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ANNUAL ENVIRONMENTAL MONITORING REPORT
OF THE
LAWRENCE BERKELEY LABORATORY

1986

Prepared by the Staff of the
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Editor

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This work was supported by the Assistant Secretary for Environment
Office of Environmental Compliance and Overview
Environmental Safety and Program Support Division
U.S. Department of Energy under Contract No. DE-AC03-76SF00098

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

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ABSTRACT

The Environmental Monitoring Program of the Lawrence Berkeley Laboratory is described. Data for 1986 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 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 55 years ago.

The Laboratory also supports nationwide university-based research by providing National facilities including the National Center for Electron Microscopy, four 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, when using the SuperHILAC 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. The 184-Inch Synchrocyclotron (Building 6) provides alpha particle beams with energies up to approximately 1 GeV. 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 184-Inch Cyclotron is only run for brief periods each week, mostly for tumor therapy.

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 was expanded during 1983 and is now 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 the University of California, Berkeley. The 130-acre site is located on the west-facing slope of the Berkeley Hills, at elevations ranging from 500 to 1,500 feet 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 ≈ 5.2 million (1980 census).¹

The Laboratory's activities are located both on-site and off-site. There are 67 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 UCB campus and 130,000 gsf in leased facilities in Emeryville and Berkeley.

The Laboratory's population is approximately 3,850 including about 600 visiting scientists and engineers. About 3,100 are located on-site, 700 are located in campus buildings, and about 50 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 percent in the early morning to 65-75 percent in the afternoon. The average annual rainfall is 25 inches. About 95 percent 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. Ground-water wells are not used as a source of Laboratory or local community drinking water. 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 Berkeley 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 insure that its wastewater complies with the EBMUD discharge limits, the Laboratory monitors its wastewater for pH, toxic metals, and radioactivity. 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 1960's, 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.

1986 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 1986, 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.]

We define the maximum effective dose equivalent delivered to a hypothetical member of the community as the maximum perimeter dose equivalent. That value [the 1986 dose equivalent measured at the Olympus Gate Environmental Monitoring Station (MS) B-13D] was ≤ 3.5 mRem, about 4% of the RPG. The hypothetical maximum exposure to an individual from airborne radionuclides would be to a person residing just outside the east-southeast LBL perimeter. The 1986 effective dose equivalent to such a person would have been ≤ 0.2 mRem--less than 0.2% of the RPG. The total population dose equivalent attributable to LBL operations during 1986 was ≤ 5 man-Rem, an average of about 0.001% 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 , ^{125}I , ^{131}I , and unidentified alpha and beta-gamma emitters were released from LBL laboratory stacks. The collective effective population dose equivalent attributable to the foregoing releases is ~ 0.03 man-Rem. The majority of the impact of LBL radionuclide operations is from the airborne release of 80 Ci of tritium (as HTO), which is responsible for a CEDE of approximately ≤ 2.0 man-Rem, and a hypothetical maximum off-site individual exposure (from airborne radionuclides) of ≤ 0.2 mRem.

To put the Laboratory's impact into perspective, an approximate value for absorbed dose from external natural sources (e.g., cosmic rays, radiation from continental rocks) to each person within 80 km (50 mi) of LBL is roughly 0.1 Rem/yr, which produces a natural annual population dose of $\sim 520,000$ man-Rem.

As widely reported in news media around the world, on or about April 26, 1986, a large graphite power reactor located at Chernobyl in the Ukraine S.S.R. suffered an explosion and fire that had serious consequences in the Ukraine and elsewhere. Radioactive fallout from Chernobyl was quickly observed in environmental samples in Europe and also produced a very small, but measurable, increase in airborne radioactivity at LBL. This increase was first detected in samples collected on May 8, 1986.

A number of nuclides normally produced by fission reactors were detected in the LBL samples including: ruthenium-103, tellurium-132, cesium-134 and -137, and iodine-131. The isotope that reached the highest average and highest peak concentrations during the 43-day sampling period was iodine-131, whose peak concentration (25-hour sample) reached 1.4×10^{-12} $\mu\text{Ci/ml}$ (May 11th sample) and whose average concentration during the 43 days it was detected at LBL was 1.2×10^{-13} $\mu\text{Ci/ml}$. An individual exposed to such a concentration of I-131 would have received an Effective Dose Equivalent (EDE) of less than 0.1 mRem. The EDE would have been about 50% as large for Cs-137 and considerably less for the remaining "Chernobyl nuclides."

Gross data for radioactivity in air and water for the period 1977-1985 are presented for comparison with the 1986 data. These gross data show that, except for atmospheric nuclear weapons tests (China, 1980) and the Chernobyl event (1986), gross radioactivity concentrations in air and water in the vicinity of LBL show only small fluctuations about background levels.

1986 ENVIRONMENTAL ACTIVITIES AND PERMITS ISSUED

Pursuant to LBL's long-term development plan, two environmental assessments (EAs) were prepared in 1986 by the Laboratory's Plant Engineering Department in consultation with Ira Fink and Associates of Berkeley, California. These assessments have the following titles:

1. 1-2 GeV Synchrotron Radiation Source Initial Study Draft
2. Lab-Wide Site Development Plan

Copies of these assessments were presented to the San Francisco Operations Office of DOE and to the University of California. The assessments were prepared in compliance with the National Environmental Policy Act (NEPA).

For further information about these assessments contact

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In order to comply with DOE Order 5480.14, Comprehensive Environmental Response Compensation and Liability Act (CERCLA), LBL submitted a Phase I Assessment Report on three of LBL's underground tanks to the DOE San Francisco Operations Office.

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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, 1987.
 - Solvent Spray Hood, Building 25
 - Solvent Hood, Building 50
 - Ultrasonic Degreaser, Building 53
 - Machine Shop Tools, Building 53
 - Machine Shop Tools, Building 58
 - Machine Shop Tools, Building 70A
 - Sawdust Collector, Building 74
 - Machine Shop Tools, Building 76
 - Sawdust Collector, Building 76
 - Paint Spray Booth, Building 76
 - Gasoline Storage Tank, Building 76
 - Solder/Grinding Hood, Building 77
 - Vapor/Spray Degreaser, Building 77
 - Machine Shop Tools, Building 77
 - Paint Spray Booth, Building 77
 - Sandblast Exhaust, Building 77
 - Beryllium Machine Shop Tools, Building 77
 - Ceramic Machine Shop Tools, Building 77
 - Paint Drying Oven, Building 77
 - Machine Shop Tools, Building 88, Room 134
 - Machine Shop Tools, Building 88, Room 147
 - Solder Hood, Building 88
- 2) Wastewater Discharge Permit, East Bay Municipal Utility District, Expires June 10, 1987.
 - Plating Shop, Building 25
 - Plating Shop, Building 77
- 3) Hazardous Waste Facility Part B Permit, California Department of Health Services, Expires November 7, 1988.

- 4) Storage Tank Registration. California Department of Health Services. Eight underground storage tanks, seven for petroleum fuel, one for waste oil.

Environmental Activities

1) A program designed to comply with regulations governing the storage of hazardous materials in underground tanks has been implemented. These regulations are defined in Title 23, Subchapter 16, of the California Administrative Code. The regulations establish construction standards for new underground storage tanks; establish uniform standards for release-reporting, repair, and closure requirements; and establish permit applications procedures. The City of Berkeley's Department of Health and Human Services has been designated the local agency responsible for administering and enforcing these requirements.

At LBL there are currently twelve underground tanks that are used for storing hazardous materials. Four of these are newly installed double-walled tanks containing leak monitors within their annular spaces. In addition, there are plans to replace a fifth underground tank with a double-walled tank. A monitoring program being developed for the remaining seven tanks will use a combination of inventory control and sensitive level tests.

2) A draft Environmental Impact Report has been prepared for the University of California's proposed extension of its contract with the Department of Energy to manage the Lawrence Berkeley Laboratory. The Report assesses the potential impacts on the environment if the elements contained in the Lawrence Berkeley Laboratory Site Development Plan were to be implemented by continuation of the existing UC/DOE management arrangement. The current contract expires on September 30, 1987. The proposed extension would cover the period from October 1, 1987 through September 30, 1992. The Draft Environmental Impact Report was circulated for public review, and a public hearing was held January 21, 1987.

3) Equipment for recycling machine-tool coolants has been installed. Since used coolants contain petroleum oils, either by virtue of their composition or because of contamination, disposal of these materials into the sanitary sewer had the potential for exceeding the discharge limits for oil. Collection and disposal at commercial treatment facilities was considered relatively more difficult and expensive.

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).

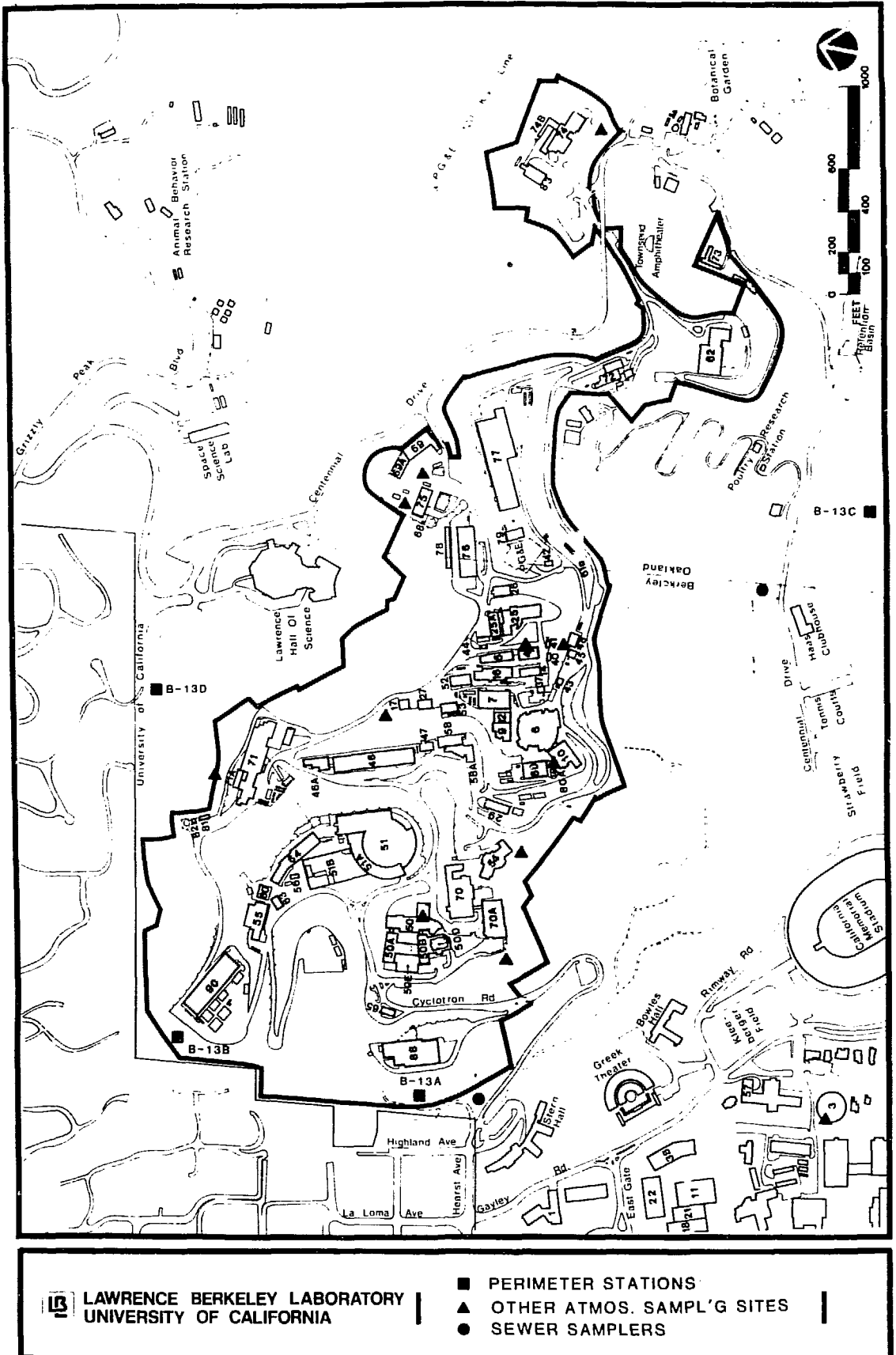


Figure 1. Lawrence Berkeley Laboratory buildings.

XBL 844-1478

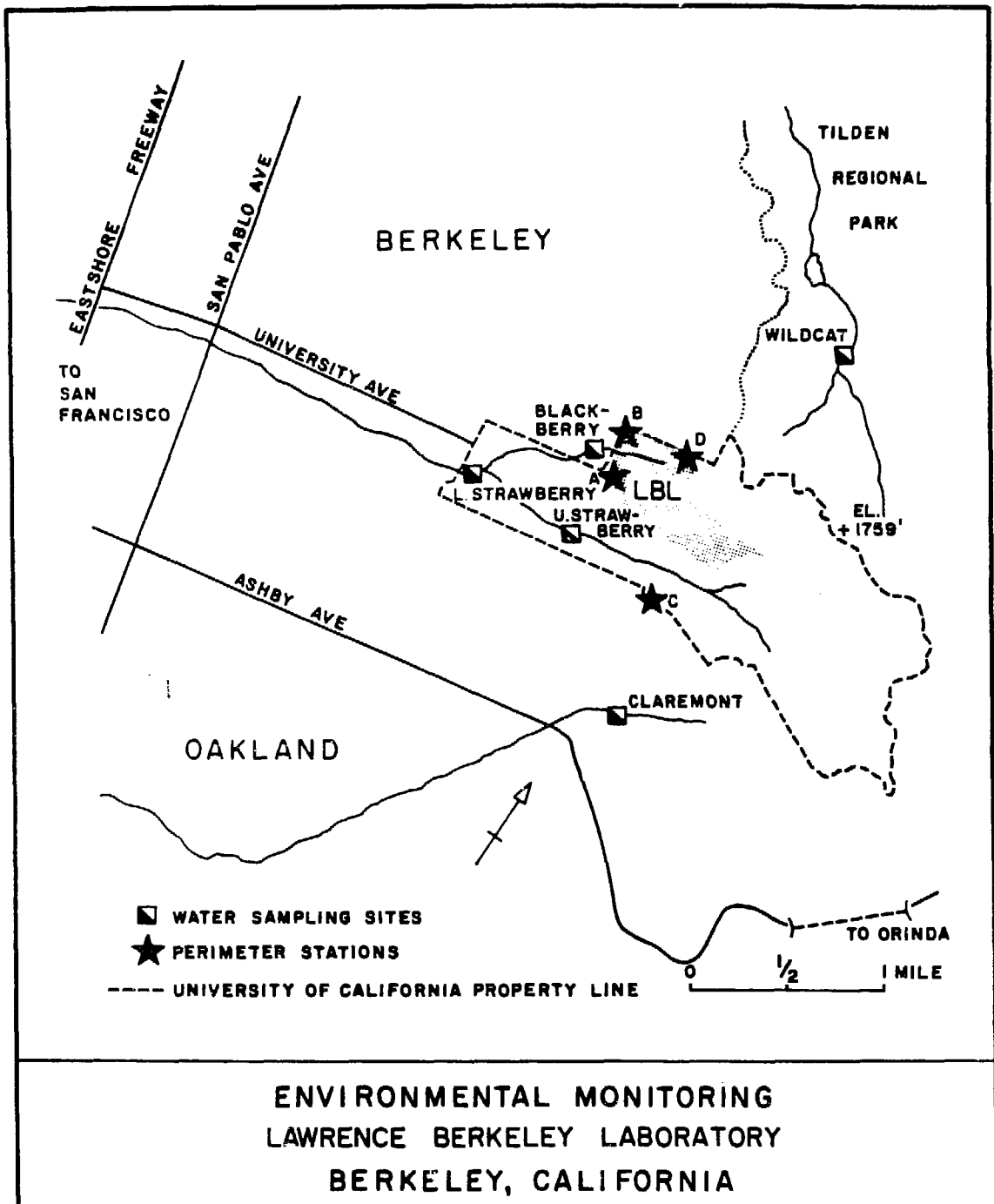


Figure 2. Environmental Monitoring, Lawrence Berkeley Laboratory.

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

Each station contains sensitive neutron and gamma pulse counters. The neutron detectors are $\sim 500\text{-cm}^3$ 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. A typical dose equivalent value for a perimeter-monitoring-station neutron detector corresponds to $0.43 \mu\text{Rem/pulse}$. A gamma register-pulse corresponds to about $1.3 \mu\text{R}$.

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 1986.

Table 2. Fence-post annual effective dose equivalent at the LBL boundary due to accelerator operation, 1986.

Station	1986 total above background		
	gamma (mRem)	n (mRem)	Total ^a (mRem)
Olympus Gate MS	0	3.5 ± 0.6	3.5 ± 0.6
Building 90 MS	0	< 0.9	< 0.9
Building 88 MS	0	0.6 ± 0.1	0.6 ± 0.1
Panoramic MS	0	0	0
Standard for comparison (Dose to individuals at maximum point of exposure)		100 ^b	

^aThe 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.

^bSource: Reference 3.

The fence-post neutron dose equivalent and gamma-ray dose equivalent attributable to LBL accelerator operations in 1986 (see Table 2) are characterized as follows.

1. The 184-Inch Cyclotron produced no dose discernible above background as measured at the Panoramic Environmental Monitoring Station.
2. The SuperHILAC and Bevatron each contributed 50% to the fence-post dose equivalent measured at the Olympus Gate Environmental Monitoring Station. The 3.5 mRem was delivered fairly uniformly during the operating year.
3. The 88-Inch Cyclotron fence-post dose equivalent of 0.6 ± 0.1 mRem is primarily attributable to 16 light-ion (helium-3, p^+ , D^+ , helium-4) runs that occurred at roughly even intervals during 1986.

The U.S. Department of Energy 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 the interest of more accurately reporting the impact of the 88-Inch Cyclotron on LBL's neighbors, measurements of the average energies of the stray neutrons that were produced during the 88-Inch Cyclotron light-ion runs were made at the 88-Inch Environmental Monitoring Station (EMS) in 1985. The measurements⁶ indicated that previously reported values of fence-post dose equivalent were conservatively reported by a factor of more than five. The value of 0.6 ± 0.1 mRem

reported for 1986 reflects less conservative but more realistic neutron energy vs. dose equivalent conversion factors.

4. The continuous gamma measurements telemetered from the four monitoring stations showed no significant correlation with LBL accelerator operation and were thus interpreted as constituting the natural background for 1986. The mean value of gamma background inside the monitoring stations was 83 ± 8 mRem for 1986.

LBL's Environmental Health and Safety Department (EH&S) operates a radiological and chemical waste storage yard 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 in the southeast corner of Building 75B continuously monitors impact from waste handling and calibration activities. The instrument recorded a total exposure of 141 ± 9 mRem during 1986 for a net annual effective dose equivalent of 58 ± 9 mRem.

The instrument is located roughly 10 m from sources of radiation, 70 m from the perimeter fence, 270 m from the nearest commercial (40 hour/wk) occupancy [the Lawrence Hall of Science (LHS)], and 500 m from the nearest home.

The ≈ 60 mRem net exposure at 75B predicts an impact of ~ 1.4 mRem/yr at the perimeter; < 0.02 mRem/yr (40 hours/wk occupancy) at LHS; and < 0.03 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 loaded found no area where the stray radiation field exceeded 1 mRem/hr 1 meter from the outside walls or ceiling. This irradiator is ~ 80 meters from the LBL perimeter fence, 150 meters from the nearest "commercial" occupancy (a UCB Botanical Garden building), and more than 700 meters 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 beta and alpha activities are measured by air sampling at 14 points: Four perimeter environmental monitoring stations and 10 of the 12 "other atmospheric 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 Building 3 site contains samplers for HTO (tritiated water) and $^{14}\text{CO}_2$.

The gross beta and alpha sampling media are 10 cm \times 23 cm (4 \times 9 inch) fiberglass-polyester filters through which air is pumped at 113 l/min (4 ft³/min). 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/cm² windows. The detection limit for alpha emitters is 2×10^{-15} $\mu\text{Ci/ml}$. The detection limit for beta emitters is 80×10^{-15} $\mu\text{Ci/ml}$. 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.

Inasmuch as the DOE orders³ 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 ⁹⁰Sr and ²³²Th 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 ²²⁷Ac, which is 4500 times more restrictive a beta emitter than ⁹⁰Sr, is also found at LBL, its most likely state is in equilibrium with its alpha emitting daughters, 18-day ²²⁷Th and 14-day ²²³Ra, and it would thus be detected as an alpha emitter.

On April 29, 1986 an additional sampler was set up outside Building 48 (LBL Firehouse) at the request of DOE in order to quickly determine the presence of local radioactivity attributable to the Chernobyl event. The samples were initially taken at two-hour intervals and analyzed by gamma spectroscopy the following day. Analyses were performed by Alan R. Smith of the Engineering Division using a hyperpure germanium detector in the LBL Low Background Facility (LBF) in Building 72. The minimum detectable limit was approximately 3×10^{-16} $\mu\text{Ci/ml}$ for both I-131 and Cs-137 for a 24-hour aggregate sample counted for 800 minutes (typical sample grouping and counting times).

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 scintillation counter. The detection limit for HTO in air is 700×10^{-12} $\mu\text{Ci/ml}$.

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, not shown on Fig. 1, is sampled for airborne HTO. The sample is designated ENV 69A and is located at the northeast corner of Building 69A.

The concentration of ¹⁴CO₂ 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 ¹⁴CO₂ is 200×10^{-12} $\mu\text{Ci/ml}$.

Table 3. Total quantities of radionuclides discharged into the atmosphere, 1986.

Nuclide	Quantity discharged (Ci)
Unidentified alpha emitters ^a	$< 1 \times 10^{-7}$
Unidentified beta-gamma emitters ^b	7×10^{-5}
Carbon-14	2×10^{-3}
Tritium	80
Iodine-125	4×10^{-3}
Iodine-131	4×10^{-3}

^aConservatively assumed to be ^{232}Th

^bConservatively assumed to be ^{90}Sr

The total quantities of radionuclides discharged into the atmosphere are summarized in Table 3. 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, 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).

Although small quantities of radionuclides (Table 3) were discharged into the atmosphere during 1986, aside from a short period following the Chernobyl event, the data from the general environmental air sampling were within the range of normal background. The Table 4 data for 1986 may be compared with data from Table 5, which lists LBL perimeter air sample data maxima and averages for the period 1977-1986. The results from the "Special Firehouse" samples taken between April 29, 1986 and July 1, 1986 are tabulated in Table 6 and plotted in Fig. 3.

The environmental air sampling program for ^{14}C and ^3H 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

Table 4. Summary of air samples, 1986.

	No. of samples	Concentration (10^{-9} μ Ci/ml)						Average as % of standard	
		Alpha			Beta				
		Avg.	Min.	Max. ^a	Avg.	Min.	Max. ^a	Alpha	Beta
On-site average of 10 locations	487	0.27 \pm 0.11	\leq 2	6 \pm 2	29 \pm 4	\leq 100	900 \pm 100	4	0.3
<u>Perimeter Stations</u>									
Bldg. 88	43	\leq 0.4	\leq 2	4 \pm 2	50 \pm 10	\leq 100	600 \pm 100	6	0.6
Bldg. 90	51	\leq 0.4	\leq 2	9 \pm 3	40 \pm 10	\leq 100	700 \pm 100	6	0.4
Panoramic Way	52	0.8 \pm 0.3	\leq 2	5 \pm 2	40 \pm 10	\leq 100	600 \pm 100	11	0.4
Olympus Gate	49	\leq 0.3	\leq 2	3 \pm 2	30 \pm 10	\leq 100	600 \pm 100	4	0.3
Standard for Comparison ^b		7			9,000				

^aHighest single weekly sample. The maximum concentrations were found in samples taken on May 14 and May 21, 1986.

^bReference 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, 1977-1986.

Year	No. of Samples	Concentration (10^{-15} $\mu\text{Ci/ml}$)			
		Alpha		Beta	
		Avg.	Max.	Avg.	Max.
1977	201	0.9 ± 0.2	4	90 ± 12	450
1978	198	0.8 ± 0.2	5	60 ± 10	210
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
Standard for comparison ^c		7		9000	

^aThe Peoples 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.

^bChernobyl event, April 26, 1986.

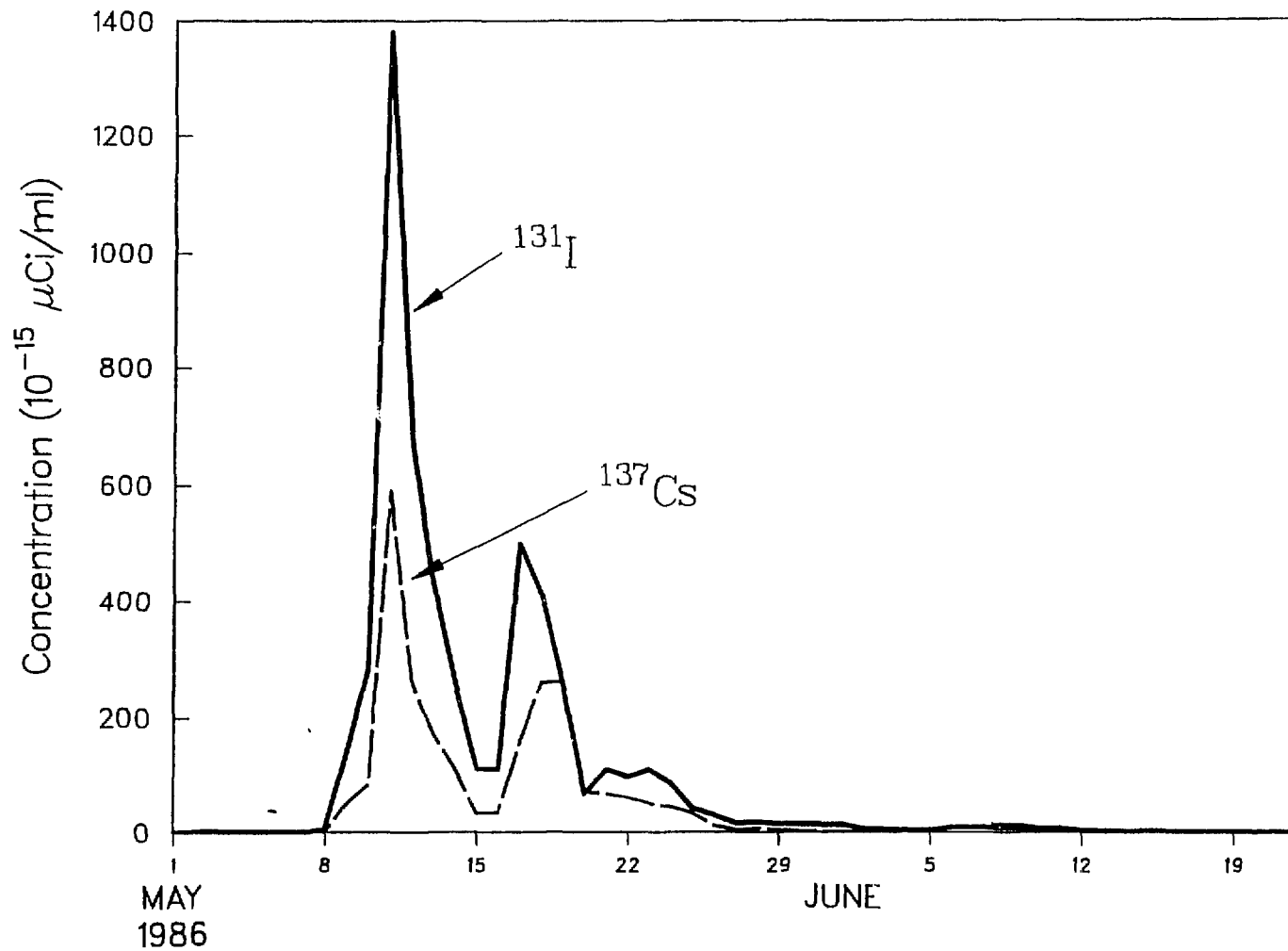
^cReference 3: alpha conservatively assumed to be ^{232}Th ; beta conservatively assumed to be ^{90}Sr .

Table 6. Summary of special Chernobyl samples taken at LBL Firehouse (Bldg. 48) for the period 4/29/86 to 7/1/86.

No. of Samples ^a	Concentration (10^{-15} $\mu\text{Ci/ml}$)					
	I-131			Cs-137		
	Avg.	Min.	Max.	Avg.	Min.	Max.
41	120 \pm 10	\leq 0.3	1300 \pm 100	49 \pm 5	\leq 0.3	590 \pm 10
Standard for comparison ^b	400,000			400,000		
Average as a % of STD	0.03			0.01		

^a Actually the number of groups of samples (1 or 2 days elapsed time per group) with measurable I-131 or Cs-137 above background levels.

^b Reference 3.



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Figure 3. I-131 and Co-137 concentrations in LBL air samples attributable to the Chernobyl "event," May-June 1986.

Table 7. Summary of airborne environmental HTO and $^{14}\text{CO}_2$ sampling, 1986.

	No. of samples	Concentration (10^{-9} $\mu\text{Ci/ml}$)			Average as % of standard ^a
		Avg.	Min.	Max.	
Samples for Tritium as HTO					
<u>On-Site</u>					
ENV 69A	48	0.8 \pm 0.2	\leq 0.7	5 \pm 1	0.4
Bldg. 3 roof	51	0.4 \pm 0.1	\leq 0.7	4 \pm 1	0.2
<u>Perimeter</u>					
LHS	51	0.4 \pm 0.1	\leq 0.7	3 \pm 0.8	0.2
B-13D (Olympus)	49	0.5 \pm 0.1	\leq 0.7	12 \pm 3	0.2
Standard for Comparison ^a		200			
Samples for Carbon-14 (as $^{14}\text{CO}_2$)					
<u>On-Site</u>					
Bldg. 3 roof	51	0.07 \pm 0.02	\leq 0.2	0.4 \pm 0.1	0.01
Standard for Comparison ^a		500			

^aReference 3.

Table 8. Summary of airborne environmental HTO and $^{14}\text{CO}_2$ sampling, 1977-1986.

Year	No. of Samples	Concentration (10^{-9} $\mu\text{Ci/ml}$)				
		HTO		No. of Samples	$^{14}\text{CO}_2$	
		Avg.	Max.		Avg.	Max.
1977	100	1.8 ± 0.2	8	51	0.02	0.9
1978	101	2.2	9	50	0.12	0.45
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
Standard for comparison ^a		200			500	

^aReference 3.

Table 9. Summary of atmospheric deposition, 1986.

	Total deposition (10^{-3} $\mu\text{Ci}/\text{m}^2$)						Tritium in rainfall as HTO ^a ($\mu\text{Ci}/\text{m}^2$)		
	No. of samples	Alpha		Beta			No. of samples	Avg.	Max. ^b
		Avg.	Max. ^b	Avg.	Min.	Max. ^b			
On-Site (9 locations)	108	0.018 \pm 0.004	0.15 \pm 0.03	0.6 \pm 0.2	\leq 1	1.3 \pm 0.3	105	4 \pm 1	35 \pm 7 ^c
Perimeter (4 locations)	48	0.027 \pm 0.005	0.037 \pm 0.007	0.8 \pm 0.2	0.3 \pm 0.1	2.0 \pm 0.6	29	0.1 \pm 0.02	0.3 \pm 0.06
Perimeter Averages as a % of Standard		0.07		0.1				0.004	
Drinking-water standard \times 810 ^c		40		810				2430	

^aThe on-site tritium-in-rainfall data are computed from samples taken at 11 locations.

^bHighest total for any one site.

^cThe standards used for comparison are derived from Reference 3 for ²³²Th (alpha values) and ⁹⁰Sr (beta values). The deposition represents that quantity of activity found in 810 liters of water (the average quantity of rainfall/m² during 1986). Thus, the values used are 810 times the Reference 3 values. [No standards for comparison have been established, so drinking-water standards (radionuclide concentration/l) are used.]

Table 10. LBL perimeter station deposition trends, 1977-1986.

Year	No. of Samples	Rainfall (cm)	Concentration ($10^{-3} \mu\text{Ci}/\text{m}^2$)				$(\mu\text{Ci}/\text{m}^2)$		
			Alpha		Beta		No. of Samples	^3H	
			Avg.	Max.	Avg.	Max.		Avg.	Max.
1977	48	48.2	0.02	0.05	4.5	9 ± 0.2	36	0.4	0.5
1978	46	73.6	0.18	< 0.8	11	16	24	1.4	2
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 ± 1	29	0.1	0.3

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 both). The drinking-water tritium standard is used for tritium in Table 9, of course.

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 (the Building 75 tritium labeling facility does not release liquid effluent into surface streams).

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 only.

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 flaming the filtrate planchette, the filter containing any precipitated radioiodine is placed in the planchette and 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 cm²), assuming an alpha energy of 5.2 MeV and a beta energy of 1 MeV.

Table 11 summarizes the 1986 data from the surface-water and tap-water sampling programs. These results are similar to those obtained in past years and all lie within the normal range of background activity. There is no reason to suspect that any of the observed radioactivity originated from LBL. Table 12 summarizes the surface- and drinking-water samples for 1977-1986.

Table 13 summarizes the sewage sampling data for 1986. 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 1977-1986.

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 the East Bay Municipal Utility District (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

Due to the nature of its operations, wastewater samples taken from this shop are analyzed for chromium, copper, and lead. Table 15 shows these results.

Table 11. Summary of surface-water and drinking-water samples, 1986.

	No. of samples	Concentration (10^{-9} $\mu\text{Ci/ml}$)						Average as % of standard	
		Alpha			Beta			Alpha	Beta
		Avg.	Min.	Max.	Avg.	Min.	Max.		
<u>On-site streams</u>									
Blackberry	51	< 0.2	≤ 0.3	1.4 ± 1.1	2.1 ± 0.1	≤ 0.8	11 ± 2	≤ 0.4	0.2
Lower Strawberry	51	≤ 0.1	≤ 0.3	≤ 1.3	2.8 ± 0.1	≤ 0.6	27 ± 2	≤ 0.2	0.3
Upper Strawberry	50	0.3 ± 0.2	≤ 0.5	8 ± 5	2.1 ± 0.1	≤ 0.7	10 ± 2	0.6	0.2
Average		≤ 0.2			2.3 ± 0.1			≤ 0.2	0.2
<u>Off-site streams</u>									
Claremont	51	0.4 ± 0.3	≤ 0.8	4 ± 3	2.0 ± 0.1	≤ 0.7	10 ± 2	0.8	0.2
Wildcat	51	≤ 0.2	≤ 0.4	≤ 3	1.2 ± 0.1	≤ 0.7	8 ± 2	≤ 0.4	0.1
<u>Tap Water</u>	51	0.06 ± 0.04	≤ 0.2	≤ 0.4	1.1 ± 0.1	≤ 0.6	6 ± 2	0.1	0.1
Standard of Comparison ^a		50			1000				

^aReference 3: alpha assumed to be ^{232}Th ; beta assumed to be ^{90}Sr .

Table 12. Summary of surface- and drinking-water samples, 1977-1986.

Year	Concentration (10^{-9} $\mu\text{Ci/ml}$)											
	Three On-site Streams				Two Off-site Streams				Drinking Water			
	Alpha		Beta		Alpha		Beta		Alpha		Beta	
	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
1977	< 0.3	5	5.5 ± 0.1	208^a	0.3	5	1.5 ± 0.1	6	< 0.1	8	1.1 ± 0.1	2
1978	< 0.1	6	3.5 ± 0.1	17	< 0.3	4	1.8 ± 0.1	9	< 0.1	0.3	1.3 ± 0.1	3
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

^aIdentified as ³²P.

Table 13a. Summary of sewage sampling data, 1986.

Total quantities discharged	Total volume (10 ⁶ liters)	Alpha (μ Ci)	Beta (mCi)	Tritium (Ci)
Hearst Sewer	200	≤ 20	2 ± 0.5	≤ 0.02
Strawberry Sewer	110	≤ 12	40 ± 8	1.4 ± 0.3

Table 13b. Summary of sewage sampling data, 1986 (continued).

Net concentrations	No. of samples	Concentration (10 ⁻⁹ μ Ci/ml)						No. of samples	Concentration (10 ⁻⁶ μ Ci/ml)			Average as % of drinking-water standard		
		Alpha			Beta				Tritium			Alpha	Beta	Tritium
		Avg.	Min.	Max.	Avg.	Min.	Max.		Avg.	Min.	Max.	%	%	%
Hearst	47	≤ 0.1	≤ 0.5	1 \pm 0.3	10 \pm 1	≤ 2	50 \pm 10	49	≤ 0.07	0.8 \pm 0.5	9 \pm 1	< 0.2	1	≤ 0.1
Strawberry	47	≤ 0.1	≤ 0.6	1.1 \pm 0.3	400 \pm 10	≤ 3	4200 \pm 700	49	13 \pm 2	3.3 \pm 3	150 \pm 20	< 0.2	40	0.4
Overall	94	≤ 0.08			150 \pm 10			98	5 \pm 1			< 0.2	15	0.2
Standard for comparison ^a	50 ^b				1000 ^c				3000					

^aSource: Reference 3.^bConservatively assumed to be ²³²Th.^cConservatively assumed to be ⁹⁰Sr.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, 1977-1986

Concentration (10^{-9} μ Cl/ml)												
Year	No. of Samples	Hearst						No. of Samples	Strawberry			
		Total Flow (10^6 l)	Gross alpha		Gross beta		Total Flow (10^6 l)		Gross alpha		Gross beta	
			Avg.	Max.	Avg.	Max.			Avg.	Max.	Avg.	Max.
1977	38	244	0.2	2.4	14	40	42	228	0.2	6	420	5300
1978	50	229	0.9	34	33	824	48	233	0.6	9	14000	92000
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	281	< 0.2	1	21	150	43	89	0.5	14	240	2500
1982	42	300	0.05	1.1	20	460 \pm 20	29	180	0.5	17 \pm 12	60	640 \pm 40
1983	49	190	0.06	< 5	9	80 \pm 7	38	140	< 0.4	< 20	60	800 \pm 40
1984	51	170	0.02	< 5	80	1100 \pm 50	39	74	0.02	< 2	70	250 \pm 10
1985	50	160	< 0.2	< 3	15	90 \pm 10	49	120	< 0.2	< 2	140	1600 \pm 30
1986	47	200	< 0.1	1 \pm 0.3	10 \pm 1	50 \pm 10	47	110	< 0.1	1.1 \pm 0.3	400 \pm 10	4200 \pm 700

Table 15. Building 25 wastewater sample results, 1986.

Sample Date	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)
02-20-86	< 0.05	16.30	< 0.05
02-27-86	0.09	3.78	< 0.05
02-28-86	< 0.05	1.19	< 0.05
03-04-86	0.74	< 0.05	< 0.05
03-05-86	< 0.11	0.26	< 0.05
03-06-86	< 0.05	0.38	< 0.05
03-12-86 ^a	< 0.05	1.4	0.01
04-17-86	0.36	1.6	0.13
06-10-86 ^a	0.12	1.5	0.1
06-29-86	1.0	3.0	0.2
09-23-86 ^a	0.05	23.0	0.9
11-12-86	0.20	1.6	< 0.05
11-25-86 ^a	0.09	1.0	0.2
Minimum:	< 0.05	< 0.05	0.01
Maximum:	1.0	23.0	0.9
Average:	< 0.23	< 4.24	< 0.15
Discharge Limit:	2.77	3.38	0.69
% of Limit:	8.3	125	22

^aSample collected and analyzed by EBMUD.

The elevated levels of copper, found in samples dated February 20, 27, and 28, occurred during the initial shake-down phase of the treatment unit. Once the operating parameters had been determined, the wastewater levels were well within the discharge limits.

On September 23, 1986, the copper and lead discharge violations were the result of inadequate settling of the flocculant. Process changes introduced high concentrations of soap into the treatment unit, which caused the flocculant to remain suspended. Discharge levels returned to normal after removal of the concentrated soap.

Building 77 Plating Shop

Due to the nature of its operations, wastewater samples from this shop are analyzed for cyanide, cadmium, chromium, copper, lead, nickel, and zinc. The sample results are shown in Table 16.

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 in order to assure compliance with the site discharge limits mandated by the East Bay Municipal Utility District Ordinance No. 270. In this case the East

Table 16. Building 77 wastewater sample results, 1986.

Sample Date	CN (mg/l)	Cd (mg/l)	Cr (mg/l)	Cu (mg/l)	Pb (mg/l)	Ni (mg/l)	Zn (mg/l)
03-12-86 ^a	< 0.2	0.01	0.35	1.3	0.2	0.14	0.16
04-18-86	0.02	0.01	0.86	0.18	0.01	0.20	0.08
06-02-86 ^a	< 0.2	0.1	0.13	0.82	0.1	0.1	0.04
07-29-86	0.15	0.1	0.2	0.3	0.2	0.1	0.1
09-08-86	0.03	< 0.05	< 0.1	0.69	< 0.02	0.21	0.1
10-20-86 ^a	0.2	< 0.01	0.07	0.21	< 0.1	0.01	0.09
11-12-86	0.005	0.07	0.60	0.86	< 0.05	0.50	0.05
Minimum:	0.005	0.01	0.07	0.18	0.01	0.01	0.04
Maximum:	0.2	0.1	0.86	1.3	0.2	0.50	0.16
Average:	< 0.12	< 0.05	< 0.33	0.62	< 0.10	0.18	0.09
Discharge Limit:	1.2	0.69	2.77	3.38	0.69	3.98	2.61
% of Limit:	< 10	< 7.2	< 12	18	< 14	4.5	3.4

^aSample collected and analyzed by EBMUD.

Bay Municipal Utility District does not require a compliance report from the Laboratory.

At both sites, a series of flow-proportioned grab samples is collected and composited for a four-week period. Each composite sample is analyzed for a set of regulated heavy metals.

Tables 17 and 18 summarize the heavy metal released from the Strawberry and Hearst Sanitary Sewers.

POPULATION DOSE RESULTING FROM LBL OPERATIONS

The development of LBL's two models used to assess the population dose equivalent attributable to penetrating radiation and airborne radionuclides, respectively, is detailed in Ref. 5. Both of the models 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^{1,7,8} from 4.6 to 5.2 million people, the populations of Berkeley and Oakland, the two cities immediately adjacent to LBL, declined. Recomputing the population dose models with population statistics from the 1980 census produced no significant difference in the impact/insult values for either the penetrating radiation or radionuclide release models.

Accelerator-Produced Radiation

The LBL model developed by Thomas⁵ for determining population dose equivalent from the maximum measured value of perimeter (fence-post) dose assumes that the fence-post rate changes are uncorrelated with fluctuations in population. During 1986 the maximum fence-post dose was measured at the Olympus Gate Monitoring Station and was 3.5 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 approximately half the time and with the peaks from the HILAC detector the other half of the time. The Bevatron operated continuously seven days a week during 1986 except for maintenance, a "summer" shutdown from June 1 through October 1, and a year-end shutdown December 23, 1986 to January 6, 1987.

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_0 (in Rem) is

$$M < 10^3 \times H_0 (1.0 - 0.56f) , \quad (1)$$

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

Table 17. Strawberry monitoring station sampling data, 1998.

Sample Date	Flow M	pH	Cd mg/L	Cu mg/L	Pb mg/L	Fe mg/L	Pb mg/L	Mn mg/L	Ag mg/L	Zn mg/L
1-08	1.4	6.9								
1-15	1.6	6.5								
1-22	1.7	--								
Composite			0.03	0.05	0.12	6.5	0.33	0.24	< 0.07	0.44
1-29	1.7	6.2								
2-05	2.0	6.5								
2-12	--	6.2								
2-19	3.1	6.3								
Composite			0.03	< 0.05	0.60	3.5	< 0.73	0.17	< 0.08	0.85
2-26	1.4	6.8								
3-05	1.3	7.0								
3-12	2.9	6.9								
3-19	2.3	6.9								
Composite			0.03	0.10	0.92	30.5	0.4	0.38	< 0.08	1.1
3-26	2.6	6.8								
4-02	1.4	6.3								
4-09	2.4	--								
4-16	--	6.5								
Composite			< 0.03	0.11	0.75	7.75	< 0.79	0.23	< 0.08	0.95
4-23	2.4	6.7								
4-30	1.6	6.4								
5-07	1.5	6.7								
5-14	1.2	6.7								
Composite			< 0.05	0.12	0.25	7.43	0.15	0.13	< 0.07	0.78
5-21	1.4	6.7								
5-28	1.8	--								
6-4	1.4	6.5								
6-11	--	6.4								
Composite			< 0.03	0.06	1.26	4.03	< 0.76	0.13	< 0.04	0.73
6-18	1.3	6.4								
6-25	1.8	6.2								
7-02	1.5	6.6								
7-09	1.4	6.7								
Composite			0.03	< 0.05	0.41	3.28	< 0.35	0.10	< 0.04	0.47
7-16	1.5	6.3								
7-23	1.7	6.5								
7-30	1.4	6.4								
8-06	1.5	6.3								
Composite			0.05	0.13	0.68	16.45	< 0.35	0.15	< 0.04	1.25
8-13	1.5	6.3								
8-20	1.6	6.8								
8-27	1.5	6.0								
9-03	1.2	7.0								
Composite			< 0.05	0.16	0.5	2.45	< 0.35	< 0.10	< 0.04	0.75
9-10	1.2	6.2								
9-17	1.3	6.2								
9-24	0.8	6.7								
10-01	1.0	6.5								
Composite			0.03	0.06	0.43	4.75	< 0.36	0.33	< 0.05	0.55
10-08	1.0	6.8								
10-15	1.0	6.6								
10-22	0.9	6.4								
10-29	0.9	6.4								
Composite			< 0.03	< 0.05	0.19	6.4	0.1	0.10	< 0.04	0.35
11-05	1.2	6.2								
11-12	1.3	6.5								
11-19	1.0	6.4								
11-25	0.8	6.4								
Composite			< 0.03	< 0.05	0.70	5.75	< 0.41	0.16	< 0.04	0.43
12-03	--	6.1								
12-10	1.4	--								
12-17	1.5	--								
12-22	0.9	6.6								
Composite			0.05	< 0.05	0.66	5.3	< 0.40	< 0.11	< 0.04	0.58
Minimum:		5.1	< 0.03	< 0.05	0.12	2.45	0.1	< 0.10	< 0.04	0.35
Maximum:		7.0	0.05	0.16	1.26	30.5	0.79	0.38	0.08	1.25
Average:		6.5	< 0.04	< 0.08	0.58	7.98	< 0.42	< 0.18	< 0.06	0.71
Limit:		5.5	1	2	5	100	2	5	1	5
% of Limit:		N/A	< 4.0	< 4.0	12	8.0	< 21	< 3.6	< 6.0	14

Table 18. Hearst monitoring station sampling data, 1986.

Sample Date	Flow (MI)	pH	Cd (mg/l)	Cr (mg/l)	Cu (mg/l)	Fe (mg/l)	Pb (mg/l)	Mn (mg/l)	Ag (mg/l)	Zn (mg/l)
1-08	3.7	5.9								
1-15	1.7	6.3								
1-22	2.7	6.1								
Composite			0.03	0.29	0.77	10.3	0.30	0.13	0.19	2.03
1-29	2.3	6.2								
2-05	1.5	6.4								
2-12	1.5	6.5								
2-19	2.3	6.1								
Composite			0.03	0.40	2.40	2.28	< 0.73	< 0.10	0.09	1.25
2-26	1.7	6.2								
3-05	1.8	6.7								
3-12	2.1	5.8								
3-19	2.4	6.5								
Composite			< 0.05	0.72	0.64	4.25	0.5	< 0.22	0.06	1.9
3-26	2.3	6.5								
4-02	2.1	6.3								
4-09	3.1	6.3								
4-16	3.5	6.4								
Composite			< 0.03	0.14	0.44	4.98	< 0.79	< 0.22	0.11	1.3
4-23	2.6	6.5								
4-30	2.5	--								
5-07	2.5	--								
5-14	2.1	6.7								
Composite			< 0.05	< 0.09	0.51	1.16	0.16	< 0.18	0.18	0.98
5-21	2.2	6.3								
5-28	2.7	6.7								
6-04	1.8	6.0								
6-11	3.5	--								
Composite			< 0.03	1.56	3.78	6.98	< 0.76	< 0.1	0.05	2.63
6-18	2.2	--								
6-25	2.1	5.7								
7-02	2.0	5.9								
7-09	3.3	5.9								
Composite			0.04	0.44	1.14	6.18	0.35	0.13	0.06	4.38
7-16	10.8	5.8								
7-23	10.3	--								
7-30	8.8	6.2								
8-06	8.0	5.8								
Composite			0.04	3.5	2.65	10.63	0.85	0.11	0.06	9.63
8-13	5.8	5.9								
8-20	6.5	6.0								
8-27	3.0	6.3								
9-03	4.9	5.9								
Composite			< 0.05	0.39	2.93	12.55	< 0.35	0.10	0.04	2.25
9-10	7.0	5.5								
9-17	4.0	6.0								
9-24	6.5	5.9								
10-01	--	6.0								
Composite			< 0.03	0.74	1.01	10.18	0.41	0.15	0.05	2.85
10-08	--	6.1								
10-15	13.1	6.0								
10-22	8.4	5.7								
10-29	6.7	5.7								
Composite			< 0.03	0.17	0.62	3.55	0.25	< 0.10	0.04	1.00
11-05	3.8	6.1								
11-12	3.7	5.8								
11-19	3.7	6.1								
11-25	3.1	6.2								
Composite			0.03	< 0.05	0.60	0.69	< 0.41	< 0.11	< 0.04	0.35
12-03	3.6	5.9								
12-10	3.4	--								
12-17	4.4	6.1								
12-22	3.6	5.9								
Composite			0.04	< 0.05	0.51	1.66	< 0.40	< 0.11	< 0.04	0.83
Minimum:		5.5	< 0.03	< 0.05	0.44	0.69	0.16	< 0.10	< 0.04	0.35
Maximum:		6.8	0.05	3.5	3.78	12.55	0.85	0.22	0.19	9.63
Average:		6.1	< 0.04	< 0.66	1.39	5.80	< 0.48	< 0.14	< 0.08	2.41
Limit:		5.5	1	2	5	100	2	5	1	5
% of Limit:		N/A	< 4.0	< 33	28	5.8	< 24	< 2.8	< 8.0	48

Note: The sample dated 5-14 represents 1.5 days.

Thus the expression becomes

$$M < 10^3 (1 - 0.28) H_0 . \quad (2)$$

Since H_0 was 3.5 mRem (or 0.0035 Rem), the population dose equivalent attributable to LBL accelerator operation during 1986 was

$$< 2.5 \text{ man-Rem.}$$

Airborne Radionuclides

The CEDE resulting from airborne releases of radionuclides is listed in Table 19. The values used in this report were calculated by F.R. O'Donnell and S. Cotter at Oak Ridge National Laboratory (ORNL) using LBL release data and the "EPA/AIRDOSE/DARTAB" Code. The dose to a maximally exposed individual (radionuclide releases only) was also computed using that computer code. The United States Environmental Protection Agency (EPA) regulations in 40 CFR 61 require that facilities releasing airborne radionuclides compute the impact of such releases using EPA/AIRDOSE/DARTAB (RADRISK) or "an approved code," so in this report the EPA/AIRDOSE/DARTAB values are used. The EDE values computed using LBL's model⁵ are also presented. The contribution from C-14 was not computed at ORNL since it was expected to be trivial nor was the contribution from uncharacterized α and β emitters. The substantial difference between the LBL model's value and the EPA/AIRDOSE model for tritium is largely due to assumptions made (in the EPA AIRDOSE model) about food and water exposures. The code defaults assume all food and water consumed by the local population are produced locally and that $\geq 80\%$ the EDE from tritium is due to ingestion. Although a number of outlying communities store water in open reservoirs, little of the food consumed by the population within 80 km of LBL is produced locally. Thus, the EPA/AIRDOSE calculation substantially overestimates the CEDE from tritium. The foregoing notwithstanding, we used the EPA/AIRDOSE/DARTAB estimate of CEDE as computed. Table 20 summarizes the total CEDE due to LBL operations.

Table 19. Collective effective dose equivalent resulting from LBL airborne nuclide releases, 1986.

Nuclide	EPA-Airdose DARTAB (man-Rem)	LBL Model (man-Rem)
H-3	≤ 2.0	0.7
C-14	NC ^a	0.000006
I-125	≤ 0.018	0.014
I-131	≤ 0.0074	0.013
Unidentified alpha emitters	NC	0.02
Unidentified beta emitters	NC	0.014
Total	≤ 2.03	0.8

^aNC = not calculated.

Table 20. Population effective dose equivalent, 1986.^a

Contributing factor	Population effective dose equivalent (man-Rem)
Penetrating radiation from accelerator operations	≤ 2.5
Radionuclide release (from Table 19)	≤ 2.03
LBL-produced effective population dose equivalent	≤ 5

^aFor 1986, the population dose attributable to natural background sources for the population within 80 km (50 mi) of LBL was approximately 5.2×10^6 persons \times 0.1 Rem/person-yr = 5.2×10^5 man-Rem.

TRENDS--LBL ENVIRONMENTAL IMPACT

Accelerator-Produced Penetrating Radiation

Figures 4-7 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 Environmental Monitoring Station somewhat. That upward trend was reversed in 1983. The maximum perimeter dose equivalent (Fig. 5) remains a diminishing fraction of the radiation protection guidelines³ reflecting improvements in accelerator beam optics, local shielding, and cave selection.

Airborne and Waterborne Radionuclides

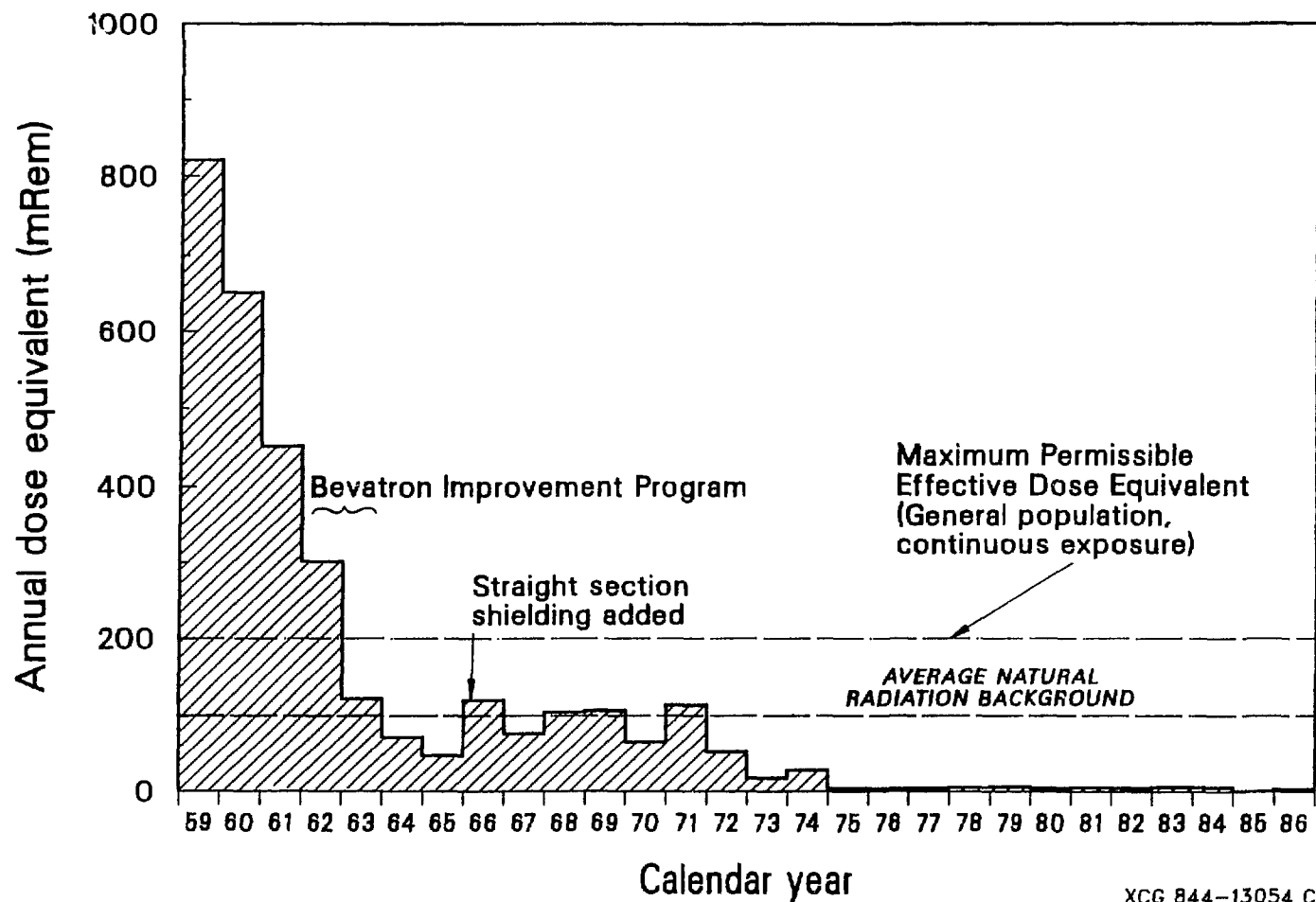
Figure 8 shows the annual releases of tritium (as HTO) from the Building 75 Tritium Facility from 1973 through 1986.

The 80 curies released during routine operations in 1986 is approximately 40% of the 1985 releases and is responsible for approximately 45% of the LBL-produced population-dose equivalent from all sources for 1986. 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.

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.

The 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 University of California Berkeley 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.



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Figure 4. Annual accelerator-produced dose equivalent reported by the Olympus Gate Environmental Monitoring Station, 1959-1986. 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.

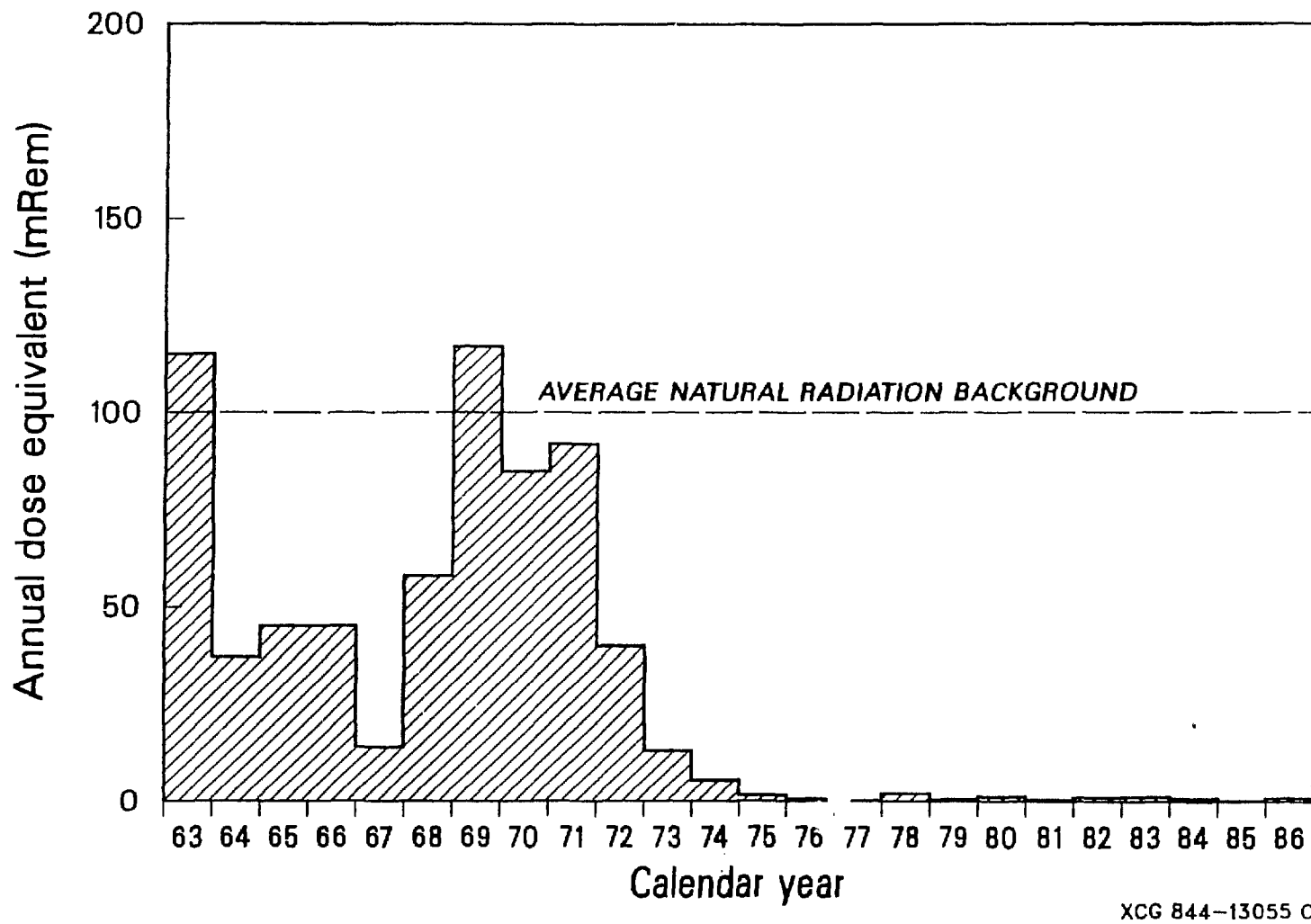


Figure 5. Annual accelerator-produced dose equivalent reported by the Building 90 Environmental Monitoring Station, 1962-1986.

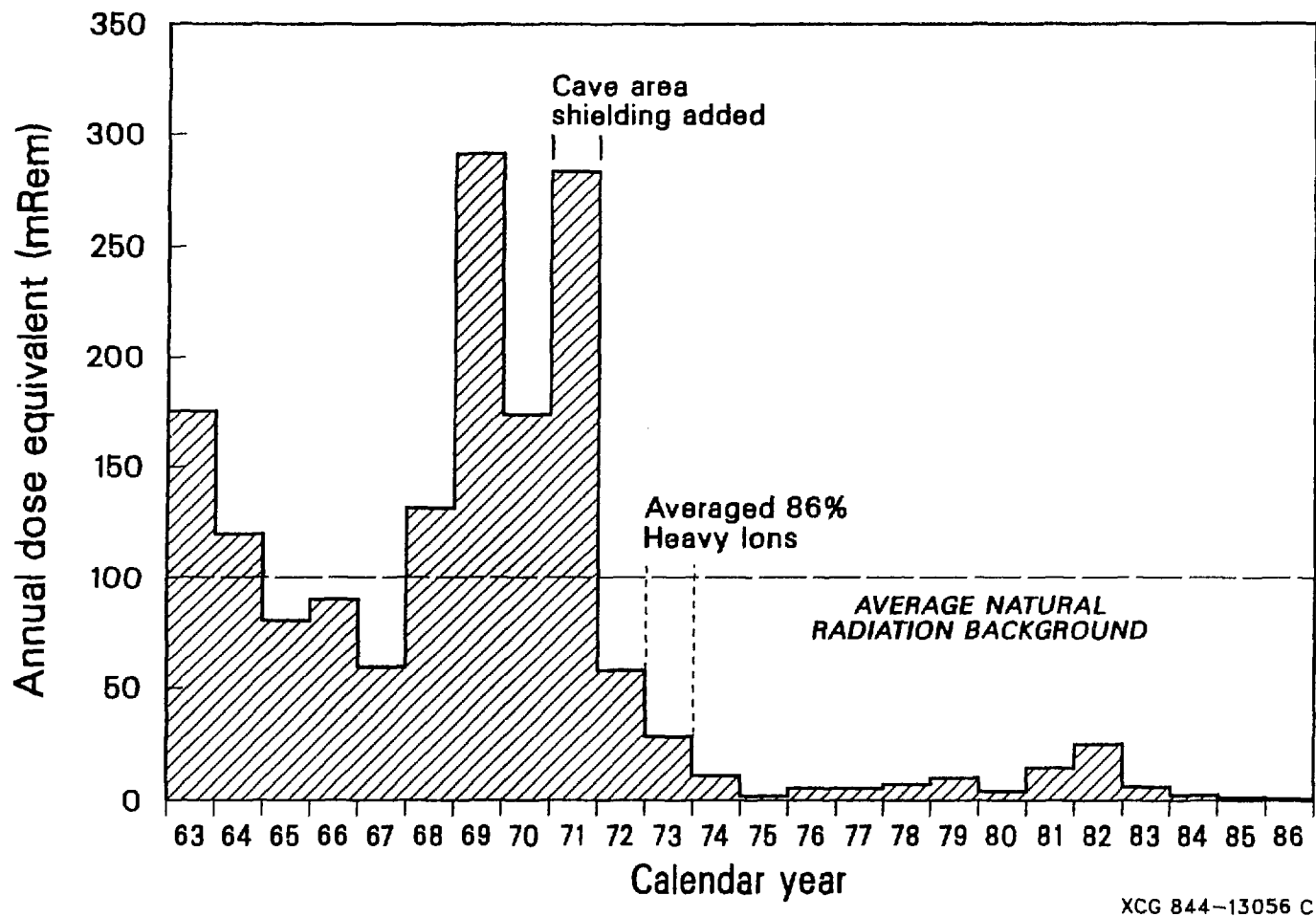


Figure 6. Annual accelerator-produced dose equivalent reported by the 88-Inch Cyclotron Environmental Monitoring Station, 1963-1986.

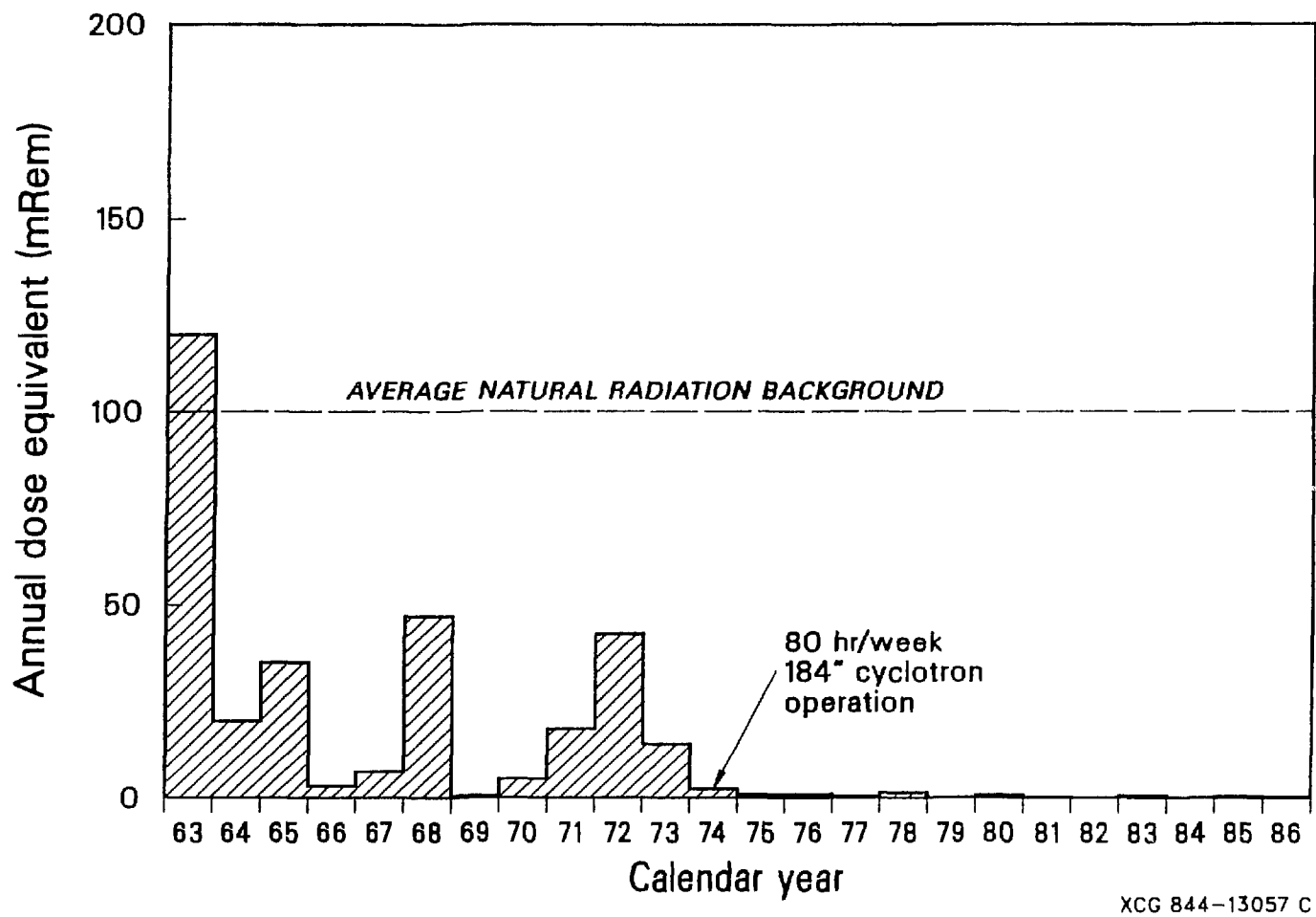


Figure 7. Annual accelerator-produced dose equivalent reported by the Panoramic Way Environmental Monitoring Station, 1963-1985.

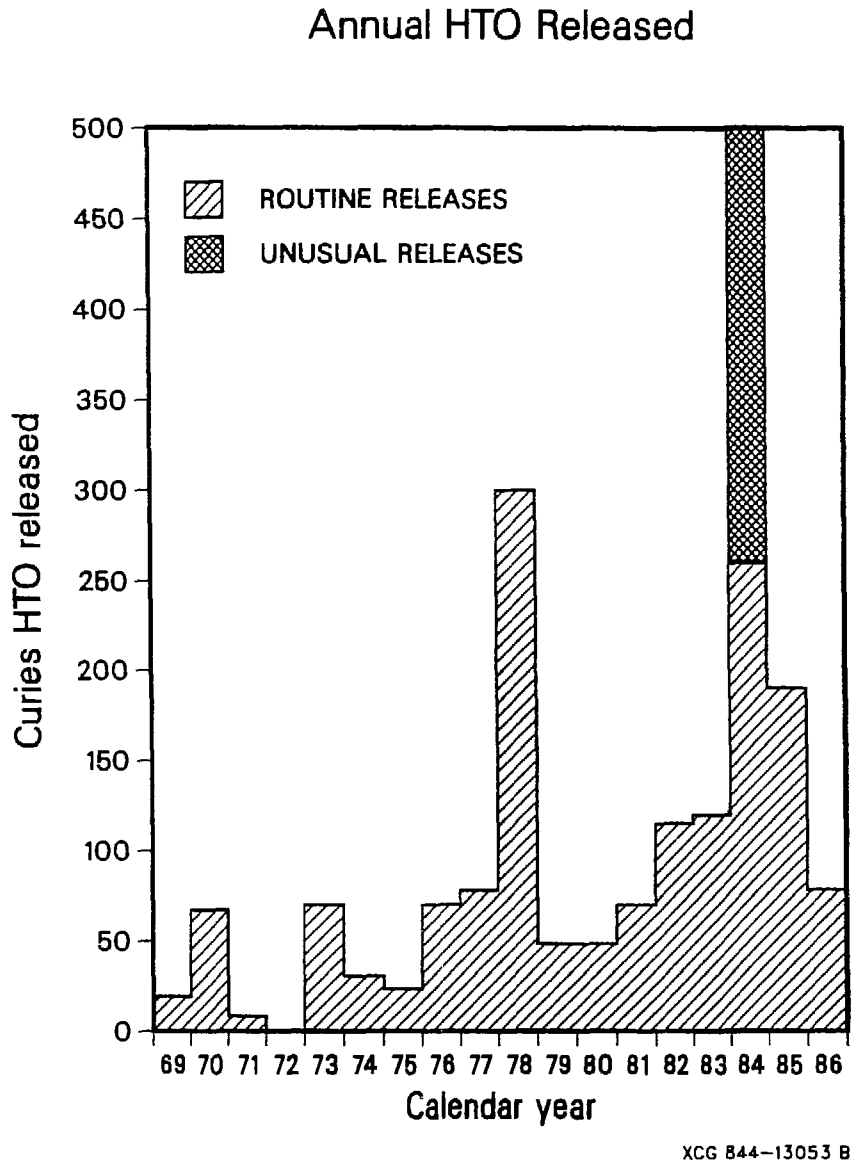


Figure 8. Annual releases of tritium (HTO) from the Building 75 Tritium Facility, 1969-1986.

QUALITY ASSURANCE

The Engineering Division of LBL has developed a comprehensive division-wide quality assurance program. During 1986, 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 QAPXXV Water Sample (reported in Ref. 9) for tritium, with the following results:

LBL Value (pCi/ml HTO)	EML Value (pCi/ml HTO)	Ratio LBL/EML
21 ± 3	21.8 ± 0.22	0.96 ± 0.14

GROUND-WATER MONITORING

LBL is developing a formal program to assay ground water at this time. As mentioned previously, the Laboratory does analyze the grab samples taken weekly from all permanent creeks that drain the LBL watershed (see Fig. 2 and Tables 11 and 12).

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