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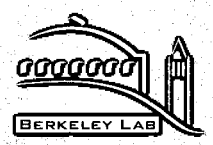

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Site Environmental Report for 1997
Volume I

Environment, Health, and Safety Division

September 1998

DISCLAIMER

Site Environmental Report for 1997

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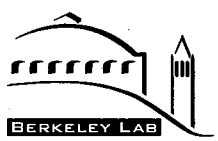

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NUMBER DE-AC03-76SF00098

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Preface

Each year, Ernest Orlando Lawrence Berkeley National Laboratory prepares an integrated report on its environmental programs to satisfy the requirements of U.S. Department of Energy Order 231.1. The Site Environmental Report for 1997 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 1997.

This report is structured into three basic areas that cover a general overview of the Laboratory, the status of environmental programs, and the results from surveillance and monitoring activities. The report is separated into two volumes. Volume I contains the body of the report, a list of references, a list of acronyms and abbreviations, a glossary, Appendix A (NESHAPs annual report), and Appendix B (distribution list for volume I). Volume II contains Appendix C, the individual data results from monitoring programs.

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. Although a printed version of volume II (Appendix C) 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 Patrick Thorson of the Environmental Protection Group (Ron Pauer, Leader). Iraj Javandel, Ginny Lackner, Mike Ruggieri, Patrick Thorson, and Henry Tran were the primary authors of the report.

Other key contributors of programmatic information include David Balgobin, David Baskin, Robert Fox, Rich McClure, Gale Moline, Ron Pauer, Nancy Rothermich, Jack Salazar, Nancy Shepard, Brian Smith, Charles Smith, Dave Tudor, Mark Turner, and Steve Wyrick.

This report was prepared through Berkeley Lab's Technical & Electronic Information Department (Dennis Hall, Head). Maryann Aberg managed technical editing, design, and production of the report, assisted by Rich Albert and Hilary Mullins (editing); Jean Wolslegel (composition); Flavio Robles, Jr. (illustration); and Chris Lema and Erik Richman (Web services).

Copies of the report are available from several resources: the Office of Scientific and Technical Information and the National Technical Information Service (see inside front cover), the Berkeley Lab Web site (http://www.lbl.gov; choose "Site Index"), or the following contact:

Ernest Orlando Lawrence Berkeley National Laboratory
Environmental Protection Group
1 Cyclotron Road, Mailstop B75B-101
Berkeley, CA 94720
Attention: Patrick Thorson
Phone: (510) 486-5852
E-mail: pathorson@lbl.gov

Requests for the printed version of volume II should also be directed to Patrick Thorson.

1

Executive Summary

§1.1 I. INTRODUCTION

Published annually to summarize environmental activities at the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab), this Site Environmental Report covers activities for calendar year 1997. The eleven chapters of the report are grouped into the following three categories:

- *Site Overview*
  Chapter 2: Introduction
- *Compliance and Performance Status*
  Chapter 3: Environmental Program Summary
- *Environmental Monitoring and Reporting*
  Chapter 4: Air Quality
  Chapter 5: Surface Water
  Chapter 6: Groundwater
  Chapter 7: Sanitary Sewer
  Chapter 8: Soil and Sediment
  Chapter 9: Vegetation and Foodstuffs

Chapter 10: Radiation Dose Assessment
Chapter 11: Quality Assurance

An outline precedes each chapter to assist the reader in selecting or finding specific topics. This outline lists all sections, figures, and tables found in the chapter.

The report includes a list of references, a list of acronyms and abbreviations, a glossary, and three appendices. Appendix A contains Berkeley Lab's annual compliance report required by the U.S. Environmental Protection Agency's (US/EPA) NESHAPs (National Emission Standards for Hazardous Air Pollutants) regulation.[1] Appendix B contains a list of persons to whom volume I of the report is officially distributed. Appendix C, printed in volume II, contains all original analytical data used to summarize the environmental monitoring results in chapters 4–10. Volume II is available on request (for details, see preface).

Data presented in the report follow the Laboratory policy of using the International System of Units measuring system, more commonly referred to as the metric system. For the convenience of readers accustomed to seeing data in the more traditional inch-pound system of measures, those values either are explicitly displayed or can be calculated with an accompanying conversion factor. The last section of the glossary contains a more complete set of conversion factors.

Both volumes of this report can be accessed on the Web using the index found on the Berkeley Lab home page, which is located at http://www.lbl.gov. 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 electronic version of this report. The format and content of this report satisfy the requirements of U.S. Department of Energy (DOE) Order 231.1, Environment, Safety and Health Reporting,[2] and the contract between the University of California (UC) and DOE.[3]

§1.2 II. ENVIRONMENTAL PROGRAM PERFORMANCE

Berkeley Lab recognizes the need to protect its workers, the public, and the environment from any adverse impacts caused by its research or support activities. To do so, it has established a comprehensive environmental program that must be followed by everyone working at the Laboratory. This program covers the following subject areas:

- Air quality;
- Water quality;
- Hazardous and radioactive materials;
- Waste management;
- Waste minimization/pollution prevention; and
- Soil/groundwater characterization and remediation.

Environmental services available to the Laboratory and its employees include regulatory compliance oversight and training, technical and permit assistance, emergency response, regulatory reporting, and other liaison activities involving regulatory agencies. Permitting, inspecting, and performance ranking are discussed briefly below. For further discussion of the compliance or performance status of the entire environmental program, see chapter 3.

§1.3 A. Permitting

At the end of 1997, Berkeley Lab held 24 environmental operating permits from various regulatory agencies:

- Air emissions (nine permits);
- Hazardous waste handling and treatment operations (two permits);
- Stormwater discharges (one permit);
- Underground storage tanks (eight permits); and
- Wastewater discharges (four permits).

§1.4 B. Violations, Findings, and Incidents

Twenty-six inspections of Berkeley Lab's environmental programs occurred during 1997, with no report of violations issued from these inspections by regulatory agencies. Three minor incidents involved administrative deficiencies in waste programs, but these incidents did not pose a danger to humans or the environment or result in issuance of a violation by an agency. For further discussion of these incidents, see §§3.5, 3.17.

§1.5 C. Performance Measures

To determine a program's effectiveness, an objective assessment must be made to measure performance against set criteria. Since 1994, the operating contract between UC and DOE has required Berkeley Lab to perform such an assessment of its environmental program (one of nine program areas) each year, using criteria and measures developed jointly by Berkeley Lab, UC, and DOE. Each year brings the opportunity for improvement on these measures, and 1997 was no exception.

Historically, performance measures have focused on "outcomes," such as the number of violations or the radiation dose to the public. Current environmental program outcome measures include:

- Radiation Protection of the Public and the Environment;
- Tracking Environmental Incidents; and
- Waste Reduction and Recycling.

From possible ratings of "outstanding," "excellent," "good," and "no ranking," Berkeley Lab achieved a rating of "excellent" on the first outcome measure and "outstanding" on the other two for the 1997 evaluation period.[4]

Although outcome measures still provide valuable information, "process" measures were added in 1997 to determine a program's ability to manage the Laboratory's environmental compliance. Current process measures, which will first be evaluated in 1998, include:

- Radiation Protection of the Public and the Worker; and
- Waste Minimization, Pollution Prevention, and Protection of the Environment.

For additional information on the performance review program, see §§3.28–3.31.

§1.6 III. ENVIRONMENTAL MONITORING

Berkeley Lab's monitoring program for environmental media 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.

The Environmental Monitoring Plan[5] developed and maintained by the Laboratory provides the rationale behind the monitoring program, which consists of both radiological and nonradiological elements.

§1.7 A. Radiological Monitoring

Berkeley Lab devotes a large part of its monitoring program to efforts intended to satisfy agencies and the public that radiological material from its activities affects people and the environment at levels well below standards established by appropriate regulatory agencies. The Laboratory monitors the release of two types of radiation: (1) penetrating radiation from ionizing sources such as accelerators and (2) dispersible radionuclides from a wider range of laboratory research activities. Specially designed shielding blocks are in place to control the release of penetrating radiation into the environment, and special high-efficiency exhaust system filters capture nearly all emissions of dispersible radionuclides into the atmosphere.

The primary radiological compliance standards affecting the Laboratory are based on the estimated maximum dose that a member of the public would receive from both direct penetrating radiation and dispersible radionuclide activities coming from the site. For 1997, this maximum annual dose to an individual was calculated at 0.011 millisieverts (mSv) (1.1 millirem (mrem)) or only about 1% of the applicable DOE radiological standard of 1 mSv/yr (100 mrem/yr).[6] This estimate is also about 0.4% 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).[7] Figure 1-1 shows that Berkeley Lab ranks as a minor contributor to the dose received by a typical member of the public from other contributing sources of radiation (i.e., natural terrestrial background, medical, and consumer products).

Berkeley Lab also estimates the cumulative dose impact from its penetrating and dispersible radiological activities to the entire population found within a 80-kilometer (50-mile) radius of the Laboratory. Although no regulatory standard exists for this measure, this so-called collective population dose is the sum of all individual doses (i.e., ranging from a maximum of 0.011 mSv near the site boundary to a minimum of 0 at an 80-kilometer distance) within the specified region. The value of this parameter is in assessing the Laboratory's goal of keeping the impact from its activities to as low as reasonably achievable. The collective population dose for 1997 was estimated at 0.023 person-Sv (2.3 person-rem) or about one-thousandth of one percent of the dose that the population within this region received from background radiation. For further discussion

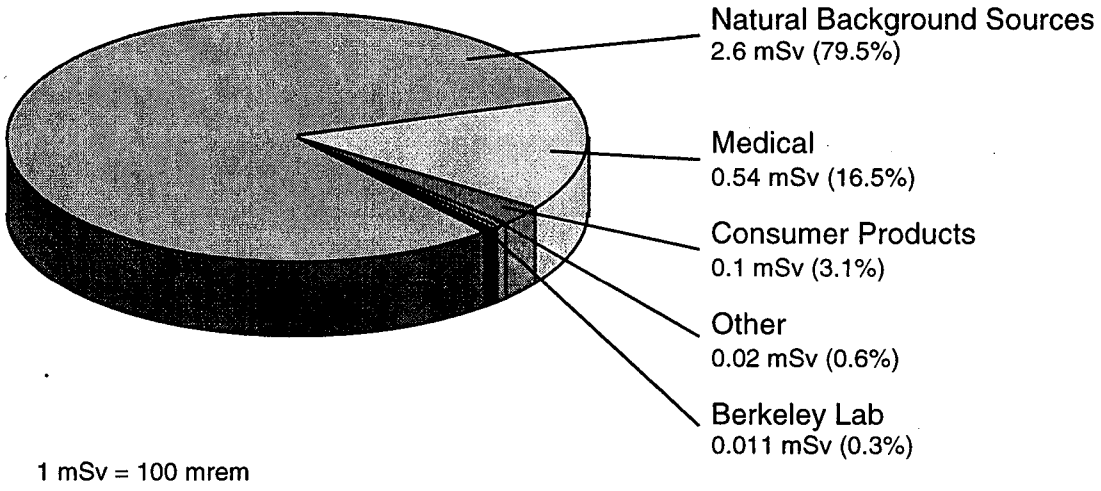


Figure 1-1 Typical Radiation Doses Received by Public, Including Maximum Contribution from Berkeley Lab

of the estimated dose impacts to the neighboring community from both direct and dispersible radiation, see chapter 10.

Dispersible radionuclide sources are subject to a separate regulatory standard. The US/EPA has set 0.1 mSv/yr (10 mrem/yr)[8] as the maximum allowable dose to the public from all exposure pathways (e.g., inhalation, ingestion) resulting from airborne releases of radionuclides. The estimated dose from all airborne radionuclides released from the site for 1997 was 0.0016 mSv (0.16 mrem), with tritium accounting for nearly 90% of that amount. This dose is about 2% of the US/EPA limit and only about 15% of Berkeley Lab's total dose.

The water, groundwater, soil and sediment, and vegetation monitoring programs also gather results on radiological parameters in these media. In nearly all cases, results for 1997 for each parameter were below or near analytical detection limits. Analyses from each media are further described in their respective chapters.

§1.8 B. Nonradiological Monitoring

Berkeley Lab's nonradiological monitoring program focuses primarily on waterborne media. The one exception is the soil and sediment program, although the results from this program can provide useful information for understanding migration of contaminants to either surface water or groundwater.

Under the requirements of the four wastewater discharge permits[9] issued to the Laboratory by the East Bay Municipal Utility District, Berkeley Lab must sample for metals, toxic organics, and other specified parameters in the sanitary sewer system on specific dates during the year. In 1997, all wastewater discharge levels were below permit limits. For details on the wastewater discharge sampling program, see chapter 7.

Stormwater discharges at Berkeley Lab are authorized under a general permit[10] issued by the State Water Resources Control Board. Stormwater discharges are regulated

differently from wastewater in that no specific discharge limits are cited in the general permit. References in the permit to the Water Quality Control Plan (Basin Plan)[11] 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 near sample detection limits. For the results from stormwater sampling efforts throughout the year (along with the results from sampling of rainwater, creeks, lakes, and hydraugers), see chapter 5.

For a number of years, groundwater monitoring by Berkeley Lab's site restoration program has identified eight groundwater contamination plumes on site. The groundwater in the vicinity of the Laboratory is not a source of drinking water. These plumes are categorized into the following four types:

- Volatile organic compounds (four plumes);
- Fuel (two plumes);
- Freon (one plume); and
- Tritium (one plume).

The program 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 agencies quarterly, along with other program developments and planned activities. For further discussion of this sampling program, see chapter 6.

Soil and sediment monitoring is not required by regulatory agencies. The Laboratory undertakes this effort as part of its overall objective of assessing the impact of its activities on the surrounding environment. The current 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. It is not uncommon to observe elevated results for this parameter in an urban setting. For more on Berkeley Lab's impact on soil and sediment, see chapter 8. The Laboratory's nonradiological environmental surveillance program for 1997 did not include elements for ambient air or vegetation and foodstuffs. This approach is consistent with regulatory requirements and the overall risk on the environment of Laboratory operations.

§1.9 IV. SUMMARY

Berkeley Lab's mission 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 nonradiological activities are thoroughly monitored to assess or verify their potential impact on the environment. The results presented in this report confirm that Laboratory activities in 1997 resulted in levels that are far below environmental protection and compliance standards.

2
Introduction

§2.1 I. HISTORY

Berkeley Lab was founded by Ernest O. Lawrence in 1931 on the Berkeley campus of the University of California. It was the first of the Department of Energy national laboratories. Winner 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.

Today, team science is still the driving force behind Berkeley Lab's success. Its employees 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 8 kilometers (5 miles) east of San Francisco Bay (see Figure 2-1) on 479 hectares (1,183 acres) of land owned by the University of California. The Laboratory's 80-hectare (200-acre) main site is under long-term lease to DOE.

The main site lies in the hills above the UC Berkeley campus, on the ridges and draws of Blackberry Canyon (which forms the central part of the site) and Strawberry Canyon (which forms the southern boundary). The Laboratory's hillside location, with elevations ranging from 200 to 330 meters (650 to 1,000 feet) above sea level, affords dramatic views of nearby San Francisco Bay and its surrounding urban areas. The western portion of the site is in Berkeley, with the eastern portion in Oakland. Berkeley is a residential, university, and industrial city that is internationally known for the presence of the University of California at Berkeley (see Figure 2-2). The population of Berkeley was estimated at 106,000 in 1997. To the south and east of Berkeley is Oakland, the urban hub of the East Bay. Oakland is a cultural, commercial, governmental, and transportation center with a population of approximately 387,000 (1997).

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

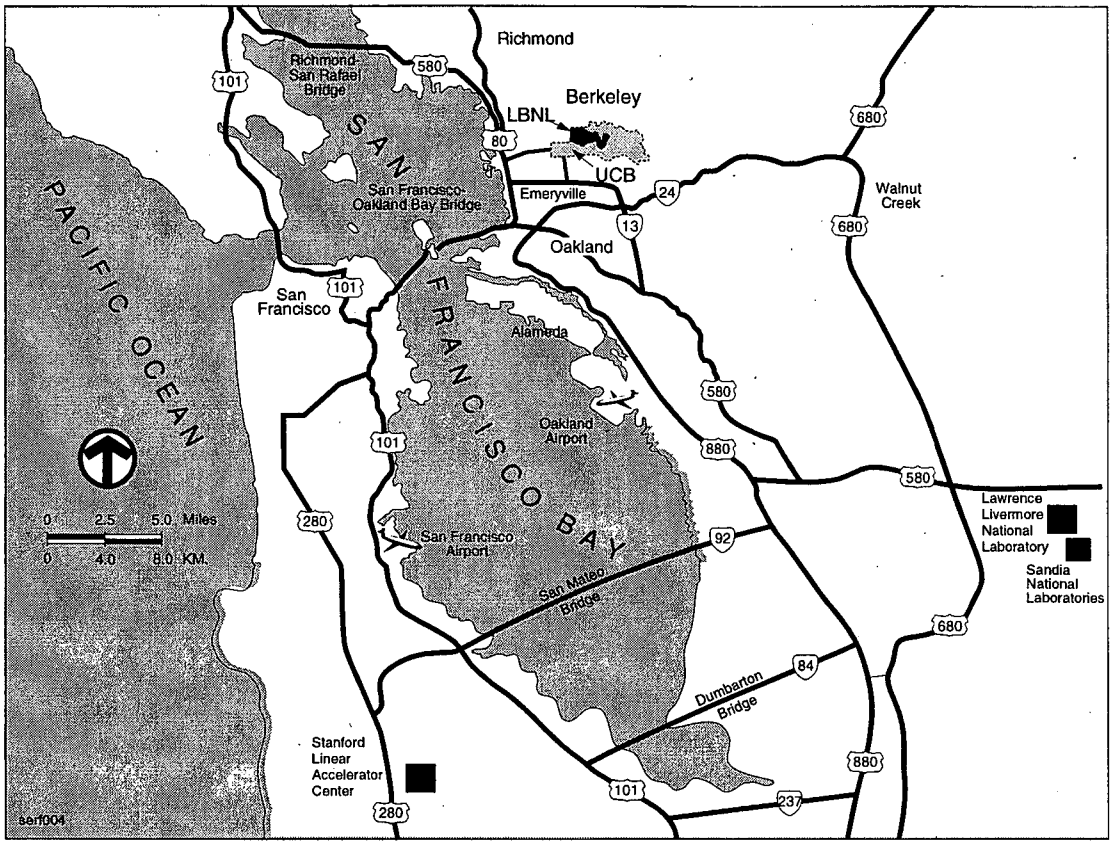


Figure 2-1 San Francisco Bay Area Map

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

The most recent staffing figures for Berkeley Lab indicate almost 3,200 full- and part-time employees. Additionally, the Laboratory provided facilities for approximately 1,900 guests who worked at the site for varying lengths of time in 1997. About 100 of the Laboratory's scientists also serve as faculty members at UC Berkeley or UC San Francisco.

Berkeley Lab research and support activities are conducted in structures having a total area of 186,000 gross square meters (2,000,000 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 offsite buildings. The first onsite building was constructed in 1940. There are 76 permanent buildings and 113 trailers and temporary buildings on the main site. Figure 2-4 shows the Berkeley Lab space distribution for 1997.

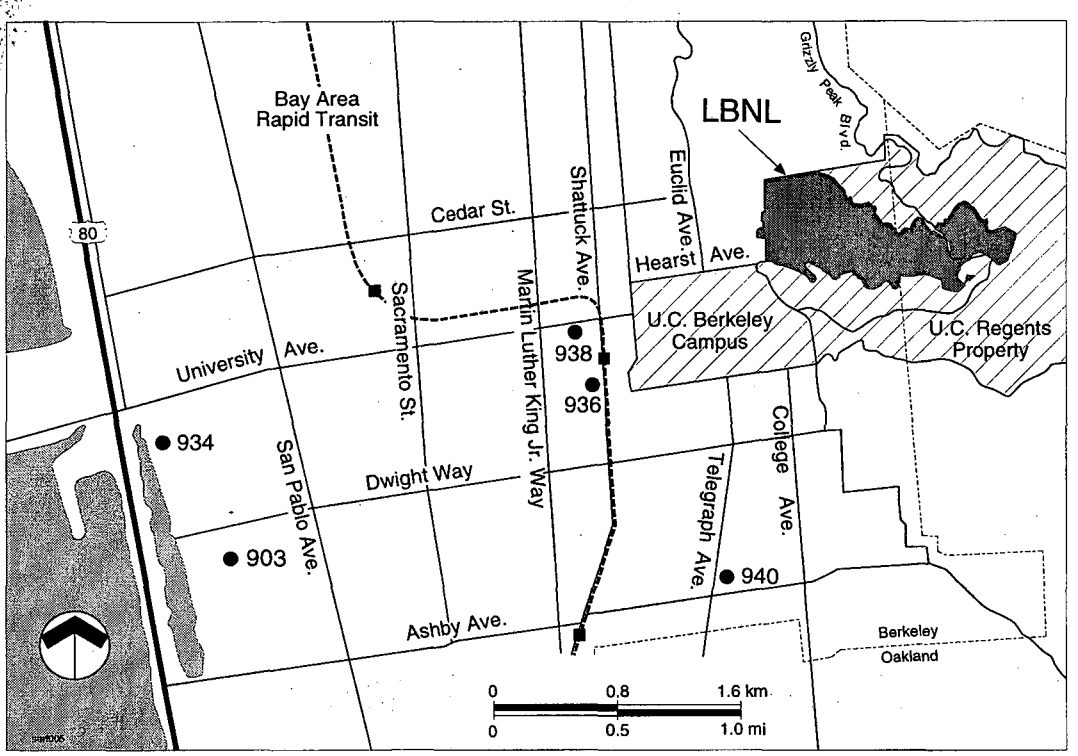


Figure 2-2 Vicinity Map

The offsite space, excluding campus space, is based in six buildings. Five of the six are located in Berkeley:

- Building 903 (warehouse and receiving on 7th Street);
- Building 934 (Dymo Building near Aquatic Park, with laboratory space used primarily by Life Sciences);
- Building 936 (Hink's Building on Allston Way, housing Berkeley Lab's financial services);
- Building 938 (Promenade Building on University Avenue, housing Human Resources and Information Systems and Services);
- Building 940 (Cholesterol Research Center on Telegraph Avenue in Berkeley, used by the Life Sciences Division); and
- Building 960 (The Portals in Washington, D.C., with office space available for general Berkeley Lab use as well as specific use by the Environmental Energy Technologies Division).

§2.4 C. Water Supply

All the Laboratory's water is supplied by the East Bay Municipal Utility District (EBMUD). There are no drinking water wells on site. The primary source of treated water is EBMUD's Shasta Reservoir, located in the Berkeley hills to the north of

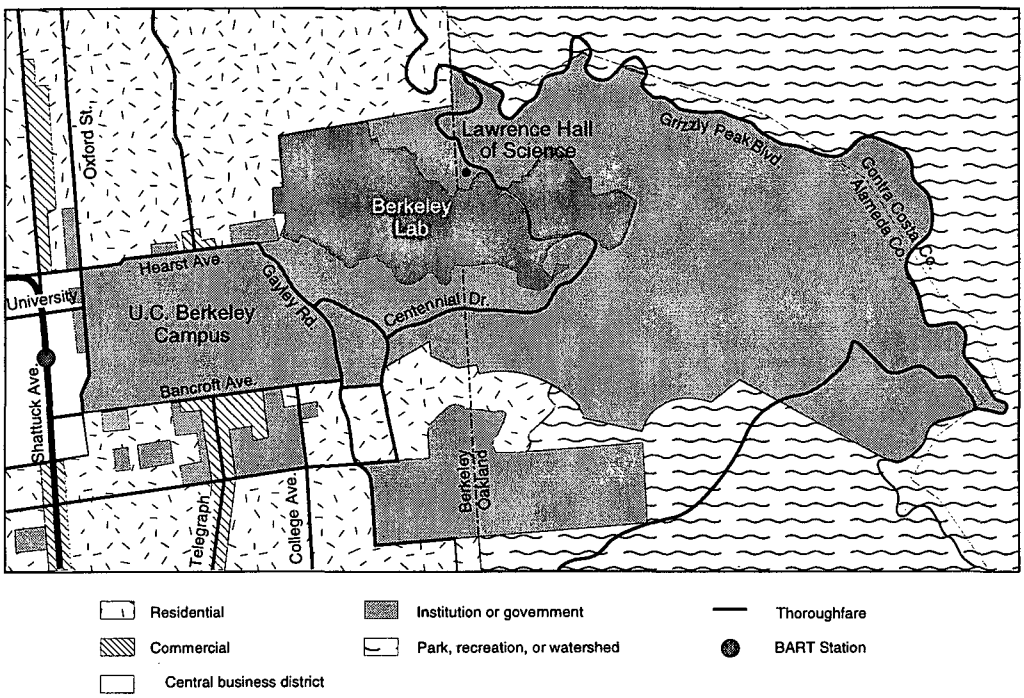


Figure 2-3 Adjacent Land Use

Berkeley Lab. A secondary source is EBMUD's Berkeley View tank, also located north of the Laboratory. All Laboratory water is supplied by gravity feed.

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, and treatment plants, and pumping stations. EBMUD tests for contaminants and meets disinfection standards required by the Safe Drinking Water Act.

The water 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

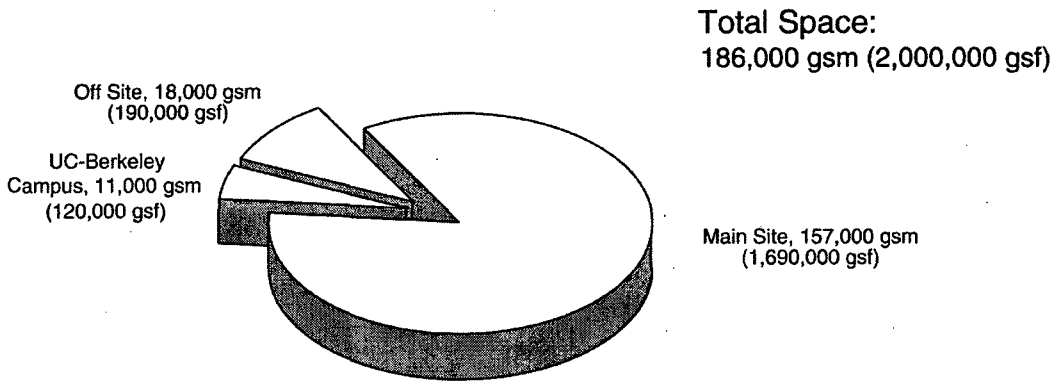


Figure 2-4 Space Distribution

View sources and two 760,000-liter (200,000-gallon) onsite storage tanks. The entire system has sufficient capacity to meet the flow-rate and duration requirements for fire protection.

III. ENVIRONMENTAL SETTING

§2.5 A. Meteorology

Characterized as Mediterranean, the climate at the site is influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west and the sheltering effects of the hills that stretch along the eastern shore of San Francisco Bay. These physical barriers contribute significantly to the site's relatively cool, dry summers and warm, wet winters. The mean annual temperature for 1997 was 13.4°C (56°F). The coolest month occurred in January, with an average temperature of 9.2°C (48.5°F), while September was the warmest month at 17.8°C (64°F). The yearly extremes ranged from a high of 32.4°C (90°F) on September 23 to a low of –0.6°C (31°F) on January 14. Figure 2-5 traces the monthly temperature extremes for the year, recorded at the onsite weather station.

Onsite wind patterns change little from one year to the next. These patterns reveal two distinctively different meteorological influences. The most common wind pattern occurs when larger-scale high-pressure systems block storm currents from reaching the area, bringing the fair weather typical of California. The resultant winds at the Laboratory are highly predictable, with daytime westerly winds blowing off the Bay and moderating

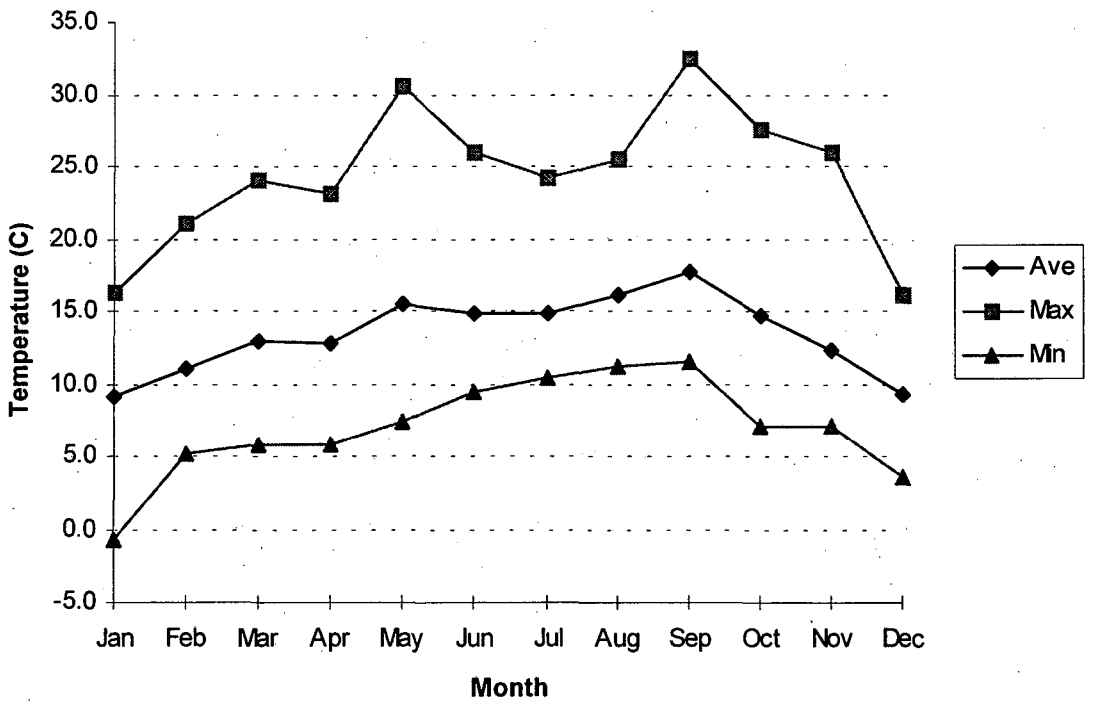


Figure 2-5 Temperature Summary by Month

temperatures relative to locations found east of the hills in the interior valleys. Nighttime winds ordinarily reverse direction, driven by lighter southeasterly drainage winds that originate in the East Bay hills.

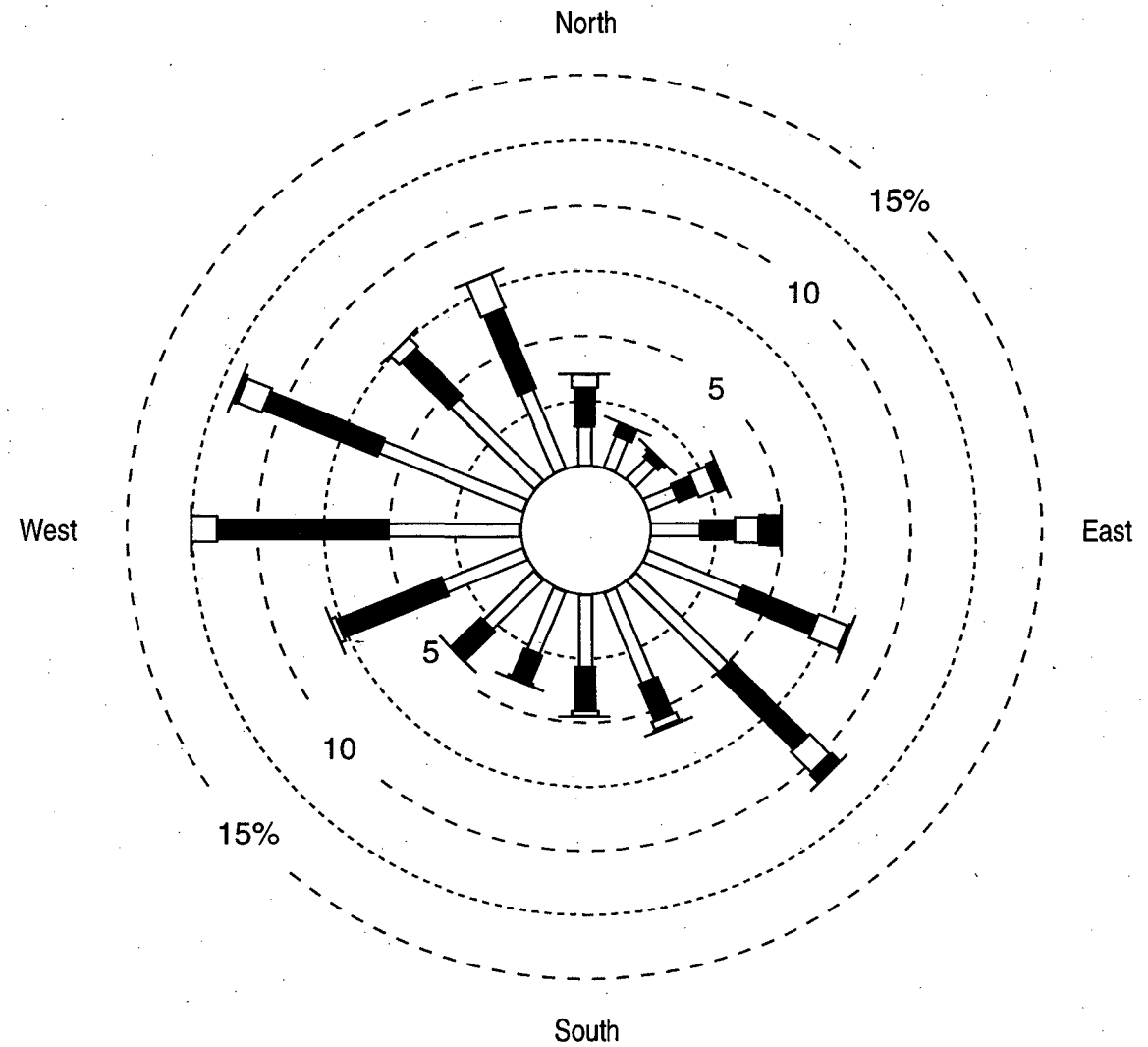
The other predominant wind pattern occurs when storm systems pass through the region. These systems arise most frequently during the winter months. South to southeast winds pass over the site before storms, shifting to the west or northwest after passage of each storm. Winter storms usually bring the highest wind speeds of the year. A graphical summary of the annual wind patterns, called a windrose, visually illustrates the high frequency of the two predominant patterns. The windrose for 1997 is displayed in Figure 2-6. The average wind speed for the year was 2.1 meters per second (4.6 miles per hour). The maximum wind speed during 1997 occurred on November 18, when winds gusted to almost 20 meters per second (45 miles per hour).

Yearly precipitation is totaled over a period called the water year, which runs from October 1 to the following September 30. The storms of the winter months produce nearly all the precipitation that the Laboratory receives during the water year. The average annual precipitation at the site since the 1974/1975 water year is about 72 centimeters (28 inches). For the last five water years, which includes the record-setting 1997/1998 water year when over 152 centimeters (60 inches) of precipitation fell, annual precipitation has been above normal. The annual average precipitation since 1993/1994 has been 96 centimeters (38 inches). Figure 2-7 compares 1997 water-year precipitation monthly totals to the average since 1974/1975.

§2.6 B. Vegetation

In its landscape management program, Berkeley Lab seeks to respect and encourage as much as possible the native and naturalized vegetation found in the hills. Another goal of the program is to revegetate aging areas to ensure long-term continuity in the Berkeley Lab landscape. Some of the issues considered include (1) screening portions of Berkeley Lab buildings from public view through tree height planning, (2) blending the site with the hillside, (3) slope stability, (4) habitat size, (5) connections between habitat areas, (6) longevity and maintenance requirements, and (7) species richness. Figure 2-8 shows vegetation types at Berkeley Lab.

The Laboratory has a nationally recognized wildland fire management program to reduce and control fire hazards from vegetation. Berkeley Lab updated and intensified its fire management efforts after the major fire in October 1991 that occurred in the Berkeley/Oakland Hills to the south. The basic strategy of the program involves using (1) natural vegetation patterns to establish or maintain a low-fuel fire break to the east of the Laboratory (the direction from which come the hot, dry "Diablo winds") and (2) effective management of vegetation throughout the site to reduce the risk of multiple ignitions from firebrands. Berkeley Lab works with the East Bay Hills Vegetation Management Consortium (the neighboring cities of Berkeley and Oakland, the East Bay Regional Park District, the East Bay Municipal Utility District, and UC Berkeley) to consider improvements in fire defense in the general vicinity. Figures 2-9 and 2-10 show the significant reduction in estimated flameheights from onsite vegetation between the years 1995 and 1997 as a result of the Laboratory's fire management program. Additional



Note: wind direction vane is the direction the wind is blowing from

Figure 2-6 Annual Wind Patterns

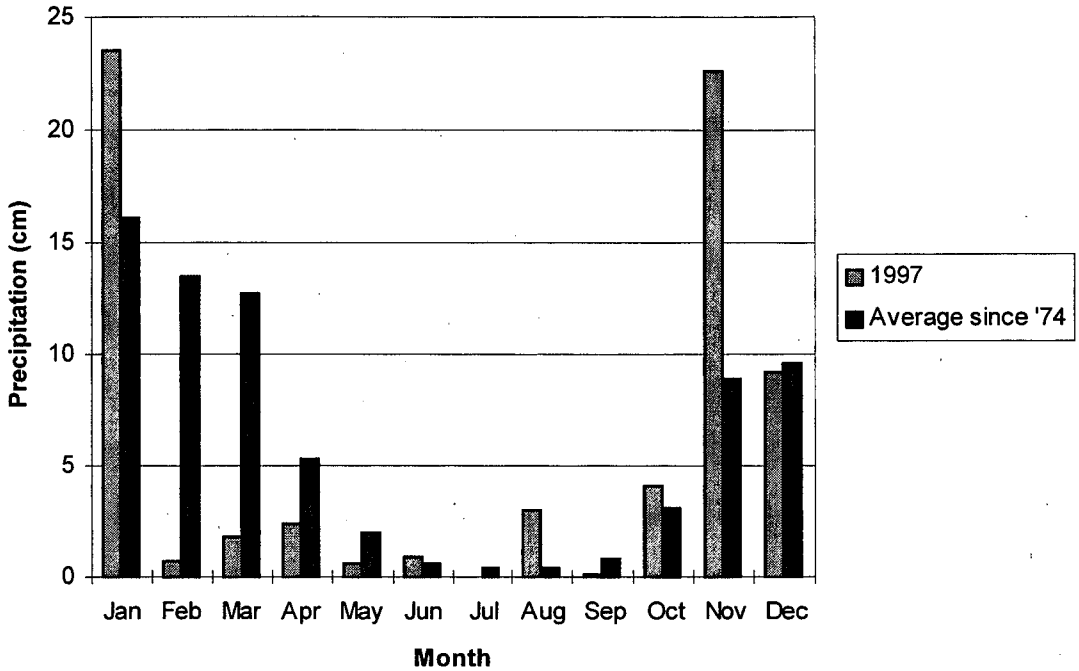


Figure 2-7 Rainfall by Month

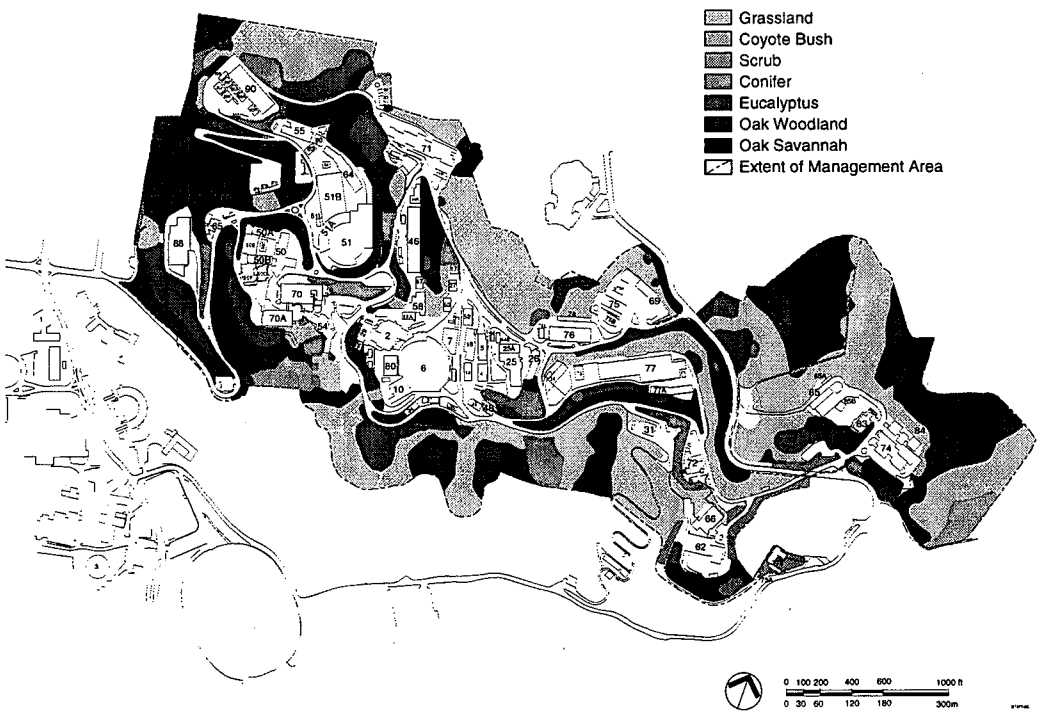


Figure 2-8 Vegetation Types

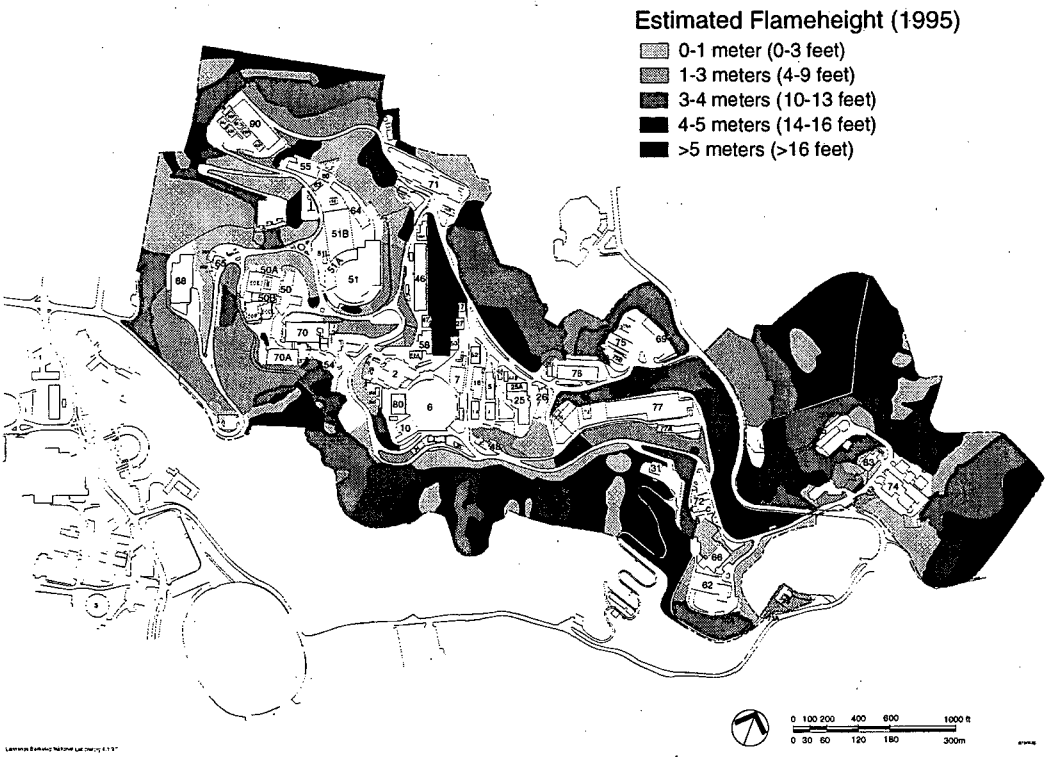


Figure 2-9 Estimated Flameheights from Vegetation (1995)

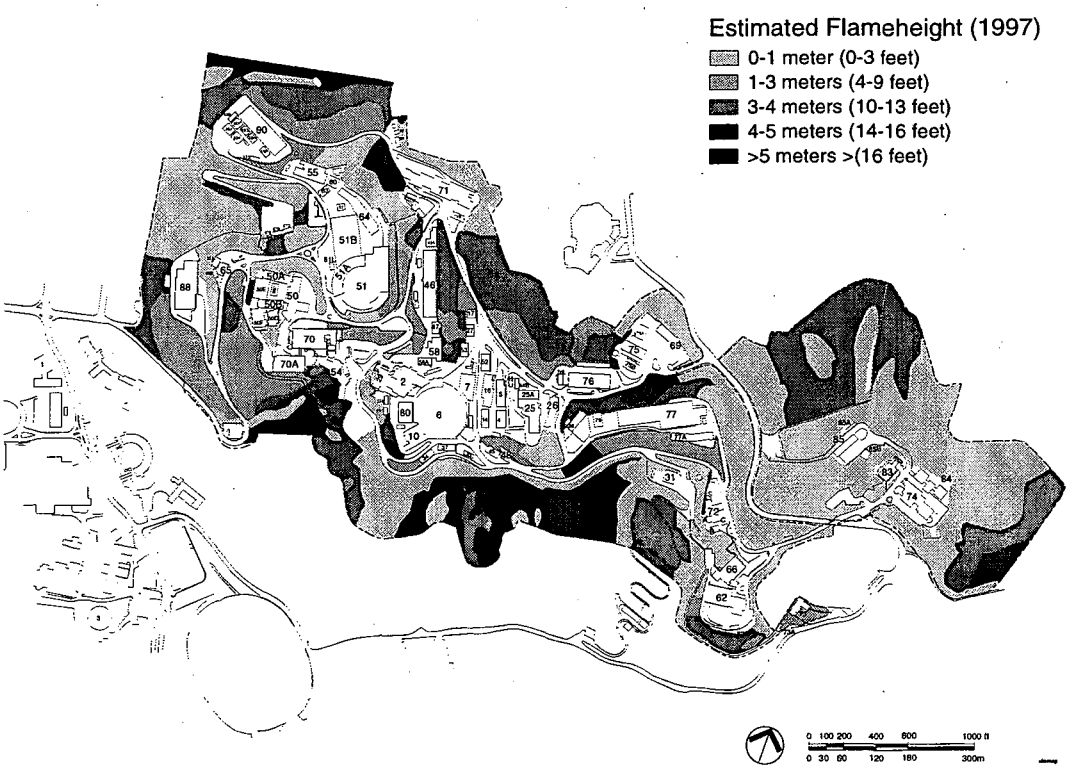


Figure 2-10 Estimated Flameheights from Vegetation (1997)

equally impressive reductions in flameheights from the ongoing efforts of this program are projected by the year 2000. "Flameheight" is defined as the height of the flame above ground level.

§2.7 C. Wildlife

In general, Berkeley Lab supports habitats and associated wildlife typical of disturbed portions of the Berkeley/Oakland hills. Approximately 120 species of birds, mammals, and reptiles/amphibians, none of which are threatened or endangered, exist on the site.

The Laboratory's grasses and brushlands provide cover, food, and breeding sites for this wildlife, the dominant mammals of which are Columbian blacktail deer. Its tree stands offer nesting sites for many bird species. In general, the sparse tree understory offers limited wildlife habitat.

§2.8 D. Geology

Berkeley Lab is underlain by sedimentary and volcanic rocks whose interbedding, faulting, and folding have created a complex geological structure. In general, the bedrock is relatively weak and has weathered deeply, forming soils several meters thick. Three major geologic formations have been identified at the site:

- The western and southern parts are underlain by moderately to well-consolidated upper Cretaceous marine sediments known as the Great Valley Group. These formations consist of shales, mudstones, siltstones, sandstones, and conglomerates, interspersed among moderately spaced fractures.
- The upper Miocene or lower Pliocene Orinda formation overlies the Cretaceous rocks and underlies most of the site. It consists of claystones, mudstones, siltstones, sandstones, and conglomerates of relatively low strength and hardness. Although similar in materials to that of the Great Valley Group, the Orinda formation is of nonmarine origin.
- The volcanic 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 overlies the Orinda formation. In some areas, the volcanic rocks of the lower Moraga are interbedded with sedimentary rocks similar to the Orinda. The Moraga formation consists of basalt and andesite lava flows, agglomerates, and pyroclastic tuffs. This material is typically highly fractured, jointed, or brecciated.

The Claremont formation and the San Pablo Group are two additional geologic formations found on site, but only in the far easternmost area and of limited size.

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 in some of the ridges and high ground, and fills up to tens of meters thick are present in some of the original ravines and depressions.

Landslide deposits appear in numerous locations within the site. Many of these slides are related to the contact between the Orinda and the Moraga formations and/or to cutting and filling of the original topography. A soft clay bed up to 0.3 meter (one foot) thick

typically exists at the Orinda/Moraga contact. Slide planes develop readily in this material. During the past 20 years, the Laboratory has carried out a successful program of slope stabilization (including shallow dewatering wells, vegetation cover, and soils management) to reduce the risk of property damage caused by potential soil movement.

§2.9 E. Hydrogeology

The 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, while the sedimentary rocks consist of interbedded impervious 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 relation between the high-permeability volcanic rocks and the low-permeability sedimentary rocks is complex due to paleotopography, interbedding, faulting, and folding.

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 fractures and low-matrix permeability 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 the Orinda formation usually underlies the Moraga formation, it forms a relatively impermeable boundary for groundwater flow. Zones of coarser-grained, more permeable sandstone and conglomerate channel fills occur locally in the Orinda formation.
- 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. Groundwater flows primarily through fractures in this formation. The presence of low-permeability interbeds of fine-grained sediments, as well as zones with little fracturing, create perched water conditions at many locations.

The fractured bedrock underlying the Laboratory 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.

3
Environmental Program Summary

§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 1997.

§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 the EH&S Division for 1997 is shown in Figure 3-1.

The Environmental Protection Group (EPG) oversees sitewide environmental compliance activities, provides technical assistance to Laboratory staff, and assesses site characterization and cleanup. Environmental monitoring programs are an important component, providing critical information to demonstrate compliance and make programmatic decisions. For 1997 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. In addition to managing day-to-day activities at the Hazardous Waste Handling Facility, the group is responsible for ensuring that Laboratory waste is properly characterized and providing assistance to the Laboratory community on hazardous waste issues, with particular emphasis on incorporating opportunities for pollution prevention or waste minimization.

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. RPG also manages shipping and receipt of radioactive materials, accountability for the inventory of radiation sources at the Laboratory, and radiation monitoring of workers, workspaces, and the environment (penetrating radiation only).

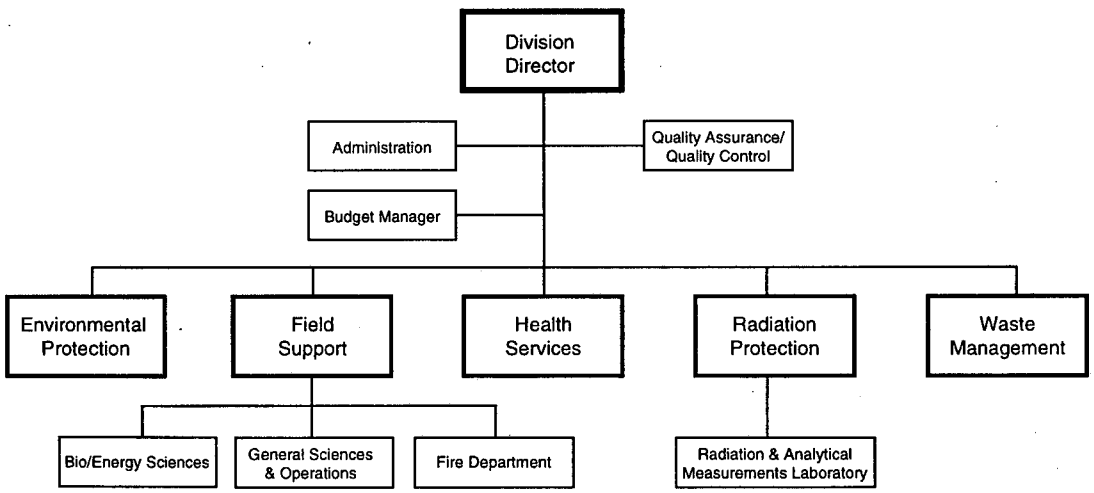


Figure 3-1 Berkeley Lab Environment, Health, and Safety Division Organization

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 at the end of the year by area of environmental activity.

§3.4 B. Summary of Audits and Inspections

The agencies regulating the environmental programs at Berkeley Lab have a legal responsibility to implement a periodic inspection program. Table 3-2 lists the inspections by these agencies that occurred at Berkeley Lab during 1997. The list includes self-monitoring inspections conducted by Berkeley Lab as required by EBMUD wastewater discharge permits because these events expose the Laboratory to potential regulatory violations. None of the regulatory reviews produced any violations requiring the Laboratory to pay a fine or incur other formal penalties.

Table 3-1 Environmental Permits Held by Berkeley Lab at End of 1997

Type of permit	Issuing agency	Description	Number of permits	Section for more information
Air quality	BAAQMD	Various activities with atmospheric emissions	9	§3.8
Hazardous waste	DTSC	Hazardous Waste Handling Facility operations and hazardous waste treatment units	2	§3.17
Stormwater	SWRCB	Sitewide stormwater discharges	1	§3.24
Underground storage tank	City of Berkeley	Underground storage tanks containing petroleum products	8	§3.20
Wastewater	EBMUD	Sitewide and operation-specific wastewater discharges to sanitary sewer	4	§3.24

Table 3-2 Environmental Audits, Inspections, and Appraisals in 1997

Organization	Inspection title	Start date	Length (days)	Violations
City of Berkeley/DTSC	Fixed Treatment Units	July 23	1	0
DHS	Medical Waste Program	March 5	1	0
DTSC	Hazardous Waste Handling Facility	June 16	2	0*
EBMUD	Wastewater Monitoring Inspections at B25 Treatment Unit	February 14	1	0
		July 22	1	0
	Wastewater Monitoring Inspections at Hearst and Strawberry Outfalls	February 18	1	0
		March 24	1	0
		June 24	1	0
		July 14	1	0
		November 4	1	0
	Wastewater Monitoring Inspection at B77 Treatment Unit	March 24	1	0
		June 24	1	0
		July 17	1	0
		November 21	1	0
LBNL	EBMUD Self-Monitoring Inspections at Hearst and Strawberry Outfalls	January 6	1	0
		March 10	1	0
		May 12	1	0
		June 9	1	0
		July 14	1	0
		November 17	1	0
	EBMUD Self-Monitoring Inspection at B77 Treatment Unit	January 8	1	0
		April 7	1	0
		July 7	1	0
		November 3	1	0
	EBMUD Self-Monitoring Inspection at B25 Treatment Unit	May 9	1	0
		December 4	1	0
US/NRC	Simulated Regulation Under a Pilot Appraisal on External Regulation	December 8	4	0

*DTSC identified four minor hazardous waste labeling deficiencies that Berkeley Lab promptly corrected. DTSC was immediately notified of these corrective actions and did not issue a report of violation.

§3.5 C. Summary of Reportable Environmental Incidents

Berkeley Lab filed three reports with DOE for minor environmental incidents in 1997 that qualified under the DOE occurrence reporting program.[1] No violations, injuries, accidents, or damage resulted from these incidents. Table 3-3 identifies these incidents and the sections that provide additional details on each incident.

Table 3-3 Summary of Environmental Incidents During 1997

Incident date	Reporting number	Description	Section for more information
January 22	SAN—LBL-EHS-1997-0001	Inaccurate characterization of low-level waste shipments	§3.17
June 6	SAN—LBL-EHS-1997-0002	Transfer of hazardous waste before final characterization	§3.17
June 20	SAN—LBL-EHS-1997-0003	Improper marking of low-level radioactive waste containers	§3.17

IV. PROGRAM REVIEW

§3.6 A. Air Quality (Clean Air Act)

The Clean Air Act[2] is the key statutory reference for federal, state, and local air pollution control programs. It classifies air pollutants into several main categories:

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

The State of California's own air pollution control program[3] gives it additional powers to control sources of air emissions. Berkeley Lab divides its air quality protection and compliance activities into two categories: radiological and nonradiological.

§3.7 1. Radiological

Radionuclides released to the atmosphere from Laboratory research activities must adhere to the standards in 40 CFR 61, Subpart H (National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities[4]) as well as DOE Orders 5400.1[5] and 5400.5.[6] Subpart H is part of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) program. US/EPA administers NESHAPs, while DOE administers Orders 5400.1 and 5400.5. Berkeley Lab has no radiological emission sources that need operating permits from US/EPA.

The vast majority of the Laboratory's radiological emissions are associated with research activities. Research projects typically are dynamic and have a limited duration. New projects may begin in different laboratory spaces and use different radionuclides. These changes affect both the emissions sampling strategy and sampling instrumentation.

To properly account for these changes, Berkeley Lab conducts a preliminary review of all projects that may release radionuclides. The review includes a determination of the dose to the nearest offsite member of the public following NESHAPs regulations and DOE EH-0173T[7] guidance. The assessment takes a conservative or overpredictive

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 US/EPA and is summarized in Table 4-2 (see §4.2). Results of the emissions-sampling and monitoring program are also presented throughout chapter 4. The Laboratory documents its NESHAPs compliance status with an annual report, which is attached to this report as Appendix A.

§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 1997, Berkeley Lab had nine activities with BAAQMD operating permits.[8] Operating permits are renewed annually, at which time BAAQMD also requests information required by the state's Air Toxics "Hot Spots" Information and Assessment Act of 1987.[9] For a list of operating permits held at the end of 1997, see Table 3-4. The most recent annual inspection recategorized a number of previously permitted operations to exempt status, reducing the number of permitted sources significantly from the preceding year.

Emphasis on reducing the use of ozone-depleting substances (ODSs) has increased during the 1990s. Berkeley Lab continues to mark significant progress in its goal of eliminating ODSs from the site. The largest remaining source of ODS usage onsite is a vapor degreasing system located in the Ultra High Vacuum Cleaning Facility (UHVCF)

Table 3-4 BAAQMD Permitted Air Emission Sources Renewed in 1997

BAAQMD category	BAAQMD source #	Description	Building	Abatement type
Gasoline dispensing	76	Gasoline pumps	76	Vapor recovery
Miscellaneous	159	Vacuum coating chambers	25	Baghouse
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	92	Vapor/spray degreaser	77	Refrigeration
	97	Sandblast booth	77	Baghouse
	140	Vapor degreaser	52	—
	188	Wipe-cleaning	Site-wide	—

in Building 77. In anticipation of eventually removing this system from operation, the Laboratory began working with a new multistage ultrasonic cleaning system at this facility later in the year. Berkeley Lab will assess the feasibility of removing the present vapor degreaser after initial parallel comparison testing of the two systems against stringent precision cleaning specifications is completed. The Laboratory anticipates completion of testing sometime in 1998.

§3.9 B. Environmental Restoration (Comprehensive Environmental Response, Compensation, and Liability Act)

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 are low and do not warrant a CERCLA-based investigation. In 1997, a local citizens group formally requested that US/EPA reconsider this decision. The agency is reviewing all environmental data, including that generated since the earlier decision, and is expected to make an updated determination in 1998.

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 (RCRA).[11] Because these areas of interest relate to groundwater protection, all monitoring efforts for the year are contained in chapter 6.

The Laboratory is also subject to the requirements of CERCLA for its offsite activities. There were no incidents of this nature to report during the year.

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] These requirements include:

- Notification from facilities handling greater than threshold amounts of extremely hazardous materials;
- Emergency notification of certain hazardous-material releases;
- For facilities subject to MSDS requirements, preparation of an annual emergency and hazardous chemical inventory form (Hazardous Materials Management Plan) and an acutely hazardous materials registration form; and
- For facilities using, handling, or storing more than specified amounts of certain toxic chemicals, a report of annual emissions.

Berkeley Lab activities addressing these requirements are summarized in the following three sections.

§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 1997 exceeded the TRI criterion of 4,536 kilograms (10,000 pounds) for a listed substance, and therefore no Form R preparation was needed. Table 3-5 shows the highest usage levels of the chemicals from the Laboratory's assessment over the last several years, including several substances either recently removed from the TRI list by US/EPA or now listed by US/EPA for reasons of use or production not found at Berkeley Lab.

§3.12 b. Hazardous Materials Management 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 Management Plan (HMMP)[15] to the City of Berkeley each year, although federal sovereign immunity from such regulations has not been waived.

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

Substance	1993 (kg)	1994 (kg)	1995 (kg)	1996 (kg)	1997 (kg)
Acetone	475	495	—[a]	285[a]	—[a]
Chlorofluorocarbons	1305	130	—[b]	120	185[c]
Hydrochloric acid	—[d]	205	2722	468	—[e]
Isopropyl alcohol	—[d]	315	—[b]	294	493[e]
Methanol	—[d]	145	—[b]	158	260
Nitric acid	525	645	—[b]	1030	727
Sulfuric acid	4265	2195	—[a]	1161[a]	—[e]
1,1,1-Trichloroethane	1715	1565	1148	1023	1521

[a] Substance no longer required by US/EPA under this program.
[b] Usage for year less than US/EPA reporting threshold.
[c] Amount includes only 6 kilograms of Class I ozone-depleting substance released; remainder is considered Class II.
[d] Only seven major TRI chemicals reviewed in 1993.
[e] Substance not reportable because use at Berkeley Lab does not meet recently updated TRI use or production criteria for listing.

The 1997 HMMP 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 corresponding hazard lists for each building as well as 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)[16] for operations using acutely hazardous materials above certain thresholds established in 40 CFR Part 355. Berkeley Lab does not have any operations that contain hazardous substances above the threshold quantities, and therefore no RMPP documents are required for the site.

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

Passed by Congress in 1972, the Federal Insecticide, Fungicide, and Rodenticide Act[17] restricts the registration, sale, use, and disposal of pesticides. Pesticides, including insecticides and herbicides, are applied at the Berkeley Lab site by licensed contractors only. Insecticides are limited to as-needed application in and near buildings. 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 is one of the few regulations affecting Berkeley Lab that is still administered by a federal agency. 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 regulated PCB transformers. The remaining sources of regulated PCBs are primarily large low- and high-voltage capacitors. Less than 50 of these capacitors are still in use or storage, containing an estimated 190 kilograms (420 pounds) of regulated PCBs. The estimated volume of PCBs in electrical transformers is less than 1 kilogram (2.2 pounds). Figure 3-2 shows the trends in reducing regulated PCB transformers and capacitors from the site.

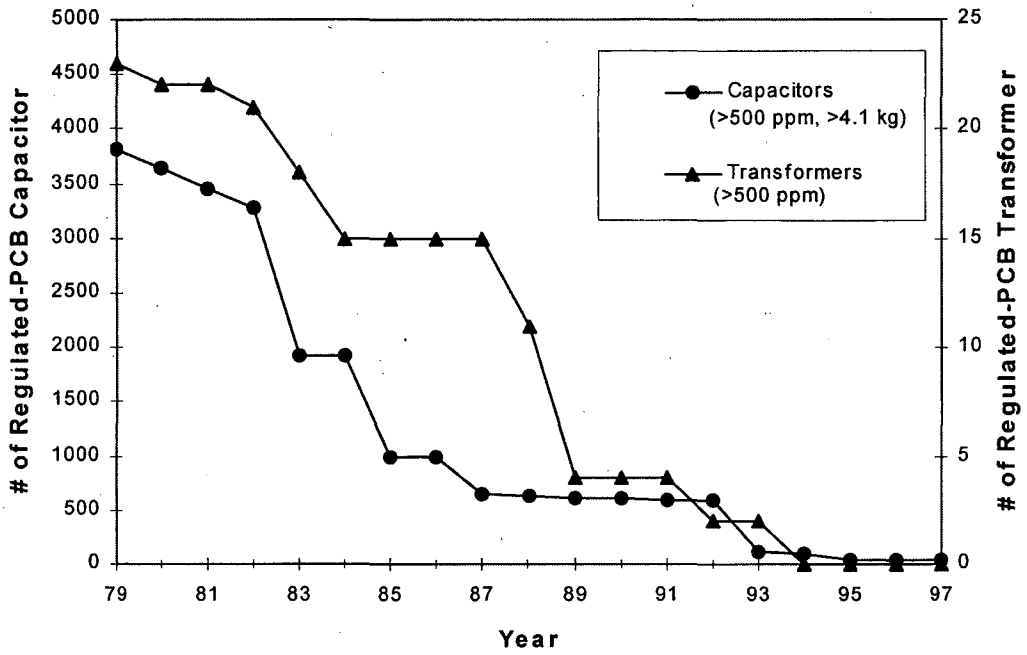


Figure 3-2 Trends in Eliminating Regulated PCBs

§3.16 D. Hazardous Waste (Resource Conservation and Recovery Act)

The primary goal of the Resource Conservation and Recovery Act of 1976 (RCRA)[19] is to ensure that hazardous waste management practices are conducted in a manner that protects human health and the environment. RCRA affects waste treatment, storage, and disposal activities at Berkeley Lab in three areas: hazardous waste (including the hazardous portion of mixed waste), medical waste, and underground storage tanks.

§3.17 1. Hazardous Waste

In California, DTSC administers the RCRA hazardous waste program. The California program incorporates the provisions of both the federal and state hazardous waste[20] laws. The state program includes both permitting and enforcement elements. The state's permitting program for hazardous waste treatment and storage facilities consists of five tiers. 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 HWHF[21] was approved by DTSC on May 4, 1993, and is valid for ten years. All Berkeley Lab's hazardous, radioactive, and mixed (radioactive and

hazardous) waste is packaged for transport to offsite disposal facilities. The permit allows for storage and simple treatment of certain hazardous and mixed wastes at the HWHF. Simple treatment includes neutralization, consolidation, solidification, and loose desensitization. Any change in operations must receive prior approval from DTSC. For example, the startup and transfer of operations into the new replacement HWHF that was completed in April 1997 had prior authorization from DTSC.

A permit modification request filed by Berkeley Lab remains under consideration by DTSC. This request asked for certain changes in waste streams, storage designations, treatment methods, training, and sampling. Details of the request have been included in earlier site environmental reports. A consent order by DTSC from May 1996 allows the Laboratory to continue HWHF operations under a revised set of permit conditions until DTSC decides on the requested modifications. That decision had been on hold pending a court decision on a lawsuit filed by a local citizen's group in June 1997. The lawsuit alleged that the Regents of the University of California (contract managers of Berkeley Lab) had failed to adhere to the requirements of the California Environmental Quality Act by not preparing a full environmental impact report covering the permit modification request. In June 1998, the court dismissed this lawsuit. At the time this report was prepared, DTSC had not yet responded with a decision on the permit request.

Berkeley Lab has an additional hazardous waste permit[22] to operate six 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 three are authorized to operate under the "permit-by-rule" tier. The level of treatment determines which tier applies. DTSC requests renewal of this permit each year. The Laboratory submitted the 1997 FTU renewal package to DTSC in April.

In June 1997, DTSC inspected the HWHF, a treatability study at the National Tritium Labeling Facility, and several waste storage areas around the site used by specific programs or operations. DTSC noted four minor labeling, storage, and characterization concerns. Berkeley Lab subsequently provided additional documentation to DTSC after the inspection supporting the acceptability of the work practices. DTSC has not issued a report of violation.

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

FTU	Building	Description of treatment	Permit tier
001	77	Metals precipitation and acid neutralization	Permit-by-rule
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

In July, DTSC also coordinated an inspection of several fixed treatment units with the City of Berkeley. Under the state's new Certified Unified Program Agency program, the City of Berkeley will administer the FTU regulations that affect the site. The inspection was limited to the fixed treatment units at Buildings 25 and 70A. DTSC asked that the daily log for the Building 70A FTU be modified to more clearly indicate that inspections of the treatment unit had occurred during each of the three daily shifts, even though this had already been the Laboratory's standard practice. Berkeley Lab revised the daily logs at all the fixed treatment units to unequivocally indicate the recording of the internal inspections. No other observations were made by DTSC or the City of Berkeley during the inspection.

Waste management permits and regulations require several reports for the year. Berkeley Lab prepared the Biennial Hazardous Waste Report for 1997[23] for DTSC. This report contains specific generator and transport information for all activities at the HWHF during the reporting year. In addition, Berkeley Lab prepared the annual waste reduction report[24] for DOE, also covering 1997. This report contains a detailed analysis of waste minimization efforts made by waste generators. The Laboratory generated quarterly reports on the inventory of mixed waste greater than one year old to meet a DTSC operating permit requirement. Quarterly mixed waste management reports were also prepared in accordance with the previously mentioned DTSC consent order. These reports 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] The STP documents the procedures and conditions used by Berkeley Lab to manage its mixed waste streams. Berkeley Lab prepares update reports that quantify the amount of mixed waste in storage at the end of a reporting period and the anticipated amount that will be placed in storage in the next five fiscal years. These updates are prepared twice each year covering the periods ending in March and September.

The Department of Energy'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. Three minor incidents during the year involving the HWHF led to notifications at the program's lowest possible grade (see Table 3-3 for summary):

- The first incident was discovered in January and involved the inaccurate radiological characterization of small amounts of low-level waste shipped to the Westinghouse Hanford Company's disposal site in Hanford, Washington, over a period of several years. Berkeley Lab had correctly quantified the total amount of activity in this waste, but inaccurately allocated the amounts to individual disposal drums. After improving program procedures to the satisfaction of the Hanford facility, Berkeley Lab was able to resume shipments to the Hanford disposal site in March 1997.
- The second incident occurred in early June, when a contractor at the HWHF transported a container of hazardous waste for offsite disposal before Berkeley Lab verified its final characterization. The Laboratory was able to retrieve the waste immediately. Berkeley Lab acted promptly to improve the oversight of its waste handling contractors.

- The final incident occurred later in June. A number of drums of waste were being prepared for shipment to the Allied Technology Group facility in Richland, Washington, for further preparation and disposal. Berkeley Lab reclassified four of the 74 drums before shipment. The documentation that must accompany the drums was adjusted correctly, but labeling on the four drums was not updated. When surveying the shipment on arrival, Allied Technology Group discovered the discrepancy and worked with Berkeley Lab personnel to quickly resolve the error.

Because of the administrative nature of all three incidents, no danger was posed to human health or the environment.

§3.18 2. RCRA Corrective Actions Program (Site Environmental Restoration)

The environmental restoration program at Berkeley Lab is conducted under the RCRA corrective action program, as mentioned in §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. In February 1997,[27] Berkeley Lab submitted a Draft Final RCRA Facility Investigation Report to regulatory agencies involved in the investigation (i.e., DTSC, RWQCB, and the City of Berkeley). The report is awaiting DTSC approval. The report documents RFI activities through September 1996. A report addendum on subsequent RFI activities (October 1996 to June 1998) is expected in late 1998.

Berkeley Lab also submits RFI Work Plan Addenda before initiation of specific site activities. Now into the third phase of the RCRA Facility Investigation, Berkeley Lab submitted three such addenda[28] to regulators in 1997. One addendum submitted in January considered soil-investigation activities at various locations around the site. The other two addenda, submitted in April and August, were for construction of groundwater monitoring wells. Finally, DTSC received four quarterly progress reports[29] from the program in accordance with RCRA Part B Permit requirements. The quarterly progress reports detail project activities conducted during a given period and activities planned for upcoming periods.

The Environmental Restoration Program maintains a proactive interaction with stakeholders, including DTSC, the Regional Water Quality Control Board, 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 Act[30] contains requirements designed to ensure the proper storage, treatment, and disposal of medical waste. The state program is administered by DHS. Berkeley Lab does not treat any medical waste; this is done at offsite vendor facilities.

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. DHS conducted an inspection of the program in March 1997, reviewing program documentation (including tracking records) and visiting several medical waste generation sites. This inspection uncovered no violations.

The Laboratory generates medical waste at about 100 different locations distributed over 12 buildings, including four offsite buildings. The Life Sciences programs, including the Human Genome project, are the primary generators of medical waste.

In 1997, Berkeley Lab shipped about 22,120 kilograms (48,760 pounds) of medical waste off site for treatment through incineration or steam sterilization. The majority of the waste was treated via steam sterilization before disposal at a landfill. About 5% of the waste total underwent incineration.

§3.20 4. Underground Storage Tanks

In the early 1980s, California started addressing the serious threat of groundwater contamination from leaking underground storage tanks (USTs) through a rigorous regulatory and remediation program.[31] 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.[32] The City of Berkeley is the local administering agency for UST regulations applicable to the Laboratory.

At the end of 1997, eight permitted USTs remained at Berkeley Lab (see Table 3-7). The tanks contain either diesel fuel or unleaded gasoline. All tanks are double-walled and meet the upcoming December 1998 regulatory standards for construction, monitoring, leak containment, and design of operating tanks. No new tanks were added during the year. A ninth tank, the last single-walled tank on the site, was removed in November 1997, conforming to a city-approved workplan. The tank was located near Building 70A and had previously contained diesel fuel. Visual inspection of the soil and soil sampling in various locations surrounding the former UST gave no indication of soil contamination from significant leaks or spills at the tank. The City of Berkeley recommended that Berkeley Lab proceed to the formal closure phase with this tank. The Laboratory has removed a total of seven tanks from the site since 1993 as part of its efforts to meet the new regulatory standards.

Table 3-7 Underground Storage Tank Operating Permits from City of Berkeley

Registration tank ID #	LBNL building #	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

E. Pollution Prevention and Waste Minimization

§3.21 1. Executive Order 12873 (Federal Acquisition, Recycling, and Waste Prevention)

A key objective of Executive Order 12873 (Federal Acquisition, Recycling, and Waste Prevention)[33] is to integrate recycled materials into the procurement and acquisition process. The categories of products identified include:

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

The Executive Order further mandates that all federal agencies buy printing and writing paper consisting of at least 20% post-consumer material by December 31, 1994, and at least 30% post-consumer material by December 31, 1998. No increase in federal spending on paper products is allowed under the order. Instead, agencies must compensate for price increases by reducing paper use and waste.

Berkeley Lab has had an affirmative procurement program since 1992. The Laboratory's buyers now 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 targeted 2000 as the year when only products produced from recycled materials will be purchased as long as these materials are available at no extra cost and are compatible with the Laboratory's operating needs.

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

The California State Legislature passed the Hazardous Waste Source Reduction and Management Review Act[34] in 1989. The main emphasis of this Act is on waste minimization and pollution prevention. In particular, its goals are as follows:

- To reduce hazardous waste at its source;
- To encourage recycling wherever source reduction is not feasible or practicable;
- To treat 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 maintains and certifies a two-part report for compliance with this Act: the Source Reduction Evaluation Review Plan and Plan Summary[35] and the Hazardous Waste Management Report Summary.[36] This report is scheduled for updating in 1999.

§3.23 3. Pollution Prevention Act of 1990

The Pollution Prevention Act[37] of 1990 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)[38] regulates the discharge of pollutants to the waters of the United States from both point and nonpoint sources using various means, including development of pollutant discharge standards and limitations and a permit and licensing system to enforce such standards. California is authorized by US/EPA to administer the principal components of the federal water quality management program.

Additionally, the Porter-Cologne Water Quality Control Act[39] established a comprehensive statewide system for regulating water use in California. This 1969 Act provides for the three-tiered system that is still in use today: the State Water Resources Control Board (SWRCB), the nine Regional Water Quality Control Boards (RWQCB), and local governments.

For Berkeley Lab, the regional authority is the San Francisco Bay RWQCB. The local authorities are the Cities of Berkeley and Oakland for their stormwater ordinances, and the East Bay Municipal Utility District (EBMUD) for water supply and wastewater. The regulatory programs for wastewater and stormwater discharges are independent of each other. Each program, however, integrates federal, state, and local requirements.

The Laboratory has four wastewater discharge permits[40] issued by EBMUD for the following activities:

- General sitewide wastewater discharge;
- Discharge from treatment unit at metal finishing operations in Building 25;
- Discharge from treatment unit at metal finishing operations in Building 77; and
- Sitewide 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.

EBMUD occasionally inspects the Laboratory's sanitary sewer discharge activities without prior notice. The agency conducted inspections on nine separate occasions throughout the year. Table 3-2 (see §3.4) contains these dates. Neither these inspections nor the required self-monitoring resulted in any regulatory concerns on the part of the agency. For the results of the Laboratory's annual self-monitoring program, see chapter 7.

The wastewater discharge permits for Buildings 25 and 77 require that the Laboratory maintain a Toxic Organics Management Plan (TOMP). Each TOMP outlines facility management practices designed to minimize the release of toxic organics to the sanitary sewers or external environment. The TOMP for Building 25 was updated in 1997.[41] The TOMP for Building 77 was combined with the Accidental Spill Prevention and Containment Plan[42] (ASPCP; see below) to reduce duplication of information and paperwork. Berkeley Lab expects to make a similar consolidation to the TOMP and ASPCP for Building 25 during its next revision cycle.

An Accidental Spill Prevention and Containment Plan is required under the terms of the wastewater discharge permits. Specifically, Berkeley Lab must maintain this plan for areas where spills have the greatest potential to occur. EBMUD leaves selection of areas to the discretion of the permit holder. Berkeley Lab has prepared operational-specific plans for photoprocessing activity, Building 25, Building 77, the motor pool at Building 76, and the fixed treatment units at Buildings 2 and 70A. EBMUD requires that these documents be maintained on file in the relevant areas and that essential emergency information be posted. The plans need not be submitted to the agency.

Berkeley Lab's stormwater releases are permitted under the California-wide General Permit for Stormwater Discharges Associated With Industrial Activity.[43] The general permit is issued by the State Water Resources Control Board but administered and enforced by the Regional Water Quality Control Board and the City of Berkeley. Under the permit, the Laboratory has implemented a Stormwater Pollution Prevention Plan[44] and a Stormwater Monitoring Program.[45] 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 Regional Water Quality

Control Board and the City of Berkeley.[46] For detailed discussion of stormwater results for 1997, see §5.6. The City of Berkeley has the authority to inspect Berkeley Lab's stormwater program. No inspections of, or incidents involving, this program took place in 1997.

Aboveground storage tanks (ASTs) also fall under the authority of the Clean Water Act.[47] The Clean Water Act and the state's Aboveground Petroleum Storage Act[48] outline the regulatory requirements for these tanks. 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. Certain types of aboveground storage tanks require secondary containment to capture any potential spills. Berkeley Lab added secondary containment around the FTU at Building 2 in December. No other 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.

§3.25 2. Safe Drinking Water Act

The Safe Drinking Water Act[49] established requirements to protect underground sources of drinking water and set primary drinking water standards for public water

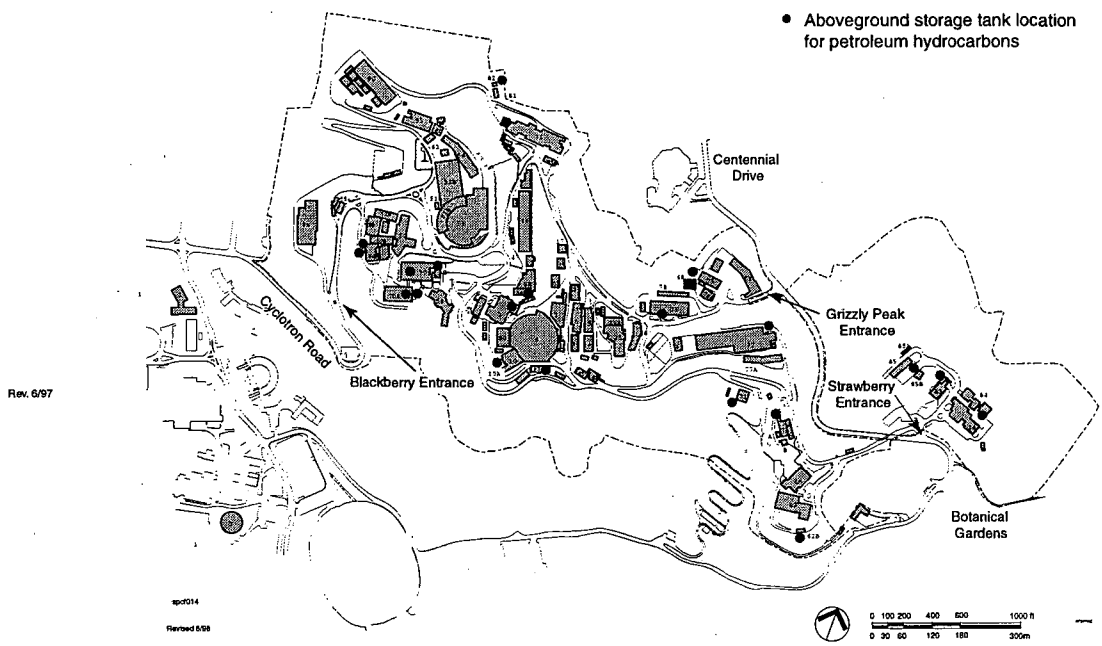


Figure 3-3 Aboveground Storage Tank Locations

systems. Berkeley Lab has no drinking water wells on site. The drinking water provided to the site comes from EBMUD's 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.

V. PROGRAM PERFORMANCE

§3.26 A. Overview

Since 1994, Berkeley Lab, DOE, and Berkeley Lab's managing partner, the University of California Office of the President, have had a system to measure the effectiveness of the Laboratory's environmental programs. These performance measures have been an annual requirement integrated directly into the operating contract for the site. Early performance measures focused on more traditional indicators, such as the radiological dose to the nearest receptor or the number of violations issued by environmental agencies during a given period.

As the performance measures have matured since their inception, the goal has been to make them as comprehensive as possible using readily available data and information. To this end, further and substantial changes were made in 1997. Specifically, measures were categorized into two types: process and outcome. Process can be thought of as the foundation for building programs. Outcome is the ultimate product of a program's performance. Although the importance of process was recognized before this change, a clear separation of the two was not made. The remainder of this chapter outlines each type of measure and presents the most current results on their effectiveness.[50]

§3.27 B. Process Performance Measures

Process performance measures evaluate how well Berkeley Lab has implemented the core principles of DOE's integrated safety management system. This integrated system examines the overall environment, health, and safety performance in terms of the following core elements:

- Work planning;
- Hazard analysis;
- Establishment of controls;
- Work performance; and
- Feedback and improvement.

The working group (i.e., the Laboratory, DOE, and UCOP) settled on two process measures to summarize Berkeley Lab's environmental programs:

- Radiation Protection of the Public and the Worker; and
- Waste Minimization, Pollution Prevention, and Protection of the Environment.

Each measure includes a set of criteria used to evaluate a program's structure and its implementation. These criteria consider all phases of Laboratory work processes to determine the degree to which systems are in place to properly address the core elements

listed above. Factors considered include peer reviews, procedures and implementing memoranda, tracking data systems, and other work products that allow for the ranking of the process system on a gradient scale. Finally, each process measure is linked to a set of outcome measures agreed on by Berkeley Lab and DOE. This linkage provides integration of the overall approach to reviewing performance.

The performance period for the two process measures runs from July 1 through the following June 30. First-year results will be published in next year's annual report.

§3.28 C. Outcome Performance Measures

Outcome performance measures focus on bottom-line results during a specified period. Three measures track environmental performance by Berkeley Lab:

- Radiation Protection of the Public and the Environment;
- Tracking Environmental Incidents; and
- Waste Reduction and Recycling.

As is done with the process measures, a set of assumptions and criteria are jointly established by Berkeley Lab, DOE, and UCOP that lead to a rating on a gradient scale (i.e., "good," "excellent," "outstanding") when the measure is assessed. Unlike the process performance measures, the outcome measures are subject to a performance period that runs from January 1 through December 31. The following sections contain a brief discussion of each measure.

§3.29 1. Radiation Protection of Public and Environment

The goal of this measure is to ensure that radiation doses to the maximally exposed individual member of the public and radiological emissions to the environment from Berkeley Lab operations remain well below applicable regulatory limits. This measure considers the impact from penetrating radiation and dispersible radionuclide sources. Supporting information used to derive the measure's results comes from established Laboratory environmental monitoring activities.

Specifically, real-time dose detection instrumentation gives the estimated dose from penetrating radiation, continuous stack sampling provides data on tritium air emissions, and integrated sewer samples collected over two-week intervals at the site's outfalls track any tritium in discharged wastewater. Figures 3-4 through 3-6 display the quarterly results for 1997 from each of these media. In every case, close communication with source operators is critical in managing emission levels. Together, these indicators received a performance ranking of "excellent."

§3.30 2. Tracking Environmental Incidents

Environmental incidents considered by this measure are either (a) violations resulting from regulatory inspections or regulatory reporting or (b) reportable occurrences of environmental releases exceeding regulatory or permitted levels. Under these criteria, Berkeley Lab did not have any environmental incidents in 1997, leading to an "outstanding" performance rating.

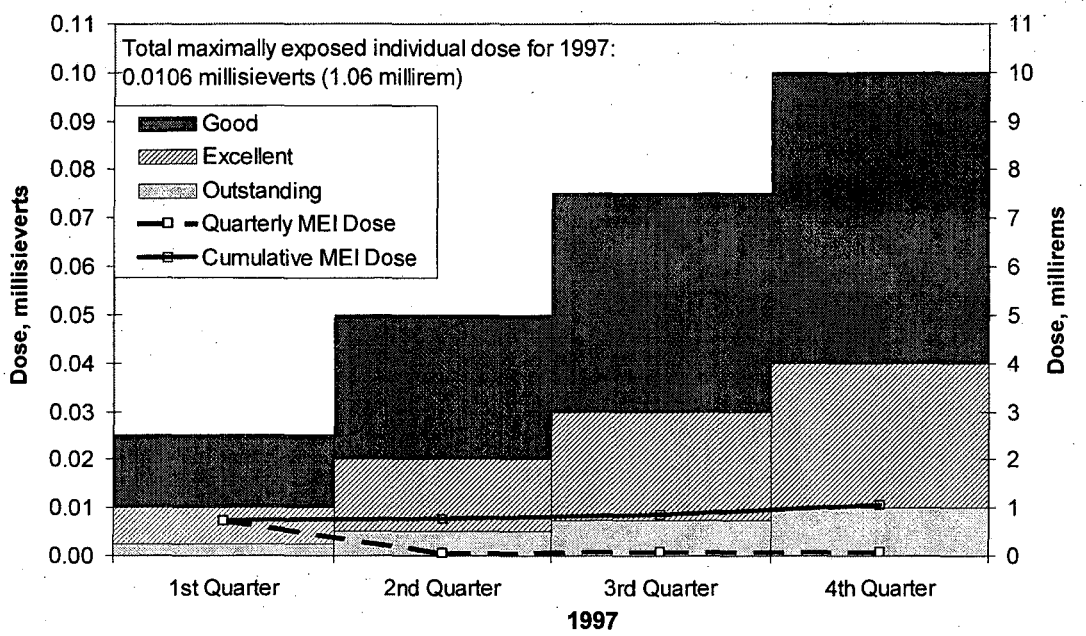


Figure 3-4 Quarterly Radiation Dose to Public

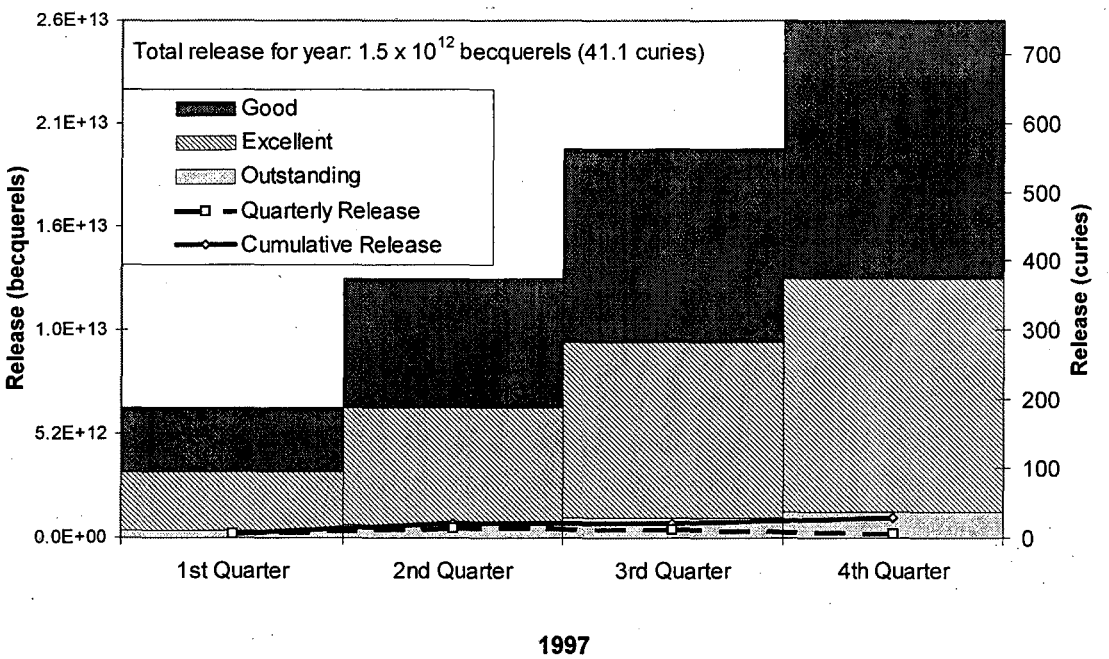


Figure 3-5 Quarterly Radiological Emissions to Air

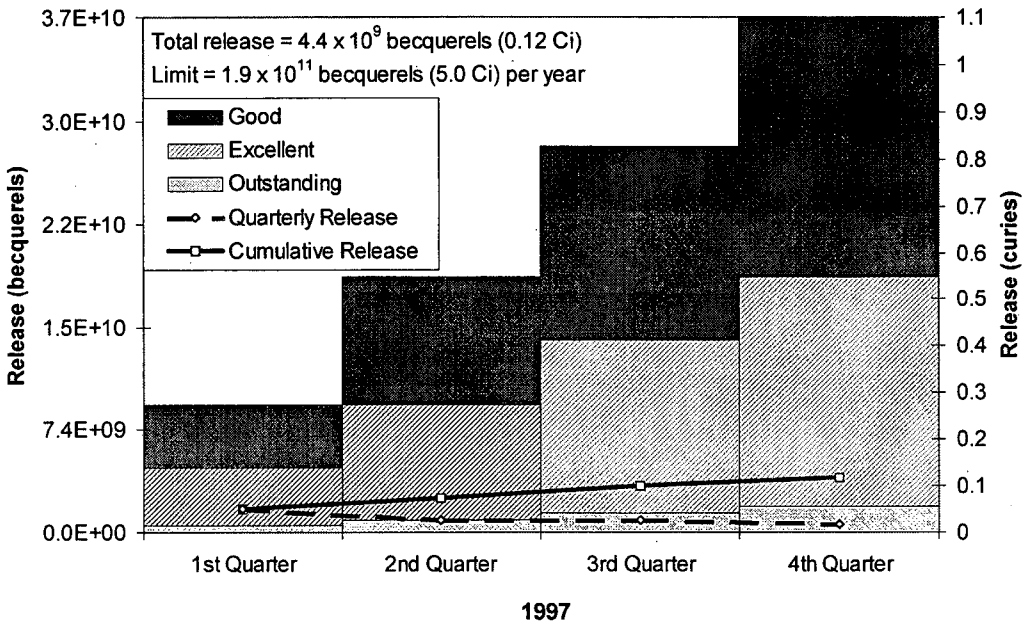


Figure 3-6 Quarterly Radiological Effluent Discharged to Sanitary Sewer

§3.31 3. Waste Reduction and Recycling

This measure tracks the progress of Berkeley Lab toward the pollution prevention goals that DOE has established for the beginning of the year 2000. The routine waste streams targeted by this measure are:

- Nonhazardous or sanitary waste;
- Hazardous waste;
- Low-level mixed waste (waste that contains both RCRA hazardous and radioactive components); and
- Low-level radioactive waste.

The overall goal of the measure is a 33% reduction in the first waste stream and a 50% reduction for the last three waste streams by the DOE deadline, using 1993 as the baseline year for comparison. Each waste stream is tracked separately. Figures 3-7 through 3-10 summarize the status of each of these four waste streams. On each graph, the year represents the reduction status at the end of the year.

Overall, Berkeley Lab has achieved a score that qualifies for an "outstanding" rating with this measure. Although this rating is based on the combined performance in all four categories, an individual waste stream's performance can be understood by comparing its trend against the ranking dividers displayed in each graphic. Additional information on the Laboratory's extensive waste minimization and pollution prevention program can be found on the Web at http://www-ehs.lbl.gov/wastemin/home.html.

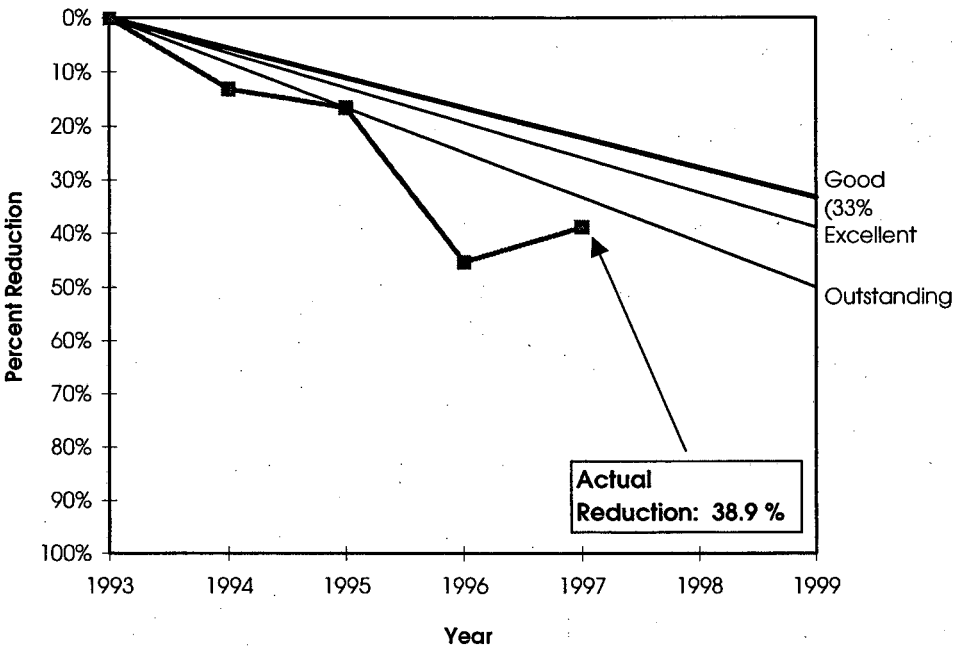


Figure 3-7 Trends in Reducing Routine Nonhazardous or Sanitary Waste

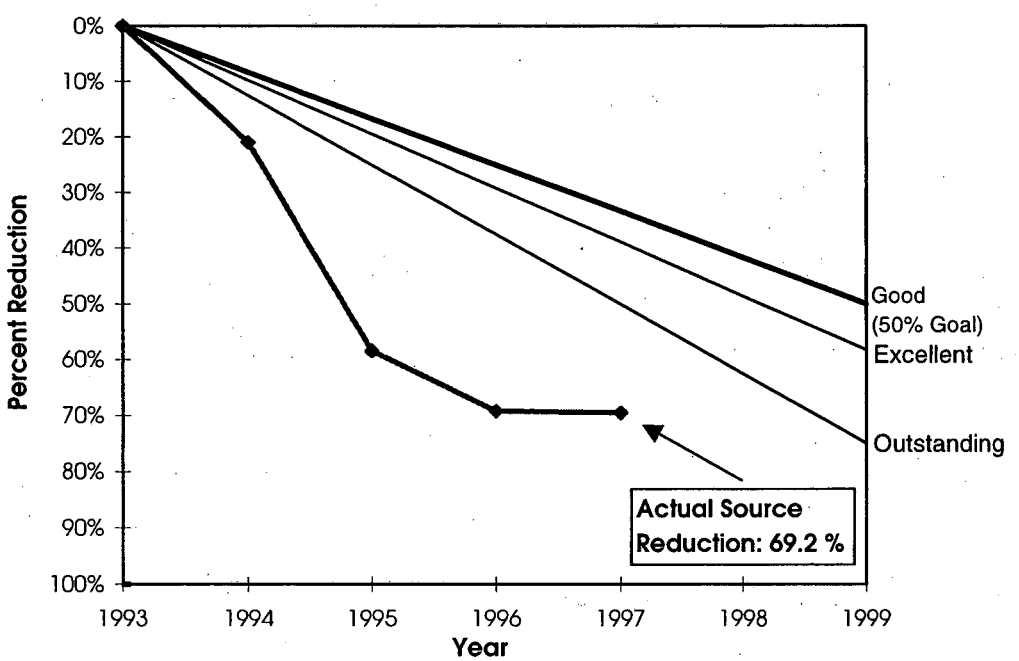


Figure 3-8 Trends in Reducing Routine Hazardous Waste

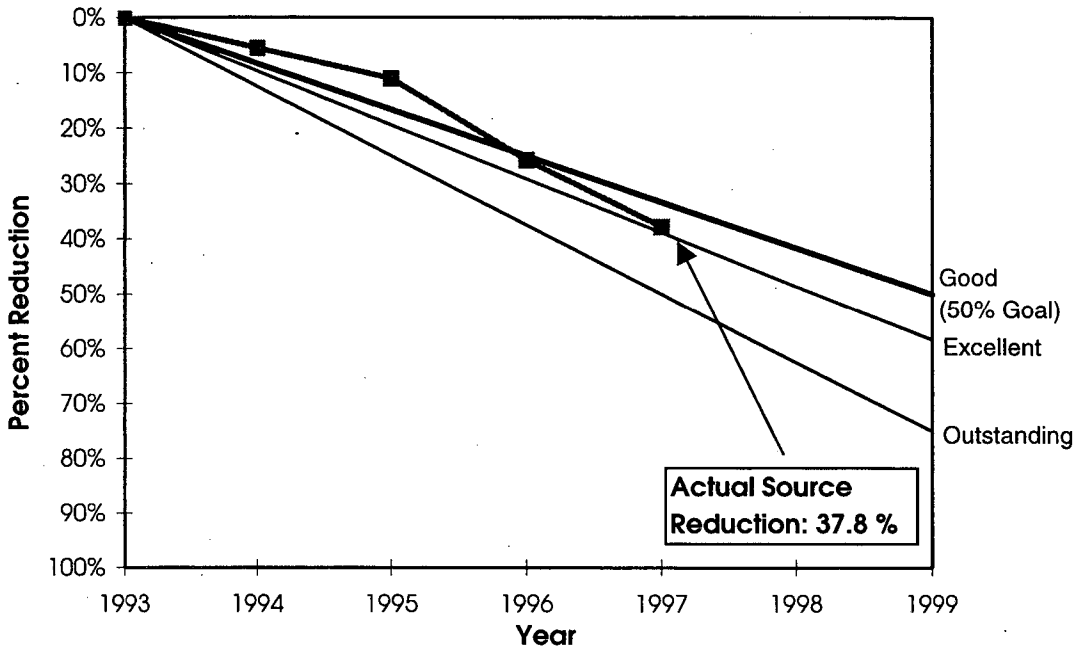


Figure 3-9 Trends in Reducing Routine Low-Level Radioactive Waste

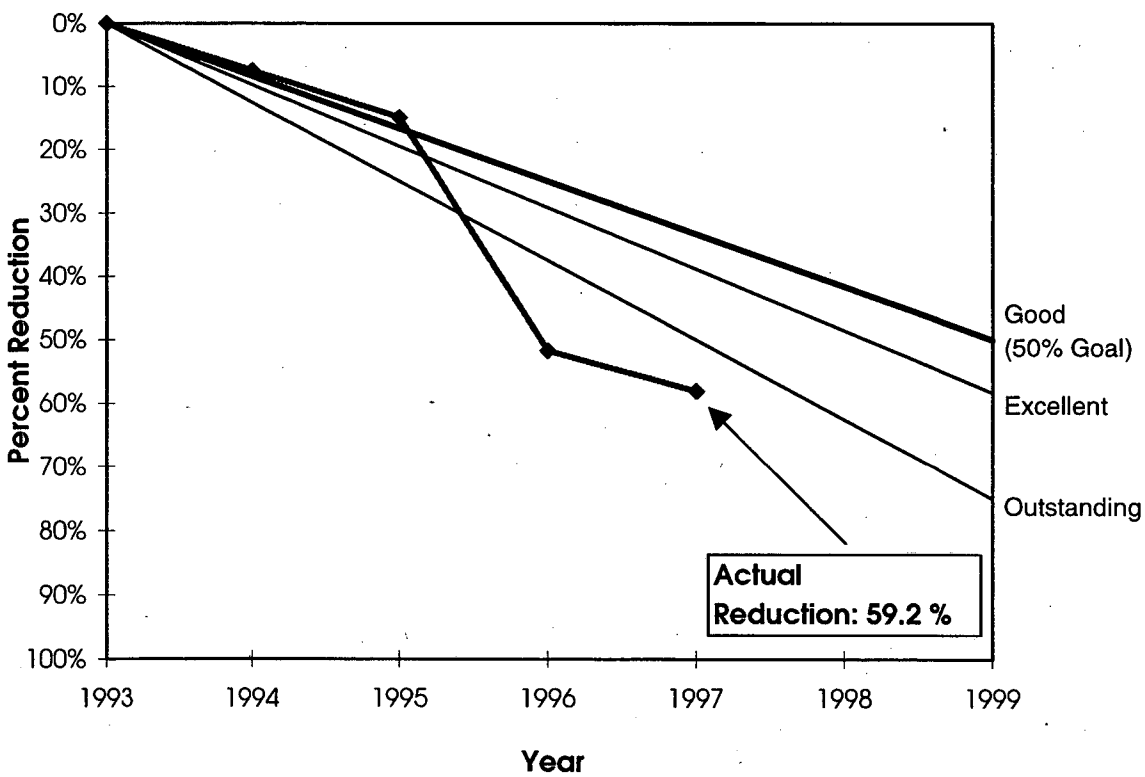


Figure 3-10 Trends in Reducing Routine Mixed Waste

4
Air Quality

§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 the present requirements, Berkeley Lab must measure only the radiological components in exhaust emissions and ambient concentrations. Estimates of nonradiological air emissions using alternative methodologies (such as engineering calculations, record-keeping, and dose/risk modeling) currently satisfy regulatory requirements. The comprehensive Environmental Monitoring Plan[4] describes the basis and current scope of the air monitoring network at the Laboratory. The plan is reviewed and revised at least once every three years. The plan was last revised in October 1997.

The air monitoring program consists of two separate components: exhaust-emissions monitoring and ambient-air surveillance. Exhaust-emissions monitoring measures airborne contaminants in building exhaust streams, usually coming from a known source. Ambient-air surveillance measures air contaminants in the outside environment, usually near ground level to represent air breathed by humans. 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, however, ambient-air surveillance results can help characterize the impact of Laboratory activities on the surrounding region. The number and placement of monitoring stations, as well as the parameters monitored and their frequency, are routinely evaluated to account for changes in Laboratory operations or external requirements.

§4.2 II. EXHAUST SYSTEM SAMPLING RESULTS

As a research facility, Berkeley Lab uses various radionuclides in its radiochemical and biomedical research programs. In addition, radioactive materials are generated from the operations of the charged-particle accelerators.

Table 4-1 contains the names and decay characteristics of the most significant radionuclides used at Berkeley Lab. The annual NESHAPs report, attached as Appendix

Table 4-1 Most Significant Radionuclides Used During 1997*

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)	^{15}O	positron/gamma	122 seconds
Phosphorus (15)	^{32}P	beta	14.3 days
	^{33}P	beta	25.3 days
Sulfur (16)	^{35}S	beta	87.44 days

*For a complete list of radionuclides evaluated under NESHAP regulations, see Appendix A.

A, includes the entire list of radionuclides used at the Laboratory and evaluated under the NESHAPs regulation.

Radioactive gases produced by accelerator operations are mainly short-lived radionuclides, such as carbon-11, nitrogen-13, oxygen-15, and argon-41 (see glossary for a reference table on radionuclides and their symbols). These radioactive gases are normally produced in areas where the beam strikes metal components within the chamber.

Radionuclide releases from onsite building exhaust systems usually are in the form of vapor or gas, with particulate matter being the least common form. The NESHAPs regulations require source measurement if the dose, or exposure over time, from emissions exceeds 1.0×10^{-3} mSv/yr (0.1 mrem/yr).[5] As discussed in §3.7, Berkeley Lab uses a comprehensive tiered strategy approved by US/EPA to meet this requirement. See Table 4-2. This strategy involves three distinct levels of assessment:

- *Real-time monitoring.* With this sophisticated and complex monitoring, results are determined in place.
- *Continuous sampling.* Located in 26 exhaust systems around the site, in-line sampling instrumentation collects time-integrated air samples that undergo laboratory analysis following US/EPA-approved protocols.
- *Administrative controls.* The Laboratory's 99 remaining applicable exhaust systems use strict administrative controls on radionuclide inventories and engineering techniques to estimate emission quantities. Many of these systems have high-efficiency filters that further reduce the minute amount of material released to the environment.

Berkeley Lab's assessment approach is overcautious by design. For example, only the tritium stack at Building 75 is considered to be more than a "small source" of

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 > AEDE > 0.001	US/EPA Application to Construct or Modify required.
		Continuous sampling with telemetry to central computer for half-life less than 100 hours and weekly analysis for half-life greater than 100 hours.
II	0.001 > AEDE > 0.0005	Continuous sampling with weekly analysis.
III	0.0005 > AEDE > 0.0001	Continuous sampling with monthly analysis.
IV	0.0001 > AEDE > 0.00001	Sampled annually during project activity.
V	0.00001 > AEDE	Inventory controlled by administrative methods (Radiation Work Authorization/Permit). No monitoring required.

emissions under the regulations, but the Laboratory applies the more rigorous real-time monitoring associated with this category to four locations in three different buildings. The number and location of sources under each assessment category change in response to the changing research at Berkeley Lab. The program analyzed emission samples for five radiological parameters in 1997: gross alpha, gross beta, carbon-14, iodine-125, and tritium. Table 4-3 lists the breakdown of source assessment by category for 1997.

As in past years, tritium in the form of tritiated water vapor was the predominant radionuclide emitted from Berkeley Lab activities. Table 4-4 provides the list of the most significant radionuclide emissions from site activities for the year. On the projected dose from all radionuclide emissions, see chapter 10. Tritium emissions totaling 1.50×10^{12} Bq (41 Ci) were measured during the year, with nearly all tritium emitted from the National Tritium Labeling Facility's exhaust stack.

Table 4-3 NESHAPs Building Exhaust Sampling and Monitoring Profile

Monitoring type	Method	Location
Real-time	Real-time monitoring of HT and HTO	Bldg. 75 NTLF exhaust
	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	10 locations
	Sampling with monthly analysis	16 locations
No monitoring	Inventory (administrative) control	99 locations

Table 4-4 Summary of Radiological Air Emissions Released During 1997

Nuclide	(Bq/yr)[a]	(Ci/yr)	% Total
H-3	$1.52 \times 10^{+12}$	$4.12 \times 10^{+1}$	93.00%
C-11	$5.55 \times 10^{+10}$	$1.50 \times 10^{+0}$	3.39%
F-18	$5.55 \times 10^{+10}$	$1.50 \times 10^{+0}$	3.39%
N-13	$3.11 \times 10^{+9}$	$8.40 \times 10^{+2}$	0.19%
C-14	$4.08 \times 10^{+8}$	$1.10 \times 10^{+2}$	0.025%
O-15	$2.22 \times 10^{+8}$	$6.00 \times 10^{+3}$	0.014%
I-125	$8.33 \times 10^{+6}$	$2.25 \times 10^{+4}$	0.0005%
All others[b]	$4.46 \times 10^{+6}$	$1.21 \times 10^{+4}$	0.0003%
Total	$1.64 \times 10^{+12}$	$4.43 \times 10^{+1}$	100.0%

[a] 1 Ci = 3.7×10^{10} Bq

[b] For a complete list of radiological air emissions, see Appendix A.

Since 1988, the NTLF has significantly reduced its tritium emissions from both planned and unplanned releases through a series of modifications. This effort has resulted in a notable decrease from a high of 2.13×10^{13} Bq (575 Ci) in 1988 (see Figure 4-1). Additionally, the NTLF has not had a significant unplanned release in more than four years because of improved engineering of the emissions control system, revised procedural operations, and the installation of an alarm system monitored during off-hours by the Berkeley Lab Fire Department. The Laboratory considers a significant unplanned release as one greater than 1.85×10^{12} Bq (50 Ci).[6] This is much less than the federal reportable quantity of 3.70×10^{12} Bq (100 Ci) for tritium.[7]

III. AMBIENT-AIR MONITORING RESULTS

§4.3 A. Tritium

Berkeley Lab operated six monitoring sites in 1997 to determine levels of airborne tritium in the environment. Three of the locations were on site and three were off site, as seen in Figure 4-2. The sites were chosen based on known emission sources, local wind patterns, and proximity to sensitive receptors. Stations ENV-B13D and ENV-85 were added to the network during the year. Monitoring equipment at all sites sample outdoor air continuously and at a constant rate. The sampling media are replaced and analyzed monthly.

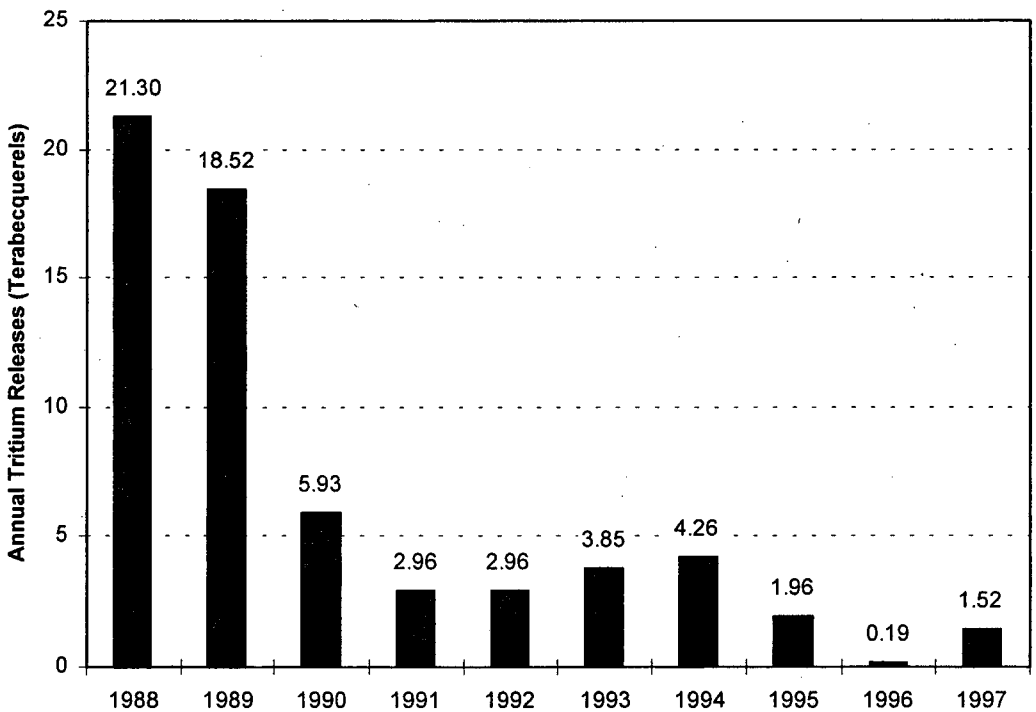


Figure 4-1 Trends in Annual Tritium Releases from NTLF in Terabecquerels (10^{12} Bq)

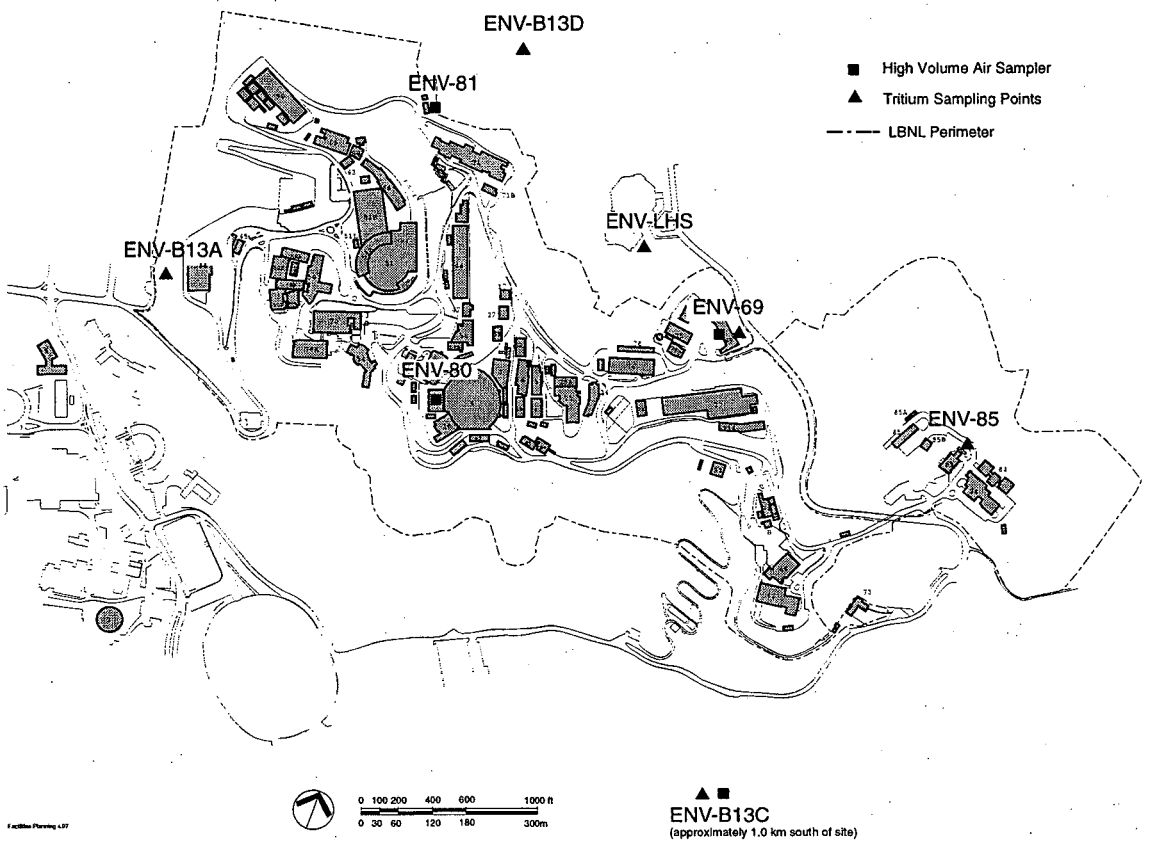


Figure 4-2 Ambient Air Monitoring Network Sampling Locations

Table 4-5 summarizes the network's atmospheric tritium concentrations for the year. Average concentration values are far below 1% of the allowable DOE annual exposure standard for tritium in air.[8] Similar results hold true for maximum monitored levels. The 1997 ambient air results are consistent with the historical reduction in emissions of tritium from the NTLF. The results are also consistent with the dispersion modeling of these emissions required by NESHAPs (see §10.5 and Appendix A).

Table 4-5 Summary of Ambient Tritium Sampling

Station ID	Number of samples	Mean (Bq/m^3)[b]	Mean as percent of standard[a]	Median (Bq/m^3)	Maximum (Bq/m^3)
ENV-B13A	12	< 0.7[c]	—	< 0.7[c]	1.7
ENV-B13C	12	< 0.7[c]	—	< 0.7[c]	1.42
ENV-B13D	6	0.24	0.006	0.22	0.57
ENV-69	12	< 5[c]	—	<5[c]	11.1
ENV-85	3	0.13	0.004	0.06	0.28
ENV-LHS	12	1.41	0.04	1.39	3.03

[a] Standard of comparison = 3.7×10^3 Bq/M^3 (source: DOE Order 5400.5)
[b] 1 Bq = 27 pCi
[c] Both the mean and median were below the maximum MDA for this site.

§4.4 B. Gross Alpha/Beta

The ambient air sampling network also included a series of stations designed to detect gross alpha and gross beta levels in particulate emissions. This network complements the exhaust system sampling for the same parameters, discussed earlier in this chapter. The network consisted of four monitoring sites: three sites on the main grounds of the Laboratory and the fourth site at the monitoring program's background station, ENV-B13C. These are labeled as high-volume air samplers in Figure 4-2. As with tritium sampling, the samplers draw air past sampling media at a constant rate, with the media replaced monthly and samples analyzed by certified laboratories.

Gross alpha and beta results from sampling activities in 1997 are summarized in Table 4-6. Although DOE Order 5400.5 does not provide a standard for particulate gross alpha and beta radiation,[9] several observations about these results are apparent. First, they are extremely low, approaching the analytical detection limits for each parameter. Second, there is little variability from station to station, including station ENV-B13C located over 1.0 kilometer (0.6 mile) south of the site. These observations indicate that environmental impacts due to 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^b)	Maximum (Bq/m^3)
Alpha	ENV-B13C	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	1.2×10^{-4}
	ENV-69[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	1.5×10^{-4}
	ENV-80[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	1.5×10^{-4}
	ENV-81[b]	12	$<1.1 \times 10^{-4}$	$<1.1 \times 10^{-4}$	1.1×10^{-4}
Beta	ENV-B13C	12	4.95×10^{-4}	4.54×10^{-4}	8.21×10^{-4}
	ENV-69	12	4.62×10^{-4}	4.46×10^{-4}	8.33×10^{-4}
	ENV-80	12	5.08×10^{-4}	5.00×10^{-4}	8.21×10^{-4}
	ENV-81	12	4.79×10^{-4}	4.37×10^{-4}	8.00×10^{-4}

[a] 1 Bq = 27 pCi
[b] Both the mean and median were below the maximum MDA for this site.

5
Surface Water

§5.1 I. BACKGROUND

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 orders[1] that prescribe the monitoring of radioisotope activity. 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 undertaken under the California General Permit for Stormwater Discharges Associated with Industrial Activities[2] and includes monitoring for metals and other constituents. The monitoring programs for each type of surface water are further described in this chapter.

To place the Laboratory's results into a familiar context, this chapter compares results from certain sampling programs to drinking water standards. 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.

Surface water samples were analyzed in 1997 by both commercial and in-house state-certified laboratories.

II. SURFACE WATER RESULTS

§5.2 A. Rainwater

During the rainfall season, generally October through April, a monthly rainwater sample is collected. In 1997, March, April, June, and July were dry months, so no samples were collected during those months.

Samples collected throughout the year came from three locations (see Figure 5-1). One location (ENV-75) is on site, on the north side of Building 75. Of the two offsite locations, one (ENV-B13C) is about one kilometer south of Berkeley Lab on Panoramic Hill, and one (ENV-B13D) is situated at the edge of the parking lot located northwest of the Lawrence Hall of Science. Sampling at the latter location began in early 1997. Both sites ENV-75 and ENV-B13D are in the downwind direction of the average windflow patterns found at the Laboratory (see Figure 2-6 for windrose).

Samples were analyzed for tritium and gross alpha and beta. Table 5-1 summarizes the levels of alpha, beta, and tritium seen in rainwater samples taken during 1997. Alpha activity was not detected in most samples (five of eight), and only near-detection limits were found in the remaining samples. Low amounts of beta were seen at all stations. Although the high for gross beta in the sampling network was 0.245 Bq/L (6.6 pCi/L) at ENV-B13C, most measurements were well below 0.1 Bq/L (2.7 pCi/L). For comparison, federal and state maximum contaminant levels (MCLs) for drinking water are 0.6 Bq/L (15 pCi/L) for alpha and 1.9 Bq/L (50 pCi/L) for beta.[3]

Tritium was often not detected in rainfall at the offsite locations. At Building 75, the highest amount seen was 54.4 Bq/L (1,469 pCi/L) for February, while ENV-B13C and ENV-B13D showed peak values of 9.7 Bq/L (262 pCi/L) and 4.6 Bq/L (124 pCi/L), respectively, for the same collection period. The February maximum at Building 75 represented less than 8% of the US/EPA drinking water limits for tritium (740 Bq/L or 20,000 pCi/L).[4] In general, tritium levels at all stations decreased from the previous year.

§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 they flow, a grab sample is collected and analyzed at least quarterly for alpha, beta, and tritium activity. Creeks sampled during 1997 were Chicken Creek, Claremont Creek, the North Fork of Strawberry Creek, Strawberry Creek (UC), and Wildcat Creek (see Figure 5-2 for locations).

A second set of creeks was sampled and analyzed once for tritium. These creeks (also shown in Figure 5-2) included Botanical Garden Creek, Cafeteria Creek, No Name

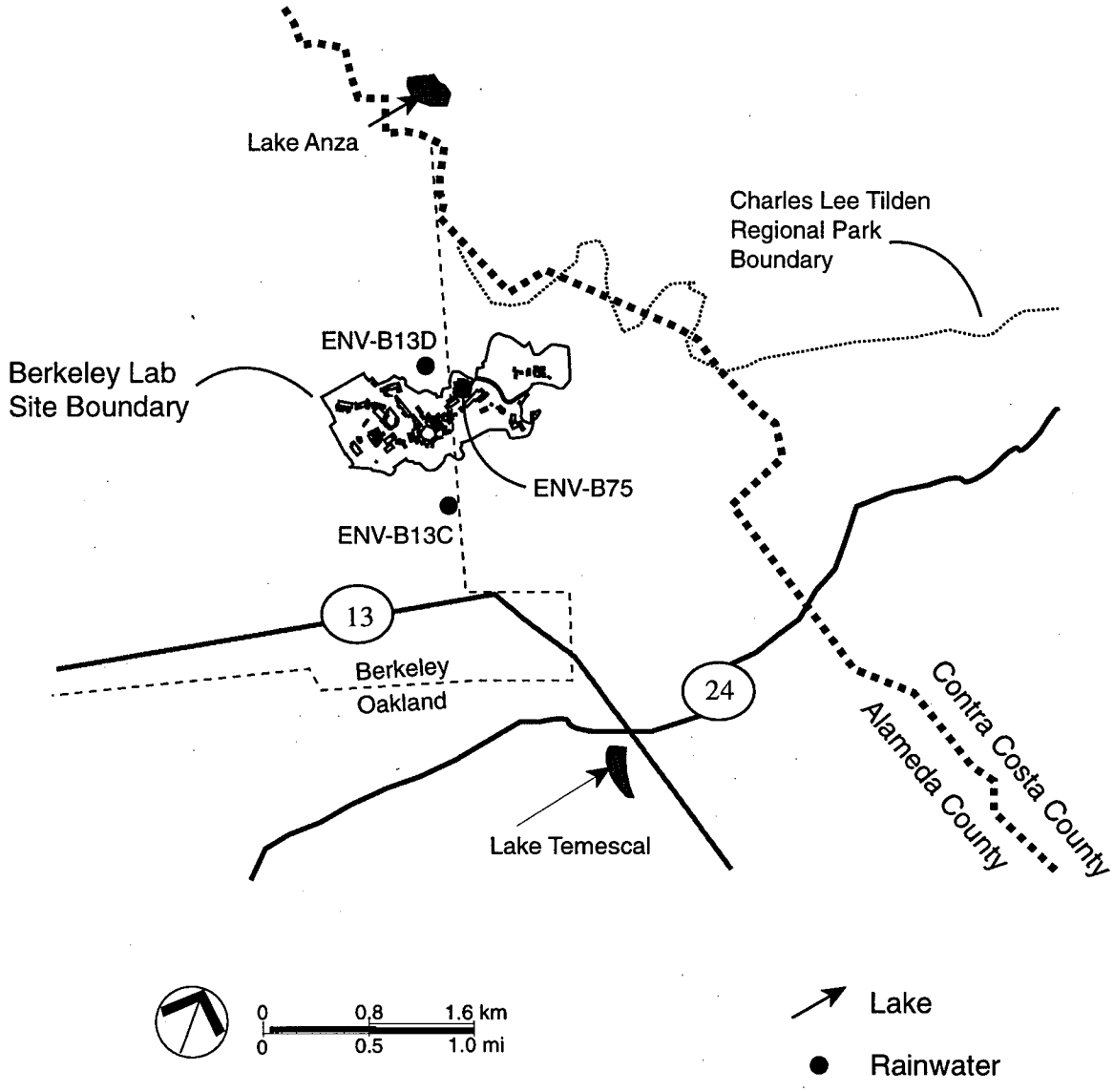


Figure 5-1 Rainwater and Lake Sampling Locations

Creek, and Ravine Creek. Data summaries of radiological analyses from creek sampling are shown in Table 5-2.

No alpha and beta activity was detected at any sampling site, with the exception of three very low beta results at Chicken Creek (maximum of 0.085 Bq/L (2.3 pCi/L)). Tritium was also not detected at any site, except Chicken Creek (five samples), North Fork Strawberry Creek (three samples), and Strawberry Creek (UC) (one sample). At Chicken Creek, the highest level seen was 26.6 Bq/L (718 pCi/L)—a considerable decrease over last year.

Table 5-1 Rainwater Radiological Monitoring Results[a]

Location	Number of samples	Beta, Bq[b]/L			Tritium, Bq/L		
		Mean	*Median*	*Maximum*	*Mean*	*Median*	*Maximum*
ENV-75	8	0.035	0.028	0.056	22	18	54.4
ENV-B13C	8[c]	0.15	0.23	0.245	4.1	< 4[d]	9.7
ENV-B13D	8[c]	0.044	0.036	0.104	5.4	4.1	14.4

[a]Alpha was at or below the minimum detectable amount (yearly maximum of 0.02 Bq/L) for all samples.
[b]1 Bq = 27 pCi
[c]ENV-B13C and ENV-B13D had 7 samples for alpha and beta, 8 samples for tritium.
[d]Yearly median was less than the highest minimum detectable amount for the analyte at this site.

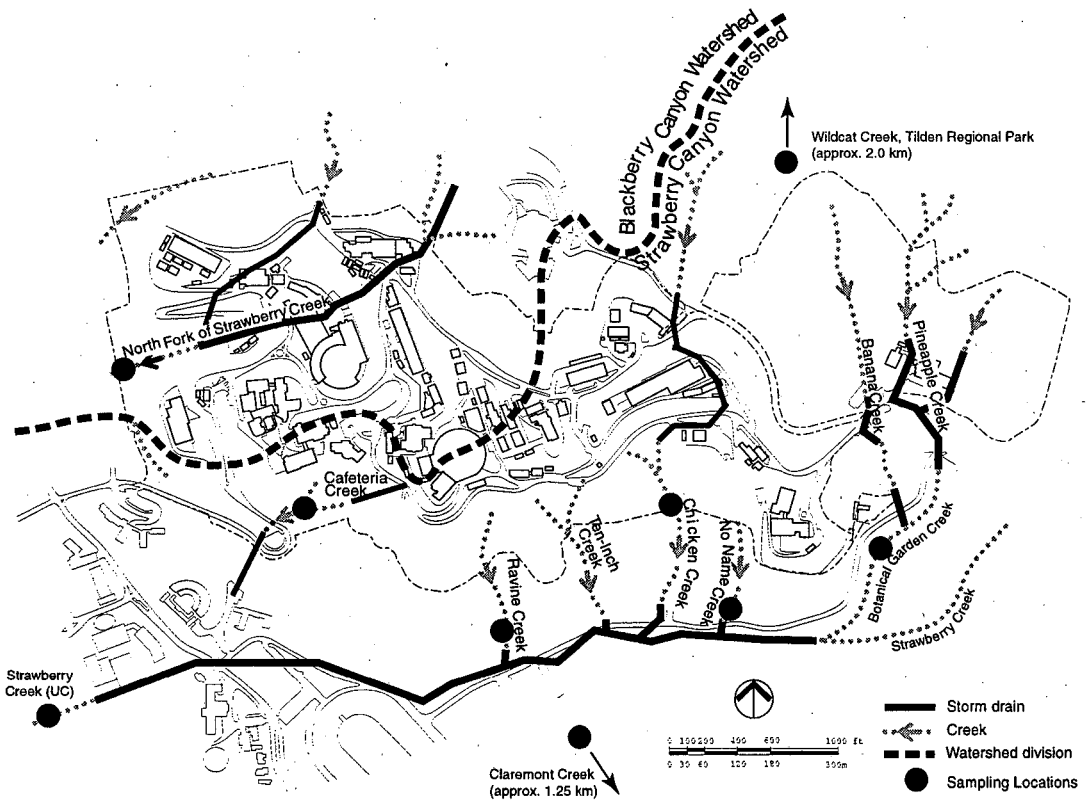


Figure 5-2 Creek Sampling Locations

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Table 5-2 Creek Radiological Monitoring Results[a]

Location	Number of samples	Tritium, Bq[b]/L		
		Mean	*Median*	*Maximum*
Botanical Garden Creek	1	<15[c]	<15[c]	<15[d]
Cafeteria Creek	1	<15[c]	<15[c]	<15[d]
Chicken Creek	5	21.4	24.3	26.6
Claremont Creek	4	<3[c]	<3[c]	<3[d]
No Name Creek	1	<15[c]	<15[c]	<15[d]
North Fork Strawberry Creek	5	<15[c]	<15[c]	<15[d]
Ravine Creek	1	<15[c]	<15[c]	<15[d]
Strawberry Creek (UC)	4	3.1[e]	<3[c]	3.6
Wildcat Creek	4	<3[e]	<3[c]	<3[d]

[a]Alpha and beta were always below the minimum detectable activity (yearly maximum of 0.07 Bq/L and 0.15 Bq/L, respectively), with the exception of three Chicken Creek beta results: one of 0.085 Bq/L and two at the sample detection limits of 0.06 and 0.044 Bq/L, respectively.
[b]1 Bq = 27 pCi
[c]The yearly mean and median were less than the highest minimum detectable amount for the analyte at this site.
[d]The maximum was less than the highest minimum detectable amount for the analyte at this site.
[e]Some results were nondetect; for those results, the minimum detectable amount was used in computing the average.

One sample was taken during the year from the second set of creek sites and analyzed for the nonradiological parameters of volatile organic compounds (VOCs) and certain metals. All VOCs remained below detectable levels. Trace levels of arsenic, barium, chromium, and selenium were found at practical quantitation limits. These levels were consistent with past results and with natural background levels.

§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). For 1997, no samples from either lake contained gross alpha, gross beta, or tritium activity above minimum detectable amounts.

§5.5 D. Hydraugers

Hydraugers are perforated pipes inserted into a hillside to improve drainage of groundwater on potentially unstable slopes. Because of its steep hillsides, Berkeley Lab has many of these hydraugers. Figure 5-3 shows the locations of monitored hydraugers. Summary data for hydraugers are displayed in Table 5-3.

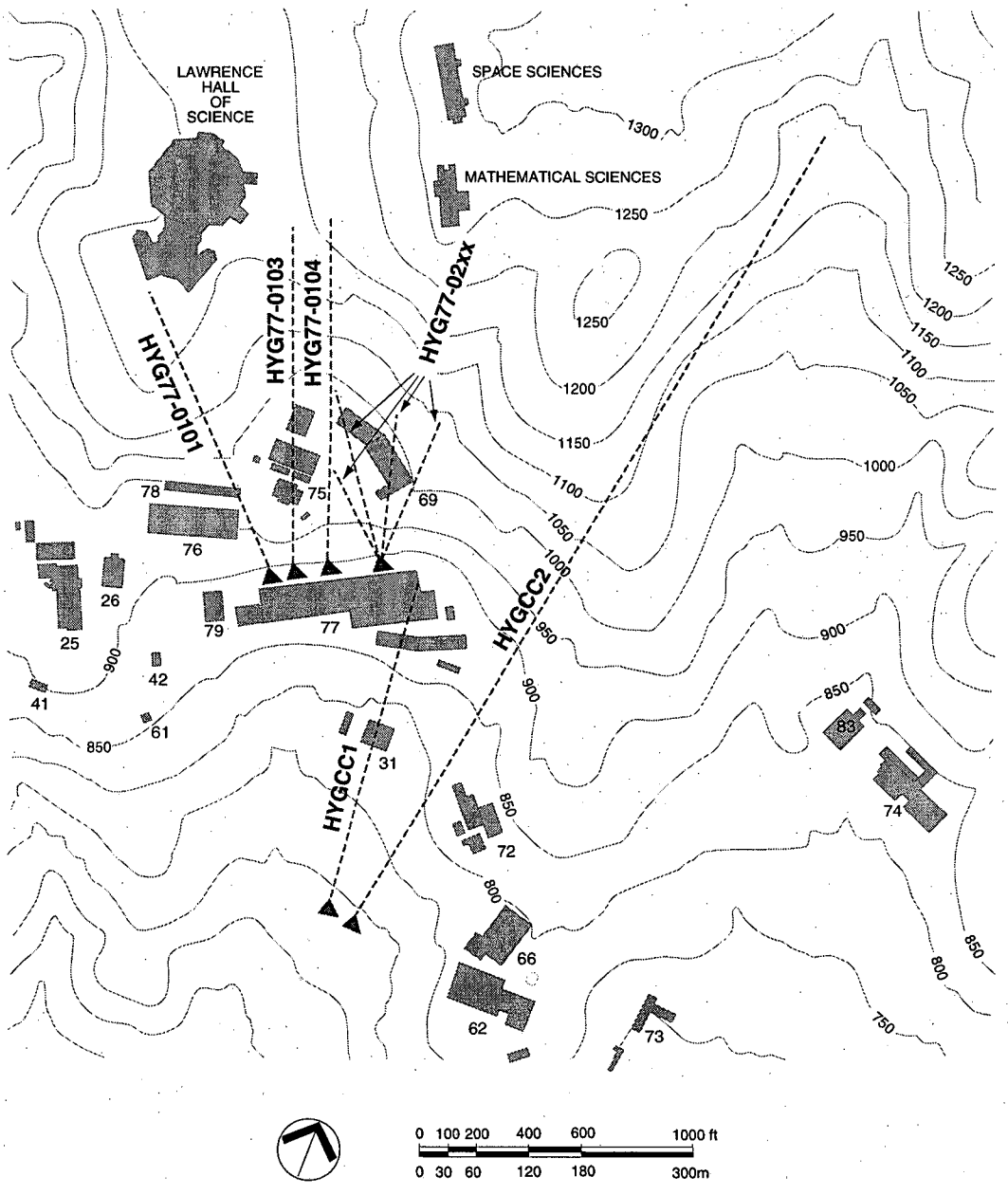

Figure 5-3 Hydrauger Sampling Locations

Six hydrauger sites (HYG77-0101, HYG77-0103, HYG77-0104, HYG77-02XX, HYGCC1, and HYGCC2) were routinely monitored in 1997 for potential surface water contamination. HYG77-02XX is a manifold of several hydraugers (HYG77-0204 through HYG77-0207) and is sampled at the common discharge point. Hydraugers 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. Each hydrauger was routinely monitored quarterly for alpha, beta, and tritium.

Table 5-3 Hydrauger Tritium Monitoring Results[a]

Location	Number of samples	Tritium, Bq[b]/L		
		Mean	*Median*	*Maximum*
HYG77-0101	3	470	509	577
HYG77-0104	1	286	286	286
HYG77-02XX	4	135	135	154
HYGCC1	4	< 3[c]	< 3[c]	< 3[c]
HYGCC2	4	3.7	3.3	5.1

[a]Alpha and beta were always below the minimum detectable activity (yearly maximum of 0.2 Bq/L and 0.3 Bq/L, respectively), except for one beta result at HYG77-0101 (0.19 Bq/L).
[b]1 Bq = 27 pCi
[c]The yearly mean, median, and maximum were less than the minimum detectable amount for the analyte at this site.

Because hydrauger flow depends on several factors (including rainfall), it can vary considerably. A low flow sometimes prevents samples from being taken. For example, HYG77-0103 was dry in all four quarters during 1997, and samples could not be taken for the third consecutive year. For this reason and because of the site's close proximity to HYG77-0104, HYG77-0103 will be dropped from the program next year. HYG77-0101 was also dry during one sampling, and HYG77-0104 was dry for three of the four scheduled samplings.

At the hydraugers that could be sampled, alpha and beta were always undetectable, with the exception of one sample collected at HYG77-0101. This sample recorded a beta result of 0.19 Bq/L (5.1 pCi/L). Tritium results, however, varied considerably. At HYGCC1 and HYGCC2, it was not detected—with one exception slightly above detection limit. At HYG77-02XX, tritium was measured at levels up to 154 Bq/L (4,158 pCi/L). The one sample that was collected at HYG77-0104 showed a level of 286 Bq/L (7,722 pCi/L). At HYG77-0101, the tritium maximum was 577 Bq/L (15,579 pCi/L)—well below the US/EPA drinking water limit of 740 Bq/L (20,000 pCi/L).[5] The US/EPA drinking water limit is used for comparison purposes only, because this water is not used for human consumption.

In this area, where there is a known plume of tritium in the groundwater, hydrauger data indicate that tritium contamination decreases considerably over the rather short spatial separation of these horizontal wells. Comparing the results to previous years also shows that the higher levels seen last year at HYG77-0104 have decreased considerably, while levels in HYG77-02XX and HYG77-0101 have remained relatively stable or have decreased slightly.

§5.6 E. Stormwater

Berkeley Lab lies within the Strawberry Creek watershed, which covers an area of about 354 hectares (874 acres). There are two main creeks in the watershed, Strawberry Creek and the North Fork of Strawberry Creek, plus several small tributaries that generally do not flow all year long. This watershed includes other University of California property, public streets in both Oakland and Berkeley, and private property. Near Berkeley Lab, the Strawberry Creek watershed is further subdivided into the Blackberry Canyon and Strawberry Canyon watersheds (see Figure 5-4).

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. In the 1960s, Berkeley Lab began installation of its storm drain system, which is designed to handle runoff intensities expected in a 25-year maximum-intensity storm. All stormwater runoff from the site drains through this system to Strawberry Creek or its north fork, which join below the Laboratory on the UC Berkeley campus.

Under the State of California's NPDES program, Berkeley Lab must follow the General Permit for Stormwater Discharges Associated with Industrial Activities.[6] Permit

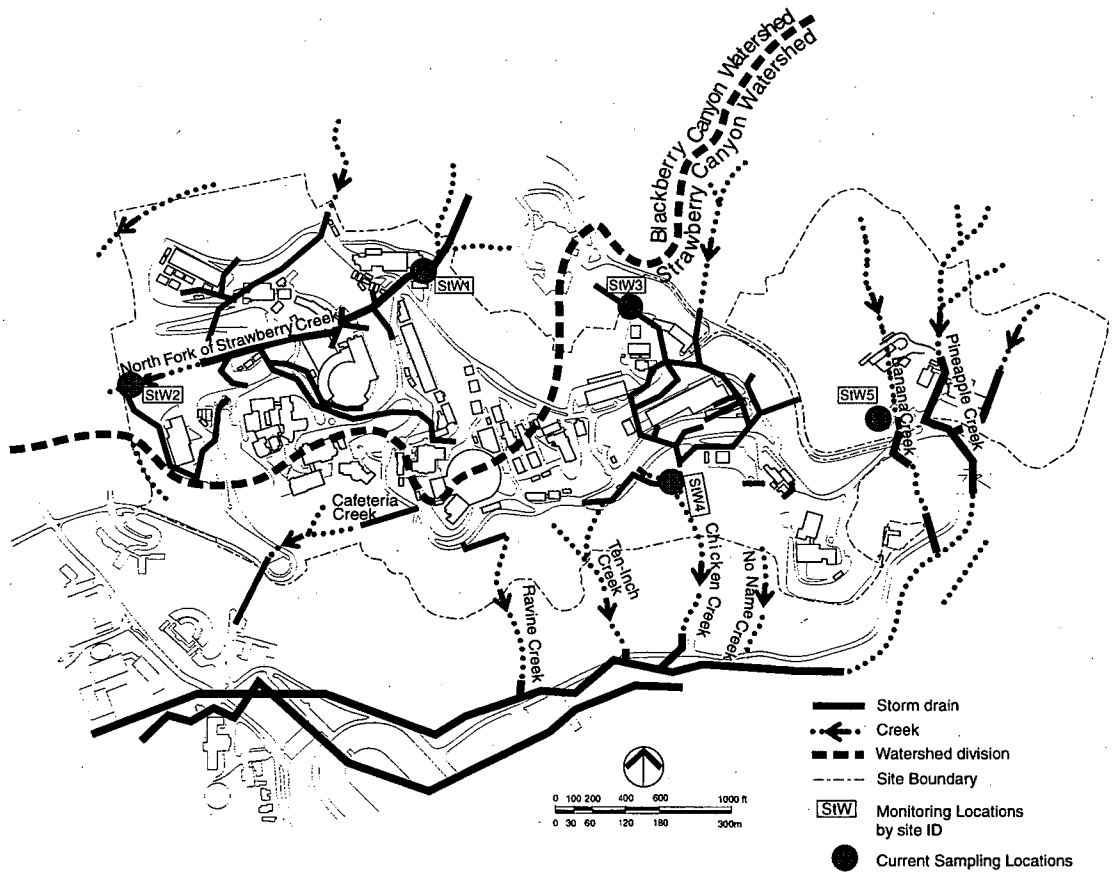

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Figure 5-4 Stormwater Sampling Locations

holders must develop and maintain a Storm Water Monitoring Plan (SWMP)[7] and a Storm Water Pollution Prevention Plan (SWPPP).[8] These are the guiding documents for the Lab's compliance with stormwater regulations. For further discussion of this compliance program, see §3.24.

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 year for both total and dissolved metals as a comparison. In 1997, both samples taken were analyzed for total and dissolved metals. Dissolved metals are consistently lower than total metals. Sampling points are shown in Figure 5-4.

In April, the State Water Resources Control Board reissued the general permit and added certain required analyses, depending on a facility's Standard Industrial Classification code. This change affected Berkeley Lab so that, beginning with the 1997–1998 stormwater season, certain parameters were added to the stormwater monitoring program. Metal analyses added were iron, aluminum, and magnesium. Additionally, analysis is now also performed for ammonia, nitrate plus nitrite as nitrogen, and chemical oxygen demand.

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 year under specific conditions. For example, a sample is valid only if the discharge was preceded by 72 hours of dry weather. 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.
- Toxic chemicals and other pollutants that are likely to be present in stormwater discharge in significant quantities.

In 1997, the pH was always near neutral, and PCBs and BTEX (benzene, toluene, ethylbenzene, and xylenes) were never detected. Total petroleum hydrocarbons (diesel) and oil and grease (both tests for gas or oil) were often detected in very low quantities. 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, in this case mostly a measure of water clarity, was also usually quite low, indicating clear water. Metals results were in general "nondetect." Only aluminum, iron, and magnesium were seen at low levels. Because of the large number of metals sampled that were below the minimum quantitation level, no table of metals results is presented in this report. For detailed results, see Appendix C.

The general permit does not contain specific discharge limits for metals. For comparison purposes, Table 4-3 of the Basin Plan[9] 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. Alpha radiation was not detected. Beta radiation ranged from not detectable to a one-time high of 0.127 Bq/L (3.4 pCi/L) at the Building 69 influent storm drain manhole (StW03). All tritium values were low, ranging from not detectable at Building 71 and the North Fork of Strawberry Creek (StW02) to 32.2 Bq/L (869 pCi/L) at Building 69 Influent (StW03). This represents a decrease over the maximum for 1996, which was 94 Bq/L (2,540 pCi/L) at StW03. Summaries of radiological results for stormwater sampling during 1997 are shown in Table 5-4.

During 1997, Berkeley Lab undertook a special creek water baseline project. The goal of this internal project was to establish a baseline for the quality of the creek water being discharged from the site. The project was divided into two phases, with the first phase scheduled to take place before the rainy season.

The first phase occurred in September 1997 and included samples taken from the North Fork of Strawberry Creek, Strawberry Creek above the Botanical Garden, Chicken Creek, and the B71 Storm Drain Manhole, an influent point. The other planned location, B69 Storm Drain Manhole (also an influent point), was dry and could not be sampled. Analyses were run for the following:

- Metals;
- Volatile organic compounds;
- Semivolatile organic compounds;
- Total petroleum hydrocarbons as diesel, oil, and grease;
- General minerals;
- Nitrate/nitrite;
- Total suspended solids;
- Chemical oxygen demand;
- Gross alpha and beta; and
- Tritium.

Table 5-4 Stormwater Radiological Monitoring Results[a]

		Beta, Bq[b]/L			Tritium, Bq/L		
Location	Number of samples	*Mean*	*Median*	*Maximum*	*Mean*	*Median*	*Maximum*
StW01	2	< 0.15[c]	< 0.15[c]	< 0.15[d]	6.7	6.7	10
StW02	2	0.032	0.032	0.035	5.2	5.2	7.4
StW03	2	0.124	0.124	0.127	20.2	20.2	32.2
StW04	2	0.055	0.055	0.074	25.2	25.2	29.6
StW05	3	< 0.15[d]	< 0.15[d]	< 0.15[d]	4.8	4.5	6

[a] Alpha was always less than the minimum detectable amount (yearly maximum of 0.11 Bq/L).
[b] 1 Bq = 27 pCi
[c] The yearly mean and median were less than the highest minimum detectable amount for the analyte at this site.
[d] The yearly maximum was less than the highest minimum detectable amount for the analyte at this site.

No volatile or semivolatile organic compounds, oil and grease, TPH diesel, chemical oxygen demand, or gross alpha or beta radiation were detected. Aluminum, boron, iron, and manganese were detected in almost all locations—all below 1 mg/L. Traces of nitrate/nitrite were detected in most locations. Tritium was found at Chicken Creek at very low levels.

The second phase took place in October and November 1997 and coincided with stormwater sampling. Locations sampled in addition to the five mentioned above were Strawberry Creek above the Botanical Garden and an influent point on the North Fork of Strawberry. A normal range of constituents was found in the general minerals analysis. Gross alpha and beta were almost never detected, with low levels of beta seen occasionally. Tritium was detected at low levels at all sites. Complete results of the Creek Water Baseline Project can be found in Appendix C.

6
Groundwater

§6.1 I. BACKGROUND

This section reviews the groundwater monitoring program at Berkeley Lab, emphasizing the 1997 results. Additional details on the program can be obtained in the Environmental Restoration Program (ERP) 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. The quarterly progress reports are available for public review at the UC Berkeley campus Doe Library.

The Berkeley Lab 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 Plan[1] established the program to accomplish these objectives by providing a framework for preventing future groundwater contamination and for remediating existing contamination at the site. Berkeley Lab 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 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, the San Francisco Bay Regional Water Quality Control Board, and the City of Berkeley. These agencies review and provide comment on the work plans prepared for all activities. Berkeley Lab submits quarterly progress reports to these agencies and meets with them each quarter to review results of the previous quarter's activities.

Results in this chapter, like those reported in chapter 5, 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 nor is the program held to these standards for compliance purposes.

§6.2 II. HYDROGEOLOGIC CHARACTERIZATION

This section discusses the hydrogeological setting of Berkeley Lab and includes a review of the hydrogeologic units, a discussion of groundwater flow, and a description of the hydrologic properties of the shallow water-bearing zones. For more detailed information on hydrogeology, see the 1994 Berkeley Lab RCRA Facility Investigation Progress Report.[3]

§6.3 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 the 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. For further discussion of the hydrogeological characteristics of the three main units, see §§2.8–2.9.

§6.4 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. The map indicates that the direction of groundwater flow generally follows the topography. In the western part of Berkeley Lab, groundwater flow directions are generally to the west; over the rest of the Laboratory, flow is generally 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 1 meter per day (3.3 feet per day).

§6.5 C. Groundwater Fluctuations

Fluctuations in measured groundwater levels in wells generally show a good correlation with rainfall, as shown in Figure 6-2. Generally, there is a fairly rapid response (on the order of days) of water levels in most site wells after rainfall occurs. Fluctuations as great as 4.2 meters (14 feet) are common in wells in the Old Town area.

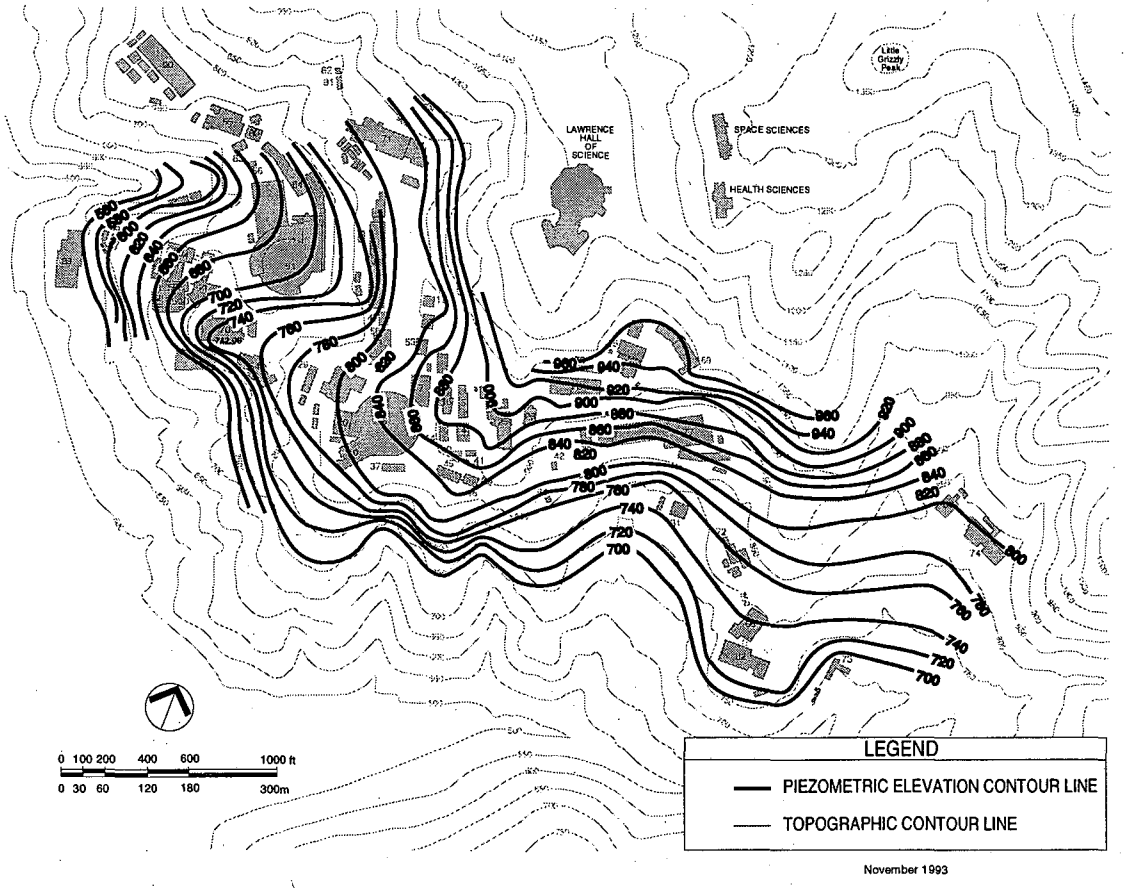


Figure 6-1 Groundwater Piezometric Map

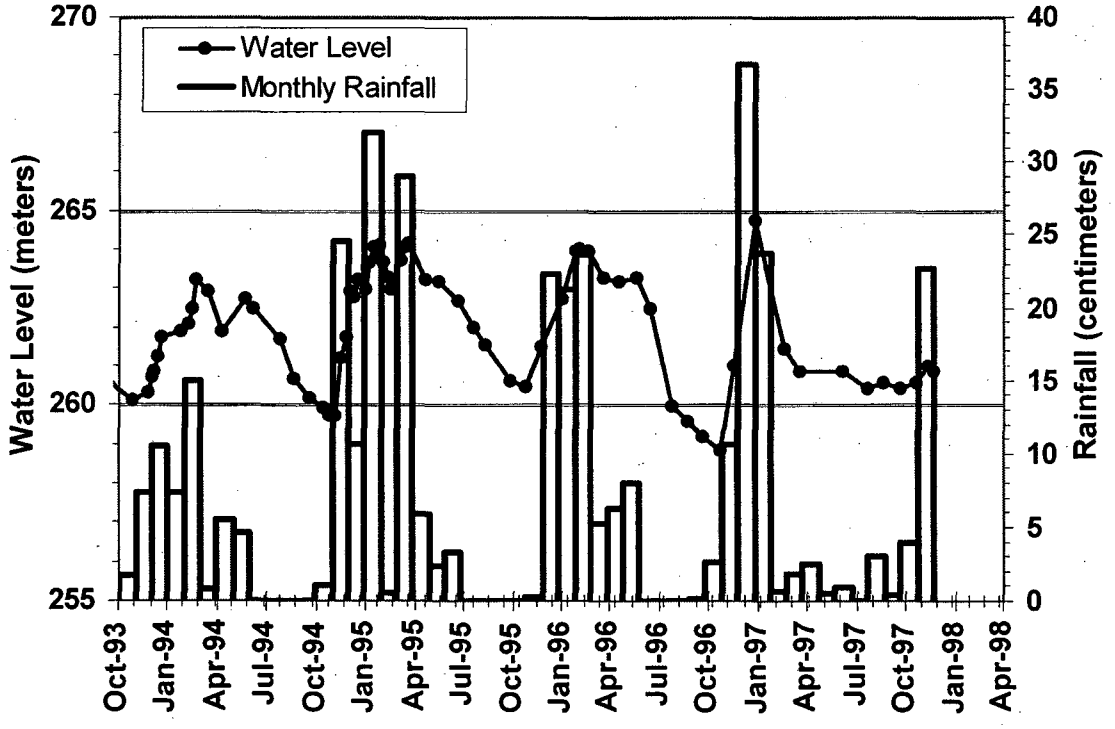


Figure 6-2 Groundwater Fluctuation in Monitoring Well MW7-92-19 Versus Rainfall

§6.6 D. 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 4460 mg/L. Water in the Orinda formation typically has a high TDS concentration, indicating a long residence time. Average mineral concentrations for the three primary geologic units are listed in Table 6-1.

§6.7 III. GROUNDWATER MONITORING RESULTS

In 1997, 23 new monitoring wells were installed, bringing the total in the program to 152 wells. Of the total number of wells, four are considered multilevel in that they allow groundwater sampling of more than one interval. Twenty monitoring wells are located close to the site boundary, and one well is located downgradient from the Laboratory (see Figure 6-3).

Tables 6-2, 6-3, and 6-4 summarize groundwater monitoring results for 1997. Tables 6-2 and 6-3 summarize the metals results and VOC results, respectively. The tables show the drinking water standard (maximum contaminant level or MCL) for the analyte,[4] the number of monitoring wells sampled, the number of wells in which the analyte was detected, and the ranges in concentrations detected. Table 6-4 presents tritium results. Periods in which either multiple samples or quality assurance samples were gathered from a location are included in this table.

Table 6-1 Long-Term Average Mineral Concentrations in Different Formations

Parameter	Drinking water standard (mg/L)	Average concentration (mg/L)		
		Orinda formation	*Moraga formation*	*Great valley formation*
Total dissolved solids	500[a]	794	485	712
Nitrate (as NO_3)	45	26	16	5
Sulfate	500	135	32	173
Chloride	250[a]	84	31	49
Bicarbonate	—[b]	467	413	419
Potassium	—[b]	4	2	5
Sodium	—[b]	199	61	119
Magnesium	—[b]	25	32	33
Calcium	—[b]	51	69	76
pH	6.5 to 8.5 pH units	7.9 pH units	7.7 pH units	7.7 pH units

[a] Indicates secondary standard (aesthetic standard).
[b] No drinking water standard exists for substance.

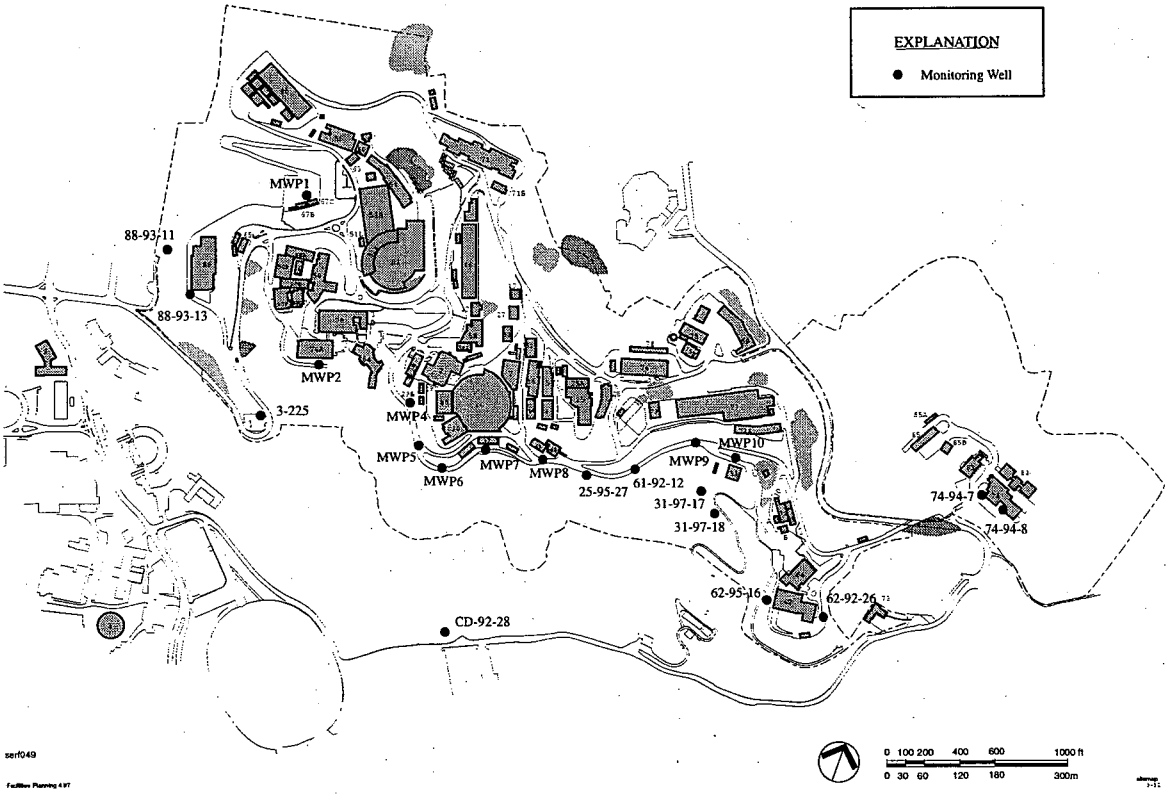


Figure 6-3 Approximate Locations of Monitoring Wells Closest to Berkeley Lab Property Line

§6.8 IV. GROUNDWATER CONTAMINATION PLUMES

Based on groundwater monitoring results, eight principal groundwater contamination plumes have been identified on site. The plumes are listed below, and the locations are shown in Figure 6-4:

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

Contamination was also detected in groundwater in other areas of the site in 1997. Based on the present information, however, the extent of contamination in these areas is limited.

§6.9 A. VOC Plumes

Covering the area of Buildings 7, 53, 27, and 58A and the slope west of Building 53, the Old Town VOC plume is the most extensive plume at Berkeley Lab. This plume is defined by the presence of tetrachloroethene (PCE), trichloroethene (TCE), and lower

Table 6-2 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)
Arsenic	75	132	42	2.1 – 123	50
Barium	75	121	53	22 – 920	1000
Beryllium	75	121	1	6.7	4
Chromium	75	121	4	5.2 – 19	50
Cobalt	75	121	3	5.5 – 12.6	NS[b]
Copper	75	121	18	3.3 – 18.7	1000[c]
Mercury	75	124	1	1.75	2
Molybdenum	75	121	18	5.1 – 460	NS[b]
Nickel	75	121	4	6 – 9.1	100
Selenium	75	121	22	2.0 – 9.0	50
Vanadium	75	121	19	1.1 – 93.8	NS[b]
Zinc	75	121	10	6.7 – 99	5000[c]

[a] Metals not detected in any samples include antimony, cadmium, lead, silver, and thallium.
[b] NS = Not specified
[c] Secondary MCL

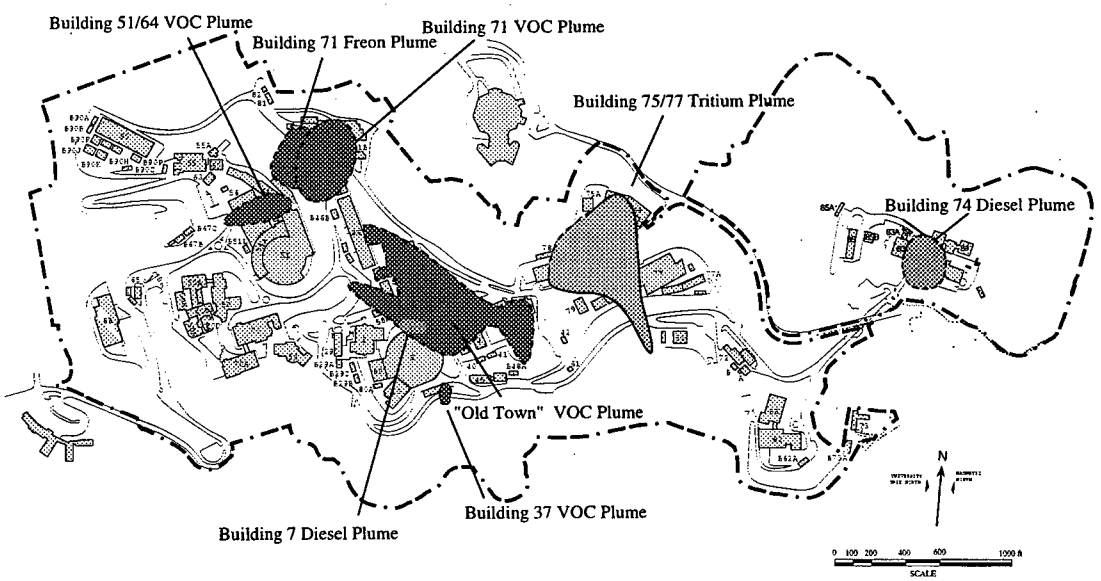


Figure 6-4 Groundwater Contamination Plumes (December 1997)

Table 6-3 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	1	11.1 – 47.7	1
Bis(2-ethylhexyl)phthalate	1	46 – 133	NS[b]
sec-Butylbenzene	2	1.3 – 4.1	NS
1,4-Dichlorobenzene	2	0.71 – 0.87	NS
Toluene	2	0.7 – 1.7	150
1,2,4-Trichlorobenzene	1	0.76	NS
1,3,5-Trimethylbenzene	1	1.2	NS
Halogenated hydrocarbons			
Bromoform	2	1.4 – 2.3	NS
Carbon tetrachloride	20	1.2 –1700	0.5
Chloroethane	1	0.72	NS
Chloroform	38	0.77 – 280	100
1,1-Dichloroethane	32	0.51 – 3100	5
1,2-Dichloroethane	4	1.2 – 38.3	0.5
1,1-Dichloroethene	40	0.57 – 730	6
cis-1,2-Dichloroethene	47	1 – 4400	6
trans-1,2-Dichloroethene	15	0.56 – 51.1	10
Methylene chloride	3	1.1 – 34.7	5
Methyl tert-butyl ether	1	5.5	
1,1,1,2-Tetrachloroethene	3	16.9 – 31	NS
Tetrachloroethene	62	1 – 73,000	5
1,1,1-Trichloroethane	18	0.68 – 450	200
1,1,2-Trichloroethane	5	0.58 – 13.8	5
Trichloroethene	69	0.54 – 39,000	5
1,1,2-Trichlorotrifluoroethane (CFC-113)	6	1.2 – 141	1200
Vinyl chloride	16	0.85 – 110	0.5

[a] 522 samples taken from sampling at 151 wells during the year, except for Bis(2-ethylhexyl)phthalate (5 samples from 2 wells) and Methyl tert-butyl ether (238 samples from 145 wells).
[b] NS = Not specified

Table 6-4 Tritium Detected[a,b] in Groundwater Samples from Monitoring Wells

Well number	January–March (Bq/L)	April–June (Bq/L)	July–September (Bq/L)	October–December (Bq/L)
MW91-4	31	NS[c]	19	NS
MW91-5	120	NS	90	NS
MW91-6	223	NS	131	NS
75-92-23	63	NS	222, 292	NS
75B-92-24	172	NS	199	NS
75-96-20	10, ND[d] (D[e])	ND	ND	ND, ND (D)
75-97-7	NS	NS	36, 40	39
MW76-1	23	NS	22	NS
76-93-6	154	NS	72	NS
78-97-20	NS	NS		175, 237, 181
MW91-2	18	NS	14	NS
77-94-5	ND	NS	29, ND	ND
77-94-6	356, 369 (D)	365, 460 (D)	308	333
77-97-9	NS	NS	381, 478 (D)	505
77-97-11	NS	NS	190, 242 (D)	228
31-97-17	NS	NS	12	37, 46
MWP-8	ND	ND, 5 (S)[f]	ND	ND
MWP-7	ND, 9 (D)	ND, 7 (S)	27, 6 (D)	ND, ND (S)

[a] Wells without detectable results in all quarters of sampling include MW90-3, 46A-92-15, 71-93-1, MW91-3, 69A-92-22, 75-97-6, 69-97-21, 76-92-25, 76-93-7, MW91-1, MWP-9, MWP-10, 77-92-10, 61-92-12, 77-93-8, 31-97-18, MWP-2, OW3-225, MW91-9, 52-94-10, 52-95-2, 62-92-27, 62-92-26, MWP-4, MWP-5, MWP-6, 37-92-6, 37-92-18, 37-92-18A, 37-93-5, 37-94-9, MWP-1, and CD-92-28.

[b] For comparison, the drinking water standard determined by California Department of Health Services is 740 Bq/L (20,000 pCi/L).

[c] NS = Not sampled

[d] ND = Nondetected

[e] D = Duplicate sample

[f] S = Split sample

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. The maximum concentration of total halogenated hydrocarbons detected in 1997 in groundwater samples collected from wells monitoring the Old Town VOC plume was 92,800 µg/L, which primarily consisted of PCE (73,000 µg/L), TCE (18,000 µg/L) and carbon tetrachloride (940 µg/L). Figure 6-5 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

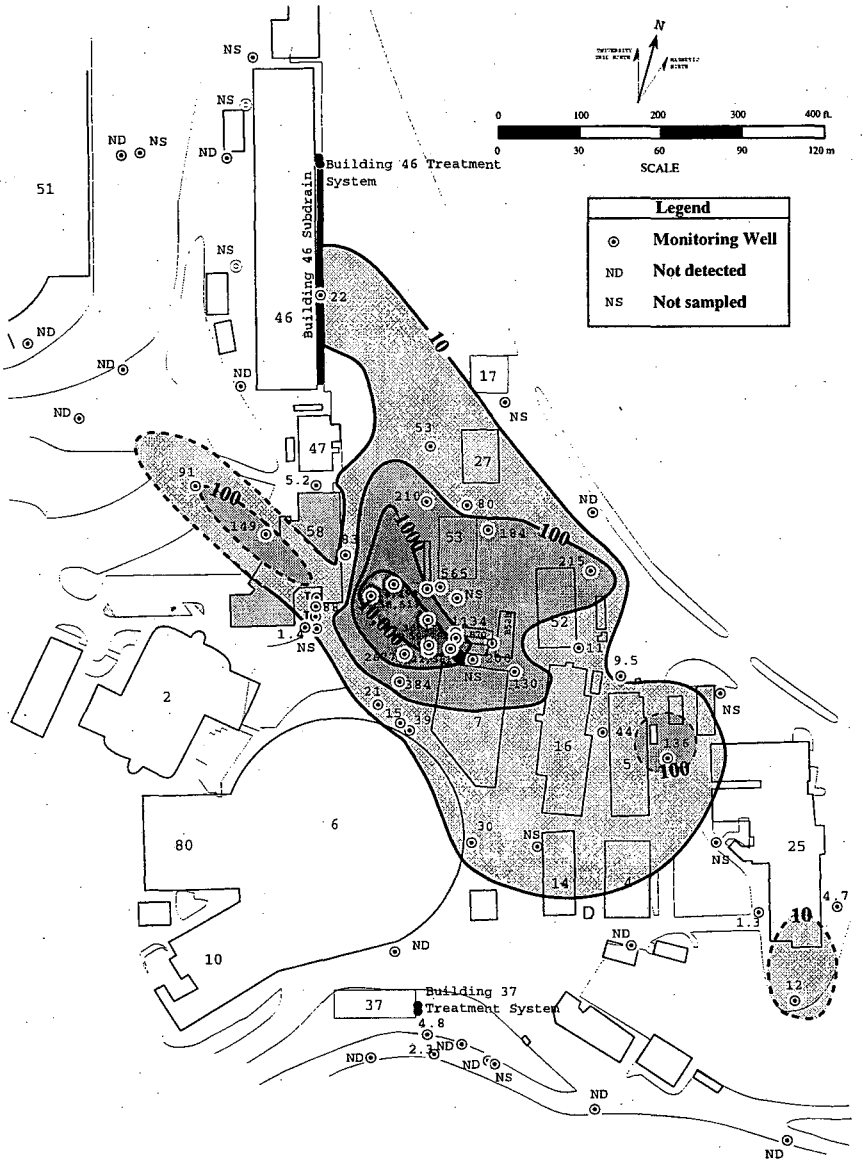


Figure 6-5 Groundwater Contamination (Total Halogenated Hydrocarbons in µg/L) in Old Town Area (December 1997)

sump were relocated. Other less significant source areas for groundwater contamination are indicated by relatively high concentrations of halogenated hydrocarbons detected in groundwater samples from monitoring wells west of Building 16, east of Building 52, and west of Building 25A. The sources of the contamination detected in these wells have not been identified. The contaminated groundwater from these sources flows westward, where it intermixes with the main Old Town plume.

Three interim corrective measures (ICMs) have been instituted to manage the Old Town VOC Plume (see §6.13):

- A groundwater collection trench was installed downgradient from the former Building 7 sump.
- A subdrain located east of Building 46 intercepts the northern lobe of the plume.
- Groundwater is extracted from MW58-95-18 at the southern lobe of the plume and treated.

Other VOC plumes have been identified south of Building 71 (Building 71 VOC plume), near Buildings 51 and 64 (Building 51/64 VOC plume), and east of Building 37 (Building 37 VOC plume). These plumes cover less area than the Old Town plume, and fewer contaminants have been detected. The sources of these contaminant plumes are not known.

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 1997 in wells monitoring the plume was 71 µg/L. 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.

The Building 37 VOC plume is defined by the presence of halogenated hydrocarbons, primarily TCE and PCE 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 1997 was 8.9 µg/L.

The Building 51/64 VOC plume is defined by the presence of halogenated hydrocarbons, including 1,1-DCA, TCE, vinyl chloride, PCE, trans-1,2-DCE, and 1,1,1-TCA. Although the source of the contamination is not known, multiple sources appear to exist, based on the suite of chemicals detected in each of the wells in the area. The maximum concentration of total halogenated hydrocarbons detected in 1997 in wells monitoring the plume was 5,328 µg/L, which primarily consisted of 1,1-DCA (3,100 µg/L).

§6.10 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 34 µg/L in December 1997. The MCL for freon-113 is 1200 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.

§6.11 C. Tritium Plume

The tritium plume appears to be limited to 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 1997 was about 505 Bq/L (13,640 pCi/L), which is well below the drinking water standard of 740 Bq/L (20,000 pCi/L).[5]

§6.12 D. Fuel Contamination and Fuel 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 1997 are listed in Table 6-5.

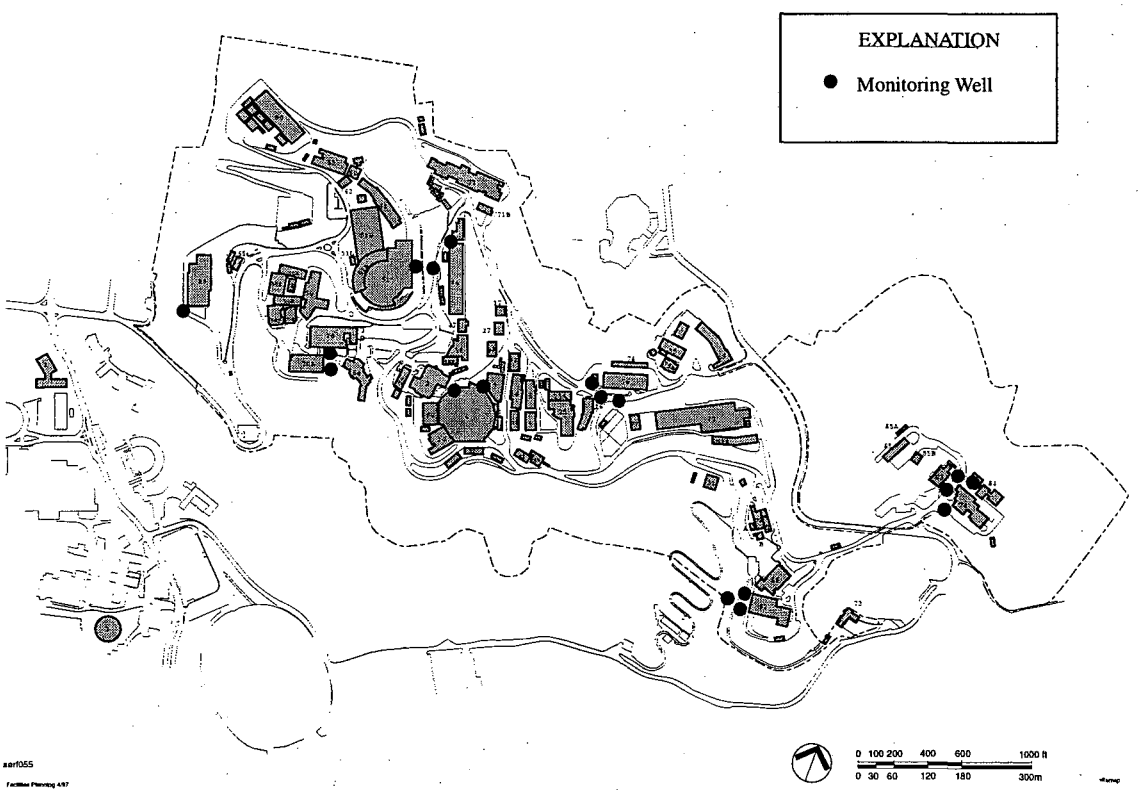


Figure 6-6 Approximate Locations of Monitoring Wells Associated with Underground Storage Tanks

Table 6-5 Total Petroleum Hydrocarbon Concentrations at UST Sites

UST location	Status	Present or previous contents	Maximum concentration (µg/L)
Building 51	Removed	Diesel	ND[a]
Building 70A	Removed	Diesel	TPH-D[b] = 150
Building 62	Removed	Diesel	TPH-D = 59
Building 74	Removed	Diesel	TPH-D = 200
Building 76	Removed	Diesel	TPH-D = 350
Building 76	Removed	Gasoline	TPH-G[c] = 56
Building 7E	Removed	Kerosene	TPH-D = 5,800
Building 88	Abandoned	Diesel	ND
Building 46A	Abandoned	Gasoline	NS[d]

[a] ND = not detected
[b] TPH-D = TPH quantified as diesel range hydrocarbons
[c] TPH-G = TPH quantified as gasoline range hydrocarbons
[d] NS = not sampled

The only UST site where aromatic hydrocarbons were detected in 1997 was the Building 7E former kerosene tank. The plume (Building 7 Diesel Plume) is located north of Building 6. No BTEX components (i.e., benzene, toluene, ethyl benzene, xylene) were detected at UST sites in 1997.

Methyl tertiary butyl ether (MTBE) was detected in one monitoring well in 1997 at a concentration of 5.5 µg/L. The USEPA Drinking Water Advisory for MTBE is 20 to 40 µg/L. The source of the MTBE is not known. MTBE is the controversial new additive in gasoline sold in California.

§6.13 V. INTERIM CORRECTIVE MEASURES

Interim corrective measures are used to remediate contaminated media or prevent movement of contamination, especially where the presence or movement of contamination poses an immediate risk to human health or the environment. Throughout the RCRA corrective actions process, Berkeley Lab has conducted interim corrective measures in consultation with regulatory agencies. These measures include:

- 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.

Berkeley Lab has undertaken these measures even though there are no immediate risks to health posed by the contaminations. In addition, Berkeley Lab conducts pilot testing to evaluate potential methods for remediating contaminated soil and groundwater.

§6.14 A. Source Removal or Control

Berkeley Lab has attempted to identify potential sources of contamination by reviewing site records; conducting visual site inspections; and sampling soil, soil gas, and groundwater.

If the contaminant concentrations pose a threat to human health or leaching of contaminants from the soils can affect groundwater, the need for interim corrective measures is evaluated. Several sources of contamination have been removed at the Laboratory, including the following sources removed in 1997:

- The Building 52B abandoned liquid waste aboveground storage tank was removed on September 6, 1997. Approximately 120 cubic yards of contaminated soil were also excavated. Soil at the abandoned tank site was contaminated with polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), fuel hydrocarbons (primarily diesel fuel), and crude/waste oil. The abandoned tank site was a potential source of groundwater contamination.
- 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, a groundwater collection trench was constructed immediately downgradient from the former sump location in 1996. Contaminated groundwater is extracted from the collection trench and treated. The treatment system removed approximately 14 kg of VOCs (consisting primarily of PCE, TCE, and carbon tetrachloride) from the groundwater in 1997. The treated water is either released under permit to the sanitary sewer or reinjected with the approval of the RWQCB to continuously flush subsurface contaminants to the trench for collection and treatment.

§6.15 B. Preventing Discharge of Contamination to Surface Waters

Slope stability is a concern at Berkeley Lab because of the geology and topography of its 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 the contaminated groundwater to the creeks, Berkeley Lab installed a system to collect and treat the hydrauger effluent where the water was contaminated with VOCs.

§6.16 C. Eliminating Potential Contaminant Pathways to Groundwater

To reduce the risk of landslides, Berkeley Lab has installed numerous large-diameter slope-stability wells. The well casings are slotted and the exterior of the casings backfilled with gravel to allow the maximum volume of groundwater to be extracted. Because of the lack of a surface seal, the backfill is a potential conduit for the migration of contaminated water from the surface to groundwater. Three approaches have been selected as interim corrective measures to prevent these wells from acting as potential contaminant pathways to groundwater:

- If a slope-stability well is needed for slope-stability purposes, its construction is modified by redrilling the well and installing at least 6.1 meters (20 feet) of an impermeable cement seal in the annular space from the ground surface to the screened interval. To date, nine slope-stability wells have been modified.
- If a slope-stability well is not needed, it is abandoned in accordance with regulatory requirements. Five slope-stability wells were abandoned in 1997, bringing the total number of wells abandoned to ten.
- If a slope-stability well is needed to monitor groundwater contamination, the well is reconstructed into a monitoring well. To date, five slope-stability wells have been reconstructed into monitoring wells.

§6.17 D. 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.

§6.18 E. 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. Six 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 the Berkeley Lab's treated groundwater discharge permit from EBMUD,[6] or recirculated to flush contaminants from the subsurface. Table 6-6 lists both the volume of contaminated groundwater treated by each system in 1997 and the total volume treated since the treatment systems were first placed in operation.

Table 6-6 Treatment of Contaminated Groundwater

Source of contamination	Treatment system	Volume of water treated in 1997 (liters)*	Volume of water treated to date (liters)
Building 37 VOC plume	Building 37	532,765	2,309,263
Old Town VOC plume	Building 46	3,902,797	16,476,839
Water collected from purging monitoring wells	Building 51 firetrail	105,212	325,839
VOC-contaminated hydrauger effluent	Building 51 hydraugers	3,006,683	28,394,854
Building 51 subdrain system	Building 51 sump	1,327,237	1,564,113
Old Town VOC plume	Building 7 trench	967,643	1,030,360
Total volume treated		9,842,336	50,101,269

*1 liter = 0.264 gallons

7
Sanitary Sewer

§7.1 I. BACKGROUND

The Laboratory's sanitary sewer system is based on gravity flow and discharges through one of two monitoring stations: Hearst or Strawberry (see Figure 7-1):

- Hearst Station, located at the head of Hearst Avenue below Berkeley Lab, monitors discharges from the western and northern portion 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. Beyond the monitoring station, this section of the discharge system first ties into 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, which 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 Gardens).

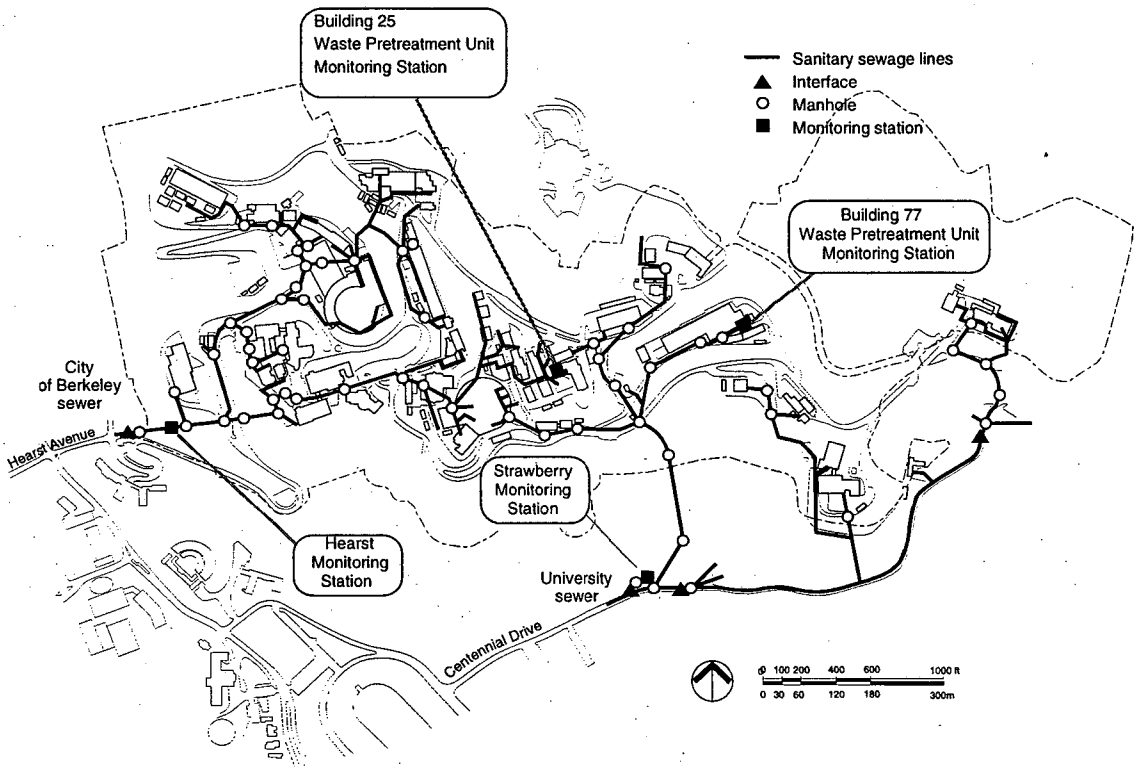


Figure 7-1 Sanitary Sewer System

Self-monitoring of wastewater discharge within Berkeley Lab also occurs at Buildings 25 and 77 and at groundwater treatment units, according to the terms of their respective East Bay Municipal Utility District (EBMUD) permits.[1]

§7.2 II. WASTEWATER DISCHARGE PROGRAM

Berkeley Lab currently has four wastewater discharge permits issued by EBMUD: one for general sitewide discharges, two for the metal finishing operations found in Buildings 25 and 77, and one for the discharge of treated groundwater from hydraugers. EBMUD renews the site's wastewater discharge permits each 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.

Berkeley Lab's wastewater management program has an outstanding record. As a measure of its effectiveness, the Laboratory has not violated its wastewater discharge permits since 1994. Operational changes in metals finishing and implementation of programs designed to reduce pollutant discharges have contributed significantly to this record.

Because of this outstanding ongoing compliance record, EBMUD relaxed certain requirements for the Laboratory's 1997–1998 permit. Monitoring was reduced to quarterly (from six times per year), and metals analysis was reduced to once per year (from twice per year). EBMUD will perform unannounced monitoring only four times

per year (reduced from six times per year). The Laboratory's sitewide limit for methylene chloride was made tougher (reduced to 0.01 mg/L), but self-monitoring analysis for total chlorinated hydrocarbons is no longer required.

III. SANITARY SEWER RESULTS

§7.3 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. Sitewide samples are always analyzed for pH, methylene chloride, total suspended solids, and chemical oxygen demand, with additional analyses for metals required at specific times during the permit year. Analysis is performed by a state-certified outside contract laboratory. Results are compared against the discharge limits for each parameter given in the permits, and self-monitoring reports are submitted to EBMUD.

Radiological monitoring is required by DOE guidance[2] and orders,[3] but it also ensures compliance with the radiological limits given in the California Code of Regulations.[4] California regulations now incorporate by reference the applicable federal regulations[5] and associated discharge limits.

Sanitary sewers are normally monitored for gross alpha, gross beta, iodine-125, and tritium. Gross alpha and gross beta results are used to determine whether specific radionuclide measurements are required. During most of 1997, radiological samples were generally split between two outside laboratories as a quality control measure.

Radiological monitoring is performed biweekly, and flow measurements are made concurrently. The biweekly flow data form the basis for annual flow information, which is provided to EBMUD as part of the annual renewal of the discharge permits.

§7.4 1. Nonradiological Monitoring

Six nonradiological self-monitoring samples were taken from the Hearst and Strawberry outfalls during 1997. All results were well within discharge limits, as were all measurements made by EBMUD in its independent samplings. Analyses for metals were required for only three of the six samples: the second and fourth sampling events of the 1996–1997 permit, and the first sampling event of the 1997–1998 permit. Table 7-1 illustrates the average and maximum annual levels of metals found in these three samples. Permit discharge limits are given for comparison.

Laboratory analysis for methylene chloride was also done on six different samples collected at both Hearst and Strawberry stations during the year. Only one of the 12 samples detected methylene chloride. This sample from Strawberry Station had a concentration of 8.2 μg/L. The discharge limit for this substance is 10 μg/L.

§7.5 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

Table 7-1 Metals in Sewer Water Samples[a]

Parameter	Hearst Station		Strawberry Station		Permit limit
	Mean[b]	*Maximum*	*Mean[b]*	*Maximum*	
Cadmium	< 0.01[c]	< 0.01[d]	< 0.01[c]	< 0.01[d]	1
Chromium	< 0.01[c]	< 0.01[d]	0.011	0.014	2
Copper	0.061	0.07	0.064	0.072	5
Lead	< 0.05[c]	< 0.05[d]	< 0.05[c]	< 0.05[d]	2
Nickel	< 0.05[c]	< 0.05[d]	< 0.05[c]	0.05	5
Silver	< 0.01[c]	< 0.01[d]	< 0.01[c]	< 0.01[d]	1
Zinc	0.22	0.23	0.17	0.23	5
Total no. of samples	3	—	3	—	

[a] All results are in mg/L.
[b] For "nondetect" results, the practical quantitation limits were used in computing means.
[c] The yearly mean was less than the highest practical quantitation limit for this analysis.
[d] The yearly maximum was less than the practical quantitation limit for this analysis.

collected biweekly by technicians 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.

Regulatory limits used to evaluate radioactive sewer discharge data are not concentrations, as they are with surface water. Rather, the federal[6] and state[7] regulatory limits are total amounts per year. For tritium, this amount is 1.85×10^{11} Bq (5 curies) per year. For carbon-14, the limit is 3.7×10^{10} Bq (1 curie) per year. The limit for all other radioisotopes is a combined 3.7×10^{10} Bq (1 curie) per year.

Radioanalyses of Berkeley Lab's sewer wastewater for 1997 are summarized in Table 7-2. Twice during the year, Strawberry could not be sampled because debris blocked the sampler's inlet; the same was true for Hearst once. Alpha emitters, which come from transuranic and heavy-element research, were never seen at either Hearst or Strawberry. Beta emitters, including iodine-125 from biomedical research, were detected in both sewers at low levels, with less at Strawberry than at Hearst. Iodine-125 was detected in very low amounts at Hearst, and either nondetectable or in very low amounts at Strawberry.

Tritium was often below the minimum detectable activity at Hearst but was usually seen at Strawberry. The total yearly discharge of tritium in wastewater was 4.4×10^9 Bq (0.12 Ci), and the total for other radioisotopes was 3.3×10^8 Bq (0.009 Ci). Both measures are down considerably from last year. These values are well below allowable limits. Tritium, for example, was only 2.4% of the allowable federal and state limit, while all other isotopes together are less than 1% of the limit.

Table 7-2 Radionuclide Analyses of Sewer Water Samples

	Hearst Station			
	Concentration, Bq/L[a]			
Parameter	*Mean*	*Median*	*Maximum*	Total amount, Bq[b]
Alpha	< 0.11[c]	< 0.11[c]	< 0.11[d]	$<3.7 \times 10^6$
Beta	0.42	0.37	1.03	3.2×10^7
Iodine 125	1.9	1.8	4.85	1.4×10^8
Tritium	4.2	3.5	9.2	3.3×10^8
Total no. of samples	24	24	—	
	Strawberry Station			
	Concentration, Bq/L			
Parameter	*Mean*	*Median*	*Maximum*	Total amount, Bq[b]
Alpha	< 0.11[c]	< 0.11[c]	< 0.11[d]	$<1.2 \times 10^7$
Beta	0.18	0.17	0.26	2.3×10^7
Iodine 125	< 1.1[c]	< 1.1[c]	1.4	1.2×10^8
Tritium	31.4	21.5	119	4.2×10^9
Total no. of samples	23	23	—	

[a] Bq = 27 pCi
[b] Combined totals from both outfalls are compared against regulatory limit. The sitewide limit for tritium is 1.85×10^{11} Bq. Total effluent of all other parameters presently monitored by Berkeley Lab must not exceed 3.7×10^{10} Bq.
[c] Yearly mean and median were less than the highest minimum detectable amount for the analyte at this site.
[d] Maximum was less than the highest minimum detectable amount for the analyte at this site.

§7.6 B. Building 25 Photo Fabrication Shop Wastewater

The Photo Fabrication Shop in Building 25 manufactures electronic printed wiring boards and screen print nomenclature on panels to support the needs of Berkeley Lab research and operations. Wastewaters containing metals and other hazardous materials from these operations are routed to a fixed treatment unit (FTU) before discharge to the sanitary sewer. The changing nature of the work affects the amount of water, types of chemicals, and equipment used. The Building 25 FTU treats wastewater in batch mode.

In December 1997, a web filter system was installed in-line with the scrubbing process for copper panels used in the manufacture of printed circuit boards. This filter traps and collects copper particulates from the waste stream so that it can then be treated and recycled. The process reduces hazardous waste in the form of sludge, decreases the burden on the treatment unit, and allows the recycling of both copper and water in the process.

All sampling performed by Berkeley Lab and EBMUD yielded results well within EBMUD[8] discharge limits.

§7.7 C. Building 77 Fixed Treatment Unit Discharge

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 vapor degreasing. The UHVCF anticipates that vapor degreasing will be phased out during 1998, to be replaced by a recently installed ultrasonic cleaning system that is currently being tested extensively to prove its serviceability for the exacting demands placed on the UHVCF.

Acid and alkaline rinsewaters containing metals from UHVCF operations are routed to a nearby 227-liter (60-gallon) per minute FTU.

Four self-monitoring samples were taken from the Building 77 FTU during 1997. None of the sample analyses, nor any sampling done by EBMUD, exceeded any of the discharge limits in the permit.[9] Based on this facility's compliance record, EBMUD reduced monitoring for the 1997–1998 permit from four to three times per year. Sampling results from the Building 25 and Building 77 FTUs are available in Appendix C.

§7.8 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 quarterly report on the volumes treated and discharged and any contaminants found.

Tests using US/EPA methodologies are run quarterly on treated groundwater to determine levels of volatile organic compounds. In general, all results have been "nondetect." Occasional detections of certain chlorinated hydrocarbons have been extremely low (parts per billion) and do not exceed allowable limits. As a precautionary measure not required by the permit, 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.

8
Soil and Sediment

§8.1 I. BACKGROUND

The analysis of soil and sediment can provide information of 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 1997, sampling was done in October before the rainy season. All sampling results are presented in Appendix C.

§8.2 II. SOIL AND SEDIMENT SAMPLING

In 1997, 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 offsite environmental monitoring station (see Figure 8-1). Locations were chosen to coincide with ambient-air sampling stations. Samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, semivolatiles, and pH.

Sediment samples were collected during the same period from both the main and tributary creek beds of the North Fork of Strawberry Creek and Chicken Creek, which are both continually flowing creeks (see Figure 8-1). Samples were analyzed for gross alpha and gross beta radiation, gamma emitters, tritium, metals, semivolatiles (including PCBs, diesel, and oil and grease), and pH.

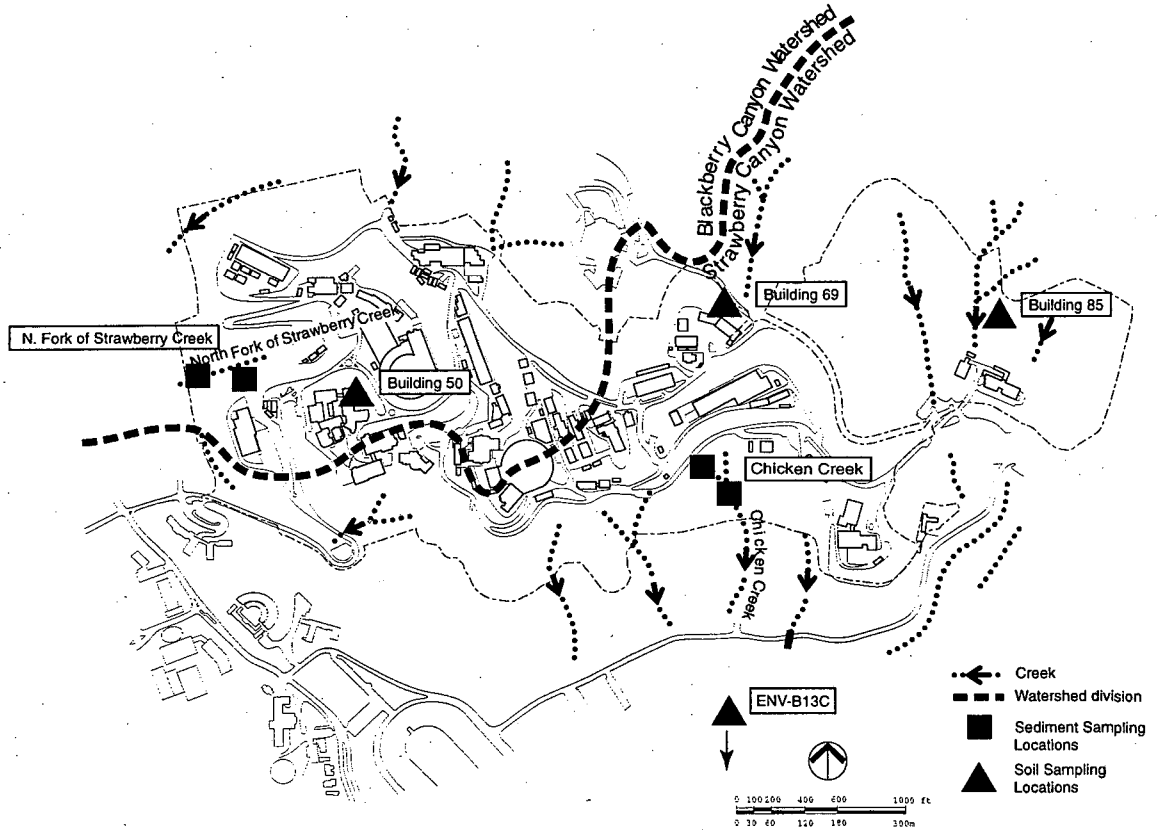


Figure 8-1 Soil and Sediment Sampling Sites

§8.3 III. SOIL AND SEDIMENT 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. The maximum tritium level in soil was 744 Bq per liter of soil water (0.026 Bq per gram of soil) near Building 69. The maximum tritium level in sediment was 120 Bq/L (0.028 Bq/g) at the Chicken Creek–Main location. Berkeley Lab is currently conducting a RCRA corrective action program 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.

All analysis results for metals analyses and pH were within normal levels for soil and sediment and well below regulatory levels.[3] All analyte results for semivolatile organic compounds were below or near analytical quantification limits, except for oil and grease in sediment. The maximum level of oil and grease (2,600 mg/kg) was measured at the Chicken Creek–Main location. Oil and grease contamination is commonly associated with motorized vehicles on roads and parking lots. The Laboratory's Cyclotron Road traverses the grade directly above the sampling site. This location will be sampled in future years to monitor any changes. Tables 8-1 and 8-2 summarize the soil analysis results for tritium, metals, and oil and grease.

Table 8-1 Tritium Results in Soil and Sediment Sampling[a]

Sampling location	Matrix	Tritium (Bq/L)[b]	Tritium (Bq/g)[c]	% Moisture
Building 50	Soil	16	0.0014	8.5
Building 69	Soil	744	0.026	3.5
Building 85	Soil	13	0.00081	6.2
ENV-B13C	Soil	12	0.0050	42.0
Chicken Creek–Main	Sediment	120	0.028	23.0
Chicken Creek–Tributary	Sediment	64.4	0.00966	15.0
North Fork Strawberry Creek–Main	Sediment	10	0.0009	8.8
North Fork Strawberry Creek–Tributary	Sediment	36	0.0079	22.0

[a] One sample per location
[b] 1 Bq = 27 pCi
[c] The amount of tritium per mass of soil or sediment is dependent on the water content of the material, which varies from sample to sample.

Table 8-2 Metals and Oil/Grease Results in Soil and Sediment Sampling[a]

	Sample Location								
	Soil				Sediment				
Analyte	*ENV-B13C*	*ENV-B50*	*ENV-B69*	*ENV-B85*	*Chicken Creek–Main*	*Chicken Creek–Tributary*	*N. Fork Strawberry Creek–Main*	*N. Fork Strawberry Creek–Tributary*	*Regulatory criteria (TTLC[b])*
Antimony	< 10[c]	< 10[c]	< 10[c]	< 10[c]	< 10[c]	< 10[c]	< 10[c]	< 10[c]	500
Arsenic	3.5	10	14	5.7	3.3	5	4.5	4.7	500
Barium	77	232	159	118	627	135	90	91	10,000
Beryllium	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	75
Cadmium	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	100
Chromium	18	47	83	72	56	69	21	30	2,500
Cobalt	< 5[c]	14	13	13	15	9.9	5.9	7.7	8,000
Copper	16	95	91	35	41	26	11	18	2,500
Lead	46	58	57	7.7	39	32	7	22	1,000
Mercury	0.25	< 0.2[c]	0.24	< 0.2[c]	< 0.2[c]	< 0.2[c]	< 0.2[c]	0.4	20
Molybdenum	< 5[c]	< 5[c]	< 5[c]	< 5[c]	< 5[c]	< 5[c]	< 5[c]	< 5[c]	3,500
Nickel	17	45	64	49	45	50	16	20	2,000
Selenium	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	< 1[c]	100
Silver	< 2[c]	< 2[c]	< 2[c]	< 2[c]	< 2[c]	< 2[c]	< 2[c]	< 2[c]	500
Thallium	< 10[c]	< 10[c]	< 10[c]	< 1[c]	< 1[c]	< 10[c]	< 10[c]	< 10[c]	700
Vanadium	22	63	54	71	51	43	37	44	2,400
Zinc	72	112	328	67	167	131	70	95	5,000
Oil & Grease	—	—	—	—	2,600	540	110	310	—

[a] One sample per location, all results in mg/kg
[b] Total Threshold Limit Concentration
[c] Below detection limit

9
Vegetation and Foodstuffs

§9.1 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 above 0.001 mSv (0.1 mrem), but below 0.01 mSv (1 mrem), a minimal vegetation and foodstuff surveillance program is required.[1] Using conservative assumptions regarding public consumption of locally grown vegetation and foodstuffs, Berkeley Lab estimated that the maximum individual dose attributable to airborne radionuclides was well below the threshold 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 over-estimate 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 free-water tritium or organically bound tritium.

The Laboratory's Environmental Monitoring Plan[2] 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.

§9.2 II. TREE SAMPLING RESULTS

Berkeley Lab manages onsite trees and brush as part of an ongoing fire prevention and control program (see §2.6). Eucalyptus and pine trees, which burn readily, are being strategically removed so that less combustible native trees such as redwood and oak may establish themselves. In 1997, the Laboratory thinned a stand of trees to the north and east of Building 84. In April, before the trees were thinned, 28 tree heartwood and foliage samples were collected at 13 locations (26 samples plus 2 quality control duplicates) throughout the stand to determine the free water and organically bound tritium concentrations within those trees. Figure 9-1 illustrates the tree sampling locations.

The tree sample analytical results indicated that average tritium concentrations within the trees were below or near analytical detection levels (see Table 9-1). These analytical results were used in evaluating feasible and cost-effective disposal alternatives for the subsequent removal of trees from nearby areas later in the year. The removed trees were shipped off site for conversion into paper products after the Laboratory confirmed that tritium levels within the tree material were at the limits of analytical quantification and indistinguishable from regional background levels.

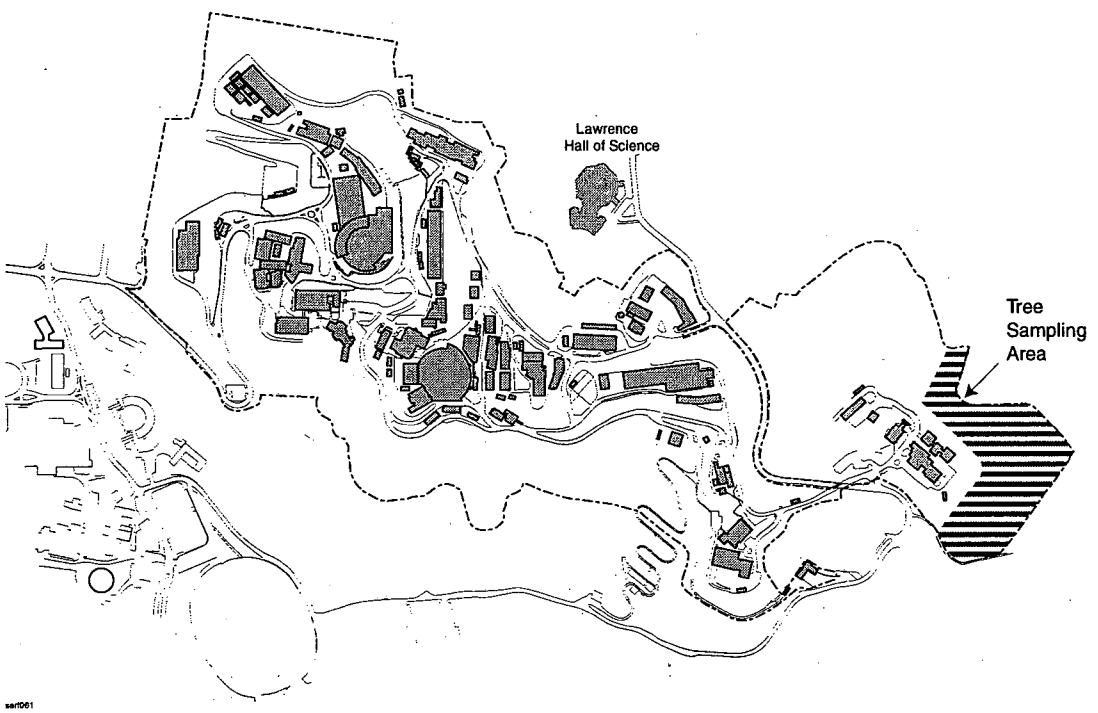


Figure 9-1 Tree Sampling Locations

Table 9-1 Summary of Free-Water and Organically Bound Tritium in Tree Samples

Tree sample analysis	Number of samples	Mean (Bq/g)[a]	Median (Bq/g)	Maximum (Bq/g)
Free-water tritium	14	0.010	0.0091	0.025
Organically bound tritium	14	< 0.18[b]	< 0.18[b]	< 0.18[b]

[a] 1 Bq = 27 pCi
[b] All results were "nondetect." The highest detection limit is reported.

§9.3 III. SUMMARY

Sampling of vegetation and foodstuffs is not required under any applicable environmental regulations. Berkeley Lab undertakes voluntary sampling efforts to better understand the integrated impact of its operations on all media in the surrounding environment and to verify its overall dose-assessment program. This assessment program, which is presented in chapter 10, includes vegetation and foodstuffs as one of the contributing pathways in determining the overall impact from Berkeley Lab's airborne radionuclides.

10
Radiological Dose Assessment

§10.1 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 referred 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 distance from the activity, complexity of terrain, meteorological conditions, emission levels, food production and consumption patterns, and length of exposure.

§10.2 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 mainly associated with accelerator and irradiator operations at the Laboratory. Accelerators produce both gamma and neutron forms of radiation. Irradiators are primarily limited to gamma radiation.

Historically, DOE facilities have reported "fence-post doses." These 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. In keeping with the DOE trend toward presenting realistic assessments of exposures to actual individuals (not overly conservative and unrealistic estimates), this chapter provides both maximum fence-post dose estimates and estimates of exposures to workplaces or residences of Berkeley Lab's nearest neighbors.

§10.3 A. Accelerator-Produced Penetrating Radiation

Berkeley Lab operates detection equipment at environmental monitoring stations near the site's research accelerators that generate direct radiation when operational. These accelerators are the Advanced Light Source (Building 6), the Biomedical Isotope Facility (Building 56), and the 88-Inch Cyclotron (Building 88). Combined operations of the accelerator are limited to an offsite exposure of less than the Laboratory's established environmental "as low as reasonably achievable" goal of 0.04 mSv per year (4 mrem/yr).[1]

Berkeley Lab uses two methods to determine the environmental radiological impact from accelerator operations. One method utilizes a network of three real-time environmental monitoring stations located around the site's perimeter to track the instantaneous gamma and neutron radiation impact from accelerator operations. Figure 10-1 shows the location of these stations. The second method uses 27 passive detectors known as thermoluminescent detectors (TLD) located near the site boundary and six additional TLDs located around two offsite facilities (Building 903 Warehouse and Building 934). TLDs consider only gamma radiation because TLDs do not have sufficient sensitivity to measure environmental levels of neutron radiation. The TLDs are not able to exclude background radiation from their results and give time-average dose results that must be determined by an analytical technique rather than real-time instrumentation. Figure 10-1 shows the locations of the TLD sites near the main facility.

Each real-time station contains sensitive gamma and neutron pulse counters, which continuously detect and record direct gamma and neutron radiation—both of which are forms of direct or prompt radiation. The calibrated output pulses from these detectors are transferred electronically to a central computer in Building 75. The gamma and neutron doses to an individual are derived from measurements at the three monitoring stations and result from accelerator operations for the year. These doses are listed in Table 10-1.

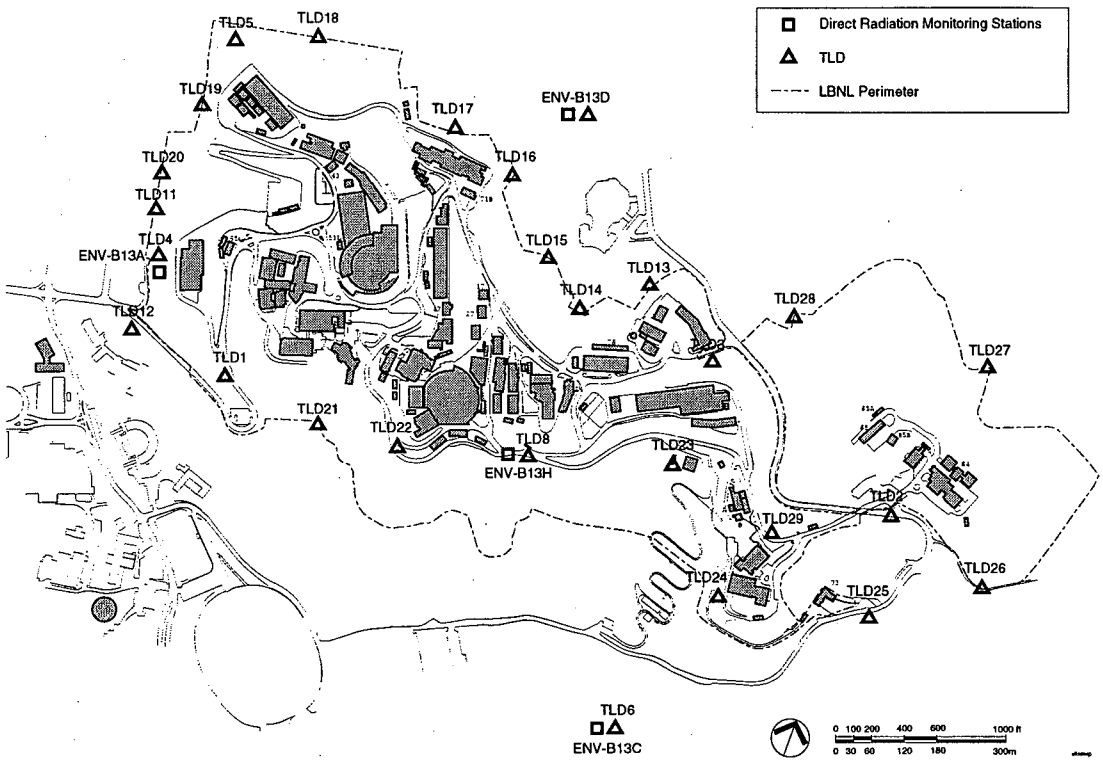


Figure 10-1 Environmental Radiological Monitoring Stations

The objectives of the TLD measurement are to record the gross penetrating radiation exposures (from background and from LBNL operations) and to ensure that public radiation exposure is kept well below allowable regulatory limits. The TLDs use aluminum oxide, which can measure low-level gamma and photon radiation with a minimum detection level of 0.001 mSv (0.1 mrem). Table 10-2 summarizes the calculated annual average TLD gamma radiation dose equivalents from the environmental TLD monitoring program, organizing the 33 monitoring locations into similar groups.

In general, annual radiation dose levels across all sites seldom deviate from the average value by more than 10%. These results suggest that the external direct radiation

Table 10-1 Annual Penetrating Radiation Dose at 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)	0.002	0.008	0.010
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.

Table 10-2 Summary of Environmental TLD Monitoring Results[a]

Location	Number of sites	Average annual dose (mSv)[b]
Laboratory gate entrances	3	0.62
Environmental monitoring stations	5	0.61
Laboratory perimeter	19	0.64
Offsite facilities	6	0.58
Average dose	33	0.62

[a] Results include background dose. Average background in Bay Area, including all of Berkeley Lab, is 0.72 mSv.
[b] 1 mSv = 100 mrem

exposure at Berkeley Lab is primarily attributable to background radiation. A typical background level for gamma radiation in California from natural activity is 0.72 mSv (72 mrem).[2] Considering that background radiation is included in Table 10-2, the TLD results confirm the low dose values from Laboratory activities that are presented in Table 10-1.

Another measure of the potential impact of accelerator-produced penetrating radiation is the population dose equivalent. For many years, Berkeley Lab has used a site-specific model to estimate the population dose equivalent resulting from penetrating radiation.[3] Population data from the 1980 United States Census[4] are used in this calculation. Although the population within 80 km (50 miles) of Berkeley Lab increased by about 20% during the 1970s and 1980s from 5 to 6 million, the populations of Berkeley and Oakland (the two cities immediately adjacent to the site) declined. Population statistics from the 1990 census have not produced noticeable differences in dose.

In the Laboratory's model, population dose equivalent is computed from the maximum measured value of perimeter dose. For 1997, this maximum dose was collected at monitoring station ENV-B13A near Building 88 (see Table 10-1). The collective effective dose equivalent to the approximately 5 million people within 80 kilometers (50 miles) of Berkeley Lab attributable to penetrating radiation from Laboratory accelerator operation during 1997 was estimated at 0.011 person-Sv (1.1 person-rem).

§10.4 B. Irradiator-Produced Penetrating Radiation

Used for radiobiological and radiochemical research, Berkeley Lab has a single gamma irradiator, with a 1400 curie cobalt-60 source. This unit is housed in a massive interlocked, reinforced-concrete-covered labyrinth built as part of Building 74. Routine surveys taken 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 equivalent 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. The remaining smaller, well-shielded gamma irradiators pose considerably less environmental impact than the Building 74 irradiator and do not increase the cumulative dose level. The maximum dose at the fence line is less than the maximum dose from accelerator activities, but more than that from dispersible airborne radionuclides. Because the locations of the maximum doses are different for each radiological-producing activity, the type of maximum cumulative dose is not additive. See §10.6.

§10.5 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 pathways 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 basic radionuclide inputs for this modeling are the airborne emissions presented in chapter 4.

The NESHAPs regulation requires that any facility that releases airborne radionuclides, like Berkeley Lab, must compute the impact of such releases using an approved computer program.[5] Berkeley Lab uses CAP88-PC for this purpose.

This program is a radionuclide 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 quite 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 continuously throughout the year, and that all the radioactivity released was the most hazardous form. Consequently, this worst-case dose is not a dose likely to be received by anyone, but merely an upper-bound estimate.

Besides the emissions information alluded to earlier, dose-assessment modeling requires the meteorological parameters of wind speed, wind direction, and atmospheric stability. Before 1995, Berkeley Lab's dose-assessment modeling efforts used Oakland airport data that US/EPA distributed with the model. Although the Oakland data had been formally approved by US/EPA for use, onsite meteorological data more accurately reflect the local wind directions and atmospheric stability categories. Berkeley Lab started using onsite data with the 1995 NESHAPs assessment because it had recently completed a project to upgrade its meteorological network in terms of both station siting and quality assurance of data.

Berkeley Lab set up 18 individual CAP88-PC modeling runs to predict the impact from groupings of the Laboratory's release points. Table 10-3 lists the attributes of these groupings. For details on these groupings and modeling runs, see Appendix A, Section II. The location of the maximally exposed individual was determined from the complete set of modeling runs. The source groupings listed in Table 10-3 give the orientation of their release point relative to the location of the maximally exposed individual (distance and direction). The combined dose from airborne radionuclides for 1997 was 1.6×10^{-3} mSv (0.16 mrem).

Collective population dose is calculated as the average radiation dose in a specified region, multiplied by the number of individuals in that area. The region is defined by regulation as a circular area around the site with a radius of 80 kilometers (50 miles). Berkeley Lab divided this region into 208 sectors (i.e., 13 increasingly smaller circles,

Table 10-3 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	1.40×10^{-3}	87.94%
55/56	Research Medicine/BIF	490	E	6.90×10^{-5}	4.33%
85	New Hazardous Waste Handling Facility	730	WNW	6.50×10^{-5}	4.08%
75A/75	Old Hazardous Waste Handling Facility	150	NW	3.80×10^{-5}	2.39%
88	88-Inch Cyclotron	670	ENE	8.10×10^{-6}	0.51%
70/70A	Nuclear / Life Sciences	510	NE	5.20×10^{-6}	0.33%
74/74B/83	Buildings 74/74B/83 Research Medicine	730	WNW	3.80×10^{-6}	0.24%
1	Donner Laboratory (UC-Berkeley)	980	ENE	1.70×10^{-6}	0.11%
75A (D)	Waste Storage Area	150	NW	9.50×10^{-7}	0.060%
2/6	Advanced Material Laboratory/ALS	370	NE	2.60×10^{-7}	0.016%
26/76	RAML/Counting Laboratory.	240	N	2.80×10^{-8}	0.002%
934	Molecular & Cell Biology (off site)	4900	ENE	2.60×10^{-8}	0.002%
71/72	HILAC/NCEM	220	E	7.30×10^{-11}	0.000%
3	Calvin Lab (UC-Berkeley)	1070	NE	3.90×10^{-12}	0.000%
50/51	NSD/Bevatron	N/A	N/A	$0.00 \times 10^{+0}$	0.000%
62	Materials & Chemical Science	650	NW	$0.00 \times 10^{+0}$	0.000%
75C	EHS Calibration Sources	150	NW	$0.00 \times 10^{+0}$	0.000%
903	Receiving Warehouse	N/A	N/A	$0.00 \times 10^{+0}$	0.000%
			Total	**1.59×10^{-3}**	**100.0%**

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

each divided into 16 equally spaced sectors) and again used CAP88-PC to estimate the average dose to each sector. Input parameters for the model used those from the Building 75 dose assessment, with the exception that the source term was expanded from tritium to include all the radionuclides used at the Laboratory. Population data for each area from the 1980 census were then used to estimate the population dose within each area. The total collective population dose represents the summation of the population doses from all the areas. This approach projected a total collective population dose from all airborne radionuclides at 0.012 person-Sv (1.2 person-rem).

§10.6 IV. COMBINED DOSE ASSESSMENT

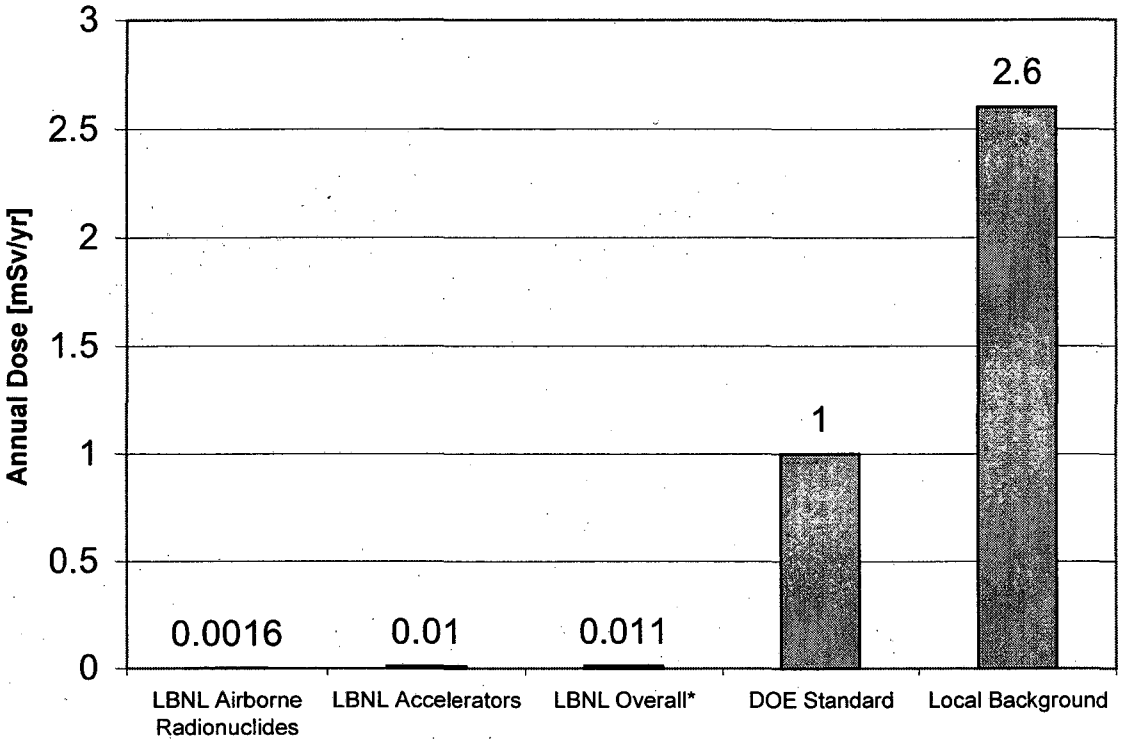
The total radiological impact from accelerator operations and airborne radionuclides is well below applicable standards and nominal background radiation. As presented in Table 10-4 and Figure 10-2, the maximum effective dose equivalent to an individual from all Berkeley Lab operations in 1997 is about 0.011 mSv (1.1 mrem) per year. This value is about 0.4% of the nominal background[6] in the Bay Area and less than 2% of the DOE annual limits.[7] The estimated dose to the population within 80 kilometers of Berkeley Lab from these same activities was 0.023 person-Sv (2.3 person-rem) in 1997. With the dose from natural background sources alone to this same population base estimated at 13,000 person-SV (1,300,000 person-rem) for the same period, the Laboratory's collective population dose is a mere two ten-thousandths of one percent (0.00018%) of the background level.

Table 10-4 Summary of Radiological Dose Impacts

	Maximum individual (direct radiation)	Maximum individual (airborne nuclides)	Maximum individual (direct and airborne)
Annual EDE[a]	0.01 mSv/yr[b]	0.0016 mSv/yr	0.011 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	1.0%	1.6%	1.1%
Annual background	1 mSv/yr	1.6 mSv/yr	2.6 mSv/yr
Impact as % of background	1.0%	0.1%	0.5%

[a] EDE = Effective Dose Equivalent

[b] 1 mSv = 100 mrem



*Different MEIs account for the overall dose being slightly less than the arithmetic sum of the airborne and accelerator doses

Figure 10-2 Comparison of Radiological Dose Impact

11
Quality Assurance

§11.1 I. BACKGROUND

Quality assurance (QA) activities and processes ensure that environmental monitoring data meet user requirements. Quality control (QC) procedures verify that Berkeley Lab attains prescribed standards of performance for environmental monitoring. This chapter contains a summary discussion of QA and QC activities performed routinely by the environmental monitoring program to support this report.

Berkeley Lab's policy on QA 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. The monitoring and sampling activities and results presented in this report were conducted in accordance with the OAP, Berkeley Lab's Environmental Monitoring Plan (EMP),[2] and applicable DOE[3] and US/EPA[4] guidance.

§11.2 II. SAMPLE COLLECTION

Berkeley Lab collects environmental monitoring samples in accordance with the specifications of the EMP and associated implementation procedures. Sampling procedures include:

- EPA or internally developed methods are used to obtain representative matrix samples;

- Qualified and experienced field staff perform the sample collections using standard procedures and calibrated sampling instrumentation;
- All necessary field sampling information is documented on chain-of-custody forms and other field notes;
- Samples are packaged and shipped to analytical laboratories using standard handling procedures and containers that preserve sample integrity;
- When possible, field QC samples (i.e., duplicates, splits, blanks) are submitted to the analytical laboratories with each batch of samples; and
- Sample disposition and status are tracked using chain-of-custody sheet information.

§11.3 III. SAMPLE ANALYSIS

Berkeley Lab's onsite and offsite service contract laboratories analyze samples for the environmental monitoring program and are required to meet demanding QA/QC specifications and certifications.[5] These requirements were established to define, monitor, and document laboratory performance.

The following list is a summary of QA/QC requirements that analytical laboratories must meet:

- The laboratory must have a written and implemented QA/QC plan that meets Berkeley Lab requirements and specifications.
- The laboratory must be certified by the California Department of Health Services Environmental Laboratory Accreditation Program.
- The laboratory must participate in interlaboratory QA programs such as the Environmental Monitoring Sampling Laboratory and the DOE Environmental Measurement Laboratory. Berkeley Lab reviews results from these programs, and follow-up actions are pursued when data do not fall within satisfactory limits.
- The laboratory must meet the following documented internal QC requirements (when applicable):
  (a) Control limits;
  (b) Method detection limit studies;
  (c) Matrix spikes, matrix spike duplicates, and laboratory control samples;
  (d) Method blanks;
  (e) Surrogates;
  (f) Initial and ongoing calibration checks; and
  (g) Sample duplicates.
- The laboratory must have documented analytical control limits approved by Berkeley Lab, along with the basis for the control limits, derivation of method, and method for retaining control limits. Berkeley Lab uses these control limits to assess analytical data quality.
- The laboratory must analyze performance evaluation samples submitted by Berkeley Lab. Results from these samples are reviewed by Berkeley Lab, and follow-up actions are pursued when data do not fall within satisfactory limits.

- The laboratory must participate in annual audits and assessments by Berkeley Lab personnel (or other designated staff), with formal written reports that summarize findings and requirements for follow-up actions.
- Laboratory deliverables must include the following items:
  (a) Case narrative;
  (b) Chain-of-custody documentation;
  (c) Sample and hard-copy retention; and
  (d) Summary of results, QC data, and data validation (electronic data deliverables).

§11.4 IV. DATA QUALITY ASSESSMENT

Each analytical data batch is evaluated and compared to established data quality objectives by conducting a systematic data quality assessment. Data quality is assessed for each analytical batch before the data 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 perform the large number of QC checks necessary to determine whether data quality objectives are achieved, the electronic data deliverables provided by the analytical laboratories are uploaded into a Berkeley Lab environmental monitoring database. The database is used to perform computer-automated data quality checks that interrogate the laboratory data package for QC results. Data quality discrepancies are flagged, investigated, and resolved by Berkeley Lab staff. Following the automated data validation/verification checks and any necessary discrepancy resolution, Berkeley Lab environmental monitoring specialists perform final data authentication by reviewing the data and QC results before they are accepted.

§11.5 V. OVERSIGHT OF ENVIRONMENTAL MONITORING QUALITY ASSURANCE

To provide confirmation 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 monitoring 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 federal, state, and local regulations with general applicability to DOE facilities and applicable DOE requirements. In addition, US/EPA conducts external audits of the NESHAP monitoring program under 40 CFR 61, Subpart H.

§11.6 VI. SUMMARY

Quality assurance for environmental monitoring at Berkeley Lab is a continuous and comprehensive process designed to ensure that monitoring results meet documented requirements. All results generated and reported by the environmental monitoring program undergo a stringent data quality assessment to verify that data quality objectives are met. Throughout the QA process, data quality checks and communication links are in place to identify, document, and correct data quality discrepancies.

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Acronyms and Abbreviations

AEDE	Annual Effective Dose Equivalent
ALARA	As Low As Reasonably Achievable
ALS	Advanced Light Source
ANSI	American National Standards Institute
ASPCP	Accidental Spill Prevention and Containment Plan
AST	Aboveground Storage Tank
BAAQMD	Bay Area Air Quality Management District
Bq	Becquerel
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
°C	degrees Celsius
CAA	Clean Air Act
Cal/EPA	California Environmental Protection Agency
CCR	California Code of Regulations
CEDE	Collective Effective Dose Equivalent
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
cm	centimeter
COB	City of Berkeley
CWA	Clean Water Act
CY	Calendar Year
DHS	Department of Health Services
DOE	U.S. Department of Energy
DOE/BSO	U.S. Department of Energy/Berkeley Site Office
DOE/OAK	U.S. Department of Energy/Oakland Operations Office

DOT	U.S. Department of Transportation
DTSC	Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EDE	Effective Dose Equivalent
EH&S	Environment, Health, and Safety
EM	Environmental Management
EMP	Environmental Monitoring Plan
EMS	Environmental Monitoring Station
EPCRA	Emergency Planning and Community Right-to-Know Act
EPG	Environmental Protection Group
ERP	Environmental Restoration Program
ERWM	Environmental Restoration and Waste Management
ES&H	Environment, Safety, and Health
°F	degrees Fahrenheit
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
ft	foot or feet
FTU	Fixed Treatment Unit
FY	Fiscal Year
gpm	gallons per minute
gsf	gross square feet
gsm	gross square meters
HEPA	High Efficiency Particulate Air
HGL	Human Genome Laboratory
HT	Tritium Gas
HTO	Tritium Oxide (Tritiated Water)
HWHF	Hazardous Waste Handling Facility
in	inch
kg	kilogram
km	kilometer
L	Liter
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley Laboratory
LLNL	Lawrence Livermore National Laboratory

m	meter
MCL	Maximum Contamination Limit
MDA	Minimum Detectable Activity
mg	milligram
Mgsf	Million gross square feet
MEI	Maximally Exposed Individual
ml	milliliter
mrem	millirem
MSDS	Material Safety Data Sheet
mSv	millisievert
MTBE	Methyl Tertiary Butyl Ether
MW	Mixed Waste
ND	non-detectable
NERSC	National Energy Research Scientific Computer Center
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOV	Notice of Violation
NRC	Nuclear Regulatory Commission
NPDES	National Pollutant Discharge Elimination System
NTLF	National Tritium Labeling Facility
OAP	Operating and Assurance Program
ODS	Ozone-Depleting Substance
pCi	picocurie (one billionth of a curie)
PCB	Polychlorinated Biphenyl
PCE	Perchloroethylene
PM	Performance Measure
POTW	Publicly Owned Treatment Works
ppbv	parts per billion by volume
ppm	parts per million
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAML	Radiation and 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
SAA	Satellite Accumulation Area
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SI	Systéme Internationale or International System of Units (the metric system)
SOP	Standard Operating Procedure
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 trillionth of a Becquerel)
TCE	Trichloroethylene
TDS	Total Dissolved Solids
TICH	Total Identifiable Chlorinated Hydrocarbons
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
TTO	Total Toxic Organics
UC	University of California
UCB	University of California at Berkeley
UCOP	University of California Office of the President
µCi	microcurie
µg	microgram

UHVCF	Ultra-High Vacuum Cleaning Facility
URL	Uniform Resource Locator
US/EPA	U.S. Environmental Protection Agency
UST	Underground Storage Tank
UV	Ultraviolet
VOC	Volatile Organic Compound
WAA	Waste Accumulation Area
WMG	Waste Management Group

Glossary

Accuracy

The closeness of the result of a measurement to 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 restoring a contaminated area to a noncontaminated or safe condition.

Exposure

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

External radiation

Radiation originating from a source outside the body.

Gamma radiation

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

Groundwater

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

Half-Life, radioactive

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

Hazardous waste

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

Internal radiation

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

Millirem

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

Nuclide

A species of atom characterized by what constitutes the nucleus, which is specified by the number of protons, number of neutrons, and energy content; or, alternatively, by the atomic number, mass number, and atomic mass. To be regarded as a distinct nuclide, the atom must be able to exist for a measurable length of time.

Organic compound

A chemical whose primary constituents are carbon and hydrogen.

Part B permit

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

Person-rem

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

Pollutant

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

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

Energy emitted from the nucleus of an atom 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

Stands 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[a]
deka	10 = 10^{1}	da[a]
deci	0.1 = 10^{-1}	d[a]
centi	0.01 = 10^{-2}	c[a]
milli	0.001 = 10^{-3}	m
micro	0.000001 = 10^{-6}	μ
nano	0.000000001 = 10^{-9}	n
pico	0.000000000001 = 10^{-12}	p
femto	0.000000000000001 = 10^{-15}	f
atto	0.000000000000000001 = 10^{-18}	a

[a]Avoid where practical.

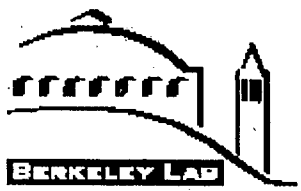
Table G-2 Conversion Factors for Selected SI (Metric) Units

To convert SI unit	To U.S. conventional unit	Multiply by
Area		
square centimeters	square inches	0.155
square meters	square feet	10.764
square kilometers	square miles	0.3861
hectares	acres	2.471
Concentration		
micrograms per gram	parts per million	1
milligrams per liter	parts per million	1
Length		
centimeters	inches	0.3937
meters	feet	3.281
kilometers	miles	0.6214
Mass		
grams	ounces	0.03527
kilograms	pounds	2.2046
kilograms	ton	0.00110
Pressure		
pounds per square foot	pascal	0.000145
Radiation		
becquerel	curie	2.7×10^{11}
gray	rad	100
sievert	rem	100
coulomb per kilogram	roentgen	3876
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

Appendix A

U.S. Department of Energy
Air Emission Annual Report
(NESHAPs)

US Department of Energy
Radionuclide Air Emission Annual Report
(Subpart H of 40 CFR 61)
Calendar Year 1997



Site Name: **Ernest Orlando Lawrence Berkeley National Laboratory (LBNL)**

Operation Office Information

Office: Oakland Operations Office

Address: 1301 Clay St. Room 700 N
Oakland, CA 94612

Contact: Steven Lasell Phone: (510) 637-1602

Site Information

Operator: Ernest Orlando Lawrence Berkeley National Laboratory

Address: 1 Cyclotron Road
Berkeley, CA 94720

Contractor Contact: Henry Tran Phone: (510) 486-7623

DOE Site Contact: Carl Schwab Phone: (510) 486-4298

Section I. Facility Information

Site Description:

Laboratory Operations

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is a multi-program national laboratory managed by the University of California (UC) for the US Department of Energy (DOE). The Berkeley Lab's major role is to conduct basic and applied research in biology, physics, chemistry, materials, and energy. The Berkeley Lab, birthplace of the cyclotron, was founded by the late Nobel Laureate Ernest Orlando Lawrence in 1931.

Berkeley Lab operates facilities which contain Radioactive Material Areas (RMAs) that are subject to the radioactive air emission regulations of the "National Emission Standard for Hazardous Airborne Pollutants other than Radon from DOE Facilities" (NESHAPs). Figure 1 illustrates the Berkeley Lab general site configuration and locations of facilities with RMAs (potential NESHAPs source terms). Table 1 identifies the buildings illustrated in Figure 1. Figure 2 identifies other Berkeley Lab off site locations (Buildings 1, 3, 903, and 934) that potentially involve radioactive air emissions.

Radiochemical and radiobiological studies performed in many on site/off site laboratories at Berkeley Lab typically use millicurie quantities of a variety of radionuclides. (One millicurie is equal to 3.7×10^7 Becquerel (Bq).)

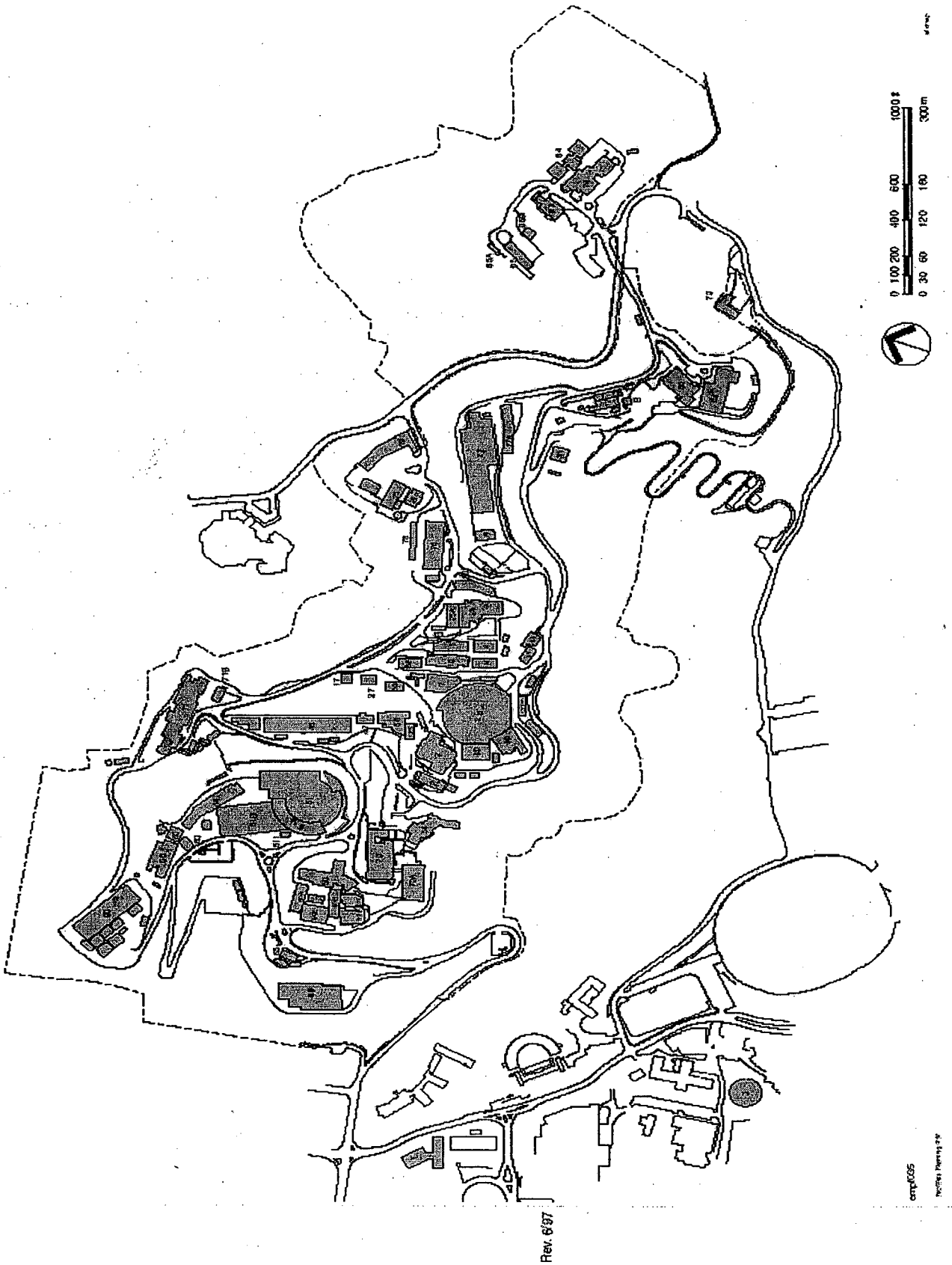


Figure 1. LBNL on Site Buildings

HILL-SITE BUILDINGS

2 Advanced Materials Laboratory (AML) & Center for X-ray Optics (CXRO)
4 Magnetic Fusion Energy (MFE)
5 Magnetic Fusion Energy (MFE)
6 Advanced Light Source (ALS)
7 Central Stores & Electronics Shops
10 Cell & Molecular Biology Research & Photography
14 Accelerator & Fusion Research & Earth Sciences
16 Magnetic Fusion Energy Laboratory
17 EH&S/Applied Sciences Lab
25 Mechanical Technology
25A Electronics Shops
26 Medical Services
27 High Voltage Test Facility & Cable Shop
29 Electronics Engineering, Research Medicine/Radiation Biophysics Offices
31 Chicken Creek Maintenance Bldg.
36 Grizzly Substation Switchgear Bldg.
37 Utilities Service
40 Electronics Development Lab
41 Magnetic Measurements Lab
42 Salvage
43 Compressor Bldg.
44 Indoor Air Pollution Studies
45 Fire Apparatus
46 RTSS, ALS, Accelerator Development
46A Real Time Systems Section (RTSS)
47 Advanced Accelerator Study
48 Fire Station
50 Physics, Accelerator & Fusion Research & Nuclear Science
50A Director's Office, Environment & Laboratory Development, Administration Division, Patents
50B Physics, Computer Center, IRD & ICSD
50C PID, Physics
50D MCSD & Nuclear Science
50E Earth Sciences
50F Computing Services, IRD
51 Bevalac/Bevatron (decommissioned)
51A Bevatron Experimental Area
51B External Particle Beam (EPB) Hall
52 Magnetic Fusion Energy Laboratory
53 SuperHILAC Development
54 Cafeteria
55 Research Medicine/Radiation Biophysics
55A Nuclear Magnetic Resonance (NMR)
56 Biomedical Isotope Facility
58 Accelerator Research & Development
58A Accelerator Research & Development Addition
60 High Bay Laboratory
61 Standby Propane Plant
62 Materials & Chemical Sciences
63 Accelerator & Fusion Research
64 Accelerator & Fusion Research
65 Data Processing Services
66 Surface Science & Catalysis Lab
68 Upper Pump House
69 Business Services, Materiel Management, Mail Room & Purchasing
70 Nuclear Science, Applied Science & Earth Sciences
70A Nuclear Science, Materials & Chemical Sciences & Earth Sciences
71 Heavy Ion Linear Accelerator (HILAC)
71A HILAC Rectifier
71B HILAC Annex
72 National Center for Electron Microscopy (NCEM)
72A High Voltage Electron Microscope (HVEM)
72B Atomic Resolution Microscope (ARM)
72C ARM Support Laboratory
73 Atmospheric Aerosol Research
74 Research Medicine/Radiation Biophysics, Cell & Molecular Biology Laboratory
75 Radioisotope Service & National Tritium Labeling Facility (NTLF)
75A Compactor, Processing & Storage Facility
76 Construction & Maintenance & Craft Shops
77 Mechanical Shops
77A Ultra High Vacuum Assembly Facility (UHV)
78 Craft Stores
79 Metal Stores
80 Electronics Engineering
80A Office Building
81 Liquid Gas Storage
82 Lower Pump House
83 Lab Cell Biology
85 Hazardous Waste Handling Facility
88 88-Inch Cyclotron
90 Applied Science, Employment, Engineering, Occupational Health, Personnel, Protective Services

Off-Site Facilities

1 Donner Laboratory
3 Melvin Calvin Laboratory
903 Receiving
934 Life Sciences

Table 1. Key to LBNL Buildings Shown in Figure 1

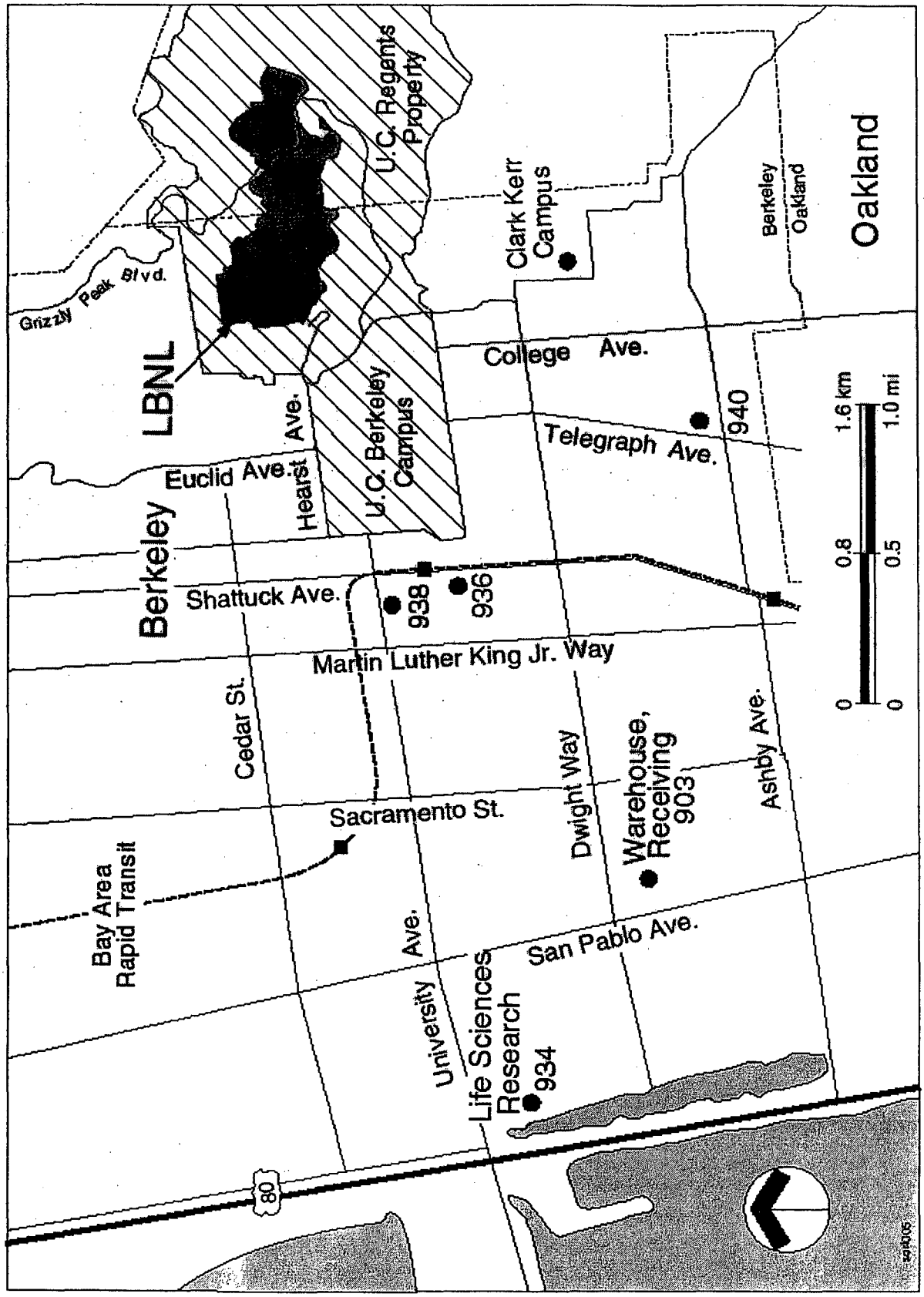


Figure 2. LBNL Off Site Research Locations & Vicinity Map

The Site

Berkeley Lab is situated upon a hillside above the main campus of the University of California at Berkeley (UCB). The 80-hectare (200-acre) site is located on the west-facing slope of the Berkeley Hills, at elevations ranging from 150 to 300 meters (500 to 1,000 feet) above sea level within the Cities of Berkeley and Oakland. It is located about five kilometers (three miles) east of San Francisco Bay and about 25 kilometers (fifteen miles) east of the City of San Francisco (Figure 3).

Berkeley Lab is located in an urban environment on land owned by the UC. On all sides of the Laboratory is a buffer zone of UC-owned land. In addition, the Laboratory maintains a landscape buffer zone between its facilities and the site boundary. Beyond the northern sides of the buffer zone there are predominantly single-family homes and beyond the west side are multiunit dwellings, student residence halls, and commercial districts. The area to the east and south, which is part of the University lands, is maintained in a largely natural state and includes recreational facilities and the University Botanical Garden. Although the population within 80 km (50 miles) of LBNL increased by about 20% during the 1970s and 1980s from 5 to 6 million, the populations of Berkeley and Oakland, the two cities immediately adjacent to LBNL, declined. Changes in population statistics from the 1990 census have not produced significant differences in dose.

The Laboratory's activities are conducted on site and off site. Berkeley Lab activities take place in structures totaling 186,000 gross square meters (gsm), or 2,000,000 gross square feet (gsf). The buildings are on the Berkeley Lab hillside site, plus additional facilities located on the University campus, notably the Donner Laboratory of Biology and Medicine (Building 1) and the Melvin Calvin Laboratory (Building 3). The main site space consists of 157,000 gsm in 190 permanent buildings and trailers. Off site space consists of 11,000 gsm in various University buildings on the UC at Berkeley (UCB) campus and 18,000 gsm in leased facilities in Emeryville and Berkeley.

On average, the population figures for the Laboratory show over 3,400 full- and part-time employees. In addition, Berkeley Lab provided services for approximately 1,850 guests who worked at the site for varying lengths of time

The Climate

The climate of the Berkeley Lab site is greatly influenced by its close proximity to the Pacific Ocean and its exposure to the maritime air that flows in from San Francisco Bay. Seasonal temperature variations are small, with an approximate mean temperature difference between the summer [17°C (63°F)] and winter [9°C (48°F)] of only 8.5°C (15°F). The site proximity to San Francisco Bay and the Pacific Ocean keeps the humidity relatively high. The average annual rainfall is about 68 cm (27 inches). About 95% of the rainfall occur from October through April, and intensities are seldom greater than 1.3 cm/hr (0.5 in/hr).

Thunderstorms, hail and snow are extremely rare. Winds are usually light, but summer sea breezes can reach up to 9-13m/s (20-30 mph). Winds from winter storm can reach speeds of 13 to 18 m/s (30 – 40 mph). The predominant wind directions are westerly during fair weather and southeasterly in advance of storms.

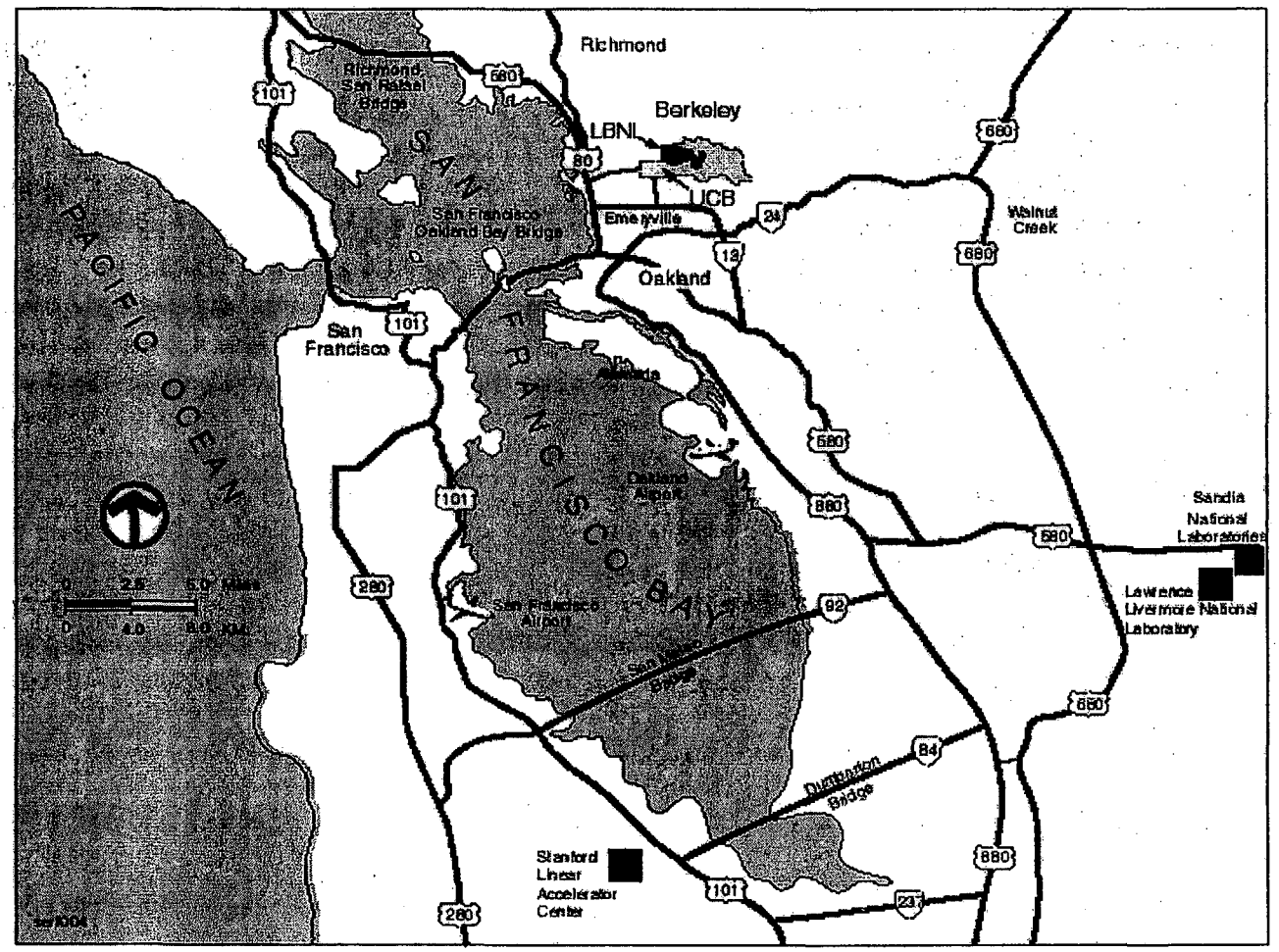


Figure 3. San Francisco Bay Area Map

Compliance Status of Lawrence Berkeley National Laboratory:

Berkeley Lab has been in full compliance with the requirements set forth in 40 CFR Part 61, Subpart H since 1995. Prior to reaching full compliance, a Federal Facilities Compliance Agreement (FFCA) with Region IX EPA was finalized and executed in August 1993. Berkeley Lab submitted a final report to US/EPA on February 1, 1995, to inform the agency that it had completed all milestones and contractual obligations of the FFCA, including stack-monitoring upgrades. On June 29, 1995 US/EPA conducted a final evaluation of compliance projects and documentation relative to NESHAPs requirements. The agency sent DOE written confirmation on November 8, 1995 that Berkeley Lab had satisfactorily completed all requirements of the FFCA.

As a part of the FFCA, Berkeley Lab formalized all phases of its NESHAPs program and proposed a graded strategy for performing the "periodic confirmatory monitoring" called for in Section 61.93 (b)(4)(i) of the 40 CFR 61. Monitoring requirements are determined by dose modeling without taking credit for emission controls in place. Table 2 summarizes the US/EPA approved NESHAPs compliance strategy for monitoring requirements at Berkeley Lab, which has been implemented since the beginning of 1995.

Table 2. Summary of NESHAPs Compliance Strategy for Monitoring Emissions in 1997

EDE Criteria [mrem/year]	Category	Monitoring Requirements	Number of Potential Release Points
EDE $\geq$ 10.0	Non-compliant	Reduce or relocate source term and re-evaluate prior to authorization.	0
$10.0 > EDE \geq 1.0 \times 10^{-1}$	I	• Continuous sampling or monitoring required • Telemetry for nuclides with half-lives < 100 hours • EPA Application to Construct or Modify required.	1
$1.0 \times 10^{-1} > EDE \geq 5.0 \times 10^{-2}$	II	Continuous sampling with weekly analysis.	10
$5 \times 10^{-2} > EDE \geq 1.0 \times 10^{-2}$	III	Continuous sampling with monthly analysis.	16
$1.0 \times 10^{-2} > EDE \geq 1.0 \times 10^{-3}$	IV	Sampled annually during project activity.	0
$EDE < 1.0 \times 10^{-3}$	V	Inventory controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring required	99

Source Description:

Berkeley Lab utilizes a wide variety of radionuclides in its radiochemical and biomedical research programs. In addition, radioactive materials are inevitably produced by the operations of the charged particle accelerators. Table 3 characterizes the predominant radionuclides potentially used/monitored at Berkeley Lab during 1997.

Table 3. Radionuclides Potentially Used/Monitored at Berkeley Lab During 1997

Nuclide Name (Atomic Number)	Symbol	Principal Radiation Types	Energy (MeV)	Half-Life
Americium (95)	^{241}Am	alpha gamma	5.40 0.06	432 years
Argon (18)	^{41}Ar	beta gamma	1.2 1.3	1.83 hours
Californium (98)	^{250}C	alpha gamma	6.03 0.043	13.1 years
Carbon (6)	^{11}C ^{14}C	positron/gamma beta	0.511 0.156	20.5 minutes 5730 years
Cesium (55)	^{137}Cs	beta gamma	0.514 0.043	30.2 years
Cobalt (27)	^{60}Co	beta gamma	0.318 1.33	5.27 years
Copper (29)	^{64}Cu ^{67}Cu	beta positron beta gamma	0.578 0.650 0.577 0.184	12.70 hours 61.9 hours
Curium (96)	^{248}Cm	alpha	5.08	3.39×10^5 years
Fluorine (9)	^{18}F	positron/gamma	0.511	109.7 minutes
Gallium (31)	^{68}Ga	beta	0.739	68.1 minutes
Germanium (32)	^{68}Ge	E.C.	0.005	288 days
Holmium (67)	^{166M}Ho	beta	1.855	1,200 years
Hydrogen /Tritium (1)	^{3}H	beta	0.0186	12.28 years
Indium (49)	^{111}In ^{114M}In	E.C./gamma I.T./E.C./gamma	0.170 0.190	2.81 days 49.51 days
Iodine (53)	^{123}I ^{125}I ^{131}I	E.C./gamma gamma beta gamma	0.159 0.027 0.606 0.159	13.1 days 60.14 days 8.04 days
Iron (26)	^{55}Fe ^{59}Fe	E.C./gamma beta gamma	 0.475 1.100	2.73 years 44.51 days
Manganese (25)	^{54}Mn	E.C./gamma	0.834	312 days
Nickel (28)	^{63}Ni	beta	0.066	100.1 years

Table 3 (Cont.). Radionuclides Potentially Used/Monitored at Berkeley Lab during 1997

Nitrogen (7)	^{13}N	positron/gamma	0.511	9.97 minutes
Oxygen (8)	^{15}O	positron/gamma	0.511	122 seconds
Phosphorus (15)	^{32}P ^{33}P	beta beta	1.71 0.249	14.3 days 25.3 days
Plutonium (94)	^{239}Pu ^{242}Pu	alpha alpha	5.155 4.901	2.411 x 10^4 years 3.76 x 10^5 years
Radium (88)	^{226}Ra	alpha gamma	4.784 0.186	1.60 x 10^3 years
Rubidium (37)	^{86}Rb	beta gamma	1.77 1.08	18.66 days
Selenium (34)	^{75}Se	E.C./gamma	0.265	118.5 days
Sodium (11)	^{22}Na	positron gamma	0.545 1.27	2.605 years
Strontium (38)	^{90}Sr	beta	0.546	28.6 years
Sulfur (16)	^{35}S	beta	0.167	87.44 days
Thorium (90)	^{232}Th	alpha beta	4.01 0.04	1.4 x 10^{10} years
Thallium (201)	^{201}Tl	E.C./gamma	0.167	3.05 days
Uranium (92)	^{233}U ^{238}U	alpha alpha beta	4.825 4.2 0.029	1.59 x 10^5 years4.47 x 10^9 years
Xenon (54)	^{122}Xe	E.C./gamma	0.350	20.0 hours
Zinc (30)	^{62}Zn ^{65}Zn	positron gamma	0.661.12	9.26 hours 244 days
Zirconium (40)	^{95}Zr	beta gamma	0.4 0.757	64 days

Of these radionuclides, the most commonly and widely used radionuclides in the research program are: H-3, C-14, F-18, P-32, S-35, and I-125. Radioactive gases produced by the accelerator operations are mainly short-lived radionuclides such as C-11, N-13, O-15, and Ar-41. These induced radioactive gases are normally produced in areas where the beam strikes beamline components.

During 1997, 24 laboratory buildings at Berkeley Lab included areas that have the potential to emit radionuclides into the atmosphere. These areas are called Radioactive Material Areas (RMAs) at Berkeley Lab. Based on historical operations and monitoring data, one source release points was identified for 1997 that are potentially within Category I; Building 75. All other Berkeley Lab's sources that were operational during 1997 are "small sources." That is, the effective dose equivalent (EDE) from each source is much less than 0.1 mrem/yr (1.0E-3 mSv/yr), the NESHAPs threshold limit for continuous real-time monitoring. Table 4 is a list of RMAs at Berkeley Lab and NESHAPs sources by category derived from the RMAs.

Table 4. Potential NESHAPs Sources by Category

	NESHAPs Compliance Strategy Category					
Buildings with Radioactive Material Areas (RMAs)	**Category I**	**Category II**	**Category III**	**Category IV**	**Category V**	**TOTAL**
1	0	0	2	0	11	**13**
2	0	0	0	0	0	**0**
3	0	0	0	0	3	**3**
6	0	0	0	0	1	**1**
26	0	0	0	0	3	**3**
50	0	0	0	0	0	**0**
51	0	0	0	0	2	**2**
55	0	0	1	0	6	**7**
56	0	2	0	0	0	**2**
62	0	0	1	0	0	**1**
70	0	1	4	0	2	**7**
70A	0	0	7	0	9	**16**
71	0	0	0	0	5	**5**
72	0	0	0	0	2	**2**
74	0	0	0	0	11	**11**
75	1	3	0	0	3	**7**
75A	0	1	1	0	0	**2**
75C	0	0	0	0	1	**1**
76	0	0	0	0	1	**1**
83	0	0	0	0	8	**8**
85	0	2	0	0	0	**2**
88	0	1	0	0	13	**14**
903	0	0	0	0	2	**2**
934	0	0	0	0	16	**16**
TOTAL:	1	10	16	0	99	**126**

During 1997, air discharge points with the most significant potential for a routine or an accidental release were continuously monitored (sampled and analyzed) or periodically sampled and analyzed. Many very small sources, that is, sources with potential for routine annual off site EDE impacts of less than 1.0E-3 mrem (1.0E-5 mSv) are, in general, not sampled/monitored (category V sources). The total number of category V reported this year is based on the number of RMAs in the database maintained by Radiation Protection Group. All the potential RMAs locations, rather physical stacks, are counted in this category,

regardless of whether there were any usage/storage of radioactive material within these locations.

Many of Berkeley Lab release points qualify as "grouped sources" as described in the NESHAPs DOE guidance for the preparation of this document. The following grouping criteria were used:

- The sum of the EDEs attributable to all stacks in the group must be < 0.1 mrem (< 10^{-3} mSv).
- Sources must be in close proximity (same or nearby building), and/or similar operations with similar nuclides are carried out in the facilities.
- Sources grouped in the description section may not be grouped in the dose assessment section if the critical receptors are not the same.

Using this grouping scheme, Berkeley Lab created 18 NESHAPs sources (Table 5). For each source, Berkeley Lab used the EPA-approved atmospheric dispersion dose calculation computer code CAP88-PC to estimate the Effective Dose Equivalent (EDE) to an offsite maximally exposed individual (MEI). The eighteen CAP88-PC computer model assessments were separately performed to simulate ten point sources, seven grouped sources, and one non-point (diffuse) source for dose assessment during 1997. The remainder of this section will discuss the results of these assessments.

As identified in Figure 2, Buildings 1, 3, 903, and 934 are located outside of Berkeley Lab's main perimeter and should technically be labeled as separate "facilities" since they are not on one "contiguous site." However, Building 1 and Building 3 are located on UC land and are within walking distance from the main Berkeley Lab site. Buildings 903 and 934 are about five kilometers from the main site. Annual radioactive air emissions from these offsite buildings and associated EDE at each local receptor is several orders of magnitude lower than the highest emissions and doses from the main Berkeley Lab site. Thus, it would be inappropriate and misleading to model and report these much lower EDEs separately. Therefore, for reporting and dose modeling purposes, all of these offsite buildings will be considered as being on one contiguous Berkeley Lab site.

Table 5. Berkeley Lab NESHAPs Grouped Sources During 1997

NESHAPs Sources (point, group and diffuse)
Building 1
Building 2 and 6
Building 3
Building 26 and 76
Building 50 and 51
Building 55 and 56
Building 62
Building 70/70A
Building 71/72
Building 74 and 83
Building 75
Building 75A
Building 75A Diffuse
Building 75C
Building 85
Building 88
Building 903
Building 934

1. **Building 1 (Donner Laboratory)**: Donner Laboratory conducts research in nuclear medicine through the use of new chemical probes and new instrumentation for applications to aging, atherosclerosis, and cancer. The building is located at the eastern edge of the University of California at Berkeley campus. The predominant nuclides used are H-3, C-14, P-32, S-35, and I-125 as labeled amino acids and DNA precursors. Many non-LBNL employees (i.e., UC) also share this building for various other research activities. Work is mostly done on bench tops and in hoods. Releases are from building vents and hoods. Many of these release points are classified as Category V. Two stacks in Building 1 are sampled and analyzed monthly for I-125, C-14, gross alpha, gross beta, and tritium. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 6.

Table 6. Building 1 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
9	10	ESE	UC Berkeley	C-14	1.60E-03	1.53E-04	90.17%
				H-3	6.60E-04	2.73E-06	1.61%
				I-125	9.20E-07	1.39E-05	8.15%
				P-32	4.80E-07	1.24E-07	0.07%
					TOTAL:	**1.70E-04**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

2. Buildings 2 and 6 (*Advanced Material Laboratory*, Center for X-Ray Optics and Advanced Light Source): The Center for Advanced Material does fundamental research in areas of materials science that US Industry and DOE Technology Offices have identified as critical to their missions and objectives. In this way it provides a basic research underpinning for more applied and development work in industrial, government, and academic laboratories. The Center for X-ray Optics addresses national needs in the technical areas of efficient and high precision transport, focusing and spectroscopic analysis of electromagnetic radiation in the soft x-ray and extreme ultraviolet (EUV) regions of the spectrum. Progress in the physical, chemical, and life sciences is enhanced by the broad availability of these new resources.

The Advanced Light Source (ALS) is the world's brightest synchrotron radiation source in the extreme ultraviolet and soft x-ray regions of the spectrum. The ALS is a national facility open to qualified scientists and engineers in a broad range of disciplines. The ALS injector produces stray neutrons during its operation, which activate the air in the injector vault. As the ALS is a low power accelerator, compared to LBNL's other accelerators, its inventory of air activation products is substantially lower than the 88-inch Cyclotron. The maximum potential annual releases of N-13 and O-15 (the important air activation products of the ALS) are computed to be 0.084 Ci (3×10^9 Bq) and 0.006 Ci (2×10^8 Bq), respectively.

Buildings 2 and 6 are classified as Category V release points and the radiological inventory is controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 7.

Table 7. Building 2/6 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
20	370	NE	UC Lawrence Hall of Science	U-238	8.00E-11	4.87E-09	0.02%
				N-13	8.40E-02	2.49E-05	95.86%
				O-15	6.00E-03	1.07E-06	4.12%
					TOTAL:	**2.60E-05**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

3. Building 3 (Calvin Laboratory): The Calvin Laboratory conducts basic research on the dynamics of living cells and on the interaction of radiant energy with organic matter. The Laboratory has made significant contributions to our understanding of the molecular mechanisms of photosynthesis and of the effects of environmental pollutants on plant and animal cells. Cell and molecular biology studies are performed in this laboratory. As with Building 1, this building is also located in the eastern portion of the University of California at Berkeley campus. The predominant radionuclides used are H-3, P-32, S-35, and C-14 as labeled amino acids and DNA precursors. $^{14}CO_2$ is also used in this laboratory as an "incubant." Building 3 is wholly occupied by Berkeley Lab personnel. Work is done on bench tops and in hoods. Releases are from building vents and hoods. Building 3 is classified as a Category V release point and the radiological inventory is controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 8.

Table 8. Building 3 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
15	60	S	Res. & Business	P-32	5.00E-09	4.30E-10	100.00%
					TOTAL:	4.30E-10	**100.000%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

4. Building 26 and 76 (Medical Services and Bioassay, Radioanalytical Laboratory and Counting Laboratory): Low-level radiochemical analyses of bioassay and environmental samples and hazardous waste are performed by Berkeley Lab's Radiation and Analytical Measurements Laboratory (RAML). In addition, Building 76 has some counter calibration sources. RAML is the only radionuclide user in these buildings. Only trace quantities of radionuclides are used in sample spiking and standards preparation. The Building 26/76 grouping is classified as a Category V release point and the radiological inventory is

controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 9.

Table 9. Building 26/76 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
8	240	N	UC Lawrence Hall of Science	CO-60	4.00E-11	3.04E-09	0.11%
				I-125	1.00E-08	9.09E-08	3.25%
				I-131	6.10E-07	2.04E-06	72.87%
				U-238	4.80E-10	6.66E-07	23.77%
					TOTAL:	**2.80E-06**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

5. Buildings 50 and 51 (Physics, Accelerator and Fusion Research, Nuclear Science, Bevalac/Bevatron). The Physics Group research includes experiments at particle accelerators, design and preparation for particle detectors at future machines, theoretical physics, astrophysics, and other activities . The Accelerator and Fusion Research Groups study and apply the physics of beams -- beams of ions, electrons, and light -- and to advance related technologies. The Nuclear Science Division's programs include nuclear structure and reactions, relativistic nuclear collisions, nuclear & particle astrophysics, nuclear data evaluation, and the nuclear theory. The Bevalac/Bevatron is no longer in operation. Building 50/51 grouping is classified as a Category V release point and the radiological inventory is controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 10.

Table 10. Building 50/51 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
N/A	N/A	N/A	N/A	N/A	0	0	0
					TOTAL:	**0**	**0**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

6. Buildings 55 and 56 (Research Medicine & Radiation Biophysics, Biomedical Isotope Facility): The Research Medicine & Radiation Biophysics and Biomedical Isotope Facility develops radiopharmaceuticals and advanced medical imaging technologies including positron emission tomography (PET), single photon emission computed tomography

(SPECT), and nuclear magnetic resonance imaging (MRI) and applies them to the study of atherosclerosis, heart disease, aging, neurological and psychiatric diseases, and cancer. The primary radiological activities carried out in Building 55 are positron emission tomography (PET) using F-18, and metabolic studies using I-125. The radiological activities take place in 2 laboratories and a PET camera room. Operations with radioiodine are done in a HEPA and Tetraethylene Diamine (TEDA)-doped carbon-filtered enclosures. Building 56 houses a small accelerator to produce F-18 for PET and other experimental studies. Airborne emission from Building 56 is only limited to the F-18 positron emitter. Two locations in Building 56 are continuously monitored (real-time) for positron emitters. One stack in Building 55 is sampled and analyzed monthly for I-125, gross alpha, and gross beta. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 11.

Table 11. Building 55/56 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem**/yr]	% Total EDE
9	170	N	Residence	C-14	3.90E-08	1.21E-09	0.00%
				H-3	7.50E-09	9.45E-12	0.00%
				I-125	2.00E-04	9.51E-04	11.74%
				I-131	1.20E-04	2.03E-04	2.51%
				F-18	1.50E+00	6.95E-03	85.75%
				CR-51	8.00E-09	9.23E-11	0.00%
					TOTAL:	**8.10E-03**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

7. Building 62 (Materials & Chemical Sciences): The Materials Sciences Division performs research in the discovery, creation, characterization, and development of new materials and materials phenomena. The Chemical Sciences Division conducts research in the areas of chemical physics and the dynamics of chemical reactions, the structure and reactivity of transient species, electron spectroscopy, surface chemistry and catalysis, electrochemistry, chemistry of the actinide elements and their relationship to environmental issues, and atomic physics. Historically, Building 62 has only a few small laboratories working with trace amounts of common radionuclides. A thorium aerosol study with milligram quantities of 0.1 μCi thorium spheres is performed in one lab in Building 62. Operations in Building 62 are carried out in enclosures that have HEPA filters. Building 62 is classified as a Category V release point and (although not required by NESHAPs) effluent is sampled and analyzed monthly at one location for I-125, C-14, alpha, beta and tritium emissions. Currently, all RMA's in this building had been decontaminated and decommissioned. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 12.

Table 12. Building 62 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
13	240	E	Workplace	N/A	0	0	0.0%
					TOTAL:	**0**	**0.0%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

8. **Buildings 70 & 70A (Nuclear, Materials, Chemicals, Earth Sciences, and Life Sciences):** The Nuclear Science programs include nuclear structure and reactions, relativistic nuclear collisions, nuclear & particle astrophysics, nuclear data evaluation, and nuclear theory. Materials Sciences performs research in the discovery, creation, characterization, and development of new materials and materials phenomena. The Chemical Sciences Programs conducts research in the areas of chemical physics and the dynamics of chemical reactions, the structure and reactivity of transient species, electron spectroscopy, surface chemistry and catalysis, electrochemistry, chemistry of the actinide elements and their relationship to environmental issues, and atomic physics. The Earth Sciences programs perform fundamental and applied research related to energy and environmental resources. Programs carried out in these facilities include super-heavy nuclear studies, waste migration studies (tracer amounts), and nuclear chemical studies. There are also two biological science groups in 70A. Research activities using radioactive material are carried out by various research groups in 27 of the many small laboratories within the two buildings. Eleven sources in Building 70 and 70A are classified as a Category V release points and the remaining 12 locations are sampled continuously and analyzed periodically; one is analyzed weekly, and eleven are analyzed monthly. Monitoring analytes include I-125, C-14, gross alpha, gross beta and tritium. A summary of the CAP88-PC source term input parameters and EDE results for these release points is presented in Table 13.

Table 13. Buildings 70&70A Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
13	330	W	UCB Dormitory	C-14	3.40E-05	2.15E-07	0.04%
				H-3	5.80E-05	1.44E-08	0.00%
				I-125	7.00E-09	6.90E-09	0.00%
				SR-90	1.30E-05	1.33E-05	2.26%
				TH-232	1.40E-06	5.76E-04	97.70%
					TOTAL:	**5.90E-04**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

9. Buildings 71 and 72 (Heavy Ion Accelerator, National Center for Electron Microscopy (NCEM)) The Heavy Ion Accelerator is no longer in operation. The NCEM provides the electron microscopy community with advanced instrumentation for electron-optical characterization of materials. With the highest resolution (1.6Å) electron microscope in the US and the highest-energy microscope, NCEM is a national facility open to qualified researchers in materials science and associated disciplines. The building 71/72 grouping is classified as a Category V release point and the radiological inventory is controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required. A summary of the CAP88-PC source term input parameters and EDE results for these release points is presented in Table 14.

Table 14. Buildings 71/72 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem**/yr]	% Total EDE
13	220	E	UC Lawrence Hall of Science	U-238	1.00E-11	7.30E-09	100.000%
					TOTAL:	**7.30E-09**	**100.000%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

10. Buildings 74 and 83 (Research Medicine, Cell Biology): These buildings include a wide variety of cell biology, virology, research medicine, and human genome projects. The Human Genome Center (HGC) of the Lawrence Berkeley National Laboratory is oriented almost exclusively towards developing and implementing directed methodologies for cost-effective and accurate high throughput human DNA sequencing. Releases from 74 come from hoods and stacks that vent individual workplaces. Building 83 vents are through HEPA-filtered biological cabinets. Research activities involving I-125 are normally carried out in TEDA-doped activated-carbon-filtered enclosures. The building 74/83 grouping is classified as a Category V release point and the radiological inventory is controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required or performed. A summary of the CAP88-PC source term input parameters and EDE results for these release points is presented in Table 15.

Table 15. Buildings 74/83 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem**/yr]	% Total EDE
7	120	S	UC Berkeley	C-14	2.20E-09	2.70E-10	0.00%
				H-3	5.00E-09	2.76E-11	0.00%
				I-125	2.10E-05	3.90E-04	99.97%
				P-32	2.70E-07	7.97E-08	0.02%
				S-35	4.80E-07	2.53E-08	0.01%
				CU-64	2.50E-07	4.09E-09	0.00%
				TC-99M	3.80E-07	1.71E-09	0.00%
					TOTAL:	**3.90E-04**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

11. Building 75 (National Tritium Labeling Facility): The National Tritium Labeling Facility (NTLF) is a designated Department of Energy (DOE) National User Facility engaged in tritium labeling research and development. It offers the US and international biomedical research community a fully equipped laboratory for the synthesis and analysis of tritium labeled compounds. The NTLF is mainly used for activities in which a wide variety of molecules are labeled with tritium and purified for further use in chemical, biochemical, and radiopharmaceutical studies. There are two stack release points for these activities; real time monitoring is performed continuously on one and continuous sampling (with off-line analysis) is performed on both. The radionuclide releases are in the form of gaseous tritium (HT, T_2) and tritiated water (HTO, T_2O). Gaseous tritium releases are quantified as tritiated water even though their impacts are 1/25,000 of those of comparable releases of tritiated water resulting in a very conservative dose estimate. Normally, tritium release at Berkeley Lab mainly comes from the stack located in the northern hillside near Building 75. This stack is the closest discharge point to the maximally exposed offsite individuals (MEI) which is the UC Lawrence Hall of Science, located 110 meters northwesterly. Other discharge points from the Building 75 roof are further from offsite individuals. Using a very conservative approach, it is assumed that all tritium emissions are released from the hillside stack.

In 1990 the NTLF began a program to reduce both planned and unplanned releases of HTO. This program has resulted in a very notable decrease in stack emissions from a maximum of 575 Ci in 1988 to 46 Ci in 1995, 5 Ci in 1996, and 41 Ci in 1997. Reviewing historical release records, there are two noticeable periods of tritium reductions: An initial steep reduction in 1990 and a second decline beginning in 1995. This second period is noteworthy because of the added difficulty in reducing tritium emissions appreciably from their present already low level. Several factors have contributed to the recent reduction of tritium emissions. First, there were no significant (>25 Ci) unplanned releases since 1995. The off-hours monitoring of tritium alarms by the Berkeley Lab Fire Department was an important contributor to this improvement. Two significant engineering changes during 1995 included

the addition of redundant valving on vacuum pumps close to the tritium source, and the replacement of the existing silica gel traps with broader traps that give the same flow, but give higher HTO trapping efficiency. Many other minor engineering changes and procedural revisions were implemented during 1995, and these all combined to markedly diminish HTO releases from the NTLF, especially since the later half of CY95.

For CAP88-PC modeling, all tritium releases from the NTLF (tall stack plus hood vents) are conservatively assumed to be originated from the hillside stack. This release point is the only source at Berkeley Lab that potentially/historically results in more than 1% of the NESHAPs EDE dose standard. For reporting purposes, the MEI of this release point is also identified as the MEI for the whole Berkeley Lab site during 1997. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 16.

Table 16. Building 75 (NTLF) Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem**/yr]	% Total EDE
8.5	110	NW	UC Lawrence Hall of Science	H-3	41.0	1.4E-1	100.00%
					TOTAL:	**1.4E-1**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

12. Buildings 75A and 85 (Hazardous Waste Handing Facility): During the first half of 1997, the Berkeley Lab Hazardous Waste Handling Facility (HWHF) was located in Buildings 75A and part of Building 75. Radioactive waste from various laboratories was processed and stored in these buildings. The effluent was sampled and analyzed monthly for I-125, C-14, gross alpha, gross beta, and tritium. Currently, all RMAs in this old facility have been decontaminated and decommissioned. A summary of the CAP88-PC's source term input parameters and EDE results from Building 75A is presented in Table 17.

Table 17. Building 75A (Old HWHF) Release Point Characteristics (Point Source) and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
8	150	NW	UC Lawrence Hall of Science	H-3	9.20E-02	1.75E-04	4.59%
				I-125	6.00E-08	4.14E-07	0.01%
				C-14	4.80E-04	2.15E-05	0.57%
				SR-90	1.10E-06	7.24E-06	0.19%
				TH-232	1.10E-06	3.60E-03	94.64%
					TOTAL:	**3.80E-03**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

During the second half of 1997, the waste operations moved to the newly constructed HWHF Building 85. This building has two radiological stacks equipped with continuous air sampling system to monitor for gross alpha, gross beta, C-14, I-125, and tritium. A summary of the CAP88-PC's source term input parameters and EDE results for this point source Building 85 is presented in Table 17A

Table 17A. Building 85 (New HWHF) Release Point Characteristics (Point Source) and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
7	120	S	UC Berkeley	C-14	9.40E-03	1.46E-04	3.57%
				H-3	1.70E-01	1.20E-04	2.92%
				I-125	3.10E-06	7.25E-06	0.18%
				SR-90	5.20E-06	1.27E-05	0.31%
				TH-232	2.90E-06	3.81E-03	93.02%
					TOTAL:	**4.10E-03**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

13. Building 75A (Hazardous Waste Handing Facility / Diffuse Source): During 1997 Building 75A was also considered as a diffuse source of HTO, as HTO waste was processed and stored in the building. One storage location was sampled and analyzed weekly for tritium. Since all radioactive materials from this location were moved to the new HWHF at the end of 1997, all RMAs in this 75A facility have been decontaminated and decommissioned. A summary of the CAP88-PC's source term input parameters and EDE results for this diffuse source of Building 75A is presented in Table 18.

Table 18. Building 75A Release Point Characteristics (Diffuse Source) and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
1	150	NW	UC Lawrence Hall of Science	H-3	3.20E-3	9.50E-5	100.00%
					TOTAL:	**9.50E-5**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

14. Building 75C (Calibration Sources): Building 75C is a storage facility for calibration sources. Building 75C is classified as a Category V release point and the radiological inventory is controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required. A summary of the CAP88-PC source term input parameters and EDE results for these release points is presented in Table 19.

Table 19. Building 75C Release Point Characteristics (Diffuse Source) and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
N/A	N/A	N/A	N/A	N/A	0	0	0
					TOTAL:	**0**	**0**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

15. Building 88 (88-inch Cyclotron): The Cyclotron accelerates beams from hydrogen to uranium in support of national programs in nuclear science, biology, medicine, and industrial applications. The Cyclotron is the site of Gammasphere, a high resolution gamma-ray detector array. The primary airborne impact to an offsite individual from this facility is attributable to short-lived air activation radionuclides (mostly positron emitters) produced in the cyclotron vault during the fraction of the beam year when intense light ions are accelerated, approximately 15% (1300 hr) of the time during 1997. Positron releases were measured directly using the real-time monitoring system and were significantly smaller than the theoretical values used in previous years. The quantity of activation products is controlled by the fraction of the beam year spent running light ions, and limits on circulating beam current. In addition to accelerator-produced positrons, small amounts of actinide radionuclides and other radioactive targets and radioisotopes are also used in experimental caves, fume hoods, and glove boxes. Releases are estimated based on isotope inventories/receipts. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 20.

Table 20. Building 88 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
12	110	W	Residence	FE-59	2.00E-10	3.24E-11	0.00%
				P-32	7.50E-08	1.72E-09	0.00%
				U-235	1.20E-10	2.33E-08	0.00%
				C-11	1.50E+00	1.50E-03	100.00%
				C-14	1.50E-09	1.59E-11	0.00%
				NA-24	1.00E-10	1.22E-12	0.00%
					TOTAL:	**1.50E-03**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

16. Building 903 (Receiving Warehouse): Building 903 is located off-site at 2700 Seventh Street in Berkeley. The 903 warehouse functions include central receiving, bulk storage, bulk issue, and used furniture storage. Currently there are some induced radioactive components (i.e., accelerator shielding blocks or beam magnets) stored inside and outside the building. Building 903 is classified as a Category V release point and the radiological inventory is controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. No monitoring is required. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 21.

Table 21. Building 903 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
N/A	N/A	N/A	N/A	N/A	0	0	0
					TOTAL:	**0**	**0**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

17. Building 934 (Molecular and Cell Biology): This building is located off site, roughly 5 kilometers (3 miles) from Berkeley Lab. The radiological activities include cell and molecular biology research. The research employs RNA and DNA precursors and amino acids labeled with H-3, C-14, P-32, S-35, and I-125. Metabolism of S-35 amino acids produces $^{35}SO_2$, which is released to the atmosphere. All release points in this building are classified as Category V release points. A summary of the CAP88-PC source term input parameters and EDE results for this release point is presented in Table 22.

Table 22. Building 934 Release Point Characteristics and Dose Impacts

Release Height [meter]	Local MEI Distance [meter]	Local MEI Dir.	Local MEI Description	Radio Nuclide	Annual Release [Ci*/yr]	LOCAL MEI EDE [mrem** /yr]	% Total EDE
4	38	N	Business	C-14	1.50E-09	5.49E-10	0.01%
				H-3	6.20E-07	1.07E-08	0.28%
				I-125	5.00E-08	2.82E-06	74.10%
				P-32	1.00E-06	9.28E-07	24.42%
				S-35	3.00E-07	4.49E-08	1.18%
					TOTAL:	**3.80E-06**	**100.00%**

(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv

Section II. Air Emissions Data

Point Source	# of Sources	Type Control	Efficiency [%]	Distance to Nearest Receptor
Building 1	14	None(3)	0	10 m (School in the same Building)
Building 3	3	None(3)	0	60 m (Workplace)
Building 62	1	HEPA	> 99	240 m (Workplace)
Building 75 (NTLF)	7	Silica Gel(5) HEPA	>99 >99	110 m (UC Lawrence Hall of Science)
Building 75A	2	TEDA-DAC HEPA(2)	> 75	150 m (UC Lawrence Hall of Science - LHS)
Building 75C	1	None	0	150 m (UC Lawrence Hall of Science - LHS)
Building 85	2	HEPA TEDA-DAC	>99 >75	120 M (UC Berkeley)
Building 88 Vault	11	None(1)	0	110 m (Residence)
Building 903	2	None	0	10 m (Business)
Building 934	16	None(3)	0	38 m (Business)

Grouped Source	# of Sources	Type Control	Efficiency [%]	Distance to Nearest Receptor
Building 2/6	2	None	0	370 m (UC Lawrence Hall of Science)
Buildings 26/76	4	HEPA	>99	240 m (UC Lawrence Hall of Science)
Building 50/51	0	None	0	Decommissioned
Building 55/56	11	HEPA TEDA-DAC(2)	>99 >75	170 m (Residence)

Buildings 70 & 70A[4]	27	HEPA (Manifolds) None (Hood)	>99 0	330 m (UCB Dormitory)
Building 71/72	7	None	0	220 m (UC Lawrence Hall of Science)
Buildings 74/74B/83	21	TEDA-DAC[2] None	>75 0	120 m (UC Berkeley)

Non-Point Source	Radionuclide	Annual Quantity
Building 75A (Waste processing Area)	HTO	0.006 Ci (2.0×10^8 Bq)

Notes:

(1) The radionuclides released from the accelerators are air activation products, for which is impractical to control.

(2) Tetraethylene Diamine (TEDA) -doped activated carbon traps.

(3) The uncontrolled releases are from Berkeley Lab fume hoods, which are unfiltered.

(4) The stacks included in this group source vent a number of laboratories whose research employs μCi and mCi (between 3.7×10^4 and 3.7×10^7 Bq) quantities of a number of actinides. The most conservative dose-equivalent representative of the actinides was used.

(5) Silica gel traps are >99% efficient traps for HTO as long as they are changed before breakthrough. NTLF personnel regularly change traps when working in the facility.

Quantities of nuclides released from Berkeley Lab stacks during 1997 are given in Table 23. These data are used to calculate the collective population dose for 1997.

Table 23. Total Radioactivity in Air Effluent Potentially Released During 1997

Nuclide	Total Air Effluent [Ci/yr]	[Bq/yr]	% Total Effluent
H-3	4.12E+01	1.52E+12	92.9952%
C-11	1.50E+00	5.55E+10	3.3879%
F-18	1.50E+00	5.55E+10	3.3879%
N-13	8.40E-02	3.11E+09	0.1897%
C-14	1.10E-02	4.08E+08	0.0249%
O-15	6.00E-03	2.22E+08	0.0136%
I-125	2.25E-04	8.33E+06	0.0005%
I-131	1.21E-04	4.46E+06	0.0003%
SR-90	1.82E-05	6.73E+05	0.0000%
TH-232	4.30E-06	1.59E+05	0.0000%
P-32	1.83E-06	6.77E+04	0.0000%
S-35	7.80E-07	2.89E+04	0.0000%
TC-99M	3.80E-07	1.41E+04	0.0000%
CU-64	2.50E-07	9.25E+03	0.0000%
CR-51	8.00E-09	2.96E+02	0.0000%
U-238	1.29E-09	4.77E+01	0.0000%
FE-59	2.00E-10	7.40E+00	0.0000%
U-235	1.20E-10	4.44E+00	0.0000%
NA-24	1.00E-10	3.70E+00	0.0000%
CO-60	4.00E-11	1.48E+00	0.0000%
TOTAL:	**4.43E+01**	**1.64E+12**	**100.0000%**

Section III. Dose Assessments

Description of Dose Model

To meet DOE guidance, the EPA atmospheric dispersion/radiation dose calculation computer code, CAP88-PC version 1.0, was used to calculate the Effective Dose Equivalent (EDE) to an individual within each population segment at various distances and from various release points. A total of seventeen CAP88-PC "individual" runs were executed to model 18 single/grouped release points as described in Section II. As mentioned previously, the NTLF (Building 75) was identified as the major release point at Berkeley Lab. Therefore, the Maximally Exposed Individual (MEI) associated with this facility was also specified (with appropriate distances and directions) in each of these seventeen "individual" CAP88-PC runs. The reported EDE to an MEI at Berkeley Lab includes contributions from all of these eighteen CAP88-PC models (see Table 24).

Collective population dose is calculated as the average radiation dose to an individual in a specified area, multiplied by the number of individuals in that area. One "population" CAP88-PC run was used to carry out this population dose assessment. This CAP88-PC model is based on the input parameters from the Building 75 computer run, with the source terms replaced by all the radionuclides listed in Table 23. A summary of this collective dose assessment attributed to each radionuclides is given in Table 25.

Summary of Input Parameters

The 1997 radioactive air emissions were either measured or conservatively derived based on the inventory received during the year, and are shown in Table 23 in Section II.

Berkeley Lab used onsite meteorological data for performing dose assessments. The network began collecting data in early 1994. These data more accurately reflect the local wind directions and atmospheric stability categories in the EPA computer model. The meteorological data input to the CAP88-PC for 1997 are based on the local meteorological data collected during 1997 from the main weather tower at the Berkeley Lab.

Table 24. Summaries of Dose Assessment from All Berkeley Lab Release Points

		Relative to the Specified Building					Relative to the MEI of Building 75			
Building Number	**Building Name**	**Release Height [meter]**	**Local MEI Distance [meter]**	**Local MEI Dir.**	**Local MEI Description**	**Local MEI Dose [mrem*/yr]**	**BLD-75 Distance [meter]**	**BLD-75 MEI Dir.**	**BLD-75 MEI Dose [mrem*/yr]**	**% Total EDE**
BLD-1	Donner Laboratory @UCB	9	10	ESE	UC Berkeley	1.70E-04	980	ENE	1.70E-04	0.107%
BLD-2/6	Advanced Material Lab/ALS	20	370	NE	UC Lawrence Hall of Science	2.60E-05	370	NE	2.60E-05	0.016%
BLD-3	Calvin Lab @UCB	15	60	S	Res. & Business	4.30E-10	1070	NE	3.90E-10	0.000%
BLD-26/76	RAML/Counting Lab.	8	240	N	UC Lawrence Hall of Science	2.80E-06	240	N	2.80E-06	0.002%
BLD-50/51	NSD/Bevatron	N/A	N/A	N/A	N/A	0.00E+00	N/A	N/A	0.00E+00	0.000%
BLD-55/56	Research Medicine/BIF	9	170	N	Residence	8.10E-03	490	E	6.90E-03	4.334%
BLD-62	Materials & Chem. Science	13	240	E	Workplace	0.00E+00	650	NW	0.00E+00	0.000%
BLD-70/70A	Nuclear / Life Sciences	13	330	W	Dormitory	5.90E-04	510	NE	5.20E-04	0.327%
BLD-71/72	HILAC/NCEM	13	220	E	UC Lawrence Hall of Science	7.30E-09	220	E	7.30E-09	0.000%
BLD-74/83	Buildings 74/83 Research Med.	7	120	S	UC Berkeley	3.90E-04	730	WNW	3.80E-04	0.239%
BLD-75	National Tritium Labeling Facility	8.5	110	NW	UC Lawrence Hall of Science	1.40E-01	110	NW	1.40E-01	87.936%
BLD-75A/75-127	Old Hazardous Waste Handling Facility (HWHF)	8	150	NW	UC Lawrence Hall of Science	3.80E-03	150	NW	3.80E-03	2.387%
BLD-75C	EHS Calibration Sources	N/A	150	NW	UC Lawrence Hall of Science	0.00E+00	150	NW	0.00E+00	0.000%
BLD-75A (D)	Waste Storage Area (Diffuse)	1	150	NW	UC Lawrence Hall of Science	9.50E-05	150	NW	9.50E-05	0.060%
BLD-85	New Hazardous Waste Handling Facility (HWHF	7	120	S	UC Berkeley	4.10E-03	550	WNW	6.50E-03	4.083%
BLD-88	88-Inch Cyclotron	12	110	W	Residence	1.50E-03	670	ENE	8.10E-04	0.509%
BLD-903	Receiving Warehouse	N/A	N/A	N/A	N/A	0.00E+00	N/A	N/A	0.00E+00	0.000%
BLD-934	Molecular & Cell Bio. (off site)	4	38	N	Business	3.80E-06	4900	ENE	2.60E-06	0.002%
								TOTAL:	**1.59E-01**	**100.000%**

(*) 1 mrem = 1.0E-2 mSv

Table 25. Summary of Collective (Population within 80 km of Berkeley Lab) EDE Assessment

Nuclide	Collective EDE [Person-rem* /yr]	% Total Collective EDE
H-3	9.67E-01	81.31%
TH-232	1.27E-01	10.70%
F-18	6.14E-02	5.16%
C-11	2.62E-02	2.20%
C-14	4.56E-03	0.38%
N-13	9.23E-04	0.08%
I-125	8.36E-04	0.07%
SR-90	7.35E-04	0.06%
I-131	3.30E-04	0.03%
O-15	1.88E-05	0.00%
U-238	1.12E-05	0.00%
P-32	1.32E-06	0.00%
U-235	1.12E-06	0.00%
S-35	8.33E-08	0.00%
CO-60	2.17E-08	0.00%
CU-64	1.12E-08	0.00%
TC-99M	4.31E-09	0.00%
FE-59	1.59E-09	0.00%
CR-51	1.27E-09	0.00%
NA-24	5.69E-11	0.00%
TOTAL:	**1.19E+00**	**100.00%**

(*) 1 Person-rem = 1.0E-2 Person-Sv

Compliance Assessment

This compliance assessment uses the computer code CAP88-PC Version 1.0 to calculate the Effective Dose Equivalent to an off site Maximally Exposed Individual. This exposure represents the sum of impacts from all seventeen release points modeled to that location (the MEI of Building 75). Summaries of the dose assessment from each release point are presented in Table 24.

Effective Dose Equivalent: 0.16 mrem/year (1.6E-3 mSv/year)

Location of Maximally Exposed Individual: UC Lawrence Hall of Science at 110 meters Northwest of Building 75

Certification

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate and complete. I am aware that there are significant penalties for submitting false information including the possibility of fine and imprisonment. (See, 18 U. S. C. 1001).

Signature: Date: 6·26·98

David C. McGraw
Division Director, Environment, Health and Safety

Signature: R. Nolan Date: 6/29/98

Richard H. Nolan
Director, DOE Berkeley Site Office

Section IV. Additional Information

Additions or Modifications

- **Building 85 (Hazardous Waste Handling Facility):** Berkeley Lab recently completed the construction of the new Hazardous Waste Handing Facility (HWHF). The waste operations at the old HWHF (in building 75A and part of building 75) were moved this new building in June 1997. This building has two radiological stacks equipped with continuous air sampling system to monitor for gross alpha, gross beta, C-14, I-125, and tritium.

- **Building 75A and part of Building 75 (Old Hazardous Waste Handling Facility):** Currently, all RMAs in this old facility have been decontaminated and decommissioned.

Unplanned Releases

During 1997, there were no unplanned releases to the atmosphere from Berkeley Lab.

Diffuse Emissions

Fugitive emissions from stored tritium waste are measured and found to be about 0.003 Ci (1.1 x 10^8 Bq) during 1997. The estimated EDE to an offsite MEI from this diffuse emission was calculated to be 9.5E-5 mrem/yr. (9.5E-7 mSv/yr.). This estimate is based on the "area" source CAP88-PC model, which is highly conservative for the diffuse source (see the "BLD-75AD" CAP88-PC run).

Section V. Supplemental Information

- *Provide an estimate of collective effective dose equivalent (person-rem/yr.) for 1997 releases.*

  The estimated collective effective dose equivalent (CEDE) to persons living within 80 km of Berkeley Lab is 1.19 person-rem/year (1.19E-2 person-Sv) attributable to 1997 Berkeley Lab airborne releases (see Table 25).

- *Provide information on the status of compliance with Subparts Q and T of 40 CFR Part 61 if applicable. Although exempt from Subpart H, provide information on Rn-220 emission from sources containing U-232 and Th-232 where emissions potentially can exceed 0.1 mrem/yr. (10^{-6} Sv/a) to the public or 10% of the non-radon dose to the public. Provide information on non-disposal/non-storage sources of Rn-222 emissions where emissions potentially can exceed 0.1 mrem/yr. (10^{-6} Sv/a) to the public or 10% of the non-radon dose to the public.*

  Subparts Q and T of 40 CFR 61 are not applicable to Berkeley Lab, as the Laboratory does not process, manage or possess significant enough quantities of uranium mill tailings, Ra-226, U-232, or Th-232, to produce an impact of 0.1 mrem/yr. (10^{-6} Sv/yr.) to a member of the public.

- *For the purpose of assessing facility compliance with the NESHAPs effluent monitoring requirements of Subpart H under Section 61.93(b), give the number of emission points subject to the continuous monitoring requirements, the number of these emission points that do not comply with the Section 61.93(b) requirements, and if possible, the cost for upgrades. Describe site periodic confirmatory measurement plans. Indicate the status of the QA program described by Appendix B, Method 114.*

  Berkeley Lab has identified 1 point subject to the continuous monitoring requirements of 40 CFR subpart H, Section 61.93(b). During 1997, only one point produced discharges exceeding 0.1 mrem/yr (1.0E-3 mSv/yr.). The Category I release point at Berkeley Lab was the NTLF main stack whose EDE was modeled at 0.14 mrem/yr (1.4 x 10^{-3} mSv) for 1997. Berkeley Lab has upgraded the monitoring and analytical methods to fully conform to Section 61.93(b) monitoring requirements. Berkeley Lab has: a) identified all emission points and evaluated releases, b) categorized stacks by EDE, and c) suggested suitable monitoring methodology for each point. The information developed in a - c above was sent to EPA region IX during CY91 and finalized in CY93.

  The program meets or exceeds all provisions contained in Appendix B method 114. The current Berkeley Lab Environmental Monitoring Plan and

Environmental Protection Group Procedures contain QA elements consistent with method 114. The Berkeley Lab site specific NESHAPs QA Project Plan was developed and approved in August 1994, and revised in March of 1997.

Appendix B

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P.O. Box 2528
Mailstop 6000
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Alameda, California 94502

Association of Bay Area Governments
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Oakland, California 94604-2050

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939 Ellis Street
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Environment and Safety Protection
Building 535A
P.O. Box 5000
Upton, New York 11973-5000

California Air Resources Board
Jim Morgester
Compliance Division
P.O. Box 2815
Sacramento, California 95812

California Department of Health Services
Ed Bailey
Environmental Management Branch
601 North 7th Street, MS 178
Sacramento, California 94234-7320

California Department of Health Services
Steve Hsu
Environmental Management Branch
601 North 7th Street, MS 178
Sacramento, California 94234-7320

California Department of Health Services
Gerard Wong
Radiological Health Branch
601 No 7th Street
Sacramento, California 95814

California Department of Health Services
William Lew
Radiological Health Branch
2151 Berkeley Way, Annex Z
Berkeley, California 94704

California Department of Toxic Substances Control
Salvatore Cirello
Facility Permitting Branch
700 Heinz Avenue, Suite 200
Berkeley, California 94710

California Regional Water Quality Control Board, San Francisco Bay Region
Keith Lichton
1515 Clay Street Suite 1400
Oakland, California 94612

California Regional Water Quality Control Board, San Francisco Bay Region
Tom Mumley
Watershed Management Division
1515 Clay Street, Suite 1400
Oakland, California 94612

California State Water Resources Control Board
Heidi Temko
Clean Water Programs Division
2014 T Street, Suite 130
P.O. Box 944212
Sacramento, California 94244-2120

City of Berkeley
James Keene
City Manager
Civic Center Building
2180 Milvia Street
Berkeley, California 94704

City of Berkeley
Nabil Al-Hadithy
Office of Emergency and Toxics Management
Civic Center Building
2180 Milvia Street
Berkeley, California 94704

City of Oakland
Leroy Griffin
475 14th Street
Oakland, California, 94612

Community Environmental Advisory Commission
John Selawsky, Chair
1912 Blake Street
Berkeley, California 94704

East Bay Municipal Utility District
Mirtha Ninayahuar
Source Control Division
P.O. Box 24055
Oakland, California 94612-1055

Fermi National Accelerator Laboratory
Bill Griffing
Environment, Safety, and Health Section
Mailstop 119
P.O. Box 500
Batavia, Illinois 60510

Idaho National Engineering Laboratory
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Environmental Operations
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Mailstop 3940
Idaho Falls, Idaho 83415-3898

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Environment, Health, & Safety
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Mailstop 626
Livermore, California 94551

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Mailstop K491
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Environment, Safety, and Health
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Environment, Safety, and Health
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Mailstop P7-79
Richland, Washington 99352

Sandia National Laboratories, Albuquerque
Lynn Jones
Environment, Safety and Health
Laboratory Services
Sandia National Laboratories
P.O. Box 5800
Mailstop 0361
Albuquerque, New Mexico 87185-0361

Sandia National Laboratories, California
Robert Holland
Environmental Protection Division
P.O. Box 969
Mailstop 9221
Livermore, California 94551-9221

Savannah River Plant
Dennis Stevenson
Environmental Monitoring
Health Protection Department
Building 735A
Aiken, South Carolina 29808

Stanford Linear Accelerator Center
Gary Warren
Environmental Safety and Health Division
P.O. Box 4349
Mailstop 84
Stanford University
Stanford, California 94309

University of California,
Office of the President
Howard Hatayama
300 Lakeside Drive, 7th Floor
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Berkeley, California 94720

University of California at Berkeley
Paul Laveley, Director
Office of Radiation Safety
359 University Hall
Berkeley, California 94720

University of California at San Francisco
Environment, Health, and Safety
Ara Tahmassian
50 Medical Center Way
San Francisco, California 94143

University of California at Berkeley
Lawrence Hall of Science, #5200
Barbara Ando
Berkeley, California 94720-5200

U.S. Department of Energy
Richard Nolan, Director
Berkeley Site Office
Lawrence Berkeley Laboratory
Mail Stop 50B-3238
Berkeley, California 94720

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, Tennessee 37831

U.S. Environmental Protection Agency
Region 9
David Howekamp
Air and Toxics Division
75 Hawthorne Street
San Francisco, California 94105

Ernest Orlando Lawrence Berkeley National Laboratory
One Cyclotron Road | Berkeley, California 94720

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