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1996 Site Environmental Report Volume I

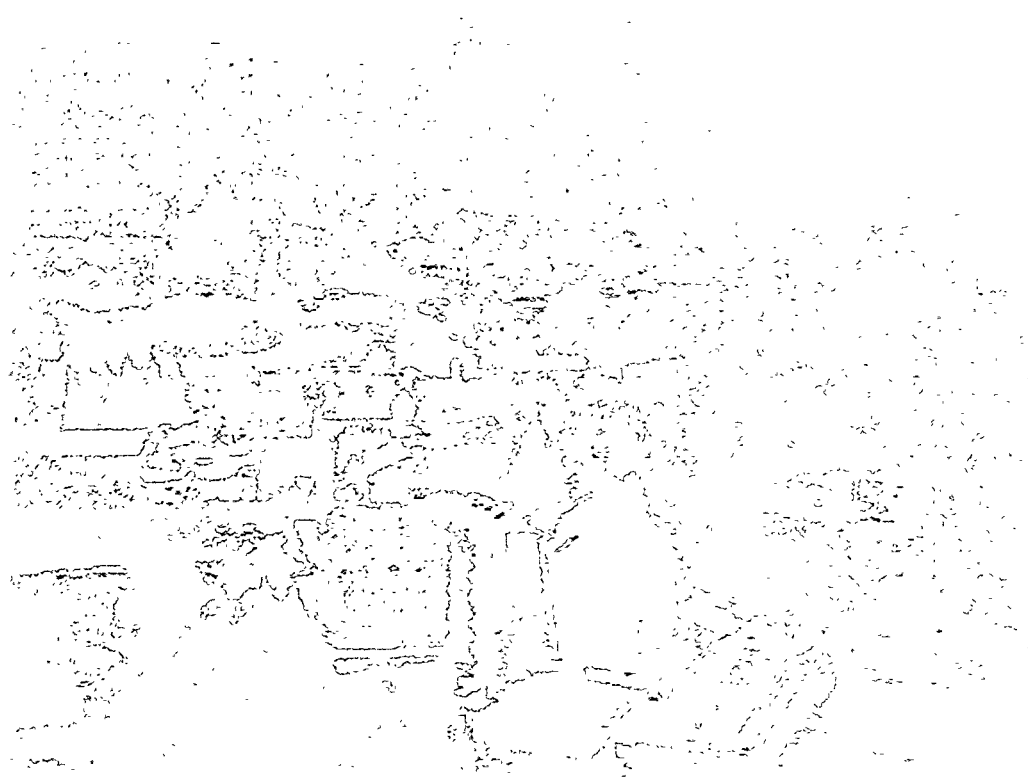
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1996 Site Environmental Report Reader Survey

To Our Readers:

Each annual Site Environmental Report publishes the results of environmental monitoring at the Ernest Orlando Lawrence Berkeley National Laboratory and documents our compliance with federal, state, and local environmental regulations. Our goal is to give our readership—whether regulators, scientists, or the public—a clear accounting of the range of environmental activities we undertake, the methods we employ, the degree of accuracy of our results, the status of our programs, and significant issues affecting programs.

It is also important that the information we provide is easily understood, of interest, and communicates Berkeley Lab's effort to protect human health and minimize our impact on the environment. We would appreciate a few moments of your time to complete the following reader survey as a way for us to determine whether we are successful in achieving these goals.

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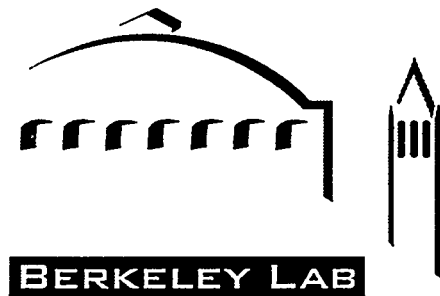
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Lawrence Berkeley National Laboratory



1996 Site Environmental Report

Volume I

September 1997



Department of Energy

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Distribution:

SUBJECT: 1996 Site Environmental Report (SER) for the Lawrence Berkeley National Laboratory (LBNL)

This report, prepared by LBNL for the U.S. Department of Energy, Oakland Operations Office (DOE/OAK), provides a comprehensive summary of the environmental program activities at Lawrence Berkeley National Laboratory (LBNL) for Calendar Year 1996. Site Environmental Reports (SERs) are prepared annually for all DOE sites with significant environmental activities, and distributed to relevant external regulatory agencies and other interested organizations or individuals.

To the best of my knowledge, this report accurately summarizes the results of the 1996 environmental monitoring, compliance, and restoration programs at LBNL. This assurance can be made based on DOE/OAK and LBNL review of the SER, and quality assurance protocols applied to monitoring and data analyses at LBNL.

A reader survey form is provided with the SER to provide comments or suggestions for future versions of the report. Your response is appreciated. Questions or comments regarding this report may also be made directly to DOE/OAK, by contacting Steve Black of the Environment, Safety, and Health Division at (510) 637-1595, or by mail to the address above.

Sincerely,

Richard H. Nolan, Director
Berkeley Site Office

The 1996 Site Environmental Report for Ernest Orlando Lawrence Berkeley National Laboratory is prepared for the U.S. Department of Energy under the requirements of DOE Order 231.1. The report is intended to present the status of Berkeley Lab's compliance programs and environmental surveillance activities, as well as an assessment of the impacts of its operations on the environment for calendar year 1996. The report uses the International System of Units (SI) as the primary means of presenting data.

The report was prepared under the direction of Patrick Thorson of the Environmental Protection Group. The primary authors of the report include Iraj Javandel, Ginny Lackner, Mike Ruggieri, Charles Smith, Patrick Thorson, and Henry Tran.

Other contributors of information on Environment, Health, and Safety programs, other than monitoring and sampling, include David Balgobin, David Baskin, Paul Davis, Robert Fox, Gale Moline, Ron Pauer, Nancy Rothermich, Jack Salazar, Nancy Shepard, Brian Smith, Dave Tudor, Mark Turner, Tim Wan, Robin Wendt, Shelley Worsham, and Dave Yeager.

Environmental monitoring and sampling programs represent an important element for assessing the impact of Berkeley Lab operations on the nearby environment. David Balgobin, David Baskin, Tom Donovan, Iraj Javandel, Ginny Lackner, Vic Montoya, Ron Pauer, Mike Ruggieri, Charles Smith, Patrick Thorson, Henry Tran, and Randy Yow all played a role in designing, coordinating, collecting, and maintaining environmental monitoring and sampling programs. Steve Wyrick managed the variety of data collected by the environmental surveillance program.

Production of the report, including the electronic version on the World Wide Web, was handled by Chip Seward. In addition, Rich Albert assisted with editing of the report.

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Chapter 1

Executive Summary

Introduction

This report summarizes environmental activities at the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) for 1996. It presents data and information that characterize the Laboratory's environmental management performance measured against applicable regulatory standards and DOE requirements. The report also discusses significant highlights of Berkeley Lab's environmental programs.

The format and content of the report satisfy the requirements set forth in applicable sections of U.S. Department of Energy (DOE) Order 231.1, *Environment, Safety and Health Reporting*¹, and included in the contract between the University of California (UC) and the DOE.²

Environmental Performance Measures

Also included in the Laboratory's operating contract between UC and DOE, Berkeley Lab

is required to assess its environmental protection effectiveness using performance objective criteria and measures. The criteria and measures were jointly developed by Berkeley Lab, UC, and DOE, and are reviewed annually for possible improvements. Berkeley Lab measures this performance annually and submits a report to UC for verification by DOE.

Berkeley Lab achieved at least a *Meets Expectations* rating in 1996 for all the graded criteria measures. The measures and their performance ratings are presented in Table 1-1.

Environmental Compliance Programs

Preventing adverse impacts to workers, the public, and the environment from its activities is the responsibility of everyone working at the Laboratory. Berkeley Lab's Environment, Health and Safety (EH&S) Division is responsible for overseeing that this objective is achieved.

Table 1-1. Berkeley Lab Environmental Performance Ratings for 1996

Criteria Measure	Needs Improvement	Meets	Exceeds	Far Exceeds
Radiation Protection of the Public			✓	
Waste Reduction and Recycling				✓
Source Reduction and Pollution Prevention			✓	
Tracking and Trending of Findings and Violations			✓	
Tracking and Trending of Environmental Releases		✓		
Customer Focus				✓

1-Executive Summary

Areas of support provided to the Laboratory by EH&S include:

- air quality
- water quality
- hazardous materials
- hazardous/radioactive/medical waste
- waste minimization/pollution prevention
- soil/groundwater characterization and remediation.

Environmental services include overseeing compliance with environmental regulations and providing technical assistance. Examples include:

- obtaining and complying with permits
- conducting audits and inspections
- providing regulatory liaison between Lab and agencies
- training
- reporting
- initiating and supporting corrective action
- conducting environmental monitoring and sampling
- responding to spills and accidental releases.

Environmental Permitting

At the end of 1996, Berkeley Lab had 38 environmental operating permits issued by regulatory agencies for activities on site. The type of permits and the number within each category include the following:

- air emissions (22)
- hazardous waste handling and treatment operations (2)
- stormwater discharges (1)
- underground storage tanks (9)
- wastewater discharges (4)

Violations, Findings, and Environmental Incidents

A total of 27 external audits and inspections of Berkeley Lab's environmental programs occurred during 1996. The Laboratory did not receive any citations from these inspections. However, one incident in December, involving the accidental discharge of a nontoxic fire suppressant into Strawberry Creek, resulted in an administrative violation from the City of Berkeley.

Environmental Monitoring

Monitoring of environmental media is a major way to demonstrate that Berkeley Lab activities remain within regulatory and DOE requirements. Monitoring also provides a historical record of measured changes in the environment. The *Environmental Monitoring Plan*³, developed and maintained by the Laboratory, provides the rationale of the monitoring program for both radiological and nonradiological issues.

Berkeley Lab devotes a large part of its monitoring effort assessing the impact of its radiological activities. Laboratory activities can potentially release two types of radiation: penetrating radiation and dispersible radionuclides. Penetrating radiation is generated by ionizing sources such as accelerators. Shielding with specially designed blocks is the predominant method of controlling the release of penetrating radiation to the environment.

Dispersible radionuclides can result from a wider range of research activities than penetrating radiation, although Berkeley Lab has comparable programs in place to control use and potential release of both types. The predomi-

nant method of releasing dispersible radionuclides into the environment is via emission to the atmosphere. High efficiency filters on exhaust systems can effectively capture over 99% of the emissions.

Berkeley Lab monitors for both direct penetrating radiation and dispersible radionuclides. The primary radiological compliance standards are based on dose, or the estimated maximum amount of potential radiation a member of the public would receive from Berkeley Lab operations, both direct penetrating radiation and dispersible radionuclides. The 1996 estimated maximum annual dose from Berkeley Lab operations to an individual member of the public is 0.019 millisieverts (mSv), or 1.9 millirem (mrem). This is less than 2% of the applicable DOE radiological standard of 1 mSv/yr (100 mrem/yr)⁴, and an even smaller fraction of the total natural radiation background of approximately 2.66 mSv/yr (266 mrem/yr)⁵. This dose compared to typical radiation doses received by the general public is summarized in Figure 1-1.

An additional measure of the overall impact from Berkeley Lab's radiological activities is the population dose, which is defined as the sum of the doses to all individuals within an 80-kilometer (50-mile) radius of the Laboratory. The collective population dose for 1996 is estimated at 0.021 person-Sv (2.1 person-rem). There is no regulatory standard for this measure.

Berkeley Lab is also subject to standards specifically set for dispersible radionuclide sources. The U.S. Environmental Protection Agency (US/EPA) establishes a dose standard of 0.1 mSv/yr (10 mrem/yr)⁶ 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 in 1996 was 0.00025 mSv (0.025 mrem), or well less than 1% of the US/EPA limit.

When assessing airborne radionuclides alone, tritium from the National Tritium Labeling Fa-

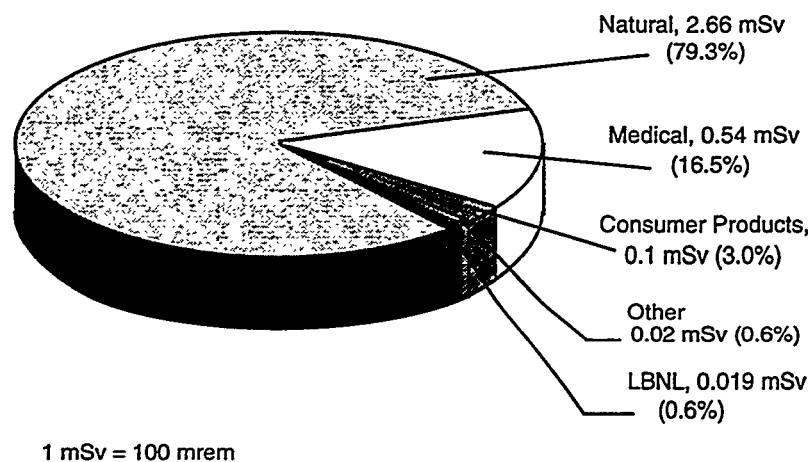


Figure 1-1. Typical Radiation Doses Received by the General Public, Including the Maximum Contribution From LBNL

1-Executive Summary

cility accounted for the majority of the Laboratory's estimated dose, as well as the majority of its emissions. For 1996, tritium contributed about 57% of the total dose, and over 60% of the site's total airborne radionuclide emissions. Tritium emissions from the NTLF for 1996 were about 0.19 terabecquerels (TBq), or 5 curies (Ci). This represented a drop of 90% from the previous year's emissions level. Figure 1-2 shows a continuing decline of tritium emissions from the NTLF, a trend that started in the late 1980's.

Other environmental monitoring at the Laboratory is not limited to radiological parameters. Under the requirements of the Laboratory's four wastewater discharge permits⁷ issued by the East Bay Municipal Utility District, Berkeley Lab is required to sample for metals, toxic organics, and other specified parameters in the sanitary sewer system on specific dates during

the year. All wastewater discharge levels were below the limits established in the applicable permit.

Stormwater discharges at Berkeley Lab are authorized under a general permit⁸ issued by the State Water Resources Control Board. Stormwater discharges are regulated differently from wastewater in that there are no specific discharge limits cited in the general permit. References in the permit to the *Water Quality Control Plan* (Basin Plan)⁹ for the San Francisco Bay Basin are intended as guidelines, not measures of compliance for stormwater discharges.

Stormwater samples are analyzed for a variety of possible contaminants, depending upon the location of the sample. Levels of the metals chromium, copper, lead, and zinc exceeded guidance levels in the Basin Plan, but were con-

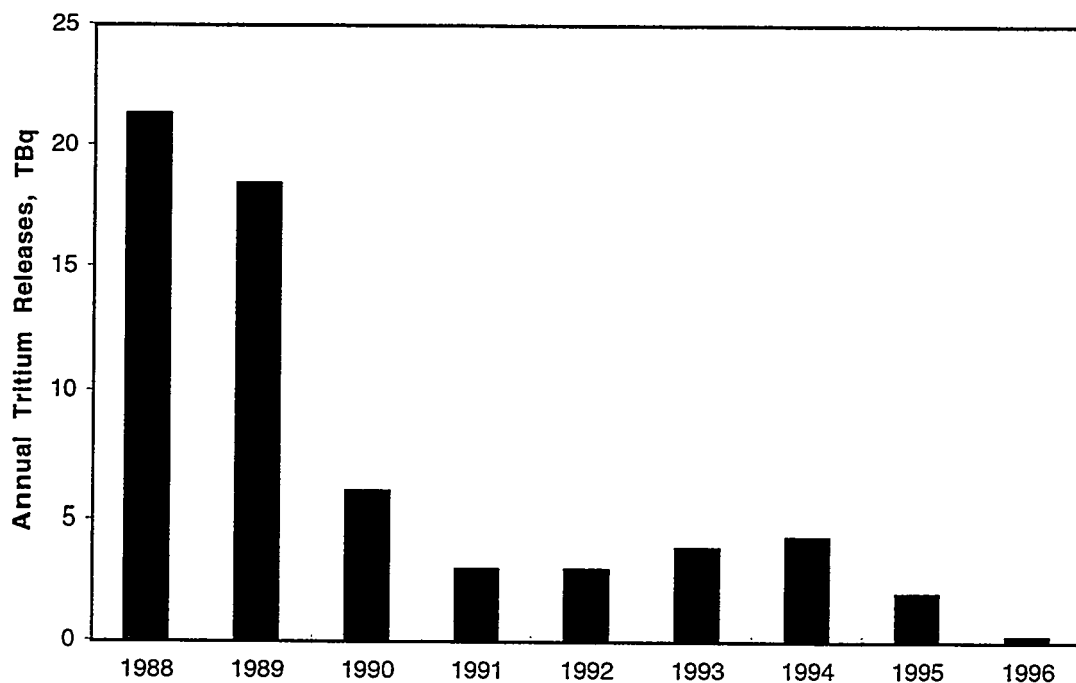


Figure 1-2. Trends in Annual Tritium Releases from NTLF; 1988-1996

sistent with levels of metals in other urban runoff areas. The Laboratory has a series of best management practices in place to minimize contamination in stormwater runoff. These practices are identified in its *Stormwater Pollution Prevention Plan*¹⁰. A survey of prevailing site conditions was reported as part of the annual report submitted to the Regional Water Quality Control Board on July 1.

Groundwater monitoring by Berkeley Lab's site restoration program have identified eight groundwater contamination plumes on site. These plumes are categorized into the following four types:

- volatile organic compounds (4 plumes)
- fuel (2 plumes)
- freon
- tritium.

Concentrations of contaminants are reported to agencies quarterly, along with other program developments and planned activities.

Soil and sediment samples, taken on site and in the area surrounding the Laboratory, were also analyzed for radiation, including tritium, metals and a suite of toxic organics, including polychlorinated biphenyls, diesel, kerosene, and oil. All analyses indicated levels of contaminants below regulatory concern.

Conclusion

A major goal of Berkeley Lab is to continue the long tradition of outstanding research that has made the facility a premier national and international multiprogram laboratory. Activities are planned and conducted with full regard to protecting the public and the environment and complying with appropriate environment, health, and safety laws and regulations. Berkeley Lab maintains environmental compliance programs that offer expertise to the entire Laboratory community. Additionally, cross-media environmental monitoring is performed for both radiological and nonradiological parameters. Results from 1996 confirm that no environmental protection or compliance standards were exceeded by Laboratory activities.

In addition to this paper version, the entire 1996 Site Environmental Report can be viewed electronically at the Berkeley Lab's website. The current URL address for the Berkeley Lab's website is <http://www.lbl.gov>. Readers are encouraged to comment on this report by completing the survey card located at the inside cover page, or the survey form found in the electronic version of this report.

1-Executive Summary

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Chapter 2

Introduction

History

Berkeley Lab was founded in 1931 on the Berkeley campus of the University of California by Ernest O. Lawrence. It is the oldest of the Department of Energy national laboratories. Lawrence, winner of the 1939 Nobel Prize in Physics for his invention of the cyclotron (particle accelerator), is generally credited with the modern concept of interdisciplinary science, where scientists, engineers, and technicians from different fields work together on complex scientific projects directed at national needs and programs. A great tradition of scientific inquiry and discovery ensued as a result of Lawrence's pioneering work, including the awarding of Nobel Prizes to eight other Berkeley Lab scientists.

Today, team science is still the driving force behind Berkeley Lab's success. Berkeley Lab employees work in such diverse fields as fundamental physics, energy conservation technology, materials science, structural biology, medi-

cal 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.

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.

Location

Berkeley Lab is located 8 kilometers (5 miles) east of San Francisco Bay (Figure 2-1) on the

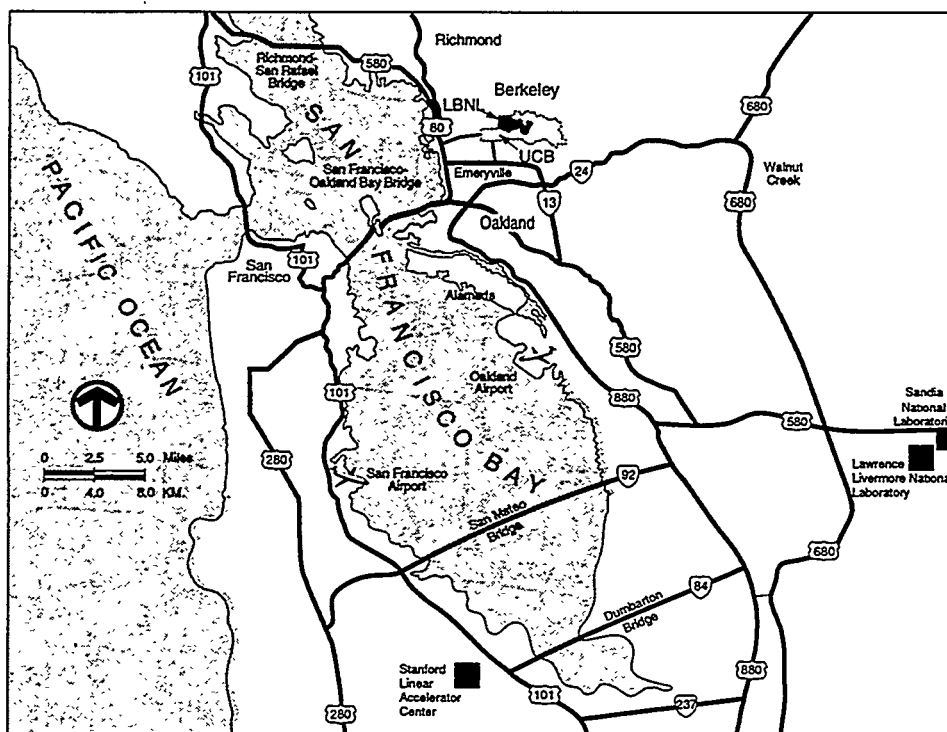


Figure 2-1. San Francisco Bay Area Map

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slopes of the Coast Range within 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 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 and the eastern portion in Oakland. Berkeley is a residential, university, and industrial city and is best known for the presence of the University of California at Berkeley (Figure 2-2). The population of Berkeley was estimated

at 106,000 in 1995. 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 (1995).

Adjacent land use consists of residential, institutional, and recreation areas (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. Above and to the east of the Laboratory are the University's Lawrence Hall of Science, Space Sciences Institute, and Mathematical Sciences Research Institute. Berkeley Lab is bordered on the north by predominantly single-family homes and on the west by multiunit dwellings, student residence halls, and private homes. The area to the west of Berkeley Lab is highly urbanized.

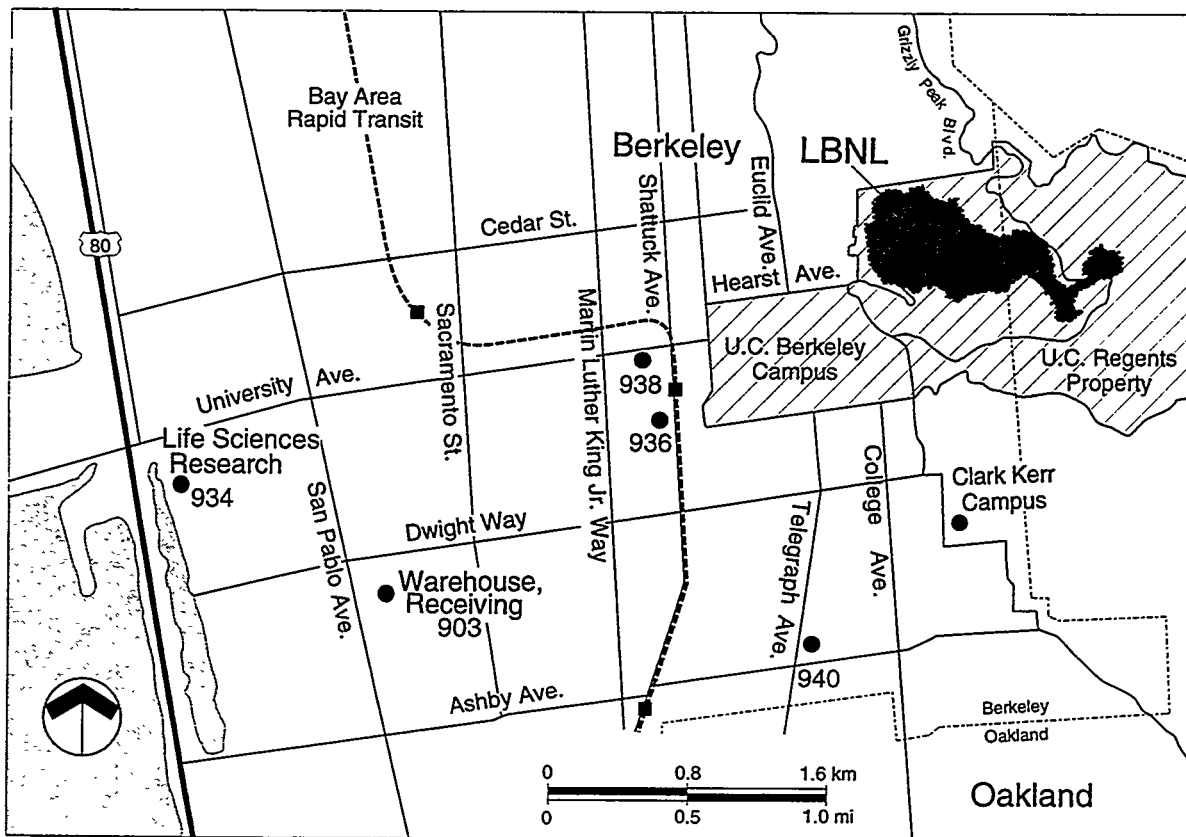


Figure 2-2. Vicinity Map

Laboratory Population and Space Distribution

The most recent staffing figures for the Laboratory indicate almost 3,400 full- and part-time employees. Additionally, Berkeley Lab provided facilities for approximately 1,850 guests who worked at the site for varying lengths of time in 1996. About 250 scientists are also faculty members at UC Berkeley or UC San Francisco.

Berkeley Lab research and support activities are conducted in structures having a total space of 182,900 gross square meters or 1,970,000 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 Buildings), and the remaining 10% is offsite leased

space. 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 1996.

The offsite leased space is included in six buildings. Five of the six are located in Berkeley.

- 903 - warehouse and receiving, on Carleton Street
- 934 - Dymo Building, laboratory space used primarily by Life Sciences, near Aquatic Park
- 936 - Hink's Building, housing Berkeley Lab's financial services, on Shattuck Avenue
- 938 - Promenade Building, housing Human Resources and Information Systems and

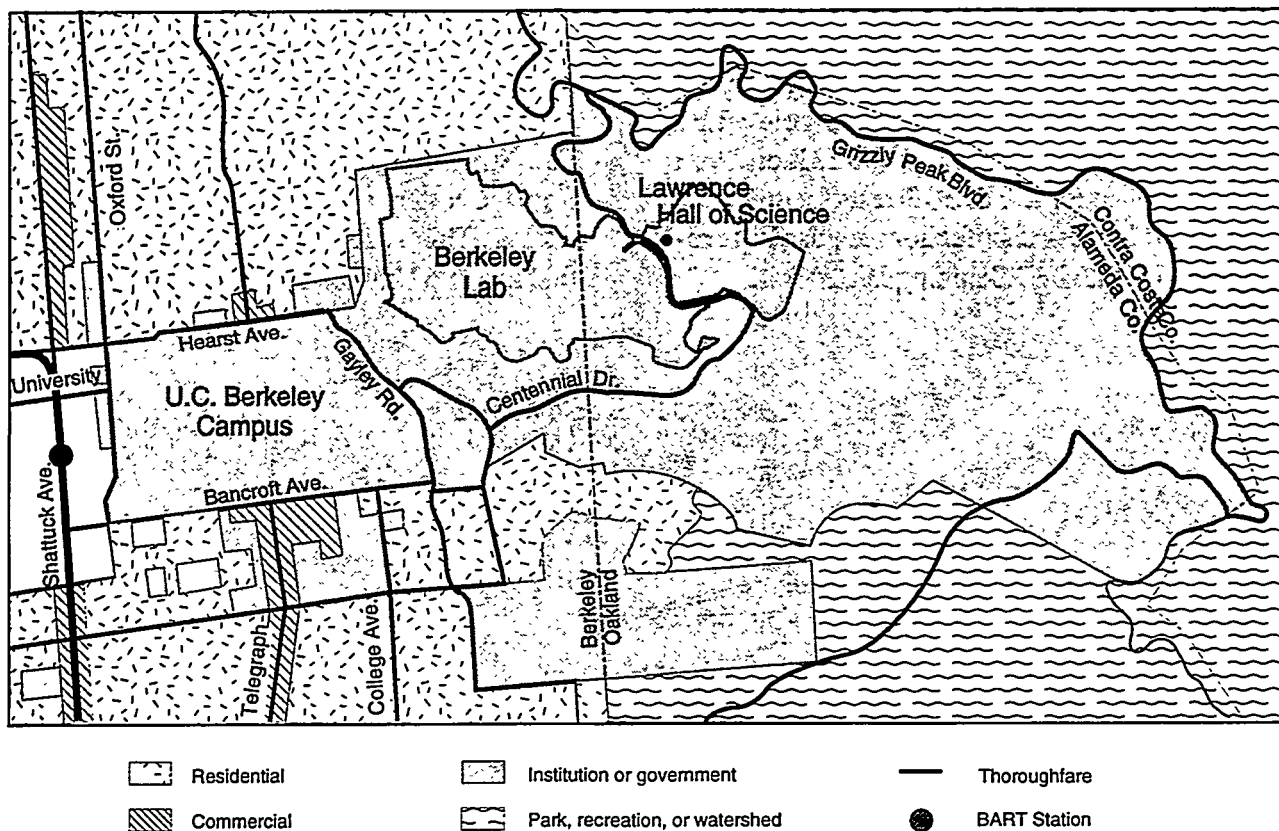


Figure 2-3. Adjacent Land Use

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Services, between University Avenue and Addison Street

- 940 - Cholesterol Research Center on Telegraph Avenue in Berkeley; used by the Life Sciences Division
- 960 - The Portals in Washington, D.C.; office space available for general Berkeley Lab use, as well as specific use by the Environmental Energy Technologies Division.

Water Supply

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

Domestic water originates in Sierra Nevada watershed lands before being brought to the Bay Area and ultimately to Berkeley Lab through a system of lakes, aqueducts, and treatment stations. EBMUD tests for contaminants and meets disinfection standards as required by the Safe Drinking Water Act.

The water system is highly reliable for both domestic use and emergency purposes. This reliability is due to the two separate connections to EBMUD's Shasta and Berkeley View sources, and two 760,000 liters (200,000 gallons) onsite storage tanks. The entire system has sufficient capacity to meet the flow-rate and duration requirements for fire protection.

Sanitary Sewer Systems

The Laboratory's sanitary sewer system is based on gravity flow and discharges through either a monitoring station at Hearst Avenue or one located adjacent to Centennial Drive in Strawberry Canyon (Figure 2-5).

The Hearst station monitors discharges from the western and northern portion of the site. This monitoring station is located prior to where the Laboratory's sanitary sewer system connects to the City of Berkeley sewer main.

The Strawberry station monitors discharges from the eastern and southern parts of the Laboratory. This section of the discharge system first ties into University-owned piping and then

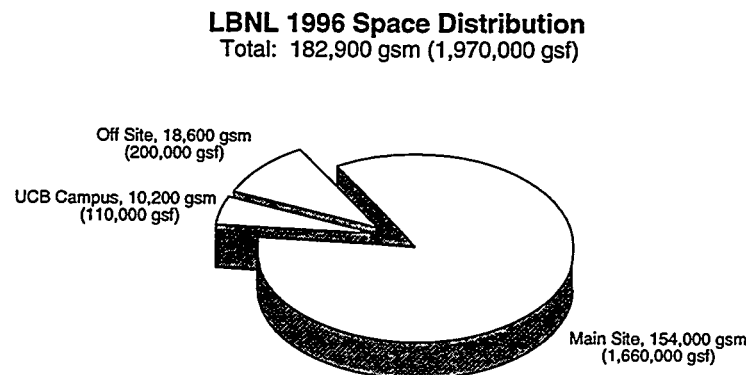


Figure 2-4. Space Distribution

into the City of Berkeley system. Both junctions occur on the lower portion of Centennial Drive. Because of the design of the network, the Strawberry monitoring station also receives effluent from several UCB campus facilities, the Lawrence Hall of Science, the Space Sciences Laboratory, the Mathematical Sciences Research Institute, and the Botanical Gardens.

Storm Drainage System

Berkeley Lab lies within the Strawberry Creek watershed, which contains about 354 hectares (874 acres). There are two main creeks in the watershed: Strawberry Creek and the North

Fork of Strawberry Creek. This watershed includes other University of California property, public streets in both Oakland and Berkeley, and private property. In the vicinity of Berkeley Lab, the Strawberry Creek watershed is further subdivided into the Blackberry Canyon and Strawberry Canyon watersheds (Figure 2-6).

Surface runoff from Berkeley Lab is substantial because of the site's hillside location and moderate annual rainfall. Berkeley Lab installed its storm drain system in the 1960's. This system is designed to handle runoff intensities expected in a 25-year maximum-intensity storm. The drainage facilities in this

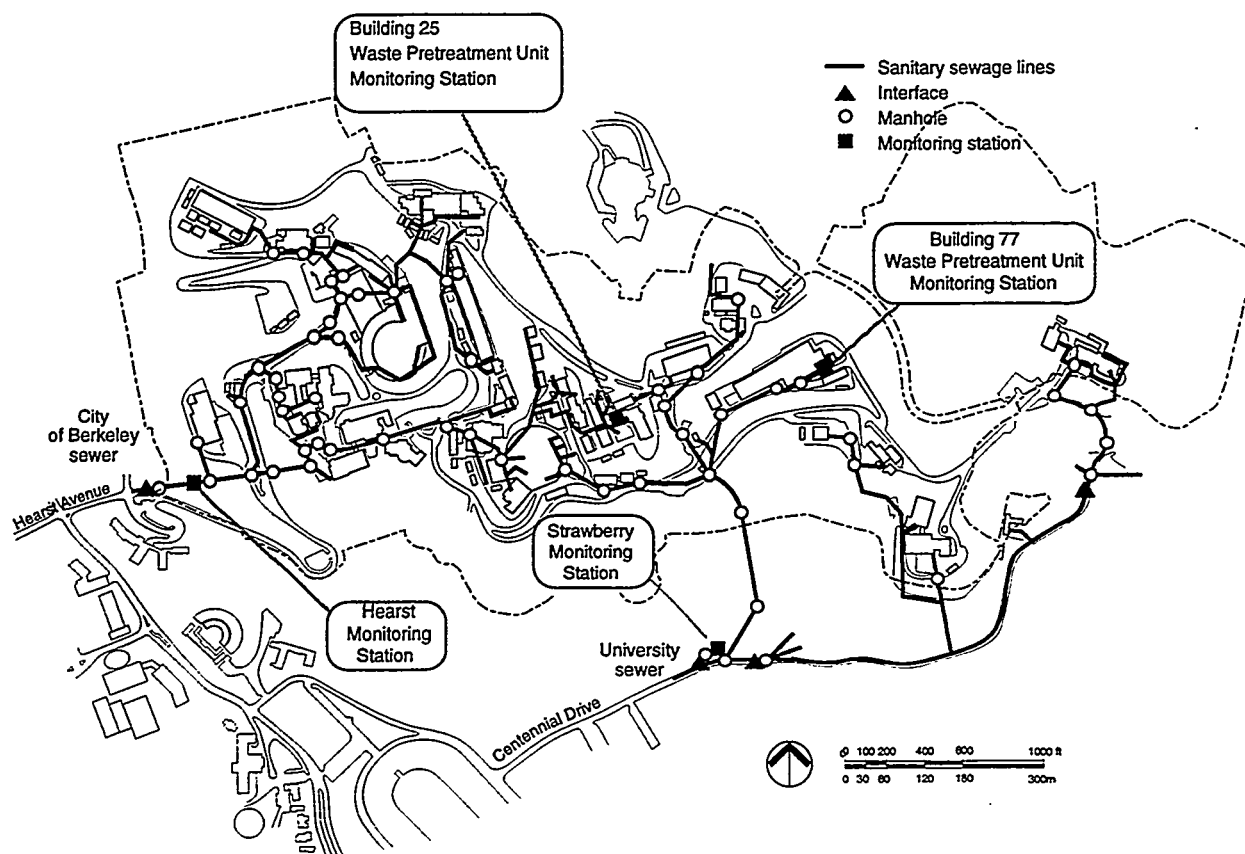


Figure 2-5. Sanitary Sewer System

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watershed have proven to be adequate during the heavy rains of the mid 1980s and the recent rainy seasons.

Meteorology

The climate of the site is influenced greatly by its physical setting. The moderating effect created by the nearby San Francisco Bay and Pacific Ocean to the west combined with the shielding effect of the hills that frame the eastern shore of San Francisco Bay contributes to the site's relatively cool, dry summers and warm, wet winters. The mean annual temperature at the site for 1996 was about 14°C (57°F). January was the coolest month with an average temperature of 10°C (50°F), while August was the warmest at just over 17°C (63°F). The extreme temperatures for the year included a maximum of 36°C (97°F) on October 7 and a

minimum of 2°C (35°F) on February 25. Figure 2-7 shows the monthly temperature extremes for the year recorded at the on site weather station.

The predominant onsite wind patterns reveal two distinctively different meteorological influences. The most prevalent pattern occurs when larger-scale high pressure systems block storm currents from reaching the area, bringing the fair weather symbolic of California. The resultant winds at the Laboratory are highly predictable, with daytime westerly winds blowing off the Bay, moderating 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.

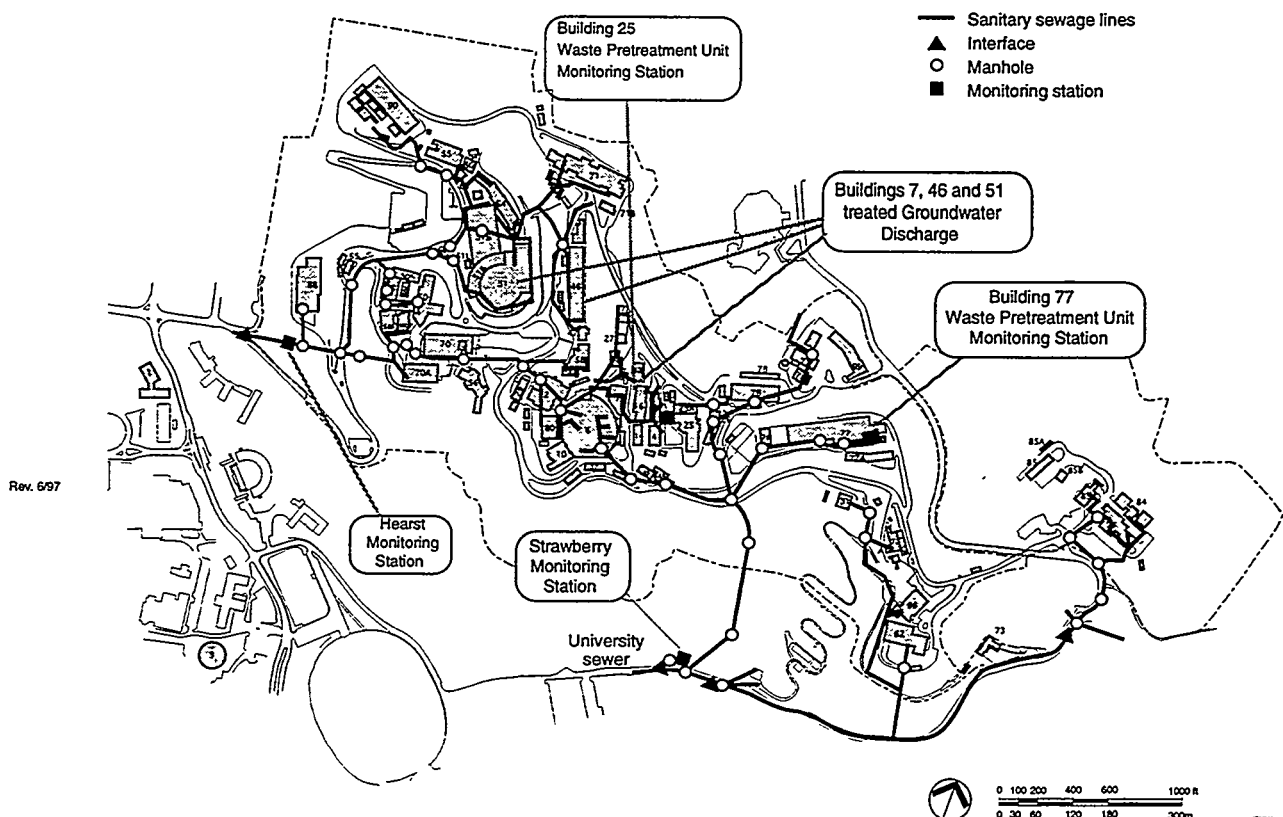


Figure 2-6. Stormwater Drainage in the Strawberry Creek Watershed

The other predominant wind pattern occurs when storm systems pass through the region. These systems are most frequent during the winter months. South to southeast winds pass over the site in advance of storms, shifting to the west or northwest after passage of each storm. Winter storms usually bring the highest wind speeds of the year. The maximum wind speed during 1996 occurred on December 29 when a gust reached 23 meters per second (52 miles per hour). The average wind speed for the year was 2.1 meters per second (4.7 miles per hour). A graphical summary of the annual wind patterns, called a windrose, is displayed in Figure 2-8. The windrose for 1996 illustrates the high frequency of the two predominant patterns. The windrose pattern for Berkeley Lab changes little from year to year.

Precipitation is recorded during the period called the water year, which runs from July 1 to the following June 30. The storms of the winter months produce nearly all of the precipitation that the Laboratory receives during the water year. The average annual precipita-

tion at the site over the past five water years is more than 80 centimeters (32 inches). Since the 1993/1994 water year, annual precipitation has been above normal, reversing the trend of drought seasons that persisted from the late 1980's through the early 1990's. Figure 2-9 compares monthly precipitation totals for 1996 with averages from the past five years. Figure 2-10 compares water year precipitation totals going back to 1991/1992.

Vegetation

The Laboratory has an extensive fire management program to reduce and control fire hazards from vegetation. Berkeley Lab has updated and intensified its fire management efforts since the major fire in October 1991 that occurred in the Berkeley/Oakland Hills to the south. The basic strategy of the program involves reducing fuel loads and fire "laddering" capabilities. Within the site fence line, most of the northern perimeter is managed as a fuel or fire break. Fire protection along the southern and eastern perimeters is complicated by

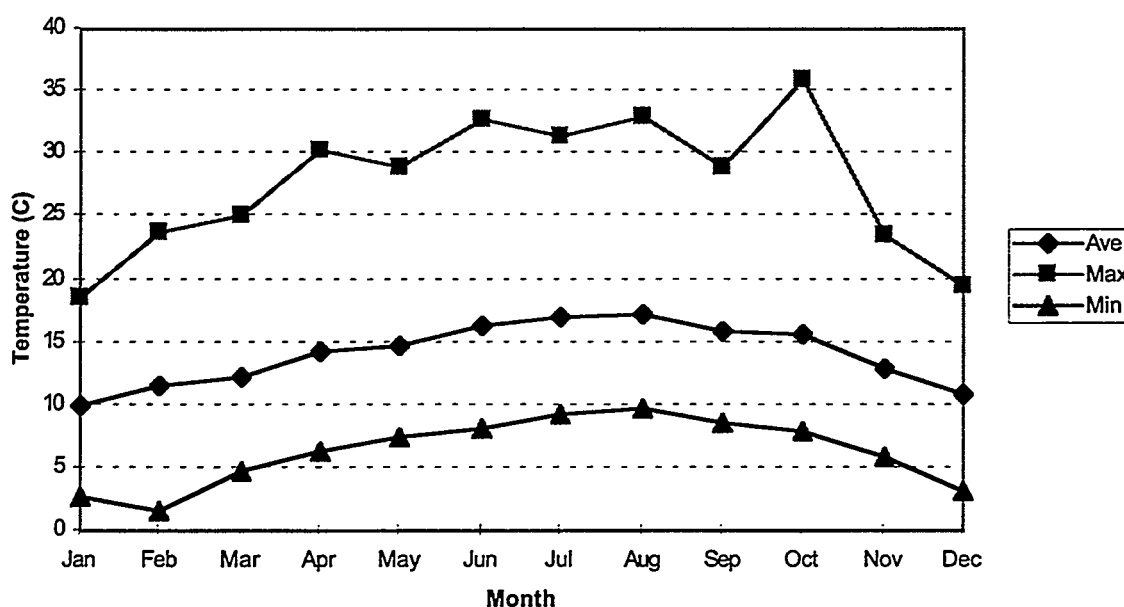


Figure 2-7. Temperature Summary by Month

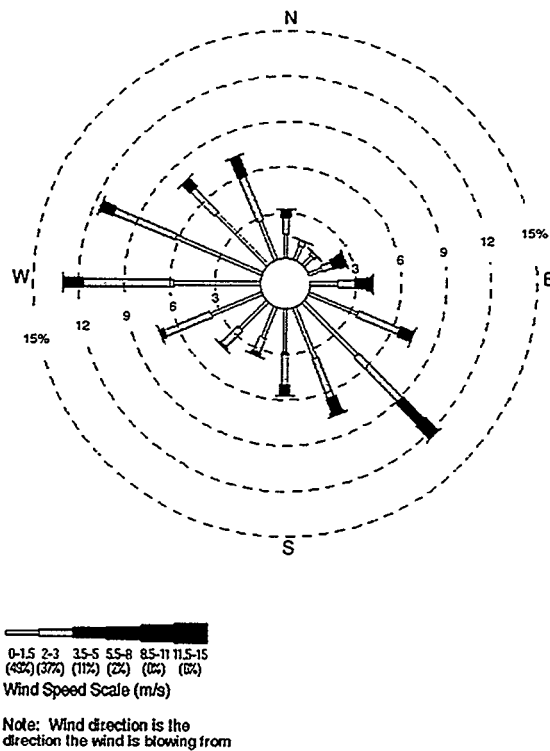


Figure 2-8. Annual Wind Patterns at LBNL for 1996

limited landscape space within the fence line and proximity to less-managed University lands. Berkeley Lab works with the East Bay Hills Vegetation Management Consortium and UCB to consider improvements in fire defense

at the site's perimeter.

Revegetation issues that assure long-term continuity in Berkeley Lab's landscape value is another goal of the program. Some of the is-

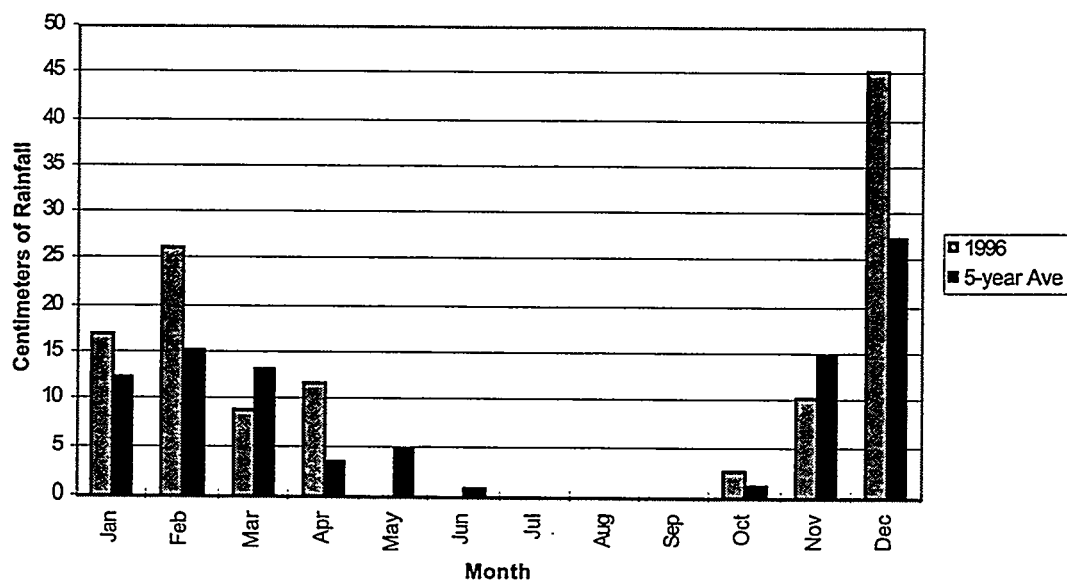


Figure 2-9. Rainfall at Berkeley Lab in 1996

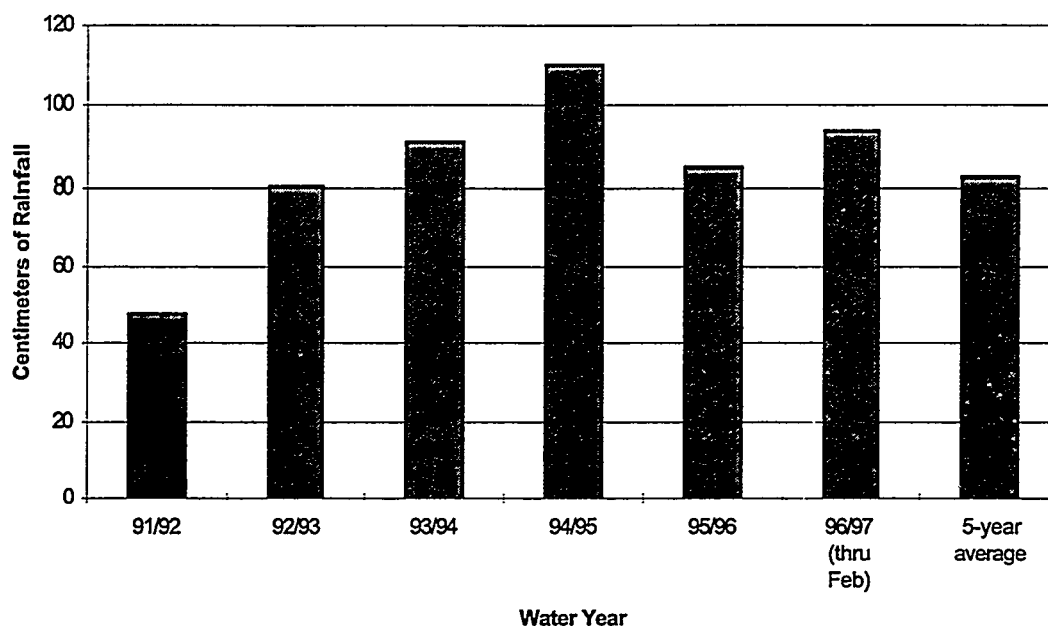


Figure 2-10. Trends in Water Year Rainfall at Berkeley Lab

sues considered include screening Berkeley Lab buildings from public view through tree height planning, blending the site with the hillside, maintaining the view of the Cyclotron as an historical landmark, and preserving bay views. Figure 2-11 shows vegetation types at Berkeley Lab, while Figure 2-12 shows the landscape buffers.

Wildlife

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

The Laboratory's *Baccharis* brushland provides cover, food, and breeding sites for this wildlife, the dominant mammals of which are brush rabbits and mule deer. Its tree stands offer nesting sites for many bird species; during the flowering season, the eucalyptus provide food for

nectar-eating birds. In general though, the sparse tree understory offers poor wildlife habitat.

Geology

The Berkeley Lab site 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:

- 1) The western and southern parts are underlain by moderately- to well-consolidated upper Cretaceous marine sediments. These rocks consist of shales, siltstones, sandstones, and conglomerates.
- 2) The upper Miocene or lower Pliocene Orinda formation overlies the Cretaceous rocks and underlies most of the property. It consists of poorly consolidated claystones, siltstones,

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sandstones, and conglomerates of relatively low strength and hardness. These rocks are blanketed by clay soils having high shrink-swell characteristics.

3) The volcanic Moraga formation underlies most of the higher elevations of the Laboratory as well as much of the "Old Town" area around the Advanced Light Source. The Moraga formation overlies the Orinda formation. However, 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 flows and pyroclastic tuffs.

Due to the hilly terrain, extensive grading and filling has 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 program of slope stabilization, including shallow dewatering wells, vegetation cover, and soils management, to reduce the risk of property damage due to soil movement.

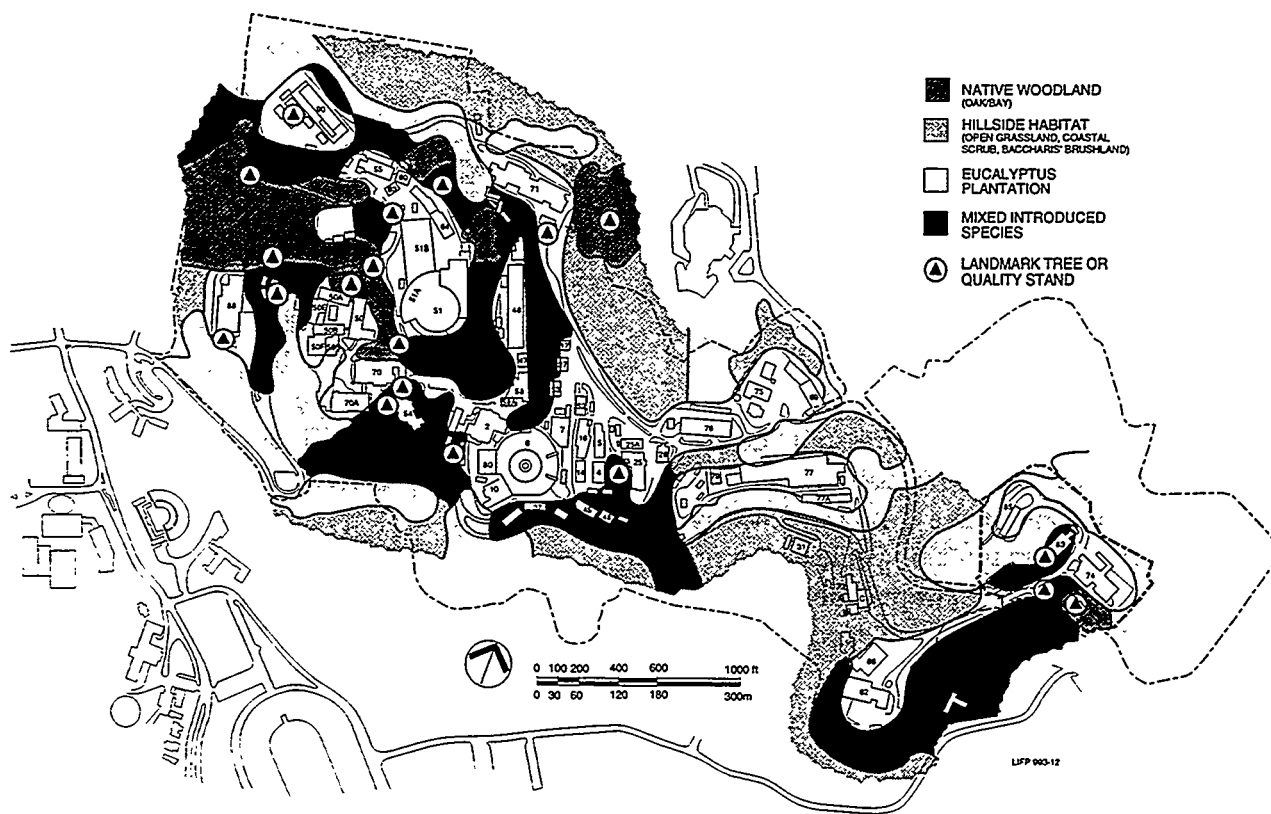


Figure 2-11. Vegetation Types

Hydrogeology

The hydrogeology at Berkeley Lab is also complex. Year-round springs, annual surface seeps, and variable water levels in observation wells indicate discontinuous and localized aquifers. These conditions are due to a number of factors. The different rock units underlying the site have contrasting 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.

The flow of groundwater is a concern at the Laboratory because of its potential effect on slope stability. The fractured bedrock underlying the Laboratory allows percolation that augments groundwater. Faults that cut through bedrock tend to drain groundwater, whereas clay layers impede or direct flow. The complex geology at the laboratory results in water-table depths that vary from less than 3 meters (10 feet) to more than 27 meters (90 feet) across the site.

Seismicity

Berkeley Lab is located in a seismically active region (Figure 2-13). The Hayward Fault, a branch of the San Andreas Fault System, trends northwest-to-southeast along the base of the hills at the Laboratory's western edge. It has the potential to produce an earthquake of ap-

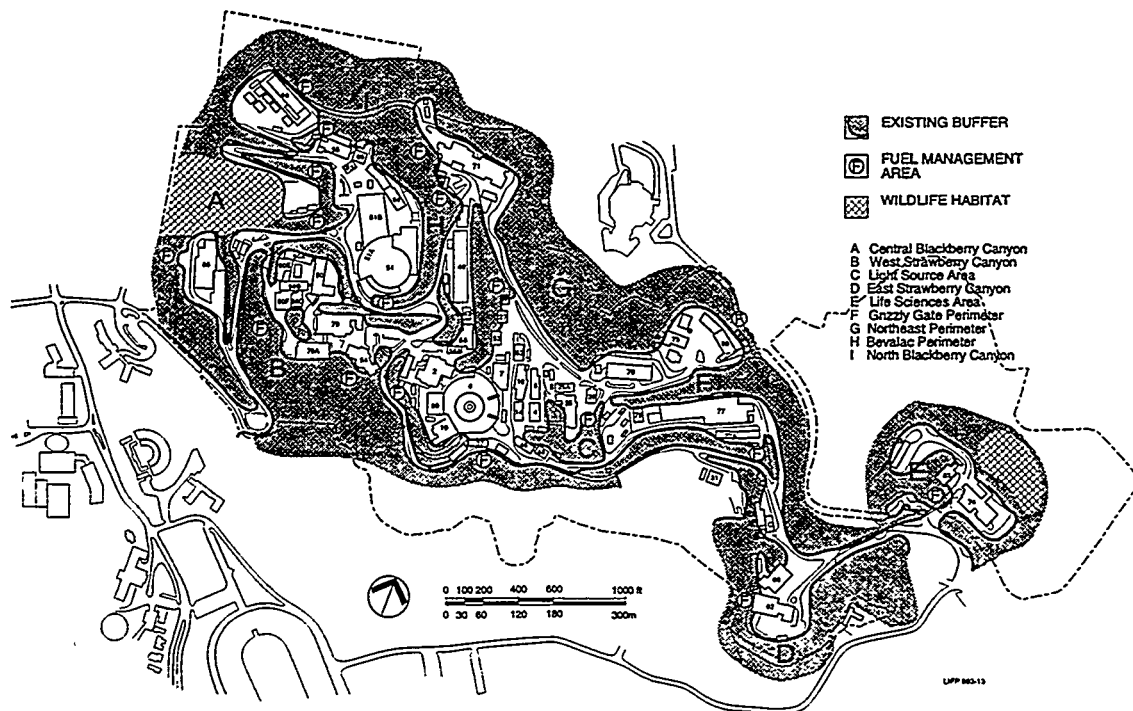


Figure 2-12. Landscape Buffers

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proximately 7.5 on the Richter scale. Traces of the Wildcat Fault, also part of the San Andreas system, traverse the site on the east, but analysis indicates no evidence that the fault is active in this area. Shorter, apparently inactive, subsidiary faults also transect the Laboratory.

The San Andreas Fault zone, which has potential for a magnitude 8.3 earthquake, lies about 32 kilometers (20 miles) west of Berkeley Lab, offshore beyond the Golden Gate. The Calaveras Fault, another branch of the San Andreas, lies about 24 kilometers (15 miles) east of the site. For an earthquake of any given

magnitude, the Hayward Fault would produce the most intense ground shaking at Berkeley Lab because of its proximity. No buildings or building additions are sited across the fault.

To reduce the potential for damage from seismic activity, the Laboratory has carried out a comprehensive earthquake safety program since 1971. All new facilities have been designed and constructed to resist the maximum credible earthquake estimated for the site. All existing buildings have been reviewed, and many have been strengthened to meet current risk criteria.

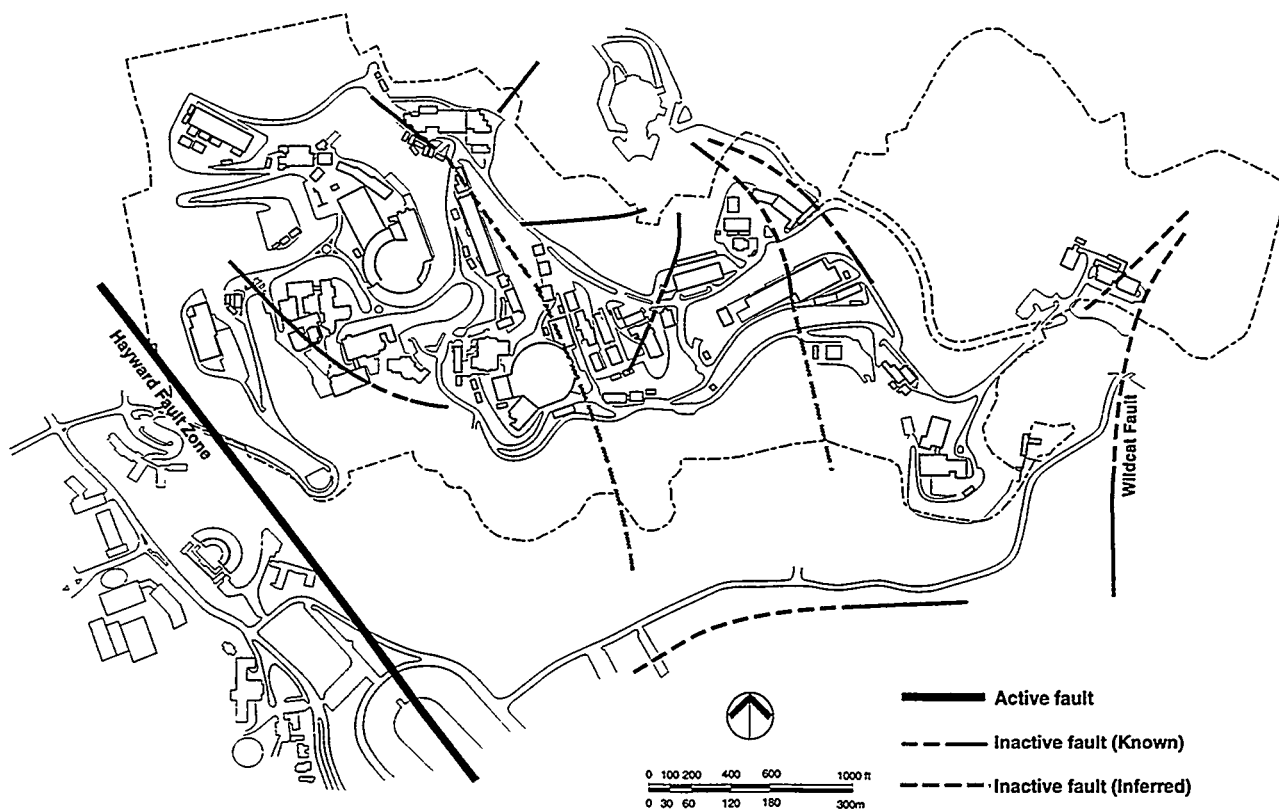


Figure 2-13. Mapped Seismic Faults

Chapter 3

Environmental Program

Summary

Introduction

This chapter summarizes the effectiveness of the Laboratory's environmental programs during 1996. The chapter begins with a brief overview of the organizational framework for managing environmental programs at Berkeley Lab. Most of the chapter discusses various compliance programs and activities, such as environmental permits, regulatory inspections or other audits, and significant regulatory developments. The chapter closes with an update on a series of criteria designed to measure environmental performance at the Laboratory in key areas.

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 majority of environmental regulatory programs are managed by one of two groups found within the Services Department: the Environmental Protection and Waste Management Groups. The organizational structure of the EH&S Division for 1996 is shown in Figure 3-1.

The Environmental Protection Group (EPG) oversees site-wide environmental compliance efforts, provides related technical assistance, and assesses site and groundwater characterization and cleanup. Environmental monitoring programs are an important component, providing critical information used in demonstrating compliance and making programmatic decisions. Results from the monitoring programs are discussed in chapters 4 through 11 of this report.

The Waste Management Group (WMG) manages hazardous, medical, radioactive, and mixed (hazardous and radioactive) waste gen-

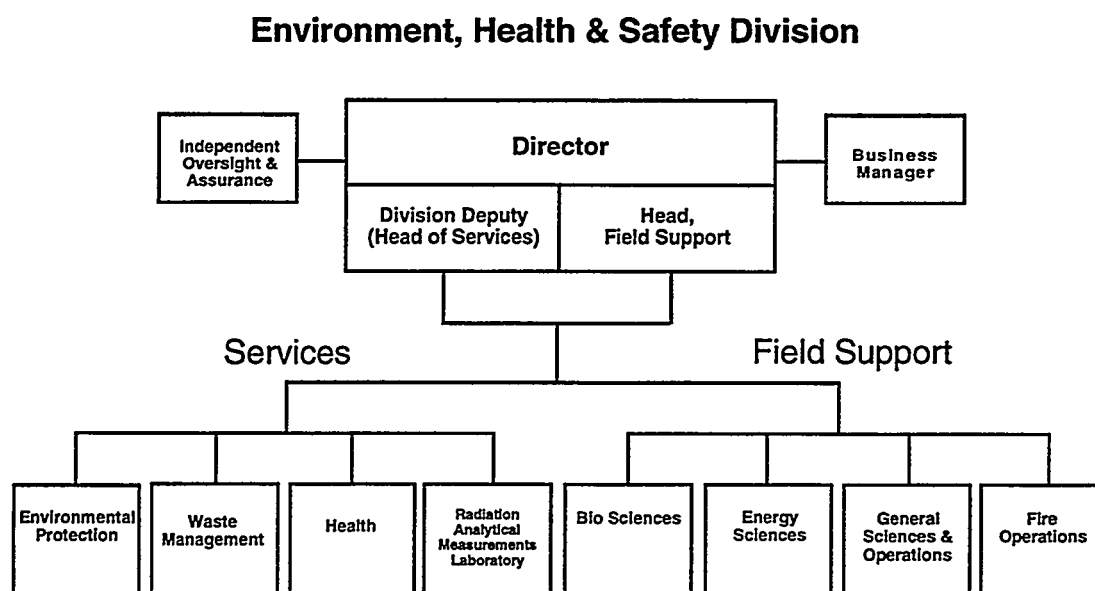


Figure 3-1. LBNL Environment, Health and Safety Division Organization

3-Environmental Program Summary

erated at the Laboratory. In addition to managing day-to-day activities at the Hazardous Waste Handling Facility, the group's responsibilities include ensuring that Laboratory waste is characterized properly and providing assistance to the Laboratory community on hazardous waste issues, with particular emphasis on incorporating opportunities for pollution prevention or waste minimization.

Program Summary

Summary of Environmental Permits

Various Berkeley Lab activities require operating permits from environmental regulatory agencies. Table 3-1 lists the different categories of permits, the number of permits within each category, the issuing agency and the section of this chapter that describes the permits more fully.

Summary of Audits and Inspections

Obligated by mandated responsibilities, numerous regulatory agencies inspect Berkeley Lab each year. Table 3-2 lists the visits for 1996. Also included in the list are appraisals performed by DOE, and self-monitoring events required by EBMUD wastewater discharge permits, since self-monitoring events have the potential for a regulatory violation. Not included on the list were agency visits involving only onsite informational meetings. As seen in this table, none of the regulatory reviews produced any violations in 1996.

Summary of Environmental Incidents

Although Berkeley Lab received no inspection violations in 1996, the Laboratory filed three

Table 3-1. Summary of Environmental Permits Held by LBNL During 1996

Type of Permit	Issuing Agency	Description	Number of Permits	Section for More Information
Air Quality	BAAQMD	Variety of individual activities with atmospheric emissions	22	Air Quality—Nonradiological
Hazardous Waste	DTSC	Hazardous Waste Handling Facility operations and hazardous waste treatment units	2	RCRA, Hazardous Waste
Stormwater	SWRCB	Sitewide stormwater discharges	1	Water Quality — Clean Water Act
Underground Storage Tank	City of Berkeley	Underground storage tanks containing petroleum products	9	RCRA, Underground Storage Tanks
Wastewater	EBMUD	Sitewide and operation-specific wastewater discharges to sanitary sewer	4	Water Quality — Clean Water Act

Table 3-2. Environmental Audits, Inspections, and Appraisals at LBNL During 1996

Organization	Inspection Title	Start Date	Length (days)	Violations
BAAQMD	Annual Inspection of Permitted Sources	October 23	1	0
City of Berkeley	Buildings 70 and 85 USTs	July 22	1	0
	Building 58 UST	September 16	1	0
DTSC	Hazardous Waste Handling Facility	April 2	1	0
DOE	Environment, Safety, and Health Appraisal	October 7	10	0
EBMUD	Wastewater Monitoring Inspections at B25 Treatment Unit	February 8	1	0
		July 3	1	0
	Wastewater Monitoring Inspection at Hearst and Strawberry Outfalls	January 17	1	0
		February 26	1	0
		April 8	1	0
		July 2	1	0
		August 13	1	0
	Wastewater Monitoring Inspection at B77 Treatment Unit	February 8	1	0
LBNL	EBMUD Self-Monitoring Inspection at Hearst and Strawberry Outfalls	January 9	1	0
		March 11	1	0
		May 14	1	0
		June 6	1	0
		July 16	1	0
	EBMUD Self-Monitoring Inspection at B77 Treatment Unit	November 4	1	0
		January 9	1	0
		April 2	1	0
		May 14	5 ^a	0
		July 10	1	0
		August 22	1	0
		October 29	1	0
		May 6	1	0
		December 3	1	0

^a Startup testing of new fixed treatment unit

3-Environmental Program Summary

reports to DOE for environmental incidents in 1996 under the DOE occurrence reporting program.¹ Each of these incidents will be discussed in greater detail later in the program compliance section of this chapter. Table 3-3 summarizes these incidents and refers to the section that contains the detailed discussion.

Summary of Program Compliance

Air Quality

Clean Air Act

The Clean Air Act² is the key statutory reference for federal, state, and local air pollution control programs. It classifies air pollutants into several main classes, including

- criteria air pollutants (e.g., carbon monoxide, nitrogen oxides, particulate matter)
- hazardous air pollutants (e.g., radionuclides, volatile air toxics)
- ozone-depleting substances, such as chlorofluorocarbons or “freons”.

The State of California has its own statutory air pollution control program³ giving it additional powers to control sources of air emissions. In following the federal and state requirements, air quality protection and compliance activities at Berkeley Lab are divided into two categories: radiological and nonradiological.

Radiological

Radionuclides released to the atmosphere from Laboratory research activities must adhere to the standards found 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 5400.1⁵ and 5400.5.⁶ Subpart H is part of the National Emission Standards for Hazard-

ous Air Pollutants (NESHAPs) program. US/EPA administers the NESHAPs regulations, while DOE oversees the requirements of the DOE orders. There were no US/EPA inspections of the Berkeley Lab radiological program in 1996.

Many research projects at the Laboratory that emit NESHAPs-regulated radionuclides are dynamic. Research projects often have a fixed duration, and new projects may occur at new locations and use a different set of radionuclides. Such changes affect both the sampling strategy and sampling instrumentation.

To track compliance and assess emission monitoring requirements, Berkeley Lab reviews all activities that may release radionuclides before a project starts. This review is achieved through the Laboratory's *Radiological Work Authorization* program, which tracks the use and inventory of all radionuclides on site. An assessment based on the nature of the proposed work and the type of radionuclide provides a basis for determining the dose to the nearest offsite member of the public. Observing US/EPA regulations and DOE EH-1073T⁷ guidance, this assessment assumes that no portion of the release is collected by emission controls even if such controls exist. Berkeley Lab has formalized internal guidance to determine the appropriate level of sampling, monitoring, or administrative controls necessary to maintain compliance with NESHAPs. This methodology has been approved by US/EPA and is summarized in, Table 4-2 of Chapter 4, *Air Quality*.

Berkeley Lab also prepares an annual summary report to document NESHAPs compliance. The 1996 NESHAPs report for the Laboratory is attached as Appendix B. Chapter 4 also presents the results and discussion on the Laboratory's radiological emissions exhaust sampling and ambient air monitoring program for the year.

Table 3-3. Summary of Environmental Incidents at LBNL During 1996

Incident Date	Reporting Number	Description	Section for More Information
1/25/96	SAN--LBL-OPERATIONS-1996-0001	Discharge of Diesel-Contaminated Water into Storm Drain	Water Quality — Clean Water Act
3/7/96	SAN--LBL-EHS-1996-0001	Improper Characterization of Mixed Waste Shipments to Hanford	Hazardous Waste — Resource Conservation and Recovery Act
12/24/96	SAN--LBL-OPERATIONS-1997-0003	Discharge of Fire Suppressant Foam into Strawberry Canyon Creek	Water Quality — Clean Water Act

Nonradiological

The Bay Area Air Quality Management District (BAAQMD) implements federal and state air quality requirements for most air-emission activities that fall outside of NESHAPs, aside from mobile sources. BAAQMD takes a two-fold approach in implementing its program:

- issues operating permits for certain stationary sources of air pollutant emissions
- developing standards of operation for categories of activities or products.

At the end of 1996, Berkeley Lab had 22 specific operations or sitewide activities with BAAQMD operating permits.⁸ Operating permits are renewed annually. BAAQMD also requests information on the state's Air Toxics "Hot Spots" Information and Assessment Act of 1987 (AB2588)⁹ during the annual permit renewal process. A listing of operating permits renewed by Berkeley Lab in 1996 is provided in Table 3-4. Many more sources of air emissions do not require operating permits because of categorical exclusions specified in BAAQMD regulations.

All activities, however, are subject to the standards of operations found in the BAAQMD

regulations.¹⁰ The diversity of research and support activities creates an extensive set of Laboratory operations affected by BAAQMD emission source categories. The list of BAAQMD source categories includes:

- casting and molding
- chemical processing
- furnaces, ovens, and kilns
- gasoline dispensing
- general combustion
- liquid storage and loading
- material working and handling
- miscellaneous equipment (e.g., vacuum devices, welding tools, wastewater separators)
- semiconductor manufacturing
- surface coating and printing
- surface preparation and cleaning.

BAAQMD conducted its annual inspection of permitted sources on October 23. There were no violations.

Under other permitting activities, the Laboratory submitted three permit modification requests in 1996. The first application requested a consolidation of the 14 building-wide permits into a single facility-wide wipe-cleaning permit. BAAQMD approved this request in

3-Environmental Program Summary

late May. The change did not alter the total amount or type of solvent that could be used for wipe cleaning activities, but it streamlined the permit's recordkeeping and provided the Laboratory with the flexibility to perform wipe cleaning anywhere on site.

The second permit modification asked for a minor increase in solvent usage at a source subject to semiconductor manufacturing regulations. The third modification requested the use of two additional solvents in a vapor degreasing system previously permitted to use only 1,1,1-

Table 3-4. BAAQMD Permitted Air Emission Sources Renewed in 1996

BAAQMD Category	BAAQMD Source #	Description	Building	Permit Conditions	Abatement Device	Abatement Type
Furnaces, Ovens, and Kilns	104	Paint drying oven	77			
	145	Crystal Growth Furnace	2	X	X	Mist Eliminator
	148	Epoxy Curing Oven	53			
	149	Epoxy Curing Oven	53			
	150	Epoxy Curing Oven	53			
Gasoline Dispensing	76	Gasoline Pumps	76		X	Vapor recovery
Material Working and Handling	64	Sawdust collector	74		X	Cyclone
	73	Machine shop tools	76		X	Cyclone
	116	Machine shop tools	79		X	Cyclone
Miscellaneous	124	Sulfur hexafluoride chamber	58A		X	Refrigeration
	159	Vacuum coating chambers	25	X	X	Baghouse
Semiconductor	168	Instrument Support Laboratory	70A	X		
	186	Semiconductor Fabrication	70A	X		
Surface Coating and Printing	74	Paint spray booth	76	X	X	Liquid Separator
	96	Paint spray booth	77		X	Dry Filter
	147	Epoxy Mixing Hood	53	X		
Surface Preparation and Cleaning	92	Vapor/spray degreaser	77	X	X	Refrigeration
	97	Sandblast booth	77		X	Baghouse
	130	Solvent cleaning	77			
	140	Vapor degreaser	52	X		
	166	Sandblast booth	71B	X	X	Baghouse
	188	Wipe-cleaning	site-wide	X		

trichloroethane (a Class I ozone-depleting substance or ODS). This system, located in the Ultra High Vacuum Cleaning Facility (UHVCF) in Building 77, is the largest remaining source of ODS usage onsite.

With the global ban on the production of Class I ODSs¹¹ now in effect, this permit modification gave Berkeley Lab additional operational flexibility while efforts to acquire a non-ODS cleaning system for the UHVCF continued. The Laboratory received shipment of a new multistage ultrasonic cleaning system in January 1997. It is expected that the present vapor degreaser and the new system will initially operate in parallel until testing is completed.

Environmental Restoration

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA¹² was passed in 1980 to regulate actual or threatened releases into the environment. Actions under CERCLA and related statutes include removal and/or remedial action where the release may present an imminent danger, as well as remedial investigations and feasibility studies that determine site cleanup options.

Based on information provided by Berkeley Lab in 1991 about its historical onsite activities, US/EPA determined that the risks to the environment are low and do not trigger a CERCLA-based investigation. However, as a condition of its hazardous waste permit, an investigation is being performed based on the requirements of the Corrective Action Program¹³ of the Resource Conservation and Recovery Act (RCRA). See Chapter 6, *Groundwater Protection*, of this report for a discussion of environmental restoration efforts in 1996.

CERCLA also has implications for offsite incidents associated with Berkeley Lab activities. There were no new incidents to report in 1996.

One offsite incident remained open in 1996. In late 1995, Berkeley Lab received a *Proposed Finding of Potential Liability Status* letter from the state of Washington Department of Ecology (WDOE) concerning a hazardous substance release in Yakima, Washington. Berkeley Lab was notified because of eight used carbon drums it previously sent to this site in Yakima for recycling. Berkeley Lab disputed any contribution to contamination at the site, based on the nature of the material sent and associated shipment dates. According to Laboratory records, these carbon drums contained an extremely small amount of contaminated solvent, approximately 28.8 grams (0.06 pounds) of perchloroethylene from treated groundwater at the Laboratory site. Furthermore, these shipment dates were after the Department of Ecology became involved in the site and during a period when WDOE itself sent used carbon to the site, according to the Yakima site records. Nevertheless, WDOE named Berkeley Lab as a Potentially Liable Party (PLP) in March 1996.

In late 1996, Berkeley Lab joined a *de minimis* PLP group, which has now reached a settlement agreement with WDOE. The agreement provides for payment by PLP group members of amounts based on pounds of carbon sent to the Yakima site, in exchange for a covenant not to sue by WDOE and statutory contribution protection under both state and federal Superfund statutes. Once all PLP group members have made payments required by the consent decree, a motion for dismissal of WDOE's action against the PLP group members will be filed.

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Hazardous Materials

Emergency Planning and Community Right-To-Know Act

This Act was passed in 1986 as Title III of the Superfund Amendments and Reauthorization Act (SARA).¹⁴ The Act establishes requirements for emergency planning, notification, and reporting. The California Hazardous Materials Release Response Plans and Inventory Law¹⁵ incorporates the requirements of SARA Title III, which include:

- notification from facilities handling greater than threshold amounts of extremely hazardous materials
- emergency notification in the event of certain hazardous-material releases
- availability of material safety data sheets (MSDSs) for all hazardous substances on the site
- facilities subject to MSDS requirements prepare an annual emergency and hazardous chemical inventory form (Hazardous Materials Management Plan) and an acutely hazardous materials registration form
- facilities using, handling, or storing more than specified amounts of certain toxic chemicals to report annual emissions.

Compliance activities under these sections of the law are summarized below.

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*,¹⁶ to evaluate the applicability of the Toxic Release Inventory (TRI) reporting requirements of EPCRA. TRI reporting consists of two steps:

determining usage, and submitting US/EPA Form R if threshold quantities are exceeded.

Berkeley Lab determined that no chemical usage during 1996 exceeded the 4,536-kilogram (10,000-pound) criterion under the TRI law, and thus, no Form R preparation was needed. Table 3-5 compares the highest usage levels of the chemicals from the Laboratory's TRI assessment over the last several years. Notice that several of the substances previously tracked by the Laboratory have been officially removed from the TRI list by US/EPA.

Hazardous Materials Management Plan

The City of Berkeley is the local administering agency for certain hazardous materials regulations pursuant to state law. Berkeley Lab voluntarily submits a *Hazardous Materials Management Plan (HMMP)*¹⁷ to the City of Berkeley each year, although federal sovereign immunity from such regulations has not been waived.

The 1996 Plan included summary reports of the inventory of containers present on site in various hazardous or regulatory areas of concern. The reports included summaries of all carcinogens, reproductive toxins, ozone-depleting substances, and extremely hazardous substances. In addition, a report was provided which included all substances 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. Accompanying the 1996 Plan was the documentation (i.e., emergency plans and procedures and training) that must be updated a minimum of every two years.

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

Substance	1993 (kg)	1994 (kg)	1995 (kg)	1996 (kg)
Acetone	475	495	— ^b	285 ^b
Chlorofluorocarbons	1305	130	— ^a	120
Hydrochloric Acid	— ^a	205	2722	468
Isopropyl Alcohol	— ^a	315	— ^c	294
Methanol	— ^a	145	— ^a	158
Nitric Acid	525	645	— ^c	1030
Sulfuric Acid	4265	2195	— ^b	1161 ^b
1,1,1-Trichloroethane	1715	1565	1148	1023

^aOnly seven major TRI chemicals reviewed in 1993^bSubstance no longer required by US/EPA under this program^cUsage for year less than US/EPA reporting threshold***Risk Management and Prevention Plan***

The City of Berkeley requires a *Risk Management and Prevention Plan* (RMPP)¹⁸ for operations using acutely hazardous materials above certain thresholds established in 40 CFR Part 355. Berkeley Lab does not have any operations which contain hazardous substances above the threshold quantities. In the interest of best management practices, an RMPP was prepared for the Ultra High Vacuum Cleaning Facility in Building 77 because the facility uses common industrial chemicals which deserve attention to assure the safest possible environment.¹⁹ The RMPP was completed in 1995. Revision to the plan is anticipated now that the UHVCF is operational. The newly-completed facility functions with a significantly reduced or eliminated acutely hazardous materials inventory.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

Passed by Congress in 1972, FIFRA's²⁰ purpose is to restrict the registration, sale, use, and disposal of pesticides. Pesticides, including insecticides and herbicides, are applied at the

Berkeley Lab site only by licensed contractors. Insecticides are limited to as-needed application in and near buildings. To minimize the use of herbicides and to reduce solid waste, the Laboratory runs a composting program consisting of a chipper and two mulchers. In 1996, the chipper produced an estimated 160 metric tons (175 tons) of chipped wood that was subsequently used for onsite landscaping. All of the trees used to produce the wood chips had been removed as part of the Laboratory's fire management program. The composters generated about 6 cubic meters (8 cubic yards) of mulch that was used onsite for weed screening and landscaping where herbicides were previously applied.

Toxic Substances Control Act (TSCA)

TSCA²¹ is designed to minimize the exposure of humans and the environment to the many chemical substances and mixtures found in manufacturing, processing, commercial distribution, or disposal activities. TSCA establishes a means of evaluating these products before they are introduced into the marketplace and controlling their use once they are approved for manufacturing. TSCA is one of the few

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regulations affecting Berkeley Lab that is still administered at the federal level. The most prominent substance at Berkeley Lab affected by the TSCA regulations is polychlorinated biphenyls or PCBs.

Since the US/EPA program began, the Laboratory has aggressively inventoried and removed all regulated PCB transformers. The remaining sources of PCBs are primarily large low- and high-voltage capacitors. Approximately 50 of these capacitors are still in use or storage, containing an estimated 192 kilograms (424 pounds) of PCBs. The estimated volume of PCBs in electrical transformers is less than 1 kilogram. Figure 3-2 shows the trends in reducing regulated-PCB transformers and capacitors from the site.

Hazardous Waste

Resource Conservation and Recovery Act and California Hazardous Waste Control Law

The primary goal of the Resource Conservation and Recovery Act of 1976²² is to assure 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. In California, DTSC, rather than US/EPA, administers the RCRA program.

Hazardous Waste

The California hazardous waste program administered by DTSC incorporates the provisions of both the federal and state hazardous waste²³ 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
- Conditional exemption.

Berkeley Lab's Hazardous Waste Handling Facility operates under the "full permit" tier of the program. All Berkeley Lab hazardous, radioactive, and mixed (radioactive and hazardous) waste is packaged for transport off site for ultimate disposal. The current permit for the HWHF²⁴ was approved by DTSC on May 4, 1993, and is valid for ten years. The permit allows storage and simple treatment of certain hazardous and mixed wastes at the HWHF. Simple treatment includes neutralization, consolidation, solidification, and desensitization. Any change in operations must receive prior approval from DTSC.

In 1994, DTSC modified the permit at the request of Berkeley Lab. Currently, a permit modification request that originally was submitted in 1995 is under review by DTSC. The original request was revised in January 1996. The current request applies to operations at the existing and replacement HWHF and includes the following issues:

- convert certain waste storage units from radioactive and hazardous waste units to mixed waste units
- store three new waste streams
- use the existing treatment method of desensitization for reactive metal mixed waste
- use additional treatment methods for hazardous and mixed waste
- delete the requirement to maintain and inspect high efficiency particulate air filters in the hood exhaust systems of certain treat-

- ment units in the existing HWHF
- revise the current HWHF training plan and waste analysis sampling plan
- addressing the transfer of operations from the existing HWHF to the replacement facility, including methods for inspecting for contamination.

The Laboratory held a required public meeting on the revised request in early February 1996. The Laboratory previously held a public meeting on the original modification request in October 1995 and a public meeting in November 1995 to gain input for the purpose of developing a California Environmental Quality Act²⁵ document for the proposed changes. Additionally, DTSC held a non-required public hearing on the matter in March 1996.

Originally, DTSC expected to make a decision on the permit modification by early May 1996 when a temporary authorization covering certain aspects of the modification request would expire. The period for public comment on the

revised request was extended twice at the request of the public and did not end until April 19, 1996. As of early May 1996, DTSC and Berkeley Lab were just beginning the process of responding to the public comments. As a result of the delays with the Laboratory's request, DTSC issued a consent order that allows the HWHF to operate under a revised set of permit conditions until the agency makes a decision on the request.

In a separate request to DTSC, Berkeley Lab received approval in July to relocate 7 storage units from the existing HWHF to the replacement HWHF. The approval outlined the training of workers involved, acceptable methods of transporting the units the short distance (i.e., approximately 500 meters), and reporting requirements surrounding the move. DTSC approved the move activities until June 15, 1997.

Berkeley Lab has an additional hazardous waste permit²⁶ to operate six fixed treatment units (FTU) (Table 3-6). These treatment units

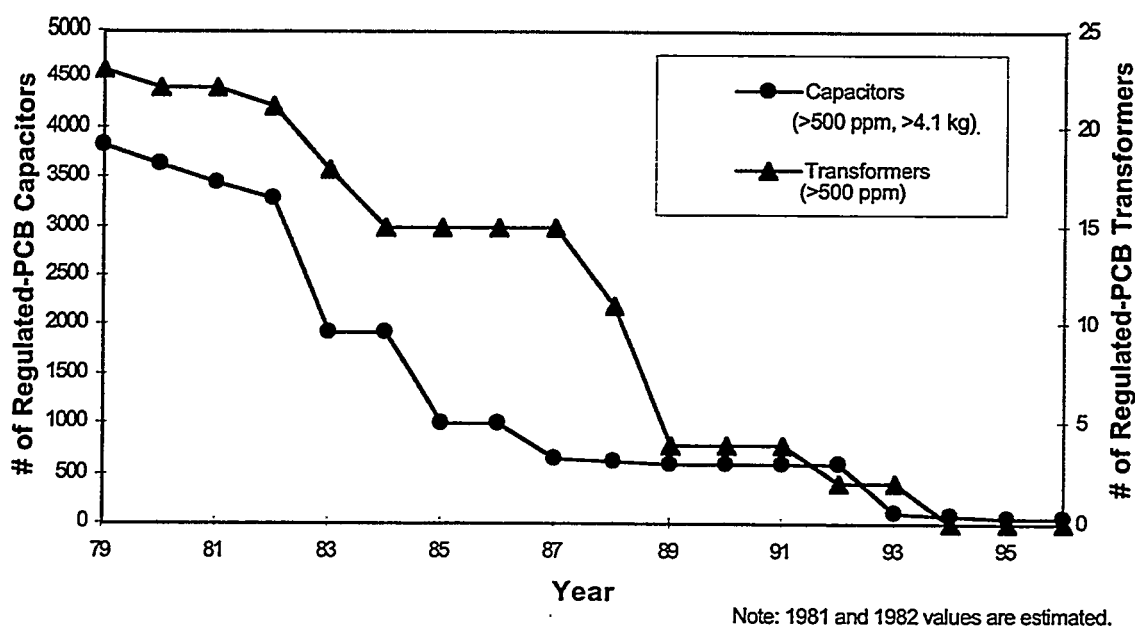


Figure 3-2. Trends in Onsite Inventory of Regulated-PCB Capacitors and Transformers

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are located separate from 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. DTSC requests renewal of this permit each year in March or April. The Laboratory submitted the 1996 renewal package for five of the six FTUs to DTSC, the City of Berkeley, the City of Oakland, Alameda County, and EBMUD.

The sixth FTU under this permit (FTU 006) first received authorization from DTSC to begin operations in May, after the Laboratory submitted a permit amendment in April to reflect operation upgrades at Building 77. FTU 006 includes a 227-liter per minute (60-gallon per minute) treatment unit capable of treating acidic rinse water containing metals and alkaline rinse water generated by the Ultra High Vacuum Cleaning Facility in Building 77. FTU 001, previously serving the UHVCF, remains operational although in a backup role.

In 1996, DTSC was the regulatory agency authorized to perform inspections of both the HWHF and the fixed treatment units. DTSC did not inspect the fixed treatment units in 1996. However, it did conduct a limited-scope inspection at the HWHF in April. DTSC did not have any findings or observations from this sole inspection.

Waste management permits and regulations require several reports during the year. Berkeley Lab updated the contingency plan at the Building 75 complex as called for in the facility's operating permit. It also prepared the *Annual Hazardous Waste Report for 1995*²⁷ for DTSC, with a copy to the RWQCB. It contains specific generator and transport information for all activities at the Hazardous Waste Handling Facility during the reporting year. Also, quarterly reports on the Laboratory's mixed waste inventory were provided to DTSC,

again with a copy to the RWQCB. Berkeley Lab also prepared the *Annual Waste Reduction Report*²⁸ for DOE, covering the previous calendar year. It contains a detailed analysis of waste minimization efforts made by waste generators.

In late 1995, DTSC approved the Laboratory's *Mixed Waste Site Treatment Plan* (STP).²⁹ The STP documents the procedures and conditions used by Berkeley Lab to manage its mixed waste streams. These reports identify the quantity of new mixed waste generated by waste stream, as well as the quantity of waste treated, reclassified, or shipped offsite. The Laboratory submitted several requests during 1996 to modify the STP to address anticipated changes in operations. The requests include adding new waste streams for both solid and particulate material, deleting several waste streams dealing with gases, and adding an option to treat several waste streams from the National Tritium Labeling Facility (NTLF) with a catalytic oxidation unit, as well as adding several EPA codes.

One incident initiated special reporting under the DOE's occurrence reporting program. Using process flow methods, Berkeley Lab determined that two waste streams from the NTLF characterized as radioactive-only should have been characterized as mixed waste (i.e., waste that contains both hazardous and radioactive components). Berkeley Lab determined that its previous characterization affected three shipments of NTLF waste sent to the Westinghouse Hanford Company's disposal site in Hanford, Washington. The shipments were in 1989, 1990, and 1995, and represented less than one percent by volume of the total waste shipped. An estimated 13 liters (3.4 gallons) of organic solvents were included in the three shipments.

The findings prompted a continuation of the suspension of waste shipments to the Hanford

site until Westinghouse Hanford Company, DOE, and the Washington state Department of Ecology were all satisfied that Berkeley Lab had adequately updated its waste management policies to properly characterize its waste. Berkeley Lab was given approval to resume shipments to the Hanford site in the first quarter of 1997.

Table 3-7 shows the total radioactivity contained in radioactive and mixed waste generated by Berkeley Lab activities in 1996, as well as the total inventory of these wastes in storage at the HWHF at the end of the year. The total volume of hazardous waste from routine and nonroutine activities generated during the year and in storage at the end of the year is also presented in the table. About 35% of the hazardous waste came from routine activities.

During 1996, the HWHF shipped the following amounts of waste for offsite disposal:

- almost 125 metric tons (137 tons) of total hazardous waste
- 0.7 metric tons (0.8 tons) of mixed waste.

No radioactive waste was shipped while the waste characterization issues with the Westinghouse Hanford Company were being resolved.

RCRA Corrective Actions Program — Site Environmental Restoration

The environmental restoration program at Berkeley Lab is conducted under the RCRA Corrective Action Process and is intended to satisfy three criteria:

- Identify areas of contamination that may have resulted from past releases of contaminants to the environment.
- Determine the sources and extent of contamination.
- Develop and implement plans to remediate contaminated areas.

The *RCRA Facility Investigation Work Plan*,³⁰ which details environmental investigations necessary to characterize the site, was submitted to DTSC in October 1992. Berkeley Lab submits *RFI Work Plan Addenda* prior to initiation of specific site activities. The Laboratory submitted eight such addenda to regulators (i.e., Department of Toxic Substances Control, Regional Water Quality Control Board, and the City of Berkeley) in 1996. Two applications for well construction in addition to the associated addenda were submitted to the City of Berkeley. Four quarterly progress reports³¹ were submitted to DTSC in accordance with RCRA Part B Permit requirements. The quar-

Table 3-6. LBNL's Fixed Treatment Units Subject to Tiered Permitting During 1996

FTU	Building	Description of Treatment	Permit Tier
001	77	Metals precipitate and acid neutralization	Permit-by-Rule
002	25	Metals precipitate 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 precipitate and acid neutralization	Permit-by-Rule

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terly 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 with stakeholders where the status of performed and planned activities is discussed. The program also holds technical working group 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. In addition, Berkeley Lab provided updates on program activities at a City of Berkeley Community Environmental Advisory Commission meeting held in early April, and participated in a public workshop on environment, health, and safety activities later that same month.

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 Act³² 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, since it generates more than 91 kilograms (200 pounds) of medical waste each month. The Laboratory completed its annual renewal of its registra-

Table 3-7. Radioactive and Mixed Waste Generated in 1996 and in HWHF Inventory

	Radioactive Waste		Mixed Waste		Hazardous Waste	
	Generated	Inventory	Generated	Inventory	Generated	Inventory
All Waste						
Activity Level						
Bequerels ^a	6.629 x 10 ¹³	2.386 x 10 ¹⁴	7.377 x 10 ¹³	7.111 x 10 ¹³	N/A	N/A
Curies	1,790	6,440	1,990	1,920	N/A	N/A
Volume						
Liters ^b	5,330	82,560	465	5,150	124,450	5,040
Gallons	1,048	21,810	123	1,361	32,880	1,331
Tritium						
Activity Level					N/A	N/A
Bequerels	6.629 x 10 ¹³	2.385 x 10 ¹⁴	7.377 x 10 ¹³	7.111 x 10 ¹³	N/A	N/A
Curies	1,789	6,339	1,990	1,920		

^a1 Becquerel (Bq) = 2.7 x 10⁻¹¹ Curies

^b1 liter = 0.2642 gallons

tion in November. There were no audits or inspections of the program by DHS in 1996.

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 1996, Berkeley Lab shipped about 18,714 kilograms (41,257 pounds) of medical waste off site for treatment either through incineration or steam sterilization. The majority of the waste was treated via steam sterilization prior to disposal at a landfill. About 5% of the waste total underwent incineration.

Underground Storage Tanks

In the early 1980s, California first began addressing the serious threat to groundwater contamination from underground storage tanks (USTs) by establishing a rigorous regulatory and remediation program.³³ The state requirements for USTs containing hazardous materials include permitting, construction design, monitoring, recordkeeping, inspection, accidental releases, financial responsibility, and tank closure. The state program underwent modifications after US/EPA adopted federal regulations for USTs in late 1988 under the provisions of RCRA.³⁴ These modifications were needed for the state program to obtain federal approval. The City of Berkeley is the local administering agency for UST regulations applicable to the Laboratory.

At the beginning of 1996, there were 11 USTs on site (see Table 3-8). The tanks contain diesel fuel, gasoline, or transformer oil. Ten of these tanks were already permitted by the City of Berkeley. The eleventh UST, located at the new HWHF site (Building 85), was granted a permit from the City during the year to store

diesel fuel for an emergency generator.

Of the eleven permitted tanks, eight are double-walled and meet the pending December 1998 regulatory standards for construction, monitoring, leak containment, and design of operating tanks. Two of the remaining three single-walled tanks were removed in 1996, leaving only the diesel tank at Building 70A subject to upgrade or removal to meet the new standards. Berkeley Lab expects to remove this tank prior to the deadline and replace it with an aboveground storage tank. The City conducted inspections during each tank removal. The City also inspected the new HWHF tank in July to witness precision testing. There were no findings from any of these inspections.

Pollution Prevention and Waste Minimization

Executive Order 12873, "Federal Acquisition, Recycling, and Waste Prevention"

A key objective of this Executive Order³⁵ is to integrate recycled materials into the procurement and acquisition process. The categories of products identified by the order included:

- paper and paper products
- vehicular products
- construction products
- transportation products
- park and recreation products
- landscaping products
- non-paper 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 will be allowed under the order.

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Instead, agencies must compensate for price increases by reducing paper use and waste.

Hazardous Waste Source Reduction and Management Review Act

The California State Legislature passed the Hazardous Waste Source Reduction and Management Review Act³⁶ in 1989 (SB14). The main emphasis of SB14 is on waste minimization and pollution prevention. In particular, the goals of SB14 are as follows:

- reduce hazardous waste at its source
- encourage recycling wherever source reduction is not feasible or practicable
- treat hazardous waste in an environmentally safe manner to minimize the present and future threat to health and the environ-

ment where it is not feasible to reduce or recycle

- 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 SB14 compliance: (1) *Source Reduction Evaluation Review Plan and Plan Summary*,³⁷ and (2) *Hazardous Waste Management Report Summary*.³⁸ The report was not scheduled for updating in 1996.

Pollution Prevention Act of 1990

The Pollution Prevention Act³⁹ 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

Table 3-8. Underground Storage Tank Operating Permits from City of Berkeley for 1996

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
Single-walled tanks					
6	70	Diesel	2,300 (600)	Steel	1953 ^a
7	70A	Diesel	3,800 (1,000)	Fiberglass	1975
11	58	Transformer oil	7,600 (2,000)	Steel	1978 ^a

^a removed in 1996

pollution remain below the *de minimis* numbers identified in the Act and are not subject to its reporting requirements.

Water Quality

Clean Water Act

The purpose of the Clean Water Act (CWA)⁴⁰ is to control 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.

Furthermore, the Porter-Cologne Water Quality Control Act⁴¹ established a comprehensive statewide system for regulating water use in California. This 1969 act provides for the three-tiered system that is in use in California 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 City of Berkeley for its stormwater ordinance, and the East Bay Municipal Utility District (EBMUD) for water supply and wastewater. The regulatory programs for stormwater and wastewater discharges are independent of one another. Each program, however, integrates federal requirements with state regulations, plus any plans promulgated by the SWRCB.

EBMUD issued wastewater discharge permits⁴² for four Laboratory activities in 1996:

- 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
- sitewide discharge of treated groundwater from hydraugers and wells.

Berkeley Lab has held the first three permits for a number of years. EBMUD first issued the last permit in September. Permits are renewed annually. The permits incorporate standard terms and conditions, as well as individual discharge limits, provisions, and monitoring and reporting requirements.

EBMUD occasionally inspects the Laboratory's sanitary sewer discharge activities without prior notice. Included in Table 3-2 are such inspection dates in 1996. Neither any of these EBMUD inspections nor any of the self-monitoring required in the individual discharge permits resulted in any concerns on the part of EBMUD. In fact, there were no violations issued to the wastewater discharge program in 1996. The results of the Laboratory's self-monitoring program for 1996 are presented and discussed in Chapter 7, *Sanitary Sewer*.

The wastewater discharge permits for Buildings 25 and 77 require that the Laboratory maintain a relevant 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 TOMPs for both Buildings 25 and 77 were last updated in 1995.⁴³

Also under the terms of its wastewater discharge permits, Berkeley Lab must maintain an *Accidental Spill Prevention and Containment Plan* for areas where spills have the greatest potential to occur. EBMUD leaves selection of such sites to the discretion of the permit

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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.⁴⁴ EBMUD does not require that these documents be submitted, but that they are on file in the relevant areas and the emergency information given is also posted.

Until the fourth permit from EBMUD was issued, treated groundwater discharge activities were regulated under the sitewide wastewater discharge permit. Under a requirement of that permit, in June, Berkeley Lab submitted a report on these activities during the past permit year.

Berkeley Lab's stormwater releases are permitted under the California-wide *General Permit for Stormwater Discharges Associated With Industrial Activity*.⁴⁵ The general permit is issued by the State Water Resources Control Board but is administered and enforced by the Regional Water Quality Control Board. Under the permit, the Laboratory has implemented a *Stormwater Pollution Prevention Plan*⁴⁶ and a *Stormwater Monitoring Program*.⁴⁷ Together, these documents represent the Laboratory's plan and procedures for identifying, monitoring, and reducing pollutants in its stormwater discharges.

The general permit requires submission of an annual report on stormwater activities by July 1. Berkeley Lab transmitted its annual report to the Regional Water Quality Control Board and the City of Berkeley. Detailed discussion of stormwater results for 1996 are found in Chapter 5, *Surface Water*.

The City of Berkeley performs stormwater inspections of the Berkeley Lab. No inspections of this program took place in 1996. However, two incidents during the year initiated city notification.

The first incident occurred in late January at the construction site of the new Human Genome Laboratory near Building 74. A contractor set up a sump pump to drain a trench of runoff rainwater following a series of heavy seasonal storms. The hose from the sump drained to a nearby storm drain. The contractor was unaware that the trench was within 6 meters (20 feet) of the site of an underground storage tank that had been removed in 1994. Laboratory staff overseeing the efforts of the construction project detected traces of volatile organic compounds in the air at the outlet of the hose. Actions taken by Berkeley Lab included:

- immediate cessation of this discharge
- notification of the City of Berkeley
- containment of potentially contaminated water in special vessels until results from sampling could be evaluated and a course of action could be determined
- improvement of administrative controls, both internally and with contractors, to prevent recurrences of similar incidents.

Later, laboratory results of the sample indicated a diesel concentration of 51 micrograms per liter, a level that posed no hazard to personnel or the surrounding environment. Prior to initial detection, an estimated 5110 liters (1350 gallons) of diesel-contaminated rainwater had been pumped into the storm drain. After sampling determined that the water was within discharge limits, the contained water was pumped to the sanitary sewer.

The second incident occurred in December when a fire alarm at the new Hazardous Waste Handling Facility malfunctioned, resulting in a continuous release of the aqueous fire suppression foam in the system. The suppressant was not considered toxic, consisting of more than 80% water and containing no ingredients on regulatory emergency reporting lists. Be-

cause the incident happened during the holiday break and prior to the alarm being connected to the lab-wide communication system, the incident went undetected until after the fire suppression foam entered Strawberry Creek. There was no waste stored in the facility, since the building was still undergoing final construction activities at the time of the incident. The City of Berkeley responded to investigate the incident. Berkeley Lab received a citation for a violation of the Clean Water Act and a bill for the time of City employees involved.

Aboveground storage tanks (ASTs) also fall under the authority of the Clean Water Act.⁴⁸ The Clean Water Act and the state's Aboveground Petroleum Storage Act⁴⁹ outline the regulatory requirements for these tanks. The Laboratory submitted its annual storage statement for aboveground petroleum storage tanks to SWRCB in June. 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 that will capture any potential spills. There were no ASTs identified in 1996 that needed new or upgraded secondary containment.

Safe Drinking Water Act

The Safe Drinking Water Act⁵⁰ established requirements for the protection of underground sources of drinking water and sets primary drinking water standards for public water systems. Berkeley Lab has no drinking water wells on site. The drinking water provided to the site comes from EBMUD's supply and distri-

bution 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.

Updates on Nonregulatory, Multiprogram Reviews

Work Smart Standards

DOE and various National Laboratories began field testing a "necessary and sufficient" program in 1994. Based on this pilot test, DOE extended this program to a laboratory-wide level in 1996.⁵¹ Berkeley Lab was selected as the first multi-program laboratory within the DOE system to participate in this program, now called Work Smart Standards, at the laboratory-wide level. The goals of the Work Smart Standards program include:

- enhancing public and worker safety
- building public trust and confidence
- developing reference points for measuring excellence
- providing for easier and more effective planning and implementation of work practices
- improving efficiency.

Berkeley Lab established a set of Work Smart Standards⁵² that includes federal, state, and local laws and, additionally, national and international standards that represent the highest operating standards of industrial and commercial institutions for environment, health, and safety. The set of standards is tailored to the work performed and the hazards associated with this work, yet sufficient to ensure appropriate compliance. The set of standards was approved by Berkeley Lab and DOE's Oakland Operations Office in November, and became effective immediately upon signing.

3-Environmental Program Summary

DOE ES&H Oversight Appraisal

In October, the Oakland Operations Office of DOE conducted its annual evaluation of the performance of Berkeley Lab's ES&H management systems. The scope of the appraisal included the following three laboratory programs:

- sealed sources
- seismic safety
- waste characterization;

and the following seven laboratory systems:

- calibration and traceability of equipment
- employee concerns
- fire protection
- lessons learned
- procedures
- self-assessment
- training.

DOE limited the review to three divisions: Energy and Environment; Environment, Health, and Safety; and Nuclear Science.

Overall, DOE concluded that Berkeley Lab has effectively established and implemented its EH&S programs and systems. DOE identified minor opportunities for improvement in both programs and systems, but acknowledged that these were not indications of missing programs or systems. Additional details on the appraisal can be found in the DOE report.⁵³

Summary of Program Performance — UC/DOE Contract 98 Performance Measures

The present five-year operating contract for Berkeley Lab between the University of California and the Department of Energy requires performance-objective criteria and measures in

many areas of management, including environmental compliance. All performance objectives are developed by representatives of the University's Office of the President, Berkeley Lab, and DOE.

In 1996, there were six measures evaluated for environmental protection management. Results for each measure are discussed below.

Radiation Protection of the Public

This measure provides an incentive to reduce the radiological dose to the public and the environment from all Berkeley Lab activities to levels that are as low as reasonably achievable. The current control level for the site is 0.03 mSv (3 mrem) per year. The adequacy of this control level is reviewed annually by Berkeley Lab, UCOP, and DOE. The most recent annual review left this value unchanged.

Methods used to minimize radiological impacts to the public and environment include engineering controls (e.g., absorber and filter installations in fume hoods and glove boxes), administrative controls (e.g., radiation work permits, beamline schedules), and inventory controls (e.g., limit on annual possession quantity of radioisotopes, central control of radioisotope ordering and purchasing). Success in achieving this goal is verified through environmental monitoring and sampling results.

During 1996, the dose that a maximally exposed individual could receive from Laboratory operations was determined to be 0.019 mSv (1.9 mrem). For the Laboratory, this value represents an upper bound dose to the public, because this maximum dose is calculated at the site boundary, rather than in the surrounding residential or workplace areas, and the dose assumes full-time occupancy at the location. This dose level is below the established Berkeley Lab control level and about 1.9% of the

allowable DOE limit (1 mSv or 100 mrem).⁵⁴ The comparable value reported in 1995 was 0.021 mSv (2.1 mrem). Figure 3-3 shows the cumulative public dose for 1996 at the location of the maximally exposed individual. The figure also indicates both the DOE reporting limit and Berkeley Lab's control level. For 1996, the Laboratory has met all the success gradients for an *Exceeds Expectations* rating.

Waste Reduction and Recycling

This measure provides an incentive for the Lab to reduce waste generation from routine operations, and consequently reduce costs and minimize environmental impacts. The Laboratory has targeted principal waste streams for waste reduction. These streams are:

- nonhazardous or sanitary waste
- hazardous waste
- low-level mixed waste (waste that contains both RCRA hazardous and radioactive components)

- low-level radioactive waste.

The overall goal of the measure is to reduce the last three waste streams by 50% and the first waste streams 33% by the year 2000, using 1993 as the baseline year for comparison. Each of the four waste stream categories is tracked separately. The charts that summarize the status of each of these four waste streams are presented in Figures 3-4 through 3-7.

To achieve the results depicted in the charts, Berkeley Lab has aggressive source reduction, reuse, and recycling programs for all major types of waste generated at the facility. Berkeley Lab reviews all major waste streams annually with these factors in mind.

In the category of sanitary waste, typically more than 80% of Berkeley Lab's paper waste is recycled. Also, the Laboratory's vegetative waste program recycles all of its green waste for on-site use.

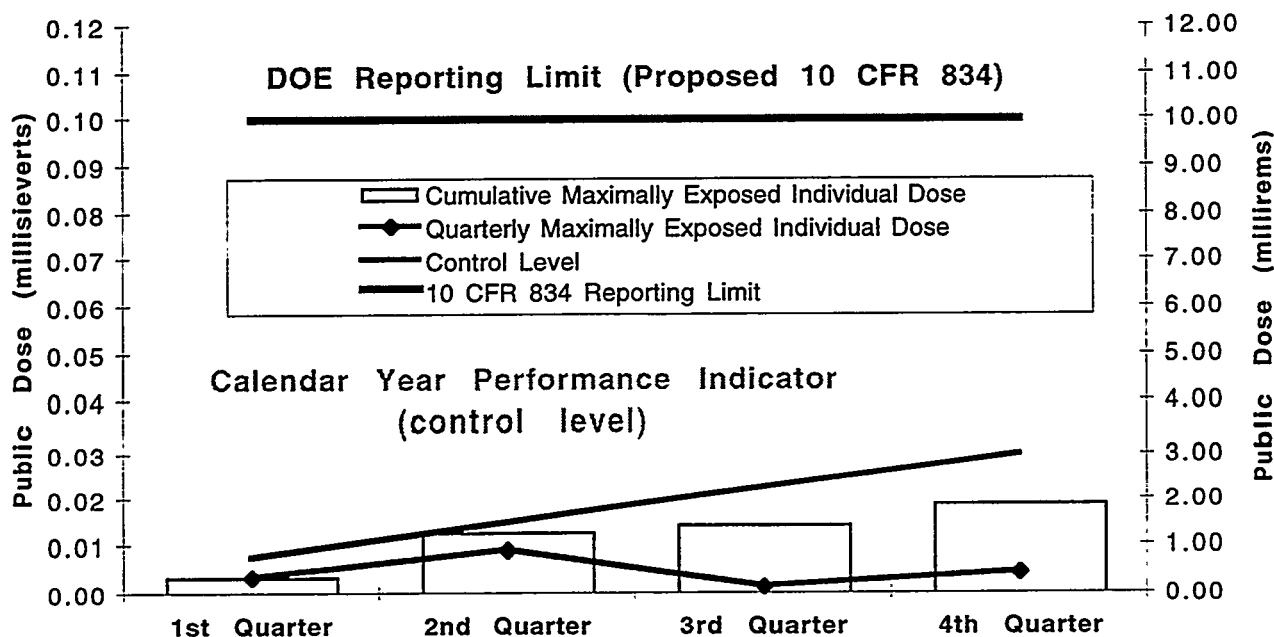


Figure 3-3. Cumulative Public Dose for 1996 at Maximally Exposed Individual Location

3-Environmental Program Summary

Proactive efforts surrounding reuse of hazardous substances include listing hazardous chemicals on the Berkeley Lab chemical exchange database for reuse, and reusing, treating, or recycling other large hazardous waste streams either on site or offsite whenever practicable.

Similarly, in the area of low-level and low-level mixed waste, noteworthy source reduction, reuse, or recycling highlights of the program include the following:

- Several thousand metric tons of concrete shielding blocks were shipped to Brookhaven National Laboratory for reuse. This project was recognized by DOE and received a special award.
- Researchers at the Building 88 accelerator recycled organic solvents through their research apparatus, reducing the amount of

activated solvents by several hundred liters.

- Several metric tons of lead glass were recycled into glass art.
- 88% of the volume of coolants from Building 77 were reduced on site, with the remaining 12% recycled off site.

The Laboratory has met all the success gradients for a *Far Exceeds Expectations* assessment for this measure.

Source Reduction and Pollution Prevention

This measure provides an opportunity for the Laboratory to showcase the many projects that it funds whose objective is to reduce waste generation and environmental pollution. Waste reduction and pollution prevention opportunities at Berkeley Lab are prioritized using a risk-

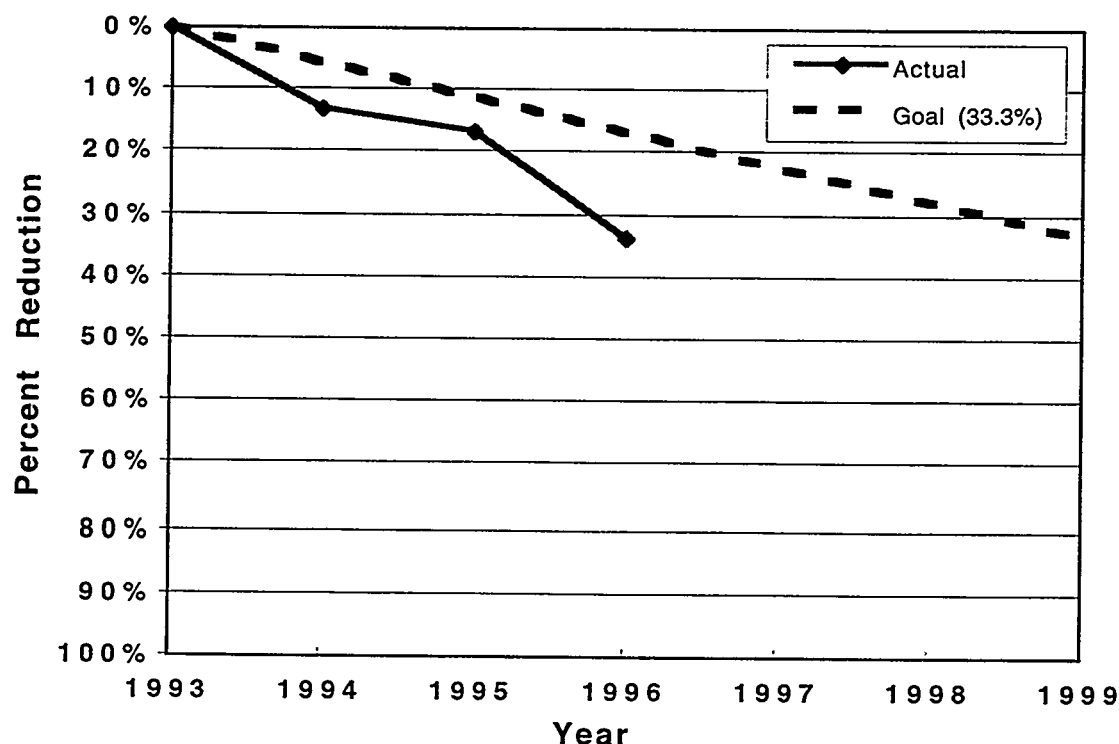


Figure 3-4. Trends in Reducing Routine Nonhazardous or Sanitary Waste

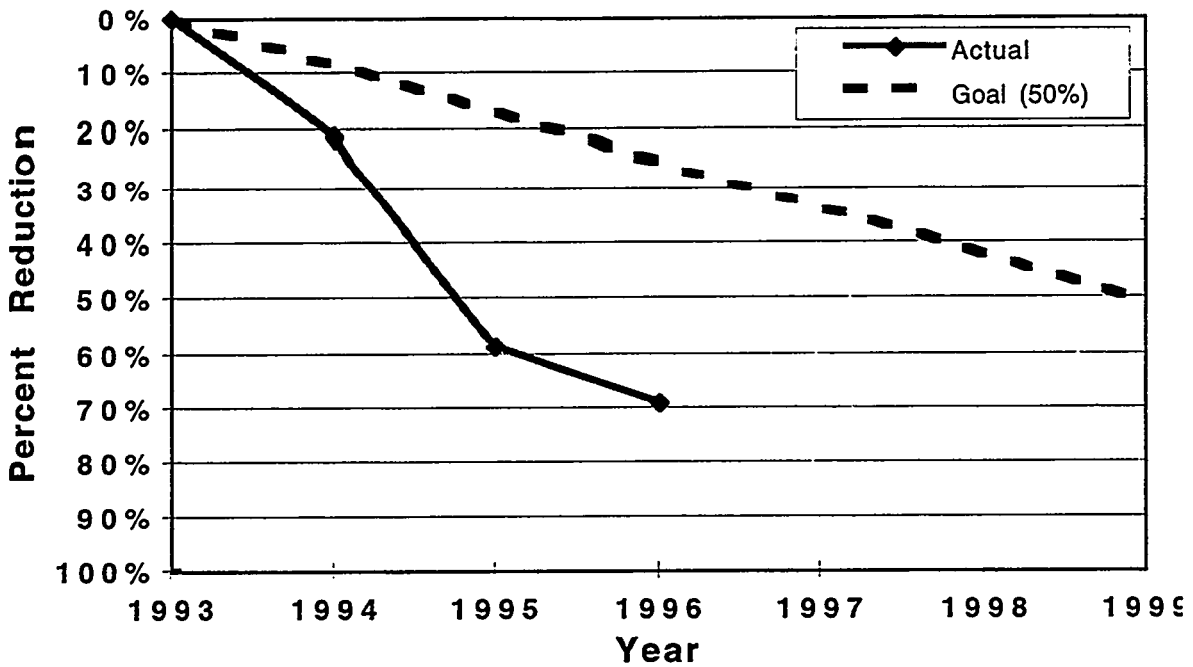


Figure 3-5. Trends in Reducing Routine Hazardous Waste

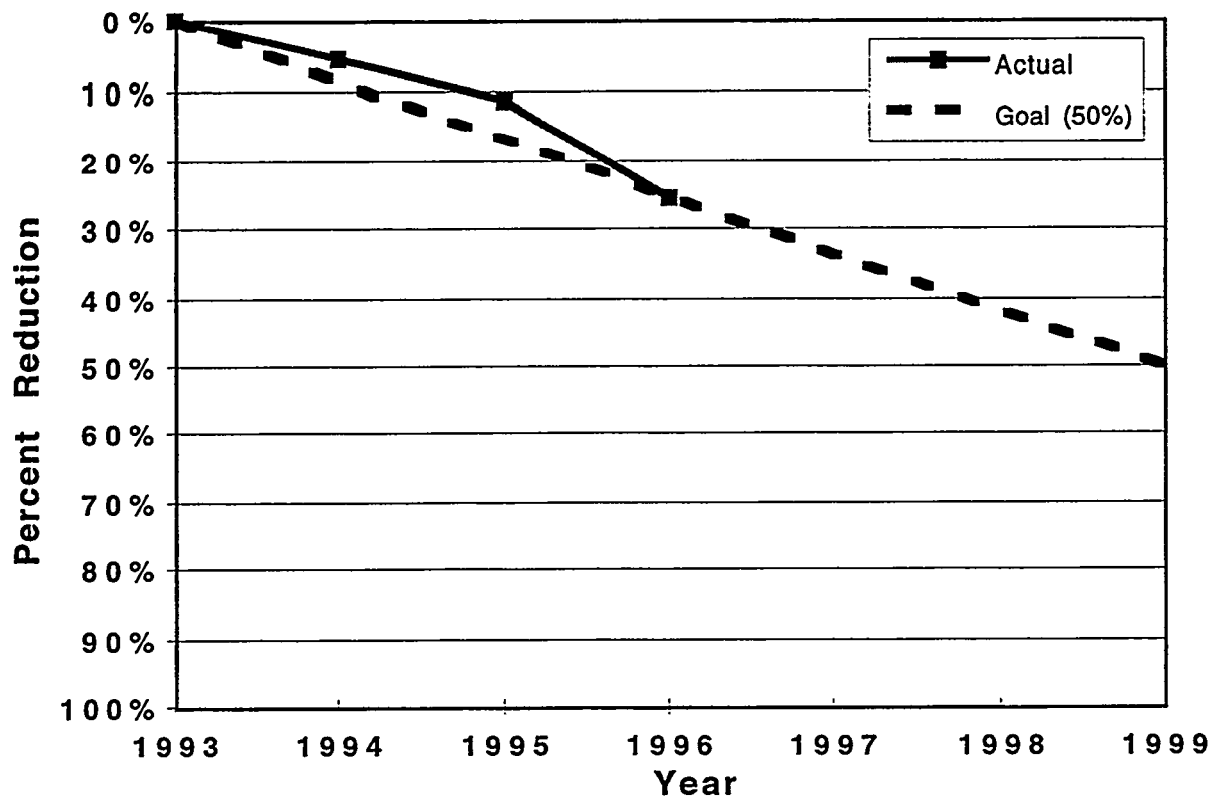


Figure 3-6. Trends in Reducing Routine Low-Level Radioactive Waste

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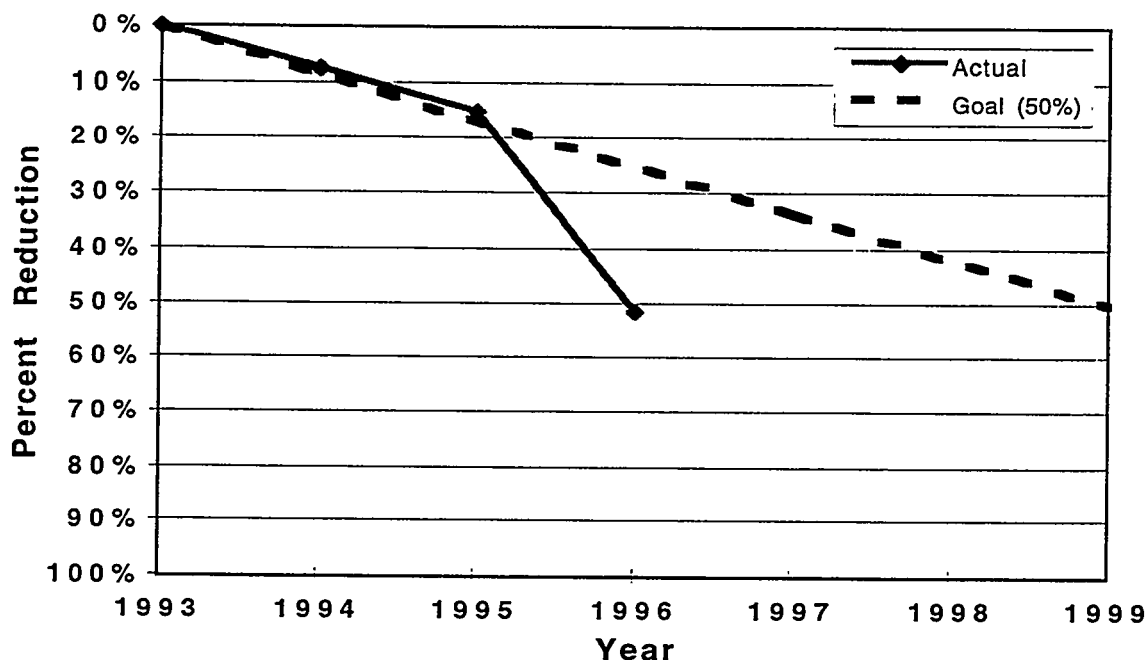


Figure 3-7. Trends in Reducing Routine Mixed Waste

based prioritization model described in the institution's five-year plan. Several of the newer projects added to the list include the following. See Table 3-9 for a more complete list.

Luminometer in Building 83: The purchase and use of a luminometer resulted in a 98% decrease in the generation of tritiated low-level radioactive and mixed waste from research experiments. This project resulted in a national "Zero Generation" award from DOE.

Compressed Natural Gas Station at Building 76: Preliminary construction work was completed for a compressed natural gas station. A request for the remainder of the funding needed to make the station operational has been made.

Sanitary Sewer Upgrade: The goal of the sanitary sewer upgrade project is to repair leaks

and broken sections revealed during an inline survey. This project will contribute to the site's commitment to eliminate releases to surface and subsurface waters as part of the Storm Water Pollution Prevention Plan.

Berkeley Lab has met all success gradients for an *Exceeds Expectations* rating in the Source Reduction and Pollution Prevention measure.

Tracking and Trending of Findings and Violations

The goal of this performance measure is a downward trend in findings and violations. It does not have a target or control level below which annual findings and violations are considered negligible. The basis for evaluating this measure in 1996 was the 58 regulatory inspections and permit-required self-monitoring samples. Each source reviewed was treated as a separate inspection when referencing the list

Table 3-9. Process Waste Minimization Milestones for 1996 and 1997

Proposed Project	Milestone	Actual completion date
Complete installation of Building 77 alternative cleaning system.	10/1/96	5/1/97
Remove Building 70 UST and replace with compliant system.	6/30/96	6/22/96
Remove Building 58 UST and replace with compliant system.	9/30/96	9/16/96
Complete purchase of vapor/degreaser replacement.	10/30/96	10/1/96
Replacement of Building 50B Class I Ozone-Depleting Substance (ODS) chiller	6/1/96	6/1/96
Replacement of electron microscope ODS operating fluid	10/1/96	6/30/96
Purchase and install Luminometer in Building 83	11/1/96	11/1/96
Perform preliminary construction, Building 76 Compressed Natural Gas Station	12/31/96	12/31/96
Perform sanitary sewer upgrades:		
— issue notice to proceed	10/96	10/96
— complete construction	11/97	On schedule

of inspections in Table 3-2. For example, BAAQMD visited the site one day, but inspected 21 permitted sources.

The assessment for this measure is based on the ratio of findings or violations per inspection for the year compared to the average number of findings and violations per inspection over the prior three years. In this case, that means comparing 1996 results with the average results from 1993 through 1995. 1996 yielded one finding from the 58 inspections, or a ratio of 0.0172 findings per inspection. The average ratio of findings to inspections for the prior three years was 0.793, indicating that the ratio for this metric is still decreasing. Table 3-10 contains detailed data on findings and inspections for the comparison period.

The Laboratory continues to demonstrate that its environmental protection program functions well. Berkeley Lab has achieved all success gradients for an *Exceeds Expectations* rating in this measure for 1996.

Tracking and Trending of Environmental Releases

Similar to the previous measure, a downward trend is sought in the number of reportable occurrences of environmental releases that exceed regulatory or permitted levels. The metric being used with this performance measure is the average of the number of environmental releases over the prior three years. There has been one release over the prior three years, representing an average of 0.33 releases per year.

3-Environmental Program Summary

Table 3-10. Trends in Findings and Violations Since 1993.

Year	Number of Violations ^a	Number of Findings ^b	Total Findings & Violations (F)	Number of Inspections & Audits (I)	Ratio of Findings to Inspections (F/I)
1993	2	96	98	52	1.88
1994	0	22	22	44	0.5
1995	0	0	0	66	0
1996	1	1	1	58	0.0172
Prior three-year ('93, '94, '95) running average F/I					0.793
% improvement F/I (1996 versus prior three-year average)					97.9%

^aViolations include only citations from regulatory agencies for noncompliant activities.

^bFindings are documented observations from regulatory agencies or DOE for suggested improvements in a program.

Findings do not indicate noncompliance.

There was one release in 1996. Although this represents a two-fold increase in the annual release rate, the number of releases is hovering around zero, which indicates that the environmental programs are remaining at or around a sustained level of quality. Berkeley Lab's performance for this measure meets all success gradients for *Meets Expectations*.

Customer Focus

The intent of this measure is to integrate Berkeley Lab's external customer concerns into its decision-making process and communicate its actions back to the customer. External customers in this context include both regulatory agencies and the local community. In previous years, this measure was evaluated by a survey of the regulatory agencies to determine their satisfaction with the Laboratory's environmental programs. No surveys were conducted in 1996, and the need for future surveys was completely eliminated from the performance objective during the recent annual review. In its place, Berkeley Lab will now evaluate how well it responds to the concerns of its external customers. There were two environmental issues that attracted the attention of the external customers.

Local community concern over the release of tritium

The City of Berkeley expressed concern over the release of tritium into the environment. The Laboratory listened to and continues to be highly responsive to all concerned parties by participating in meetings and providing information regarding tritium levels in the environment. In early 1997, Berkeley Lab agreed to provide \$100,000 to support an independent assessment of tritium releases from the NTLF. A Tritium Issues Work Group has been established to oversee and implement the assessment. The work group is co-chaired by US/EPA and DHS, and consists of regulatory agencies, community organizations, DOE, UCB, LLNL, and Berkeley Lab. The assessment will include development of a sampling program, collection of environmental samples, and evaluation of the sample results.

Hazardous Waste Handling Facility Part B Permit Modification Review

A HWHF Part B Permit modification request is under DTSC review. In 1996, some members of the public expressed concerns regarding proposed changes to the waste facility's ca-

capacity for certain waste types and proposed treatment methods to minimize or reduce waste. Berkeley Lab has conducted many public meetings covering a wide range of issues, granted interviews to media representatives, and conducted site tours to showcase safety features that minimize potential environmental impacts.

The Laboratory has demonstrated that it incorporates public concern into its decision-making process and communicates its actions back to concerned communities in a responsive manner. The Laboratory has met all success gradients for a *Far Exceeds Expectations* rating in this measure.

3-Environmental Program Summary

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Chapter 4

Air Quality

Background

Berkeley Lab's current air monitoring program is based on the following set of requirements:

- 40 CFR Part 61, Subpart H (NESHAPs)¹
- DOE Order 5400.1 (General Environmental Protection Program)²
- DOE Order 5400.5 (Radiation Protection of the Public and the Environment).³

NESHAPs and DOE Order 5400.5 mandate monitoring requirements for radiological air emissions, while DOE Order 5400.1 includes additional requirements for nonradiological air emissions. The present air monitoring program at Berkeley Lab needs only to measure radiological components in exhaust emissions and ambient concentrations. Alternatives to monitoring, such as engineering calculations, recordkeeping, and dose/risk modeling, currently satisfy regulatory requirements for estimating nonradiological air emissions.

The Berkeley Lab *Environmental Monitoring Plan*⁴ documents the requirements and design of the air monitoring network as part of this plan's comprehensive assessment of monitoring and surveillance activities at Berkeley Lab. The plan was revised in early 1996.

The air monitoring program consists of two elements: exhaust emissions monitoring and ambient air surveillance. Exhaust emissions monitoring measures the concentration of airborne contaminants in the exhaust stream usually coming from a single source or activity. Ambient air surveillance measures the concentration of air contaminants at surface level near the Berkeley Lab. The purpose of the ambient air monitoring network is to detect and quantify the impacts from Laboratory activities and

to confirm the radiological dose assessment modeling required by NESHAPs and the DOE orders. The number and placement of monitoring stations, as well as the parameters monitored and their frequency, is routinely evaluated to account for changes in Laboratory operations or external requirements.

Exhaust Sampling of Airborne Radionuclides

As a research facility, Berkeley Lab uses various radionuclides in its radiochemical and biomedical research programs. In addition, radioactive materials are a resultant by-product from the operations of the charged-particle accelerators such as the 88-Inch Cyclotron. Table 4-1 includes the names and decay characteristics of the most significant radionuclides used at Berkeley Lab. The annual NESHAPs report, attached as Appendix B, contains 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. These radioactive gases are normally produced in areas where the beam strikes beam-line components. A reference table on radionuclides and their symbols is given in the glossary.

Radionuclide releases from onsite building exhaust systems are usually in the gas or vapor phase. As discussed in the air quality section of the *Environmental Program Summary* (Chapter 2), Berkeley Lab has a comprehensive strategy to assess emissions of radionuclides to the environment. This tiered approach to define the minimum degree of sampling, monitoring, or administrative controls necessary to maintain compliance with the NESHAPs regulations⁵ has been approved by US/EPA, and is presented in Table 4-2.

Table 4-1. Most Significant Radionuclides Used at LNBL During 1996

Nuclide Name (Atomic Number)	Symbol	Principal Radiation Types	Half-Life
Argon (18)	⁴¹ Ar	beta gamma	1.83 hours
Carbon (6)	¹¹ C ¹⁴ C	positron/gamma beta	20.5 minutes 5730 years
Fluorine (9)	¹⁸ F	positron/gamma	109.7 minutes
Hydrogen /Tritium (1)	³ H	beta	12.28 years
Iodine (53)	¹²³ I ¹²⁵ I ¹³¹ I	gamma beta gamma	13.1 days 60.14 days 8.04 days
Nitrogen (7)	¹³ N	positron/gamma	9.97 minutes
Oxygen (8)	¹⁵ O	positron/gamma	122 seconds
Phosphorus (15)	³² P ³³ P	beta beta	14.3 days 25.3 days
Sulfur (16)	³⁵ S	beta	87.44 days

^a Complete list of radionuclides evaluated under NESHAP regulations is found in Appendix B

Table 4-2. Summary of LBNL's US/EPA-approved NESHAPs Compliance Strategy

Compliance Category	Annual Effective Dose Equivalent (millirem/year)	Sampling/Monitoring Strategy
Non-compliant	AEDE ≥ 10.0	Reduce or relocate source term and reevaluate prior to authorization.
I	$10.0 > \text{AEDE} \geq 0.1$	- US/EPA Application to Construct or Modify required, - Continuous sampling with: * <u>telemetry</u> to central computer for half-life less than 100 hours * <u>weekly</u> analysis for half-life greater than 100 hours.
II	$0.1 > \text{AEDE} \geq 0.05$	Continuous sampling with <u>weekly</u> analysis.
III	$0.05 > \text{AEDE} \geq 0.01$	Continuous sampling with <u>monthly</u> analysis.
IV	$0.01 > \text{AEDE} \geq 0.001$	Sampled <u>annually</u> during project activity (continuous two-week sampling run).
V	$0.001 > \text{AEDE}$	Inventory controlled by administrative methods (Radiation Work Authorization/Permit). <u>No monitoring</u> required.

Based on historical emissions activity and using this sampling strategy, Berkeley Lab has identified four release points that qualify for continuous monitoring. For particulate releases, the effluent systems with the greatest potential for release have in-line sampling instrumentation. On the remaining exhausts, radionuclide inventories are strictly controlled and engineering techniques estimate quantities of releases. Many of these exhausts have high efficiency filters, which further reduce the small amount of material released to the environment. A summary of the monitoring program for building exhaust systems is given in Table 4-3.

During 1996, all sources operational during the year were classified as "small sources." In other words, the effective dose equivalent (EDE) from each source is much less than 1.0×10^{-3} mSv/yr (0.1 mrem/yr), the NESHAPs threshold limit for continuous monitoring.⁶ Despite having only small sources, Berkeley Lab still continuously monitored five exhaust points in four different buildings as a safeguard to effectively manage radiological emissions. Estimated dose results from exposure to all

Laboratory releases of radionuclides will be discussed in Chapter 11, *Radiological Dose Assessment*.

Exhaust system monitoring during 1996 ranged from real-time monitoring with continuous readout capability to administrative methods of documenting the emissions from small sources. In between these extremes are methods that collect samples of emissions for analysis by analytical laboratories following US/EPA-approved protocols. The Berkeley Lab program analyzed emission samples for five radiological parameters in 1996: gross alpha, gross beta, carbon-14, iodine-125, and tritium (in both gaseous and vapor forms). Table 4-4 provides an overall summary of the type of parameter and number of sampling locations for each parameter in the air quality sampling program.

Consistent with past years, tritium in the form of tritiated water vapor was the predominant radionuclide emitted from Berkeley Lab activities in 1996. Table 4-5 provides the list of the most significant radionuclide emissions from site activities for the year. Tritium emissions

Table 4-3. LBNL NESHAPs Sampling and Monitoring Profile for 1996

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 , ^{15}O	Bldg. 88 accelerator exhaust
	Real-time monitoring of ^{11}C , ^{13}N , ^{15}O , ^{18}F	Bldg. 56 Biomedical Isotope Facility accelerator exhaust (2 locations)
	Real-time monitoring of particulates and iodine	Bldg. 75 mixed and radioactive waste handling area
Continuous	Sampling with weekly analysis	4 locations
	Sampling with monthly analysis	19 locations
No monitoring	Inventory (administrative) control	101 locations

Table 4-4. Number of Routine Radiological Monitoring Locations

Parameter	Number of Locations
Alpha	22
Beta	22
Carbon-14	6
Iodine-125	10
Tritium (in form of HTO)	9
Tritium (in form of HT)	1

totaling 1.87×10^{11} Bq (5 Ci) were measured during the year, with nearly all emitted from the National Tritium Labeling Facility's exhaust stack. Tritium emissions from this facility decreased significantly from 1995's total of 1.96×10^{12} Bq (53 Ci), due to the combined factors

of further improvements in process control technology at the NTLF and an extended period of down time.

Since 1988, the NTLF has consistently reduced its tritium emissions from both planned and un-

Table 4-5. Summary of Radiological Air Emissions Released During 1996

Nuclide	Total Air Effluent		
	[Ci/yr] ^a	[Bq/yr]	% of Total Effluer
H-3	5.05×10^0	1.87×10^{11}	61.2%
F-18	1.60×10^0	5.92×10^{10}	19.4
C-11	1.50×10^0	5.55×10^{10}	18.2
N-13	8.40×10^{-2}	3.11×10^9	1.02
I-123	1.00×10^{-2}	3.70×10^8	0.12
O-15	6.00×10^{-3}	2.22×10^8	0.07
I-125	3.29×10^{-4}	1.22×10^7	0.004
C-14	2.44×10^{-4}	9.03×10^6	0.003
I-131	6.00×10^{-5}	2.22×10^6	0.001
Sr-90	1.12×10^{-5}	4.15×10^5	0.0001
P-32	4.83×10^{-6}	1.79×10^5	0.0001
All Others ^b	2.89×10^{-6}	1.07×10^5	0.000
TOTAL:	8.25×10^0	3.05×10^{11}	100.0

^a 1 Ci = 3.7×10^{10} Bq

^b A complete list of radiological air emissions is found in Appendix B.

planned release through a series of modifications. This program has resulted in a very notable decrease from a maximum of 2.13×10^{13} Bq (575 Ci) in 1988 to 1.87×10^{11} Bq (5 Ci) in 1996 (see Figure 4-1). The NTLF has not had a significant unplanned release in more than three years due to improved engineering of the emissions control system, revised procedural operations, and the installation of an alarm system that is monitored during off-hours by the Berkeley Lab Fire Department. A significant unplanned release is defined as one greater than 9.26×10^{11} Bq (25 Ci).

Ambient Air Monitoring

Tritium

Berkeley Lab operated four monitoring sites in 1996 to evaluate the environmental impact of tritium releases. The stations are intended to detect tritium releases, measure ambient concentrations, and identify trends. Two of the locations were on site and two were off site, as

seen in Figure 4-2. The sites were strategically chosen based on known emission sources, local wind patterns, and sensitive receptor locations. Monitoring equipment at each site samples continuously and at a constant rate. The sampling media are replaced and analyzed monthly.

The minimum detection limit for tritium and all other radionuclides is based on the sample counting time, counter background rates, and counter detection efficiency. The analytical methodology used during the year resulted in detection limits for atmospheric tritium ranging from 0.3 to 1.7 Bq/m³ (8 to 46 pCi/m³).

Table 4-6 summarizes atmospheric tritium concentrations measured by the network of stations for 1996. Average concentration values are all well less than 1% of the allowable DOE annual exposure standard for tritium in air.⁷ Similar results are found when comparing maximum monitored levels against this standard. The 1996 monitoring network results were significantly less than those collected the previous

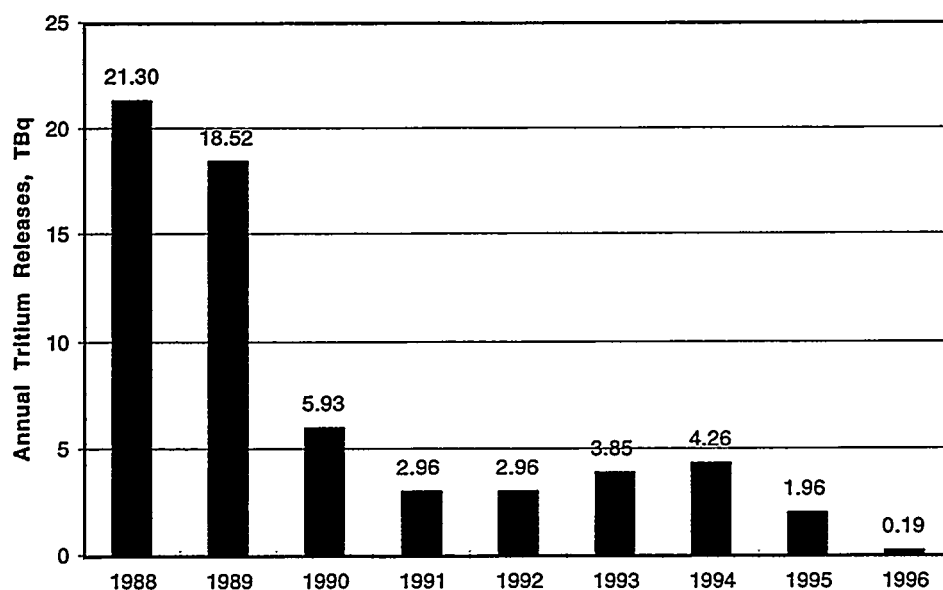


Figure 4-1. Summary of Annual Tritium Releases from NTLF; 1988-1996

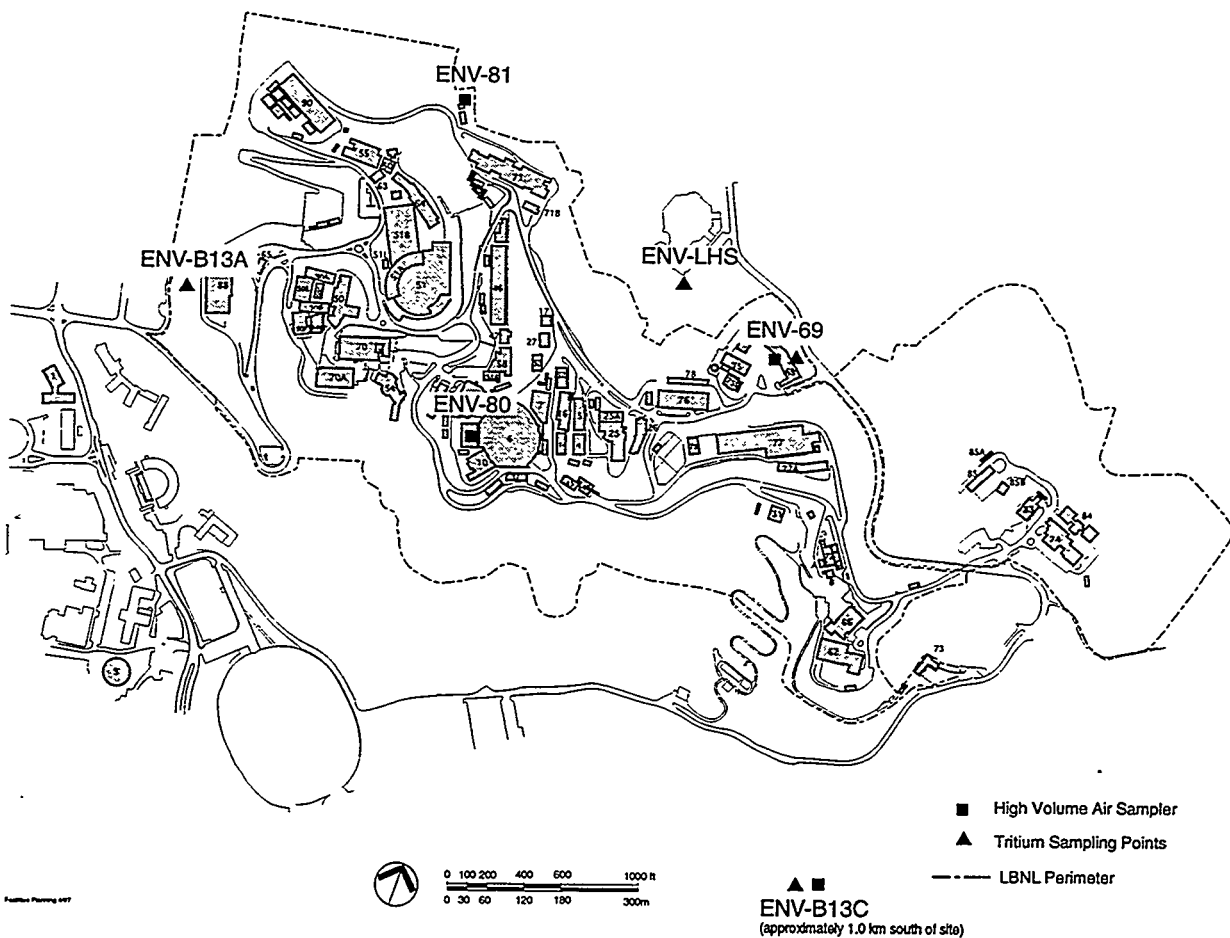


Figure 4-2. Ambient Air Monitoring Network for Tritium and Particulate Matter

year at the same locations. Average and maximum results were less than 10% of those from 1995. The 1996 ambient air results are consistent with the considerable reduction in emissions of tritium from the NTLF.

Gross Alpha/Beta

In addition to exhaust system sampling for gross alpha and gross beta discussed earlier in this chapter, the Laboratory has a network of ambient air sampling stations designed to detect these parameters in particulate emissions and assess their potential environmental impact. The network in 1996 consisted of four monitoring sites; 3 sites are on the main grounds of the Laboratory, and the fourth site is off site at the monitoring program's back-

ground station, ENV-B13C. These are shown as high-volume air samplers in Figure 4-2.

These samplers draw air past sampling media at a constant rate. As with tritium sampling, sampling media are replaced monthly, with collected samples analyzed by certified laboratories.

Gross alpha and beta concentrations from the particulate air samples are presented in Table 4-7. DOE Order 5400.5 does not list any standards for comparing the general classifications of alpha and beta particles.⁸ Nevertheless, there are several significant observations about these results. First, they are extremely low, approaching the analytical detection limits for each parameter. Second, there is little variability from

Table 4-6. Summary of Tritium Concentrations from Ambient Monitoring Network

Station ID	Number of Samples	Average (Bq/m ³) ^a	Average as Percent of Standard ^b	Maximum (Bq/m ³)
ENV-B13A	10	<1.7 ^c	—	2.6
ENV-B13C	10	<3 ^c	—	<3 ^d
ENV-69 ^e	11	5.5	0.15	26
ENV-LHS	10	<1.7 ^c	—	2.6

^a 1 Bq = 27 pCi^b Standard of comparison = 3.7×10^3 Bq/m³ (source: DOE Order 5400.5)^c Average was below the maximum MDA for this site^d Maximum was below the maximum MDA for this site^e For comparing with historical data, name changed from ENV-69A to ENV-69 on 10/1/96

site to site. Third, the highest of the readings for both gross alpha and gross beta occurred at the Laboratory's background station, over 1.0 kilometers (0.6 miles) to the south of the site, which is not in the downwind direction of the predominant airflow patterns. These findings indicate that environmental impacts due to the

Laboratory's radioactive releases of alpha and beta materials to the atmosphere are negligible. The results from the Laboratory's network of dose sensors, which will be discussed in Chapter 11, present a similar finding. In general, the overall 1996 results show little difference from previous years' sampling data.

Table 4-7. Summary of Gross Alpha and Beta Concentrations from Ambient Monitoring Network

Station ID	Number of Samples	Alpha		Beta	
		Average (Bq/m ³) ^a	Maximum (Bq/m ³)	Average (Bq/m ³)	Maximum (Bq/m ³)
ENV-B13C	10	$< 1.1 \times 10^{-3}$	—	1.1×10^{-3}	1.8×10^{-3}
ENV-69	11	$< 1.2 \times 10^{-4}$	1.2×10^{-4}	5.9×10^{-4}	7.9×10^{-4}
ENV-80	10	$< 1.2 \times 10^{-4}$	—	5.3×10^{-4}	7.6×10^{-4}
ENV-81	11	$< 1.1 \times 10^{-4}$	1.8×10^{-4}	4.8×10^{-4}	7.6×10^{-4}

^a 1 Bq = 27 pCi^b For comparing with historical data, name changed from ENV-69P to ENV-69 on 10/1/96

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Chapter 5

Surface Water

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 orders¹ that prescribe the monitoring of radioisotope activity. Occasional nonradiological sampling of surface water occurs as part of the Laboratory's ongoing efforts to characterize and manage its historical impact on the environment. Stormwater monitoring is undertaken pursuant to 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 below.

Surface water samples were analyzed in 1996 by both commercial and in-house state certified laboratories.

Rainwater

During the rainfall season, generally October through April, a monthly rainwater sample is collected. During 1996, June through September were dry months, and no samples were collected.

The rainwater monitoring program collected samples at two locations throughout the year. One location is on site, on the north side of the National Tritium Labeling Facility at Building 75, and the second location is about one kilometer south of the site at the environmental monitoring program's background station, ENV-B13C. During the last quarter of the year, a second offsite location, ENV-B13D, was prepared for sampling. This station is situated at the edge of the parking lot that is located northwest of the Lawrence Hall of Science. Both the NTLF and the Lawrence Hall of Science

sampling sites are in the downwind direction of the average windflow patterns found at the Laboratory (see wind rose in Figure 2-8 for illustration). Sampling at this location began in early 1997. Results from this station will appear in next year's Site Environmental Report.

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 1996. Alpha activity was never detected, and low amounts of beta were seen at both stations. These amounts ranged from nondetect to a one-time high of 0.596 Bq/l (16.1 pCi/l) at ENV-B13C, with most measurements well below 0.2 Bq/l (5 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 always detected at very low levels at both sites. At Building 75, the highest amount seen was 16 Bq/l (432 pCi/l), while ENV-B13C showed a maximum of 9.8 Bq/l (266 pCi/l), and all other results were considerably less than that. The highest tritium result of the year represented less than 1/40th or about 2% of the US/EPA drinking water limits for tritium (740 Bq/l or 20,000 pCi/l).⁴ Tritium levels at these two locations were down considerably from the previous year.

Creeks

Given Berkeley Lab's location in the hills of the Strawberry Creek watershed, many streams and creeks near the site flow at varying intensities depending on the time of the year. When flowing, they are sampled and analyzed at least quarterly for alpha, beta, and tritium activity by means of a grab sample. Creeks sampled during 1996 were Chicken Creek, Claremont Creek, the North Fork of Strawberry Creek, Strawberry Creek (UC), and Wildcat Creek.

Table 5-1. Rainwater Radiological Monitoring Results

Location:	Number of Samples	Alpha (Bq/l) ^a		Beta (Bq/l)		Tritium (Bq/l)	
		Average	High	Average	High	Average	High
ENV-75	8	< 0.03 ^b	< 0.03 ^c	0.05	0.164	< 16 ^b	16
ENV-B13C	8	< 0.03 ^b	< 0.03 ^c	0.22	0.596	< 16 ^b	< 16 ^c

^a 1 Bq = 27 pCi

^b Yearly average was less than the highest minimum detectable amount for the analyte at this site.

^c Maximum was less than the highest minimum detectable amount for the analyte at this site.

(See Figure 5-1 for locations.) A second set of creeks was sampled and analyzed only for tritium activity. These creeks included Botanical Garden Creek, Cafeteria Creek, No Name Creek, Ravine Creek, and Ten-Inch Creek. Data summaries of radiological analyses from creek sampling are shown in Table 5-2.

Alpha activity was not detected at any sampling site. Similarly, beta activity was seen only

twice, once in the North Fork of Strawberry Creek and once in Strawberry Creek (UC), at levels of 0.04 Bq/l (1 pCi/l) and 0.06 Bq/l (1.5 pCi/l), respectively.

In general, detection limits vary slightly from sample to sample. Tritium was not found above the highest detection limit at Claremont Creek or Wildcat Creek. At Strawberry Creek (UC), tritium was found once at 7.3 Bq/l (196 pCi/l),

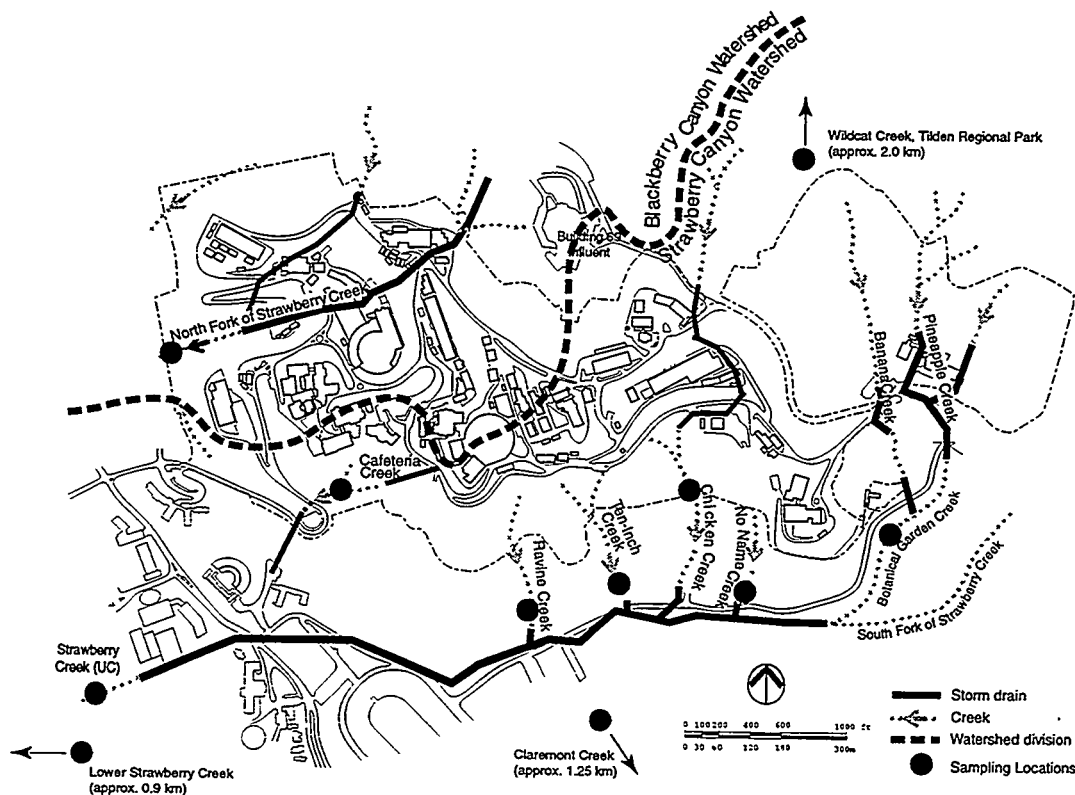


Figure 5-1. Creek Sampling Locations

while in the North Fork of Strawberry Creek it was found twice at 10.1 Bq/l (273 pCi/l). These levels were still less than the highest detection limits for samples collected from both locations. Most of Chicken Creek's samples remained below minimum detectable activity, although two results indicated small, but measurable levels at about 38 Bq/l (1,000 pCi/l). This value represents about an 80% decrease over last year, when a high of 179 Bq/l (4,840 pCi/l), and several other results above 37 Bq/l (1,000 pCi/l), were measured at this site. These results are consistent with the significant reduction in tritium emissions from the NTLF for the year, as noted in earlier chapters.

Some creeks (Botanical Garden Creek, Cafeteria Creek, Chicken Creek, No Name Creek, the North Fork of Strawberry, Ravine Creek, and Ten Inch Creek) were also sampled and ana-

lyzed randomly for nonradiological parameters. Twice during the year certain creeks were sampled for volatile organic compounds (VOCs). All results remained below detectable levels. Also, certain creeks were sampled for metals twice during the year. Trace levels of arsenic, barium, copper, and zinc were found at around method detection limits. These levels were consistent with past results and consistent with natural background levels.

Lakes

Lake sampling became a new element of the surface water program in 1996. Two lakes were chosen for their proximity to Berkeley Lab, Lake Anza in Tilden Regional Park, and Lake Temescal in Oakland's Temescal Regional Park (see Figure 5-2). The lakes will be sampled annually. For 1996, samples from both lakes

Table 5-2. Creek Radiological Monitoring Results^a

Location	Number of Samples	Tritium (Bq/l) ^b	
		Average	High
Botanical Garden Creek	3	< 15 ^c	< 15 ^d
Cafeteria Creek	2	< 15 ^c	< 15 ^d
Chicken Creek	6	23	38
Claremont Creek	4	< 16 ^c	< 16 ^d
North Fork Strawberry Creek	6	< 19 ^c	< 19 ^d
No Name Creek	2	< 15 ^c	< 15 ^d
Ravine Creek	2	< 15 ^c	< 15 ^d
Strawberry Creek (UC)	4	< 11 ^c	< 11 ^d
Ten-Inch Creek	1	< 15 ^c	< 15 ^d
Wildcat Creek	4	< 19 ^c	< 19 ^d

^a Alpha and beta were always less than minimum detectable activity except for two beta results of 0.04 Bq/L at the North Fork of Strawberry Creek and 0.06 Bq/L at Strawberry Creek (UC)

^b 1 Bq = 27 pCi

^c Yearly average was less than the highest minimum detectable amount at this site.

^d Maximum was less than the highest minimum detectable amount this site.

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detected neither tritium nor alpha activity. At Lake Anza, beta activity was seen at the 0.045 Bq/l (1.2 pCi/l). Although lake water is not considered drinking water, this result is well below the state's comparable drinking water standard for gross beta of 1.85 Bq/l (50 pCi/l).⁵ The summary table for lake water is Table 5-3.

Hydraugers

Hydraugers are perforated pipes inserted into a hillside in order to improve drainage of sur-

face and near-surface water on potentially unstable slopes. Berkeley Lab has many of these hydraugers because of its steep hillsides. See Figure 5-3 for the locations of monitored hydraugers. Summary data for hydraugers can be found in Table 5-4.

Six hydrauger sites (HYG77-0101, HYG77-0103, HYG77-0104, HYG77-02XX, HYGCC1, and HYGCC2) are used to routinely monitor sources of surface water contamination. HYG77-02XX is a manifold of several hydraugers (HYG77-0204 through HYG77-

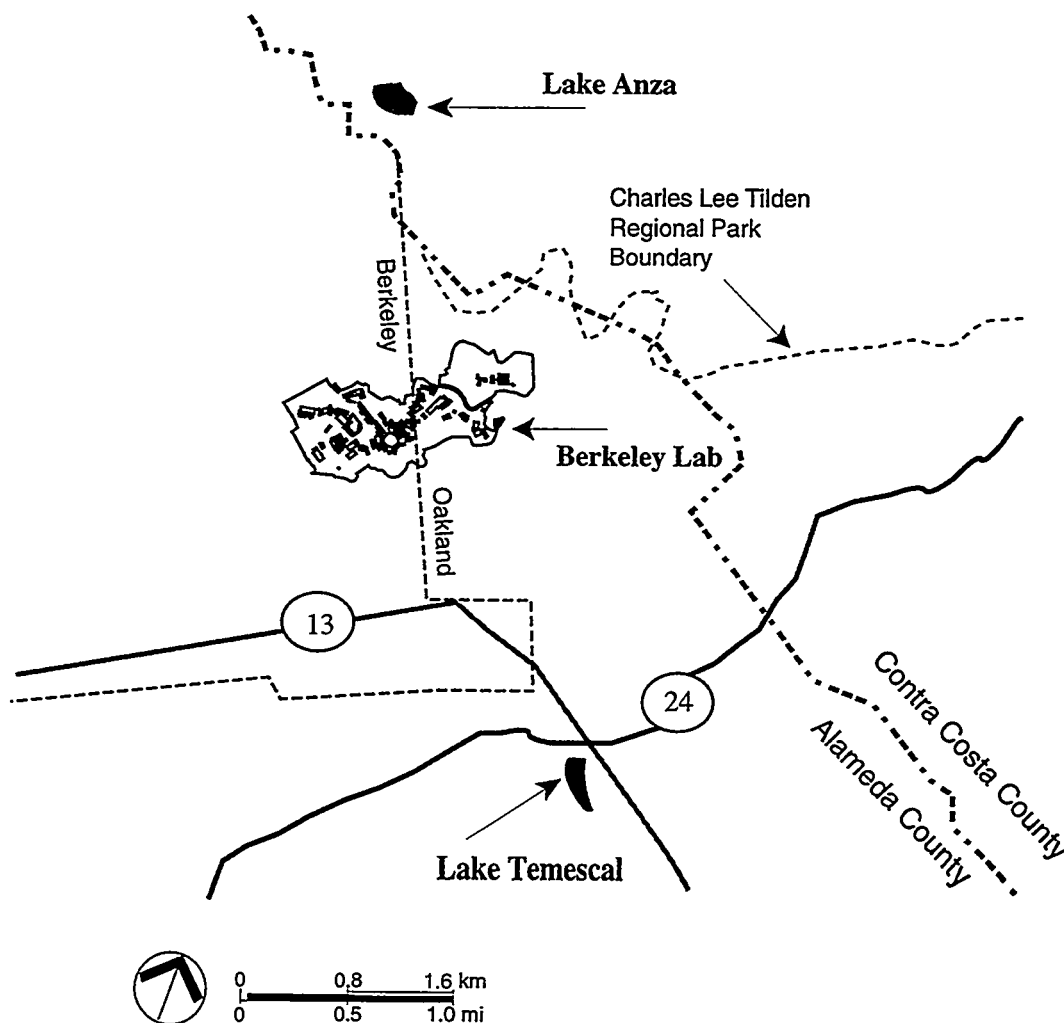


Figure 5-2. Lake Sampling Locations

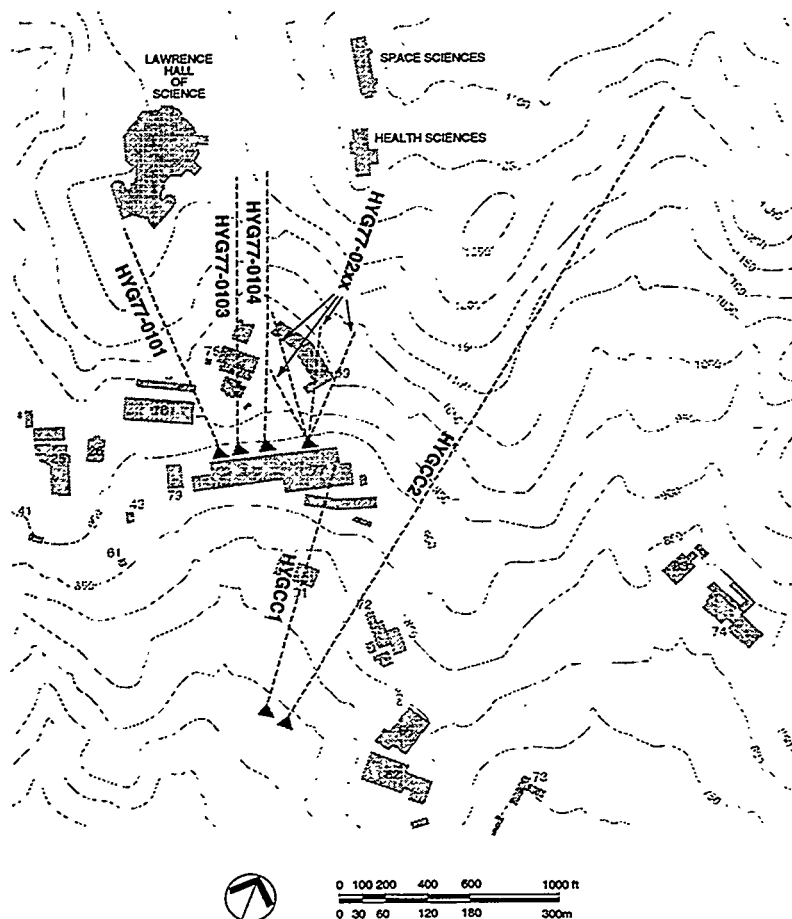
Table 5-3. Lake Radiological Monitoring Results

Location:	Number of Samples	Alpha (Bq/l) ^a	Beta (Bq/l)	Tritium (Bq/l)
Lake Anza	1	< 0.02 ^b	0.045	< 8 ^b
Lake Temescal	1	< 0.02 ^b	< 0.03 ^b	< 8 ^b

^a 1 Bq = 27 pCi^b Result was less than the highest minimum detectable amount for the analyte at this site.

0207), and is sampled at the common discharge point. Hydraugers prefixed with HYG77 are located behind Building 77, while the HYGCC prefix refers to a location near Chicken Creek further to the south and down the hillside. Each hydrauger is routinely monitored for alpha, beta, and tritium on a quarterly frequency.

Since hydrauger flow depends on several factors, including rainfall, hydrauger flow can vary considerably. This sometimes prevents samples from being taken. For example, HYG77-0103 was dry in all four quarters during 1996. Because this was the second consecutive year that samples could not be taken

**Figure 5-3. Hydrauger Sampling Locations**

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for this reason and due to its close proximity to HYG77-0104, this site may be dropped from the program.

On the other hand, additional samples were occasionally taken from hydraugers for the purpose of monitoring the groundwater tritium plume located in the vicinity of the NTLF. Further details on this plume are discussed in Chapter 6, *Groundwater Protection*. These nonroutine sampling events account for the two additional samples reported for hydrauger HYG77-0101 as well as the presence of single samples at several of the individual hydraugers that make up manifold HYG77-02XX (see Table 5-4).

At the hydraugers that could be sampled (HYG77-0101, HYG77-0104, HYG77-02XX, HYGCC1, and HYGCC2), alpha and beta were

always nondetectable. However, tritium results varied considerably over the network. At HYG77-0104, where the flow of water is consistently extremely low or nonexistent, tritium was reported at a level (879 Bq/l or 23,700 pCi/l) somewhat above the US/EPA drinking water limit⁶ during the second quarter of 1996, dropping below this limit during the third and fourth quarters. (The US/EPA drinking water limit is used for comparison only, since this water is not used for public consumption) No sample could be taken during the first quarter at this site due to lack of flow. As an indication of the persistently low flow at this location, a small collection vial (125 milliliters or 4.2 fluid ounces) consistently took between 6 to 10 days to fill with a sample.

Tritium was seen consistently at HYG77-0101, but to a noticeably lesser extent than the levels

Table 5-4. Hydrauger Tritium Monitoring Results^a

Location:	Number of Samples	Tritium (Bq/l) ^b	
		Average	High
HYG77-0101	6	406	577
HYG77-0103	0 ^c	—	—
HYG77-0104	3	565	879
HYG77-02XX ^d	4	147	170
HYG77-0205	1	129	129
HYG77-0206	1	21	21
HYG77-0207	1	< 15 ^e	< 15 ^f
HYG77-0211	1	< 15 ^e	< 15 ^f
HYGCC1	4	< 13 ^e	< 13 ^f
HYGCC2	4	11	17

^a Alpha and beta were always below the minimum detectable activity

^b 1 Bq = 27 pCi

^c No samples collected at this location due to lack of flow throughout the year

^d "02XX" refers to the manifold behind Building 77 that drains the series of individual hydraugers HYG77-0204 through HYG77-0207

^e Yearly average was less than the highest minimum detectable amount for the analyte at this site

^f Maximum was less than the highest minimum detectable amount for the analyte at this site

detected at HYG77-0104. This hydrauger is longer than HYG77-0104 and extends closer to the NTLF tritium stack. Flow of water is also more consistent from this hydrauger.

At HYG77-02XX, levels were considerably less than the levels detected at the above mentioned hydraugers. Some of the individual hydraugers that make up this manifold provided samples with nondetectable levels. At the Chicken Creek hydraugers, tritium was often not detected, and when detected was at low levels not exceeding 17.1 Bq/l (463 pCi/l).

Overall in this area of 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 of the past two years shows that levels were stable in all hydraugers except for HYG77-0101, where, as noted above, they have risen slightly from the previous year. The highest overall sampling result this year, 879 Bq/l (23,733 pCi/l), was seen at HYG77-0104, which could only be sampled three times this year due to lack of flow. Since it could not be sampled at all last year for the same reason, there is no basis for comparison or trending.

Stormwater

Under the State of California's NPDES program, Berkeley Lab must follow the *General Permit for Stormwater Discharges Associated with Industrial Activities*.⁷ Permit holders must develop and maintain a *Storm Water Monitoring Plan (SWMP)*⁸ and a *Storm Water Pollution Prevention Plan (SWPPP)*.⁹ These are the guiding documents for the Lab's compliance with stormwater regulations. Additional discussion on this compliance program is found in the water quality section of Chapter 3.

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. However, Berkeley Lab sampled and analyzed once for both total metals and dissolved metals. When a sample is analyzed for dissolved metals, it consistently shows lower levels. Berkeley Lab has committed to analyzing at least one sample per year for both total and dissolved metals as a comparison.

Sampling points are shown in Figure 5-4. Sampling point StW05 was installed in late 1996 to sample stormwater from the replacement Hazardous Waste Handling Facility.

The General Permit allows a facility to eliminate pollutants from sampling if they are not detected in significant quantities after two consecutive samplings. After the 1995/96 stormwater season, Berkeley Lab stopped sampling for PCBs and TPH/BTEX (Total Petroleum Hydrocarbons/Benzene, Toluene, Ethylbenzene, and Xylenes), which had not been detected in four years of monitoring.

Two of the monitoring points, StW01 and StW03, are influent points, where stormwater comes onto the site from residential areas, roads, and other University of California at Berkeley campus facilities located above it. These points were chosen as a basis of comparison and to aid in an investigation should contaminants be 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. During 1996, some locations at Berkeley Lab were monitored

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more than twice. Monitoring also includes visual observation of one storm per month. All sampling points must be monitored for the following:

- pH, total suspended solids, 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.

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 domes-

tic drinking water. Total suspended solids, in this case mostly a measure of water clarity, was also usually quite low, indicating clear water. Monitoring results are shown in Tables 5-5 and 5-6 for metals and radiological samples, respectively. Detailed results are presented in Volume II, *Data Appendix*.

The General Permit does not contain specific discharge limits for these metals. For comparison purposes, Table 4-3 of the Basin Plan¹⁰ gives effluent limitations, applicable to point source discharges from Publicly Owned Treatment Works, like EBMUD, and industrial effluent, for selected toxic pollutants discharged to shallow surface waters.

Metals occasionally seen as traces included arsenic, barium, chromium, cobalt, copper, lead, mercury, nickel, selenium, vanadium, and zinc.

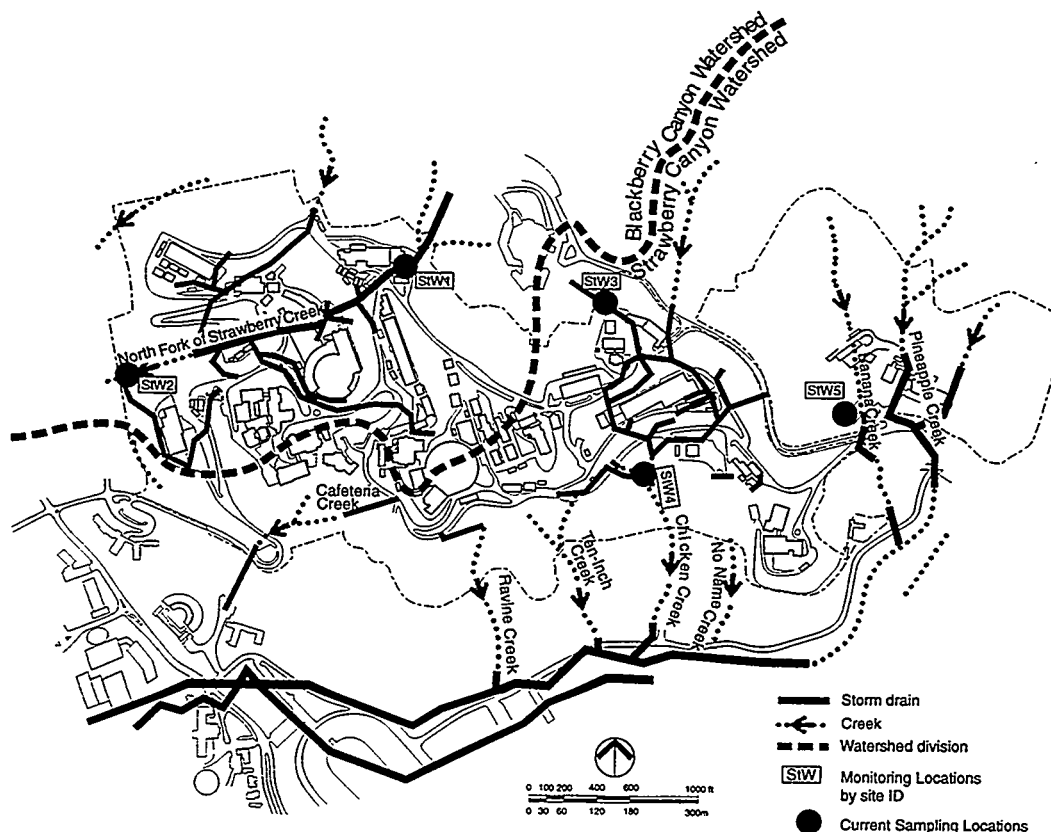


Figure 5-4. Stormwater Sampling Locations

Table 5-5. 1996 Average Stormwater Results for Metals^a

Analyte	StW01	StW02	StW03	StW04	Basin Plan (RWQCB)
Number of Samples	5	6	3	4	
Copper	ND ^b	ND	ND	0.065 ^c	0.02
Lead	ND	ND	ND	0.20 ^c	0.0056
Vanadium	0.02	ND	ND	0.05 ^c	—
Zinc	0.14	0.10 ^c	0.10	0.40	0.058

^a All results are given in mg/l. Analytes with nondetectable results are included in the complete listing presented in Volume II, Data Appendix.

^b Less than detection limit

^c Some samples were non-detect. In order to compute an average, the practical quantification limit was used for the non-detect values

Many of these were seen only one time, and many were also seen only when the sample was analyzed for total metals (see above). The only metals seen above their respective Basin Plan limits were copper, lead, and zinc in Chicken Creek (StW04), and zinc in StW03, the influent location for the Chicken Creek discharge.

Table 5-5 compares the Basin Plan limits to the average levels of metals seen in Berkeley Lab's stormwater samples for 1996. Results at Berkeley Lab are consistent with levels of urban runoff that could be expected to be present at a site such as this, with traffic and roads on site and run-on from roads and residential areas above.

Routine stormwater samples are also analyzed for alpha, beta, and tritium. Alpha was detected only once at StW04, with the concentration right at the detection limit. Beta ranged from not detectable to a one-time high of 0.25 Bq/l (6.8 pCi/l) at the Building 69 influent storm drain manhole, StW03. All tritium values were low, ranging from not detectable at StW03 and the North Fork of Strawberry Creek (StW02) to 94 Bq/l (2,540 pCi/l) at Chicken Creek (StW04). This represents a slight decrease over the maximum for 1995, which was 103 Bq/l (2,780 pCi/l) at StW03. Summaries of radiological results for stormwater sampling during 1996 are shown in Table 5-6.

Table 5-6. 1996 Average Stormwater Radiological Analysis Results^a

Location:	Number of Samples	Beta (Bq/l) ^b		Tritium (Bq/l)	
		Average	High	Average	High
StW01	3	0.16	0.25	18	24
StW02	4	< 0.11 ^c	0.12	11	19
StW03	2	0.12	0.13	15	18
StW04	3	0.11	0.12	41	94

^a Alpha was always less than the minimum detectable amount

^b 1 Bq = 27 pCi

^c Yearly average was less than the highest minimum detectable amount for the analyte at this site

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Chapter 6

Groundwater Protection

A

Background

This section contains an overview of the results of the groundwater monitoring program at Berkeley Lab for 1996. Detailed results are included in the quarterly progress reports, which contain all of 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 at the information repositories, including the Berkeley Main Public Library, where Environmental Restoration Program (ERP) documents are available for public review.

Berkeley Lab seeks to ensure that the protection of groundwater benefits the overall environmental quality. The *Groundwater Protection Management Program Plan*¹ established the program to accomplish this objective 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.

Berkeley Lab strives to protect and improve groundwater quality by containing and remediating areas of contamination. Under the RCRA Corrective Action Process,² the Laboratory identifies areas of soil and groundwater contamination that may have resulted from past releases of contaminants to the environment, 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 California Department of Toxic Substances Control, the San Francisco Bay Regional Water Quality Control Board, and the City of Berke-

ley. These agencies review and approve the work plans that are prepared for all activities. Each quarter, Berkeley Lab submits a progress report to the oversight agencies and meets with the agencies to review results of the previous quarter's activities.

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. More detailed information on the hydrogeology is provided in the 1994 *Berkeley Lab RCRA Facility Investigation Progress Report*.³

Hydrogeologic Units

Moraga formation volcanic rocks, Orinda formation sediments, and Great Valley Group sediments constitute the major rock units at the site. The structural geometry and the physical characteristics of these three units are the principal hydrogeologic factors controlling the movement of groundwater and groundwater contaminants at the Laboratory. The Claremont Formation and the San Pablo Group crop out only in the easternmost area and are of limited extent. The hydrogeological characteristics of the three main units are discussed below.

The Moraga formation consists mainly of lava flows, flow breccias, and agglomerates. The lavas are typically highly fractured, jointed, or brecciated. The hydraulic conductivity of these rocks is relatively high at 10^{-4} to 10^{-6} meters per second (3.3×10^{-4} to 3.3×10^{-6} feet per second), and they constitute the main water-bearing unit at Berkeley Lab. Groundwater flows primarily through fractures in the rock. 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 Orinda formation consists primarily of low-permeability siltstones, sandstones, mudstones, and conglomerates. The Orinda formation has a 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) and underlies the Moraga formation, constituting 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 sandstones and conglomerates may form confined aquifers, especially where they are fractured.

The Great Valley Group consists primarily of low-permeability shales, mudstones, and sandstones. Due to the presence of moderately spaced open fractures and low-matrix permeability, groundwater flows primarily through fractures in the rock. The hydraulic conductivity varies between approximately 10^{-5} and 10^{-7} meters per second (3.3×10^{-5} and 3.3×10^{-7} feet per second).

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 due to the subsurface geometry of geologic units and the contrasting hydrogeologic properties across geologic contacts. The velocity of the groundwater varies from approximately 0.001 meter per year (0.003 feet per year) to 1 meter per day (3.3 feet per day).

Groundwater Fluctuations

Fluctuations in measured groundwater levels in wells generally correlate good with rainfall data, 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 much as 4.2 meters (14 feet) are common in wells in the Old Town area.

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 2,750 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.

Groundwater Monitoring Results

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
- monitor groundwater quality near existing

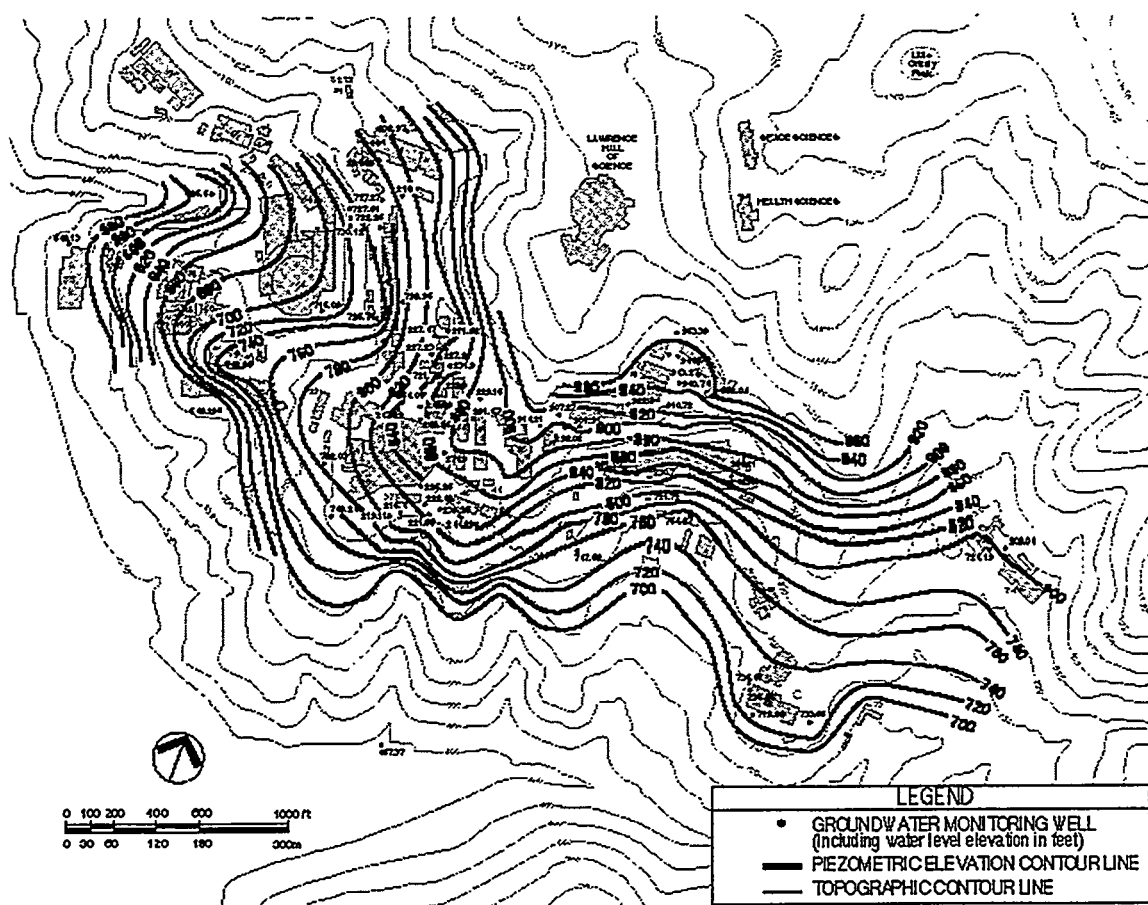


Figure 6-1. Groundwater Piezometric Map at Berkeley Lab

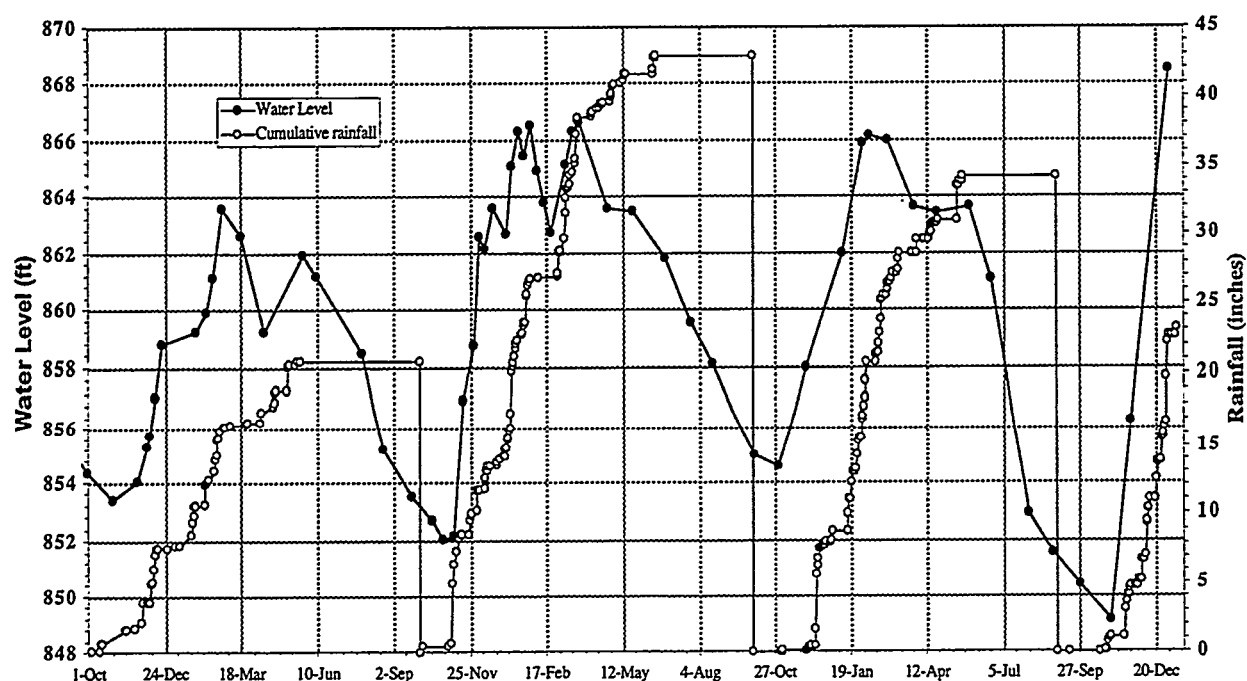


Figure 6-2. Groundwater Fluctuation in Monitoring Well MW7-92-19 Compared to Rainfall

Table 6-1. Water Quality in Different Formations

Parameter	Drinking Water Standard (MCL)	Average Concentration (mg/l)		
		Orinda Formation	Moraga Formation	Great Valley Group
Total Dissolved Solids	500 ^a	760	490	735
Nitrate (as NO ₃)	45	29	17	5
Sulfate	500	120	33	184
Chloride	250 ^a	86	32	51
Bicarbonate		450	421	420
Potassium		4	2	5
Sodium		181	61	121
Magnesium		26	33	34
Calcium		54	72	80
pH	6.5 to 8.5 pH units	7.9 pH units	7.6 pH units	7.7 pH units

^a indicates secondary standard (aesthetic standard)

and removed hazardous materials or hazardous waste storage units, including underground storage tanks.

Four categories of contaminants are monitored under the program: volatile organic compounds (VOCs), hydrocarbons, metals, and tritium. In addition, selected wells have been sampled for other potential contaminants.

In 1996, 15 new monitoring wells were installed and one existing well was reconstructed (deepened), resulting in a total of 132 wells installed by the program. Of the total number of wells, three are considered multi-level, in that they allow groundwater sampling of more than one interval.

Eighteen monitoring wells are located close to the site boundary, and one of the wells is located off site, downgradient from the site (see Figure 6-3).

Samples from wells in areas of known petroleum hydrocarbon contamination, such as underground fuel storage tanks, are also analyzed for fuel hydrocarbons approximately quarterly.

A summary of groundwater monitoring results for 1996 is presented in Tables 6-2 through 6-4. Tables 6-2 and 6-3 summarize the metal 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.

Groundwater Contamination

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

VOC Plumes

- Old Town
- Building 71
- Building 37
- Building 51/64

Freon Plume

- Building 71

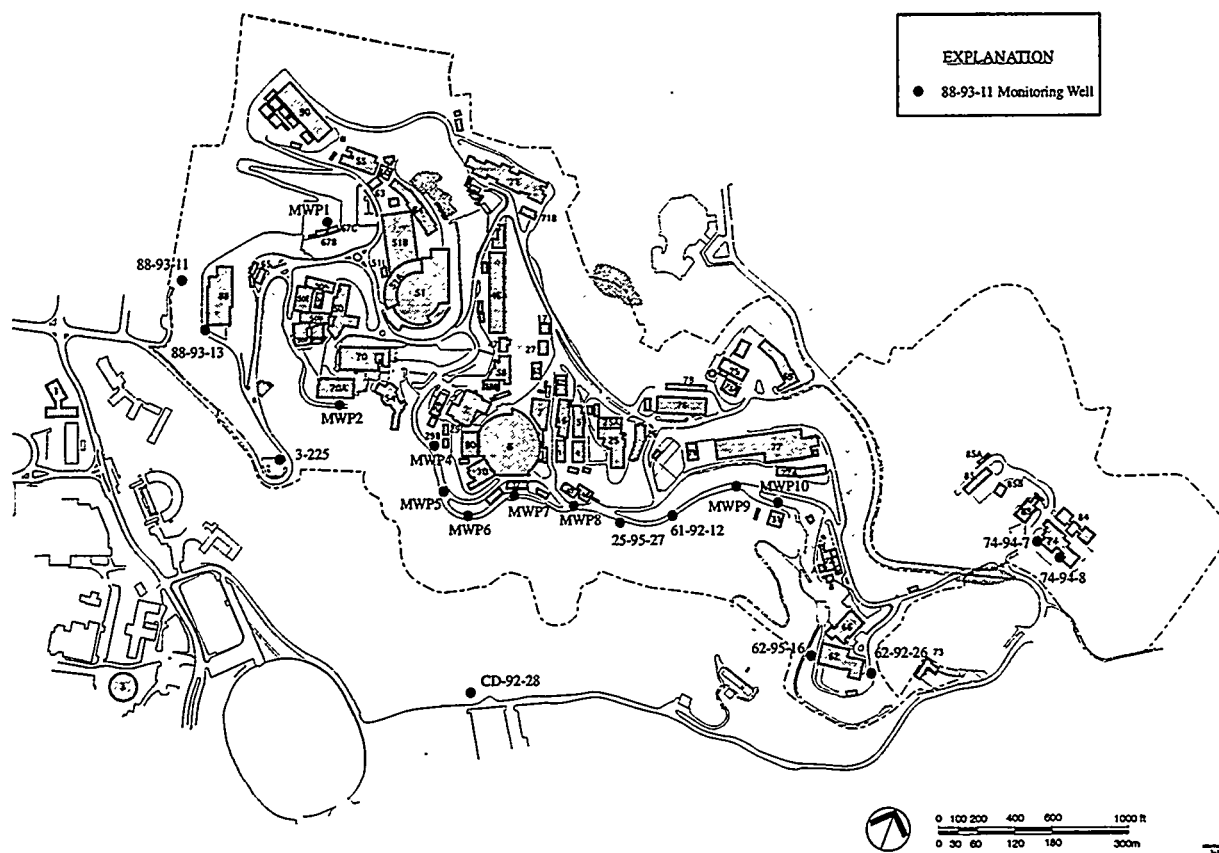


Figure 6-3. Approximate Locations of Monitoring Wells Closest to the Berkeley Lab Property Line

Tritium Plume

- Building 75

Petroleum Hydrocarbon Plumes

- Building 7
- Building 74

Contamination was also detected in groundwater in other areas of the site in 1996. However, based on the present information, the extent of contamination in these areas is limited.

VOC Plumes

The Old Town VOC Plume covers the area of Buildings 7, 53, 27, 58A, and the slope west of Building 53 and is the most extensive plume at Berkeley Lab. The plume is defined by the presence of tetrachloroethene (PCE) and trichloroethene (TCE), and by lower concentrations of other halogenated hydrocarbons in-

cluding: 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 groundwater samples collected from wells monitoring the Old Town VOC plume in 1996 was 195,600 µg/l, which primarily consisted of PCE (139,000 µg/l), TCE (50,700 µg/l), and carbon tetrachloride (5,180 µg/l). Figure 6-5 shows the areal extent of VOCs in groundwater in the Old Town area. Figure 6-6 shows the time variation of contaminant concentrations in monitoring well MW7B-95-21. MW7B-95-21 is located close to the plume source area.

The presence of the maximum VOC concentrations north of Building 7 suggests that the

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Table 6-2. Summary of Metals Results in Groundwater Samples from Monitoring Wells in 1996

Metal	Number of Wells Sampled	Number of Samples	Number of Wells Analyte Detected	Range of Concentrations (µg/l)	Drinking Water Standard (µg/l)
Antimony	73	73	4	4 - 9.1	6
Arsenic	73	73	37	2.0 - 94	50
Barium	73	73	19	20 - 427	1000
Beryllium	73	137	0	-	4
Cadmium	73	137	0	-	5
Chromium	73	73	2	10	50
Cobalt	73	73	0	-	NS ^a
Copper	73	73	0	-	1000 ^b
Lead	73	73	0	-	15 ^c
Mercury	73	73	0	-	2
Molybdenum	73	73	9	10 - 415	NS ^a
Nickel	73	73	0	-	100
Selenium	73	73	6	2.0 - 9.0	50
Silver	73	73	0	-	100 ^b
Thallium	73	137	0	-	2
Vanadium	73	73	8	7.0 - 27	NS ^a
Zinc	73	73	9	23 - 43	5000 ^b

^a NS: Not Specified

^b Secondary MCL

^c Action Level

primary source of the Old Town VOC plume was apparently leakage and/or overflow from a former abandoned sump that was located between Buildings 7 and 7B. The sump was discovered and its contents removed in 1992 and the sump was removed in 1995, after replacing underground utility lines that crossed the sump. Other less significant source areas 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 iden-

tified. 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; 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, and extraction and treatment of groundwater was started in March 1996 at monitoring well MW58-95-18. These measures will be discussed in detail later in this chapter.

Table 6-3. VOCs Detected in Groundwater Samples from Monitoring Wells^a in 1996

Analytes Detected	Number of Wells Analyte Detected	Range of Concentrations (µg/l)	Drinking Water Standard (µg/l)
Aromatic or Non-halogenated Hydrocarbons			
Benzene	5	1.2–98	1
n-Butylbenzene	1	2.6	NS ^b
sec-Butylbenzene	3	0.64–5.2	NS
ter-Butylbenzene	1	0.74	NS
1,2-Dichlorobenzene	1	1.5	NS
1,4-Dichlorobenzene	1	6.3	NS
Isopropylbenzene	1	2.4	NS
Naphthalene	2	2.2–3.1	NS
p-Isopropyltoluene	4	1.5–66	NS
Toluene	3	7.2–20	150
1,2,4-Trichlorobenzene	2	2.8–133	NS
1,3,5-Trimethylbenzene	2	2.2–110	NS
Xylenes, total	2	3.9–6	1750
Halogenated Hydrocarbons			
Bromodichloromethane	3	0.74–4.2	100
Bromoform	3	1.8–9.9	NS
Carbon Tetrachloride	24	1–5,180	0.5
Chloroethane	1	0.6	NS
Chloroform	39	0.89–365	100
1,1-Dichloroethane	31	0.68–39	5
1,2-Dichloroethane	7	0.57–9.8	0.5
1,1-Dichloroethene	41	0.52–370	6
cis-1,2-Dichloroethene	45	0.63–1,600	6
trans-1,2-Dichloroethene	19	0.57–78	10
Methylene Chloride	4	1.8–39	5
1,1,1,2-Tetrachloroethene	6	1.4–58	NS
Tetrachloroethene	75	0.6–139,000	5
1,1,1-Trichloroethane	22	0.82–303	200
1,1,2-Trichloroethane	6	0.74–15	5
Trichloroethene	67	0.84–65,800	5
Trichlorofluoromethane (CFC 11)	2	0.76–1.6	150
1,1,2-Trichlorotrifluoroethane (CFC 113)	9	1.1–665	1200
Vinyl Chloride	18	0.63–83	0.5

^a456 samples taken from sampling at 129 wells during the year^bNS: Not Specified

6-Groundwater Protection

Other VOC plumes have been identified in the area south of Building 71 (Building 71 VOC plume) and south of Building 37 (Building 37 VOC plume). These plumes cover less area than the Old Town plume, and the number of contaminants detected and magnitude of contamination are also much less. 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 wells monitoring the plume in 1996 was 80 µg/l. Contaminated groundwater from the plume is continuously dis-

charged 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 the two wells after January 1994 when pumping groundwater for plume management was initiated.

In addition, a VOC plume was identified in 1996 in the area between Buildings 51 and 64. The Building 51/64 plume is defined by the pres-

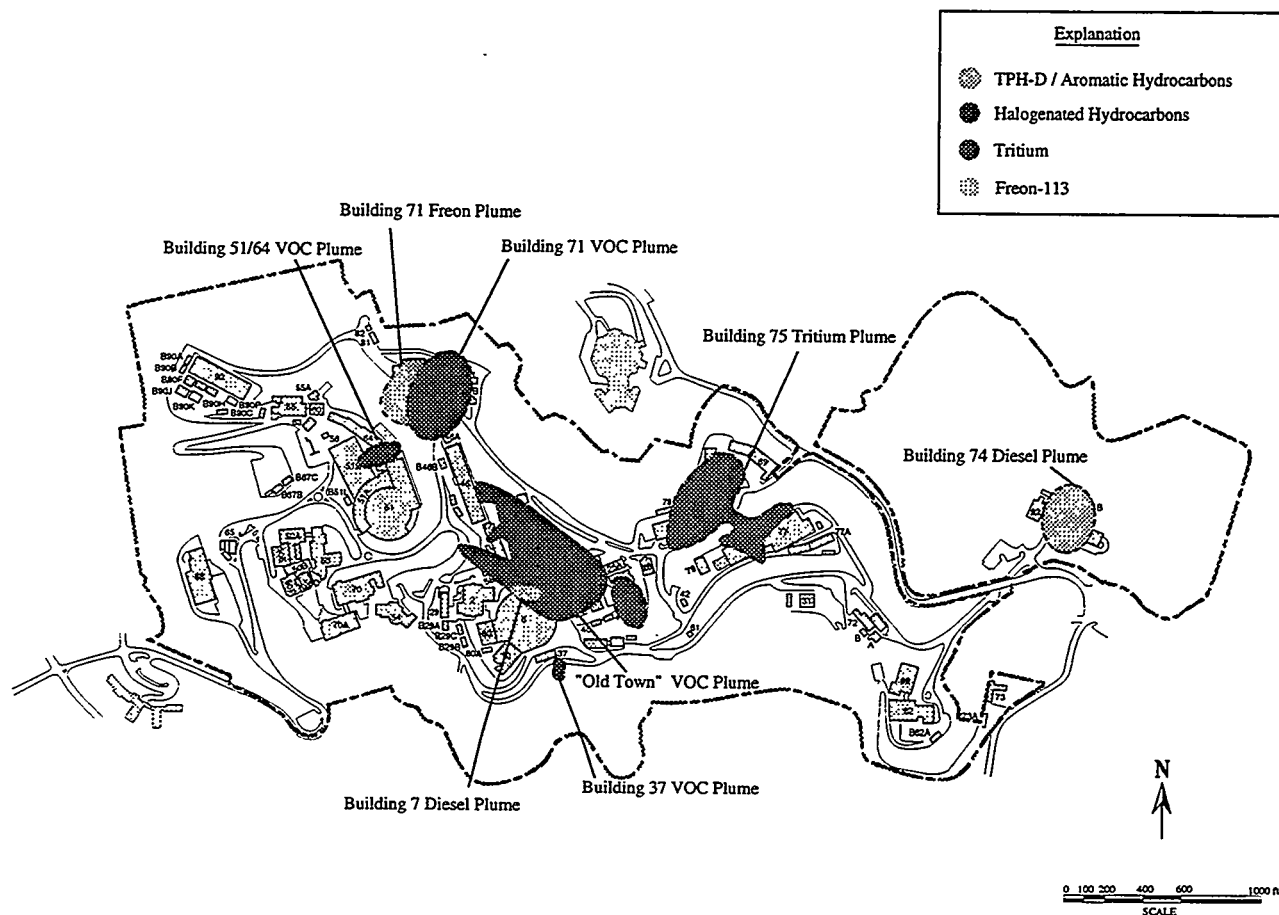


Figure 6-4. Groundwater Contamination Plumes, December 1996

ence of halogenated hydrocarbons, including 1,1-DCA, TCE, vinyl chloride, PCE, trans-1,2-DCE, and 1,1,1-TCA. The source of the contamination is not known; however, based on the suite of chemicals detected in each of the wells in the area, there appear to be multiple sources for the contamination. The maximum concentration of total halogenated hydrocarbons detected in grab samples from wells monitoring the plume in 1996 was 1103 $\mu\text{g/l}$.

Freon Plume

High concentrations of Freon-113 were detected in groundwater south of Building 71 in 1993 and 1994. The source of Freon-113 is most likely past spills from the Linear Accelerator Cooling Unit formerly located in Building 71 and which is no longer operational. Concentrations of Freon-113 increased to a maximum concentration of 8,984 $\mu\text{g/l}$ in Au-

Table 6-4. Summary of Tritium Results Detected^a in Groundwater Samples from Monitoring Wells in 1996.

Well Number	Jan-Mar 96 (Bq/l)	Apr - June 96 (Bq/l)	Jul - Sep 96 (Bq/l)	Oct - Dec 96 (Bq/l)
MCL ^b :	740	740	740	740
MW91-3				<14.8
MW91-4	29	40	25	84
MW91-5	89	164	129	127
MW91-6	214	225	225	226
69A-92-22				<7.4
75-92-23	151	169	166	208
75B-92-24	198 201 (S) ^c	230	293	156
MW76-1				18
76-93-6	123 121 (D) ^d	138	187 114 (D)	122
MW91-2	ND ^e	19	ND	ND
77-94-6		338	351	430
74-94-7		ND ND (D)	ND	16
MWP-7	ND	ND	8 16	ND ND (D)
37-93-5			5	4
MWP-1	ND	ND	ND	ND

^a Sample results from all locations are presented in Volume II, *Data Appendix*

^bMCL = Drinking water standard determined by California Department of Health Services

^cS = Split sample

^dD = Duplicate sample

^eND = Nondetect

gust 1994, and then decreased to 175 µg/l in November 1996. The MCL for Freon-113 is 1200 µg/l. The 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.

Tritium Plume

The tritium plume appears to be in the vicinity of Buildings 75, 76, 77, and 78. The source of the tritium is emissions from the NTLF stack west of Building 75. The maximum concentration of tritium detected in monitoring wells in 1996 was about 430 Bq/l (11,626 pCi/l), which is well below the drinking water standard of 740 Bq/l (20,000 pCi/l).⁵ The presence of tritium has not been confirmed in groundwater samples from monitoring wells near the site boundary.

Fuel Contamination and Fuel Plumes

Monitoring wells have been installed at, or downgradient from, one active, two abandoned, and six removed UST sites. Figure 6-7 shows the approximate locations of these wells. The maximum concentrations of total petroleum hydrocarbons (TPH) detected at these sites in 1996 are listed in Table 6-5.

Trace concentrations (less than 1 µg/l) of aromatic hydrocarbons (common components of fuels) were detected in groundwater at the former Building 76 UST site (south of Building 76) in 1996. Aromatic hydrocarbons were also detected in the three wells monitoring the former Building 7E UST site; however, no BTEX components (i.e., benzene, toluene, ethyl benzene, xylene) were detected. The plume (Building 7 Diesel Plume) is located

north of Building 6. No aromatic hydrocarbons have been detected at the other UST sites.

An interim corrective measure pilot test consisting of groundwater extraction together with a skimmer pump to collect free product, in combination with soil vapor extraction, was conducted at the Building 7E UST site in June 1996. Further discussion on this ICM/pilot test is presented in the next section.

Interim Corrective Measures

Interim corrective measures are used to remove 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.

In addition, Berkeley Lab conducts pilot testing to evaluate potential methods for remediating contaminated soil and groundwater.

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.

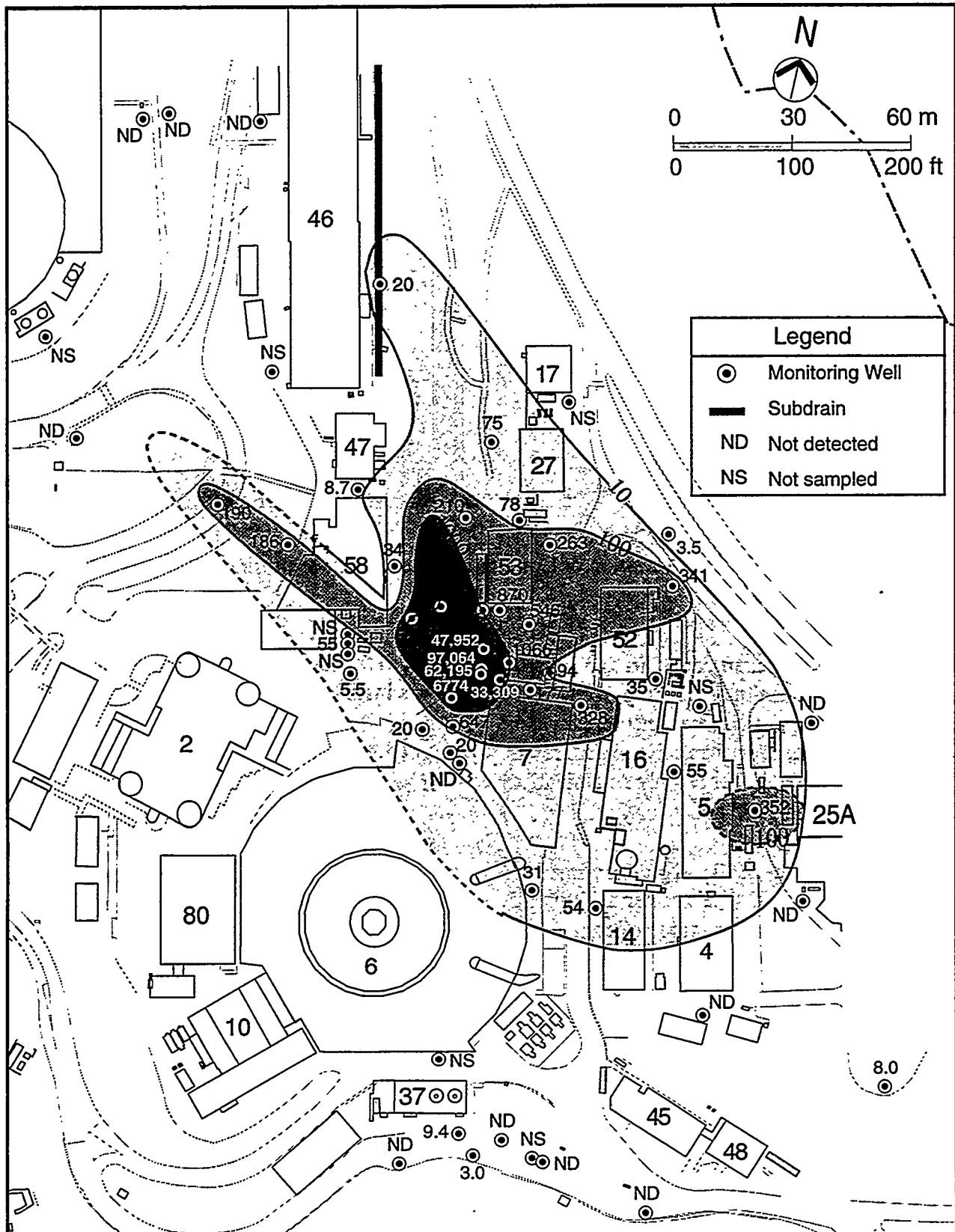


Figure 6-5. Groundwater Contamination (Total Halogenated Hydrocarbons in $\mu\text{g/l}$) in the Old Town Area, December, 1996

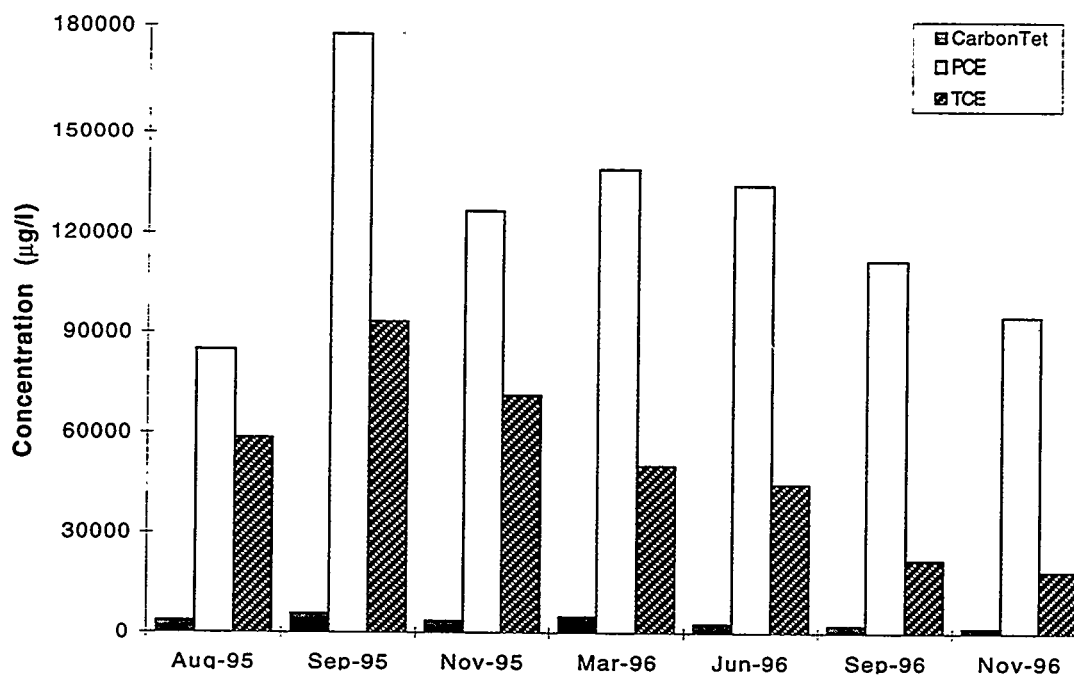


Figure 6-6. Time Variation of Contaminant Levels at Monitoring Well MW7-92-19

Where the contaminant concentrations pose a threat to human health or leaching of contaminants from the soils can impact groundwater, the need for interim corrective measures is evaluated. Several sources of contamination were removed in 1995 and prior years.

Highly contaminated soil and groundwater near the source location (the former Building 7 sump) act as 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, across the area of highest groundwater contaminant concentrations. PVC well casings were installed in the trench to extract contaminated groundwater and the trench was filled with coarse gravel to provide a good hydraulic connection for water flowing into the trench. The extracted water is treated by two 1000-pound granular activated carbon canisters in series. The effluent water is then released under per-

mit to the sanitary sewer. This control system was installed in December 1996.

Preventing Discharge of Contamination to Surface Waters

Slope stability is a concern at Berkeley Lab because of the geology and topography. Free-flowing hydraugers were installed in the past to dewater and stabilize areas of potential landsliding. 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.

In 1996, VOCs and motor oil were detected in water samples collected from the Building 51 motor generator room discharge sump and filter sump. To prevent the discharge of contami-

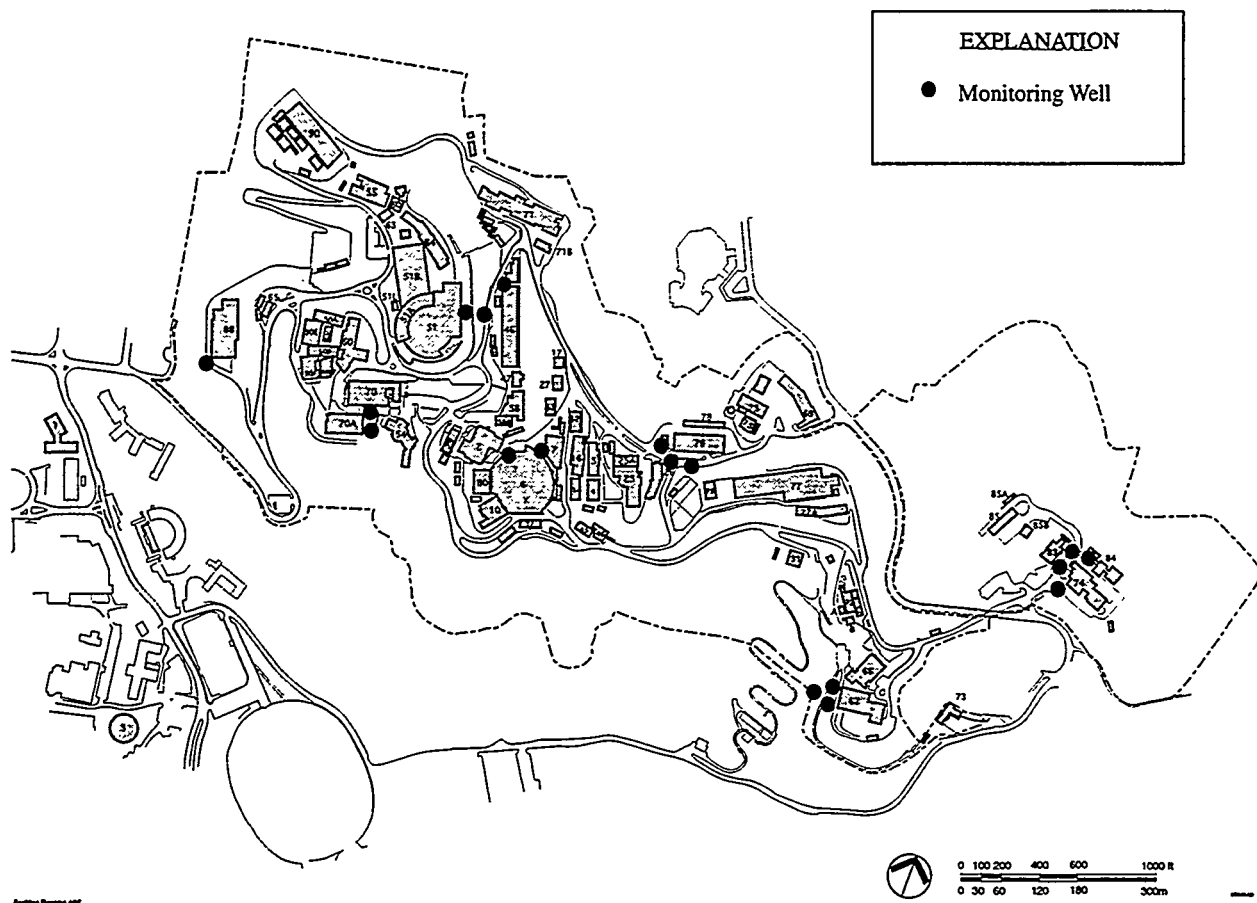


Figure 6-7. Approximate Locations of Monitoring Wells Associated With Underground Storage Tanks

Table 6-5. Total Petroleum Hydrocarbon Concentrations at UST Sites in 1996

UST Location	Status	Present or Previous Contents	Maximum Concentration ($\mu\text{g/l}$)
Building 70A	Active	Diesel	ND ^a
Building 7E	Removed	Kerosene	Kerosene = 150,000
Building 51	Removed	Diesel	ND
Building 76	Removed	Diesel	TPH-D ^b = 730
Building 76	Removed	Gasoline	TPH-G ^c = 63
Building 74	Removed	Diesel	TPH-D ^b = 410
Building 62	Removed	Diesel	TPH-D ^b = 480
Building 88	Abandoned	Diesel	TPH-D ^b = 52
Building 46A	Abandoned	Gasoline	ND

^aND = not detected

^bTPH-D = TPH quantified as diesel range hydrocarbons

^cTPH-G = TPH quantified as gasoline range hydrocarbons

nated water to the storm drain system, Berkeley Lab installed a system to treat the effluent from the discharge sump. The treated effluent is then discharged to the sanitary sewer.

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. The following interim corrective measures were implemented and pilot tests conducted in 1996.

Old Town VOC Plume

Extraction of groundwater from monitoring well MW58-95-18 for plume containment began in March 1996. MW58-95-18 is near the downgradient edge of the southern lobe of the Old Town plume west of Building 58. Groundwater is pumped from the well and piped to the Building 51 Fire trail Treatment System located east of Building 51. Groundwater monitoring well MW51-96-3 was installed downgradient of MW58-95-18 to monitor the effectiveness of pumping for plume containment.

Building 7 Hydrocarbon Plume

An ICM/pilot test consisting of groundwater pump-and-treat, recovery of free product (skimming), and soil venting, was started in June 1996. Groundwater was pumped from monitoring well MW6-95-14 in order to create a gradient to induce flow of free product to this well and MW7-92-16, located adjacent to MW6-95-14. A total of 163,000 liters (43,000 gallons) of contaminated groundwater was extracted and treated at the Building 46 Treatment System. A total of approximately 1.5 liters (0.4 gallons) of free product was removed

from MW7-92-16 by skimming. Chemical analysis quantified the recovered free product as kerosene.

After initial groundwater extraction lowered the water table, soil venting (soil vapor extraction) was started in MW6-95-14 to determine the contaminant mass recovery rates that could be achieved and to determine the radius of influence of the vapor extraction. The test was completed on June 27, 1996, at which time approximately 1440 cubic meters (48,000 cubic feet) of air had been extracted. Extracted soil gas was treated at the surface by two in-line granular activated carbon drums. Approximately 1.4 kilograms (3.2 pounds) of contaminant mass were removed during the 4 days of testing. A full-scale vapor extraction may be done in the future following consultation with regulatory agencies.

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. The backfill is a potential conduit for the migration of contaminated water from the surface to groundwater due to the lack of a surface seal. 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. To date, five slope-stability wells have been abandoned.
- If a slope-stability well is needed to monitor groundwater contamination, then the well is reconstructed into a monitoring well. To date, five slope-stability wells have been reconstructed into monitoring wells.

water plumes that could migrate off site or contaminate surface water. The extracted water is treated by granular activated carbon treatment systems prior to being recycled for industrial use on site or released to the sanitary sewer in accordance with the Berkeley Lab's treated groundwater discharge permit from EBMUD.⁶ Table 6-6 lists the volumes of contaminated water treated by the systems, both in 1996 alone and since the treatment systems were first placed in operation.

Treatment Systems

As described above, Berkeley Lab is using extraction wells and subdrains to control ground-

Table 6-6. Treatment of Contaminated Groundwater

Source of Contamination	Treatment System	Volume of Water Treated in 1996 (liters) ^a	Volume of Water Treated to Date (liters)
Building 37 VOC Plume	Building 37	935,107	1,776,497
Old Town VOC Plume	Building 46	4,707,866	12,574,043
Water Collected From Purging Monitoring Wells	Building 51 Firetrail	88,179	220,628
VOC Contaminated Hydrauger Effluent	Building 51 Hydraugers	3,221,527	7,907,906
Building 51 Subdrain System	Building 51 Sump	236,877	236,877
Old Town VOC Plume	Building 7 Trench	62,717	62,717
Total Volume Treated		9,252,273	22,778,668

^a 1 liter = 0.264 gallons

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Chapter 7

Sanitary Sewer

Background

Sanitary sewer discharge monitoring is divided into two major types: regulatory-based and DOE-based. Regulatory-based monitoring is generally termed self-monitoring, and is mandated in the wastewater discharge permits¹ granted to Berkeley Lab by the East Bay Municipal Utility District (EBMUD). Samples are analyzed for pH, total suspended solids, and chemical oxygen demand, with additional analyses for volatile organic compounds and metals included required in specific permit situations. 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.

DOE-based monitoring concentrates on radiological parameters. This type of monitoring is required by DOE guidance² and orders,³ but 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 thus making the California limits for discharge the same as the federal limits. Sanitary sewers are normally monitored for gross alpha, gross beta, iodine-125, and tritium. Gross alpha and gross beta measurements are used as a screening mechanism to determine if specific radionuclide measurements are required. Currently such monitoring is performed biweekly, and split samples are analyzed by both an outside laboratory and Berkeley Lab's in-house Radiation and Analytical Measurement Laboratory as a quality control measure.

Sanitary sewer discharge is monitored at two site outfalls, Hearst and Strawberry (see Figure 2-5 in Chapter 2 for locations). These two locations capture all wastewater leaving the site, although the discharge from Strawberry Sewer includes effluent from certain UCB fa-

cilities in Strawberry Canyon located both above and below the Berkeley Lab site. Additional details of the sewage system are given in the *Sanitary Sewer Systems* section of Chapter 2, *Introduction*. 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 EBMUD permits.

Wastewater Discharge Program

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

As the local Publicly Owned Treatment Works, EBMUD regulates all industrial discharges to its treatment facilities. The self-monitoring dates for 1996 identified by EBMUD for each Berkeley Lab permit are presented in Table 7-1. In addition, EBMUD has discretion to conduct its own monitoring at the site. Table 7-2 lists the dates and locations of these unannounced inspections by EBMUD.

Berkeley Lab's wastewater management program has an outstanding record. As a measure of the effectiveness, the Laboratory has not had any violations of its wastewater discharge permits for either technical reasons or exceedance of wastewater discharge limits since September of 1994. Operational changes in metals finishing and implementation of programs designed to reduce pollutant discharges have contributed significantly to this record.

Effective program management has also given Berkeley Lab flexibility to start several new undertakings in 1996 that reduce the amount

Table 7-1. Weeks for Required LBNL Wastewater Self-Monitoring in 1996

Hearst and Strawberry Outfalls	Building 77	Building 25
January 8	January 8	May 6
March 11	April 1	December 2
May 13	May 13 ^a	
June 10	August 19	
July 15	October 28	
November 4		

^a Required sampling for startup of new FTU added after permit issued

and cost of low-level radioactive or hazardous waste disposed to offsite facilities. In one effort, materials classified as waste only for their short-lived radiological isotope content are allowed to decay in place until they have reached insignificant levels and can be safely and legally disposed of to the sanitary sewer. This disposal activity takes place only at the HWHF. Another effort involved testing of water from the "water curtain" used in a paint spray booth to control atmospheric emissions to determine the level of hazardous constituents in the water. Results of the testing made it possible to dispose of this water to the sanitary sewer in compliance with discharge limits.

Yet another program enables selected researchers using short-lived radioactive isotopes in their laboratories to dispose of nonhazardous

liquid wastes to the sanitary sewers. Eligible research programs are selected on the following basis:

- knowledge of the isotopes used
- predictability of a process's routine waste streams, which are tested and characterized for chemical constituents and compliance with wastewater discharge limits.

Once selected, these research programs follow stringent sampling and characterization conditions.

Many of the requirements that EBMUD had mandated for Berkeley Lab in past years have been relaxed because of the Laboratory's outstanding ongoing compliance record. For example, EBMUD no longer requires calibration

Table 7-2. EBMUD Unannounced Sampling Inspections in 1996

Hearst and Strawberry Outfalls	Building 77	Building 25
January 17	February 8	February 8
February 26	August 14	July 3
April 8	August 22	
July 2		
August 13		

reports on the various equipment, such as flowmeters, that the Laboratory still calibrates. Similarly, the semi-annual flowmeter reading reports are no longer requested by EBMUD. Annual flow information is still gathered bi-weekly and provided to EBMUD as part of the annual renewal of the discharge permits.

Hearst and Strawberry Sewer Outfalls

Nonradiological

A major improvement in sanitary sewer monitoring occurred in 1996, when the Hearst monitoring station was connected to the Laboratory's communications network system. This connection allowed real-time remote viewing of station flowmeter information, giving monitoring personnel better control over the tracking of flow, and a quicker response in the event of instrumentation failure. Flowmeters provide vital information used to determine both wastewater charges from EBMUD and the accuracy of radiological sampling reports. The difficult terrain and the monitoring station's distance from telephone lines make a similar con-

nection of the Strawberry outfall to telemetry service not feasible at this time. However, the Laboratory currently uses redundant flowmeters to collect reliable backup information.

Six self-monitoring samples were taken from the Hearst and Strawberry outfalls during 1996. 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 the second and fourth sampling events. Table 7-3 illustrates the average annual levels of metals found in these two samples. Permit discharge limits are given for comparison.

Radiological

Hearst and Strawberry sewer outfalls are sampled continuously by automatic samplers that collect samples at half-hour intervals at Hearst and 20-minute intervals at Strawberry. The composite samples are collected biweekly by technicians. Analysis for iodine-125, gross alpha, gross beta, and tritium is performed by both the in-house laboratory and a state-certi-

Table 7-3. Average Annual Metals in Sewer Water Samples^a

Parameter	Hearst Station	Strawberry Station	Permit Limit
Cadmium	< 0.01 ^b	< 0.01 ^b	1
Chromium	0.032 ^c	< 0.05 ^b	2
Copper	0.22	0.31	5
Lead	0.041	0.0072	2
Nickel	< 0.1 ^b	< 0.1 ^b	5
Silver	< 0.1 ^b	< 0.034 ^c	1
Zinc	0.57	0.16	5
Total no. of samples	2	2	

^a All results in mg/l

^b Result was less than the practical quantification limit for this analysis

^c Some samples were non-detect. In order to compute an average, the practical quantification limit was used for the non-detect values

7-Sanitary Sewer

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

Regulatory guidelines used to evaluate radioactive sewer discharge data are not concentrations, as they are with surface water. Rather, the federal⁶ and state⁷ 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; and the limit for all other radioisotopes is a total of 3.7×10^{10} Bq (1 curie) per year.

Radioanalyses of Berkeley Lab's sewer wastewater for 1996 are summarized in Table 7-4. Tritium was often less than the minimum detectable activity. The total discharge of tritium

in wastewater was 6.68×10^9 Bq (0.18 Ci), and the total for other radioisotopes was 7.02×10^8 Bq (0.019 Ci). Both measures are down significantly from 1995 when the corresponding discharges were 4.81×10^{10} Bq (1.3 Ci), and 5.93×10^9 Bq (0.16 Ci), respectively. These values are well below allowable limits. Tritium, for example, was only 4% of the allowable limit. When present, tritium was found in greater concentrations at Strawberry than Hearst. Alpha, which comes from transuranic and heavy element research, was generally nondetectable at both sewers. Beta, including iodine-125 from biomedical research, was consistently low in both sewers.

The source of tritium discharged from the NTLF is wash water. This wash water is strictly

Table 7-4. Annual Radionuclide Analyses of Sewer Water Samples

Parameter	Concentration (Bq/l) ^a	
	Hearst Station	Strawberry Station
Alpha		
Average	< 0.15 ^b	< 0.14 ^b
Maximum	< 0.15 ^c	< 0.14 ^c
No. of Samples	26	26
Beta		
Average	0.33	0.26
Maximum	0.56	0.88
No. of Samples	26	26
Iodine 125		
Average	2.8	< 2.9 ^c
Maximum	9.6	8.3
No. of Samples	26	26
Tritium		
Average	< 16 ^b	35
Maximum	24	281
No. of Samples	26	26

^a 1 Bq = 27 pCi

^b Yearly average was less than the highest minimum detectable amount for the analyte at this site.

^c Maximum was less than the highest minimum detectable amount for the analyte at this site.

monitored. It is discharged only if analysis is below 7.4×10^7 Bq (2,000 μ Ci) per day. This threshold level is an LBNL-imposed administrative limit of 10% of the strictest regulatory limit mentioned above.

Building 25 Photo Fabrication Shop

The Photofabrication Shop in Building 25 manufactures electronic printed wiring boards and screen print nomenclature on panels as needed to support Berkeley Lab research and operations. Wastewaters containing metals and other hazardous materials from these operations are routed to a fixed treatment unit (FTU) prior to discharge to the sanitary sewer. The Building 25 FTU has successfully operated in batch mode since an upgrade in 1993.

In March of 1996, a reverse osmosis and ion exchange system for this unit came on line. This addition is a closed-loop recycling system that will reduce FTU wastewater volume between 50% and 90% per month. The system allows reuse of rinsewater and reduces contaminant loading, primarily copper, on the treatment unit.

In July, the Photo Fabrication Shop stopped general operations for facility improvements. During the upgrade, the shop was limited to small chemical milling and screening processes. Taking advantage of the reduced operations, the flowmeter required by EBMUD was repositioned to allow future calibrations to occur without removing the meter.

By December, the shop was gradually brought back on line. The two self-monitoring samples from this FTU for the year were taken despite the upgrade project. None of the sample analyses exceeded discharge limits set by EBMUD.⁸ All sampling performed by EBMUD also yielded results well within discharge limits.

Building 77 Fixed Treatment Unit

The Ultra High Vacuum Cleaning Facility (UHVCF) at Building 77 cleans metal parts that are used in research and support operations at Berkeley Lab. The cleaning process selected depends on the type of metal to be cleaning. Cleaning operations available include passivating, UHV cleaning, and vapor degreasing. Acid and caustic rinsewaters from these operations are routed to a nearby fixed treatment unit.

During 1996, the UHVCF completed several major changes. This facility reopened in March after undergoing a complete rebuilding. A temporary cleaning facility in adjacent Building 77H meet Berkeley Lab's interim cleaning demands.

During the upgrade project, a new 227-liter-per-minute (60-gallon per minute) FTU was installed. This unit can treat acidic rinsewaters containing metals and alkaline rinsewaters generated by the UHVCF. As part of EBMUD's approval of a permit modification for this unit, pilot testing following EBMUD procedures began in May. The unit functioned at full capacity during which time the effluent was sampled once per day for five consecutive days and analyzed for the same constituents required by the permit. All results were well below the discharge limits for each respective parameter.

As part of the approved permit, the old 57-liter per minute (15-gpm) treatment unit was left online to serve as a backup. The old unit has not operated since startup of the new unit.

In April, before the pilot testing, deionization units for rinsewaters at Building 77 were installed. They are expected to save 132 liters (35 gallons) per minute of waste from entering the treatment unit.

Four self-monitoring samples were taken from the Building 77 FTU during 1996. None of the sample analyses, nor any sampling done by EBMUD, exceeded any of the discharge limits in the permit.⁹

Treated Hydrauger Discharge

Since the latter half of 1993, Berkeley Lab has had permission from EBMUD to discharge treated groundwater (groundwater that had been contaminated with volatile organic compounds and tritium) to the sanitary sewer. The treatment process consists of passing the contaminated groundwater through a double-filtered carbon adsorption system. In 1996, EBMUD decided that this activity warranted a separate permit. Berkeley Lab received this new permit in September, initially for discharging treated groundwater from the Building 51 hydrauger system and Building 51 Fire Trail. Berkeley Lab later applied for a revision to add three areas to this permit:

- a collection trench at Building 7,
- a catch basin at Building 46, and
- a sump at the Building 51 Motor Generator Room.

EBMUD approved the request effective in late December 1996. One of the conditions for this discharge was a report on the volumes discharged and any contaminants found.

Similar groundwater treatment activity also occurs at Building 37, but the treated water is reused in cooling towers onsite and therefore does not need a permit from EBMUD.

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. Chapter 6, *Groundwater Protection*, contains further details on groundwater monitoring and treatment.

Chapter 8

Soil and Sediment

Background

Soil and sediment media can provide evidence indicative of past releases of either radiological or nonradiological contaminants to air or water. The retention properties of soil tend to leave a mark well after any release of contaminants has ceased. No 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.

The DOE guidance¹ recommends a graded approach to radiological surveillance of soil and sediment. Sampling helps establish baseline profiles, as well as provide opportunities for trend evaluation to assess long-term buildup. Details on Berkeley Lab's entire soil and sedi-

ment program are included in its *Environmental Monitoring Plan*.² Berkeley Lab conducts annual soil and sediment sampling. In 1996, sampling was done in September, prior to the rainy season. All sampling results are presented in Volume II, *Data Appendix*.

Soil Sampling

During 1996, soil samples from the top 2 to 5 centimeters (0.8 to 2.0 inches) of surface soils were taken on one occasion from three sampling locations around the site and at one off-site environmental monitoring station (see Figure 8-1). Locations were chosen to coincide with ambient air sampling stations for analytical comparison purposes. Samples were analyzed for gross alpha, gross beta, gamma, and tritium.

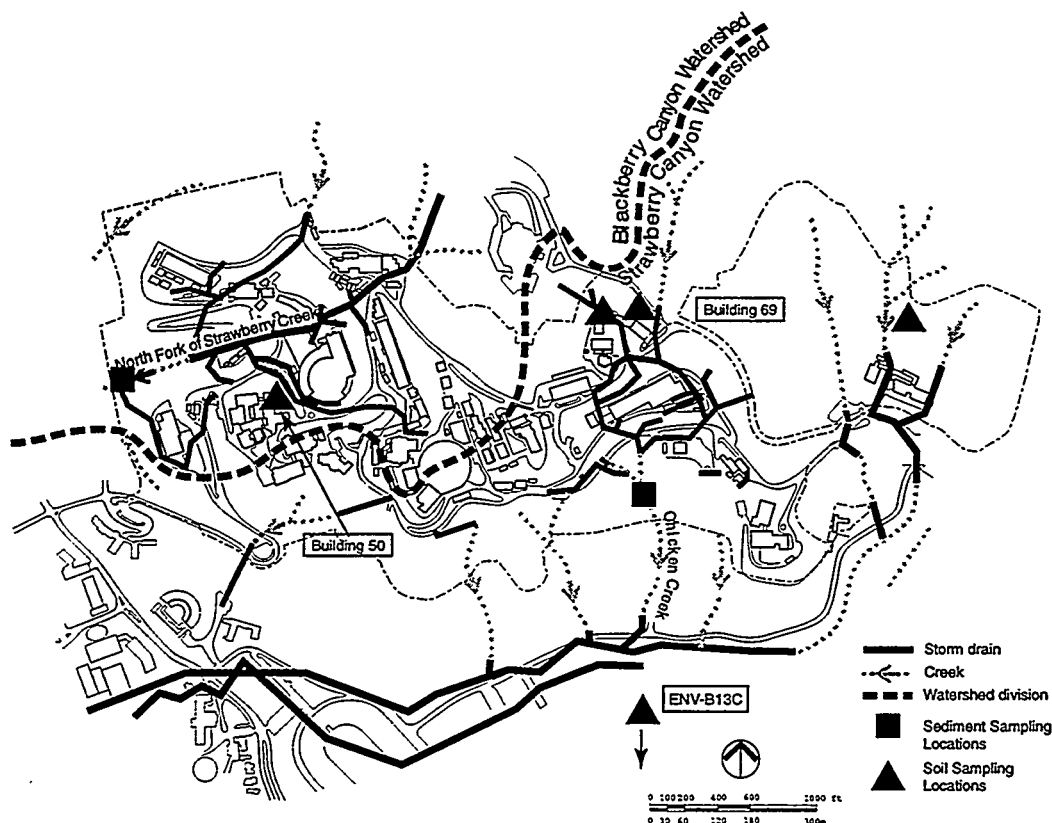


Figure 8-1. Soil and Sediment Sampling Sites

8-Soil and Sediment

Radiological levels were either not detected, or at or near detection limits at all locations. Table 8-1 summarizes the year's results. The detected gamma levels were determined to come from potassium-40, which is a common naturally-occurring background radioisotope. Analyses for metals indicated that all were well below regulatory levels³ (Table 8-2). Other soil analyses, all at nondetectable or insignificant concentrations, included pH, semivolatile organic compounds, oil and grease, and polychlorinated biphenyls.

Sediment Sampling

Sediment samples in 1996 were taken on one occasion from the creek beds of the North Fork of Strawberry Creek and Chicken Creek, both continually flowing creeks. Samples were analyzed for pH, metals, and a suite of toxic organics, including PCBs, diesel, and oil and grease. Samples were also analyzed for gross alpha, gross beta, gamma, and tritium. Tables 8-1 and 8-2 also include summaries of detectable radiological and nonradiological analytical results for both creek sampling locations.

Semivolatile organic compounds were either not detected or at insignificant levels for all locations. Levels for metals did not indicate contamination. Analysis for oil and grease at the creek outfalls revealed minor contamination. Both sides of the creek beds were sampled. The September 18 sample at Chicken Creek reported an oil and grease concentration of 1100 parts per million.

Berkeley Lab responded with several efforts upon receiving this result. The site was resampled on December 6. The analytical results from this second sample were down considerably to 250 ppm. The Laboratory also completed a detailed investigation of the site and found no evidence of any contamination. The nearest Laboratory building upgradient of the sampling location was Building 31. However, the sampling site was on the Chicken Creek bank opposite to the one where contamination would be expected if activity at this building was the contributing cause of this elevated reading. Since oil and grease contamination is commonly associated with motorized vehicles on roads and parking lots, it appears

Table 8-1. Soil and Sediment Sampling Results for Radionuclides in 1996^a

Sampling Location	Matrix	Tritium (Bq/g) ^b	Gamma ^c (Bq/g)
ENV-B13C	Soil	0.02	0.410
Building 50	Soil	0.0015	0.593
Building 69	Soil	0.00407	0.296
Building 85	Soil	<0.0011 ^d	0.270
Chicken Creek	Sediment	0.0033	0.276
N. Fork Strawberry Creek	Sediment	0.0054	0.444

^aGross alpha and gross beta were not detected in any samples during the year.

^b1 Bq = 27 pCi

^cAnalyte identified as Potassium-40

^dResult less than the minimum detectable activity for the analysis

Table 8-2. Soil and Sediment Sampling Results^a for Metals and pH from 1996^b

Parameter	Soil				Sediment		Regulatory Criteria (TTL ^c)
	ENV-B13C	B50	B69	B85	Chicken Creek	N. Fork Strawberry Creek	
Arsenic	1.7	8.3	5.8	1.8	5.0	4.8	500 mg/kg
Barium	7.7	148	110	76	128	98.5	10,000 mg/kg
Cadmium	ND ^d	ND	1.4	ND	1.6	ND	100 mg/kg
Chromium	11	43	86	10	66	34	2,500 mg/kg
Cobalt	ND	11	21	ND	123	7.4	8,000 mg/kg
Copper	18	40	38	18	37	24	2,500 mg/kg
Lead	47	16	ND	48	16	76	1,000 mg/kg
Mercury	ND	ND	ND	ND	ND	0.21 ^e	20 mg/kg
Nickel	15	39	66	14	56	23	2,000 mg/kg
Selenium	1.2	ND	4.1	1.3	3.8	ND	100 mg/kg
Vanadium	14	45	82	13	50	44	2,400 mg/kg
Zinc	135	113	75	128	200	100	5,000 mg/kg
pH	5.20	6.89	7.54	5.72	7.93	8.26	2 - 12.5 S.U.

^aUnits for results are mg/kg, except for pH where units are in S.U.

^bThe following parameters were not detected in any samples collected during the year: antimony, beryllium, molybdenum, silver, and thallium.

^cTotal Threshold Limit Concentration

^dND = nondetectable

^eOne sample was below the detection limit. Average was calculated using the detection limit for that sample.

that a likely explanation for this anomalous reading is the Laboratory's Cyclotron Road, which traverses the grade directly above the sampling site. No further action was taken at

this time because of the findings of the investigation. However, this location is expected to be sampled in future years to monitor any changes.

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Chapter 9

Vegetation and Foodstuffs

Background

Sampling 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 levels 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
- 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 below 0.001 mSv (0.1 mrem), a minimal vegetation and food stuff surveillance program is required.¹ Using very conservative assumptions regarding public consumption of locally grown vegetation and foodstuffs, Berkeley Lab estimated the maximum individual dose from the radionuclides at well below the capping limit for a minimal monitoring program. Tritium air emissions were identified as the only potentially significant contributor to these pathways.

The principal source of airborne tritium emissions is the National Tritium Labeling Facility. Tritium emissions are approximately 90% tritiated water vapor and 10% tritiated hydrogen gas. The relative dose from an exposure to tritiated hydrogen gas is much less than from an equal exposure to tritiated water. Never-

theless, in modeling and dose calculations, the Laboratory conservatively assumes that 100% of the emissions are tritiated water vapor.

Tritiated water vapor released to the environment readily mixes and exchanges with atmospheric water, such as precipitation, fog and vapor, and other sources of environmental water such as plant water, surface water, and soil water. Within plants, tritium exists as either free-water tritium or organically bound tritium. Free-water tritium, or unbound tritium, is defined as the portion of tritium that can be removed from the plant by azeotropic distillation or freeze-drying. The majority of free-water tritium in plants exists as tritiated water. Organically bound tritium is defined as the tritium fraction that remains after free-water tritium is removed and consists primarily of tritium that is chemically bonded to organic compounds such as cellulose and sugars.

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. The following four sets of data were collected at and near the site over the course of the year:

- free-water tritium levels in tree foliage samples in preparation for a tree removal project for fire prevention and control
- free-water tritium in goats' milk, excreta, and feed pasturage from a goat herd that grazed onsite for fire prevention and control
- free-water and organically bound tritium in trees as a function of distance from the NTLF stack
- free-water and organically bound tritium in fruit grown from trees in nearby residential yards.

9-Vegetation and Foodstuffs

The sections that follow discuss the collection of vegetation and foodstuff samples and the analytical results.

Trees

Berkeley Lab manages onsite trees and brush as part of an ongoing fire prevention and control program. Eucalyptus and pine trees, which burn readily, are strategically removed so that less combustible and more native trees such as redwood and oak may establish themselves. In February, 68 tree foliage samples were collected at various locations around the site to determine the range of tritium concentrations in the moisture within trees. Figure 9-1 illustrates the tree sample locations. The results of this sampling were used in part in evaluating feasible and cost-effective disposal alternatives

for a project that removed trees from nearby areas later in the year. The removed trees were shipped off site for conversion into paper products after confirming that regulations allowed the unrestricted release of tree material containing tritium concentrations at the levels measured.

At each sampling location, multiple foliage samples were collected and analyzed. Average tritium concentrations in foliage exceeded the analytical minimum detectable amount only in trees immediately adjacent the NTLF stack and at one location adjacent Building 77. Samples from near the NTLF stack had individual sample tritium activities ranging from 1060 to 4410 Bq/l (28,600 to 119,000 pCi/l). The samples from the tree near Building 77, which is 150 meters southeast from the tritium

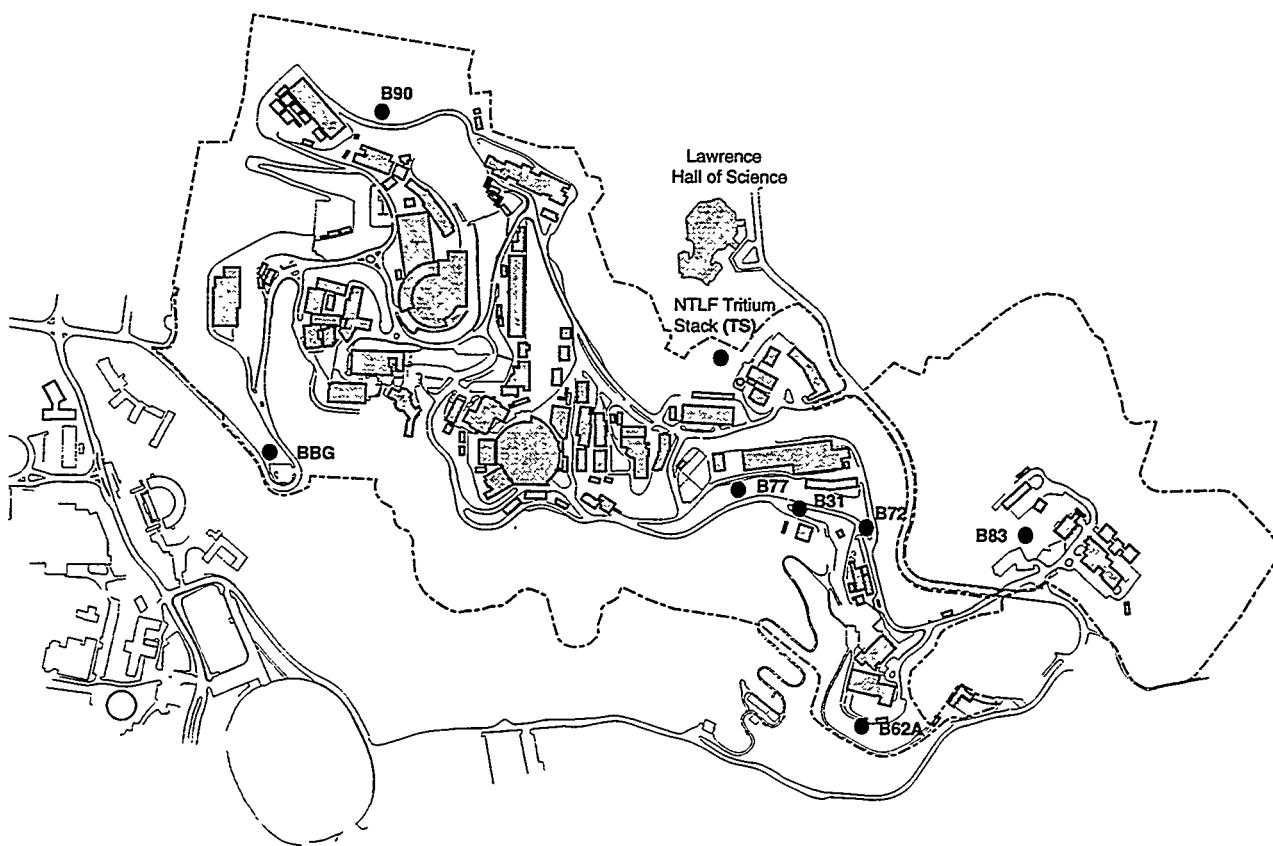


Figure 9-1. Tree Foliage Sampling Locations

stack, ranged from 160 to 330 Bq/l (4,440, to 8,860 pCi/l). Table 9-1 shows the maximum and average tritium levels for each location. There is no appropriate standard of comparison for these concentrations of tritium. For example, the US/EPA drinking water limit⁴ (740 Bq/l or 20,000 pCi/l) is not applicable since the trees are not used as a source of human water consumption. A more meaningful measure of significance is the dose from exposure to tritium in the wood compared to established standards.

To get a better understanding of the risk associated with removed trees, Berkeley Lab estimated the maximum public dose from tritium from the release and use of the wood. The assessment considered several plausible scenarios, including the one selected for the removed trees; converting the tree wood to paper products. Using the range of tritium results described above, an average tritium concentration of 370 Bq/l (10,000 pCi/l) in tree water was assumed. The length of exposure was estimated based on the number of trees that the Laboratory expected to remove. The maximum dose to a pulp mill worker from inhaling and being immersed in tree water va-

pors produced by the removed trees was estimated at 0.00005 mSv (0.005 mrem), or much less than 1% of the DOE standard.⁵ As a result of these estimates, all trees were authorized for removal with the exception of a grove directly adjacent to the NTLF stack.

Goats' Milk, Excreta, and Feed Pasturage

Berkeley Lab has used goats to reduce French broom and other shrubs as well as certain grasses from the site for several years. The purpose of this activity is fire prevention and control. In April and May, 1996, a herd of goats, varying from 50 to 300, grazed for a total of 18 days at five onsite locations and one offsite location. The goats grazed in controlled enclosed areas, none of which included the area within 100 meters of the NTLF stack. Shrubs comprised the majority of the plant matter consumed by the herd, with grasses accounting for a small fraction of the goats' diet. Figure 9-2 illustrates the grazing locations and patterns of goat herd movement. Grazing periods varied from one to four days per location, and the locations grazed ranged from 5,000 to 20,000 square meters (5,980 to 23,900 square yards)

Table 9-1. Summary of Free Water Tritium Levels in Trees
Sampled from Various Onsite Locations

Location:	Code in Figure 9-1	Number of Samples	Tritium (Bq/l) ^a	
			Average	High
Tritium Stack	TS	20	2,150	4,410
Building 31	B31	6	20	91
Blackberry Gate	BBG	10	<15 ^b	34
Building 62A	B62A	6	<20 ^b	56
Building 72	B72	6	<16 ^b	29
Building 77	B77	6	240	330
Building 90	B90	8	<16 ^b	30
Building 83	B83	6	<17 ^b	34

^a1 Bq = 27 pCi

^bAverage was less than the highest minimum detectable amount for the analyte at this site.

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in area. The grazing goats provided an excellent opportunity to measure tritium levels in goat excreta and milk while they consumed onsite vegetation. The owner of the goat herd stated that these goats do not provide milk sold for human consumption.

While the goats were grazing, excreta, milk, and feed pasturage were collected in 39 samples and analyzed for free-water tritium. A summary of the maximum and average values for excreta, milk, and feed pasturage are shown in Table 9-2. The excreta samples when the goats were at the Plot 6 location near the Lawrence Hall of Science contained the greatest tritium

levels (56 Bq/l or 1,519 pCi/l). The maximum tritium level for feed pasturage was 37 Bq/l (992 pCi/l) for grass samples collected from Plot 6. In comparison, goat milk was sampled five times: once at the first grazing site and four times at the fourth site (two of these samples were collected for quality assurance purposes). The initial goat milk sample contained less than the minimum detectable amount of tritium. The four milk samples collected at Plot 4 averaged 8.2 Bq/l (221 pCi/l), with a maximum level of 15.0 Bq/l (404 pCi/l). All tritium levels were less than 10% of the US/EPA drinking water limit,⁶ and the milk levels were about 2% of this limit.

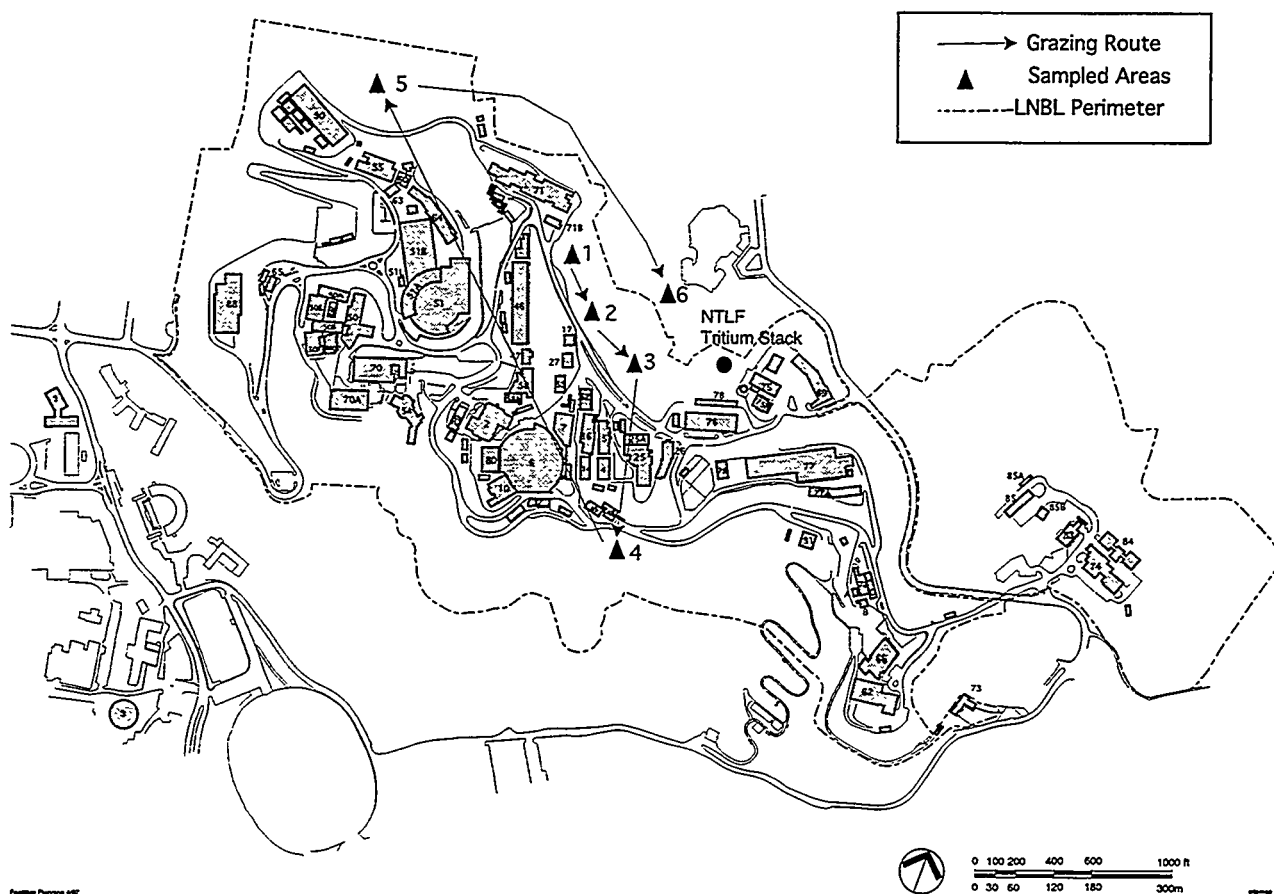


Figure 9-2. Goat Grazing Route and Sampling Locations

Table 9-2. Summary of Free Water Tritium Levels in Samples Collected During Onsite Goat Grazing

Location:	Number of Samples	Tritium (Bq/l) ^a	
		Average	High
Milk	5	7.0	15
Excreta	14	22	56
Pasturage	20	14	37

^a1 Bq = 27 pCi

Tritium as a Function of Distance from NTLF Stack

Vegetation and tree sampling was carried out in August and September to determine the distribution of tritium in vegetation with distance from the NTLF stack. The data help establish baseline values for tritium and provide infor-

mation for future modifications to the vegetation monitoring program.

The Laboratory collected and analyzed 86 foliage samples onsite for free-water tritium. Samples were collected at 50-meter intervals along two transects that intersected at the NTLF stack (see Figure 9-3). Two additional samples

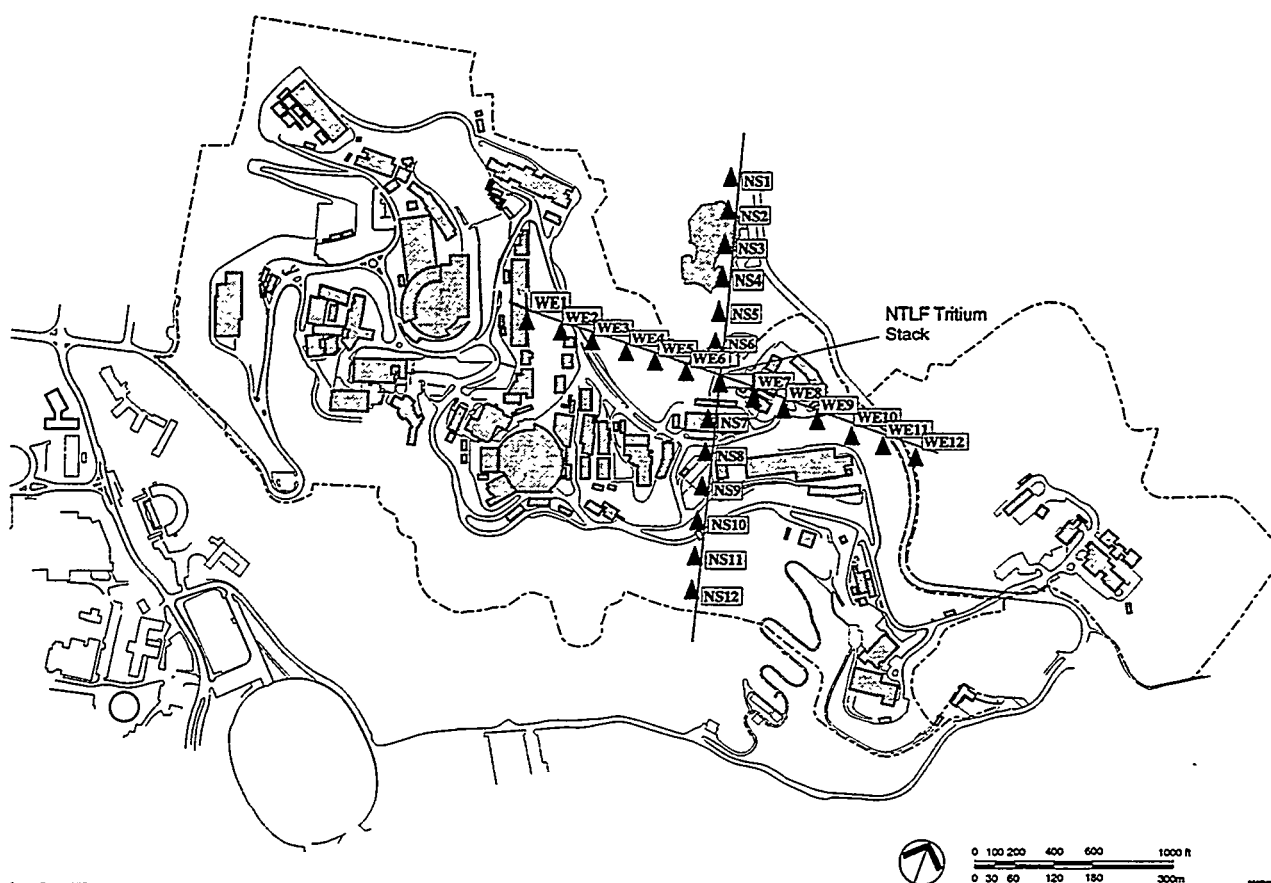


Figure 9-3. Tree and Vegetation Sampling Transect

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were collected for comparison purposes at a remote offsite location near the Berkeley Marina, approximately 4 kilometers (2.5 miles) west of Berkeley Lab. A maximum free-water tritium level of 4750 Bq/l (128,000 pCi/l) was measured at location TS, which is immediately adjacent to the NTLF exhaust stack. Tritium levels decreased rapidly as a function of distance from the stack, as indicated by the

values at 50 meters away being less than 740 Bq/l (20,000 pCi/l). In all directions this represented a decrease of between 5- and 15-fold in the concentrations.

Table 9-3 shows the maximum and average tritium values at each transect location. Comparing these results with those from the tree sampling discussed earlier (Table 9-1) in this

Table 9-3. Summary of Free Water Tritium Levels in Vegetation as a Function of Distance from the NTLF Stack

Location:	Number of Samples	Tritium (Bq/l) ^a	
		Average	High
NS-1	3	52	53
NS-2	3	64	80
NS-3	3	100	110
NS-4	3	100	110
NS-5	3	130	140
NS-6	3	300	310
NS-7	2	260	260
NS-8	3	11	12
NS-9	2	38	39
NS-10	4	25	31
NS-11	2	19	20
NS-12	3	6.2	8.2
TS	4	2,900	4,750
WE-1	3	21	25
WE-2	3	29	37
WE-3	4	160	180
WE-4	4	430	450
WE-5	4	510	550
WE-6	4	650	670
WE-7	6	190	290
WE-8	3	47	50
WE-9	6	30	51
WE-10	3	12	14
WE-11	3	8.8	11
WE-12	3	12	19
Remote Samples ^b	2	13	16

^a1 Bq = 27 pCi

^bRemote samples collected near Berkeley Marina, approximately 4 kilometers west of Berkeley Lab

chapter shows a consistent relationship in both the magnitude and distribution patterns of tritium.

Additionally, 31 tree samples were collected and analyzed for organically bound tritium. Organically bound tritium is incorporated into the

wood over the life of the tree and is therefore reflective of both current and historical emissions. The samples collected for organically bound tritium were obtained from the same locations used for collecting the samples for free-water tritium measurements (see Figure 9-3), except for 4 samples collected from trees

Table 9-4. Summary of Organically Bound Tritium Levels in Vegetation as a Function of Distance from the NTLF Stack

Location:	Number of Samples	Tritium (Bq/g) ^a	
		Average	High
NS-1	1	1.1	—
NS-2	1	ND ^b	—
NS-3	1	2.3	—
NS-4	1	2.6	—
NS-5	1	3.8	—
NS-6	1	2.4	—
NS-7	1	0.90	—
NS-8	1	0.80	—
NS-9	1	ND	—
NS-10	2	<0.36 ^c	0.48
NS-11	1	0.59	—
NS-12	1	0.58	—
TS	1	19	—
WE-1	1	ND	—
WE-2	1	ND	—
WE-3	1	1.1	—
WE-4	1	9.3	—
WE-5	1	13	—
WE-6	1	7.7	—
WE-7	1	0.49	—
WE-8	1	2.6	—
WE-9	2	ND	ND
WE-10	1	ND	—
WE-11	1	ND	—
WE-12	1	ND	—

^a1 Bq = 27 pCi

^bND = nondetectable

^cAverage was less than the highest minimum detectable amount for the analyte at this site.

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located off the transect and near the Building 75 Corporation Yard (only one of these four samples indicated a detectable amount of tritium at 0.56 Bq/g or 15.1 pCi/g). Table 9-4 shows the organically bound tritium results for the transect sampling locations. The maximum result for organically bound tritium was 19.4 Bq/gram (524 pCi/gram) at the base of the NTLF's tritium stack. As with the free-water, organically bound tritium decreased with distance from the stack.

Nearby Residential Fruit Trees

Fruit samples from four residential yards were collected in December 1996 and analyzed for tritium. Three of the residential yards were located north of the Lawrence Hall of Science, and the fourth yard was located in Albany. Albany is approximately 5 kilometers from the site and is considered outside the range of detectable environmental impacts from Berkeley

Lab tritium emissions. Samples were processed and analyzed for both free-water tritium and organically bound tritium. All results were below the minimum detectable amount for both free-water and organically bound tritium.

Conclusions

Sampling of vegetation and foodstuffs is not required under any applicable environmental regulations. Berkeley Lab undertakes voluntary sampling efforts such as this as a way of better understanding the integrated impact of its operations on all media in the surrounding environment and as a verification tool for its overall dose assessment program. This assessment program, which will be presented in Chapter 11, *Radiological Dose Assessment*, includes vegetation and foodstuffs as one of the contributing pathways in determining the overall impact from Berkeley Lab's airborne radionuclides.

Chapter 10

Special Studies

Introduction

Berkeley Lab coordinated three special environmental monitoring studies in 1996. The first study involved a continuation of the comprehensive preoperational monitoring at the site of the replacement Hazardous Waste Handling Facility. The second study assessed tritium in soil water. The last study investigated contaminant concentrations within the sediment contained in stormwater catch basins around the facility. This section presents 1996 results for each of these studies.

Building 85 Preoperational Monitoring

Background

General construction of the replacement Hazardous Waste Handling Facility was completed in 1996. This new building, designated as Building 85, replaces the former waste facility located in Buildings 75 and 69. The Department of Energy, under DOE Order 5400.1,¹ requires that an environmental study be conducted prior to startup of a new site, facility, or process to help determine the impact of new activities on the environment. The results generated by the preoperational study provide information to characterize the site by establishing preexisting chemical and radiological background levels as a baseline for environmental monitoring and surveillance during the operation, and eventual decommissioning, of the facility.

The HWHF Preoperational Sampling and Analysis Plan (SAP)² from February 1995 outlined the objectives of the sampling, specified the sampling locations and frequency, and established a schedule to fulfill the requirements of the DOE order. A *Quality Assurance Project Plan*³ for the SAP outlined the quality assur-

ance/quality control measures needed to ensure representative and valid sampling results.

The sampling plan originally defined a program for detecting radiological and nonradiological constituents in air, stormwater, sanitary sewer, sediments, groundwater, and soil. Several changes were made to the sampling plan in 1996 based on results from three factors: previous year's sampling, local construction activities, and unusual weather conditions. Changes in the plan will be mentioned in the following discussions on affected media, except for sediment. Sediment sampling did not occur during 1996 due to construction of the nearby Human Genome Facility.

This section limits discussion of preoperational monitoring activities to that performed in 1996. Results for the entire preoperational study are addressed in an October 1996 report entitled *Baseline Report for Preoperational Monitoring of Hazardous Waste Handling Facility — B85*.⁴

1996 Sampling Results

Overall in 1996, 20 radiological samples were taken from groundwater, air, and soil boring locations, providing 72 analytical results. Of these analyses, 64 were below the analytical detection limit. Ninety-six nonradiological samples were taken from groundwater, soil borings, and stormwater. Some samples were analyzed for up to 87 different organic species. In total, 4428 species analyses were performed. Excluding results for pH, nearly 97% of these analyses, or 4280 analyses, were below the detection limit of the analytical method. A complete listing of all analytical results for 1996 is given in Volume II, *Data Appendix*.

Sampling locations used during the 1996 phase of the HWHF preoperational study are shown in Figure 10-1.

Air

Six monthly radiological air samples were taken from one site location, AA-B, in 1996. Radioactive samples were analyzed for gross alpha, gross beta, gamma, iodine-125, and tritium. Results are presented in Table 10-1.

The 1996 results compared well with the 1995 analyses. Gross alpha was seen in one out of five samples. Alpha emitters were probably due to uranium isotopes such as uranium-238 and uranium-235 present in the soil. Gross beta emitters were detected in three samples out of five, and are also likely attributable to naturally occurring uranium isotopes present in the soil. In both cases, such emitters were likely due to the dust created by construction activi-

ties from both the replacement Hazardous Waste Handling Facility and the adjacent Human Genome Laboratory (Building 83 in Figure 10-1). The concentrations for gross alpha and beta emitters are consistent with the low levels recorded elsewhere at the site in the routine monitoring program and reported in Chapter 4, *Air Quality*.

Sample analyses for tritium in the form of water vapor and radioiodines were both nondetectable for all six samples.

Stormwater

Stormwater effluent sampling took place at three surface drainage points, labeled STW-A, STW-B, and STW-C on Figure 10-1. The off-

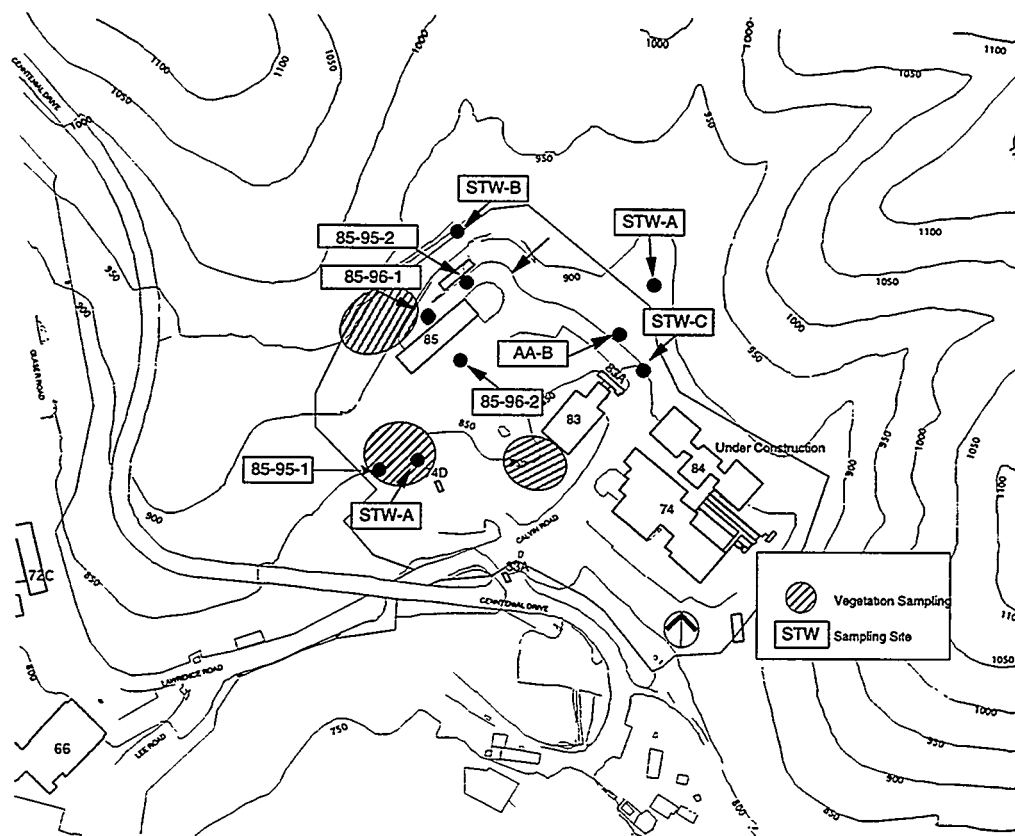


Figure 10-1. 1996 Building 85 Preoperational Sampling Locations

Table 10-1. Air Sampling Results at Station AA-B for 1996^a

Parameter	Maximum (Bq/m ³) ^b	Minimum (Bq/m ³)	Average (Bq/m ³)	Number of Samples
Gross alpha	0.00037	ND ^c	ND	5
Gross beta	0.0037	0.00037	0.00148	5

^aRadioiodines and tritium were not detected in any of the six samples collected during the year.

^b1 Bq = 27 pCi

^cND = nondetectable

site sample point, STW-D, was eliminated from the study by construction of the new Human Genome Laboratory. Twenty-eight grab samples were gathered from these three locations.

Another modification to the SAP occurred in regard to the sampling frequency. Due to the high number of storms that occurred during the rainy season, stormwater sampling could not always meet the goal of a 72-hour dry period prior to a major storm event. Sampling was instead performed whenever adequate flow was detected at the designated stormwater sampling locations.

Samples were analyzed for total petroleum hydrocarbons as diesel and gasoline (TPH-D and TPH-G), oil and grease, benzene/toluene/ethyl benzene/xylenes (BTEX), volatile com-

pounds, semivolatile compounds, metals, total dissolved solids, total suspended solids, electrical conductivity, and pH. No radiological samples were taken, since 1995 sampling activities had sufficiently characterized the site.

Overall, the sampling results for 1996 are consistent with those from 1995. Sampling results for detectable analytes at station STW-A are presented in Table 10-2. The average pH for all sampling events was slightly basic (7 is neutral), although not unusual for the area. The analysis for metals indicated that selenium was detected in one of the three samples, at about one-fourth of the federal drinking water standard.⁵ Vanadium was detected twice, although no standard exists for this compound. All other metals were below the detection limit. The average total suspended solids was very low.

Table 10-2. Stormwater Sampling Results from Location STW-A for 1996^a

Parameter	Maximum	Minimum	Average	Number of Samples
Oil and Grease	3 ppm	ND ^b	1 ppm	3
Metals (highest concentration)	0.026 ppm (selenium)	ND	0.0009 ppm (selenium)	3
Total Suspended Solids	1.2 ppm	ND	0.7 ppm	3
pH	8 SU	8 SU	8 SU	3

^aThe following parameters were not detected in any samples collected during the year: TPH-D and TPH-G, BTEX, volatile organic compounds, and semivolatile organic compounds.

^bND = nondetectable

Table 10-3. Stormwater Sampling Results from Location STW-B for 1996^a

Parameter	Concentration	Number of Samples
Metals (highest concentration)	0.071 ppm (zinc)	1
Total Suspended Solids	44.5 ppm	1
pH	8.2 SU	1

^aThe following parameters were not detected in the one sample collected during the year: TPH-D and TP oil and grease, volatile organic compounds, and semivolatile organic compounds.

Only one sample was collected at location STW-B. Results are summarized in Table 10-3. This sample returned non-detectable results for TPH-D and TPH-G, BTEX, oil and grease, and volatile and semivolatile compounds. Of this set, oil and grease and several volatile compounds had been detected in prior year sampling. The pH was slightly basic. Metals analysis, compared to federal drinking water standards,⁶ identified chromium (36%), lead (18%), copper (5.8%), zinc (1.4%), and vanadium (no standard for vanadium). This was a drop from the nine metals detected in 1995. Total suspended solids were again low.

Table 10-4 shows the results of sampling at STW-C. The average pH was very similar to that found at STW-A and STW-B. Arsenic at 4% of the federal drinking water standard and zinc at 1.0% were the only detectable metals.

In 1995, sampling detected the presence of four metals. The average total suspended solids were extremely low.

Groundwater

Four monitoring wells were sampled for groundwater quality. Each well was sampled for radioactive and nonradioactive constituents. The radioactive analyses included gross alpha, gross beta, gross gamma, and tritium. The non-radioactive analyses included total petroleum hydrocarbons (TPH-D and TPH-G), volatile compounds, semivolatile compounds, and metals. Analytical results from these locations are summarized in Tables 10-5 through 10-8.

For radiological parameters, only the gross beta samples from location 85-95-1 were at or above the analytical detection limits. All samples

Table 10-4. Stormwater Sampling Results from Location STW-C for 1996^a

Parameter	Maximum	Minimum	Average	Number of Samples
Oil and Grease	2.1 ppm	ND ^b	1 ppm	3
Metals (highest concentration)	0.053 ppm (zinc)	ND	0.018 ppm	3
Total Suspended Solids	3.6 ppm	0.7 ppm	2.1 ppm	3
pH	9.2 SU	7.7 SU	8.23 SU	3

^aThe following parameters were not detected in the samples collected during the year: TPH-D and TPH-G, BTEX, volatile organic compounds, and semivolatile organic compounds.

^bND = nondetectable

Table 10-5. Groundwater Sampling Results from Location 85-95-1 for 1996^a

Parameter	Maximum	Minimum	Average	Number of Samples
TPH-D	54 ppb	ND ^b	15 ppb	3
Metals (highest concentration)	0.004 ppm (arsenic)	ND	0.002 ppm	2
Gross beta	0.15 (Bq/l)	ND	0.037 (Bq/l)	4

^aThe following parameters were not detected in the samples collected during the year: TPH-G, volatile organic compounds, semivolatile organic compounds, gross alpha, gamma, and tritium.

^bND = nondetectable

for gross alpha, gamma, and tritium at all locations and gross beta at the three remaining locations were below detection. This pattern of non-detectable results is consistent with 1995 data.

Also consistent with the previous year, metals were detected slightly more in site well 85-95-2 than in 85-95-1, although in neither case was the presence significant. With 1996 being the first year for sampling at the other two site wells, similar comparisons could not be made. Levels of metals at all four wells were far below federal drinking water standards.⁷ Arsenic was the highest ranking metal at only 8% of this standard.

The remaining parameters analyzed indicated no detectable or unusual presence in ground-

water. Overall for the groundwater portion of the preoperational sampling program, analyses were well within the range of other site well sample analyses for 1996.

Soil/Borings

Two of the groundwater monitoring wells mentioned above first functioned as boreholes for the soil sampling portion of the preoperational monitoring program.

During the boring of these wells (85-96-1 and 85-96-2 in Figure 10-1), samples were taken at approximately 1.5-meter (5-foot) intervals. Only the first interval was analyzed for radiological constituents. Nonradiological constituents were analyzed at all depths. The results are summarized in Tables 10-9 and 10-10. Al-

Table 10-6. Groundwater Sampling Results from Location 85-95-2 for 1996^a

Parameter	Maximum	Minimum	Average	Number of Samples
Semi-volatile Organic Compounds	8 ppb	ND	1.6 ppb	5
Metals (highest concentration)	0.01 ppm (copper)	ND	0.0025 ppm	4

^aThe following parameters were not detected in the samples collected during the year: TPH-D and TPH-G, volatile organic compounds, gross alpha, gross beta, gamma, and tritium.

^bND = nondetectable

Table 10-7. Groundwater Sampling Results from Location 85-96-1 for 1996^a

Parameter	Maximum	Minimum	Average	Number of Samples
Volatile Organic Compounds	2.3 ppb	ND ^b	0.51 ppb	4

^aThe following parameters were not detected in the samples collected during the year: TPH-D and TPH-G, semivolatile organic compounds, metals, gross alpha, gross beta, gamma, and tritium.

^bND = nondetectable

though the locations for soil and groundwater sampling are the same, the soil results are prefixed with "BS-" to distinguish two different types.

At the first well boring, BS-85-96-1, tritium was detected in the soil at a low concentration of 0.010 Bq/kg at a depth of 1.77 m (5.8 feet). As the boring continued, metals were detected throughout its depth at concentrations consistent with native soils and well below any regulatory levels of concern. Metals detected included arsenic, barium, cadmium, chromium, cobalt, copper, nickel, selenium, vanadium, and zinc. The average pH was 7.9. All other sample analyses were non-detectable.

At the second well boring, all radiological analyses from the first level of testing (1.31 meters or 4.3 feet) showed no detectable levels. Of interest with samples from subsequent depths was the average concentration for total petroleum hydrocarbon for diesel (TPH-D) of

11.6 parts per billion. Because of this reading, Berkeley Lab continued to monitor the well subsequent to the initial boring. However, ensuing TPH-D analyses in the groundwater were nondetectable. Berkeley Lab's investigation determined that soil slightly contaminated with diesel was used as earth backfill during construction, but that the levels of contamination were significantly lower than those required for remediation.

Except for the TPH-D analyses, the soil-boring analyses were well within the range of similar analyses from elsewhere around the site. The same suite of metals were detected, with the addition of lead, at levels consistent or less than found during the first boring.

Soil Water Sampling for Tritium

The second nonroutine monitoring undertaking by Berkeley Lab considered soil water. Soil water is defined as water contained within the

Table 10-8. Groundwater Sampling Results from Location 85-96-2 for 1996^a

Parameter	Maximum	Minimum	Average	Number of Samples
Metals (highest concentration)	0.01 ppm (copper)	ND ^b	0.005 ppm	2

^aThe following parameters were not detected in the samples collected during the year: TPH-D and TPH-G, volatile organic compounds, semivolatile organic compounds, metals, gross alpha, gross beta, gamma, and tritium.

^bND = nondetectable

Table 10-9. Soil Boring Results from Location BS-85-96-1 for 1996^a

Parameter	Concentration	Number of Samples
Metals @ 3.2 meters (highest concentration)	130 mg/kg (barium)	1
Metals @ 4.8 meters (highest concentration)	140 mg/kg (vanadium)	1
Metals @ 6.4 meters (highest concentration)	174 mg/kg (barium)	1
Metals @ 9.2 meters (highest concentration)	162 mg/kg (nickel)	1
pH	8.35 SU (max) 7.9 SU (avg) 7.69 SU (min)	4
Tritium	0.01 (Bq/kg)	1

^aThe following parameters were not detected at any levels of the boring: TPH-D and TPH-G, oil and greas volatile organic compounds, semivolatile organic compounds, gross alpha, gross beta, and radioiodines.

subsurface soil in the unsaturated zone above the water table.

There is no regulatory standard or requirement for soil water. Therefore, it is important that these values not be equated to standards from other media such as water or air because the physical characteristics associated with each medium vary considerably. Knowledge of concentrations of contaminants within soil water is very useful in understanding, explaining, and predicting the exchange of these materials as they pass from one of the more conventional media (i.e., air, water, and soil) to another.

Samples of soil water are collected using specialized devices known as vacuum lysimeters. Soil water in this zone is at a pressure less than atmospheric, so it is not readily free to flow compared to groundwater and surface water. In fact, suction or vacuum must be used to draw the soil water into the lysimeters.

Berkeley Lab operates numerous vacuum lysimeters in the area referred to as the Corporation Yard: the area that comprises Building

69 and the Building 75 complex, including the National Tritium Labeling Facility. Tritium is the only contaminant evaluated by this effort. Since tritium in soil water may percolate to the groundwater, knowledge of the lateral distribution of tritium and its rate of migration within the soil are important.

Berkeley Lab has in place shallow lysimeters at a depth of 0.6 to 0.9 meters (2 to 3 feet) below the ground surface at 19 locations and 1.8 meters (6 feet) below ground at one additional location. In 1996, multiple lysimeters were installed at five locations near the Building 75 complex to monitor changes in tritium concentrations with depth and to determine how the tritium in the soil water migrates to the groundwater. The locations of the lysimeters are shown in Figure 10-2. Those sampling points labeled 75-96-xx (xx refers to sample location number) and *TS-1* identify the locations of the multiple lysimeters.

Berkeley Lab samples the shallow lysimeters in the winter and spring months. At other times of the year, the soil at that depth does not con-

Table 10-10. Soil Boring Results from Location BS-85-96-2 for 1996^a

Parameter	Concentration	Number of Samples
TPH-D	38 ppb (max) 11.6 ppb (avg)	5
Oil and Grease	48 ppm (max) 9.6 ppm (avg)	5
Metals @ 4.4 meters (highest concentration)	117 mg/Kg (vanadium)	1
Metals @ 7.5 meters (highest concentration)	103 mg/Kg (vanadium)	1
Metals @ 10.5 meters (highest concentration)	111 mg/Kg (vanadium)	1
Metals @ 12.1 meters (highest concentration)	171 mg/Kg (barium)	1
Metals @ 15.1 meters (highest concentration)	142 mg/Kg (barium)	1
pH	8.55 SU (max) 7.99 SU (avg) 7.73 SU (min)	5

^aThe following parameters were not detected at any levels of the boring: TPH-G, volatile organic compounds, semivolatile organic compounds, gross alpha, gross beta, radioiodines, and tritium.

tain sufficient soil water to gather adequate samples. At the sites with multiple lysimeters, successful samples were extracted from the deeper depths when the Laboratory initiated sampling at these locations during the summer months of 1996. Tritium concentrations detected in all soil water samples collected in 1996 are summarized in Table 10-11.

The highest tritium concentrations found in soil water came from lysimeters located nearest the NTLF stack. Shallow lysimeter VL-8, located less than 20 meters (60 feet) northwest of the stack, reached a maximum tritium concentration in soil water of 1382 Bq/l (37,310 pCi/l), while the multiple-depth lysimeters sited between Buildings 75 and 75A gave the overall highest readings in this dense network of samplers. The lysimeter at location 75-96-4 collecting samples at the 4.5-meter (15-foot) depth recorded a maximum of 3164 Bq/l (85,428 pCi/l) on one occasion. At the same time, the tri-

tium concentration at the 2.3-meter (7.5-foot) depth was only about 50% of this reading. Possible explanations for these results that the Laboratory is exploring are a leak in either the sanitary sewer line located between these two depths or an upgradient holding tank for a shower used in Building 75 for decontamination activities.

Results also showed a drastic decline with distance from the stack. Lysimeters at the Berkeley Lab fenceline did not exceed tritium concentrations of 500 Bq/l (13,500 pCi/l), or about 15% of the maximum recorded at site 75-96-4. The three lysimeters in the vicinity of the Lawrence Hall of Science all remained below tritium concentrations of 100 Bq/l (2,700 pCi/l), or only 3% of the maximum level seen less than 125 meters (400 feet) to the southeast. Sampling results showed only minor variations across the sampling events of the year. Sampling is expected to continue in coming years,

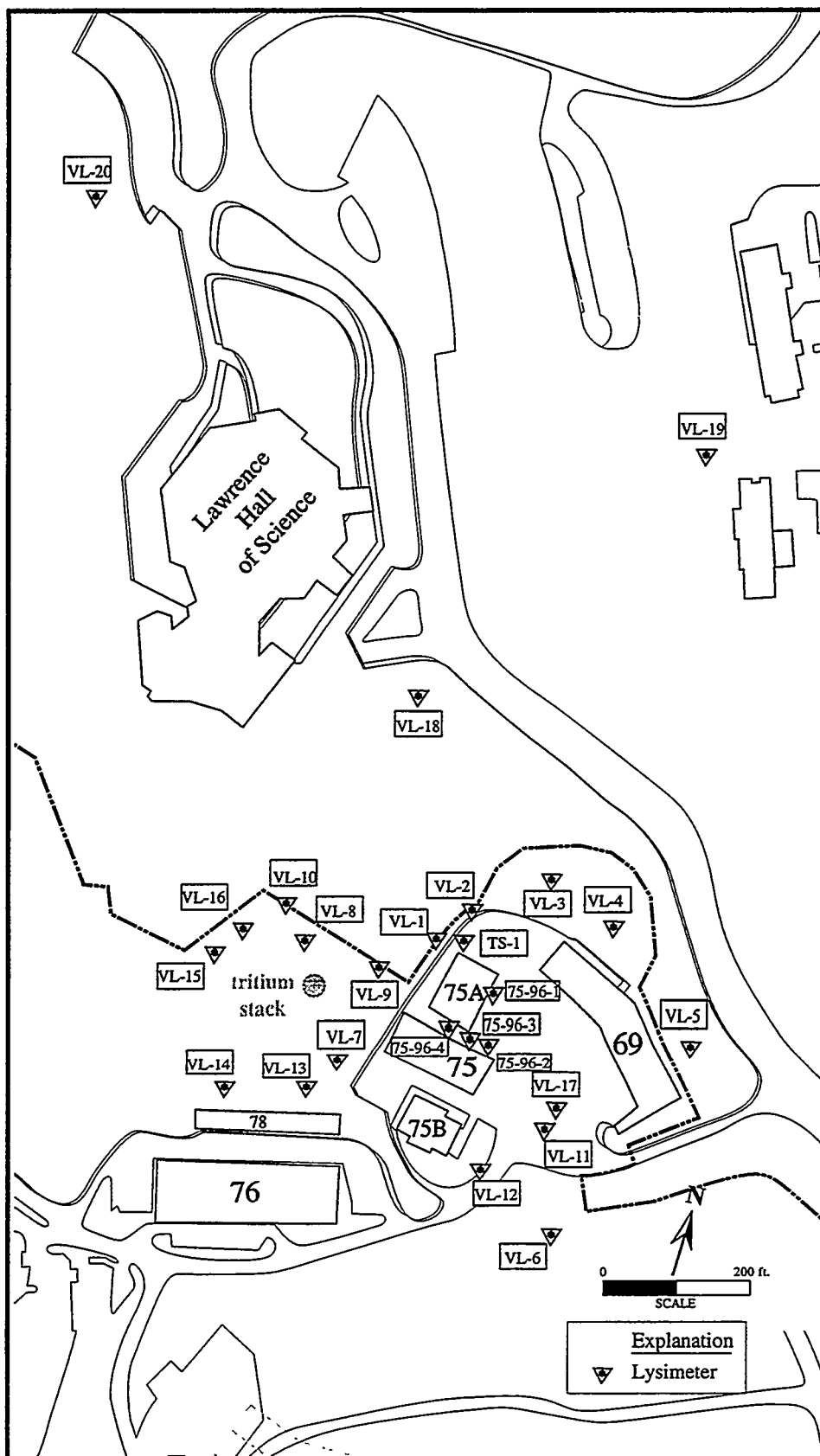


Figure 10-2. Locations of Lysimeters Surrounding the Corporation Yard

Table 10-11. Summary of Tritium in Lysimeter Samples in 1996

Type of Lysimeter	Number of Lysimeters	Number of Samples	Maximum (Bq/l) ^a	Average (Bq/l)
Shallow depth	20	100	1382	168
Multiple depth	5	45	3164	681
Total	25	145	3164	327

^a 1 Bq = 27 pCi

providing additional insights into the potential for the migration of contaminated soil water into groundwater. Individual sampling results from 1996 are available in quarterly progress reports⁸ produced by the environmental restoration program for regulatory agencies.

Sediment in Stormwater Catch Basins

In the fall of 1996, the Laboratory teamed up with an environmental science student from the UC Berkeley campus to sample the sediment within some of the site's stormwater catch basins, not normally part of the routine sampling program. Samples were analyzed for metals, diesel, and oil and grease. In general, analyses of the samples showed that Berkeley Lab does not have elevated levels of metals in the catch basin sediments. Diesel and oil and grease were found also in small amounts, with the highest

concentrations generally downstream of the motor pool at Building 76. Results from these analyses may be found in Volume II, *Data Appendix*.

Levels above the total threshold limit concentration for hazardous waste were found for lead in the catch basin at the northwest corner of Building 71 and for mercury in the catch basin near the substation behind Building 51. After receiving the results, these catch basins were cleaned out immediately. Additionally, the sediment was managed appropriately as hazardous waste. When these catch basins were resampled, the levels of metals had diminished considerably. Berkeley Lab has determined from the survey that a routine maintenance cleaning program of the catch basins is needed minimize the buildup of any contaminants present.

Chapter 11

Radiological Dose Assessment

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 combined at the end of the chapter as an effective means of summarizing the overall impact of the Laboratory's radiological activities on the surrounding region.

Earlier chapters (e.g., air quality, surface water) referred to monitoring and sampling results in terms of concentrations of a substance. The effect of being exposed to a concentration over a period of time is referred to as dose. Determining dose is 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 include the distance from the activity, complexity of terrain, meteorological conditions, emission levels, and length of exposure.

Penetrating Radiation Monitoring

Radiation-producing machines (e.g., accelerators, x-ray machines, and irradiators) and various radionuclides are used at Berkeley Lab for high energy particle studies and biomedical research. Penetrating radiation is 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 section will provide both maximum fence-post dose estimates and

estimates of exposures to workplaces or residences of Berkeley Lab's nearest neighbors.

Accelerator-Produced Penetrating Radiation

The 88-Inch Cyclotron in Building 88 contains the only remaining accelerator that could generate detectable radiation at nearby environmental monitoring stations. Since early 1991, the 88-Inch Cyclotron has administratively controlled its use of light-ion runs, which are the main contributors to an offsite exposure. Operations of the accelerator are limited to an offsite exposure of less than the Laboratory's established environmental ALARA goal of 0.03 mSv per year (3 mrem/yr). The injection source will only allow beam currents of less than 10 milliamperes.

Berkeley Lab uses two methods to determine the environmental radiological impact from accelerator operations. One method employs a network of three real-time environmental monitoring stations located around the site's perimeter to track the instantaneous gamma and neutron radiological impact from accelerator operations. Figure 11-1 displays the location of these stations. The second method uses 27 thermoluminescent detectors (TLD) located near the site boundary and six additional TLDs located around two offsite facilities (Building 903 Warehouse and Building 934). Key differences between the two methods are that TLDs only consider gamma radiation and are not able to exclude background radiation from their results. Also, TLDs give time-average dose results that must be determined by an analytical technique rather than real-time instrumentation. Figure 11-1 also 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

11-Radiological Dose Assessment

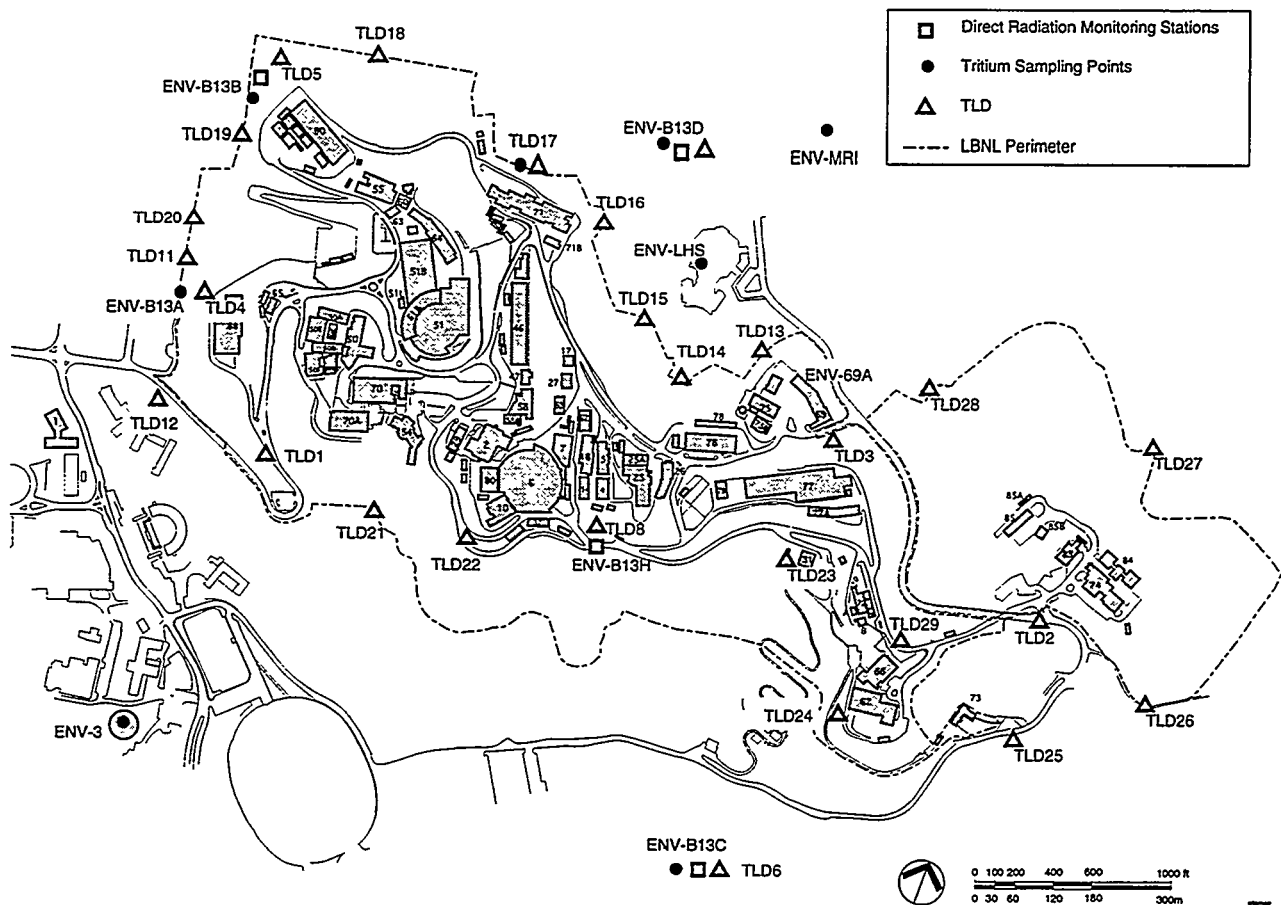


Figure 11-1. Environmental Radiological Monitoring Stations

neutron radiation. The calibrated output pulses from these detectors are transferred electronically to a central computer in Building 75. During 1996, runs generating light ions (hydrogen-1 and helium-3) in the 88-Inch Cyclotron occurred for about 1300 hours, or about 15% of the potential hours of operation for the year. The gamma and neutron doses to an individual that are derived from measurements at the three monitoring stations and are due to accelerator operations for the year are listed in Table 11-1.

The objective of the TLD network is to verify the estimated exposures from external penetrating radiation measured by the real-time instruments, 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 11-2 summarizes the annual TLD gamma radiation dose equivalents from the environmental TLD monitoring program, organizing the 33 monitoring locations into similar groups. Figure 11-2 presents a quarterly breakdown of these annual doses for these same groups.

The TLD results lead to several observations. First, levels of gamma radiation are highly consistent from one location to another, whether the location is onsite or not. In general, levels across all sites seldom deviate from average for a given observation period by more than 10%. Figure 11-2 presents this comparison graphically. Second, radiation levels are quite

Table 11-1. Annual Penetrating Radiation Dose for 1996 at Perimeter Due to Accelerators

Monitoring Station	Net Gamma Dose (mSv/yr) ^a	Net Neutron Dose (mSv/yr)	Total Dose ^b (mSv/yr)
ENV-B13A (Bldg. 88)	0.0022	0.017	0.019
ENV-B13C (Panoramic)	0.002	0.002	0.004
ENV-B13H (ALS)	0.001	0.004	0.005

^a1 mSv = 100 mrem^bStandard of comparison is DOE limit of 1 mSv/year

consistent from quarter to quarter. Third, the results have changed little from year to year as well. The latest results are less than 2% of the appropriate DOE standard.¹ These factors suggest that the external direct radiation exposure at Berkeley Lab is primarily attributable to background radiation. A typical background level for gamma radiation in California from natural and human activity is 0.90 mSv (90 mrem).² Assuming that this level is reflective of background conditions at Berkeley Lab as well, the estimated contribution to penetrating radiation dose from Laboratory activities is consistent with the real-time gamma monitoring results shown in Table 11-1.

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 figures from the 1980 US census⁴ 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 significant differences in dose.

In the Laboratory's model, population dose equivalent is computed from the maximum measured value of perimeter (fence-post) neutron dose. For 1996, this maximum dose was

Table 11-2. Summary of Environmental TLD Monitoring Results for 1996 from LBNL and Background Sources^a

Location	Number of Sites	Total Dose (mSv) ^b
Laboratory Gate Entrances	3	0.670
Environmental Monitoring Stations	5	0.723
Laboratory Perimeter	19	0.714
Off-site Facilities	6	0.668
Average Dose:	33	0.703

^aAverage background in Bay Area, including all of Berkeley Lab, is 0.72 mSv^b1 mSv = 100 mrem

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collected at monitoring station EHS-B13A near Building 88 (see Table 11-1). 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 1996 was estimated at 0.019 person-Sv (1.9 person-rem).

Irradiator-Produced Penetrating Radiation

The only gamma irradiators at Berkeley Lab have very low capacities, in the multicurie magnitude range. These irradiators are used as part of radiobiological and radiochemical research. The largest of these units is a cobalt-60 unit housed in an interlocked, massive, reinforced-concrete-covered labyrinth built as part of Building 74. This unit is also the one located closest to the Laboratory's perimeter. Routine surveys taken when the shielding for the irradiator was not in place confirmed that no area exceeded 0.01 mSv/hr (1 mrem/hr) at 1 meter from the outside walls or ceiling. The Building 74 irradiator is about 80 meters from the site's perimeter fence, 150 meters from the nearest offsite workplace (a UCB Botanical Garden building), and more than 700 meters from the nearest residence. The projected an-

nual dose equivalents to members of the public are about 0.014 mSv/yr (1.4 mrem/yr) at the perimeter fence, 0.001 mSv/yr (0.1 mrem/yr) at the Botanical Garden building, 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. These irradiators are used in sealed containers, and are located and monitored throughout the Laboratory.

Dispersible Radiation Airborne Radionuclides

Dose 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. The radionuclides that affect the environmental surroundings of Berkeley Lab, and consequently the projected dose due to Laboratory activities, originate as emissions from exhaust points, generally located on building 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

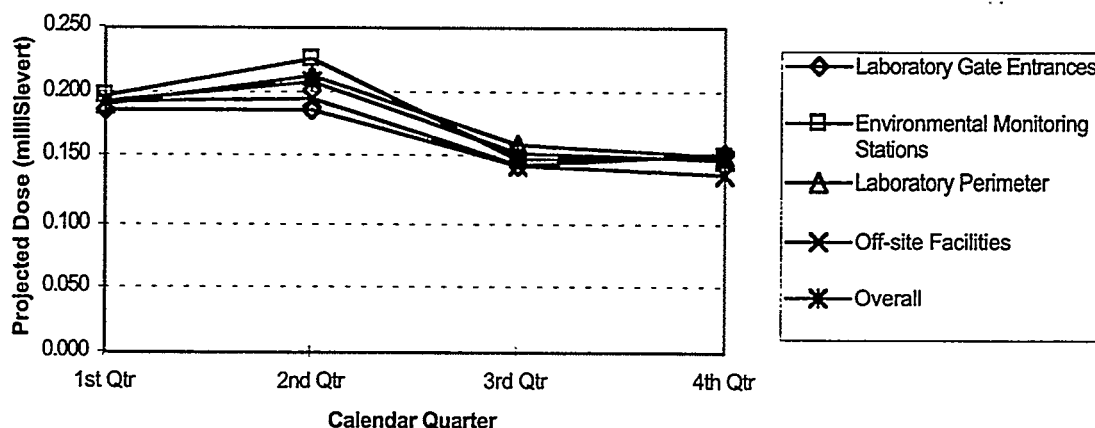


Figure 11-2. Quarterly Breakdown of Gamma Dose at TLD Sampling Locations

Table 11-3. Summary of Dose Assessment at Maximally Exposed Individual (MEI) from All Berkeley Lab Release Points for 1996

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^{-4}	56.9%
55/56	Research Medicine / Biomedical Isotope Facility	490	E	6.30×10^{-5}	25.6
1	Donner Laboratory (UC-Berkeley)	980	ENE	1.40×10^{-5}	5.7
934	Molecular & Cell Biology. (offsite)	4900	ENE	8.80×10^{-6}	3.6
88	88-Inch Cyclotron	670	ENE	8.10×10^{-6}	3.3
71/72	Ion Beam Technology / National Center for Electron Microscopy	220	E	5.40×10^{-6}	2.2
70/70A	Nuclear Science / Life Science	510	NE	2.80×10^{-6}	1.1
75A	Waste Storage Area (diffuse source)	150	NW	2.00×10^{-6}	0.81
75A/75	Hazardous Waste Handling Facility (only room 127 in B75)	150	NW	1.50×10^{-6}	0.61
2/6	Advanced Material Lab/Advanced Light Source	370	NE	2.40×10^{-7}	0.098
74/74B/83	Human Genome Laboratory	730	WNW	5.20×10^{-8}	0.021
62	Materials & Chemical Science	650	NW	6.00×10^{-9}	0.002
3	Calvin Lab (UC-Berkeley)	1070	NE	2.50×10^{-10}	0.000
26/76	Radiological and Analytical Measurements Laboratory	240	N	4.80×10^{-12}	0.000
50/51	Nuclear Science / Bevatron	N/A	N/A	0.00	0.0
75C	Environment, Health, & Safety Calibration Facility	150	NW	0.00	0.0
903	Receiving Warehouse	N/A	N/A	0.00	0.0
TOTAL:				2.46×10^{-4}	100.0%

^aRelative to the MEI of Building 75^b1 mrem = 0.01 mSv

dose to an individual and the population is accomplished using multipathway dispersion models. The basic radionuclide inputs for this modeling are the airborne emissions that were presented in the air quality chapter earlier in this report. As the dose results that follow will show, the most significant pathway contributing to dose is that of air inhalation.

The NESHAPs regulation requires that facilities such as Berkeley Lab that release airborne radionuclides compute the impact of such releases using an approved code.⁵ Berkeley Lab computes the cumulative dose from all significant exposure pathways (inhalation, ingestion, air immersion, and surface exposure) to a maximally exposed offsite person using CAP88-PC.

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This program is a radionuclide dispersion and dose-assessment predictive model supplied and approved by US/EPA. The methods and parameters used to calculate the dose are very conservative. For example, the model assumes that some portion of the food consumed by the individual was grown within the assessed area. The individual was assumed to reside at this location continuously throughout the year. In addition, all of the tritium released was assumed to be the most hazardous form, tritium oxide. Consequently, this dose is not a dose actually received by anyone, but 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. Prior to 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.

Data from the new meteorological network revealed that the average wind speed at Berkeley Lab was half that found at the Oakland airport (2 m/s vs. 4 m/s). This lower wind speed translates into a proportionately higher predicted dose for an equal amount of emissions. Physically, lighter winds do not generate as much turbulence and associated dispersion of any contaminants in the atmosphere.

Berkeley Lab set up seventeen individual CAP88-PC modeling runs to predict the impact of the same number of single or grouped release points (see Table 11-3). Details on these groupings and modeling runs are described in Section II of Appendix B, *NESHAPs*. As men-

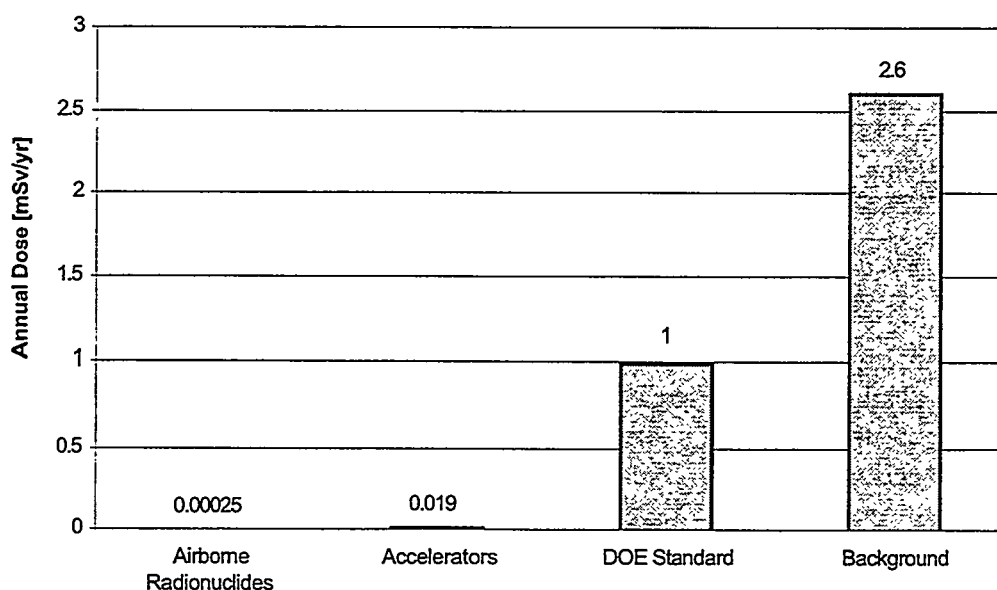


Figure 11-3. LBNL Radiological Impact for 1996

tioned previously, the NTLF emissions stack near Building 75 was identified as the largest release point at the Laboratory. With this knowledge, the maximally exposed individual determined from modeling this facility was also specified, with appropriate distances and directions, in each of the remaining CAP88-PC runs. The reported dose to a maximally exposed individual at Berkeley Lab includes contributions from all seventeen CAP88-PC models. This combined dose from airborne radionuclides for 1996 was 2.5×10^{-4} mSv (0.025 mrem). This value is included in Table 11-4 summarizing all of Berkeley Lab's doses.

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

circle around the site with a radius of 80 kilometers (50 miles). Berkeley Lab divided this region into 208 sectors (i.e., 13 smaller circles 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 (NTLF) dose assessment, with the exception that the source term was expanded from tritium to include all the radionuclides used at the Laboratory. Population figures 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 of the areas. This approach projected a total collective population dose from all airborne radionuclides at 0.002 person-Sv (0.2 person-rem).

Table 11-4. Summary of Berkeley Lab Radiological Dose Impacts for 1996

	Maximum Individual –Direct Radiation–	Maximum Individual –Airborne Nuclides–	Maximum Individual –Direct and Airborne–	Collective Dose to Population within 80 km of LBNL –All Sources–
Annual EDE	0.019 mSv/yr ^a	0.00025 mSv/yr	0.019 mSv/yr	0.021 person-Sv/yr
MEI Location	Residence (110 meters west of Bldg. 88)	Workplace (110 meters northwest of Bldg. 75 –Lawrence Hall of Science–)	Residence (110 meters west of Bldg. 88)	not applicable
Standard of Comparison	1 mSv/yr (DOE)	0.10 mSv/yr (US/EPA)	1 mSv/yr (DOE)	not applicable
LBNL impact as % of Standard	1.9%	0.3%	1.9%	not applicable
Annual Background	1 mSv/yr	1.6 mSv/yr	2.6 mSv/yr	1.3×10^4 person-Sv/yr
LBNL Impact as % of Background	1.9%	0.002%	0.7%	0.00%

^a1 mSv = 100 mrem

Combined Dose Assessment

Radiological impact from accelerator operations and airborne radionuclides is minimal compared to applicable standards and nominal background radiation. As presented in Table 11-4 and Figure 11-3, the maximum effective dose equivalent to an individual due to all Berkeley Lab operations in 1996 is about 0.019 mSv (1.9 mrem) per year. This value is about

0.7% of the nominal background⁶ 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 0.021 person-Sv in 1996. This is estimated to be well less than one-thousandth of a percent of the dose that the population within this region received from background sources during the same period.

Chapter 12

Quality Assurance

Background

Berkeley Lab's *Operating and Assurance Plan (OAP)*, PUB-3111,¹ establishes the policy on quality assurance for Laboratory programs, ranging from management's responsibility to plan for and achieve quality assurance objectives to the individual employee's responsibility for the quality of his/her work.

The basic design of the OAP contains three essential elements:

- organizational structure
- process management
- assessment.

Organizational structure consists of an appropriate management hierarchy, a proficient staff, and a systematic approach in planning work; these are key elements in sustaining a high level of performance.

Process management pulls together the following basic needs:

- communicate goals, objectives, and procedures with affected staff
- identify and mitigate the hazards and risks
- institute process controls to maximize performance and quality
- establish documentation measures to ensure the availability of accurate information.

The last integral element in the OAP is assessment. Berkeley Lab organizations must regularly evaluate and improve the performance of their units through self-assessments, peer reviews, and independent performance assessments. A feedback mechanism then allows for correcting or improving any performance deficiencies arising from these assessments.

Quality assurance in the context of environmental monitoring programs means that activi-

ties will be conducted so that any data acquired provide a valid representation of actual conditions. The need for quality assurance measures is critical in all facets of the environmental monitoring program. It is especially critical for samples subjected to analysis by laboratories. The following sections provides an overview of quality assurance activities for the two types of laboratories used by this program: Berkeley Lab's onsite laboratory and the offsite service contract laboratories.

Radiation and Analytical Measurements Laboratory

Berkeley Lab's Radiation and Analytical Measurements Laboratory (RAML) is qualified to perform radiochemical analyses on environmental samples collected by the program. RAML is accredited by the California Department of Health Services and is fully compliant with both DOE Order 5700.6C on quality assurance² and US/EPA NESHAPs regulations in 40 CFR 61.³

During 1996, RAML performed 2,744 various air and water sample analyses for the environmental sampling and monitoring program. Figure 12-1 summarizes the total number of these analyses. Over 25% of all environmental samples analyzed during the year were for quality control purposes. The types of quality control samples prepared by RAML include blanks, splits, and spikes (i.e., predetermined standard). RAML has established a detailed set of procedures for handling samples from first receipt of the sample until last issuance of the sample result. These procedures apply to quality control samples as well.

RAML participated in 27 US/EPA inter-laboratory comparison samples at various times of the year. Table 12-1 summarizes these results. All results were within the listed US/EPA control limits.

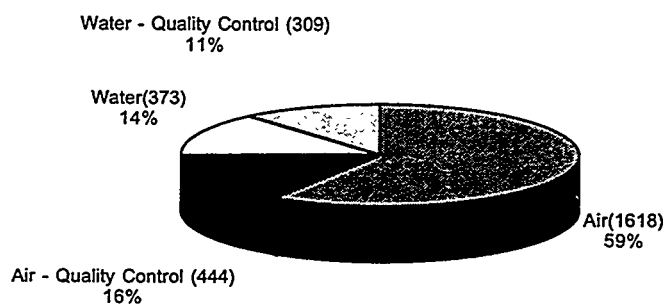


Figure 12-1. Samples Analyzed by RAML in 1996

Contract Analytical Laboratories

Berkeley Lab and Lawrence Livermore National Laboratory have entered into joint agreements with several certified commercial laboratories for radiological and nonradiological analytical services. Quality assurance and quality control requirements that each analytical services laboratory must meet are explicitly stated in the statement of work for this agreement.⁴

In order to provide the analytical tests requested by Berkeley Lab, each laboratory must remain certified under the California DHS *Environmental Laboratory Accreditation Program*⁵ for such tests. All laboratories have and maintain quality assurance plans that meet the minimum requirements of DOE Order 5700.6C.⁶ Furthermore, laboratories providing radiological analyses must have a QA program that meets the requirements of American National Stan-

Table 12-1. Summary of RAML Performance in 1996 US/EPA Intercomparison Study

Analysis Type	# of Samples	LBNL Mean (Bq/l) ^a	EPA Value (Bq/l)	EPA Control Limits (Bq/l)		Result
				Low	High	
Alpha	4	39.7	42.6	23.3	62.0	Pass
Beta	4	76.0	82.6	60.6	105.1	Pass
Cobalt-60	3	30.3	30.0	21.3	38.7	Pass
Cesium-134	4	36.9	39.0	30.3	47.7	Pass
Cesium-137	3	34.1	33.0	24.3	41.7	Pass
Tritium	2	15938.0	16440.5	13588.3	19292.8	Pass
Strontium-89	2	31.3	34.0	25.3	42.7	Pass
Strontium-90	3	15.6	17.7	9.0	26.4	Pass
Zinc-65	2	187.7	167.5	137.2	197.9	Pass

^a1 Bq = 27 pCi

dards Institute/American Society of Mechanical Engineers Nuclear Quality Assurance program NQA-1-1989.⁷ All laboratories participate in US/EPA inter-laboratory studies throughout the year.

Along with each set of sample results, the laboratory must submit a summary of the corresponding quality control sample results. The detailed list of expected quality control information with each deliverable is specified in the agreement. In addition to these quality control measures, the agreement gives Berkeley Lab and LLNL the right to periodically subject each contract laboratory to a series of performance evaluation tests. Such a test was conducted in the fourth quarter of 1996. An extensive set of sampling standards was submitted to each of

the laboratories with instructions to run analytical tests for oils and grease, minerals, trace metals, semivolatiles, and volatiles. The ensuing results were scored, with the number of points awarded depending upon the nearness to the expected value. As a result of this test, one of the laboratories was deleted from the agreement for failure to perform within the requirements of the contract.

Conclusion

This section was not meant to present a comprehensive discussion of all quality assurance measures of the environmental monitoring program. The descriptions are representative of the measures taken to ensure the quality of the analytical data collected by the program.

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Glossary

Acronyms and Abbreviations

A	Ampere
Å	Angstrom
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
CUPA	Certified Unified Program Agency
CWA	Clean Water Act
CY	Calendar Year
DHS	Department of Health Services
DOE	U.S. Department of Energy
DOE EH-24	U.S. Department of Energy, Office of Environmental Audit
DOE EM	U.S. Department of Energy, Office of Environmental Management
DOE ER	U.S. Department of Energy, Office of Energy Research

Acronyms and Abbreviations (continued)

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
ESA	Endangered Species Act
°F	degrees Fahrenheit
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
ft	foot or feet
FR	Federal Register
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
IH	Industrial Hygiene

Acronyms and Abbreviations (continued)

in	inch
kg	kilogram
km	kilometer
l	Liter
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley Laboratory
LLNL	Lawrence Livermore National Laboratory
m	meter
M&O	Maintenance and Operations
MCL	Maximum Contamination Limit
MDA	Minimum Detectable Activity
MeV	Million Electron Volts
mg	milligram
Mgsf	Million gross square feet
MEI	Maximally Exposed Individual
ml	milliliter
mrem	millirem
MSDS	Material Safety Data Sheet
mSv	millisievert
MW	Mixed Waste
ND	non-detectable
NEPA	National Environmental Policy Act
NERSC	National Energy Research Scientific Computer Center
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NIST	National Institute of Standards and Technology
NOV	Notice of Violation
NRC	Nuclear Regulatory Commission
NPDES	National Pollutant Discharge Elimination System
NTLF	National Tritium Labeling Facility
OAA	Office of Assessment and Assurance

Acronyms and Abbreviations (continued)

OAP	Operating and Assurance Program
ODS	Ozone-Depleting Substance
OMB	Office of Management and Budget
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
PRP	Potentially Responsible Party
PWA	Process Waste Assessment
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
RSU	Regulatory Structure Update
RWQCB	Regional Water Quality Control Board
SAA	Satellite Accumulation Area
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SI	Système Internationale or International System of Units (the metric system)
SOP	Standard Operating Procedure
STP	Site Treatment Plan
Sv	Sievert
SWMP	Storm Water Monitoring Program

Acronyms and Abbreviations (continued)

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
WMin/PP	Waste Minimization and Pollution Prevention

Technical Terms

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.
Angstrom	A unit of length equal to one ten-billionth (0.0000000001 or 1×10^{-10}) of a meter.
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.

Technical Terms (continued)

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.
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.

Glossary

Technical Terms (continued)

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. The term is 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.
extractable pollutants	Pollutants that can be removed from a contaminated sample by passing water through the sample.
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.

Technical Terms (continued)

half-life, radioactive	The time required for the activity of a radioactive substance to decrease to half its value by inherent radioactive decay. After two half-lives, one-fourth of the original activity remains ($1/2 \times 1/2$); after three half-lives, one-eighth ($1/2 \times 1/2 \times 1/2$); and so on.
hazardous waste	Waste exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). Because of its concentration, quantity, physical, or chemical characteristics, it may: 1) cause or significantly contribute to an increase in mortality rates or cases of serious irreversible illness; or 2) pose a substantial present or potential threat to human health or the environment when improperly treated, stored, transported, disposed of, or handled.
internal radiation	Radiation from a source within the body as a result of deposition of radionuclides in body tissues by processes such as ingestion, inhalation, or implantation. Potassium (^{40}K), a naturally occurring radionuclide, is a major source of internal radiation in living organisms.
nonattainment area	An area that does not meet the National Ambient Air Quality Standards.
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.
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.

Glossary

Technical Terms (continued)

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.
pretreatment regulations	National wastewater pretreatment regulations (40 CFR 403) adopted by US/EPA in compliance with the 1977 amendments to the Clean Water Act, which required that US/EPA establish pretreatment standards for existing and new industrial sources.
priority pollutants	A set of organic and inorganic chemicals identified by US/EPA as indicators of environmental contamination
purgeable pollutants	Pollutants that can be removed from a sample by passing nitrogen gas through the sample.
radiation protection standard	Limits on radiation exposure regarded as necessary for protection of public health. These standards are derived 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.
remediation	See environmental remediation.
scintillation cocktail	A solution of organic compounds that emits light upon interacting with radiation. For the purposes of this report, it is used primarily for the analysis of tritium.
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.

Technical Terms (continued)

thermoluminescent dosimeter (TLD)	A type of dosimeter. After being exposed to radiation, the material in the dosimeter (lithium fluoride) luminesces upon being heated. The amount of light 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.
uranium	A metallic element that is highly toxic and radioactive.
uranium, depleted	Uranium consisting primarily of ^{238}U and having less than 0.72 wt% ^{235}U . Except in rare cases occurring in nature, depleted uranium is man-made.
uranium, total	The amount of uranium in a sample, assuming that the uranium has the isotopic content of uranium in nature (99.27 wt% ^{238}U , 0.72 wt% ^{235}U , and 0.0057 wt% ^{234}U)
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 diagram that shows the frequency and intensity of wind from different directions at a particular place.

Radiological Units

becquerel (Bq)	Unit of radioactive decay equal to one disintegration per second. (SI unit)
curie (Ci)	Unit of radioactive decay equal to 2.22×10^{12} disintegrations per minute. (conventional units)
mrem	millirem (10^{-3} rem). See rem.
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.
rad	A unit of absorbed dose from ionizing radiation (0.877 rad/R).

Radiological Units (continued)

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 (rad), quality factor (Q), distribution factor, and other necessary modifying factors. It describes the effectiveness of various types of radiation in producing biological effects.
roentgen (R)	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 (R) is 2.58×10^4 coulombs per kilogram of air.
sievert (Sv)	A unit of radiation dose equivalent. The sievert is the SI unit equivalent to the rem. It is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. It describes the effectiveness of various types of radiation to produce biological effects; $1 \text{ Sv} = \text{Gy} \times Q \times N = 100 \text{ rem}$.

Units of Measure

Throughout this report, an attempt has been made to reference the International System of Units (SI) or metric system of measurements, where ever possible. Radiological quantities (activity—curies (Ci), exposure—roentgen (R), and dose—rad and rem) have also been reported in U.S. conventional units because current standards are written in terms of these units. The equivalent SI units are the becquerel (Bq), coulomb per kilogram (C/kg), gray (Gy), and sievert (Sv), respectively.

Table GLS-1 presents prefixes used with SI units of measurement. Table GLS-2 presents conversion factors for converting from SI units to U.S. conventional units.

Table GLS-1. Prefixes Used with SI (Metric) Units

Prefix	Factor	Symbol
exa	$1,000,000,000,000,000 = 10^{18}$	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

^AAvoid where practical

Table GLS-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 1996



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 (LBNL) is a multi-program national laboratory managed by the University of California Office of the President (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 "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 great variety of radionuclides. (One millicurie is equal to 3.7×10^7 Becquerel (Bq).)

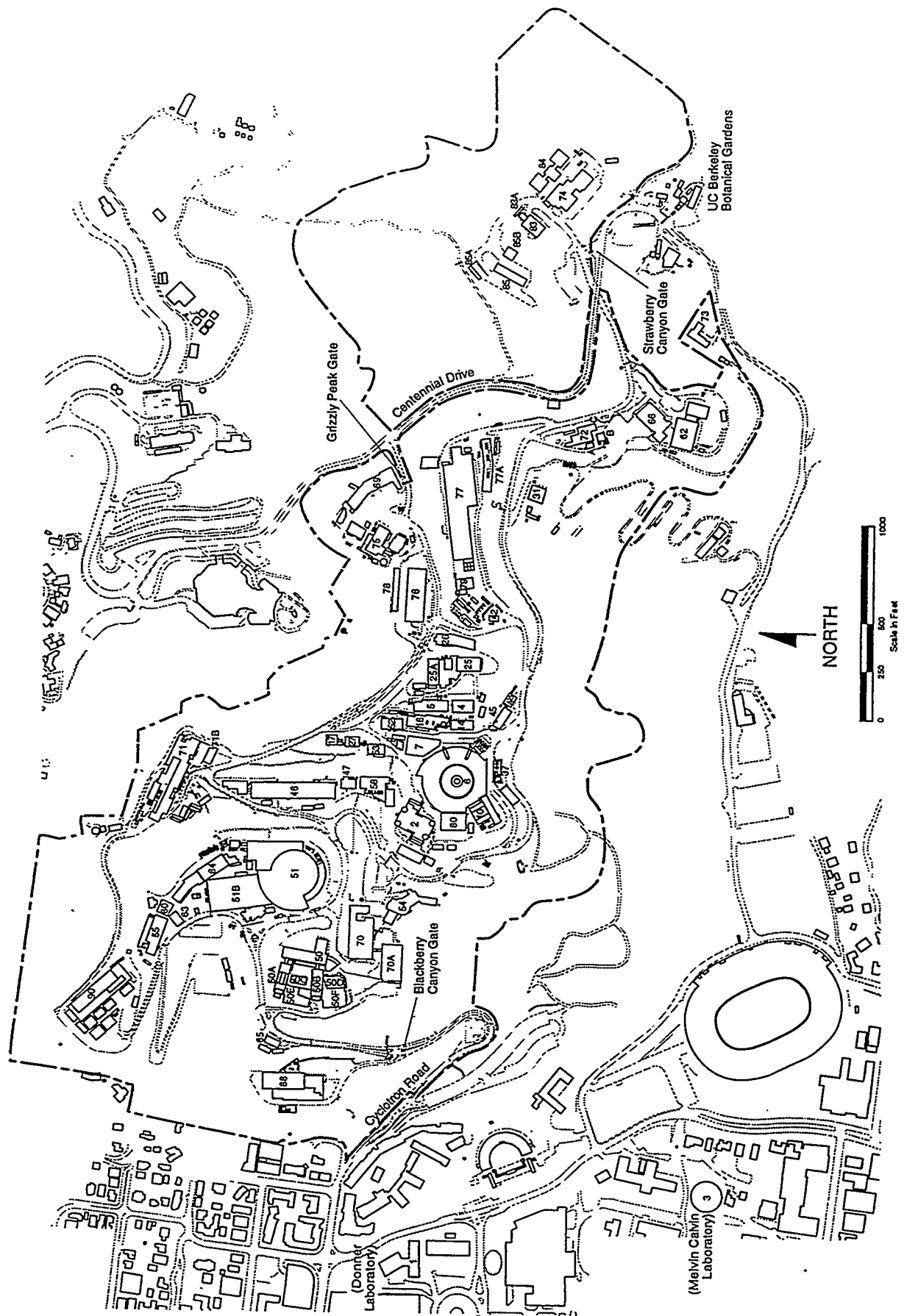


Figure 1. LBNL On Site Buildings

HILL-SITE BUILDINGS

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

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

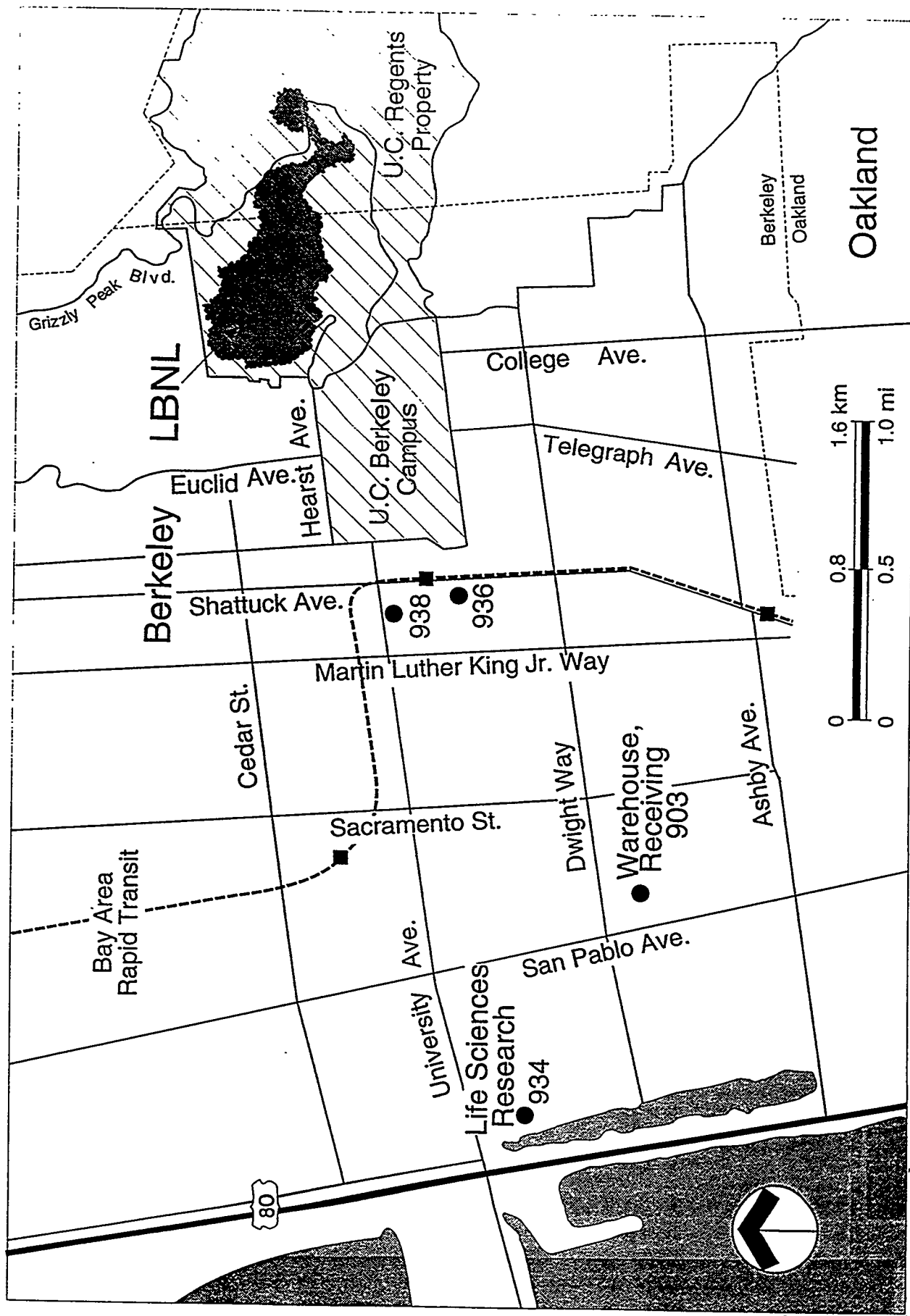


Figure 2. LBNL Off Site Laboratories & Vicinity Map

The Site

Berkeley Lab is situated upon a hillside above the main campus of the University of California at Berkeley (UCB). The 54-hectare (134-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 side 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. 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 180,000 gross square meters (gsm), or 1.94M 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 on site space consists of 125,000 gsm in about 60 buildings: 121,000 gsm in DOE buildings and trailers, and 4,000 gsm in University-owned buildings. Off site space utilized by Berkeley Lab consists of 25,000 gsm in various University buildings on the UC at Berkeley (UCB) campus and 14,000 gsm in leased facilities in Emeryville and Berkeley.

The most recent population figures for the Laboratory show over 3,200 full- and part-time employees. In addition, Berkeley Lab provided facilities for approximately 1,800 guests who worked at the site for varying lengths of time. Over 700 of these guests were on site at any one time, giving an estimated population base at the Laboratory of about 3,900.

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 a mean temperature difference between the summer 17°C (63°F) and winter 9°C (48°F) of only 8.5°C (15°F). Relative humidity ranges from 85%-90% in the early morning to 65%-75% in the afternoon. The average annual rainfall is 64 cm (25 inches). About 95% of the rainfall occurs 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 range up to 9-13m/s (20-30 mph). Winter storm winds from the south or southwest have somewhat lesser velocities.

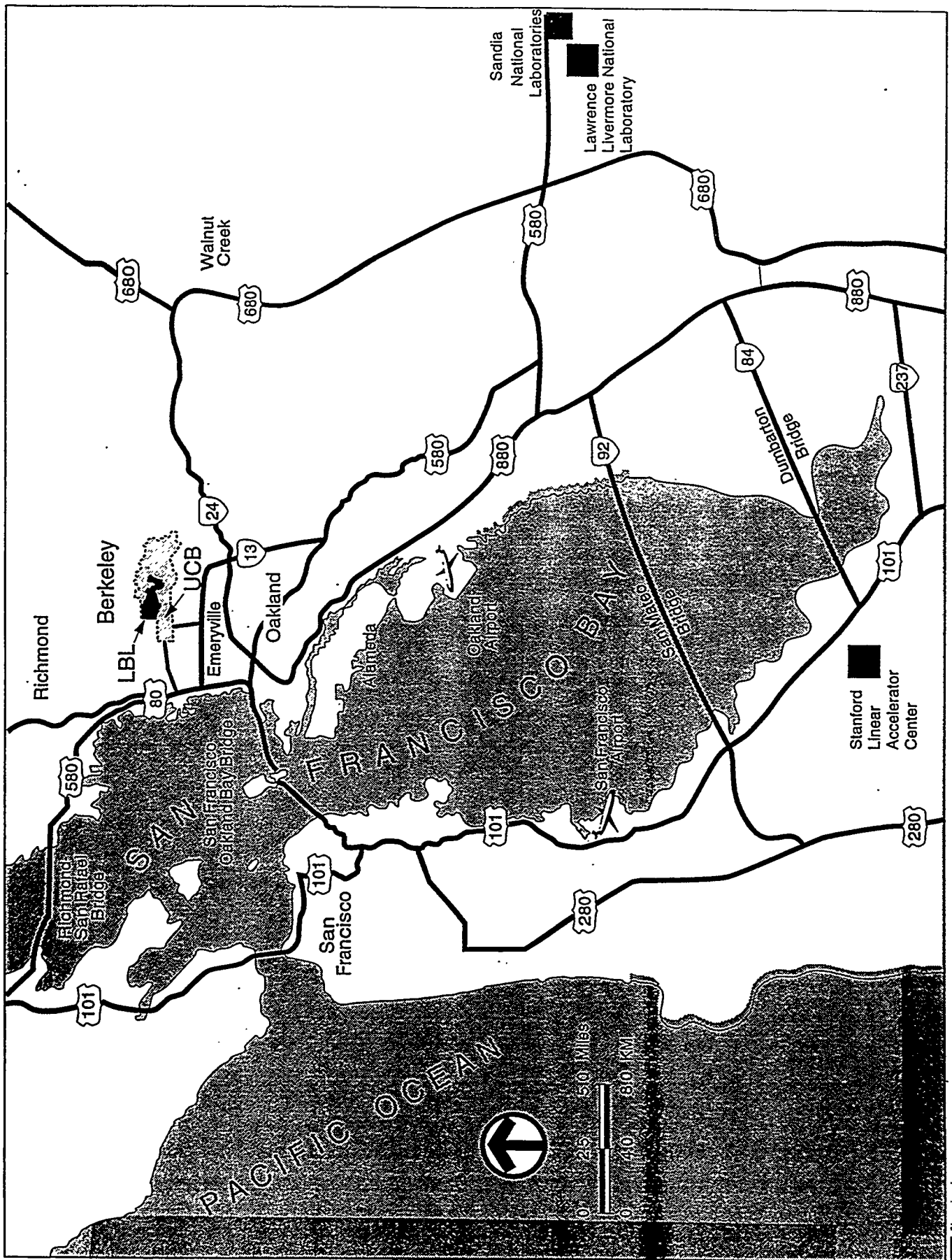


Figure 3. San Francisco Bay Area Map

Compliance Status of Lawrence Berkeley National Laboratory:

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 the foregoing process 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 based on dose modeling with no emission controls in place. Table 2 summarizes the NESHAPs compliance strategy for monitoring requirements at Berkeley Lab, which has been implemented since the beginning of 1995. Berkeley Lab has been in full compliance with the requirements set forth in 40 CFR Part 61, Subpart H since 1995.

Table 2. Summary of NESHAPs Compliance Strategy for Monitoring Emissions in 1996

EDE Criteria [mrem/year]	Category	Descriptions	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	• <u>Continuous</u> sampling or monitoring required • Telemetry for nuclides with half-lives < 100 hours • EPA Application to Construct or Modify required.	5
$1.0 \times 10^{-1} > EDE \geq 5.0 \times 10^{-2}$	II	Continuous sampling with <u>weekly</u> analysis.	4
$5 \times 10^{-2} > EDE \geq 1.0 \times 10^{-2}$	III	Continuous sampling with <u>monthly</u> analysis.	19
$1.0 \times 10^{-2} > EDE \geq 1.0 \times 10^{-3}$	IV	Sampled <u>annually</u> during project activity.	0
$EDE < 1.0 \times 10^{-3}$	V	Inventory controlled by Radiological Work Authorization/Permit (RWA/RWP) and periodic evaluation. <u>No monitoring</u> required	101

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 used/monitored at Berkeley Lab during CY96.

Table 3. Radionuclides Used/Monitored at Berkeley Lab During CY96

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 Cf	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 Ce	beta gamma	0.514 0.043	???
Cobalt (27)	⁶⁰ Co	beta gamma	0.318 1.33	5.27 years
Copper (29)	⁶⁴ Cu	beta positron beta	0.578 0.650	12.70 hours
	⁶⁷ Cu	gamma	0.577 0.184	61.9 hours
Curium (96)	²⁴⁸ Cm	alpha	5.08	3.39 x 10 ⁹ years
Fluorine (9)	¹⁸ F	positron/gamma	0.511	109.7 minutes
Gallium (31)	⁶⁸ Ga	beta		68.1 minutes
Germanium (32)	⁶⁸ Ge	E.C.	???	288 days
Holmium (67)	^{160m} Ho	beta	1.855	1,200 years
Hydrogen /Tritium (1)	³ H	beta	0.0186	12.28 years
Indium (49)	¹¹¹ In	E.C./gamma	0.170 0.190	2.81 days 49.51 days
	^{114m} In	I.T./E.C./gamma		
Iodine (53)	¹²³ I	E.C./gamma	0.159	13.1 days
	¹²⁵ I	gamma	0.027	60.14 days
	¹³¹ I	beta gamma	0.606 0.159	8.04 days
Iron (26)	⁵⁵ Fe	E.C./gamma		2.73 years
	⁵⁹ Fe	beta gamma	0.475 1.100	44.51 days
Manganese (25)	⁵⁴ Mn	E.C./gamma	0.834	312 days
Nickel (28)	⁶³ Ni	beta	0.066	100.1 years
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	beta	1.71	14.3 days
	³³ P	beta	0.249	25.3 days
Plutonium (94)	²³⁹ Pu	alpha	5.155	2.411 x 10 ⁴ years
	²⁴² Pu	alpha	4.901	3.76 x 10 ⁵ years
Radium (88)	²²⁶ Ra	alpha	4.784	1.60 x 10 ³ years
		gamma	0.186	
Rubidium (37)	⁸⁶ Rb	beta	1.77	18.66 days
		gamma	1.08	
Selenium (34)	⁷⁵ Se	E.C./gamma	0.265	118.5 days
Sodium (11)	²² Na	positron	0.545	2.605 years
		gamma	1.27	
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	4.01	1.4 x 10 ¹⁰ years
		beta	0.04	
Thallium (201)	²⁰¹ Tl	E.C./gamma	0.167	3.05 days
Uranium (92)	²³³ U	alpha	4.825	1.59 x 10 ⁵ years
	²³⁸ U	alpha	4.2	4.47 x 10 ⁹ years
		beta	0.029	
Xenon (54)	¹³² Xe	E.C./gamma	0.350	20.0 hours
Zinc (30)	⁶² Zn	positron gamma	0.661.12	9.26 hours
	⁶⁵ Zn			244 days
Zirconium (40)	⁹⁵ Zr	beta	0.4	64 days
		gamma	0.757	

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.

Currently, 24 laboratory buildings at Berkeley Lab include areas which 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, five source release points were identified for 1996 that are potentially within Category I; Buildings 88, 75 (2 sources), and 56 (2 sources). All other Berkeley Lab's sources which were operational during CY96 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

Buildings with Radioactive Material Areas (RMAs)	NESHAPs Compliance Strategy Category					TOTAL
	Category I	Category II	Category III	Category IV	Category V	
1	0	0	2	0	12	14
2	0	0	0	0	1	1
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	0	0
55	0	0	1	0	8	9
56	2	0	0	0	0	2
62	0	0	1	0	0	1
70	0	1	6	0	0	7
70A	0	0	7	0	13	20
71	0	0	0	0	5	5
72	0	0	0	0	2	2
74	0	0	0	0	11	11
74B	0	0	0	0	1	1
75	2	2	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	9	9
88	1	0	0	0	10	11
903	0	0	0	0	2	2
934	0	0	1	0	15	16
TOTAL:	5	4	19	0	101	129

During CY96, 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 $1.0\text{E-}3$ mrem ($1.0\text{E-}5$ mSv) are, in general, not sampled/monitored (category V sources). The increase in the total number of category V sources reported in CY96 compared to previous years is mainly due to the change in the classification of release points (stacks vs. RMAs). This year number is based on the RMAs in the database maintained by Radiation Assessment 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.

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.

With this grouping, there are 17 NESHAPs sources at Berkeley Lab (Table 5). For each source, the EPA-approved atmospheric dispersion dose calculation computer code, CAP88-PC, was used to estimate the Effective Dose Equivalent (EDE) to an offsite maximally exposed individual (MEI). A total of seventeen CAP88-PC computer model assessments were separately performed to simulate nine point sources, seven grouped sources, and one non-point (diffuse) source for dose assessment during CY96. These 17 sources are discussed below:

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 are very small compared to other on site emission sources. In fact, the EDE for each local receptor due to local airborne releases associated with these offsite buildings is several orders of magnitude lower than the contribution due to the tritium release 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 CY96

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 74/74B and 83
Building 75
Building 75A
Building 75A Diffuse
Building 75C
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 on 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	1.69E-04	1.27E-05	0.905%		
				H-3	7.36E-04	2.47E-06	0.176%		
				I-125	1.10E-04	1.30E-03	92.628%		
				I-131	2.00E-05	8.79E-05	6.282%		
				P-32	5.92E-07	1.20E-07	0.009%		
				S-35	5.00E-08	2.08E-09	0.000%		
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		TOTAL:	1.40E-03	100.000%

(*) 1 Ci = 3.7E10 Becquerel

(**) 1 mrem = 1.0E-2 mSv

2. Building 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	8.40E-10	4.77E-08	0.199%
				N-13	8.40E-02	2.30E-05	95.861%
				O-15	6.00E-03	9.46E-07	3.940%
					TOTAL:	2.40E-05	100.000%

(*) 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 on the University of California at Berkeley campus. The predominant nuclides used are H-3, P-32, S-35, and C-14 as labeled amino acids and DNA precursors. $^{14}\text{CO}_2$ 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	C-14	5.00E-10	1.80E-11	0.067%
				H-3	6.00E-09	8.49E-12	0.031%
				P-32	2.75E-07	2.49E-08	92.178%
				S-35	1.01E-07	2.09E-09	7.724%
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
					TOTAL:	2.70E-08	100.000%

4. Building 26 and 76 (Medical Services & 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. The RAML is the only radionuclide user in these buildings. Only trace quantities of radionuclides are used in sample spiking and standards preparation. Building 26/76 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	2.00E-11	4.80E-10	100%
(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv					TOTAL:	4.80E-10	100.000%

5. Building 50 and 51 (Physics, Accelerator and Fusion Research and Nuclear Science and 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 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
(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv					TOTAL:	0	0

6. Building 55 and 56 (Research Medicine & Radiation Biophysics and 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. Two locations in Building 56 are continuously monitored (real-time) for positron emitters. 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	1.15E-08	3.13E-10	0.000%
				Cu-64	6.00E-07	2.05E-09	0.000%
				Ga-68	3.00E-08	2.51E-10	0.000%
				H-3	2.00E-08	2.31E-11	0.000%
				I-123	1.00E-02	1.58E-04	2.026%
				I-125	1.47E-04	6.21E-04	7.962%
				I-131	4.00E-05	6.14E-05	0.788%
				P-32	1.00E-08	6.46E-10	0.000%
				F-18	1.60E+00	6.96E-03	89.225%
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
TOTAL:					7.80E-03	100.000%	

7. Buildings 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 μ Ci thorium spheres is performed in one lab in Building 62. Operations in Building 62 are carried out in enclosures whose exhaust streams are HEPA filtered. 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 buildings had been decontaminated and decommissioned. The NESHAPs dose impacts for CY96 are mainly associated with these activities. 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	I-125	7.54E-10	4.47E-09	0.344%
				C-14	1.97E-06	7.57E-08	5.820%
				H-3	1.22E-05	1.92E-08	1.480%
				Th-232	4.65E-10	1.18E-06	90.804%
				Sr-90	3.19E-09	2.02E-08	1.553%
					TOTAL:	1.30E-06	100.000%

(*) 1 Ci = 3.7E10 Becquerel

(**) 1 mrem = 1.0E-2 mSv

(*) 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. Thirteen sources in Building 70 and 70A are classified as a Category V release points and the remaining 14 locations are sampled continuously and analyzed periodically; one is analyzed weekly, and thirteen are analyzed monthly. Monitoring analytes include I-125, C-14, alpha, 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	2.95E-05	2.20E-07	0.067%
				H-3	1.60E-04	4.87E-08	0.015%
				I-125	1.42E-07	1.65E-07	0.050%
				P-32	7.78E-07	1.41E-08	0.004%
				S-35	5.50E-08	2.13E-10	0.000%
				Sr-90	1.12E-05	1.37E-05	4.162%
				U-233	2.50E-10	4.53E-08	0.014%
				Th-232	6.50E-07	3.16E-04	95.689%
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
TOTAL:					3.30E-04	100.000%	

9. Building 71/72 (Heavy Ion Accelerator and 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. Building 71/72 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	I-125	5.00E-05	4.60E-04	100.000%
				P-32	2.50E-09	3.51E-10	0.000%
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
					TOTAL:	4.60E-04	100.000%

10. Buildings 74/74B (Research Medicine)/ 83 (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 and 74B 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. Building 74/74B/83 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 74/74B/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	7.60E-10	8.75E-11	0.002%
				H-3	1.76E-08	9.60E-11	0.002%
				I-125	2.50E-07	4.52E-06	86.919%
				P-32	2.23E-06	6.48E-07	12.456%
				S-35	6.45E-07	3.23E-08	0.622%
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
					TOTAL:	5.20E-06	100.000%

(*) 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, T₂) and tritiated water (HTO, T₂O). Gaseous tritium releases are quantified as tritiated water even though its impacts are 1/25,000 of those of comparable releases of tritiated water. 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). Other discharge points from the Building 75 roof are further from offsite individuals. Thus, it is conservative to assume that all tritium emissions are released from the main tall stack on the hillside.

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 and 5 Ci in 1996. Several factors have contributed to the recent reduction of tritium emissions. First, there were no significant (>25 Ci) unplanned releases since 1995, and 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.

The marked reduction of tritium emission from the NTLF in 1996 was mainly due to the temporary closure of the NTLF from March 20 to October 1, 1996. The NTLF generates mixed waste (waste having both hazardous and radioactive constituents) for which there was no good off-site treatment and disposal options. Operations were suspended until options for the mixed waste were developed. After modifying some operating procedures and hardware, sufficient progress resolving the waste problems were made and operations at NTLF were resumed on October 1, 1996.

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 CY96. 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
10	110	NW	UC Lawrence Hall of Science	H-3	5.04	1.4E-2	100.00%
(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv					TOTAL:	1.4E-2	100.00%

12. Building 75A (Hazardous Waste Handling Facility / Point Source): During 1996, the Berkeley Lab Hazardous Waste Handling Facility is located in Buildings 75A and part of Building 75. Radioactive waste from various laboratories is processed and stored in these buildings. The effluent is sampled and analyzed monthly for I-125, C-14, gross alpha, gross beta, and tritium. A summary of the CAP88-PC's source term input parameters and EDE results for this point source Building 75A is presented in Table 17.

Table 17. Building 75A 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	I-125	1.97E-06	2.06E-05	13.729%
				C-14	4.36E-05	2.93E-06	1.950%
				H-3	7.18E-03	2.13E-05	14.187%
				Th-232	2.10E-08	1.05E-04	69.737%
				Sr-90	5.60E-08	5.95E-07	0.397%
(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv					TOTAL:	1.50E-04	100.000%

13. Building 75A (Hazardous Waste Handling Facility / Diffuse Source): In addition, Building 75A is also considered as a diffuse source of HTO, as HTO waste is processed and stored in the building. One storage location is sampled and analyzed weekly for tritium. 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	6.83E-3	2.0E-4	100.00%
(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv						TOTAL:	2.0E-4 100.00%

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
(*) 1 Ci = 3.7E10 Becquerel (**) 1 mrem = 1.0E-2 mSv						TOTAL:	0 0

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 CY96. 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. Release from these location 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-55	2.00E-09	1.10E-11	0.000%
				Fe-59	8.00E-09	1.28E-09	0.000%
				Mn-54	1.00E-09	6.74E-10	0.000%
				Na-22	2.00E-10	9.91E-10	0.000%
				P-32	2.50E-09	5.47E-11	0.000%
				S-35	5.00E-08	2.46E-10	0.000%
				Th-232	4.00E-10	2.22E-07	0.015%
				U-235	1.20E-10	2.33E-08	0.002%
				C-11	1.50E+00	1.50E-03	99.983%
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
TOTAL:					1.50E-03	100.000%	

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 (accelerator shielding blocks, 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
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
					TOTAL:	0	0

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. Also, forensic DNA investigations are carried out by a group from the California Department of Justice. 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 $^{35}\text{SO}_2$, which is released to the atmosphere. Many release points in this building are classified as Category V release points and one stack is sampled periodically at this location. 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	9.50E-09	3.62E-09	0.000%
				H-3	9.85E-07	1.87E-08	0.002%
				I-125	2.00E-05	1.20E-03	99.873%
				P-32	9.40E-07	9.11E-07	0.076%
				Ra-226	5.00E-10	4.81E-07	0.040%
				S-35	6.88E-07	1.07E-07	0.009%
(*) 1 Ci = 3.7E10 Becquerel					(**) 1 mrem = 1.0E-2 mSv		
					TOTAL:	1.20E-03	100.000%

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 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, which are 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 contributing more than 10% of the EDEs from a release point during CY96 are given in Table 23. These data are used to calculate the collective population dose for CY96.

Table 23. Total Radioactivity in Air Effluent Potentially Released During CY96

Nuclide	Total Air Effluent		% Total Effluent
	[Ci/yr]	[Bq/yr]	
H-3	5.05E+00	1.87E+11	61.2304%
F-18	1.60E+00	5.92E+10	19.3809%
C-11	1.50E+00	5.55E+10	18.1695%
N-13	8.40E-02	3.11E+09	1.0175%
I-123	1.00E-02	3.70E+08	0.1211%
O-15	6.00E-03	2.22E+08	0.0727%
I-125	3.29E-04	1.22E+07	0.0040%
C-14	2.44E-04	9.03E+06	0.0030%
I-131	6.00E-05	2.22E+06	0.0007%
Sr-90	1.12E-05	4.15E+05	0.0001%
P-32	4.83E-06	1.79E+05	0.0001%
S-35	1.59E-06	5.88E+04	0.0000%
Th-232	6.58E-07	2.43E+04	0.0000%
Cu-64	6.00E-07	2.22E+04	0.0000%
Ga-68	3.00E-08	1.11E+03	0.0000%
Fe-59	8.00E-09	2.96E+02	0.0000%
Fe-55	2.00E-09	7.40E+01	0.0000%
Mn-54	1.00E-09	3.70E+01	0.0000%
U-238	8.40E-10	3.11E+01	0.0000%
Ra-226	5.00E-10	1.85E+01	0.0000%
U-233	2.50E-10	9.25E+00	0.0000%
Na-22	2.00E-10	7.40E+00	0.0000%
U-235	1.20E-10	4.44E+00	0.0000%
Co-60	2.00E-11	7.40E-01	0.0000%
TOTAL:	8.26E+00	3.05E+11	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 17 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 seventeen 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 CY96 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 recently completed a project to collect and use quality-assured onsite meteorological data for performing dose assessments. The upgraded 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 CY96 are based on the local meteorological data collected during CY96 from the main weather tower at the Berkeley Lab.

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

Building Number	Building Name	Relative to the Specified Building					Relative to the MEI of Building 75				
		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	1.4E-03	980	ENE	1.40E-03	5.693%	
BLD-2/6	Advanced Material Lab/ALS	20	370	NE	UC Lawrence Hall of Science	2.4E-05	370	NE	2.40E-05	0.098%	
BLD-3	Calvin Lab @UCB	15	60	S	Res. & Business	2.7E-08	1070	NE	2.50E-08	0.000%	
BLD-26/76	RAML/Counting Lab.	8	240	N	UC Lawrence Hall of Science	4.8E-10	240	N	4.80E-10	0.000%	
BLD-50/51	NSD/Bevatron	N/A	N/A	N/A	N/A	0	N/A	N/A	0.00E+00	0.000%	
BLD-55/56	Research Medicine/BIF	9	170	N	Residence	7.8E-03	490	E	6.30E-03	25.620%	
BLD-62	Materials & Chem. Science	13	240	E	Workplace	1.3E-06	650	NW	6.00E-07	0.002%	
BLD-70/70A	Nuclear / Life Sciences	13	330	W	Dormitory	3.3E-04	510	NE	2.80E-04	1.139%	
BLD-71/72	HILAC/NCEM	13	220	E	UC Lawrence Hall of Science	5.40E-04	220	E	5.40E-04	2.196%	
BLD-74/74B/83	Buildings 74/74B/83 Research Med.	7	120	S	UC Berkeley	5.2E-06	730	WNW	5.20E-06	0.021%	
BLD-75	National Tritium Labeling Facility	10	110	NW	UC Lawrence Hall of Science	1.4E-02	110	NW	1.40E-02	56.934%	
BLD-75A/75-127	Hazardous Waste Handling Facility (HWHF)	8	150	NW	UC Lawrence Hall of Science	1.5E-04	150	NW	1.50E-04	0.610%	
BLD-75C	EHS Calibration Sources	N/A	150	NW	UC Lawrence Hall of Science	0	150	NW	0.00E+00	0.000%	
BLD-75A (D)	Waste Storage Area (Diffuse)	1	150	NW	UC Lawrence Hall of Science	2.0E-04	150	NW	2.00E-04	0.813%	
BLD-88	88-Inch Cyclotron	12	110	W	Residence	1.5E-03	670	ENE	8.10E-04	3.294%	
BLD-903	Receiving Warehouse	N/A	N/A	N/A	N/A	0	N/A	N/A	0.00E+00	0.000%	
BLD-934	Molecular & Cell Blo. (off site)	4	38	N	Business	1.2E-03	4900	ENE	8.80E-04	3.579%	
							TOTAL:		2.46E-02	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	1.07E-01	51.828%
F-18	5.71E-02	27.658%
C-11	2.19E-02	10.608%
TH-232	1.56E-02	7.556%
I-125	1.22E-03	0.591%
TL-208	7.65E-04	0.371%
N-13	7.55E-04	0.366%
AC-228	6.87E-04	0.333%
I-123	4.72E-04	0.229%
SR-90	4.28E-04	0.207%
I-131	1.52E-04	0.074%
BI-212	1.26E-04	0.061%
PB-212	1.15E-04	0.056%
C-14	9.46E-05	0.046%
O-15	1.52E-05	0.007%
RA-224	7.64E-06	0.004%
U-238	6.48E-06	0.003%
P-32	3.23E-06	0.002%
U-233	2.19E-06	0.001%
TH-228	1.93E-06	0.001%
U-235	9.91E-07	0.000%
RA-228	4.25E-07	0.000%
RN-220	3.80E-07	0.000%
RA-226	3.25E-07	0.000%
S-35	1.66E-07	0.000%
FE-59	5.78E-08	0.000%
NA-22	4.76E-08	0.000%
MN-54	3.28E-08	0.000%
CU-64	2.39E-08	0.000%
PO-216	1.01E-08	0.000%
CO-60	9.88E-09	0.000%
GA-67	3.29E-09	0.000%
FE-55	3.16E-10	0.000%
TOTAL:	2.06E-01	100.000%

(*) 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: _____ 0.025 mrem/year (2.5E-4 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: 6/20/97
David C. McGraw
Division Director, Environment, Health and Safety

Signature: _____ Date: 6/20/97
for 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 Handling Facility (HWHF). The waste operations at the old HWHF (in building 75A and part of building 75) will soon be moved to this new building. 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. In addition to these continuous sampling, real-time monitoring systems for gross alpha, gross beta, and I-125 are also installed to monitor exhausted air from the glove boxes.

Unplanned Releases

During 1996, 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 less than 0.007 Ci (2.2×10^8 Bq) during CY96. The estimated EDE to an offsite MEI from this diffuse emission was found to be about $2.0\text{E-}4$ mrem/yr. ($2.0\text{E-}6$ 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 CY96 releases.*

The estimated collective effective dose equivalent (CEDE) to persons living within 80 km of Berkeley Lab is 0.21 person-rem/year ($2.1\text{E-}3$ person-Sv) attributable to CY96 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^{-7} Sv/a) 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 5 points subject to the continuous monitoring requirements of 40 CFR subpart H, Section 61.93(b). During CY96 none of the 5 points produced discharges exceeding 0.1 mrem/yr ($1.0\text{E-}3$ mSv/yr), however all 5 were continuously monitored (sampled). Usually, the Category I release point at Berkeley Lab was the NTLF main stack whose EDE was modeled at 0.014 mrem/yr (1.4×10^{-4} mSv). Berkeley Lab has upgraded the monitoring and analytical methods to fully conform to Section 61.93(b) monitoring requirements. Berkeley Lab has identified: a) 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 plan has been developed and approved in August 1994.

Appendix B

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