LBL--27170

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8, line 5	(compared to >10 μCi	(compared to >10 mCi
8, line 12	^{152}En	^{152}Eu
38, line 30	EML-519, July 7 1, 1988	EML-513, July 7, 1988
38, line 32	January 2, 1988	January 2, 1989

ENVIRONMENTAL COMPLIANCE SUMMARY

LAWRENCE BERKELEY LABORATORY

A site characterization (SC) study has shown elevated levels of hazardous substances in the groundwater above the state action levels. A Conceptual Design Report (CDR) has been prepared to provide a basis for the development of a more detailed SC, which is part of the DOE Environmental Restoration and Waste Management (ERWM) Five-Year Plan. The groundwater in the contaminated area is filtered through charcoal and used as makeup water for a cooling tower. The Water District and the State of California are aware of the study and treatment. LBL has an agreement with the East Bay Municipal Utility District (EBMUD) to use the makeup water in the cooling tower.

Tritium has been detected in the groundwater (exceeding EPA community drinking water standards, but not DOE standards) near the National Tritium Labeling Facility. While the groundwater is not used for drinking water, further site characterization is needed to determine the full extent of the contamination. Soil sampling around the facility has been identified in the ERWM Five-Year Plan.

The EPA/State RCRA Part B Permit for Treatment, Storage, and Disposal of Hazardous Waste has not been issued pending completion of the California Environmental Quality Act (CEQA) process for the proposed new Hazardous Waste Handling Facility (HWHF). LBL is presently operating under an extension of the current Part B Permit. A Draft CEQA Environmental Impact Report was submitted to the State Clearing House on November 9, 1989.

A new plating shop waste water treatment plant (included with the HWHF Permit application) is currently not permitted to operate. The existing plating shop waste water treatment plant will be operated until the new unit is permitted. A variance request from the California Department of Health Services, Permits Division, is underway.

There are fifteen underground storage tanks at LBL. Through leak testing, three tanks were found to have pipe connection leaks; all three tanks have since been remediated. There continues to be close coordination with the City of Berkeley in the tank and soil removals.

LBL-27170 1989

ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY

1988

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

Gary E. Schleimer
Editor

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Office of Environmental Compliance and Overview
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U.S. Department of Energy under Contract No. DE-AC03-76SF00098

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. A format similar to LBL-4827 was used in the 1976, 1977, 1978, and 1979 Annual Monitoring Reports (LBLs 6405, 7530, 9080, and 11192, respectively).

While 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

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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.

The bulk of the sample preparation and lab work was done by V.J. Montoya. Sample assays and computer data entry were done until August 1988 by W.B. Corniea and subsequently by L.R. Gunn. Special assays of air samples were performed by A.R. Smith.

The editor wishes to gratefully acknowledge the assistance of the Technical Information Department's editorial and word processing groups.

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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 (^{3}H) 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–^{3}H) 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]

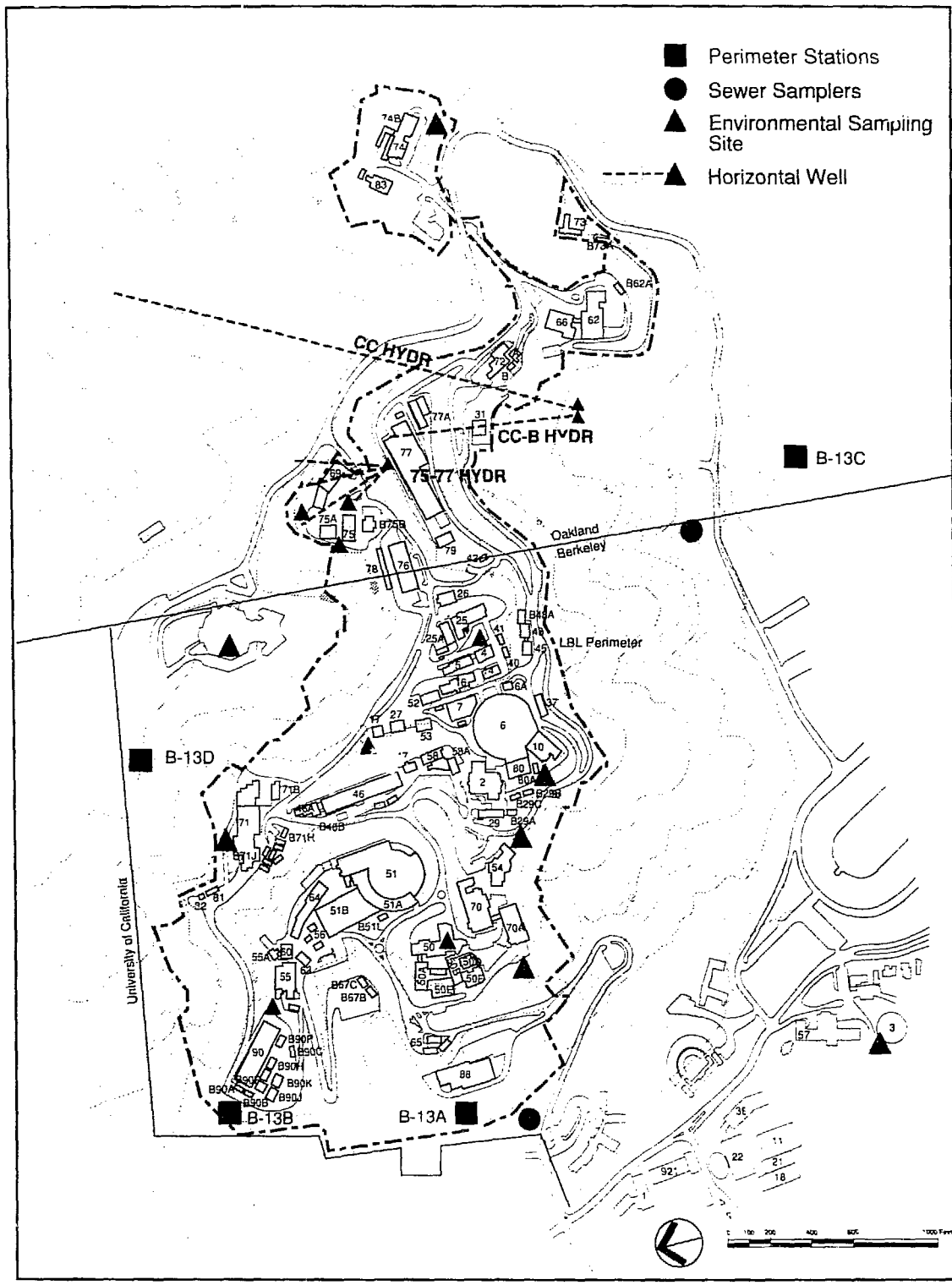

Figure 1. Lawrence Berkeley Laboratory buildings.

KEY TO LBL BUILDINGS SHOWN IN FIGURE 1

Bldg. No.	Description
	HILL-SITE BUILDINGS
4	Magnetic Fusion Energy (MFE)
5	Magnetic Fusion Energy (MFE)
6	184-Inch Cyclotron
6A	Utilities Service
7	Central Stores & Electronics Shops
9	Magnetic Fusion Energy
10	Biomedical Research and Photography
12	Central Stores Annex
14	Accelerator & Fusion Research & Earth Science
16	Magnetic Fusion Energy Laboratory
17	Solar Refrigeration Process & Salvage
25	Mechanical Technology
25A	Electronics Shops
26	Medical Services
27	Cable Shop & High Voltage Test
29	Detector & Instrumentation Projects & Biomedical Research & Radiation Effects
31	Chicken Creek Barn
37	Utilities Service
40	Electronics Warehouse
41	Computer Aided Drafting
42	Earth Science Field Service
44	Indoor Air Pollution Studies
45	Fire Apparatus
46	Accelerator Development, Electronics Projects & Real Time Systems Group (RTSG)
46A	Real Time Systems Group (RTSG)
47	Advanced Accelerator Study
48	Fire Station
50	Physics, Accelerator & Fusion Research & Nuclear Science
50A	Physics, Director's Office & Earth Science
50B	Physics & Computer Center
50C	CAM Division Office & Physics
50D	MCSD & Nuclear Science
50E	Earth Sciences
50F	Information & Computing Sciences Division, Public Information & Patents
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
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	Administrative Data Processing
66	Surface Science & Catalysis Lab
68	Upper Pump House
69	Materiel Management & 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
72A	High Voltage Electron Microscope (HVEM)
72B	Atomic Resolution Microscope (ARM)
72C	ARM Support Laboratory
73	Atmospheric Aerosol Research
74	Biomedical Laboratory
74B	Biomedical Laboratory Annex
75	Radioisotope Service & National Tritium Facility (NTF)
75A	Compactor Processing & Storage Facility
76	Craft & Maintenance Shops
77	Mechanical Shops
77A	UHV Phase I Assembly Facility
78	Craft Stores
79	Metal Stores
80	General Research Laboratory
80A	Telephone Services
81	Liquid Gas Storage
82	Lower Pump House
83	Cell Culture Laboratory
88	88-Inch Cyclotron
90	Accounting & Financial Mgmt., Applied Science, Employment, Engineering, Personnel, Protective Services, Superconducting Super Colliding Group (SSC) & TID
	SMALL BUILDINGS AND TRAILERS
B-4A	Safety Equipment Storage
B-6B	Deionizer Building
B-7A	Radio Shop
B-7B	Office Trailer
B-7C	Office Trailer
B-7E	Office Trailer
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
B-16A	Power Supply House
B-29A	Office Trailer
B-29B	Office Trailer
B-29C	Office Trailer
B-75B	Office Trailer

The Laboratory's activities are located both 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 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 the San Francisco Bay. Seasonal temperature variations are small, with a mean temperature difference between the summer 63°F and winter 48°F of only 15 degrees. Relative humidity ranges from 85–90% in the early morning to 65–75% in the afternoon. The average annual rainfall is 25 inches. About 95% of the rainfall occurs from October through April, and intensities are seldom greater than 0.5 inch per hour. Thunderstorms, hail, and snow are extremely rare. Winds are usually light, but summer sea breezes range up to 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). Although ground-water wells are not used as a source of Laboratory or local community drinking water, three hydraugers (shown as dotted lines on Fig. 1) are sampled for gross radioactivity and tritium. 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.

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 200,000-gallon 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 Berkeley system flows to the EBMUD Sewage Treatment Facility, where the wastewater undergoes primary and secondary treatment before its discharge to San Francisco Bay. To ensure that its wastewater complies with the EBMUD discharge limits, the Laboratory monitors its wastewater for chemical and radioactive hazards. In addition, wastewater from both plating shops and a chemistry building is monitored and treated appropriately before discharge.

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 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 runoff intensities expected in a 25-year maximum-intensity storm.

1988 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 1988, 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)[3] and of the natural radiation background. [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.]

The maximum effective dose equivalent delivered to a hypothetical member of the community is defined as the maximum perimeter dose equivalent. That value [the 1988 dose equivalent at the Olympus Gate Environmental Monitoring Station (MS) B-13D] was ≤ 2.2 mrem (1.9 mrem from direct radiation and 0.3 mrem from radionuclide releases), about 2% of the RPG. The hypothetical maximum exposure to an individual from airborne radionuclides would be to a person residing just outside the western LBL perimeter. The 1988 effective dose equivalent to such a person would have been ≤ 0.8 mrem—less than 1% of the RPG. The total population dose equivalent attributable to LBL operations during 1988 was ≤ 15 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. 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 ^{131}I and unidentified alpha and beta-gamma emitters were released from LBL laboratory stacks. 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 570 Ci of tritium (as HTO), which is responsible for a CEDE of approximately ≤ 14 man-rem, and a hypothetical maximum off-site individual exposure (from airborne radionuclides) of ≤ 0.8 mrem.

To put the Laboratory's impact into perspective, an approximate value for absorbed dose from external and internal natural sources (e.g., cosmic rays, radiation from continental rocks, naturally occurring radioactive potassium-40 in the muscles and bones and exposure from radon and its daughters) to each person within 80 km (50 mi) of LBL is roughly 0.3 rem/yr, which produces a natural annual population dose of ~1,500,000 man-rem (from the National Council on Radiation Protection and Measurements NCRP Report No. 94, "Exposure of the Populations in the United States and Canada from Natural Background Radiation," 1987). However, when comparing LBL's penetrating radiation impact (from accelerator operations) to natural sources, only the penetrating whole-body component or natural background (about 1/3 of the foregoing total or 0.1 rem) is used.

Gross data for radioactivity in air and water for the period 1979–1988 are presented for comparison with the 1988 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 background levels.

1988 ENVIRONMENTAL ACTIVITIES AND PERMITS ISSUED

Environmental Assessments

Environmental assessments (EA) are prepared according to the requirements of the National Environmental Policy Act (NEPA). In 1988, no EAs were completed; however, one is in progress for a new hazardous waste-handling facility.

For further information about this assessment contact

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In order to carry on its research, LBL designs and builds much of its required 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. A list of these permits by type and issuing agency, with expiration date, is given below.

Environmental Permits

1) Source Operating Permits, Bay Area Air Quality Management District, Expire July 1, 1989.
   - Vapor Degreaser, Building 25A
   - Cold Cleaner, Building 46
   - Vapor Degreaser, Building 53
   - Ultrasonic Degreaser, Building 53
   - Machine Shop Tools, Building 53
   - Machine Shop Tools, Building 58
   - Vapor Degreaser, Building 64
   - Machine Shop Tools, Building 70A
   - Sawdust Collector, Building 74
   - Cold Cleaners (2), Building 76
   - Machine Shop Tools, Building 76
   - Sawdust Collector, Building 76
   - Paint Spray Booth, Building 76
   - Gasoline Storage Tank, Building 76
   - Vapor/Spray Degreaser, Building 77
   - Solder/Grinding Hood, Building 77
   - Ultrasonic Degreaser, Building 77
   - Machine Shop Tools (2), Building 77
   - Paint Spray Booth, Building 77
   - Sandblast Exhaust, Building 77
   - Ceramic Machine Shop Tools, Building 77
   - Paint Drying Oven, Building 77
   - Solvent Cleaning, Building 77
   - Metal Rack Saw, Building 79
   - Machine Shop Tools (2), Building 88
   - Solder Hood, Building 88
   - Solvent Cleaning, Building 934
2) Wastewater Discharge Permit, East Bay Municipal Utility District, Expires June 8, 1989.
   - Plating Shop, Building 25
   - Plating Shop, Building 77

3) Hazardous Waste Facility Permit, California Department of Health Services, application pending.

4) Underground Storage Tank permits—City of Berkeley—eleven underground storage tanks.

Diesel Oil

- Building 51 – 550 gallons
- Building 55 – 1,000 gallons
- Building 66 – two—6,000 and 2,000 gallons
- Building 70 – 600 gallons
- Building 70A – 1,000 gallons
- Building 74 – 12,000 gallons
- Building 76 – 10,000 gallons

Gasoline

- Building 76 – 10,000 gallons

Waste oil

- Building 69 – 2,000 gallons

Diala Oil

- Building 58 – 2,000 gallons

Environmental Activities

1) The plating shop replaced its hexavalent chrome plating process with one that uses trivalent chrome. Recent legislation had prescribed strict controls on the emission of hexavalent chrome from plating operations. As a result, the less toxic, trivalent form has been substituted.

2) A sampling program was initiated to characterize the extent of soil/ground-water contamination in a hillside behind Building 51. The contamination consists of solvents that were commonly used in degreasing oeprations, including perchloroethylene and trichloroethylene. As a temporary control measure, ground-water discharged from this site through hydraugers is filtered using activated charcoal.

3) Six large transformers, which contained polychlorinated biphenyls (PCB) were replaced with non-PCB equipment. These transformers were located in Buildings 50A, 50B, and 51.

4) A program to replace scintillation liquids that contain volatile, toxic organic compounds (e.g., toluene, tylene) with less hazardous liquids has been completed. This program was initiated because of the difficulty of finding a disposal site capable of handling mixed chemical and radioactive wastes. Now, used scintillation liquids are disposed of as radioactive wastes.

5) On December 29, 1987, the LBL 184-Inch Synchrocyclotron, the oldest and longest continuously operating cyclotron, ran its last beam. The machine was to be dismantled to make way for a new accelerator. The decommissioning process required 13 man-years of effort and cost (as of 2/1/89) approximately $1.65 M. The cyclotron was housed in a massive vault of reinforced concrete and steel with 15-ft thick walls and 9-ft thick roof. The years of operation had activated the cyclotron structure and inner vault walls such that hundreds of tons of material contained induced radionuclides that was disposed of as radioactive waste or accepted for reuse by other DOE sites. The entire cyclotron shielding and support facilities were removed except for the magnet frame itself, which is to be used as a crane support for a new accelerator to be built on the site.

Approximately 8000 metric tons of material was removed: 2800 tons were retained for reuse; 2200 tons were shipped to other sites for reuse; 820 metric tons of steel, copper, brass, aluminum, and concrete were packaged and shipped to a radioactive waste burial site for disposal.

The material shipped for burial in the waste site contained an estimated 3 Ci of ^{60}Co, 0.4 Ci of ^{54}Mn, 0.1 Ci of ^{7}Be and ^{65}Zn and substantially smaller quantities of a variety of other nuclides. The concrete floor of the cyclotron vault was chipped up and some of the soil underneath was excavated and removed. The major induced activity in the concrete and soil was ^{152}Eu, a so-called rare earth whose concentration was found to be as high as 50 pCi/gm in vault concrete but 2 pCi/gm or less in the soil.

During the early life of the machine it had been used as an separator of uranium isotopes for the Manhattan project and a spill of an estimated 3 kgm of natural uranium salts found under the shielding blocks was chipped out of the concrete floor and buried with the rest of the radioactive waste.

Of the more than 7000 tons of shielding blocks, 2300 tons of very slightly induced reinforced concrete blocks were shipped to a sanitary landfill for burial by arrangement with the State of California

Department of Health Services. Samples of the disposed blocks were assayed; and any blocks that contained induced radioactivity whose summed concentrations ≤ 10% of the concrete and aggregates natural activity were sent to the landfill. (The natural radioactivity contained in the blocks included ^{232}Th, ^{238}U and daughters, and ^{40}K, common natural radioactive constituents of continental rocks). The total inventory of induced radionuclides buried in the sanitary landfill was 0.6 mCi (compared to > 10 μCi of natural radionuclides which would be found in an equivalent volume of ordinary uncontaminated soil). During all operations, air sampling was done and all decommissioning personnel wore dosimeters.

The total exposure to personnel was 1.6 man-rem and the average exposure was 51 mrem. The highest dose to any individual was 170 mrem, less than 4% of the maximum allowable exposure to radiation worker.

Small quantities of the radionuclides mentioned earlier were found in air samples most notably ^{60}Co, ^{152}En, ^{22}Na, and natural uranium. Overall average values for the decommissioning period were: 0.3% of the derived air concentration (DAC) for uranium and ≤ 0.01% of the DAC for ^{22}Na, ^{60}Co, and ^{152}Eu (DAC for workers per DOE Order 5480.11, "Radiation Protection for Occupational Workers," Dec. 1988).

An excellent summary of the decommissioning process titled "184-Inch Synchrocyclotron Decommissioning" by Reimers, Haley and Hampton was presented by J. Alonzo at the April 1989 IEEE Particle Accelerator Conference in Chicago. Copies of the summary may be obtained from the editor of this document.

ENVIRONMENTAL MONITORING RESULTS

Radiological Results

Penetrating Radiation

To determine the radiological impact of LBL accelerator operations, we maintain permanent monitoring stations at four points about LBL's perimeter (see Fig. 1 and Table 1).

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 semiannually. The four perimeter station neutron detectors were replaced with more sensitive units during 1988. 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.

Table 1. Location of LBL monitoring stations (MS).

Building No.	Name
B-13A	Building 88 Environmental MS
B-13B	Building 90 Environmental MS
B-13C	Panoramic Environmental MS
B-13D	Olympus Gate Environmental MS

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 1988. The fence-post neutron dose equivalent and gamma-ray dose equivalent attributable to LBL accelerator operations in 1988 (see Table 2) are characterized as follows.

1. The SuperHILAC and Bevatron contributed approximately 80% and <20%, respectively, of the fence-post dose equivalent measured at the Olympus Gate Environmental Monitoring Station. The 1 mrem was delivered fairly uniformly during the operating year.

2. The 88-Inch Cyclotron fence-post dose equivalent of 0.6 ± 0.2 mrem is primarily attributable to stray neutrons and scattered photons produced during 8 light-ion (helium-3, p^+, D^+, helium-4) runs during 1988. (The fence-post dose equivalent from radionuclide releases at this station was calculated to be 0.8 mrem for 1988.)

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 density values for neutrons of various energies.

In order to better characterize the impact of the neutrons from the 88-Inch Cyclotron a 7 detector neutron spectrometer was installed at the B13A monitoring station in January of 1988. During the year 7 light-ion beams runs (^{3}He, Pr, ^{2}H) produced measurable neutron fluences. The spectrometer data were "unfolded" by Rai Ko Sun of the LBL Environmental Health and Safety Department using the computer code LOUHI.[6,7] The historically assumed neutron fluence to dose value used by this author in the absence of spectral data was 2.45×10^4 n/cm^2/mrem. The mean value of neutron fluence to dose value established by the LOUHI runs was 2.2×10^5 n/cm^2/mrem, 1/9th of the historically conservative value and 60% of the value used in the two previous annual editions of this report (based on average neutron energy measurements). The value of 0.6 ± 0.2 mrem attributable to neutron fluence reported for 1988 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 1988 and were thus interpreted as constituting the natural gamma background for 1988. The mean value of gamma background inside the monitoring stations was 80 ± 10 mrem for 1988.

Table 2. Fence-post annual effective dose equivalent at the LBL boundary due to accelerator operation, 1988.

Station	1988 total above background		
	gamma (mrem)	n (mrem)	Total[a] (mrem)
Olympus Gate MS	0	1.9 ± 0.3	1.9 ± 0.3
Building 90 MS	0	≤ 0.2	≤ 0.2
Building 88 MS	≤ 0.1	0.5 ± 0.1	0.6 ± 0.2
Panoramic MS	0	0	0
Standard for comparison (Dose to individuals at maximum point of exposure)			100[b]

[a]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.

[b]Source: Reference 3.

LBL's Environmental Health and Safety (EH&S) Department operates a radiological and chemical waste storage yard north and an instrument calibration facility south of Building 75. (The small trailer "complex" on Fig. 1 south of Building 75 is Building 75B, which houses EH&S administrative and operational 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 247±15 mrem for a net exposure of 170±15 mrem during 1988.

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 170 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. Ignoring the shielding by the hillside, the predicted doses from waste handling facilities sources would be ~0.05 mrem/yr at the Lawrence Hall of Science (40-hr/week occupancy) or ~0.07 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 LBL's 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. This 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: at the perimeter fence <1.4 mrem/yr; at the Botanical Garden house (40-hr/wk occupancy) <0.1 mrem/yr; and at the nearest house <0.02 mrem/yr (168-hr/wk occupancy).

Airborne Radionuclides

Gross atmospheric particulate beta and alpha activities are measured by air sampling at 14 points: Four perimeter environmental monitoring stations and 10 of the 14 "environmental sampling sites" identified in Fig. 1. (The sites on the north side of Building 75 and the roof of Building 4 are rain collectors. The sites at LHS and west of Building 69 are tritium samplers.) The Building 3 site contains samplers for HTO (tritiated water) and $^{14}CO_2$. Atmospheric air is also sampled for radioiodines at the four perimeter monitoring stations.

The gross beta and alpha sampling media are 10 cm × 23 cm (4 × 9 inch) 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. TEDA-doped activated carbon cartridges are used to sample air for radioiodine at the four perimeter stations. Samples are removed weekly. Before they are counted, they are set aside for five days to enable short-lived radon and thorium daughters (naturally occurring airborne radionuclides) to decay. The filters are loaded into an automatic counter that determines their gross alpha activity by means of 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. Radioiodines in air, specifically ^{125}I and ^{131}I are assayed by analyzing the activated carbon cartridges with a sodium iodide detector connected to a multichannel analyzer. The detection limits for ^{125}I and ^{131}I are 5×10^{-15} μCi/ml and 26×10^{-15} μCi/ml, respectively.

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 (HPGE). 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 roughly 2×10^{-17} μCi/ml, about 0.000005% of the RPG), 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 7.0×10^{-14} to 4.1×10^{-13} μCi/ml and averaged 1.6×10^{-13} μCi/ml, which is 0.0003% of the RPG. 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 thorium-232 if they are alpha-emitting material or strontium-90 if beta-emitting material. The assertion of conservatism is made because, while ^{90}Sr and ^{232}Th are found 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 Reference 3. Although ^{227}Ac, which is 4500 times more restrictive a beta emitter than ^{90}Sr, is also found 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.

Tritium, as HTO, is sampled 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.

As with gross alpha and beta samples, 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. The stack from the tritium labeling facility is also monitored for tritium as described above. An additional site, is located at the northeast corner of Building 69A.

The concentration of $^{14}CO_2$ in air is determined by air sampling with NaOH. Samples 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 scintillation cocktail and counted in a liquid scintillation counter. The detection limit for $^{14}CO_2$ is 200×10^{-12} μCi/ml.

The total quantities of radionuclides discharged into the atmosphere are summarized in Table 3. Aside from the tritium release that is just under twice the 1987 value, the figures are similar to those of last year, and the releases resulted in a small collective effective dose equivalent (see Table 19). 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. The foregoing 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).

Table 3. Total quantities of radionuclides discharged into the atmosphere, 1988.

Nuclide	Quantity discharged (Ci)
Tritium (as HTO)	570
Carbon-14 (as $<^{14}CO_2$)	1×10^{-3}
Iodine-125	2.7×10^{-3}
Iodine-131	1×10^{-5}
Unidentified beta-gamma emitters[a]	$< 1 \times 10^{-5}$
Unidentified alpha emitters[b]	$< 2 \times 10^{-7}$

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

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

Table 4. Summary of air samples, 1988.

	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	501	≤ 0.12	< 2	5 ± 2	≤ 4	≤ 80	160 ± 100	≤ 2	≤ 0.04
Perimeter Stations									
Bldg. 88	50	≤ 0.48	< 3	≤ 3	≤ 16	< 120	130 ± 120	≤ 7	≤ 0.2
Bldg. 90	50	≤ 0.46	< 3	5 ± 3	≤ 16	< 120	≤ 120	≤ 7	≤ 0.2
Panoramic Way	47	≤ 0.47	< 3	5 ± 3	≤ 16	< 120	≤ 120	≤ 7	≤ 0.2
Olympus Gate	50	≤ 0.48	< 3	4 ± 3	≤ 16	< 120	≤ 120	≤ 7	≤ 0.2
Standard for Comparison[b]		7			9,000				

[a]Highest single weekly sample.

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

Table 5. Annual gross radioactivity found in LBL perimeter air samples, 1979–1988.

Year	No. of Samples	Concentration (10^{-15} µCi/ml) Alpha Avg.	Alpha Max.	Beta Avg.	Beta Max.
1979	202	1.5 ± 0.3	7	28 ± 12	230
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
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]Reference 3: alpha conservatively assumed to be ^{232}Th; beta conservatively assumed to be ^{90}Sr.

Although small quantities of radionuclides (Table 3) were discharged into the atmosphere during 1988, the data from the general environmental air sampling were within the range of normal background. The Table 4 data for 1988 may be compared with data from Table 5, which lists LBL perimeter air sample data maxima and averages for the period 1979–1988.

The radioiodine sampling program (Table 6) detected very small concentrations of ^{125}I and no significant ^{131}I in perimeter air during 1988. The environmental air sampling program for ^{14}C and ^{3}H found detectable concentrations of these nuclides (Tables 7 and 8). Essentially, 100% of the tritium released from LBL was discharged from the Building 75 stacks.

All measurements of atmospheric deposition at outlying perimeter stations lie within the range of normal background; however, tritium was detected in rainfall collected within the Laboratory boundary near the stack from the Building 75 Tritium Facility (Tables 9 and 10). The deposition values, adjusted for rainfall, are compared with drinking-water standards (Ref. 3) assuming that all beta activity is ^{90}Sr and all alpha activity is ^{232}Th (conservative assumptions for both). The drinking-water tritium standard[3] is used for tritium in Table 9. Local drinking water is supplied by the East Bay Municipal Utility District (EBMUD) from sources located > 150 km east of LBL. EBMUD uses no well water or local surface water as drinking water.

Waterborne Radionuclides

Rainwater, creek water, and sewage from LBL's two sewer outfalls are analyzed for gross beta and alpha emitters (see Fig. 1; the Strawberry Sanitary Sewer is the southern site, Hearst is the western sewer). Additionally, sewer effluent is analyzed for gross halogen (radioiodine) content and for tritium. Rainwater is also analyzed for tritium as is the ground water, which flows from the horizontal wells (hydraugers), whose bores are represented by the heavy dashed lines in Fig. 1.

Sewer outfalls are sampled continuously, sample-to-flow ratios are designed to be between 10 and 20 ppm, and composite samples are taken weekly. The five creek sample points indicated in Fig. 2 are sampled weekly. A one-quart grab sample is taken from each site and analyzed for gross alpha and beta emitters.

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 picked up monthly and analyzed for gross alpha and beta activities and for tritium. During the dry California summer, each collector is rinsed with a quart of tap water, and the rinse is analyzed for "dry deposition." The 10 other atmospheric sampling sites alluded to in the air sampling section of this report 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 collector on the north side of Building 75 is analyzed on a storm-by-storm basis 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-inch stainless steel planchettes. Organic residues not wet-ashed by the nitric acid treatment are oxidized by flaming the planchettes.

Since radioiodine is 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 1988 data from the surface-water and tap-water sampling programs. Aside from a lower Strawberry Creek sample taken May 18, 1988, these results are similar to those obtained in past years and all lie within the normal range of background activity. The May 18, 1988 lower Strawberry Creek sample contained 110 ± 20 pCi/l of ^{32}P, about 6% of the drinking-water standard for ^{32}P (see Ref. 3).

Table 6. Summary of radioiodine in perimeter air samples, 1988.

Perimeter Station	No. of[a] samples	Concentration (10^{-15} µCi/ml) ^{125}I Avg.	^{125}I Min.	^{125}I Max.	^{131}I Avg.	^{131}I Min.	^{131}I Max.	Average as % of standard ^{125}I	Average as % of standard ^{131}I
Bldg. 88	50	1.1 ± 0.3	< 5	7 ± 4	≤3	< 26	50	0.0002	< 0.0008
Bldg. 90	50	2.6 ± 0.4	< 5	80 ± 20	≤3	< 26	50	0.0005	< 0.0008
Panoramic Way	50	≤ 1	< 5	≤ 6	≤3	< 26	≤ 50	≤ 0.0002	< 0.0008
Olympus Gate	50	≤ 1	< 5	25 ± 10	≤3	< 26	≤ 50	≤ 0.0002	< 0.0008
Standard[b] for comparison		5×10^5			4×10^5				

[a]28 valid for ^{131}I
[b]Reference 3.

Table 7. Summary of airborne environmental HTO and $^{14}CO_2$ sampling, 1988.

	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	48	3.0 ± 0.6	< 0.7	19 ± 4	3
Bldg. 3 roof	51	0.17 ± 0.04	< 0.7	6 ± 2	0.2
Perimeter					
MRI	43	≤ 0.05	< 0.7	1.2 ± 0.5	≤ 0.05
LHS	51	0.35 ± 0.07	< 0.7	2.8 ± 0.9	0.4
B-13D (Olympus)	50	0.13 ± 0.04	< 0.7	1.3 ± 0.5	0.1
Standard for Comparison[a]		100			
Samples for Carbon-14 (as $^{14}CO_2$)					
On-Site					
Bldg. 3 roof	51	≤ 0.03	< 0.2	0.2 ± 0.1	≤ 0.006
Standard for Comparison[a]		500			

[a]Reference 3.

Table 8. Summary of perimeter airborne environmental HTO and $^{14}CO_2$ sampling, 1979–1988.

Year	HTO			$^{14}CO_2$		
	No. of Samples	Concentration (10^{-9} μCi/ml) Avg.	Max.	No. of Samples	Concentration (10^{-9} μCi/ml) Avg.	Max.
1979	101	1	3.4	49	0.026	0.37
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
Standard for comparison[a]		100			500	

[a]Reference 3.

Table 9. Summary of atmospheric deposition, 1988.

	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,d]
On-Site (11 locations)	157	0.039	0.19	0.51	0.11	2.3	87	13 ± 5	96 ± 15
Perimeter (4 locations)	48	0.029	0.056	0.59	0.2	1.4	35	0.55 ± 0.18	0.9 ± 0.4
Perimeter Averages as a % of Standards		0.1		0.012				0.07	
Drinking-water standard × 455[c]		23		455				844	

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

[b]Highest total for any one site (The bldg. 4 rain sample immediately downwind from the Bldg. 6 demolition project).

[c]The standards used for comparison are derived from Reference 3 for ^{232}Th (alpha values) and ^{90}Sr (beta values). The deposition represents that quantity of activity found in 455 liters of water (the average quantity of rainfall/m^2 during 1988). Thus, the values used are 455 times the Reference 3 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. The average HTO concentration in samples taken from the 75 collector was 7.2×10^{-4} µCi/ml or about 11% of the HTO drinking water standard.

Table 10. LBL perimeter station deposition trends, 1979–1988.

Year	No. of Samples	Rainfall (cm)	Concentration (10^{-3} μCi/m^2) Alpha Avg.	Alpha Max.	Beta Avg.	Beta Max.	(μCi/m^2) No. of Samples	HTO Avg.	HTO Max.
1979	47	79.9	0.04	0.1	2.6	5 ± 2	38	0.2	0.4
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

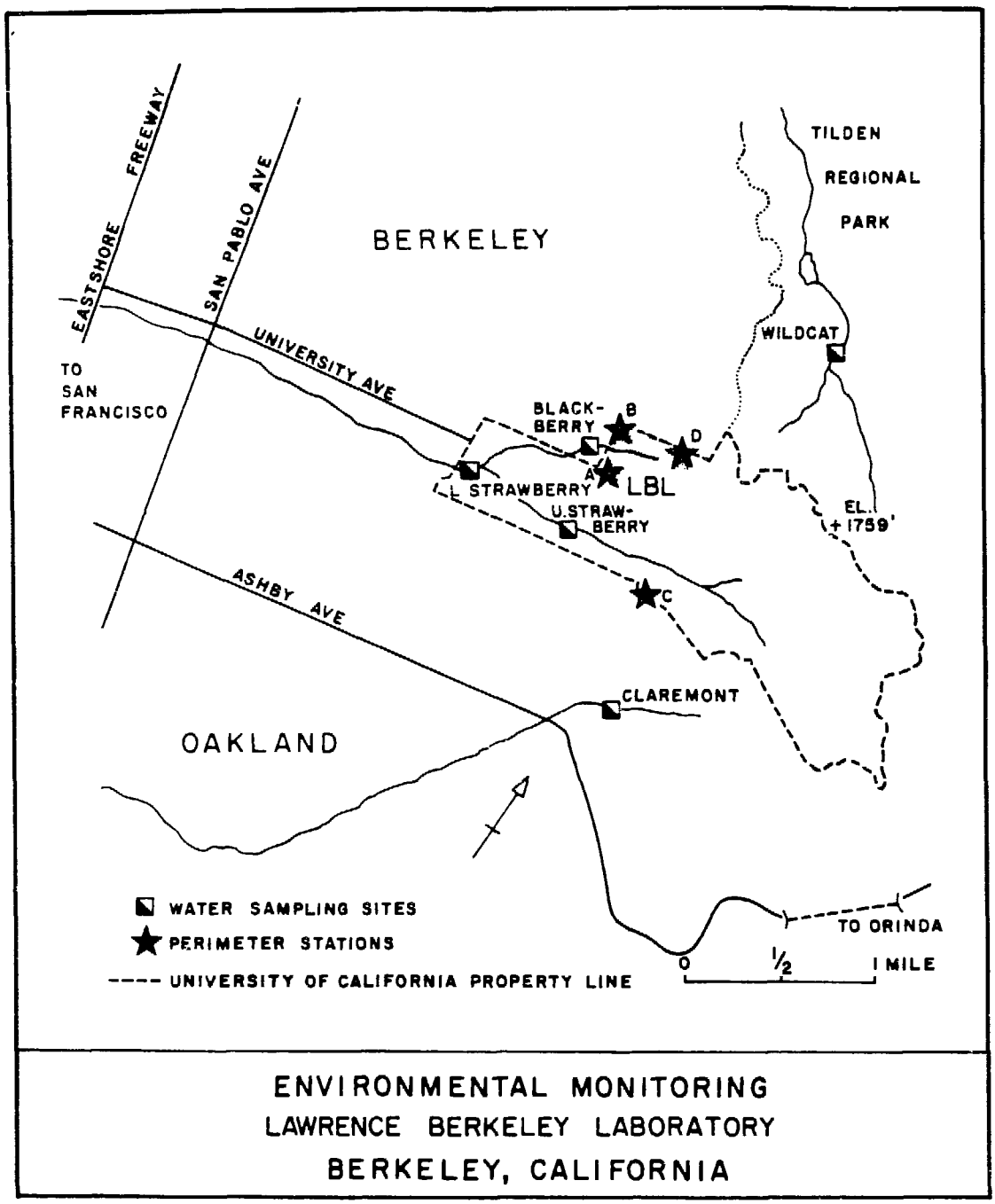

Figure 2. Environmental Monitoring, Lawrence Berkeley Laboratory.

Table 11. Summary of surface- and drinking-water samples, 1988.

	No. of samples	Concentration (10^{-9} µCi/ml)						Average as % of standard	
		Alpha			Beta				
		Avg.	Min.	Max.	Avg.	Min.	Max.	Alpha	Beta
On-site streams									
Blackberry	51	≤ 0.23	≤ 0.5	3.1 ± 2.8	1.6 ± 0.1	≤ 0.7	6 ± 1	≤ 0.5	0.2
Lower Strawberry	51	≤ 0.11	≤ 0.3	< 0.2	5.6 ± 0.2	≤ 0.7	110 ± 20[a]	≤ 0.3	0.6
Upper Strawberry	51	≤ 0.3	≤ 1. 2	5.7 ± 3.9	1.5 ± 0.1	≤ 0.7	4 ± 1	≤ 0.6	0.2
Average		≤ 0.2			2.9 ± 0.2			≤ 0.4	0.2
Off-site streams									
Claremont	51	≤ 0.23	≤ 0.5	2.9 ± 2	1.3 ± 0.13	≤ 0.9	9 ± 2	≤ 0.5	0.13
Wildcat	51	≤ 0.24	≤ 0.9	≤ 3.7	0.7 ± 0.12	≤ 0.7	3 ± 1	≤ 0.5	0.07
Tap Water	51	≤ 0.04	≤ 0.22	≤ 0.5	0.7 ± 0.1	≤ 0.6	1.7 ± 0.8	≤ 0.08	0.05
Standard of Comparison[b]		50			1000				

[a]See text.

[b]Reference 3: alpha assumed to be ^{232}Th; beta assumed to be ^{90}Sr.

Subsequent samples were normal. The Environmental Safety and Health Group on the UCB campus was contacted and advised of our findings. (The lower Strawberry Creek samples are taken at the western end of UCB, see Fig. 3). The origin of the ^{32}P remains unexplained. There is no reason to suspect that any of the observed radioactivity originated from LBL as no ^{32}P was found in either Blackberry or Upper Strawberry Creeks. Table 12 summarizes the surface- and drinking-water samples for 1979–1988.

Table 13 summarizes the sewage sampling data for 1988. 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 1979–1988.

Ground Water

During 1988 three of LBL's many hydraugers were sampled monthly. Samples taken were counted for gross alpha and beta activity and tritium. One hydrauger, designated 75-77 hydr, describes 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 hydraugers' bores). The second hydrauger, which was designated CC hydr, is an ~750 m long horizontal bore from the Chicken Creek access road into Little Grizzly Peak (see Fig. 1). The third hydrauger designated CC-B Hydr is a 150m bore. All three hydraugers continued to flow throughout 1988. 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.

Measurable tritium was found in samples taken from 75–77 hydr. Table 15 summarizes the hydrauger (ground-water) sampling data for 1988.

Nonradioactive Pollutants

Waterborne Pollutants

Plating Shop Wastewater Discharges. There are two plating shops at LBL: Building 25 and Building 77. Both shops are subject to the EPA Metal Finishing Pretreatment Standard (40 CFR 433). In general, this standard establishes wastewater discharge limits for cyanide and certain toxic metals. The Categorical Pretreatment Standards have been adopted by EBMUD in Ordinance No. 296.

Wastewater samples are taken from both plating shops to verify compliance with the discharge limits. The samples represent a 24-hour average discharge and are taken before the wastewater combines with wastewater from nonelectroplating operations.

Periodically, EBMUD also obtains samples and reports their results to LBL.

Building 25 Plating Shop

As required by the EBMUD wastewater discharge permit, wastewater samples were taken quarterly from the discharge of the Building 25 treatment unit. The parameters to be monitored were chromium, copper, and lead. In addition, EBMUD collected three samples throughout the year and reported their results to LBL.

There were no other discharge violations detected.

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

Building 77 Plating Shop

As required by EBMUD, wastewater samples were taken bimonthly from the discharge of the Building 77 treatment unit. Samples were analyzed for cadmium, chromium, copper, lead, nickel, zinc, and cyanide. In addition, EBMUD collected three samples throughout the year and reported their results to LBL. There were no discharge violations detected by LBL or EBMUD.

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

Table 12. Summary of surface- and drinking-water samples, 1979–1988.

	Concentration (10^{-9} µCi/ml)											
	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.
1979	< 0.2	14	3 ± 0.1	27	< 0.08	5	1.4 ± 0.1	3	< 0.1	---	0.8 ± 0.1	---
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

Table 13a. Summary of sewage sampling data, 1988.

Total quantities discharged	Total volume (10^6 liters)	Alpha (μCi)	Beta (mCi)	Tritium (Ci)
Hearst Sewer	160	≤ 20	1.4 ± 0.4	< 0.14
Strawberry Sewer	120	≤ 15	11 ± 3	2.0 ± 0.5

Table 13b. Summary of sewage sampling data, 1988 (continued).

		Concentration (10^{-9} μCi/ml)						Concentration (10^{-6} μCi/ml)				Average as % of drinking-water standard		
		Alpha[a,b]			Beta[c]			Tritium				Alpha[b]	Beta[c]	Tritium
Net concentrations	No. of samples	Avg.	Min.	Max.	Avg.	Min.	Max.	No. of samples	Avg.	Min.	Max.	%	%	%
Hearst	83	≤ 0.12	≤ 0.7	≤ 1.1	9.1 ± 3	≤ 2.7	25 ± 5	43	0.8 ± 0.3	≤ 0.5	31 ± 5	≤ 0.24	0.9	0.04
Strawberry	92	≤ 0.12	≤ 0.7	≤ 3.7	89 ± 20	≤3	1100 ± 300	46	16 ± 4	≤ 0.5	150 ± 20	≤ 0.24	9	0.8
Overall	176	≤ 0.09			43 ± 20			89	7 ± 4			≤ 0.18		
Standard for comparison[d]		50			1000				2000					

[a]The alpha values are based on 41 Hearst and 46 Strawberry samples, respectively.

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

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

[d]Source: Reference 3.

Note: The standards cited here are for specific radionuclides in *drinking water*, not sewage, and are provided for comparison purposes only.

Table 14. Sanitary-sewer discharge trends, 1979–1988.

	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.
1979	43	247	0.2	5	15	25	45	302	0.5	5	2600	14000
1980	48	288	0.4	3	22	220	46	135	0.3	6	180	1000
1981	49	28	<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

Table 15. Summary of ground-water samples, 1988.

Hydrauger Designation	No. of Samples	Concentration (10^{-9} µCi/ml)						Concentration (10^{-6} µCi/ml)			Average as % of drinking-water standard		
		Alpha			Beta			Tritium as HTO			Alpha	Beta	Tritium
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	%	%	%
75–77 Hydr.	12	≤ 0.9	≤ 0.9	≤ 5	0.9 ± 0.3	≤ 0.9	4 ± 1	3 ± 1	0.7 ± 0.5	9 ± 1	≤ 2	0.09	0.2
CC Hydr.	12	≤ 0.8	≤ 2	≤ 5	≤ 0.3	≤ 0.8	≤ 5	≤ 0.2	≤ 0.5	2.2 ± 1	≤ 2	≤ 0.03	≤ 0.01
CC-B Hydr.	10	≤ 1	≤ 2	≤ 5	≤ 0.4	≤ 0.9	2 ± 1	0.6 ± 0.2	≤ 0.5	3.4 ± 1	≤ 2	≤ 0.04	0.03
Drinking water standard[a]		50			1000			2000					

[a]Reference 3 alpha assumed to be ^{232}Th, beta assumed to be ^{90}Sr.

Table 16. Building 25 Treatment Effluent—1988 Sampling Data.

	Cadmium (ppm)	Chromium (ppm)	Copper (ppm)	Iron (ppm)	Lead (ppm)	Nickel (ppm)	Silver (ppm)	Zinc (ppm)
No. of Samples	4	7	7	0	7	4	0	4
Minimum Level:	0.00	0.01	0.06		0.01	0.01		0.01
Maximum Level:	0.01	0.15	3.00		0.15	0.03		0.04
Average Level:	0.01	0.04	1.42		0.08	0.02		0.03
Avg % of Limit:	1.16	1.50	42.14		11.39	0.57		0.86
2 × STD DEV:	0.01	0.09	1.65		0.10	0.02		0.02
No. > Limit:	0	0	0		0	0		0
Limit:	0.69	2.77	3.38	100.00	0.69	3.98	0.43	2.61

Table 17. Building 77 Treatment Effluent—1988 Sampling Data.

	Cadmium (ppm)	Chromium (ppm)	Copper (ppm)	Iron (ppm)	Lead (ppm)	Nickel (ppm)	Silver (ppm)	Zinc (ppm)	Cyanide Total (ppm)
No. of Samples:	8	8	8	0	8	8	0	8	7
Minimum Level:	0.00	0.01	0.19	–	0.01	0.06	–	0.02	0.01
Maximum Level:	0.03	0.31	2.60	–	0.10	0.40	–	0.10	0.20
Average Level:	0.01	0.11	1.26	–	0.05	0.19	–	0.05	0.09
Avg % of Limit:	2.14	3.90	37.16	–	6.96	4.72	–	2.01	7.67
2 × STD DEV:	0.02	0.22	1.72	–	0.09	0.24	–	0.06	0.18
No. > Limit:	0	0	0	–	0	0	–	0	
Limit:	0.69	2.77	3.38	100.00	0.69	3.98	0.43	2.61	1.20

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. Sampling is performed to ensure compliance with the site discharge limits mandated by the EBMUD Ordinance No. 270. In this case the EBMUD does not require a compliance report from the Laboratory.

At both sites, a series of flow proportioned grab samples were collected and analyzed for a set of regulated heavy metals chlorinated hydrocarbons, phenols, cyanide, and oil and grease.

Excessive discharge levels of copper and zinc are believed to be due to the on-site regeneration of building deionized water systems. These are in the process of being replaced by removable cartridges that are regenerated off site by the supplier. At the Strawberry Monitoring Station, discharges of chlorinated hydrocarbons exceeded EBMUD limits. The source of this contaminant has not been determined.

Tables 18a and 18b summarize the analytical results from the Strawberry and Hearst Sanitary Sewer samples, respectively.

Airborne Pollutants

The California Air Toxics "Hot Spots" Information and Assessment Act of 1987 requires the Air Resources Board to prepare emission inventories for substances referenced in this law. Within the Bay Area Air Quality Management District, toxic inventories were estimated based on usage data submitted by each facility. Accordingly, the toxic inventory of LBL is as follows.

Toxic Pollutant	Emissions (lb/yr)
Trichlorethane	8327.9
Methylene Chloride	613.3
Dioxane	257.6
Formaldehyde	8.4
Benzene	0.6
Chromium (hexavalent)	0.1

POPULATION DOSE RESULTING FROM LBL OPERATIONS

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

While 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 people, 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.

Accelerator-Produced Radiation

The LBL model developed by Thomas[5] for determining population dose equivalent from the maximum measured value of perimeter (fence-post) neutron dose assumes that the fence-post DOE-rate changes are uncorrelated with fluctuations in population. During 1988 the maximum fence-post dose was measured at the Olympus Gate Monitoring Station and was 1.9 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 well with the fluence peaks from the neutron detector located in the Bevatron less than 20% of the time and with the peaks from the SuperHILAC detector more than 80% of the time. The Bevatron and the SuperHILAC operated continuously seven days a week during 1988 except for maintenance, a "summer" shutdown from September 1 through October 17, and a year-end shutdown December 24, 1988 to January 6, 1989.

Table 18a. Summary of Strawberry Monitoring Station—1988 Sampling Data

	Arsenic (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Iron (mg/l)	Lead (mg/l)	Mercury (mg/l)	Nickel (mg/l)	Silver (mg/l)	Zinc (mg/l)	Chlor. HCS (mg/l)	Oil & Grease (mg/l)	Phenols (mg/l)	Cyanide (mg/l)
No. of Samples:	*8*	*25*	*25*	*40*	*25*	*25*	*8*	*25*	*25*	*40*	*5*	*21*	*4*	*4*
Minimum Level:	0.00	0.00	0.01	0.09	0.45	0.01	0.00	0.02	0.01	0.11	0.04	1.00	0.01	0.00
Maximum Level:	*0.01*	*0.04*	*0.22*	*9.60*	*7.00*	*0.17*	*0.00*	*0.36*	*0.41*	*2.60*	*1.70*	*22.00*	*0.03*	*0.00*
Average Level:	0.00	0.01	0.05	1.26	2.81	0.04	0.00	0.08	0.03	0.96	0.60	5.10	0.02	0.00
Avg. % of Limit	0.18	1.00	2.28	25.15	2.81	2.10	2.73	1.66	2.69	19.18	119.96	2.04	0.02	0.08
2 × STD DEV:	0.00	0.02	0.11	3.65	2.94	0.08	0.00	0.13	0.16	1.20	1.21	11.58	0.01	0.00
No. > Limit:	0	0	0	2	0	0	0	0	0	0	0	0	2	0
Limit:	2	1	2	5	100	2	0.05	5	1	5	0.5	250	100	5

Table 18b. Hearst Monitoring Station—1988 Sampling Data.

	Arsenic (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Iron (mg/l)	Lead (mg/l)	Mercury (mg/l)	Nickel (mg/l)	Silver (mg/l)	Zinc (mg/l)	Chlor. HCS (mg/l)	Oil & Grease (mg/l)	Phenols (mg/l)	Cyanide (mg/l)
No. of Samples:	7	24	24	34	24	24	7	24	24	34	5	21	4	4
Minimum Level:	0.00	0.00	0.01	0.02	0.79	0.01	0.00	0.01	0.01	0.17	0.01	1.00	0.03	0.00
Maximum Level:	0.01	0.03	0.35	24.00	12.00	0.24	0.02	0.12	0.69	13.00	0.05	27.00	0.12	0.00
Average Level:	0.01	0.00	0.14	2.35	4.79	0.10	0.01	0.03	0.06	3.07	0.03	8.90	0.07	0.00
Avg. % of Limit	0.34	0.49	6.79	46.94	4.79	4.75	13.29	0.63	5.66	61.45	6.04	3.56	0.07	0.08
2 × STD DEV:	0.01	0.01	0.20	8.59	6.60	0.13	0.01	0.06	0.27	5.58	0.03	14.71	0.06	0.00
No. > Limit:	0	0	0	5	0	0	0	0	0	4	0	0	0	0
Limit:	2	1	2	5	100	2	0.05	5	1	5	0.5	250	100	5

Aside from shutdown periods the modest fence-post dose equivalent was produced with reasonable uniformity throughout the year and does not seriously compromise the Thomas model's assumptions (student populations were low during the summer shutdown). The model's expression relating population dose equivalent M (in man-rem) to maximum measured fence-post dose H_o (in rem) is

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

where f = the fraction of the fence-post dose contributed by the 88-Inch Cyclotron and/or the SuperHILAC. Since only 20% of the fence-post dose has been assigned to the Bevatron, f = 0.8 [in Eq. (1)].

Thus the expression becomes

$$M < 10^3 (1 - 0.45) H_o . \quad (2)$$

Since H_o was 1.9 mrem (or 0.0019 Rem), the population dose equivalent attributable to LBL accelerator operation during 1988 was

$$< 1 \text{ man-rem.}$$

Airborne Radionuclides

The CEDE resulting from airborne releases of radionuclides is listed in Table 19. The US Environmental Protection Agency (EPA) regulations in 40 CFR 61 subpart H require that facilities releasing airborne radionuclides compute the impact of such releases using AIRDOSE-EPA or an approved code. In this report, MICROAIRDOSE, a microcomputer version of the AIRDOSE-EPA radionuclide dispersion and dose assessment code, was used (see Ref. 10). This code was used to compute both collective-effective-dose equivalent and the effective dose equivalent to a maximally exposed individual (from radionuclides only).

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

a) radionuclide release data;
b) committed dose-equivalent factors for released radionuclides;
c) site-specific meteorological data;

Table 19. Collective effective dose equivalent resulting from LBL airborne nuclide releases, 1988.

Nuclide	(man-rem)
H-3	< 14
C-14	< 0.002
I-125	< 0.05
I-131	< 0.001
Unidentified alpha emitters	< 0.01
Unidentified beta emitters	< 0.001
Total	< 14.0

d) agricultural parameters;

e) site-specific food and water source parameters;

f) radionuclide-independent parameters; and

g) distribution of the population within 80 km (50 mi) of LBL.

The data were obtained from the following sources:

a) Table 3 of this report is used.

b) values are from Ref. 11.

c) 1960–1964 Oakland Airport five-year average data were used. While it is most desirable to use on-site meteorology data for the "release year" (1987), the US EPA Region IX regional meteorologist (Ref. 12) indicated that the use of the Oakland Airport five-year average data is, for this application, an acceptable second choice.

d) Default parameters provided with the MICROAIRDOSE code were used from Ref. 13.

e) Food and water source parameters were compiled by Victor J. Montoya of LBL EH&S Department's Environmental Surveillance Group 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.)

f) Values are from Ref. 14.

g) The population distribution about LBL was compiled into 16 compass directions of 10 radial sectors each by Winifred B. Corniea of LBL EH&S Environmental Surveillance Group using data in Ref. 9.

The same values for a–d and f and g were used by MICROAIRDOSE to compute the maximally exposed individual, but it was assumed that 100% of all produce and leafy vegetables were grown locally. (More than 90% of the exposure from tritium is assigned to intakes of tritium in food and water.) However, since there are no known drinking water wells in the communities immediately adjacent to LBL, it was assumed that all water consumed by the maximally exposed individual was imported. In last year's report the opposite assumption was made inappropriately doubling the estimated doses. Table 20 summarizes the total CEDE due to LBL operations.

Table 20. Population effective dose equivalent resulting from LBL operations, 1988.[a]

Contributing factor	Population effective dose equivalent (man-rem)
Penetrating radiation from accelerator operations	< 1
Radionuclide release (from Table 19)	< 14
LBL-produced effective population dose equivalent	< 15

[a]For 1988, 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.

TRENDS—LBL ENVIRONMENTAL IMPACT

Accelerator-Produced Penetrating Radiation

Figures 3–6 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 maximum perimeter dose equivalent (Fig. 3) remains a diminishing fraction of the radiation protection guidelines[3] reflecting improvements in accelerator beam optics, local shielding, and cave selection.

Airborne and Waterborne Radionuclides

Figure 7 shows the annual releases of tritium (as HTO) from the Building 75 Tritium Facility from 1974 through 1988.

The 570 curies released during routine operations in 1988 is approximately 180% of the 1987 releases and is responsible for approximately 93% of the LBL-produced population-dose equivalent from all sources for 1988. The operational personnel of the tritium facility are continuing to investigate all sources of release so that future releases may be minimized. The releases occur during molecular tagging and tritium waste processing. The increased releases during 1988 reflect a very active program.

With the exception of occasional known releases, the atmospheric sampling program has yielded data over the past few years that are within the range of normal background.

Except as noted earlier in this report, surface-water program has always yielded results within the range of 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 UC campus has 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 remain so in the future.

QUALITY ASSURANCE

During 1988 in addition to the quality control procedures described in the body of this report, samples that were blind-spiked with tritium were worked up along with each group of environmental samples assayed for HTO.

The LBL Environmental Surveillance Group analyzed DOE's Environmental Measurements Laboratory (EML) QAPXXVIII and QAPXXIX Water Samples for tritium and air and water samples for several gamma emitting nuclides (as reported in References 15 and 16). The results are tabulated in Table 21.

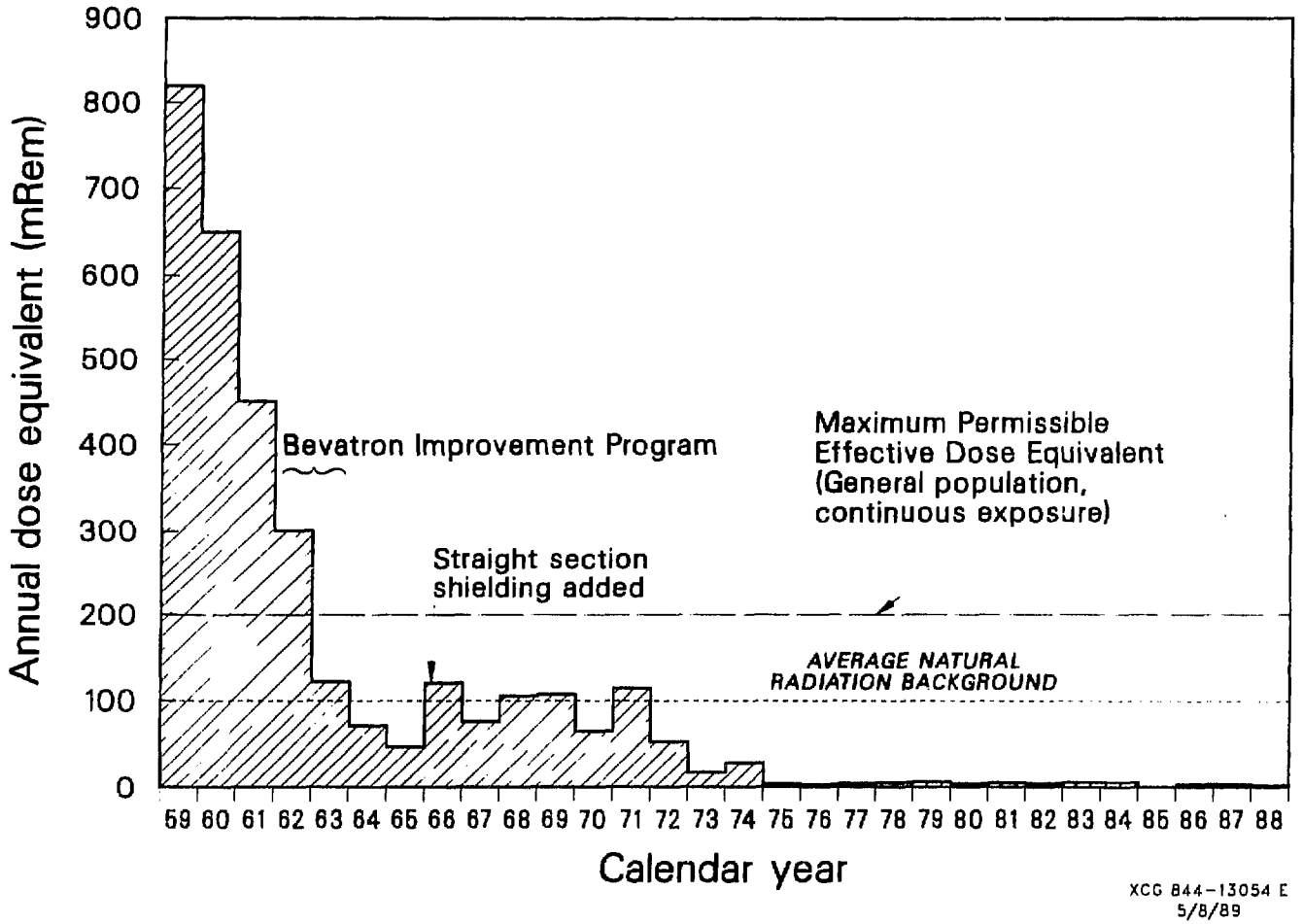

Figure 3. Annual accelerator-produced dose equivalent reported by the Olympus Gate Environmental Monitoring Station, 1959–1988. Maximum Permissible Dose (General Population) is the maximum permissible dose equivalent to any single individual in the general non-Laboratory population. The maximum permissible continuous average effective dose equivalent to the general population is 100 mrem/year (excluding natural radiation background).

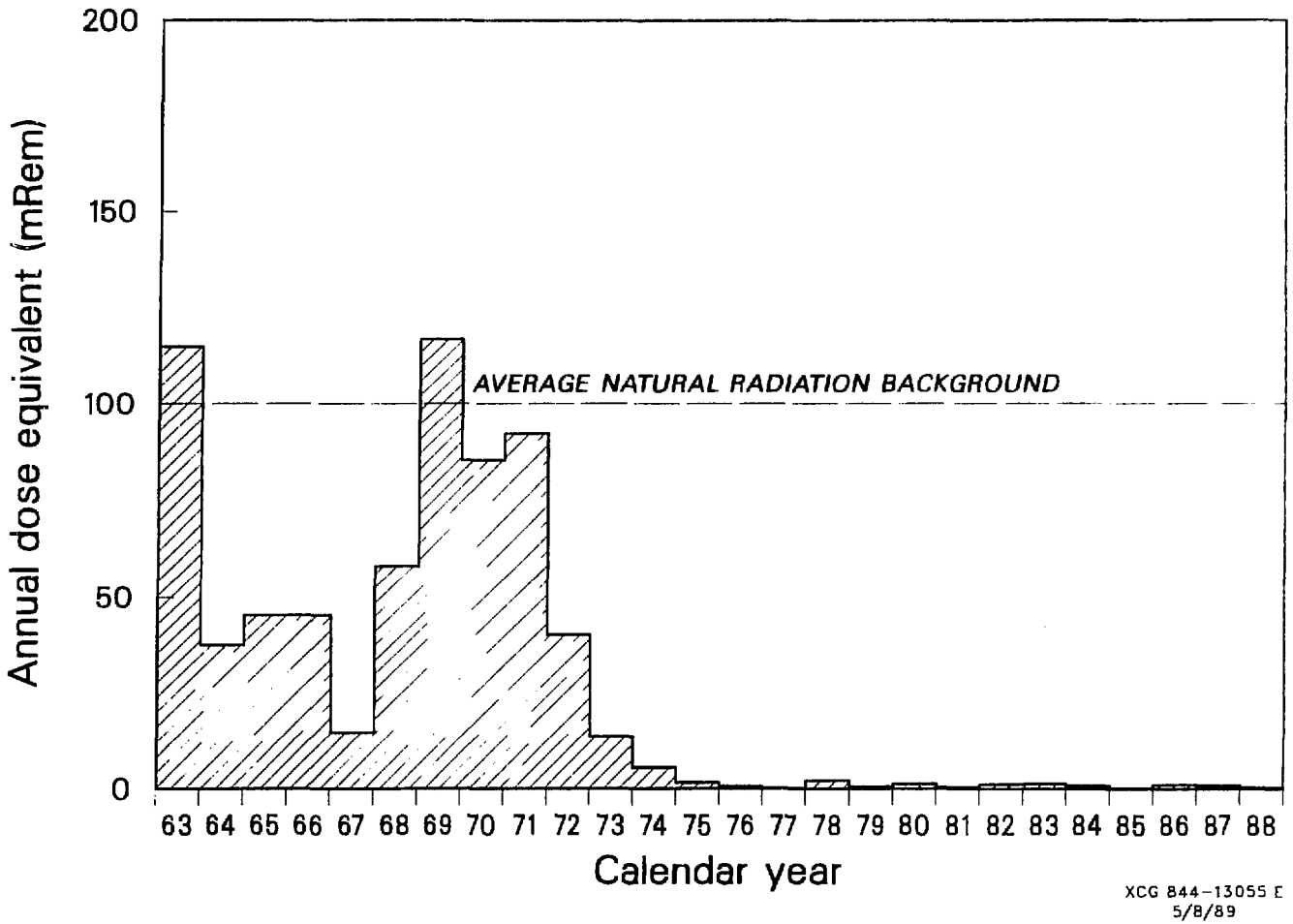

Figure 4. Annual accelerator-produced dose equivalent reported by the Building 90 Environmental Monitoring Station, 1962–1988.

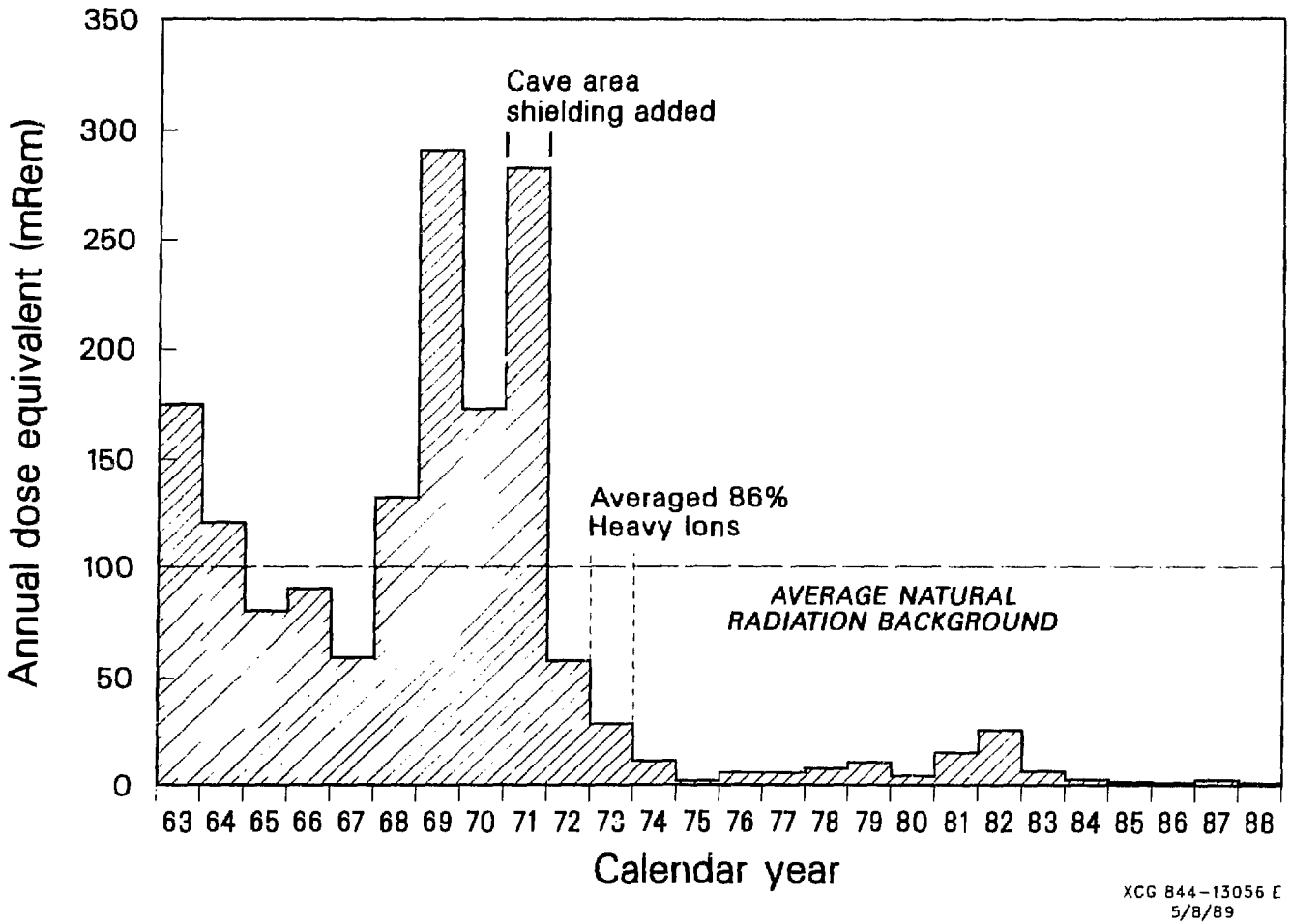

Figure 5. Annual accelerator-produced dose equivalent reported by the 88-Inch Cyclotron Environmental Monitoring Station, 1963–1988.

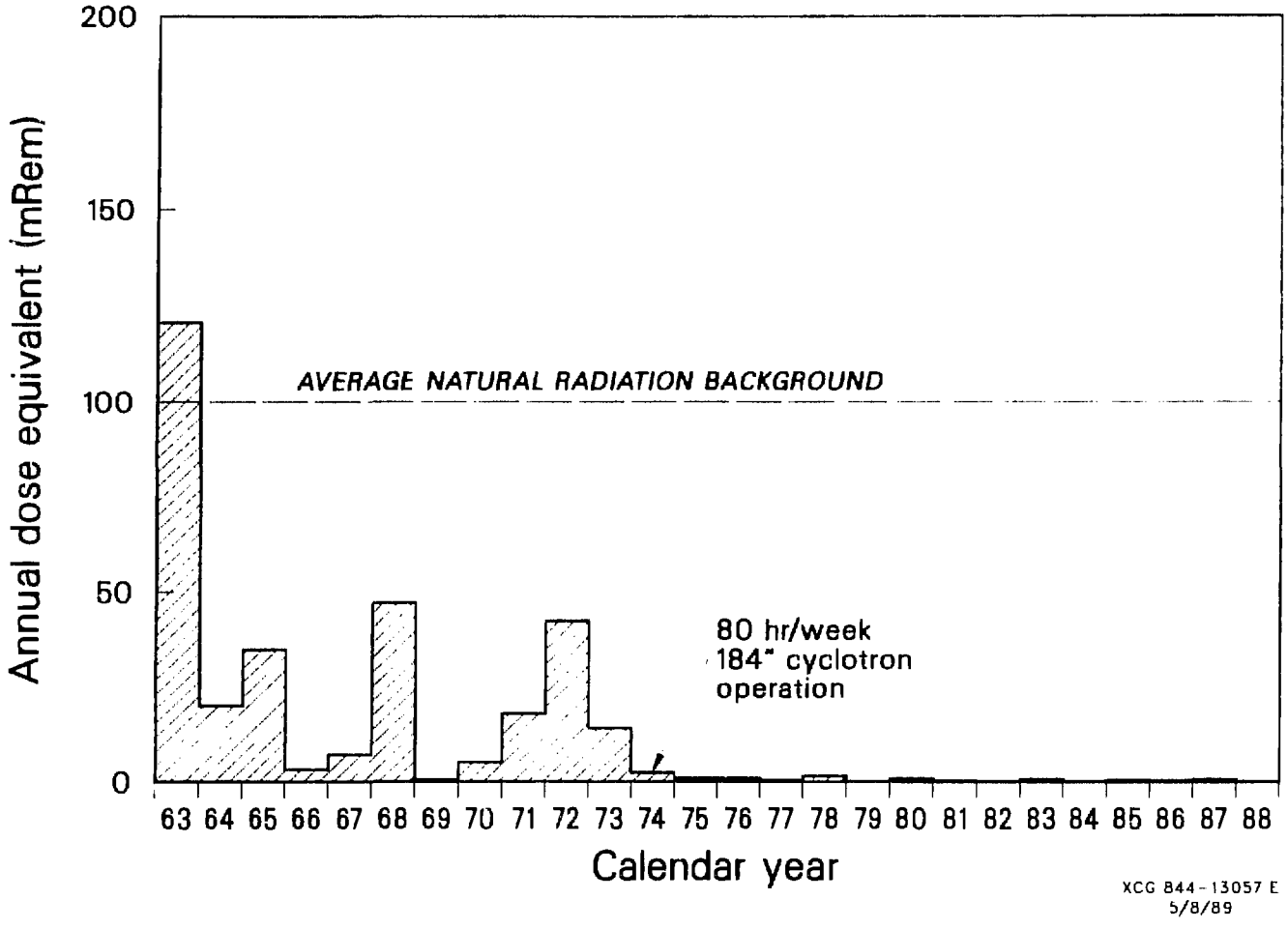

Figure 6. Annual accelerator-produced dose equivalent reported by the Panoramic Way Environmental Monitoring Station, 1963–1988.

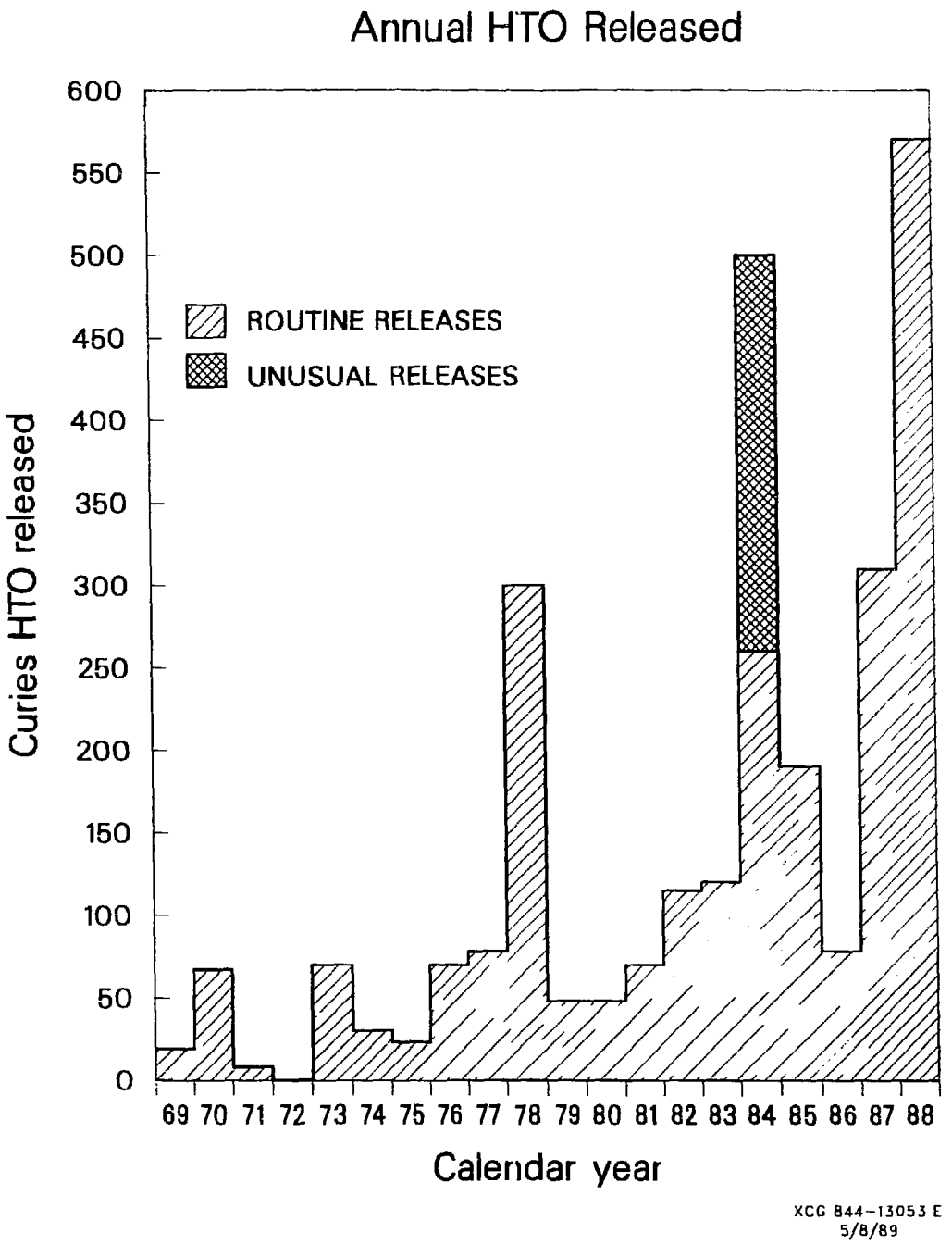

Figure 7. Annual releases of tritium (HTO) from the Building 75 Tritium Facility, 1969–1988.

Table 21. LBL QAP sample results, 1988.

QAP Sample #	Date	Media	Nuclide	Reported LBL Results[a] (± percent)	EML Value	Ratio LBL/EML
XXVIII	3/88	Air	^{7}Be	$4.9 \times 10^{3} \pm 20$	4.73×10^{3}	1.04
		Air	^{54}Mn	$4.0 \times 10^{2} \pm 15$	3.63×10^{2}	1.10
		Air	^{57}Co	$2.0 \times 10^{2} \pm 20$	1.62×10^{2}	1.23
		Air	^{60}Co	$3.1 \times 10^{2} \pm 15$	2.82×10^{2}	1.10
		Air	^{34}Cs	$3.9 \times 10^{2} \pm 15$	3.18×10^{2}	1.02
		Air	^{134}Cs	$2.6 \times 10^{2} \pm 15$	2.11×10^{2}	1.23
		Water	^{3}H	$1.94 \times 10 \pm 9$	2.07×10	0.94
XXIX	9/88	Air	^{7}Be	$2.4 \times 10^{3} \pm 41$	2.16×10^{3}	1.11
		Air	^{54}Mn	$2.3 \times 10^{2} \pm 39$	1.85×10^{2}	1.24
		Air	^{57}Co	$4.6 \times 10^{2} \pm 19$	3.94×10^{2}	1.17
		Air	^{60}Co	$3.3 \times 10^{2} \pm 24$	3.74×10^{2}	0.88
		Air	^{134}Cs	$2.1 \times 10^{2} \pm 28$	1.91×10^{2}	1.10
		Air	^{137}Cs	$3.0 \times 10^{2} \pm 26$	2.45×10^{2}	1.22
		Water	^{3}H	9.5 ± 15	1.06×10^{1}	0.90
		Water	^{57}Co	3.0 ± 23	3.36	0.89
		Water	^{60}Co	3.0 ± 20	3.68	0.82
		Water	^{137}Cs	1.8 ± 38	1.95	0.92

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

REFERENCES

1. U.S. Department of Commerce Bureau of the Census, Characteristics of the Population: Number of Inhabitants--California 1980, PC 80 1 AC (March 1982).
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