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ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY

Data for Calendar Year

1989

Prepared by the Staff of the
Occupational Health Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Gary E. Schleimer
and
Ronald O. Pauer

Editors

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PREFACE

In 1976 R.H. Thomas published the *LBL Annual Environmental Monitoring Report* in two parts. Part I (LBL-4678) discussed in detail the modeling used to determine the population dose equivalent due to Laboratory radiological operations. That volume also described natural radiation background, geological features, climate and meteorology, and the environmental surveillance program of the Lawrence Berkeley Laboratory (LBL). Part II (LBL-4827) included only the results of the sampling and measuring programs and other data necessary to determine the environmental impact of the Laboratory's radiological operations for 1975.

Although the 1980 Annual Report, LBL-12604, was kept brief, abstracted sections from LBL-4678 were included so that the document might stand alone. The same format has been used in this report, along with updates to LBL-4678, where appropriate, and a greatly expanded description of LBL's nonradiological environmental activities.

Readers wishing a more-comprehensive discussion of LBL site characteristics and population dose modeling may obtain a copy of LBL-4678 from

Gary E. Schleimer
Environmental Health and Safety Department
Building 75, Room 112
Lawrence Berkeley Laboratory
Berkeley, CA 94720

R.O. Pauer and G.E. Schleimer of the Environmental Health and Safety Department of the Occupational Health Division contributed to the preparation of this report.

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ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY, 1989

Abstract

The Environmental Monitoring Program of the Lawrence Berkeley Laboratory is described. Data for 1989 are presented, and general trends are discussed.

Introduction

Laboratory Operations

The Lawrence Berkeley Laboratory (LBL) is a multiprogram national laboratory managed by the University of California (UC) for the U.S. Department of Energy (DOE). LBL's major role is to conduct basic and applied science research that is appropriate for an energy research laboratory. LBL, birthplace of the cyclotron, was founded by the late Nobel Laureate Ernest Orlando Lawrence in 1931.

The Laboratory also supports nationwide university-based research by providing national facilities, including the National Center for Electron Microscopy, three large accelerators, several small accelerators, a number of radiochemical laboratories, several large gamma irradiators, and a tritium (^3H) labeling laboratory. The Bevatron (Building 51 in Fig. 1) is the most massive of LBL's accelerators. Originally designed as a 6-GeV proton synchrotron, it is presently capable of accelerating ions up to ^{40}Ca, from 20 MeV/nucleon to 2.1 GeV/nucleon, and ions up to uranium to 1 GeV/nucleon. For certain beams the SuperHILAC is used as an injector. (This combination is called the Bevalac.) The SuperHILAC (Building 71), a heavy-ion accelerator, produces ion beams up to 8.5 MeV/nucleon. The 88-Inch Variable Energy Sector-Focused Cyclotron (Building 88) routinely produces intense beams of protons to about 60 MeV, alpha particles to 140 MeV, and heavy ions to mass 40 to energies of 350 MeV. Aside from shutdown periods, the first two of these accelerators provide beams around the clock. The 88-Inch Cyclotron provides beams ~120 hr/wk.

The tritium facility located in Building 75 was designed to handle kilocurie quantities of tritium, ^3H (a radioactive isotope of hydrogen) used as a labeling agent for a variety of molecules subsequently employed in chemical and biomedical research. The facility is funded by the National Institutes of Health.

Radiochemical and radiobiological studies performed in many laboratories at LBL typically use millicurie quantities of a great variety of radionuclides.

The Site

LBL is situated upon a hillside above the main campus of UC. The 130-acre site is located on the west-facing slope of the Berkeley Hills, at elevations ranging from 150 to 350 meters above sea level. Most of the site is within the City of Berkeley, but about one-quarter of the eastern part is within the City of Oakland. It is located three miles east of San Francisco Bay and about fifteen miles east of the City of San Francisco (Fig. 2).

LBL is located in an urban environment on land owned by UC. The LBL site is bordered on the north by predominately single-family homes and on the west by 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. The population within an 80-km (50-mi) radius of the Laboratory is approximately 5.1 million (1980 census).[1]

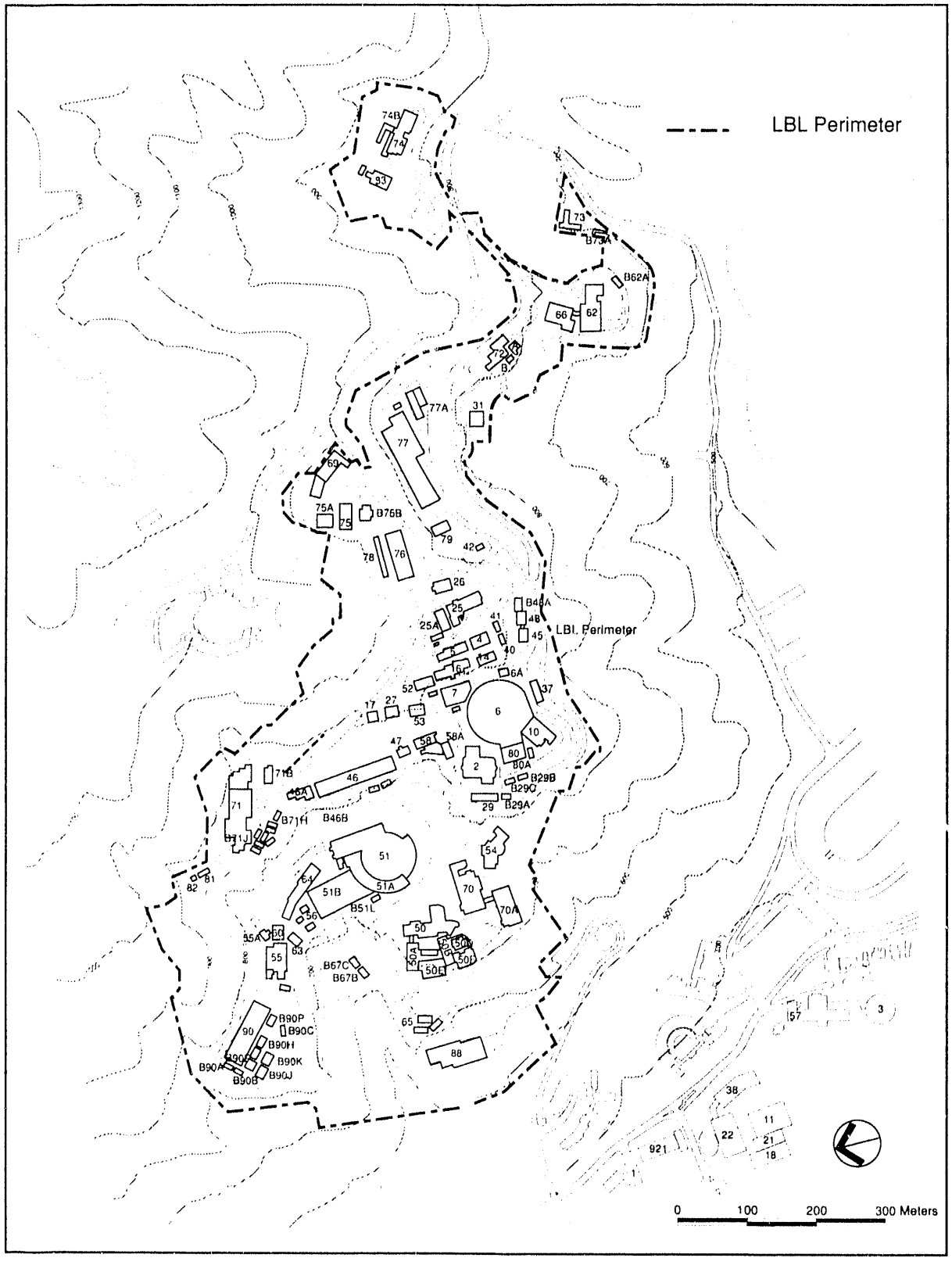


Fig. 1. Lawrence Berkeley Laboratory buildings.

Key to LBL Buildings Shown in Figure 1

Bldg. No.	Description
	HILL-SITE BUILDINGS
2	Advanced Materials Laboratory (AML) & Center for X-ray Optics (CXRO)
4	Magnetic Fusion Energy (MFE)
5	Magnetic Fusion Energy (MFE)
*6	Advanced Light Source (ALS)
7	Central Stores & Electronics Shops
10	Cell & Molecular Biology Research & Photography
14	Accelerator & Fusion Research & Earth Sciences
16	Magnetic Fusion Energy Laboratory
17	EH&S/Applied Sciences Lab
25	Mechanical Technology
25A	Electronics Shops
26	Medical Services
27	High Voltage Test Facility & Cable Shop
29	Electronics Engineering, Research Medicine/Radiation Biophysics Offices
31	Chicken Creek Maintenance Bldg.
36	Grizzly Substation Switchgear Bldg.
37	Utilities Service
40	Electronics Development Lab
41	Magnetic Measurements Lab
42	Salvage
43	Compressor Bldg.
44	Indoor Air Pollution Studies
45	Fire Apparatus
46	RTSS, ALS, Accelerator Development
46A	Real Time Systems Section (RTSS)
47	Advanced Accelerator Study
48	Fire Station
50	Physics, Accelerator & Fusion Research & Nuclear Science
50A	Director's Office, Environment & Laboratory Development, Administration Division, Patents
50B	Physics, Computer Center, IRD & ICSD
50C	PID, Physics
50D	MCSD & Nuclear Science
50E	Earth Sciences
50F	Computing Services, IRD
51	Bevalac/Bevatron
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	Cryogenic Facility
58	Accelerator Research & Development
58A	Accelerator Research & Development Addition
60	High Bay Laboratory
61	Standby Propane Plant
62	Materials & Chemical Sciences
63	Accelerator & Fusion Research
64	Accelerator & Fusion Research
65	Data Processing Services
66	Surface Science & Catalysis Lab
68	Upper Pump House
69	Business Services, Materiel Management, Mail Room & Purchasing
70	Nuclear Science, Applied Science & Earth Sciences
70A	Nuclear Science, Materials & Chemical Sciences & Earth Sciences
71	Heavy Ion Linear Accelerator (HILAC)
71A	HILAC Rectifier
71B	HILAC Annex
72	National Center for Electron Microscopy (NCEM)
72A	High Voltage Electron Microscope (HVEM)
72B	Atomic Resolution Microscope (ARM)
72C	ARM Support Laboratory
73	Atmospheric Aerosol Research
74	Research Medicine/Radiation Biophysics, Cell & Molecular Biology Laboratory
74B	Research Medicine/Radiation Biophysics, Cell & Molecular Biology Laboratory Annex
75	Radioisotope Service & National Tritium Facility (NTF)
75A	Compactor, Processing & Storage Facility
76	Construction & Maintenance & Craft Shops
77	Mechanical Shops
77A	Ultra High Vacuum Assembly Facility (UHV)
78	Craft Stores
79	Metal Stores
80	Electronics Engineering
80A	Office Building
81	Liquid Gas Storage
82	Lower Pump House
83	Lab Cell Biology
88	88-Inch Cyclotron
90	Applied Science, Employment, Engineering, Occupational Health, Personnel, Protective Services
	SMALL BUILDINGS AND TRAILERS
B-13A	Environmental Monitoring West of 88
B-13B	Environmental Monitoring West of 90
B-13C	Environmental Monitoring South of UC Recreation Area
B-13D	Environmental Monitoring North of 71
B-13E	Sewer Monitoring Station, Hearst Avenue
B-13F	Sewer Monitoring Station, Strawberry Canyon
B-13G	Waste Monitoring Station, West of 70

*Under construction.

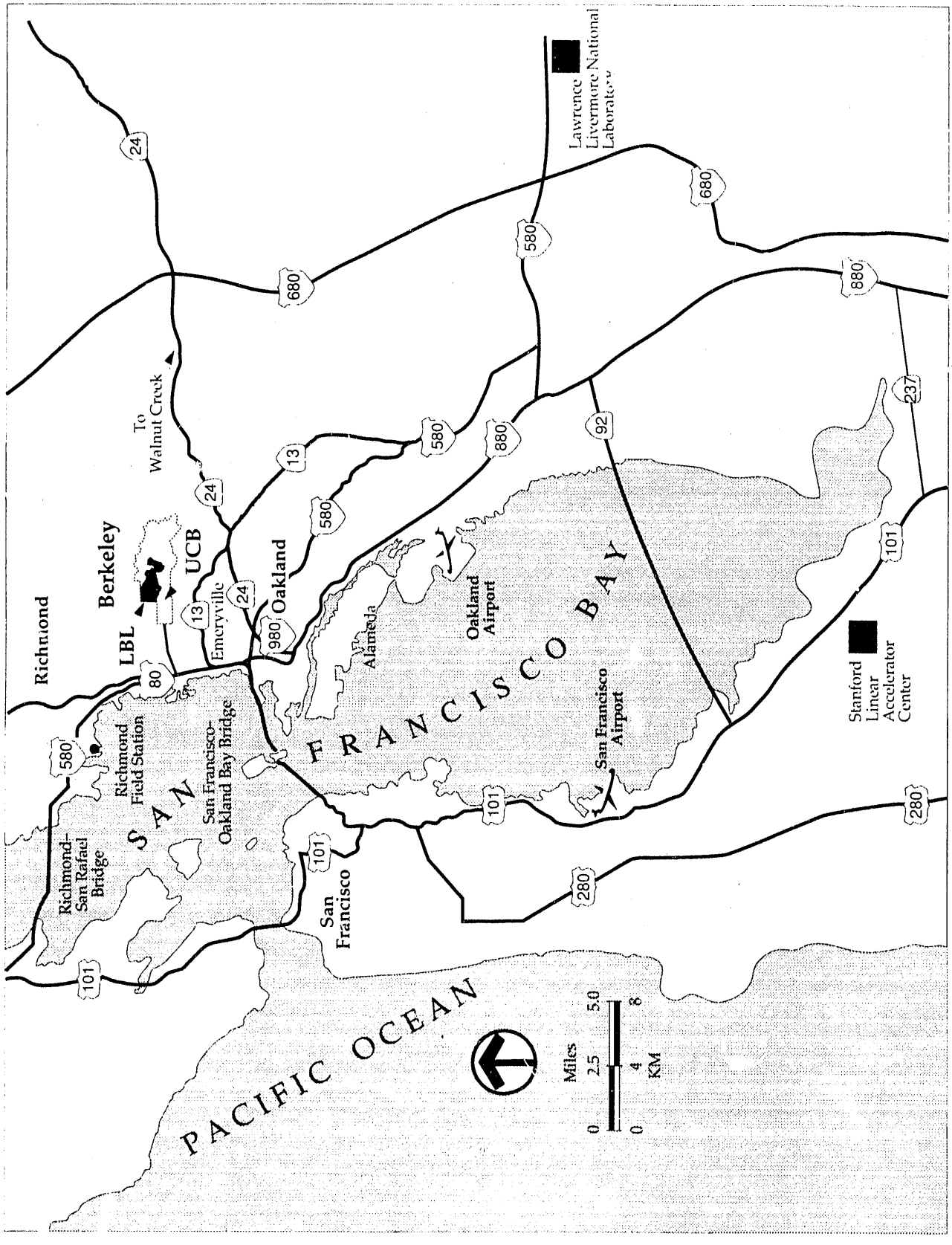


Fig. 2. Lawrence Berkeley Laboratory environs.

The Laboratory's activities are located on site and off site. There are 81 buildings on the LBL hillside site, plus additional facilities located on the University campus, notably the Donner Laboratory of Biology and Medicine and the Melvin Calvin Laboratory. The on-site space consists of 1,350,000 gross square feet (gsf) in about 60 buildings: 1,307,000 in DOE buildings and trailers, and 43,000 in University-owned buildings. Off-site space utilized by LBL consists of 260,000 gsf in various University buildings on the UC at Berkeley (UCB) campus and 130,000 gsf in leased facilities in Emeryville and Berkeley.

The Laboratory's population is approximately 4,000, including about 600 visiting scientists and engineers. About 3,200 are located on site, 700 are located in campus buildings, and about 100 are in off-site leased space.

The Climate

The climate of the LBL site is greatly influenced by its nearness 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. About 95% of the rainfall occurs from October through April, and intensities are seldom greater than 1.3 cm/hr. Thunderstorms and hail and snow are extremely rare. Winds are usually light, but summer sea breezes range up to 9–13 m/s (20–30 mph). Winter storm winds from the south or southwest have somewhat lesser velocities.

Geology

Most of the LBL site is underlain by complex sedimentary and volcanic rock. In general, the bedrock is relatively weak and weathers deeply. Consequently, a colluvial cover has been produced that is a few feet thick. The major geologic unit consists of poorly consolidated sandstones, siltstones, claystones, and conglomerates of relatively low strength and hardness. These rocks are blanketed by clay soils having high shrink-swell characteristics. The western and southern portions of the site are underlain by moderately well consolidated shales, siltstones, sandstones, and conglomerates. Throughout most of the upper elevations a volcanic unit overlays and is interbedded with the upper layers of the major geologic unit.

The Hydrogeology

Highly complex ground-water conditions are present at LBL. Year-round springs, annual surface seeps, and variable water levels in observation wells indicate discontinuous and localized aquifers. These conditions are due to a combination of factors: open fracture volcanic flow rock, impervious claystone interbeds, permeable sandstone lenses, and irregular fracture patterns associated with past folding and faulting. During the rainy season, ground-water levels increase and cause a decrease in slope stability. Consequently, the Laboratory has installed an elaborate ground-water detection and drainage system. The drainage system uses both pumped vertical and free-flowing horizontal wells (hydraugers). Ground-water drainage feeds into Blackberry Creek on the north portion and into Strawberry Creek on the south portion of the Laboratory. Both creeks eventually flow through the UCB campus and then into the City of Berkeley storm drainage system, which empties into San Francisco Bay (Fig. 3).

Water Supply

The Laboratory's primary water supply is the East Bay Municipal Utility District (EBMUD) Shasta Reservoir, which holds approximately two million gallons. The Laboratory's high pressure fire and domestic systems are supplied from this reservoir. A secondary source is the EBMUD's Berkeley View Tank, which holds approximately one million gallons. Water mains have automatic shutoff valves for protection in case of a main breakage. The LBL water distribution system operates entirely by gravity flow, requiring no pumps or energy consumption. The Laboratory has recently installed two 750,000-l (200,000-gal) water storage tanks at separate locations for fire protection. Diesel-powered pumps provide the necessary flow and pressure for maintaining a reliable fire protection system during emergencies.

Sanitary Sewer Systems

The west-side LBL sanitary system connects to the City of Berkeley sewer main at Hearst Avenue. On the south side of the Laboratory, a second connection is also made to the City of Berkeley system. The

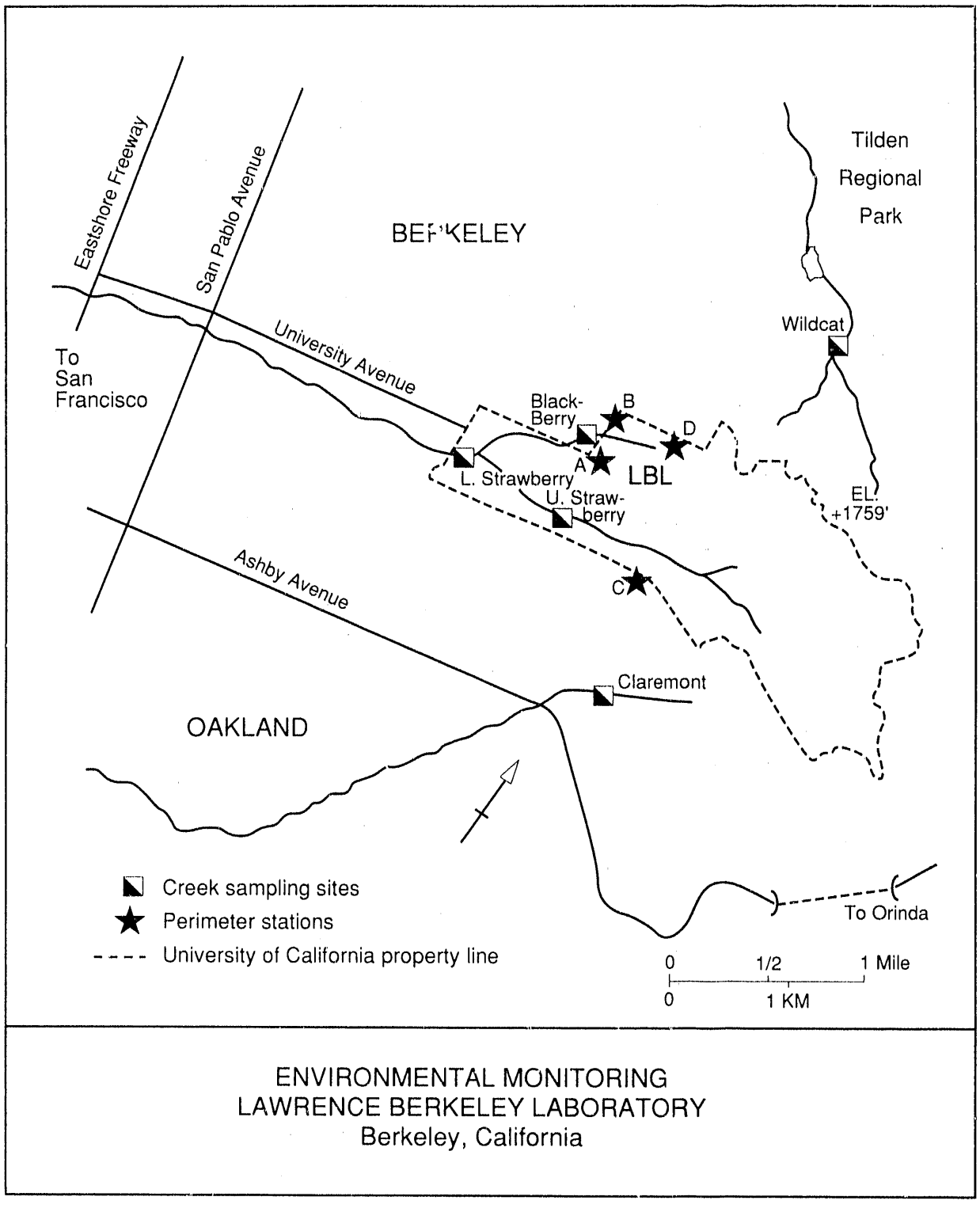


Fig. 3. Map of LBL perimeter monitoring stations and creek sampling sites.

Berkeley system flows to the EBMUD Sewage Treatment Facility, where the wastewater undergoes primary and secondary treatment before its discharge to San Francisco Bay.

Storm Drainage System

Because of its hillside location and moderate annual rainfall, surface run-off is a prevalent feature at LBL. Consequently, an inclusive storm drain system, designed and installed in the 1960s, discharges into the Blackberry Creek watershed on the north side of LBL and the Strawberry Creek watershed on the south side. This system provides for run-off intensities expected in a 25-year maximum-intensity storm.

1989 Environmental Monitoring Summary

In order to establish whether LBL research activities produced any impact on the population surrounding the Laboratory, a program of environmental air and water sampling and continuous radiation monitoring was carried on throughout the year.[2] For 1989, as in the previous several years, dose equivalents attributable to LBL radiological operations were a small fraction of both the relevant radiation protection guidelines (RPG) of 100 mrem/yr and of the natural radiation background. DOE Order 5400.5 (Ref. 3) limits the total effective dose equivalent to any member of the public from all of a facility's sources to less than 100 mrem/yr above natural background. (Typically, DOE facility impacts are a small fraction of that value.) The Order also provides tables that contain derived concentration guides (DCG) for airborne and waterborne radionuclides. A DCG is that concentration of a single radionuclide in air or water that if routinely consumed or continuously inhaled will individually produce an effective dose equivalent of 100 mrem in one year to the exposed individual. Table 1 summarizes the exposures to a hypothetical maximally exposed member of the public as well as the calculated sum of all exposures to the population within 80 km (50 mi) of LBL.

The maximum effective dose equivalent delivered to a hypothetical member of the community is defined as the maximum perimeter dose equivalent at an area where non-LBL personnel work or reside.

Table 1. Summary of LBL radiological impact.

	Maximum Individual (Accelerators)	Maximum Individual (Airborne Nuclides)	Maximum All Sources	Collective Dose to Persons < 80 km from LBL (All Sources)
Dose	2.6 mrem	0.3 mrem	2.8 mrem	≤ 17 mrem
Location	Residence NE of B13D	Residence west of B13A	Residence NE of B13D	≤ 80 km from Laboratory
DOE Radiation Protection Standard[a]	100 mrem	100 mrem	100 mrem	—
% of STD	2.6	0.3	2.8	—
Background	100 mrem	300 mrem	300 mrem	1.5×10^6 person-rem
LBL impact as a % of background	2.6	0.1	0.93	0.003

[a]Source: Ref. 3.

This value [the 1989 dose equivalent at the Olympus Gate Environmental Monitoring Station (MS) B-13D] was ≤ 2.8 mrem for the year [2.6 mrem from direct radiation (see Table 2) and 0.2 mrem from radionuclide releases], about 3% of the RPG of 100 mrem. The hypothetical maximum exposure, to an individual from airborne radionuclides, would be just outside the western LBL perimeter, west of LBL Building 88. The 1989 effective dose equivalent would have been ≤ 0.3 mrem—0.3% of the RPG.

The total population dose equivalent attributable to LBL operations during 1989 was ≤ 17 man-rem, an average of about 0.003% of the RPG of 100 mrem maximum effective dose equivalent to individual members of the surrounding population. [The reader should note that throughout this report the phrase "population dose" should be taken to mean collective effective dose equivalent (CEDE) and "dose" or "dose equivalent" to mean effective dose equivalent.] CEDE is defined as the sum of the "doses" delivered to all individuals within an 80-km (50-mi) radius of the Laboratory.

Small amounts of ^{14}C, ^{35}S, ^{125}I, and unidentified alpha and beta-gamma emitters were released from LBL laboratory stacks (Table 3). The collective effective dose equivalent attributable to the foregoing releases is <0.1 man-rem. The majority of the impact of LBL radionuclide operations is from the airborne release of 480 Ci of tritium (as HTO), which is responsible for a CEDE of approximately ≤ 15 man-rem and a hypothetical maximum off-site individual exposure (from airborne radionuclides) of ≤ 0.3 mrem.

To put the Laboratory's impact into perspective we refer to the National Commission on Radiation Protection and Measurements (NCRP) for an approximate value for absorbed dose from external and internal natural sources to residents of the U.S. (e.g., cosmic rays, radiation from continental rocks, naturally occurring radioactive potassium-40 in our muscles and bones, and exposure from radon and its daughters). The NCRP's estimate of the effective dose equivalent from the foregoing is 300 mrem/yr, which implies an annual population dose from natural sources of ~1,500,000 man-rem to the 5.1 million people within 80 km (50 mi) of LBL (from NCRP Report No. 94, "Exposure of the Populations in the United States and Canada from Natural Background Radiation," 1987). However, in this report, when comparing LBL's penetrating radiation impact (from accelerator operations) to natural sources, only the penetrating whole-body component of natural background (about 33% of the foregoing total, or 100 mrem) is used.

Tritium levels averaging 29,000 pCi/l, which exceed the EPA 40 CFR 141 Community Drinking Water Standard of 20,000 pCi/l, were found in the outflow of one of LBLs hydraugers (designated 7712H in this report), and an average of 120,000 pCi/l was found in rainwater samples taken on site 70 m from the tritium stack. The hydrauger flow rate is low (average 0.2 l/min), and the effluent eventually flows into Strawberry Creek. Neither the hydrauger water nor that of Strawberry Creek is potable or used for agriculture or recreation. Since no practical way exists to remove existing tritium from water no remediation effort is planned. However, the National Tritium Labeling Facility has instituted a program to markedly reduce airborne tritium releases (the origin of the environmental tritium). Aside from LBL sewage, no off-site water has been found to contain more than 6% of the EPA Drinking Water Standard for tritium.

A group of hydraugers that drains the slope east of Building 51 whose discharge was found to contain levels of several chlorinated hydrocarbons exceeding Safe Drinking Water Act limits, were "manifolded" together and their outflow treated by charcoal filtering. The effluent from the charcoal bed is used as make-up water for the Building 51 cooling towers. A major LBL subsurface characterization study has been funded for FY 1991 and 1992. (See the Environmental Activities section and the Trends section of this report.)

Gross data for radioactivity in environmental air and water for the period 1980–1989 are presented for comparison with the 1989 data. These gross data show that, except for periods following atmospheric nuclear weapons tests (China, 1980) and the Chernobyl fire (1986), gross radioactivity concentrations in air and water in the vicinity of LBL show only small fluctuations about historical background levels.

Table 2. Fence-post annual effective dose equivalent at the LBL boundary due to accelerator operation, 1989.

Monitoring station	1989 total above background		
	gamma[a] (mrem)	neutrons (mrem)	Total[b] (mrem)
Station 13 A (Bldg. 88)	0.45 ± 0.1	0.17 ± 0.02	0.6 ± 0.1
Station 13 B (Bldg. 90)	0	0.09 ± 0.02	0.09 ± 0.02
Station 13 C (Panoramic)	0	0	0
Station 13 D (Olympus Gate)	0	2.6 ± 0.5	2.6 ± 0.5
Standard for comparison (Dose to individuals at maximum point of exposure)	—	—	100[c]

[a]Average gamma background measured inside the 4 perimeter monitoring stations was 77 ± 11 mrem during 1989.

[b]The errors shown are those associated with the actual counts and calibration-source uncertainties. Neutron flux-to-dose equivalent conversion factors are not known to this accuracy.

[c]Source: Ref. 3.

Table 3. Total quantities of radionuclides discharged into the atmosphere, 1989.

Nuclide	Half Life	Quantity Discharged	
		(Ci/yr)	(Bq/yr)
Tritium (as HTO)	12.3 yr	480	1.8×10^{13}
Carbon-14 (as $^{14}CO_2$)	5730 yr	7×10^{-4}	2.6×10^{7}
Iodine-125	60.1 d	1.3×10^{-3}	4.9×10^{7}
Sulfur-35	87.2 d	1×10^{-5}	3.7×10^{5}
Unidentified beta-gamma emitters[a]	—	9×10^{-6}	3.3×10^{5}
Unidentified alpha emitters[b]	—	$< 2 \times 10^{-8}$	$< 7.4 \times 10^{2}$

[a]Conservatively assumed to be ^{90}Sr.

[b]Conservatively assumed to be ^{232}Th.

Environmental Compliance Summary
January 1989–May 1990

This section of the report briefly outlines areas in which LBL was out of compliance with environmental laws or regulations.

During the year there were several violations of LBL's wastewater discharge permit. The source for periodic wastewater discharge violations of copper and zinc that were measured in LBL sewers during 1989 was determined to be from the regeneration of resin columns for low-conductivity water systems. During regeneration, acid and caustic solutions are used to remove substances retained by the resin columns, including copper and zinc. Measurements of the discarded cleaning solutions verified that high levels of copper and zinc were present. In the past, the cleaning solution was discharged into the sanitary sewer system. This practice was discontinued. Stationary resin columns were replaced with portable ones that are regenerated by the supplier.

An investigation of wastewater discharge violations for chlorinated hydrocarbons has identified two potential sources. Both are research activities that discharge methylene chloride and chloroform into the sanitary sewer system. Discharge from both activities have been discontinued until an adequate collection system has been installed.

The California Department of Health Services (DHS) conducted a Resource Conservation and Recovery Act (RCRA) compliance inspection on January 24–29, 1990. During that inspection, violations of hazardous waste statutes and regulations were found for labeling, access, storage over one year, improper storage of lead/acid batteries, documentation, and separation of incompatibles. In addition, information on the chemical analysis of the Plating Shop rinse waters and the Machine Shop waste coolant were requested. LBL has submitted a response to the violations and a schedule for compliance to DHS.

The EPA conducted a Toxic Substance Control Act (TSCA) polychlorinated biphenyls (PCB) inspection on February 22, 1990. A notice of noncompliance was issued for inadequate notification and documentation. LBL has prepared a response to each issue and submitted this to the EPA.

The Bay Area Air Quality Management District inspected LBL on January 8, 1990, and issued a notice of violation for operating, without a Permit to Operate, equipment that may cause air pollution. The violation was the result of a delay in the payment of the permit fee. The fee was submitted immediately, and an operating permit was obtained.

Permits for wastewater discharges, underground storage tanks, and air pollution sources are all up to date. A permit application for a hazardous-waste storage and treatment facility had been extensively revised and resubmitted to DHS on May 14, 1990. In the meantime, LBL is operating under an extension of its existing permit. In addition, a permit application for the operation of a new wastewater treatment unit is in the progress of being revised. This wastewater is currently being processed through an older unit operating under a variance from DHS.

Environmental Program Information

Environmental Program Overview

This section of the report provides a brief overview of LBL's environmental surveillance practices and the rationale for those activities. Subsequent sections will detail the areas outlined here.

DOE Orders require that DOE Facilities and DOE Contractor-managed facilities like LBL comply with applicable DOE, Federal, State, and local environmental regulations. Furthermore it is the policy of LBL to conduct its operations in a manner that is in complete compliance with all applicable environmental laws and regulations, Executive Orders, and DOE policies.

DOE Orders

The requirement for the preparation of this report, its format, and the DOE environmental protection guidelines referenced herein are found in DOE Order 5400.1 "General Environmental Protection Program" (adopted 11/9/88). Radiation protection guidelines are found in DOE Order 5480.1A and draft order 5400.XX (adopted as order 5400.5 2/8/90) "Radiation Protection of the Public and the Environment."

To ensure that LBL research activities are carried out in compliance with the foregoing, the Laboratory supports a program of monitoring of the workplace, effluents, and environment. Elements of the program include

- Sampling of workplace and effluent air in all areas where significant quantities of radionuclides are handled. (Samplers are changed weekly.)
- Continuous monitoring of penetrating radiation at four perimeter stations and in each major accelerator complex (to quantify the impact of LBL accelerator operations). Data from the perimeter and accelerator stations are telemetered to a central location and collected by a computerized data acquisition system. The LBL waste storage yard is also so monitored since packaged radioactive materials are stored there before shipment to a radioactive-waste disposal site.
- Flow-proportional sampling of the two LBL sewer outfalls. Outfall flow and pH are continuously measured at each site. Composite samples are removed weekly and analyzed for tritium, radioiodines, and gross alpha and beta emitters. Monthly composites are analyzed for a series of regulated metals, and, at least bimonthly, "grab" samples are analyzed for chlorinated hydrocarbons, oil and grease, cyanides, phenols, total suspended solids, and filterable chemical oxygen demand. (The nonradiological assays are mandated by LBL's sitewide wastewater discharge permit.)
- Continuous sampling of environmental air at 10 points about the site and at 8 off-site and perimeter locations. Fourteen of the sites are sampled for particulates, eight for HTO, four for radioiodine, and one for $^{14}CO_2$. Samplers are changed weekly.
- Rainfall and dry-deposition sampling at 8 on-site and 4 perimeter locations. Samples are taken monthly. Two additional sites are sampled whenever there is a significant rainfall. The rainwater is analyzed for tritium and gross alpha and beta activity.
- Sampling of ground water by collecting "grab" samples at six of LBL's many hydraugers monthly and at each of the creeks that drain the LBL watershed weekly. The samples are analyzed for tritium and gross alpha and beta emitters.

The principal radionuclides released from LBL stacks are gases or vapors, specifically tritium (^3H) as HTO (water vapor), radioiodine (^{125}I) in various gaseous forms, ^{14}C as CO_2, and ^{35}S as SO_2. Stack effluent sampling is done for those species, and ambient air is sampled for HTO, radioiodines, and $^{14}CO_2$.

Significant (or even measurable) releases of particulate radioactivity from LBL are rare since all areas where significant quantities of particulate radionuclides are handled have high-efficiency particulate (HEPA) filters installed in their exhaust streams. Nonetheless, LBL samples effluent air and ambient air for particulate radioactivity to validate the efficacy of the HEPA systems, observe atmospheric trends, and detect off-site releases of particulate radionuclides (e.g., from atmospheric nuclear weapons tests and the Chernobyl fire).

Clean Air Act

The Clean Air Act is a broad Federal statute, which specifies ambient air quality standards, sets emission limits for specific air pollutants from certain sources, and determines limits and operating criteria for a number of hazardous air pollutants. In California, the Act is implemented through local Air Quality Management Districts. LBL is under the jurisdiction of the Bay Area Air Quality Management District.

The Bay Area Air Quality Management District implements the Clean Air Act by establishing a set of Rules and Regulations for operations or equipment that may cause air pollution. These regulations are enforced through an air quality permit system and periodic inspections. If a violation of the District's regulations is found, a notice of violation is issued.

The permit system requires review of equipment design and inspection of the equipment to ensure compliance with the District's requirements. Equipment requires two types of permits: an Authority to Construct, followed by a Permit to Operate. After an Authority to Construct has been issued and construction is complete, District personnel inspect the facility in operation to verify that the equipment performs as required. If it does, the District issues a Permit to Operate, which may contain specific operating conditions for equipment. Annually, all "permitted" sources are renewed and reinspected by the District.

There are 36 permitted sources at LBL. Six new sources were added in 1989; most of these were for solvent cleaning operations. A list of the permits follows in a later section of this report.

No violation notices were issued in 1989.

The National Emission Standard for Hazardous Airborne Pollutants (NESHAPs) update of 1989 detailed in the United States Code of Federal Regulations 40 CFR 61 Subpart H requires that facilities that release radionuclides into the air report those releases to the appropriate regional office of the Environmental Protection Agency (EPA) in a specific format — see Appendix for a copy of LBL's report for 1989.

California Air Toxics "Hot Spots" Information and Assessment Act (AB 2588)

The purpose of AB 2588 is to gather information on substances that may pose a chronic or acute threat to public health when present in the ambient air. It is based on the assumption that certain facilities emit enough toxic air contaminants to create localized "hot spots" where contamination exceeds typical ambient levels and may exceed health and safety thresholds. The information will be used to make emission information available to the public and will also be used by various public agencies in assessing and reducing the risk to the public. The requirements of AB 2588 are implemented through the local Air Quality Management Districts.

The Bay Area Air Quality District required the submission of two reports in 1989:

- By August 1, an emission inventory plan that identifies the substances that must be reported and provides a plan to estimate the emissions from their sources.
- By November 1, emission calculations that were specified in the emission inventory plan.

LBL prepared and submitted both of these reports; however, the reporting deadlines were not met.

Clean Water Act

The Clean Water Act was established in 1977 as a major amendment to the Federal Water Pollution Control Act of 1972 and was substantially modified by the Water Quality Act of 1987. The Act provides a set of statutes intended to support the restoration and maintenance of water quality in all waters throughout the country. To implement the Act, EPA issued pretreatment standards for industrial dischargers as well as general standards controlling toxic pollutants. In California, the authority to implement the pretreatment program had been delegated to the State. The State, in turn, has required the local Public Owned Treatment Works (POTW) to enforce its provisions.

At LBL, the pretreatment standards are enforced by EBMUD. These standards have been incorporated into EBMUD Ordinance No. 311, which established the regulations for the interception, treatment, and disposal of wastewater. The primary tool for enforcing the requirements of the EBMUD pretreatment program is a permitting process. A listing of each wastewater discharge point is included in each permit, which sets specific limits on pollutants known to be present and defines a number of conditions that must be met, including self-monitoring, sampling, analysis, reporting, and recordkeeping requirements.

At LBL, there are two operations that are regulated by the EBMUD pretreatment program and that have wastewater discharge permits:

- Plating Shop, Building 77
- Printed Circuit Board Shop, Building 25

Both operations must comply with the Metal Finishing Category Standard (40 CFR 433). In order to meet the standard's discharge requirements, wastewater pretreatment units have been installed at each shop. To ensure compliance with the pretreatment standard, the effluent from the treatment unit is tested.

In addition, a third wastewater discharge permit has been issued for the entire LBL site. This permit has established discharge requirements that must be met at the site boundary.

On January 20 and April 7, 1989, two discharge violations for copper occurred at the Building 77 Plating Shop. Subsequent investigations found that one violation was due to equipment malfunction; the cause of the other could not be determined. Maintenance procedures were changed to prevent a recurrence.

On May 11, 1989, a discharge violation for copper and lead occurred at the Building 25 Printed Circuit Shop. It was determined that the violation was due to operator error. Operational procedures were reinforced to prevent a recurrence.

At the site boundary, discharge violations were detected in 21 samples in 1989. Violations resulted from excessive levels of copper, zinc, silver, mercury, and chlorinated solvents. In order to determine the sources of these substances preliminary investigations were conducted, and a comprehensive remediation plan was prepared.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) is a complex body of regulations intended to ensure that hazardous wastes are disposed of in an environmentally safe manner and that facilities treat, store, or dispose of hazardous waste in a way that protects human health and the environment. Due to the nature of the research activities conducted at LBL, a large number of waste chemicals classified as hazardous under RCRA are generated; however, most are generated in relatively small quantities.

California has not received authorization to administer the EPA RCRA program. However, the EPA has contracted the State Department of Health Services (DHS) to perform RCRA permit reviews and inspections. In addition, California has established its own set of regulations, which are also enforced by DHS, governing the management of hazardous wastes.

In order to manage hazardous waste before off-site shipment or on-site treatment, LBL operates a RCRA permitted storage facility. This facility was initially permitted in 1983, with an expiration date established for 1988. In 1987, a new permit application was submitted because of extensive modifications needed to the original permit. However, due to an extremely large workload, DHS was unable to process this revision, and the initial permit was extended pending resolution of the new application. In 1989, the 1987 application was again revised in order to update the application, in general, and to add a new, proposed hazardous waste handling facility. This application was subsequently reviewed by DHS, and a Notice of Deficiency was sent in December 1989.

In addition, small quantities of certain hazardous chemicals are treated on site in several treatment units. These units are exempt from EPA RCRA regulations but are included in the State's regulations.

In 1984 a wastewater treatment unit was installed at the Building 77 Plating Shop and was operated under a variance granted by DHS. In 1989 a new, larger treatment unit was installed; however, its operation has been delayed pending approval of a permit application.

The remaining treatment units treat low-risk hazardous wastestreams by simple processes and will be regulated by DHS under a permit-by-rule system. In this system, DHS will use a post-audit approach of inspecting facilities they are operating, rather than extensive review of their proposed operation before permitting. Included in this category are the following four treatment units:

- Printed-circuit-board wastewater, Building 25 — neutralization and metal precipitation.
- Laboratory acid wastewater, Building 2 — neutralization.
- Laboratory acid wastewater, Building 70A — neutralization.
- Oil/Water separator, Building 76.

Comprehensive Environmental Response, Compensation and Liability Act

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) provided the regulatory framework and funding needed to properly clean up closed and abandoned hazardous waste

sites. Under the provisions of CERCLA, facilities are required to collect information on sites that are potentially contaminated by hazardous materials. This information is submitted to EPA, and the sites are ranked according to their potentials for impairing human health or damaging the environment. The sites with the highest potentials are placed on the National Priorities List (NPL) and are forced into an environmental cleanup action.

EPA has allowed DOE to establish its own independent CERCLA program, subject to EPA oversight, in DOE Order 5480.14. Under this Order, a preliminary assessment was performed for potential waste sites and submitted to EPA in 1988. No significant hazardous waste sites were identified at LBL, due to their relatively small impact to the surrounding environment, and no sites have been placed on the NPL. Further assessment and, if necessary, cleanup of sites will likely take place under RCRA authority as a condition of the hazardous waste permit, or possibly under some combined RCRA/CERCLA action, rather than under a CERCLA program alone.

Superfund Amendments and Reauthorization Act, Title III

Title III of the 1986 Superfund Amendments and Reauthorization Act (SARA) to CERCLA created a system for planning for hazardous material emergencies and for making information regarding use and storage of hazardous materials available to the public. In California, many of the SARA Title III requirements overlap with independent requirements in State-mandated programs. After two years of negotiations with EPA, the California legislature amended the State requirements to reduce inconsistencies between State and Federal requirements.

According to SARA, facilities that handle more than the threshold planning quantities of any extremely hazardous substance are required to submit three distinct planning and inventory reports to the State and local agency. In California, the reporting requirements of SARA Sections 311 and 312 were incorporated into the requirements of the Hazardous Materials Release Response Plan and Inventory Law (AB 2189). LBL is exempt from the third report, which is required by SARA Section 313, since it applies only to facilities in SIC codes 20 to 39. At LBL, AB 2189 is enforced by the City of Berkeley.

In 1989, LBL conducted a comprehensive inventory of hazardous chemicals. The three reporting thresholds of AB 2189, which are generally smaller than those found in SARA Title III, were used. The following thresholds apply to the entire facility:

- 55 gallons for liquids.
- 500 pounds for solids.
- 200 cubic feet for compressed gases.

In addition, an emergency response plan was developed to meet the requirements of AB 2189. The inventory data and emergency response plan were packaged together in a report, called a Business Plan, and submitted to the City of Berkeley on December 22, 1989.

Toxic Substance Control Act

The Toxic Substances Control Act (TSCA) establishes the legal framework for the manufacture, distribution, use, and disposal of regulated substances. The principal TSCA-regulated substances in general use at LBL are PCB oils, commonly found in electrical equipment such as capacitors and transformers. TSCA provides detailed requirements for the management of this PCB-containing equipment when the PCB levels exceed 50 parts per million.

In 1987, LBL initiated a program to reduce the inventory of PCB-containing equipment. PCB capacitors have been identified and replaced with non-PCB units whenever possible. All utility transformers have been tested. Those with PCB concentrations exceeding 50 parts per million have been replaced or put into a PCB reduction program. Replacement of the high-risk indoor PCB transformers has been completed. Currently, only three PCB transformers remain.

Safe Drinking Water Act

The Safe Drinking Water Act established a program to ensure that public drinking water supplies are free of potentially harmful chemicals. It established maximum contaminant levels to protect human health and provide aesthetically acceptable water.

The sole source of water supplied to LBL is EBMUD; there are no on-site wells. EBMUD obtains its water from western-slope Sierra Nevada surface waters >150 km east of LBL. Water from this source is piped to a nearby reservoir, where it is stored, treated, filtered, and tested before distribution.

The LBL system that distributes the EBMUD water within the site consists of an extensive piping layout providing domestic and fire-protection water to all LBL installations. The system also supplies makeup water for cooling towers, irrigation water, and water for other miscellaneous uses, including industrial, deionized, and distilled water systems. Backflow prevention devices are installed where a potential for cross-contamination of the domestic water and wastewater exists, and a regular maintenance program is also in effect. The domestic water is routinely sampled for coliform bacteria. Starting in 1988, periodic checks were also made for lead, copper, and zinc.

The National Primary Drinking Water Regulations limit exposure to the public from community drinking-water systems to 4 mrem/yr. Although no local surface or well water is used as a community drinking water supply this report uses the standards listed in 40 CFR 141 as a basis of comparison for the radiological contamination of local waters. The regulation lists limits for several radionuclides. (Consumption of water contaminated with the listed limit of a single contaminant for a year would produce an exposure of 4 mrem to the consumer.) The standard for tritium is 20,000 pCi/l. The unidentified alpha emitter limit is 5 pCi/l. The unidentified beta emitter limit is 8 pCi/l.

Federal Insecticide, Fungicide and Rodenticide Act

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) provides for the registration, transportation, use, and disposal of pesticides. At LBL, all applications of regulated pesticides are performed by licensed contractors who provide the pesticides used and remove unused portions. LBL personnel apply unregulated herbicides only.

Environmental Permits

In order to carry on its research, LBL designs and builds much of its apparatus. These activities require substantial technical support, including the operation of fabrication, assembly, testing, and waste-handling facilities. The Laboratory operates these facilities under a series of environmental permits issued by State and local agencies. These permits are listed below, by type and issuing agency, with expiration dates.

1) Source Operating Permits, Bay Area Air Quality Management District, Expire July 1, 1990

Cold Solvent Cleaning Equipment

- Building 46 – Source #121
- Building 76 – Source #67
- Building 76 – Source #72
- Building 76 – Source #122
- Building 76 – Source #123
- Building 77 – Source #119
- Building 77 – Source #130
- Building 934 – Source #118

Gasoline Dispensing Equipment

- Building 76 – Source #76

Machine Shop Exhaust System

- Building 53 – Source #39
- Building 58 – Source #46
- Building 70A – Source #55
- Building 76 – Source #68
- Building 77 – Source #84
- Building 77 – Source #85
- Building 77 – Source #89

- Building 79 – Source #105
- Building 79 – Source #116
- Building 88 – Source #114
- Building 88 – Source #115

Paint Drying Oven

- Building 77 – Source #104

Paint Spray Booth

- Building 76 – Source #74
- Building 77 – Source #96

Sandblast Exhaust Equipment

- Building 77 – Source #97

Sulfur Hexafluoride Chamber

- Building 58 – Source #124

Ultrasonic Degreaser

- Building 16 – Source #129
- Building 53 – Source #38

Vapor Degreaser

- Building 16 – Source #115
- Building 25A – Source #115
- Building 46 – Source #91
- Building 53 – Source #120
- Building 64 – Source #35
- Building 77 – Source #92

Wood Dust Exhaust System

- Building 74 – Source #64
- Building 76 – Source #73

2) Wastewater Discharge Permits, East Bay Municipal Utility District

- Plating Shop, Building 25 – Permit #776-00025 — Expires June 5, 1991
- Plating Shop, Building 77 – # 776-00077 — Expires June 5, 1991
- LBL Site – #066-00791 — Expires June 5, 1991

3) Application for construction of a Hazardous Waste Treatment, Storage and Disposal Facility Permit, EPA CA 4890008986, California Department of Health Services for the Environmental Protection Agency. The current permit extended until resolution of new Part B application.

4) Underground Storage Tank Permits, City of Berkeley, Expires July 1, 1991

Diesel Oil

- Building 2 – (2) 1,000 & 4,000 gal
- Building 51 – 550 gal
- Building 55 – 1,000 gal
- Building 66 – (2) 2,000 & 6,000 gal
- Building 70 – 600 gal
- Building 70A – 1,000 gal
- Building 74 – 12,000 gal
- Building 76 – 10,000 gal

Gasoline

- Building 76 – 10,000 gal

Transformer Oil

- Building 58 – 2,000 gal

Waste Oil

- Building 69 – 2,000 gal

Environmental Assessments

Environmental Assessment — 1–2 GeV Synchrotron Radiation Source. A National Environmental Protection Act (NEPA) Environmental Assessment document for the 1–2 GeV Synchrotron Radiation source was published in August 1989. The report found no significant environmental impact would ensue from the project as designed. A Finding of No Significant Impact was determined and documented by Peter Brush of the DOE in a memorandum dated August 11, 1989, to Robert Hunter, Director, Office of Energy Research at DOE.

Environmental Impact Report — Construction of Replacement Hazardous Waste Handling Facility. A California Environmental Quality Act (CEQA) Environmental Impact Report for the Replacement Hazardous Waste Handling Facility was submitted for public review in November 1989. The report found no significant environmental impact that could not be mitigated. The final report is due to be published in April 1990.

Environmental Impact — Construction of Replacement Hazardous Waste Handling Facility. A NEPA Environmental Assessment for the Replacement Hazardous Waste Handling Facility was submitted to the DOE for administrative review in November 1989. The report found no significant environmental impact that could not be mitigated through design and proper execution. This report is due to be published in April 1990.

Environmental Activities

Construction of a new wastewater treatment unit has been completed. The new unit is needed to maintain plating shop wastewater discharges within the limits mandated by EPA Metal Finishing Pretreatment Standard (40 CFR 433). It will replace a smaller unit that has been increasingly subject to mechanical breakdowns. Unfortunately, startup of the new unit has been delayed until an operating California hazardous waste permit is obtained.

Approximately 30 of the oldest buildings at LBL were inspected for possible asbestos-containing materials. The inspection included the assessment of friable insulation, acoustical plaster, and fireproofing, as well as nonfriable building materials. As a result of the inspection and laboratory analysis of bulk samples collected, four priority levels were generated to assist in planning and implementing a phased abatement program.

An Emission Inventory Plan and an Emission Estimates Report were prepared in compliance with the California Air Toxics "Hot Spots" Information and Assessment Act, AB 2588.

The Inventory Plan lists those regulated substances present at LBL facilities that could potentially cause toxic air emissions. It included specified locations of the emission sources and described individual processes responsible for emissions and methods that would be used to make qualitative emission estimates.

The Estimates Report calculates annual average emissions and hourly maximum emissions using mass-balance techniques where possible. Source emissions that could not be calculated will be estimated by source testing or pooled source test data. These values will be provided in a separate report in 1990.

A Business Plan was prepared in response to the California Hazardous Materials Release Response Plan and Inventory Law, AB 2187 and AB 2189, and submitted to the City of Berkeley. The law requires businesses to establish Plans that outline procedures for emergency response to releases or threatened releases of hazardous materials. The three major elements of a Business Plan are emergency response, training, and a hazardous material inventory.

An Environmental Monitoring and Remediation project was initiated as a consequence of finding elevated levels of hazardous substance in ground water and the recognition that the extensive use, handling, and storage of hazardous substances at LBL could potentially contribute to contamination at other locations. Using the limited sampling data and the known chemical usage and handling activities at LBL, a Conceptual Design Report was developed assuming a probable contamination scenario. The preliminary

investigations that have been initiated, and will continue through FY 1990, will provide further results to enhance the understanding of existing conditions. This will be followed by a detailed site characterization planned for 1991, remediation of any impaired areas, and a long-term monitoring program, if necessary.

Environmental Radiological Program

Penetrating Radiation

To determine the radiological impact of LBL accelerator operations, we maintain permanent environmental monitoring stations (EMSs) at four points about LBL's perimeter (Fig. 3).

Each station contains sensitive neutron and gamma pulse counters. The neutron detectors are ~500-cm^3 cylindrical BF_3 gas-proportional counters housed in 2.5-inch-thick cylindrical paraffin moderators. The gamma detectors are energy-compensated Geiger-Muller chambers. The output pulses from each of the eight detectors (one of each type is installed at each monitoring station) are prescaled and telemetered to registers in Building 75.[4] Each LBL accelerator building contains at least one somewhat-smaller moderated BF_3 neutron detector, whose output pulses are also prescaled and telemetered to Building 75. By comparing the accelerator neutron monitor output with the output of the perimeter-station neutron monitors, one may assign the perimeter dose equivalent to the accelerator responsible for it. Operational checks of the system are performed daily, and detectors are calibrated annually. A typical dose equivalent value for a perimeter-monitoring-station neutron detector corresponds to 0.13 μrem/pulse. A gamma register-pulse corresponds to about 1.3 μrem.

The neutron background attributable to cosmic rays measured at LBL exhibits small fluctuations about a mean value of 3.3 mrem/year.[5] Table 2 lists the accelerator-produced fence-post dose equivalents measured at each environmental monitoring station during 1989. The fence-post neutron dose equivalent and gamma-ray dose equivalent attributable to LBL accelerator operations in 1989 (see Table 2) are characterized as follows.

1. The SuperHILAC and Bevatron contributed approximately equally to the 2.6 mrem fence-post dose equivalent measured at the Olympus Gate Environmental Monitoring Station.

2. The 88-Inch Cyclotron fence-post dose equivalent of 0.6 ± 0.1 mrem is primarily attributable to scattered photons and stray neutrons produced during 10 light-ion (^3H, p^+, D^+, ^4H) runs during 1989. (The fence-post dose equivalent from radionuclide releases at this station was calculated to be 0.2 mrem for 1989.)

The DOE Orders, which provide detailed requirements for radiation protection, under which DOE contractors (LBL, for example) operate, include a table (see Ref. 3) that assigns dose equivalent rate vs. neutron flux values for neutrons of various energies.

In order to better characterize the impact of the neutrons from the 88-Inch Cyclotron, a seven-detector neutron spectrometer was installed at the B13A monitoring station in January, 1988. During that year seven light-ion beams runs (^3He, p^+, ^2H) produced measurable neutron fluences. The spectrometer data were analyzed by Rai Ko Sun of the LBL Environmental Health and Safety Department (EH&S) using the computer code LOUHI.[6,7] The historically assumed neutron fluence to dose value used by the authors in the absence of spectral data was 2.45×10^4 n/cm^2/mrem. The mean neutron fluence to dose value established by the LOUHI runs was 2.2×10^5 n/cm^2/mrem, 11% of the historically conservative value and 60% of the value used in the 1986 and 1987 annual editions of this report (based on average neutron energy measurements). The value of 0.17 ± 0.02 mrem attributable to neutron fluence reported for 1989 reflects less-conservative but more-realistic neutron energy vs. dose equivalent conversion factors.

3. With the exception of one short period at the 88-Inch Cyclotron EMS, the continuous gamma measurements telemetered from the four monitoring stations showed no significant correlation with LBL accelerator operation during 1989 and were thus interpreted as constituting the natural gamma background for 1989. The mean value of gamma background inside the monitoring stations was 77 ± 11 mrem for 1989.

LBL's EH&S operates a radiological and chemical waste storage yard and an instrument calibration facility at Building 75. (The small trailer "complex" on Fig. 1 south of Building 75 is Building 75B, which houses EH&S administration and operations personnel.)

A recording Geiger-Muller instrument located in the western end of Building 75A continuously monitors impact from waste storage in 75A and the adjacent corporation yard. The instrument measured a total exposure of 292 ± 20 mrem for a net exposure of 215 ± 20 mrem during 1989.

The sources of radiation monitored by the Building 75A instrument are both inside 75A and roughly midway between the 75A monitor and the LBL perimeter fence, thus a conservative "fence-post" dose estimate for these sources of radiation would be 215 mrem/year. However, the perimeter fence at this location is on UC land, and the nearest off-site 40-hour occupancy (The Lawrence Hall of Science) is approximately 270 m from the fence. The nearest home is approximately 500 m away, and both sites are shielded by a hillside. If the shielding by the hillside is ignored, the predicted doses from waste handling facilities sources would be ~0.06 mrem/yr at the Lawrence Hall of Science (40-hr/week occupancy) or ~0.09 mrem/yr at the nearest home.

LBL has several multicurie gamma irradiators used in radiobiological and radiochemical research. The largest of these units is a ^{60}Co unit housed in an interlocked, massive, reinforced-concrete-covered labyrinth built as part of Building 74. (This unit is also the irradiator closest to the LBL perimeter.) Surveys taken when the irradiator was upgraded and reloaded found no area where the stray radiation field exceeded 1 mrem/hr, 1 m from the outside walls or ceiling when the source was in the exposed position. The Building 74 irradiator is ~80 m from the LBL perimeter fence, 150 m from the nearest "commercial" occupancy (a UCB Botanical Garden building), and more than 700 m from the nearest house. The projected annual dose equivalents to members of the public would be <1.4 mrem/yr at the perimeter fence; <0.1 mrem/yr at the Botanical Garden house (40 hr/wk occupancy); and <0.02 mrem/yr at the nearest house (168-hr/wk occupancy).

Environmental Sampling for Radioactivity

Airborne Radionuclides

Atmospheric tritium, as HTO, is measured at 8 locations by passing atmospheric air through a column containing silica gel. Adsorbed water is "exchanged" into distilled water, and an aliquot (5 ml) is placed in a vial and counted in a liquid scintillation counter. The detection limit for HTO in air is 700×10^{-12} μCi/ml.

Silica-gel HTO samples are changed weekly. Each of the four perimeter environmental monitoring stations contains a tritium sampler, as does the Building 3 site. In addition, the Lawrence Hall of Science (LHS), a facility on UC land north of LBL's perimeter, the UC Mathematical Science Research Institute (MSRI), and an enclosure located at the northeast corner of Building 69A, are similarly monitored. These locations are identified in Fig. 4. The stack from the tritium-labeling facility is also monitored for tritium as described above.

TEDA-doped activated carbon cartridges are used to sample air for radioiodine at the four perimeter stations shown on Fig. 3. Radioiodines in air, specifically ^{125}I, is assayed by analyzing the activated-carbon cartridges with a sodium iodide detector connected to a multichannel analyzer. The detection limit for ^{125}I is 4×10^{-15} μCi/ml.

Atmospheric $^{14}CO_2$ is measured by air sampling with NaOH. Samplers are changed weekly. Air is bubbled through a jar containing 30 ml of 0.2 M NaOH and thymol blue as a pH indicator. If acid fumes in the sampled air drop the pH of the sample to about 6 a color change results, and the sample is assumed to be invalid (an infrequent occurrence). An aliquot (5 ml) of the NaOH is added to a liquid scintillation "cocktail" and counted in a liquid scintillation counter. The detection limit for $^{14}CO_2$ is 200×10^{-12} μCi/ml.

Gross atmospheric particulate beta and alpha activities are measured by air sampling at the 14 points shown on Fig. 5.

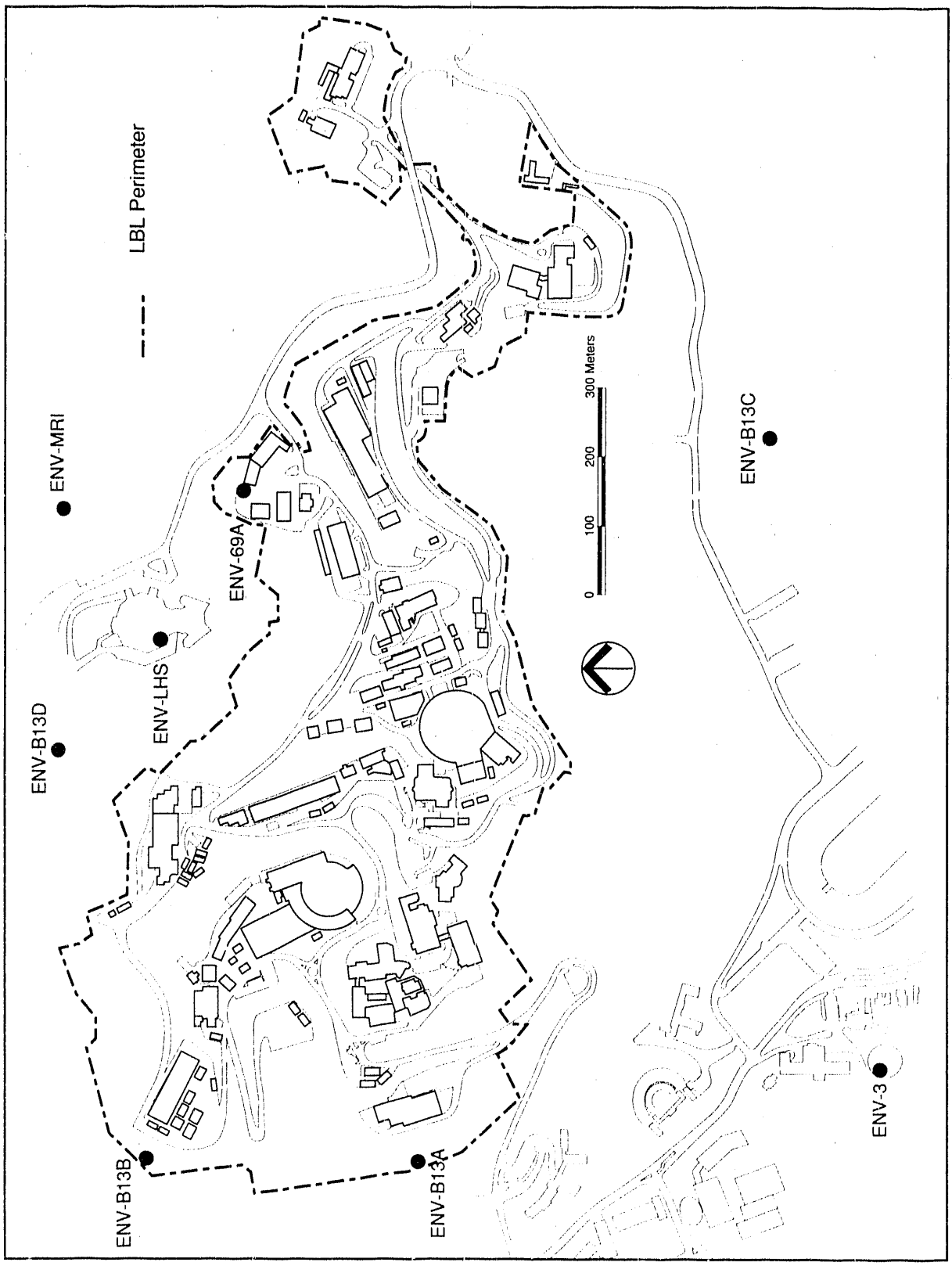


Fig. 4. Map of airborne environmental tritium sampling sites.

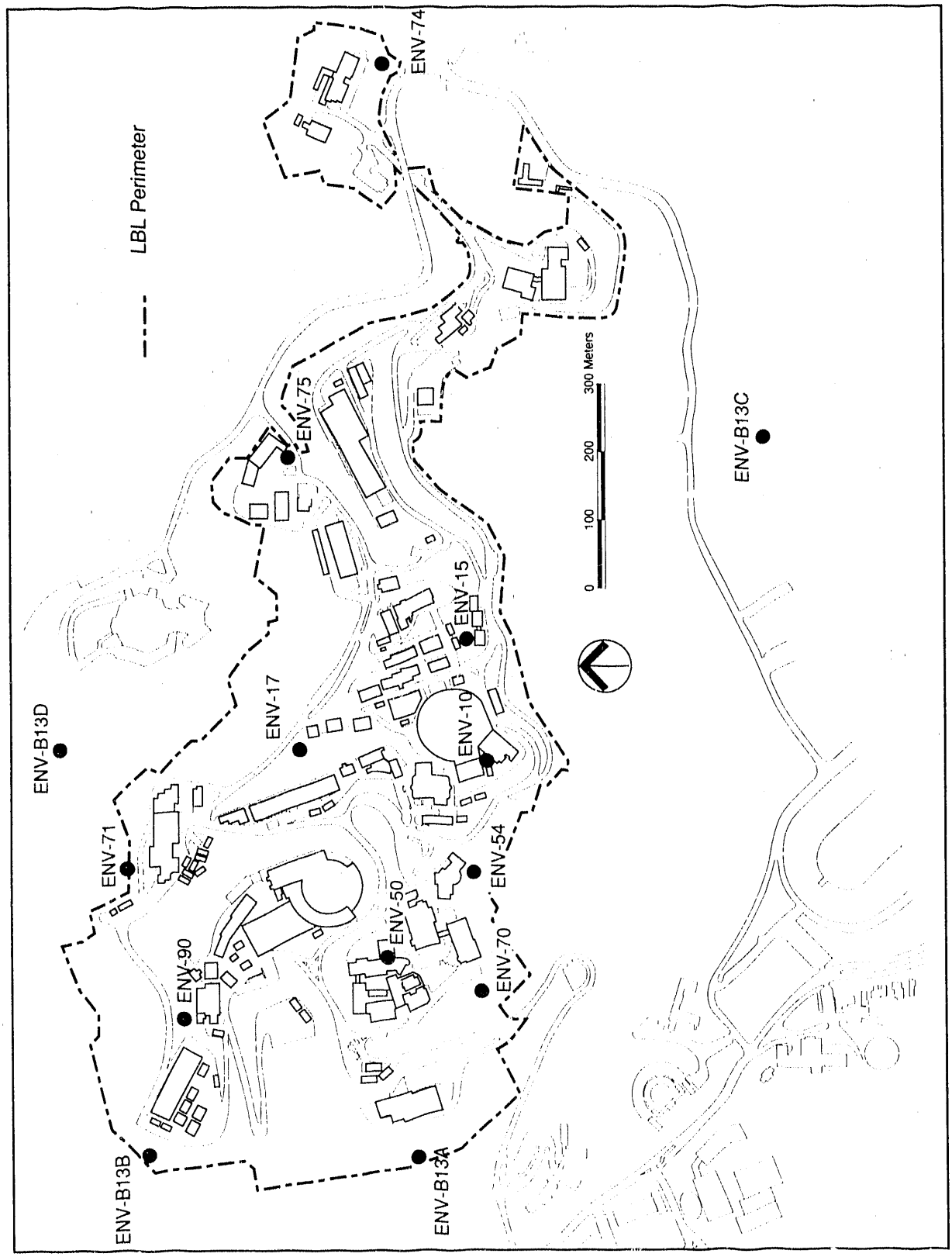


Fig. 5. Map of airborne radioactive particulate sampling sites.

The gross beta and alpha sampling media are 10 cm × 23 cm (4 × 9 in.) fiberglass-polyester filters through which air is pumped at 113 l/min (4 ft^3/min) at the on-site locations, and 75 l/min (2.7 ft^3/min) at the perimeter stations.

Samples are removed weekly. Before they are counted, they are set aside for five days to allow short-lived radon and thorium daughters (naturally occurring airborne radionuclides) to decay. The filters are loaded into an automatic counter that determines gross alpha activity by means a large-area 0.25-mil Mylar-window gas proportional counter. Gross beta activity is counted with Geiger-Muller detectors with 30 mg/cm^2 windows. The detection limit for alpha emitters is 3×10^{-15} μCi/ml. The detection limit for beta emitters is 120×10^{-15} μCi/ml. To ensure accuracy of all counting results, each group of samples counted includes at least one radiation standard sample and a number of background samples.

Alan R. Smith of LBL's low-background-counting facility (LBCF), located in Bldg. 72, aggregated the 14 weekly environmental particulate air samples into sets and analyzed the sets for airborne particulate gamma-emitting nuclides. The sets were allowed to decay for at least two weeks and then analyzed with a large high-purity germanium detector. Each set represented particulates collected from ~14,500 m^3 of air, and was counted for a minimum of 1,000 minutes. Aside from very-low concentrations of ^{137}Cs attributable to atmospheric nuclear weapons testing and the 1986 Chernobyl fire (^{137}Cs was found in concentrations of less than 4×10^{-17} μCi/ml, about 0.00001% of the applicable DCG), the only other gamma-emitters found in the samples were ^{7}Be and ^{210}Pb. The ^{7}Be is produced by cosmic-ray interactions with atmospheric nitrogen (and can also be produced by accelerators). It was found in concentrations ranging from 4.2×10^{-14} to 5.1×10^{-12} μCi/ml and averaged 1.4×10^{-13} μCi/ml, which is 0.003% of the DCG. The detection limit for ^{7}Be is 2×10^{-16} μCi/ml for a 1,000 minute count. The concentrations of ^{210}Pb, a natural air contaminant, were not computed.

Inasmuch as the DOE Orders[3] make no provision for unidentified radionuclides, throughout this report unidentified radionuclides will be conservatively labeled ^{232}Th if they are alpha-emitting material or ^{90}Sr if beta-emitting material. The assertion of conservatism is made because, although ^{90}Sr and ^{232}Th are used at LBL, they are only in a few LBL laboratories and, for isotopes used at LBL, represent the most restrictive beta and alpha emitters, respectively, listed in Ref. 3. Although ^{227}Ac, which is 4500 times more restrictive a beta emitter than ^{90}Sr, is also used at LBL, its most likely state is in equilibrium with its alpha-emitting daughters, 18-day ^{227}Th and 14-day ^{223}Ra, and it would thus be detected as an alpha emitter.

The total quantities of radionuclides discharged into the atmosphere are summarized in Table 3. Aside from the tritium release that is just under 80% of the 1988 value, the figures are similar to those of last year, and the releases resulted in a small collective effective dose equivalent (see section on Public Doses Resulting from LBL Operations and Table 1).

One may note that a number of the average values listed in several of the tables in this report (notably Tables 4, 6, 7, 9, 11, and 13) are less than the minimum values listed for individual samples. This occurs whenever the actual average value of a substance measured is less than the detection limit for that substance in an individual sample, and the average represents the arithmetic sum of all measurements divided by the number of measurements taken (as in this report). The uncertainties listed with tabular quantities represent 95% confidence limits of the assay values (or sum of assay values).

Although small quantities of radionuclides (Table 3) were discharged into the atmosphere during 1989, the data from the general environmental air sampling were within the range of historical background values.

The environmental air sampling program for ^{14}C and ^{3}H found detectable concentrations of these nuclides (Tables 4 and 5). The radioiodine sampling program (Table 6) detected no significant ^{125}I in perimeter air during 1989. Essentially, 100% of the tritium released from LBL was discharged from the Building 75 stacks. Table 7 summarizes the gross particulate radioactivity measured in LBL air samples during 1989. The Table 7 data for 1989 may be compared with data from Table 8, which lists LBL perimeter air-sample-data maxima and averages for the period 1980–1989.

Table 4. Summary of airborne environmental HTO and $^{14}CO_2$ sampling, 1989.

	No. of samples	Concentration (10^{-9} µCi/ml) Avg.	Min.	Max.	Average as % of standard[a]
Samples for Tritium as HTO					
On-Site					
ENV 69A	47	2.9 ± 0.7	< 0.7	11 ± 4	3
ENV 3	46	0.16 ± 0.04	< 0.7	4 ± 1	0.2
Perimeter					
MRI	46	0.22 ± 0.07	< 0.7	3 ± 1	0.2
LHS	46	0.22 ± 0.07	< 0.7	3 ± 1	0.2
B-13A	47	≤ 0.1	< 0.7	2 ± 1	0.1
B-13B	47	≤ 0.1	< 0.7	2 ± 1	0.1
B-13C	47	< 0.1	< 0.7	3 ± 1	0.1
B-13D (Olympus)	50	≤ 0.1	< 0.7	2 ± 1	0.1
Standard for Comparison[a]	—	100	—		—
Samples for Carbon-14 (as $^{14}CO_2$)					
On-Site					
ENV 3	50	< 0.06	< 0.2	< 0.3	0.01
Standard for Comparison[a]	—	500	—	—	—

[a]Source: Ref. 3.

Table 5. Summary of perimeter airborne environmental HTO and $^{14}CO_2$ sampling, 1980–1989.

Year	Concentration (10^{-9} µCi/ml) HTO No. of Samples	HTO Avg.	HTO Max.	$^{14}CO_2$ No. of Samples	$^{14}CO_2$ Avg.	$^{14}CO_2$ Max.
1980	103	< 0.2	0.4	52	< 0.07	0.35
1981	100	< 0.2	1.1	50	< 0.06	0.2
1982	102	0.3 ± 0.1	3 ± 1	51	< 0.04	0.3 ± 0.2
1983	101	0.4 ± 0.1	3 ± 1	49	< 0.01	0.3 ± 0.2
1984	97	0.5	7 ± 3	51	0.6	30 ± 10
1985	102	≤ 0.3	5 ± 1	50	≤ 0.1	1.1
1986	100	0.5 ± 0.1	12 ± 3	51	0.07 ± 0.02	0.4 ± 0.1
1987	97	< 0.5	5 ± 1	51	< 0.05	0.4 ± 0.1
1988	144	0.2 ± 0.1	3 ± 1	51	< 0.05	0.2 ± 0.1
1989	142	0.2 ± 0.07	3 ± 1	50	<0.06	<0.3
Standard for comparison[a]		100			500	

[a]Source: Ref. 3.

Table 6. Summary of radioiodine in perimeter air samples, 1989.

Perimeter Station	No. of samples	Concentration (10^{-15} µCi/ml) ^{125}I Avg.	^{125}I Min.	^{125}I Max.	Average as % of standard ^{125}I
Bldg. 88	45	≤ 0.6	≤ 4	5 ± 4	≤ 0.0001
Bldg. 90	47	≤ 0.6	≤ 4	< 5	≤ 0.0001
Panoramic Way	48	≤ 0.6	≤ 4	< 5	≤ 0.0001
Olympus Gate	48	≤ 0.6	≤ 4	8 ± 5	≤ 0.0001
Standard[a] for comparison		5×10^5			

[a]Source: Ref. 3.

Table 7. Summary of gross particulate radioactivity in air samples, 1989.

	No. of samples	Concentration (10^{-15} µCi/ml)						Average as % of standard	
		Alpha			Beta				
		Avg.	Min.	Max.[a]	Avg.	Min.	Max.[a]	Alpha	Beta
On-site average of 10 locations	498	0.60 ± 0.47	< 2	8 ± 3	≤ 4	≤ 100	130 ± 120	≤ 2	≤ 0.04
Perimeter Stations									
Bldg. 88	45	≤ 0.49	< 3	≤ 3	≤ 16	< 120	≤ 130	≤ 7	≤ 0.2
Bldg. 90	48	0.62 ± 0.48	< 3	9 ± 4	≤ 16	< 120	≤ 130	≤ 9	≤ 0.2
Panoramic Way	49	0.56 ± 0.48	< 3	≤ 4	≤ 16	< 120	≤ 130	≤ 7	≤ 0.2
Olympus Gate	49	≤ 0.47	< 3	5 ± 4	≤ 16	< 120	≤ 130	≤ 7	≤ 0.2
Standard for Comparison[b]		7			9,000				

[a]Highest single weekly sample.

[b]Source: Ref. 3—alpha conservatively assumed to be ^{232}Th; beta assumed to be ^{90}Sr.

Table 8. Annual gross particulate radioactivity found in LBL perimeter air samples, 1980–1989.

Year	No. of Samples	Concentration (10^{-15} μCi/ml) Alpha Avg.	Alpha Max.	Beta Avg.	Beta Max.
1980	204	1.0 ± 0.3	6	28 ± 12	240
1981	195	1.1 ± 0.2	5	120 ± 40	500[a]
1982	197	0.9 ± 0.2	4 ± 2	14 ± 10	140 ± 100
1983	201	0.49 ± 0.1	2	< 6	110 ± 80
1984	187	0.46 ± 0.1	3 ± 2	< 6	120 ± 100
1985	198	0.54 ± 0.2	4 ± 3	12 ± 6	120 ± 80
1986	195	0.5 ± 0.2	9 ± 3	40 ± 10	700 ± 100[b]
1987	191	≤ 0.5	5 ± 3	≤ 16	200 ± 160
1988	197	≤ 0.5	5 ± 3	≤ 16	130 ± 120
1989	191	0.45 ± 0.35	5 ± 3	<16	170 ± 130
Standard for comparison[c]		7		9000	

[a]The People's Republic of China conducted an atmospheric nuclear test on October 15, 1980. Radionuclides from the test were not detected in LBL air samples until early 1981.

[b]Chernobyl fire, April 26, 1986.

[c]Source: Ref. 3—alpha conservatively assumed to be ^{232}Th; beta conservatively assumed to be ^{90}Sr.

Waterborne Radionuclides

Rainwater (see Fig. 6), creek water (see Fig. 3), ground water, which flows from the horizontal wells (hydraugers), whose bores are represented by the heavy dashed lines in Fig. 7, and sewage from LBL's two sewer outfalls are analyzed for tritium, gross beta, and alpha emitters (see Fig. 7; the Strawberry Sanitary Sewer is the southern site; Hearst is the western sewer). Additionally, sewer effluent is analyzed for gross halogen (radioiodine) content. (Hydrauger sampling procedures and results are discussed in the Ground-Water Protection section of this report.)

The four perimeter environmental monitoring stations have 46-cm-diameter (18-in.) cylindrical rainfall collectors on their roofs. During rainy months (generally October through May) rainwater is collected monthly and analyzed for tritium and for gross alpha and beta activities. During the dry California summer each collector is rinsed monthly with a quart of tap water, and the rinse is analyzed for "dry deposition." The nine on-site locations shown in Fig. 6 also contain 46-cm-diameter (18-in.) combination rain/dry deposition collectors, which are sampled on a monthly basis in the same manner as the four perimeter environmental monitoring stations.

Rain that falls into the collectors on the north side of Building 75 and on the roof of Building 4 are analyzed wherever there is a significant rainfall for tritium and gross alpha and beta activities. Tritium analysis of water samples is accomplished by liquid scintillation counting. Water samples are prepared for gross alpha and beta analysis by acidification (HNO_3) and evaporation into 2-in. diameter stainless steel planchettes. Organic residues not wet-ashed by the nitric acid treatment are oxidized by flaming the planchettes.

All measurements of atmospheric deposition at outlying perimeter stations lie within the range of historical normal background measurements; however, tritium was detected in rainfall collected within the Laboratory boundary near the stack from the Building 75 Tritium Facility that exceeded the EPA Drinking Water Standards (Tables 9 and 10). The deposition values, adjusted for rainfall, are compared with the Safe Drinking Water Act standards found in drinking-water standards. As mentioned earlier, local drinking water is supplied by EBMUD from sources located > 150 km east of LBL. EBMUD uses no well water or local surface water as drinking water.

Sewer outfalls are sampled continuously, sample-to-flow ratios are designed to be between 10 and 20 parts per million, and composite samples are taken weekly. The five creek sample points indicated in Fig. 3 are sampled weekly. A 1-qt grab sample is taken from each site and analyzed for tritium and gross alpha and beta emitters.

Since radioiodine would be driven out of the water samples when they are acidified, aliquots of the sewer effluent samples are preserved for radioiodine analysis. The iodine contained in the samples is precipitated with silver using stable KI as a carrier. The iodine aliquots are filtered, and the filtrate is processed in the same manner as the acid (HNO_3) samples described earlier. After the filtrate planchette has been flamed, the filter containing any precipitated radioiodine is placed in the planchette and is counted.

The prepared planchettes are weighed (the tare weight of each planchette is first determined) and counted in a thin-window, low-background gas proportional counter for both gross alpha and beta activities. Since the samples are thick, self-absorption is computed based on areal sample density, which is the sample weight divided by the area of the planchette (20.26 cm^2), assuming an alpha energy of 5.2 MeV and a beta energy of 1 MeV.

Table 11 summarizes the 1989 data from the surface- and tap-water sampling programs. The results are similar to those obtained in past years and all lie within historical normal range of background activity. Table 12 summarizes the surface- and drinking-water samples for 1980–1989.

Table 13 summarizes the sewage sampling data for 1989. The average and maximum values listed for sewer beta concentrations reflect the weekly activity found in the hotter of the acid or radioiodine planchettes. Table 14 summarizes the sewage data for the years 1980–1989.

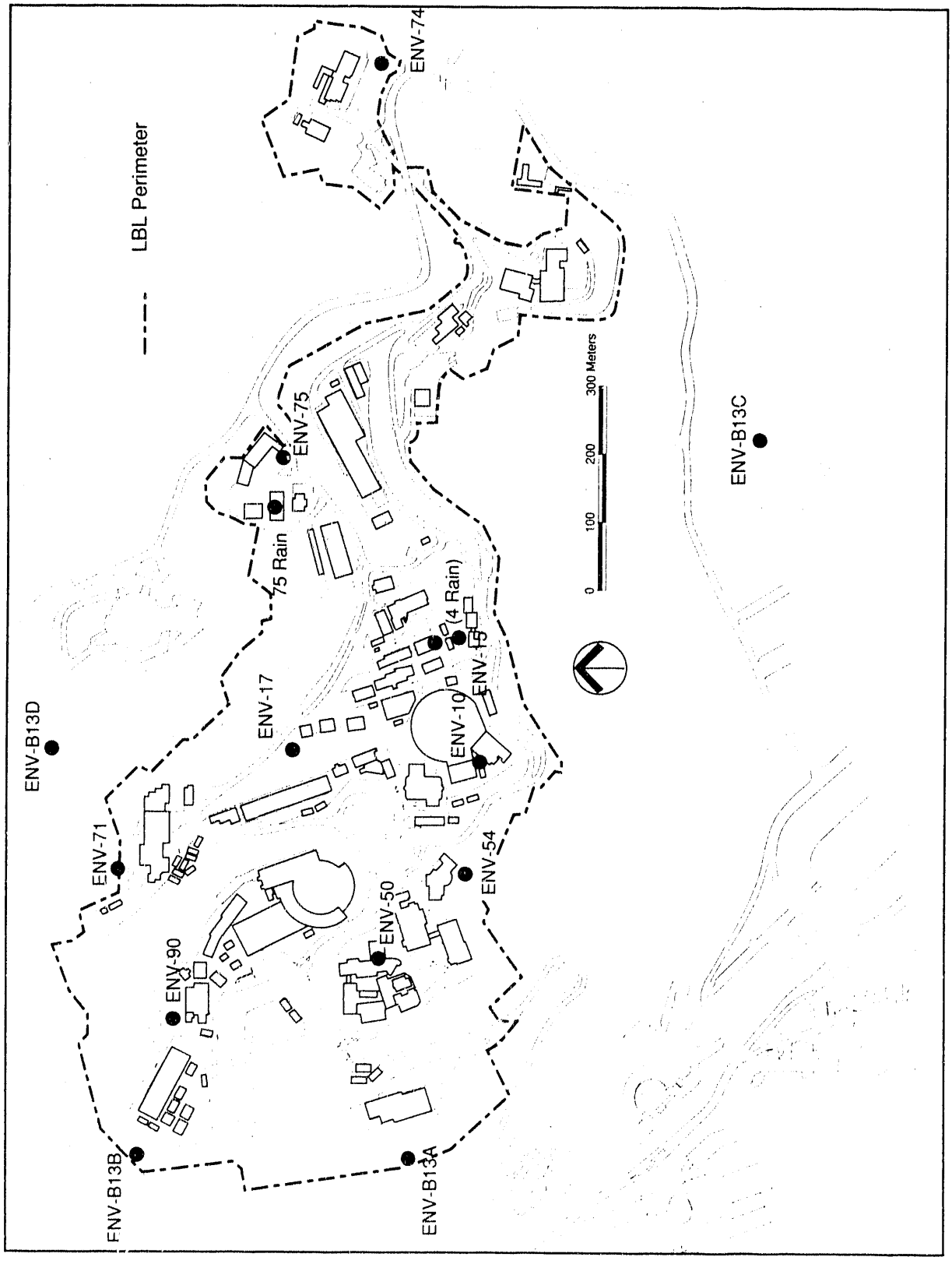


Fig. 6. Map of rain and dry deposition collectors.

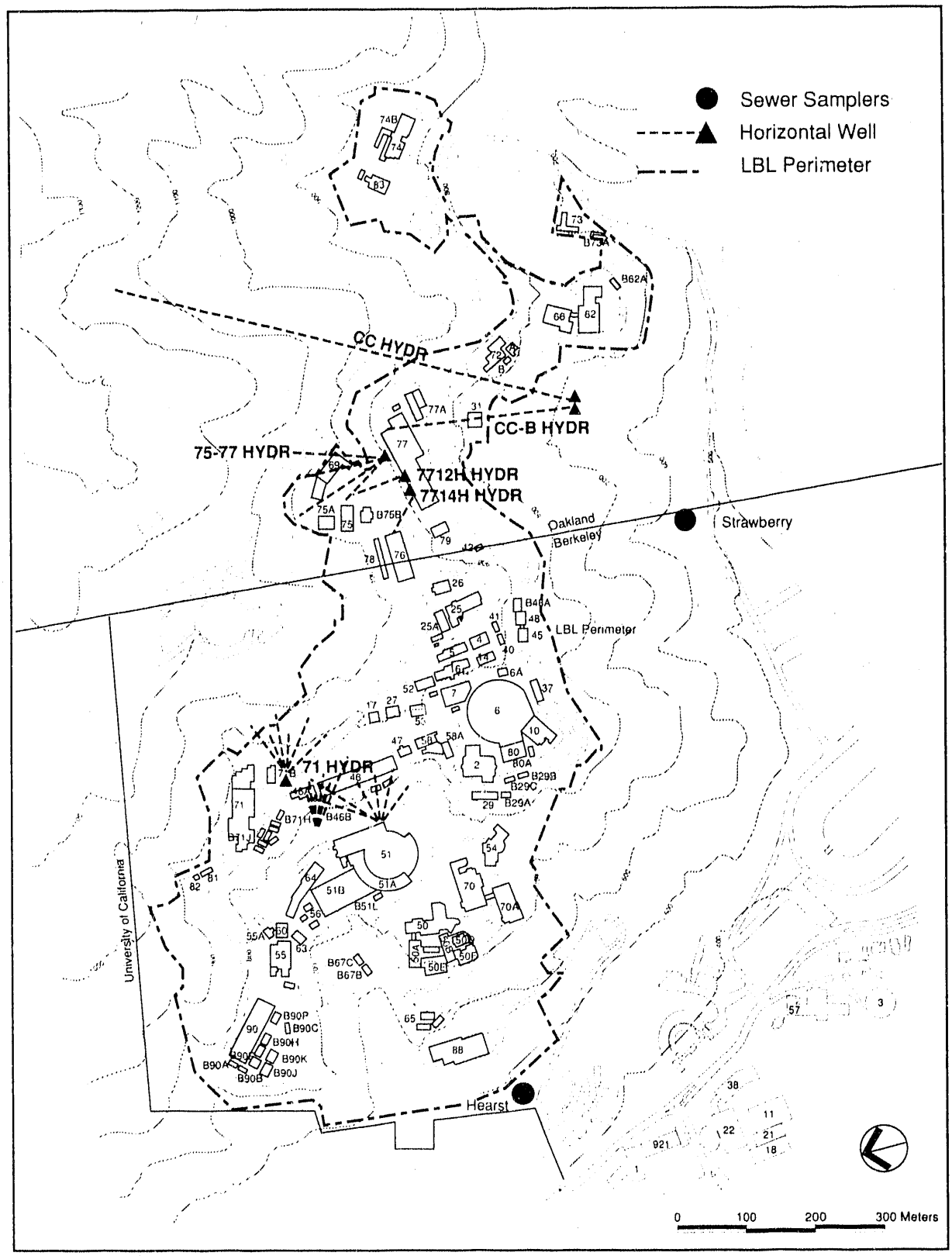


Fig. 7. Map of LBL hydrauger and sewer sampling sites.

Table 9. Summary of atmospheric deposition, 1989.

	Total deposition (10^{-3} µCi/m^2)						Tritium in rainfall as HTO[a] (µCi/m^2)		
		Alpha		Beta					
	No. of samples	Avg.	Max.[b]	Avg.	Min.	Max.[b]	No. of samples	Avg.	Max.[b]
On-Site (11 locations)	164	0.089	0.42	0.82	0.38	2.1	112	5.3 ± 2	41 ± 15[d]
Perimeter (4 locations)	48	0.040	0.045	0.85	0.41	1.7	28	0.23	0.55
Perimeter Averages as a % of Standards		4		22				2.4	
Drinking-water standard × 478[c]		2.39		3.82				9.56	

[a]The on-site tritium-in-rainfall data are computed from samples taken at 11 locations.

[b]Highest total for any one site.

[c]The standards used for comparison are derived from 40 CFR 141 for alpha and beta (^{90}Sr) values. The deposition represents that quantity of activity found in 478 liters of water (the average quantity of rainfall/m^2 during 1989). Thus, the values used are 478 times the 40 CFR 141 values. [No standards for comparison have been established, so drinking-water standards (radionuclide concentration/l) are used.]

[d]The location of this deposition collector is on the north side of Bldg. 75 (see Fig. 6). The average HTO concentration in samples taken from the Bldg. 75 collector was 1.2×10^5 pCi/l, or about 6 times the HTO drinking-water standard.

Table 10. LBL perimeter station deposition trends, 1980–1989.

Year	No. of Samples	Rainfall (cm)	Concentration (10^{-3} μCi/m²) Alpha Avg.	Alpha Max.	Beta Avg.	Beta Max.	(μCi/m²) No. of Samples	HTO Avg.	HTO Max.
1980	47	57.3	0.04	0.06	2.5	6	32	< 0.2	< 0.6
1981	48	83.1	< 0.01	0.09	6.9	9.7	36	< 0.1	< 0.2
1982	48	109.0	< 0.01	0.017	1.9	5.2	36	< 0.2	0.3
1983	48	119.4	0.02	0.07	1.6	3.5	36	< 0.2	0.4
1984	48	45.5	0.05	0.08	< 1	3	36	< 0.2	0.2
1985	48	44.5	0.02	0.4	0.7	2	27	< 0.2	0.2
1986	48	81.4	0.03	0.04	0.8 ± 0.2	2	29	0.1	0.3
1987	48	53.4	≤ 0.04	0.06	0.8 ± 0.5	2	24	0.1	0.2
1988	48	45.5	0.03	0.06	0.6	1.4	35	0.6	0.9
1989	48	47.8	0.04	0.04	0.8	1.7	28	0.2	0.6

Table 11. Summary of surface- and drinking-water samples, 1989.

	No. of samples	Concentration (10^{-9} µCi/ml)						Concentration (10^{3} pCi/l)			Average as % of standard		
		Alpha			Beta			Tritium as HTO					
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max	Alpha	Beta	Tritium
On-site streams													
Blackberry	51	≤ 0.25	≤ 0.7	5.1 ± 4.4	2.1 ± 0.1	≤ 0.5	3.7 ± 0.9	0.2 ± 0.1	< 0.7	< 2	≤ 5	26	1
Lower Strawberry	51	≤ 0.16	≤ 0.5	≤ 2	2.0 ± 0.1	1 ± 0.6	8 ± 1	≤ 0.1	< 0.7	< 3	≤ 3	25	≤ 0.5
Upper Strawberry	51	≤ 0.4	≤ 1. 2	15 ± 8	2.6 ± 1.2	≤ 0.6	22 ± 2	≤ 0.1	< 0.7	< 2	≤ 8	32	≤ 0.5
Average		≤ 0.3			2.2 ± 0.2			0.1			≤ 6	28	≤ 0.5
Off-site streams													
Claremont	51	0.36 ± 0.34	≤ 1.3	4.4 ± 3.4	1.7 ± 0.1	≤ 0.6	5.4 ± 1	≤ 0.1	< 0.7	< 4	≤ 7	21	≤ 0.5
Wildcat	51	≤ 0.3	≤ 0.9	6 ± 4	1.4 ± 0.1	≤ 0.5	3.5 ± 0.9	≤ 0.1	< 0.7	< 2	≤ 6	18	≤ 0.5
Tap Water	51	≤ 0.07	≤ 0.25	≤ 3	0.88 ± 0.08	≤ 0.5	2.1 ± 0.8	≤ 0.1	< 0.7	< 2	≤ 1	11	≤ 0.5
Standard of Comparison[a]		5			8			20					

[a]Source: 40 CFR 141.

Table 12. Summary of surface- and drinking-water samples, 1980–1989.

	Concentration (10^{-9} µCi/ml)								Concentration (10^{3} pCi/l			
	Three On-site Streams				Two Off-site Streams				Drinking Water			
	Alpha		Beta		Alpha		Beta		Alpha		Beta	
Year	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
1980	< 0.2	4	2 ± 0.1	9	< 0.3	3	1.2 ± 0.1	4	< 0.1	0.5	0.8 ± 0.1	3
1981	< 0.2	3	3.1 ± 0.1	45	< 0.2	3	1.6 ± 0.1	22	< 0.1	0.4	1.0 ± 0.1	---
1982	< 0.3	3 ± 2	1.7 ± 0.1	5 ± 1	< 0.3	5 ± 3	1.4 ± 0.1	6 ± 1	< 0.1	1.1 ± 0.5	0.9 ± 0.1	2.2 ± 1
1983	< 0.1	4 ± 2	1.5 ± 0.1	4 ± 1	< 0.3	< 2	1.2 ± 0.1	4 ± 2	< 0.04	1.2 ± 0.5	0.9 ± 0.1	2.3 ± 0.7
1984	< 0.13	< 2	1.6 ± 0.3	3 ± 1	0.6 ± 0.3	3 ± 2	1	8 ± 1	0.03	0.3	0.9 ± 0.1	7 ± 1
1985	< 0.2	< 2	2 ± 0.5	25 ± 2	≤ 0.3	≤ 3	1 ± 0.1	5 ± 1	0.06 ± 0.05	≤ 2	0.9 ± 0.1	2 ± 1
1986	< 0.2	8 ± 5	2.3 ± 0.1	27 ± 2	0.4 ± 0.3	4 ± 3	1.6 ± 0.1	10 ± 2	0.06 ± 0.04	< 0.4	1.1 ± 0.1	6 ± 2
1987	≤ 0.2	7 ± 4	1.7 ± 0.1	13 ± 2	0.4 ± 0.2	≤ 3	1.5 ± 0.2	5 ± 1	< 0.03	< 0.4	0.7 ± 0.1	1.5 ± 0.7
1988	≤ 0.2	6 ± 4	2.9 ± 0.2	110 ± 20	≤ 0.2	3 ± 2	1.0 ± 0.1	9 ± 2	≤ 0.04	≤ 0.5	0.7 ± 0.1	1.7 ± 0.8
1989	≤ 0.3	15 ± 8	2.2 ± 0.2	22 ± 2	≤ 0.4	6 ± 4	1.5 ± 0.1	5 ± 1	≤ 0.07	< 3	0.9 ± 0.1	2.1 ± 0.8

Table 13a. Summary of sewage sampling data, 1989.

	Total quantities discharged			
	Total volume (10^6 liters)	Alpha (μCi)	Beta (mCi)	Tritium (Ci)
Hearst Sewer	80	< 16	1 ± 0.3	0.04 ± 0.02
Strawberry Sewer	160	< 31	4 ± 1	0.9 ± 0.3

Table 13b. Summary of sewage sampling data, 1989 (continued).

		Concentration (10^{-9} μCi/ml)							Concentration (10^3 pCi/l)			Average as % of standard		
		Alpha[a,b]			Beta[c]				Tritium			Alpha[b]	Beta[c]	Tritium
	No. of samples	Avg.	Min.	Max.	Avg.	Min.	Max.	No. of samples	Avg.	Min.	Max.	%	%	%
Hearst	80	≤ 0.19	≤ 0.7	3 ± 2	13 ± 4	≤ 2	28 ± 10	45	0.5 ± 0.2	≤ 0.5	9 ± 3	≤ 0.38	1.3	0.02
Strawberry	88	≤ 0.18	≤ 0.7	≤ 1.7	26 ± 10	≤3	190 ± 60	49	6 ± 2	≤ 0.5	36 ± 9	≤ 0.36	2.6	0.3
Overall	168	≤ 0.18			20 ± 10			94	6 ± 2			≤ 0.36	2.0	0.2
Standard for comparison[d]		50			1000				2000					

[a]The alpha values are based on 40 Hearst and 43 Strawberry samples, respectively.

[b]Conservatively assumed to be ^{232}Th.

[c]Conservatively assumed to be ^{90}Sr.

[d]Source: Ref. 3.

Note: The standards cited here are for ingestion of specific radionuclides and are provided for comparison purposes only.

Table 14. Sanitary-sewer discharge trends, 1980–1989.

			Concentration (10^{-9} µCi/ml)						Concentration (10^{-9} µCi/ml)			
			Hearst						Strawberry			
Year	No. of Samples	Total Flow (10^6l)	Gross alpha Avg.	Gross alpha Max.	Gross beta Avg.	Gross beta Max.	No. of Samples	Total Flow (10^6l)	Gross alpha Avg.	Gross alpha Max.	Gross beta Avg.	Gross beta Max.
1980	48	288	0.4	3	22	220	46	135	0.3	6	180	1000
1981	49	280	<0.2	1	21	150	43	89	0.5	14	240	2500
1982	42	300	0.05	1.1	20	460 ± 20	29	180	0.5	17 ± 12	60	640 ± 40
1983	49	190	0.05	< 5	9	80 ± 7	38	140	< 0.4	< 20	60	640 ± 401
1984	51	170	0.02	< 5	80	1100 ± 50	39	74	0.02	< 2	70	250 ± 10
1985	50	160	< 0.2	< 3	15	90 ± 10	49	120	< 0.2	< 2	140	1600 ± 30
1986	47	200	< 0.1	1 ± 0.3	10 ± 1	50 ± 10	47	110	< 0.1	1.1 ± 0.3	400 ± 10	4200 ± 700
1987	44	140	≤ 0.1	≤ 1.4	11 ± 2	80 ± 20	48	120	≤ 0.1	1.2 ± 1.1	180 ± 40	2200 ± 500
1988	41	160	≤ 0.1	≤ 1.1	9 ± 3	25 ± 5	46	120	≤ 0.1	≤ 4	43 ± 20	1100 ± 300
1989	40	80	≤ 0.2	3 ± 2	13 ± 4	28 ± 10	43	160	≤ 0.2	≤ 2	26 ± 10	190 ± 60

Public Doses Resulting from LBL Operations

Accelerator-Produced Radiation

The development of LBL's model used to assess the population dose equivalent attributable to penetrating radiation is detailed in Ref. 5. The model used population figures from the 1970 U.S. census.

Although the population within 80 km (50 mi) of LBL increased by 13% during the 1970s[1,8,9] from 4.6 to 5.1 million, the populations of Berkeley and Oakland, the two cities immediately adjacent to LBL, declined. Recomputing the population dose model with population statistics from the 1980 census produced no significant difference in its impact/insult value.

The LBL model developed by Thomas[5] computes population dose equivalent from the maximum measured value of perimeter (fence-post) neutron dose. During 1989 the maximum fence-post dose, measured at the Olympus Gate Monitoring Station, was 2.6 mrem for the year (Table 2). An examination of the time sequence of the telemetered neutron fluence from the Olympus detector indicated that the neutron fluence peaks correlated with the fluence peaks from the neutron detector located in the Bevatron roughly 50% of the time and with the peaks from the SuperHILAC detector 50% of the time. The Bevatron and the SuperHILAC operated continuously seven days a week during 1989 except for maintenance and "summer" shutdowns. The Bevatron was shut down from July 30 to October 1 and the SuperHILAC from July 14 to July 31 and from September 1 to October 1. Both machines were shut down December 24 through January 2, 1990. The model's expression relating population dose equivalent M (in man-rem) to maximum measured fence-post dose H_o (in rem—a rem is 1000 mrem) is

$$M < 10^3 \times H_o (1.0 - 0.56f) , \qquad (1)$$

where f = the fraction of the fence-post dose contributed by the 88-Inch Cyclotron and/or the SuperHILAC. Since 50% of the fence-post dose has been assigned to the Bevatron, f = 0.5 [in Eq. (1)].

Thus the expression becomes

$$M < 10^3 (1 - 0.28) H_o . \qquad (2)$$

Since H_o was 2.6 mrem (or 0.0026 rem), the Collective Effective Dose Equivalent (CEDE) to the 5.1 million people within 50 miles of LBL attributable to LBL accelerator operation during 1989 was < 1.9 man-rem.

Airborne Radionuclides

The dose to the maximally exposed individual and the CEDE resulting from airborne releases of radionuclides are listed in Table 1. The EPA regulations in 40 CFR 61 Subpart H require that facilities releasing airborne radionuclides compute the impact of such releases using an approved code. In this report, PC AIRDOSE, a microcomputer version of the AIRDOSE-EPA radionuclide dispersion and dose assessment code supplied by EPA, was used to compute the effective dose equivalent to a maximally exposed offsite person. The code requires

- radionuclide release data;
- stack height and flow data;
- distance to the nearest off-site individual.

The data used were as follows:

- The released quantities of tritium ^{14}C, ^{125}I, "^{90}Sr," and "^{232}Th" listed in Table 3 of this report. (The ^{35}S data were not used because PC-AIRDOSE does not contain ^{35}S in its accompanying radionuclide table. The impact from ^{35}S would be insignificant compared to tritium and ^{125}I in any case.)
- The stack is 10 m high and 1 m in diameter and has an exhaust velocity of 7 m/s.
- The nearest "neighbors" houses are 500 m north of the stack and 800 m west of the stack.

The western neighbor received the highest hypothetical dose equivalent of 0.3 mrem in 1989. The northern neighbor's hypothetical dose equivalent was 0.2 mrem. (The wind blows to the west more often than it blows to the north. Thus, the western neighbor, who is farther from the stack, received a slighly higher dose equivalent.)

Since PC-AIRDOSE cannot compute population dose equivalent, a similar but more-elaborate microcomputer version of AIRDOSE-EPA "MICROAIRDOSE" (Ref. 10) was used.

MICROAIRDOSE computes contributions to the doses from inhalation, ingestion, and exposures from surface contamination and immersion. The code requires

- radionuclide release data;
- committed dose-equivalent factors for released radionuclides;
- site-specific meteorological data;
- agricultural parameters;
- site-specific food and water source parameters;
- radionuclide-independent parameters; and
- distribution of the population within 80 km (50 mi) of LBL.

The data were obtained from the following sources:

- The released quantities of ^{3}H, ^{14}C, ^{125}I, and ^{35}S listed in Table 3 of this report are used.
- Values are from three sources: values for ^{3}H and ^{14}C are from the original AIRDOS Report (Ref 11); dose conversion factors for ^{90}Sr and ^{125}I were taken from the EPA DARTAB-RADRISK data base for 70-yr dose commitment; the data for ^{35}S and ^{232}Th are from Ref. 12.
- 1960–1964 Oakland Airport five-year average data were used. Although it is most desirable to use on-site meteorology data for the "release year" (1989), the EPA Region IX regional meteorologist (Ref. 13) indicated that the use of the Oakland Airport five-year average data is, for this application, an acceptable second choice.
- Default parameters provided with the MICROAIRDOSE code were used from Ref. 14.
- Food and water source parameters were compiled by Victor J. Montoya of the LBL EH&S Environmental Monitoring Section from data provided by the water boards and agricultural commissioners of the 11 San Francisco Bay Area counties. The average values for foodstuffs and water not collected or grown within 80 km (50 mi) of LBL were found to be as follows: 35% of the drinking water is imported; 95% of the produce and leafy vegetables are imported; 25% of the milk is imported; and 90% of the meat is imported. (Imported food and water are assumed to be uncontaminated.)
- Values are from Ref. 15.
- The population distribution about LBL was compiled into 16 compass directions of 10 radial sectors each by Winifred B. Cornica, formerly of LBL EH&S Environmental Monitoring Section, using data in Ref. 9.

Table 15 summarizes the total CEDE due to LBL operations.

Table 15. Population effective dose equivalent resulting from LBL operations, 1989.[a]

Contributing factor		Population effective dose equivalent (person-rem)
Penetrating radiation from accelerator operations		≤ 2
Radionuclide release		
H-3	≤ 15	
C-14	≤ 0.0008	
I-125	≤ 0.04	
S-35	≤ 0.0001	
Unidentified alpha emitters	≤ 0.001	
Unidentified beta emitters	≤ 0.0001	
Subtotal		≤ 15.0
Total LBL-produced effective population dose equivalent		≤ 17

[a]For 1989, the population dose attributable to natural background sources for the population within 80 km (50 mi) of LBL was approximately 5.1×10^6 persons $\times$ 0.3 rem/person/yr = 1.5×10^6 man-rem.

Environmental Nonradiological Program

Waterborne Pollutants

Building 25 Plating Shop

As required by the EBMUD wastewater discharge permit #775-00025, wastewater samples were taken quarterly from the discharge to the Building 25 treatment unit. In addition, EBMUD collected five samples throughout the year and reported their results to LBL. The samples were analyzed for cadmium, chromium, copper, lead, nickel, and zinc.

There was one violation, detected in May of 1989, for exceeding the permitted discharge levels for copper and lead. This was determined to be due to operator error. It occurred when a water makeup line was accidentally left on, resulting in a wastewater flow that exceeded the capacity of the treatment unit.

Table 16 summarizes the results from the samples taken by LBL and EBMUD.

Building 77 Plating Shop

As required by EBMUD Permit #776-00077, wastewater samples were taken bimonthly from the discharge for the Building 77 treatment unit. In addition, EBMUD collected three samples throughout the year and reported their results to LBL. Samples were analyzed for cadmium, chromium, copper, lead, nickel, zinc, and cyanide.

There were two violations in 1989, found in samples taken January 20 and April 7, for excessive discharge levels of copper. It was determined that the first violation was due to the breakdown of a caustic feed pump. This produced a low pH in the treatment unit, which reduced its ability to precipitate metals, including copper. The cause of the second discharge violation was not determined. The treatment equipment was thoroughly checked and no problems were found. Subsequent monitoring showed that the copper levels were within permitted discharge levels.

Table 17 summarizes the results for the samples taken by LBL and EBMUD.

Site Wastewater Discharges

There are two sanitary sewer systems serving LBL: Strawberry Sanitary Sewer and Hearst Sanitary Sewer. Effluent from each sewer system is monitored at the LBL boundary. Continuous sampling is performed to ensure compliance with the site discharge limits mandated by EBMUD Ordinance No. 270. In this case, the EBMUD does not require a periodic compliance report; however, reports for all discharge violations detected are required.

At both monitoring stations, a series of flow-proportioned grab samples were collected and analyzed at least monthly for a set of regulated heavy metals, and at least bimonthly for chlorinated hydrocarbons, phenols, cyanide, and oil and grease.

Tables 18 and 19 summarize the site wastewater discharge sampling data. Excessive discharge levels of copper and zinc at both sites are believed to be due to the on-site regeneration of building deionized water systems. This activity was discontinued in December. Portable units, which are returned to the supplier for regeneration, are now being used.

At the Strawberry Monitoring Station, discharges of chlorinated hydrocarbons exceeded the EBMUD limits in samples taken June 9 and October 5, 1989. The predominant chemicals identified were chloroform and methylene chloride. In April of 1990 it was determined that these chemicals came from a UCB building, whose discharges entered the sewer system above the LBL monitoring station. The University has discontinued this discharge.

Excessive discharge levels of chlorinated hydrocarbons have also been found at the Hearst Monitoring Station. Just before publication of this report, discharges from a suspected source in LBL Building 55 were discontinued. No subsequent violations were found.

Table 16. Building 25 treatment effluent—1989 sampling data.

Metal	No. of Samples	Concentration (mg/l) Min.	Max.	Avg.	Avg. % of Limit	2 × Std. Dev. (mg/l).	No. over Limit	Limit (mg/l)
Cadmium	5	0.00	0.00	0.00	0	0.00	0	0.69
Chromium	9	0.01	0.08	0.03	1	0.04	0	2.77
Copper	9	0.48	3.80	1.78	53	1.88	1	3.38
Lead	9	0.03	1.30	0.32	46	0.72	1	0.69
Nickel	5	0.02	0.09	0.05	1	0.05	0	3.98
Zinc	6	0.02	0.21	0.07	3	0.13	0	2.61

Table 17. Building 77 treatment effluent—1989 sampling data.

Metal	No. of Samples	Concentration (mg/l) Min.	Max.	Avg.	Avg. % of Limit	2 × Std. Dev. (mg/l)	No. over Limit	Limit (mg/l)
Cadmium	11	0.00	0.08	0.03	4	0.06	0	0.69
Chromium	11	0.02	0.70	0.35	13	0.54	0	2.77
Copper	11	0.12	7.30	2.88	85	5.87	2	3.38
Lead	11	0.02	0.20	0.06	9	0.14	0	0.69
Nickel	11	0.16	0.10	0.54	13	0.84	0	3.98
Zinc	11	0.08	0.28	0.20	8	0.14	0	2.61
Total Cyanide	7	0.02	0.20	0.08	7	0.16	0	1.20

Table 18. Summary of Strawberry Monitoring Station—1989 sampling data.

Analyte	No. of Samples	Concentration (mg/l) Min.	Max.	Avg.	Avg. % of Limit	2 × Std. Dev. (mg/l)	No. over Limit	Limit (mg/l)
Arsenic	21	0.00	0.03	0.00	0.2	0.01	0	2
Cadmium	21	0.00	0.10	0.02	2	0.06	0	1
Chromium	21	0.01	2.00	0.19	9	0.84	0	2
Copper	44	0.03	36.00	2.28	46	11.02	3	5
Iron	21	1.70	61.00	10.28	10	25.71	0	100
Lead	21	0.01	0.65	0.13	6	0.30	0	2
Mercury	21	0.00	0.03	0.00	8	0.01	0	0.05
Nickel	21	0.01	1.00	0.14	3	0.41	0	5
Silver	21	0.01	0.20	0.03	3	0.09	0	1
Zinc	44	0.10	7.30	1.58	32	2.67	2	5
Halocarbons	9	0.01	11.43	0.71	142	7.09	2	0.5
Oil & Grease	10	4.00	24.00	12.20	5	13.23	0	250
Phenols	7	0.02	0.06	0.03	0.03	0.03	0	100
Cyanide	8	0.00	0.01	0.00	0.09	0.01	0	5

Table 19. Summary of Hearst Monitoring Station—1989 sampling data.

Analyte	No. of Samples	Concentration (mg/l) Min.	Max.	Avg.	Avg. % of Limit	2 × Std. Dev. (mg/l)	No. over Limit	Limit (mg/l)
Arsenic	17	0.00	0.07	0.02	0.8	0.04	0	2
Cadmium	17	0.00	0.02	0.01	0.9	0.01	0	1
Chromium	17	0.02	3.70	0.69	34.00	1.96	2	2
Copper	36	0.15	17.00	3.50	70.00	6.47	9	5
Iron	17	0.30	66.00	15.79	16.00	33.94	0	100
Lead	17	0.01	1.20	0.44	22.00	0.70	0	2
Mercury	17	0.00	0.05	0.01	27.00	0.03	1	0.05
Nickel	17	0.01	0.10	0.04	0.8	0.05	0	5
Silver	17	0.01	1.60	0.11	11.00	0.74	1	1
Zinc	36	0.26	17.00	4.41	83.00	7.83	11	5
Halocarbons	9	0.02	4.81	0.70	141.00	2.92	2	0.5
Oil & Grease	9	1.00	99.00	30.11	12.00	55.68	0	250
Phenols	6	0.03	0.14	0.07	0.07	0.07	0	100
Cyanide	7	0.00	0.00	0.00	0.00	0.00	0	5

Airborne Pollutants

LBL has prepared the following air toxic emission estimates to comply with requirements of the Air Toxics Information and Assessment Act, AB 2588. Air toxic emission estimates were calculated according to procedures outlined in the AB 2588 Emission Inventory Plan, which LBL submitted to the Bay Area Air Quality Management District in October 1989. Estimates were prepared for substances designated by the California Air Resources Board and submitted in the Emissions Estimates Report in December 1989.

The estimates represent emissions from the following sources: boilers, cooling towers, epoxy mixing and epoxy curing, tritium labeling, lead pot hood, metal part cleaners, nondestructive testing hood, oil tank hood, paint spray booths, printing press, sandblasting, soldering, steam evaporator, storage tanks, vacuum coating hood, vapor degreasers, and welding. Annual average emissions and hourly maximum emission were estimated for the sources analyzed.

Table 20 summarizes the emission estimates.

Some emissions, which were not estimated using mass-balance calculations, will be estimated by source testing or pooled source testing. These values will be provided in a separate report by August 1, 1990. These sources include the research laboratories, machine shops, sink hoods, plating tanks, optics hood, scintillation vial crusher, and hazardous-waste compactor.

Ground-Water Protection

As indicated earlier in this report, the hydrogeology of LBL is quite complex. Members of LBL's Earth Sciences Division have initiated preliminary investigations that include a review of historical geotechnical studies performed on the site, follow-up sampling in areas where elevated levels of hydrocarbons and other contaminants have been found, and development of a detailed site-wide characterization study plan to be carried out during 1991 and 1992. If required, remediation and a long-term monitoring program will follow the study.

During 1989 three of LBL's many hydraugers were sampled monthly. Monthly sampling was initiated at three additional hydraugers in June of that year. Samples taken were counted for tritium and gross alpha and beta activity. One sampling point, designated 75-77 hydr, collects water from a group of 4 bores, which were drilled horizontally ~60 m into the earth fill where Buildings 75, 75A, 75B, and 69 were built. The bores are manifolded together and drain north of Bldg. 77 (see Fig. 1 for the approximate "fan out" of the hydrauger bores). The second hydrauger, designated CC hydr, is an ~750-m-long horizontal bore from the Chicken Creek access road into Little Grizzly Peak (see Fig. 1). The hydrauger designated CC-B hydr is a 150-m bore. The hydrauger designated 7712H hydr is approximately 64 m long, begins under the east end of LBL Building 76, and drains through the retaining wall north of Building 77. The hydrauger designated 7714H hydr is approximately 68 m long and runs approximately north-south from its origin in the earth lens on which Building 75 was constructed 10 m southeast of Building 75 to the retaining wall north of Building 77. The hydrauger designated 71 hydr is a manifolded group of six bores that fan easterly into the hillside south and east of Building 71. All hydraugers continued to flow throughout 1989. The 75–77 hydrauger was chosen to be sampled since it drains water from the earth fill that is rained upon by the highest measured tritium-in-rainfall concentration (see Table 9). The CC hydrauger is the deepest hydrauger (below grade) at LBL and is sampled so that the deepest available ground water can be assayed. The 71 hydrauger group is sampled because it drains ground water from the western side of the hill on which the tritium stack is located. The 7712H and 7714H hydraugers are sampled because their bores begin closest to the tritium facility.

Table 21 summarizes the hydrauger data for 1989. Significant concentrations of tritium were found in three of the hydraugers sampled. Indeed, the average tritium concentration of 29,000 pCi/l found in the 7712H hydrauger exceeded the EPA 40 CFR 141 limit of 20,000 pCi/l of tritium in community drinking water. It should be noted that the flow from 7712H is low (on the order of 0.2 l/min) and that the local surface and ground water does not serve as a source of drinking water. The waters that flow from the 7712H and 14H hydraugers and the 75–77 hydrauger system are heavily mineralized. The gross radioactivity found in those three hydraugers is typical of such waters. There is no reason to attribute any of the radioactivity found in the hydraugers (aside from tritium) to LBL activities.

Table 20. Air toxics emission estimates.

Substance	Annual Average Emissions (lb/yr)	Hourly Max. Emissions (lb/hr)
Benzene	0.7	<0.1
Chromium	<0.1	<0.1
1,4-dioxane	185.4	0.2
Epichlorohydrinpolyglycol	50.0	0.1
Ethylene Glycol Butyl Ether	6.7	0.3
Formaldehyde	10.8	<0.1
Freon	195.0	4.9
Gasoline	1334.0	58.6
Isophorone Diisocyanate	0.5	0.1
Lead	2.5	0.1
Lead Chromate	1.6	<0.1
Methyl Alcohol	25.3	1.2
Methylene Chloride	398.0	0.2
Naphthalene	5.4	0.6
Nickel	<0.1	<0.1
Petroleum Hydrocarbons	<0.1	<0.1
Perchloroethylene	102.0	<0.1
Phosphoric Acid	9.5	1.0
Potassium Zinc Chromate	0.2	<0.1
Propylene Glycol Methyl Ether	33.4	1.2
Sodium Hydroxide	<100	—
Toluene	115.7	.5
Tritium	8.9×10^{-7}	1×10^{-10}
1,1,1-Trichloroethane	1278.0	5.6
Xylene	74.4	0.7
Zinc Chloride	1.2	<0.1
Zinc Chromate	0.4	<0.1

Table 21. Summary of ground-water samples, 1989.

Hydrauger Designation	No. of Samples	Concentration (10^{-9} µCi/ml)						Concentration (10^3 pCi/l)			Average as % of drinking-water standard		
		Alpha			Beta			Tritium as HTO			Alpha	Beta	Tritium
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	%	%	%
CC Hydr.	12	≤ 0.7	≤ 2	≤ 4	≤ 0.9 ± 0.2	≤ 0.6	2 ± 1	≤ 0.2	≤ 0.5	3 ± 1	≤ 14	≤ 11	≤ 1
CC-B Hydr.	12	≤ 1.3	≤ 2	≤ 5	1.4 ± 0.2	≤ 0.6	2 ± 0.8	0.5 ± 0.2	≤ 0.5	3 ± 1	≤ 26	≤ 18	2.5
71 Hydr.	4	≤ 1.3	≤ 2	≤ 3	0.7 ± 0.4	≤ 0.6	1 ± 0.6	≤0.2	≤0.5	0.4 ± 0.2	< 26	9	1
75–77 Hydr.	12	≤ 1.4	≤ 0.9	≤ 6	2.3 ± 0.3	≤ 0.9 ± 0.6	5 ± 1	3 ± 1	0.9 ± 0.5	6 ± 1	≤ 28	29	15
77 12H Hydr.	7	≤ 3	≤ 2.5	≤ 11	3.5 ± 0.5	2 ± 0.8	5 ± 2	29 ± 3	25 ± 3	32 ± 3	< 60	43	145[b]
77 14H Hydr.	7	≤ 2.6	≤ 3	≤ 10	4.4 ± 0.5	3 ± 1	6 ± 2	12 ± 2	8 ± 1	16 ± 3	< 50	55	60
Drinking-water standard[a]		5			8			20					

[a]40 CFR 141, beta assumed to be ^{90}Sr.

[b]During 1990 the Department of Energy officially adopted the Environmental Protection Agency's (EPA) values for community drinking-water standards. The EPA Standard for tritium in drinking water is 20×10^{-6} µCi/ml. Thus, the average tritum concentration in hydrauger 77 12H exceeded the EPA limit.

LBL is presently treating solvent-contaminated ground water using drums containing activated charcoal. This treated ground water is used as makeup water for a cooling tower. Discharges from the cooling tower flow into the EBMUD sanitary sewer system. The flow of treated ground water ranges from approximately 200 to 1000 gal/day.

The solvent-contaminated groundwater drains from the two groups of hydraugers east and northeast of Bldg. 51 (Fig. 7).

Laboratory analysis indicates that these solvents are initially removed to nondetectable levels using these drums. Breakthrough may take 2–6 months. The effluent from the drums is sampled monthly in order to detect breakthrough. Spare drums are available for immediate replacement.

Table 22 summarizes the activated charcoal-bed discharge sampling results.

Trends—LBL Environmental Impact

Accelerator-Produced Penetrating Radiation

Figures 8–11 show the annual accelerator-produced dose equivalent reported by the four perimeter environmental monitoring stations from the year they were established to date. During the past several years, the LBL accelerators have run heavy ions during a significant fraction of their operating schedules. Successful work in beam development had served to increase beam currents in recent years and had increased the dose equivalent at the Building 88 EMS somewhat. That upward trend was reversed in 1983. The 1989 maximum perimeter dose equivalent of 2.6 (Fig. 8) remains a small fraction of the radiation protection guideline[3] of 100 mrem/yr reflecting improvements in accelerator beam optics, local shielding, and cave selection.

Airborne and Waterborne Radionuclides

Figure 12 shows the annual releases of tritium (as HTO) from the Building 75 Tritium Facility from 1974 through 1989.

The 480 Ci released during routine operations in 1989 is approximately 85% of the 1988 releases and is responsible for approximately 88% of the LBL-produced population-dose equivalent from all sources for 1989. The releases occur during molecular tagging and tritium waste processing. The increased releases during 1989 reflect a very active program.

Early in 1990 the NTLF staff presented a five-stage proposal to be phased in over a 14-month period beginning in April 1990. The design basis of the proposal is to reduce tritium discharges by at least 75% and tritium waste shipments by an equivalent, or greater, percentage. The proposal has been approved by Laboratory management, and the first stage is, as of this publication date, underway.

Except for high readings from occasional known off-site releases (e.g., atmospheric nuclear weapons tests and the Chernobyl fire), the atmospheric sampling program has yielded data over the past few years that are within the range of historical normal background.

With historically noted exceptions, the surface-water sampling program has yielded results within the range of historical normal background. Because no substantial changes in the quantities of radionuclides used are anticipated, no changes are expected in these observations.

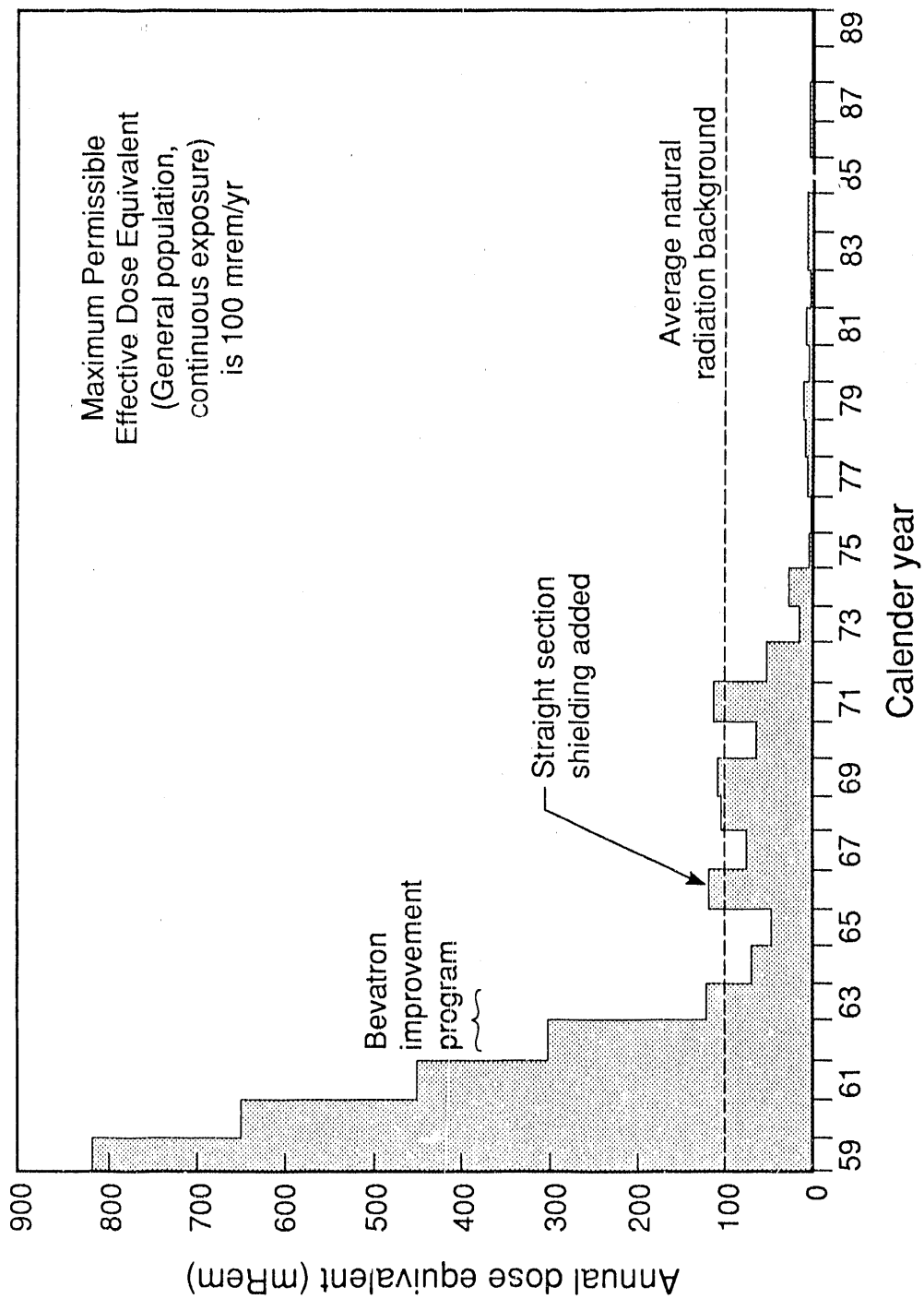
Under the terms of its license, the UCB campus had historically discharged radionuclides into the Strawberry sewer, complicating the analysis of LBL sewer-sampling data. After 1979 the University discharges were sharply curtailed and are expected to be eliminated entirely in 1990.

Table 22. Charcoal-filtered hydrauger effluent sampling summary, 1989.

Halocarbon	No. of Samples	Concentration (mg/l) Min.	Max.	Avg.	Avg. % of Limit	2 × Std. Dev. (mg/l)	No. over Limit	Limit, EPA[a] (mg/l)	Limit, CA[b] (mg/l)
1-2-Dichloroethene	16	<0.5	7	0.8	80	4.2	2	5	1
Tetrachloroethene	16	<0.5	4	0.4	10	2.4	0	not specified	4
Trichloroethene	16	<0.5	2	0.4	8	1.6	0	5	5
Trichlorofluoro-methane	16	<0.5	3	0.4	<1	1.9	0	not specified	3400
1,1,2-Trichloro-1,2,2-trifluoroethane	16	<0.5	72	7.5	<1	37.0	0	not specified	18000

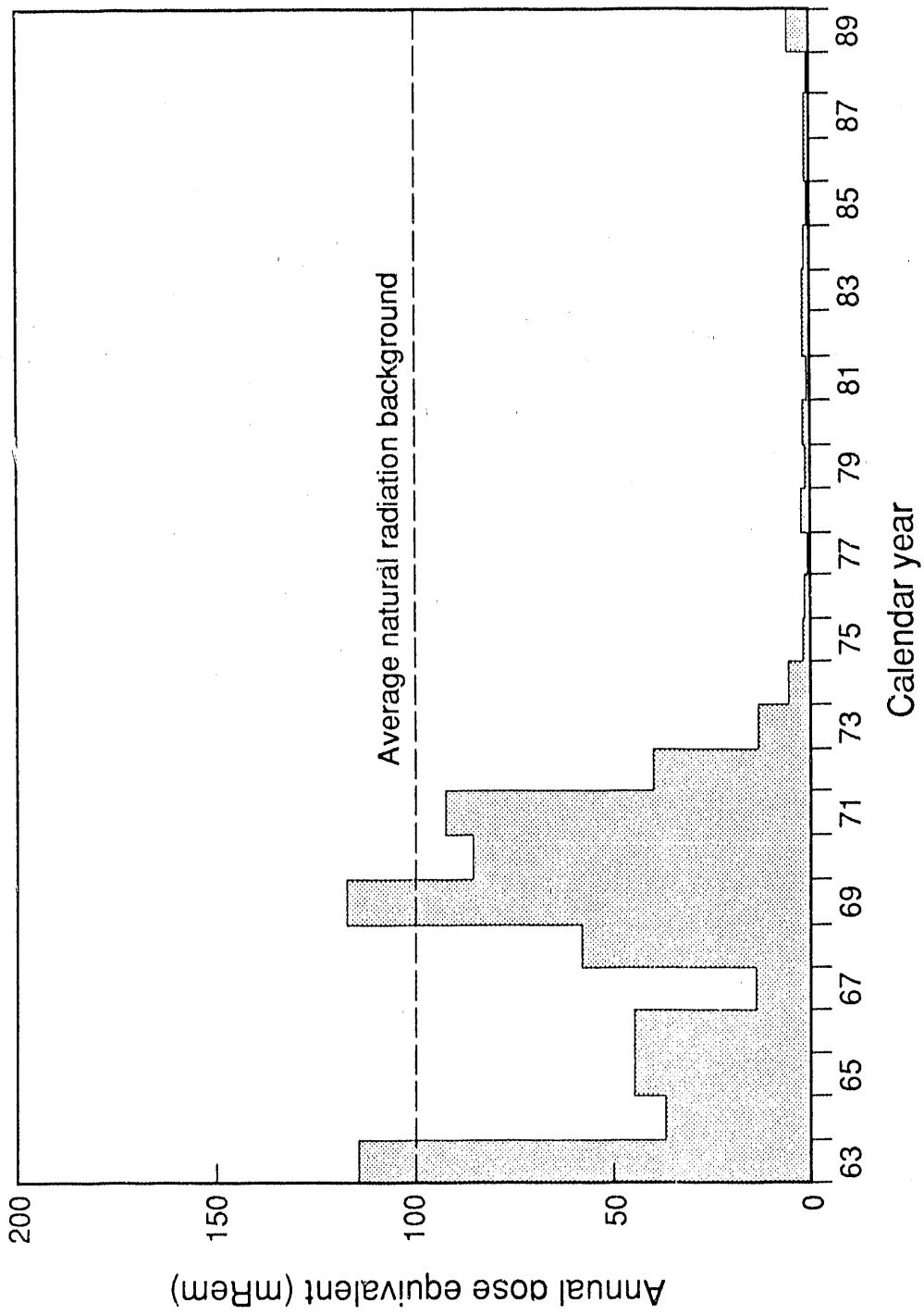
[a]Based on EPA maximum contamination level for drinking water.

[b]Based on California action levels for drinking water.



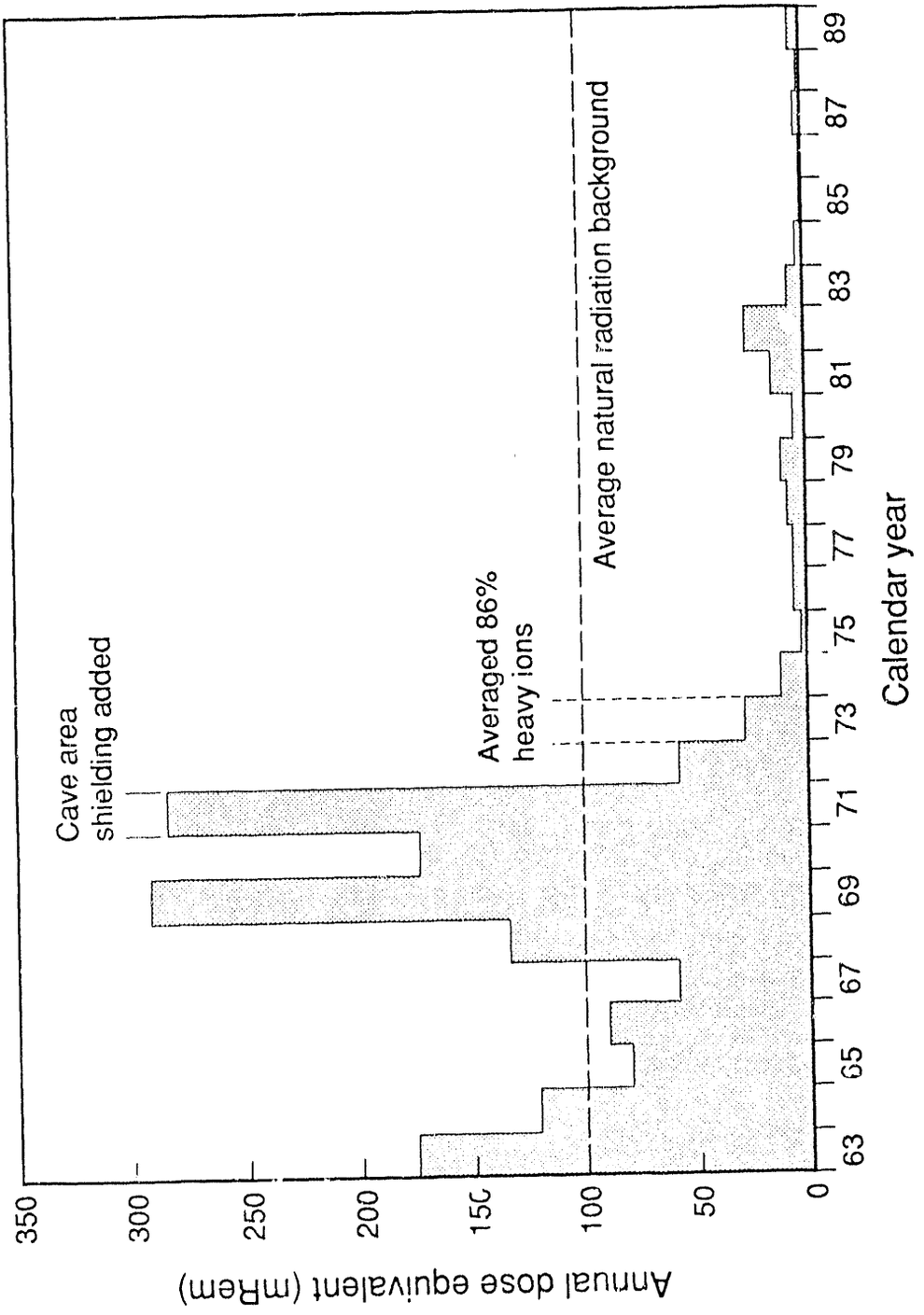
XBL 904-5842

Fig. 8. Annual accelerator-produced dose equivalent at the Olympus Gate Environmental Monitoring Station, 1959–1989.



XBL 904-5846

Fig. 9. Annual accelerator produced dose equivalent at Building 90 Environmental Monitoring Station, 1962–1989.



XBL 904-5845

Fig. 10. Annual accelerator-produced dose equivalent at the 88-Inch Cyclotron Environmental Monitoring Station, 1963–1989.

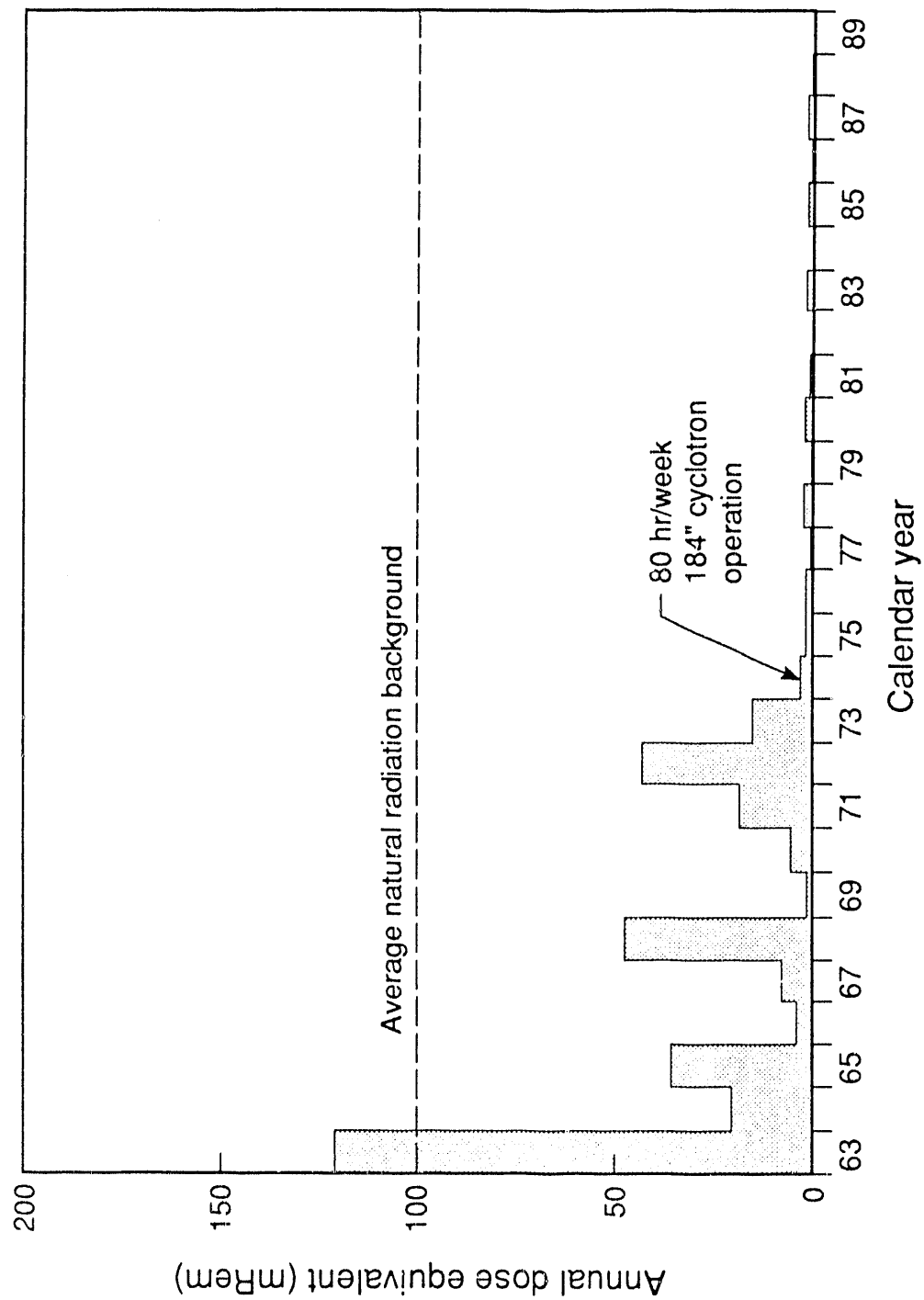


Fig. 11. Annual accelerator-produced dose equivalent at the Panoramic Way Environmental Monitoring Station, 1963–1989.

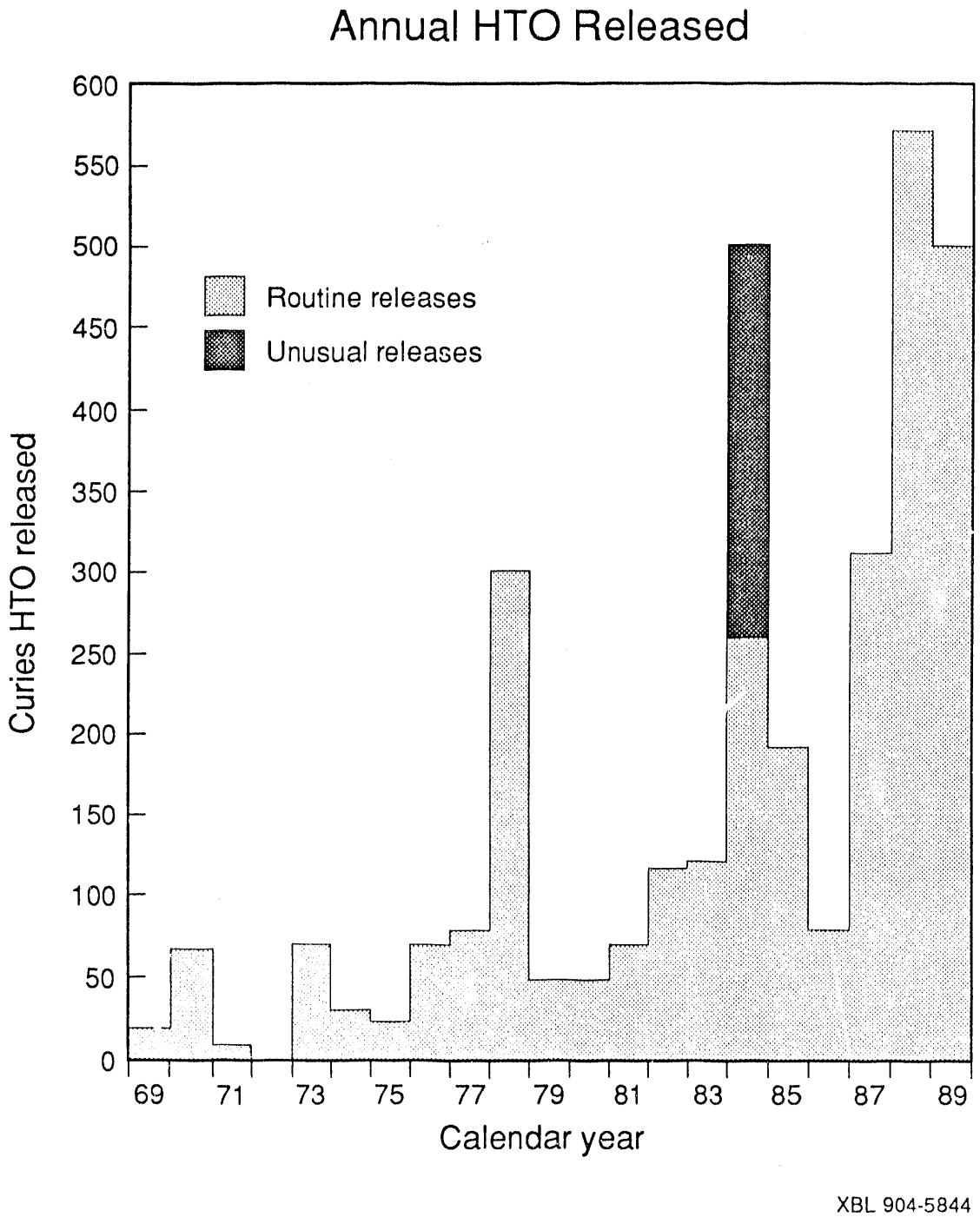


Fig. 12. Annual releases of tritium (HTO) from the Building 75 Tritium Facility, 1969–1989.

Quality Assurance

During 1989, in addition to the quality-assurance procedures described in the body of this report, samples that were blind-spiked with tritium were analyzed along with each group of environmental samples assayed for HTO.

The calibration of all penetrating radiation detectors was performed with National Institute of Standards and Technology (NIST) or NIST-traceable radioactive standards.

Particulate air sampling was performed with media certified to collect >99.9% of all particles ≥0.3μm in diameter.

The cartridges used for sampling air for radioiodine were batch certified (certificates of performance provided) by the registered independent testing lab that performed the evaluations.

The LBL Environmental Monitoring Section analyzed DOE's Environmental Measurements Laboratory (EML) QAPXXX and QAPXXXI Water Samples for tritium, as well as air and water samples for several gamma emitting nuclides. The results, as reported in Refs. 16 and 17, are tabulated in Table 23. The poor performance on the ^{137}Cs-in-water value reported for sample QAPXXX was due to a calculational error.

All nonradiological assays for contaminants in water were performed by California state-certified water-testing laboratories. Sample containers used were provided by those vendors. Sample collection, preservation, and chain-of-custody procedures were carried out by LBL personnel according to vendor specifications.

Table 23. LBL QAP sample results, 1989.

QAP Sample #	Date	Medium	Nuclide	Reported LBL Results[a] (± percent)	EML Value	Ratio LBL/EML
XXX	4/89	Air	^{7}Be	$1.62 \times 10^{3} \pm 23$	1.95×10^{3}	0.83
		Air	^{60}Co	$1.26 \times 10^{2} \pm 15$	1.26×10^{2}	1.00
		Air	^{134}Cs	$1.39 \times 10^{2} \pm 15$	1.58×10^{2}	0.88
		Air	^{137}Cs	$1.92 \times 10^{2} \pm 9$	1.89×10^{2}	1.02
		Air	^{144}Ce	$4.10 \times 10^{2} \pm 16$	3.27×10^{2}	1.25
		Water	^{3}H	8.4 ± 15	6.31	1.33
		Water	^{54}Mn	2.10 ± 38	3.00	0.70
		Water	^{57}Co	7.00 ± 14	8.80	0.80
		Water	^{60}Co	6.60 ± 13	9.40	0.70
		Water	^{134}Cs	2.07 ± 14	2.73	0.76
		Water	^{137}Cs	9.70 ± 10	2.55	0.38
XXXI	9/89	Air	^{7}Be	$1.47 \times 10^{2} \pm 19$	1.23×10^{2}	1.20
		Air	^{54}Mn	4.50 ± 22	4.17	1.08
		Air	^{60}Co	9.30 ± 24	8.17	1.14
		Air	^{134}Cs	$1.07 \times 10^{1} \pm 10$	9.33	1.15
		Air	^{137}Cs	4.9 ± 20	3.58	1.37
		Air	^{144}Ce	8.10 ± 19	7.08	1.14
		Water	^{3}H	$4.16 \times 10^{2} \pm 10$	3.95×10^{2}	1.05

[a]Results for water are in Bq/ml; results for air are in Bq/sample.

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Appendix

U.S. Department of Energy
Air Emissions Annual Report, 40 CFR 61.94
Calendar Year 1989

Site Name: Lawrence Berkeley Laboratory

Operations Office Information

Office: San Francisco

Address: 1333 Broadway

Oakland, CA 94612

Contact: Ed Ballard **Phone:** (415) 273-7967

Site Information

Operator: University of California Lawrence Berkeley Laboratory

Address: 1 Cyclotron Road

Berkeley, CA 94720

Contact: Gary Schleimer **Phone:** (415) 486-5251

Description of Site and Radioactive Materials Handled

See attached copy of page 1 of the Annual Environmental Monitoring Report of the Lawrence Berkeley Laboratory, 1988 (LBL 27170-1989).

Section I
Annual Air Emissions

Radionuclides	Quantity (Ci/yr)
^{3}H	480
^{125}I	1.3×10^{-3}
^{14}C AS $^{14}CO_2$	7×10^{-4}
^{35}S	1×10^{-5}
UNID α(1)	$< 2 \times 10^{-8}$
UNID β(2)	9×10^{-6}

(1) ^{232}Th conservatively assumed
(2) ^{90}Sr conservatively assumed

Section II
Methology for Dose Assessment

Indicate the methods used in addition to AIRDOS-SPA and RADRISK for evaluating doses from the air emissions

___ **Ambient Air Monitoring and Dose Assessment**

___ **Thermoluminescent Dosimetry and Dose Assessment**

___ **CAP-88 (AIRDOS/RADRISK with effective dose equivalent)**

__X__ **Other (explain)** PC AIRDOS Ver 3.0

Location of Receptor (for each method, if different)

Distance and direction from release points:

800 meters due west

Receptor/Use (i.e. residence, school, business)

residence

Comments/qualifications:

PC AIRDOS does not include ^{35}S in its table of nuclides. Thus the computed maximum whole body and effective dose equivalent values do not include the (small) contributions from ^{35}S.

ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY, 1988

ABSTRACT

The Environmental Monitoring Program of the Lawrence Berkeley Laboratory is described. Data for 1988 are presented and general trends are discussed.

INTRODUCTION

Laboratory Operations

The Lawrence Berkeley Laboratory (LBL) is a multiprogram national laboratory managed by the University of California (UC) for the U.S. Department of Energy (DOE). LBL's major role is to conduct basic and applied science research that is appropriate for an energy research laboratory. LBL, birthplace of the cyclotron, was founded by the late Nobel Laureate Ernest Orlando Lawrence 57 years ago.

The Laboratory also supports nationwide university-based research by providing national facilities, including the National Center for Electron Microscopy, three large accelerators, several small accelerators, a number of radiochemical laboratories, several large gamma irradiators, and a tritium (^3H) labeling laboratory. The Bevatron (Building 51 in Fig. 1) is the most massive of LBL's accelerators. Originally designed as a 6-GeV proton synchrotron, it is presently capable of accelerating ions up to ^{40}Ca, from 20 MeV/nucleon to 2.1 GeV/nucleon, and ions up to uranium to 1 GeV/nucleon. For certain beams the SuperHILAC is used as an injector. (This combination is called the Bevalac.) The SuperHILAC (Building 71), a heavy-ion accelerator, is a multiprogrammable research accelerator in its own right and produces ion beams up to 8.5 MeV/nucleon. The 88-Inch Variable Energy Sector-Focused Cyclotron (Building 88) routinely produces intense beams of protons to about 60 MeV, alpha particles to 140 MeV, and heavy ions to mass 40 to energies of 350 MeV. Aside from shutdown periods, the first two of these accelerators provide beams around the clock. The 88-Inch Cyclotron provides beams ~120 hr/wk. The venerable 184-Inch Cyclotron decommissioned during 1988 will be replaced by a synchrotron light source.

The tritium facility located in Building 75 was designed to handle kilocurie quantities of tritium (a radioactive isotope of hydrogen–^3H) used as a labeling agent for a variety of molecules subsequently employed in chemical and biomedical research. The facility is funded by the National Institutes of Health.

Radiochemical and radiobiological studies performed in many laboratories at LBL typically use millicurie quantities of a great variety of radionuclides. The workplace and effluent release points are continuously sampled at all installations where significant quantities of radionuclides are handled.

The Site

LBL is situated upon a hillside above the main campus of UC. The 130-acre site is located on the west-facing slope of the Berkeley Hills, at elevations ranging from 150 to 350 meters above sea level. Most of the site is within the City of Berkeley, but about one-quarter of the eastern part is within the City of Oakland. It is located three miles east of San Francisco Bay and about fifteen miles east of San Francisco.

LBL is located in an urban environment on land owned by the University. The LBL site is bordered on the north by predominately single-family homes and on the west by multiunit dwellings, student residence halls, and commercial districts. The area to the south, which is part of the University lands, is maintained in a largely natural state and includes recreational facilities and the University Botanical Garden. The population within an 80-km (50-mi) radius of the Laboratory is approximately 5.1 million (1980 census).[1]

Section III
Annual Dose Estimates

a. External and Uniform Internal Irradiation

EPA Air Emission Standard: 25 mrem

Whole body dose equivalent commitment: 0.3* **mrem**

b. Internally-Deposited Radionuclides (all air pathways)

EPA Air Emission Standard: 75 mrem NA * > 99% of dose from tritium

Organ #1 (_____) : _____ mrem
Organ #2 (_____) : _____ mrem
Organ #3 (_____) : _____ mrem
Organ #4 (_____) : _____ mrem

c. Effective Dose Equivalent (CAP-88/AIRDOS if available)

EPA Air Emission Standard: 10 mrem ede

Effective Dose Equivalent: 0.3 **mrem**

d. Other (reference methodology and give appropriate units)

Section IV
References/Sources of Additional Information

LBL 27170-1990, The Annual Environmental Monitoring Report of the Lawrence Berkeley Laboratory, 1989.

Acronyms and Other Initialisms

CEDE	collective effective dose equivalent
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
DCG	derived concentration guide
DHS	California Department of Health Services
DOE	Department of Energy
EBMUD	East Bay Municipal Utility District
EH&S	LBL Environmental Health & Safety Department
EMS	Environmental Monitoring Station
EPA	U.S. Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
gsf	gross square feet
HEPA	high-efficiency particulate
LBCF	low-background-counting facility
LBL	Lawrence Berkeley Laboratory
LHS	Lawrence Hall of Science
MS	monitoring station
MSRI	UC Mathematical Science Research Institute
NCRP	National Commission on Radiation Protection and Measurements
NEPA	National Environmental Protection Act
NESHAPs	National Emission Standard for Hazardous Airborne Pollutants
NIST	National Institute of Standards and Technology
NPL	National Priorities List
PCB	polychlorinated biphenyls
POTW	Public Owned Treatment Works
RCRA	Resource Conservation and Recovery Act
RPG	radiation protection guidelines
SARA	Superfund Amendments and Reauthorization Act
SIC	Standard Industrial Classification
TSCA	Toxic Substances Control Act
UC	University of California
UCB	University of California at Berkeley

END

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