine	730	WNW	5.4×10^{-8}	<0.1%
1	Donner Laboratory (UC Berkeley)	980	ENE	3.3×10^{-5}	4.1%
2/6	Advanced Material Laboratory/ALS	370	NE	2.3×10^{-7}	<0.1%
26/76	RAML/Counting Laboratory	240	N	2.0×10^{-8}	<0.1%
934	Molecular and Cell Biology (off-site)	4,900	ENE	7.4×10^{-8}	<0.1%
71/72	HILAC/NCEM	220	E	0.0	0%
3	Calvin Lab (UC Berkeley)	1,070	NE	1.8×10^{-9}	<0.1%
75C	EHS Calibration Sources	150	NW	0.0	0%
903	Receiving Warehouse	N/A	N/A	0.0	0%
Total				8.07×10^{-4}	100%

^a Distances and directions are relative to the cumulative MEI from all contributing sources.

^b 1 mSv = 100 mrem

source groupings listed in Table 9-2 give the orientation of their release points relative to the location of the maximally exposed individual (distance and direction). The combined dose from airborne radionuclides for 1999 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 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 0.007 person-Sv (0.7 person-rem).

§9.6 IV. COMBINED DOSE ASSESSMENT

The total radiological impact from accelerator operations and airborne radionuclides is well below applicable standards and nominal background radiation. As presented in Table 9-3 and Figure 9-2, the maximum effective dose equivalent to an individual from all Berkeley Lab operations in 1999 is about 0.003 mSv (0.3 mrem) per year. This value is approximately 0.1% of the nominal background radiation⁵ in the Bay Area and less than 0.3% of the DOE annual limits.⁶

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)
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

Figure 9-2 Comparison of Radiological Dose Impacts

The estimated dose to the population within 80 kilometers of Berkeley Lab from these same activities was 0.0074 person-Sv (0.74 person-rem) for the same period. From natural background sources alone, this same population faces an estimated dose of 13,000 person-Sv (1,300,000 person-rem). The Laboratory's population dose is a mere 0.00006% of the background level.

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 Plan² and applicable DOE³ and US/EPA⁴ 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 certifications⁵ 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.

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 Protection 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. EPA has also performed tritium analyses on Berkeley Lab ambient air split samples; results from those analyses are discussed in §10.3. As discussed in §3.9, 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 EPA-requested sampling was developed in 1999. In 2000, this plan will be reviewed by EPA and the Environmental Sampling Project Task Force in order to produce a final approved plan and begin implementing the sampling and analysis.

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 in order to measure the concentration of tritiated water in air. To verify the sampling efficiency for the collection of water vapor from ambient air, in 1999 Berkeley Lab compared the mass of water vapor extracted from field air samples (at all sampling locations) with the mass of water vapor available in the sampled atmosphere. 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.

To calculate the total mass of water vapor available for collection onto the silica gel column, the average absolute humidity was multiplied by the total volumetric flow through the sampler. Figure 10-1 compares the mass of water vapor collected to 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 to be collected. The observed small differences between those two values can be accounted for by the uncertainties associated with

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

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).

§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 (ENV-LHS and ENV-B13D) of the network's six sites. The samples shared with EPA are analyzed at its National Air and Radiation Environmental Laboratory (NAREL) facility and provide an inter-laboratory comparison of results.

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

For 1999, there were 24 inter-laboratory and 12 intra-laboratory result pairs. For the 1999 data collected, the average difference between all the sample- and split-result pairs was 0.7%. The average difference for the inter-laboratory result pairs was slightly higher at 1.1%, with the results from Berkeley Lab's contract analytical laboratory the higher of the two.

Figure 10-2 shows that the sample- and split-result pairs lie close to a line that represents perfect agreement between sample and split. The nearly equal distribution of the data points above and below the ideal line indicates that the sample and split differences are random and not due to systematic errors within a laboratory or between laboratories.

*1 Bq = 27 pCi

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

Additional quantitative evaluations were performed on the sample and split data in order to determine whether the two sets of results were statistically different. To do that, two statistical tests were applied: T-Test for Dependent Samples and the Wilcoxon Matched Pairs Test. Both tests indicate that sample results and split results are not significantly different at the 95% confidence level. These findings strongly confirm that the ambient air tritium monitoring program at Berkeley Lab contains the required precision and reproducibility for measuring environmental levels of tritiated water in air.

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_____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
CFR	Code of Federal Regulations
Ci	Curie
Clean Air Act	Air Quality
CMTW	Committee to Minimize Toxic Waste
CODF	Chemical Oxygen Demand, Filtered
CWA	Clean Water Act
DCA	Dichloroethane
DCE	Dichloroethene
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
EPCRA	Emergency Planning and Community Right-to-Know Act

EPG	Environmental Protection Group
FTU	Fixed Treatment Unit
FY	Fiscal Year
gsf	gross square feet
gsm	gross square meters
HMBP	Hazardous Materials Business Plan
HWHF	Hazardous Waste Handling Facility
ICMs	Interim Corrective Measures
kg	kilogram
L	Liter
LBNL	Lawrence Berkeley National Laboratory
m	meter
MCL	Maximum Contamination Level
MDA	Minimum Detectable Amount
MEI	Maximally Exposed Individual
mg	milligram
mrem	millirem
mSv	millisievert
MTBE	Methyl Tertiary Butyl Ether
MW	Mixed Waste
ND	Nondetectable
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NFA	No Further Action
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
PCE	Perchloroethylene
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	Système Internationale or International System of Units (the metric system)
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
TLD	Thermoluminescent Dosimeter
TOC	Total Organic Carbon
TOMP	Toxic Organic Management Plan
TPH	Total Petroleum Hydrocarbons
TPH-D	Total Petroleum Hydrocarbons, Diesel
TPH-G	Total Petroleum Hydrocarbons, Gasoline
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

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).

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 1000 people each received a radiation dose of 1 sievert, their population dose would be 1000 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 ($1/2 \times 1/2$); after three half-lives, one-eighth of the original activity remains ($1/2 \times 1/2 \times 1/2$); and so on.

Hazardous waste

Waste exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). Because of its concentration, quantity, 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

The unit of population dose, which expresses the sum of radiation exposures received by a population. For example, two persons, each with a 0.5-rem exposure, receive 1 person-rem, and 500 people, each with an exposure of 0.002 rem, also receive 1 person-rem.

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, non-pumping 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 radioactivity 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

A graph that shows the frequency and intensity of wind from different directions at a particular site.

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

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