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ENVIRONMENT, HEALTH AND SAFETY DIVISION

Annual Site Environmental Report of the Lawrence Berkeley Laboratory

1991

R.O. Pauer, G.E. Schleimer, and I. Javendel

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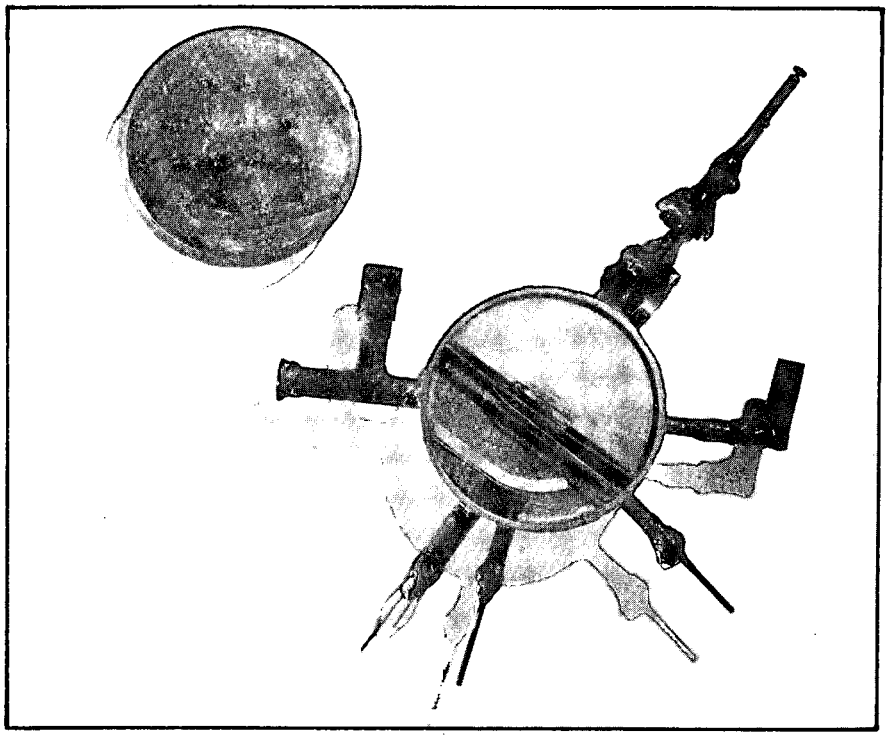

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LBL-27170 (1992)

ANNUAL SITE ENVIRONMENTAL REPORT OF THE LAWRENCE BERKELEY LABORATORY

Calendar Year

1991

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Executive Summary

This Annual Site Environmental Report (ASER) summarizes LBL environmental activities in calendar year (CY) 1991. The purpose of this Report is to present summary environmental data in order to characterize site environmental management performance, confirm compliance with environmental standards and requirements, and highlight significant programs and efforts. Its format and content are consistent with the requirements of the Department of Energy (DOE) Order 5400.1, "General Environmental Protection Program."

Compliance Summary

The emissions of radioactive materials into the atmosphere are regulated under the Clean Air Act. In 1991, LBL received a violation from the United States Environmental Protection Agency (US/EPA) for noncompliance with these regulations. A corrective action plan was prepared by LBL and submitted to the US/EPA. The US/EPA is pursuing a Federal Facilities Compliance Agreement which will incorporate this corrective action plan.

LBL operates a Hazardous Waste Handling Facility (HWHF), which is permitted under the Resource Conservation and Recovery Act (RCRA). The Laboratory is currently preparing a new application in order to renew its RCRA permit. The California Environmental Protection Agency (Cal/EPA) has established a submission deadline of July 1, 1992.

On March 21, 1991, Cal/EPA issued to LBL a Report of Violation for seventeen violations of hazardous waste control statutes and regulations. Violations were found with regards to unpermitted treatment and storage, manifests, labels, facility access, containment, training, planning documents, inspection, and storage. Although these violation were all addressed, on January 7, 1992, the Attorney General for the State of California Department of Justice notified LBL that they were initiating legal action.

The State of California has established a new permitting program for hazardous waste treatment units that do not require a RCRA permit. This program is called permit by rule. There are 5 treatment units at LBL which fall within the scope of permit by rule. The necessary permit documentation is in preparation.

The Cal/EPA performed a RCRA Facility Assessment (RFA) in 1991. This was performed to identify all hazardous waste management units and other areas of concern, and to determine whether the units and areas of concern are, or have been, sources of releases of hazardous waste or hazardous constituents to the environment. This review identified a total of 15 sites at which uncontrolled releases of hazardous substances to the environment may have occurred in the past. However, their potential impacts were judged to be small, and it was recommended to take no further remedial action under the Comprehensive Environmental Response and Liability Act (CERCLA).

Environmental Surveillance Program

In order to assess the level to which LBL research activities impact the population surrounding the Laboratory, LBL conducts a program of environmental surveillance air and water sampling and continuous radiation monitoring was carried on throughout the year.[1] For 1991, as in the previous several years, dose equivalents attributable to LBL radiological operations were a fraction of both the relevant radiation protection guidelines (RPG) of 100 mrem/yr and of the natural radiation background. DOE Order 5400.5[2] limits the total effective dose equivalent to any member of the public from all of a facility's sources to less than 100 mrem/yr above natural background. (Typically, DOE facility impacts are a small fraction of that value.) The Order also provides tables that contain derived concentration guides (DCG) for airborne and waterborne radionuclides. A DCG is that concentration of a single radionuclide in air or water that if routinely consumed or continuously inhaled will individually produce an effective dose equivalent of 100 mrem in one year to the exposed individual. Exposures to a hypothetical maximally exposed member of the public are determined, as well as the sum of all exposures to the population within 80 km (50 mi) of LBL (see Table 1).

Table 1. Summary of LBL radiological impact.

	Maximum Individual (Accelerators)	Maximum Individual (Airborne Nuclides)	Maximum All Sources	Collective Dose to Persons < 80 km from LBL All Sources
Dose	≤ 2 mrem	≤ 0.07 mrem	2.1 mrem	≤ 5 person-rem
Location	Residence NE of B13D	Residence NE of B13D	Residence NE of B13D	≤ 80 km from Laboratory
DOE Radiation Protection Standard[b]	100 mrem	10 mrem	100 mrem	—
% of STD	2	0.7	2	—
Background	100 mrem	300 mrem	300 mrem	1.5×10^6 person-rem
LBL impact as a % of background	2	0.1	1	0.001

[a]LHS = Lawrence Hall of Science
[b]Source: Ref. 2

DOE Order 5400.5 also directs DOE facilities to comply with requirements of 40 CFR 61 Subpart H, the "National Emission Standard for Hazardous Airborne Pollutants Other Than Radon From DOE Facilities" (NESHAPS). NESHAPS requires that DOE facilities limit doses to offsite individuals to less than 10 mrem per year from all exposure pathways resulting from airborne releases of radionuclides. The maximum exposure attributable to LBL airborne radionuclide releases was 0.07 mrem to an offsite worker one hundred and thirty meters north of the LBL Building 75 – 0.07% of the NESHAPS limit.

The maximum effective dose equivalent delivered to a member of the community is defined as the maximum perimeter effective dose equivalent (EDE) at an area where non-LBL personnel work or reside. The 1991 maximum annual EDE value was delivered to a resident northeast of the Olympus Gate Environmental Monitoring Station B-13D. The EDE northeast of Building B13D was estimated to be ≤ 2.1 mrem for the year.

An additional assessment of LBL radiological impact is the "population dose". [The reader should note that, throughout this report, the phrase "population dose" should be taken to mean collective effective dose equivalent (CEDE) and "dose" or "dose equivalent" to mean effective dose equivalent.] CEDE is defined as the sum of the "doses" delivered to all individuals within an 80-km (50-mi) radius of the Laboratory. The total population dose equivalent attributable to LBL operations during 1991 was ≤ 5 person-rem, an average of about 0.001% of the RPG of 100 mrem maximum effective dose equivalent to individual members of the surrounding population.

The majority of the CEDE is assignable to two sources. Approximately half of the impact of LBL radionuclide operations during 1991 is from the airborne release of 84 Ci of tritium as tritiated water (HTO), from the National Tritium Labelling Facility Stacks. The other half of the 1991 CEDE is attributable to releases of Accelerator-produced air activation radionuclides and direct radiation from accelerator operation. Small amounts of ^{14}C, ^{35}S, ^{125}I, and unidentified alpha emitters were released from various other LBL laboratory stacks. The CEDE attributable to the foregoing releases is << 0.1 person-rem. Table 2 lists the radionuclide discharges to the atmosphere from LBL during 1991.

To put the Laboratory's impact into perspective, we refer to the National Commission on Radiation Protection and Measurements (NCRP) for an approximate value for absorbed dose from external and internal natural sources to residents of the U.S. (e.g., cosmic rays, radiation from continental rocks, naturally occurring radioactive potassium-40 in our muscles and bones, and exposure from radon and its daughters). The NCRP's estimate of the effective dose equivalent from the foregoing is 300 mrem/yr[4], which implies an annual population dose from natural sources of ~1,500,000 person-rem to the 5.1 million people within 80 km (50 mi) of LBL. However, in this report, when comparing LBL's penetrating radiation impact (from accelerator operations) to natural sources, only the penetrating whole-body component of natural background (about 33% of the foregoing total, or 100 mrem) is used.

LBL measures radioactivity in onsite and offsite creeks, rainwater, sewer discharges, and horizontal wells (hydraugers). Additionally, the laboratory measures non-radioactive contaminants in hydraugers and wells. The discharges from a group of onsite hydraugers was found to contain levels of chlorinated hydrocarbons that exceed the US/EPA drinking water limits. These hydraugers are used to stabilize the slope, east of Building 51, by draining the groundwater. The discharges from these hydraugers have been combined and processed through a treatment system. The treated effluent is used as makeup water for the Building 51 cooling towers. A major LBL subsurface characterization study has been funded for FY 1991 and 1992. (See the Environmental Activities and Groundwater sections of this report.)

Tritium levels averaging 26,000 pCi/l, which exceed the US/EPA 40 CFR 141 Community Drinking Water Standard of 20,000 pCi/l, were found in the outflow of one of LBLs many hydraugers (designated 7712H in this report–most of LBLs hydraugers do not contain tritium),

LBLs many hydraugers (designated 7712H in this report–most of LBLs hydraugers do not contain tritium), and an average of 26,000 pCi/l was found in rainwater samples taken at an onsite location 70 m from the tritium stack. The hydrauger flow rate is low (average 0.2 l/min), and the effluent eventually flows into Strawberry Creek. Neither the hydrauger water nor that of Strawberry Creek is potable or used for agriculture or recreation. Since no practical way exists to remove existing tritium from water, no remediation effort is planned. However, the National Tritium Labeling Facility has instituted a program to markedly reduce airborne tritium releases (the origin of the environmental tritium). The releases from the facility during 1991 were 53% of the 1990 releases and reflect a sharp downward trend (see Figure 4-9).

Table 2. Total monitored quantities of radionuclides discharged into the atmosphere, 1991.

Nuclide	Half Life	Quantity Discharged	
		(Ci/yr)	(Bq/yr)
^{3}H as HTO	12.3 yr	84	3.1×10^{12}
^{14}C as $^{14}CO_2$	5730 yr	1.2×10^{-2}	4×10^{8}
^{125}I	60.1 d	3×10^{-4}	1×10^{7}
^{35}S	87.2 d	7×10^{-5}	2.6×10^{5}
Unidentified alpha emitters	—	$<1 \times 10^{-6}$	$<4 \times 10^{4}$
Estimated Total Accelerator Air Activation Radionuclides Discharged Into The Atmosphere, 1991			
^{11}C	20.5 min	9	3×10^{11}
^{13}N	10 min	10	4×10^{11}
^{15}O	2.1min	4	2×10^{11}
^{41}Ar	1.8 hr	0.12	4×10^{9}

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

Aside from LBL sewage, no tritium has been detected in samples taken from offsite water.

Gross data for radioactivity in environmental air and water for the period 1982–1991 are presented in this report for comparison with the 1991 data. These gross data show that, except for a period following the Chernobyl fire (1986), gross radioactivity concentrations in air and water in the vicinity of LBL show only small fluctuations about historical background levels.

1.0
Introduction

1.1 History

The Lawrence Berkeley Laboratory (LBL) began on the Berkeley campus of the University of California, where a laboratory was set up in 1931 to pursue Physics Professor Ernest Lawrence's invention of the cyclotron in 1929. In 1940, the Laboratory moved to its present hillside site just to the east of the University campus, where the first major facility, the 184-Inch Cyclotron (Building 6), was built.

From 1948 to 1972, the Laboratory was operated by the University of California for the U.S. Atomic Energy Commission. During this period, pioneering discoveries were made in nuclear and elementary particle physics, nuclear chemistry, biology, and nuclear medicine. It was at LBL that three of the basic modern types of accelerator—the cyclotron, the Alvarez linear accelerator, and the synchrotron—were invented and developed.

In 1972, the Lawrence Radiation Laboratory became the Lawrence Berkeley Laboratory, with major funding from the Federal Energy Research and Development Administration (ERDA), which replaced the Atomic Energy Commission. ERDA later was incorporated into the Department of Energy.

1.2 Laboratory Operations

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

The National Tritium Labeling Facility, located in Building 75, was designed to handle kilocurie quantities of tritium, ^3H, a radioactive isotope of hydrogen used as a labeling agent for a variety of molecules subsequently employed in chemical, pharmaceutical, 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.

1.3 Future Programs

In response to national needs for high-brightness synchrotron radiation facilities, LBL is constructing the Advanced Light Source (ALS), which will be completed in 1993. The ALS will provide the world's brightest beams of soft X-ray and ultraviolet light for use in materials

science research, chemistry, biology, and other fields. When completed and fully operational, the ALS will provide ports for up to 55 end stations, including up to 200 guests at any one time. LBL will provide the research and facilities infrastructure to support this user community.

LBL, in coordination with other national laboratories, has prepared conceptual designs for a Chemical Dynamics Research Laboratory for advanced studies in reaction science and combustion chemistry. Other future projects include improvements to the National Center for Electron Microscopy and strengthened programs in the Center for Advanced Materials, and in the life sciences.

1.4 The Site

The Laboratory is in Alameda County with most of the site within the City of Berkeley. About one-quarter of the eastern part is within the City of Oakland. It is located three miles east of San Francisco Bay and about fifteen miles east of the City of San Francisco (Figure 1-1).

LBL is situated on a hillside above the main campus of UC on the west-facing slope of the Berkeley Hills. Elevations range from 150 to 350 meters above sea level. The laboratory site itself is on a hill with areas of steep slopes and vegetation that give LBL a rural character.

The main site of the Lawrence Berkeley Laboratory totals 134 acres and is completely enclosed within the boundaries of the University of California (Figure 1-2). Of the 134 acres, 68.3 acres are leased to the Department of Energy, 11.5 acres are occupied under an occupancy agreement with the University, 50.2 acres are lands controlled by LBL within the LBL fence line but not developed, and approximately four acres are scheduled for development in the LBL east site area. Most of this remaining land is in hillside, open space, and circulation.

Immediately along the northern boundary of the central portion of the LBL site is the UC Berkeley Lawrence Hall of Science, and above Centennial Drive in the same general area are the UC Berkeley Samuel Silver Space Sciences Laboratory and UC Berkeley Mathematical Sciences Research Institute. All three of these buildings have their access from Centennial Drive and all are on slopes above the LBL site.

Along the LBL eastern boundary are undeveloped lands included in the UC Berkeley ecological study area. Also along the eastern edge of LBL and separated by Centennial Drive from LBL is the UC Berkeley Botanical Garden.

Along the southern edge of LBL, near its western boundary, the LBL site overlooks the UC Berkeley Bowles Residence Hall, the Greek Theatre, the Stern Residence Hall, and the new Foothill student housing. These latter facilities have their access, in part, from Gayley Road, or roads that intersect Gayley Road, including Stadium Rimway and Hearst Avenue.

Along LBL's western boundary and at the foot of Blackberry Canyon, LBL property abuts a multiple and single family residential area of the City of Berkeley. Below the LBL 88-Inch Cyclotron, along Highland Avenue, are a series of mid-rise apartment buildings containing between 22 and 32 units each, plus the Nynigama Institute, the new UC Berkeley student housing, and the entrance to the UC Berkely student housing on the south side of Highland Avenue.

Also along the western edge and the northern edge of the University property bordering the site are a series of single family residences that overlook LBL. These buildings are primarily uphill of the LBL SuperHILAC and Bevalac Accelerator. Most of these homes overlook UC property in the vicinity of the Lawrence Hall of Science.

The University of California, including LBL, as a state agency, and the Department of Energy, as a federal agency, are exempt from local zoning and planning regulations.

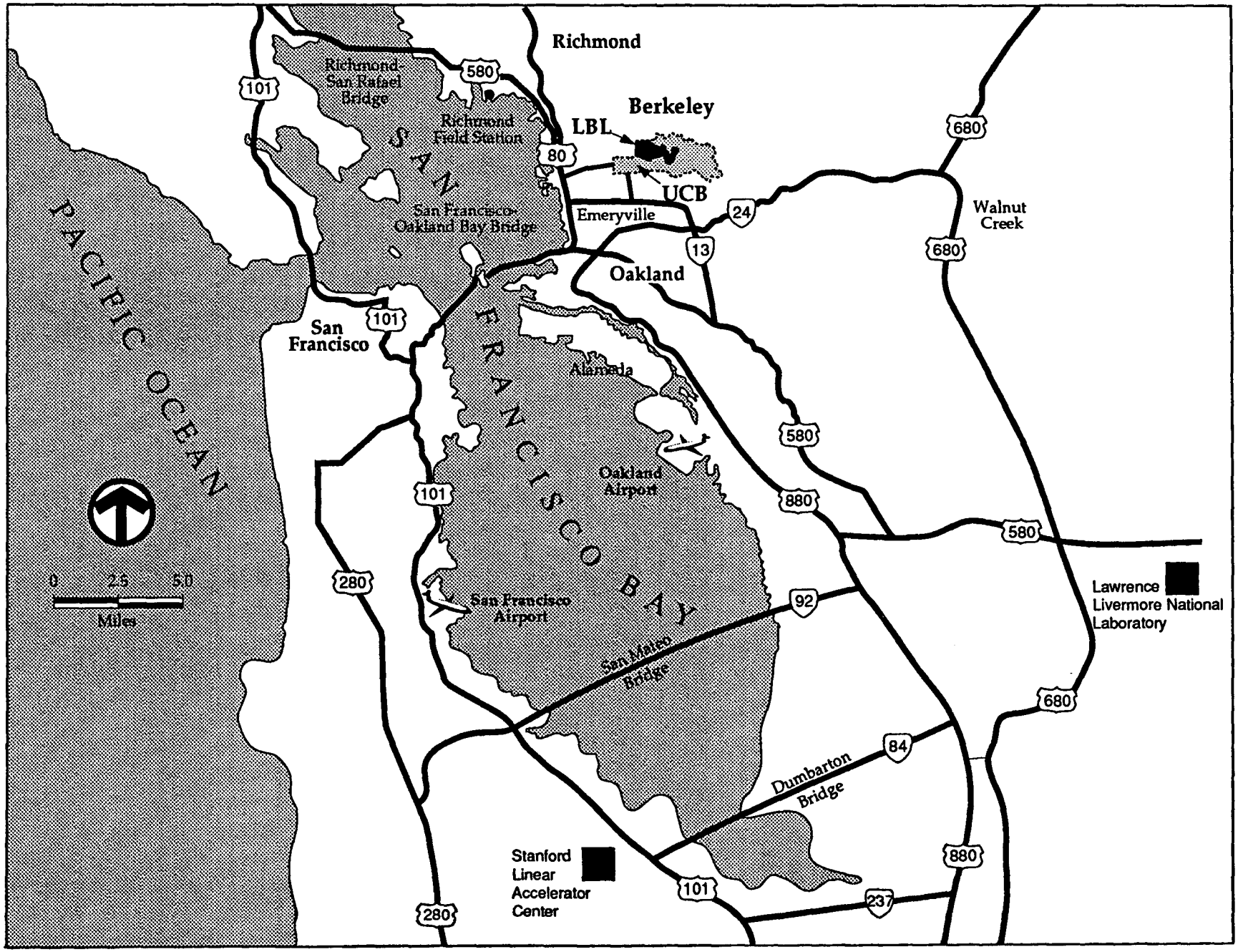

Figure 1-1. San Francisco Bay Area Map.

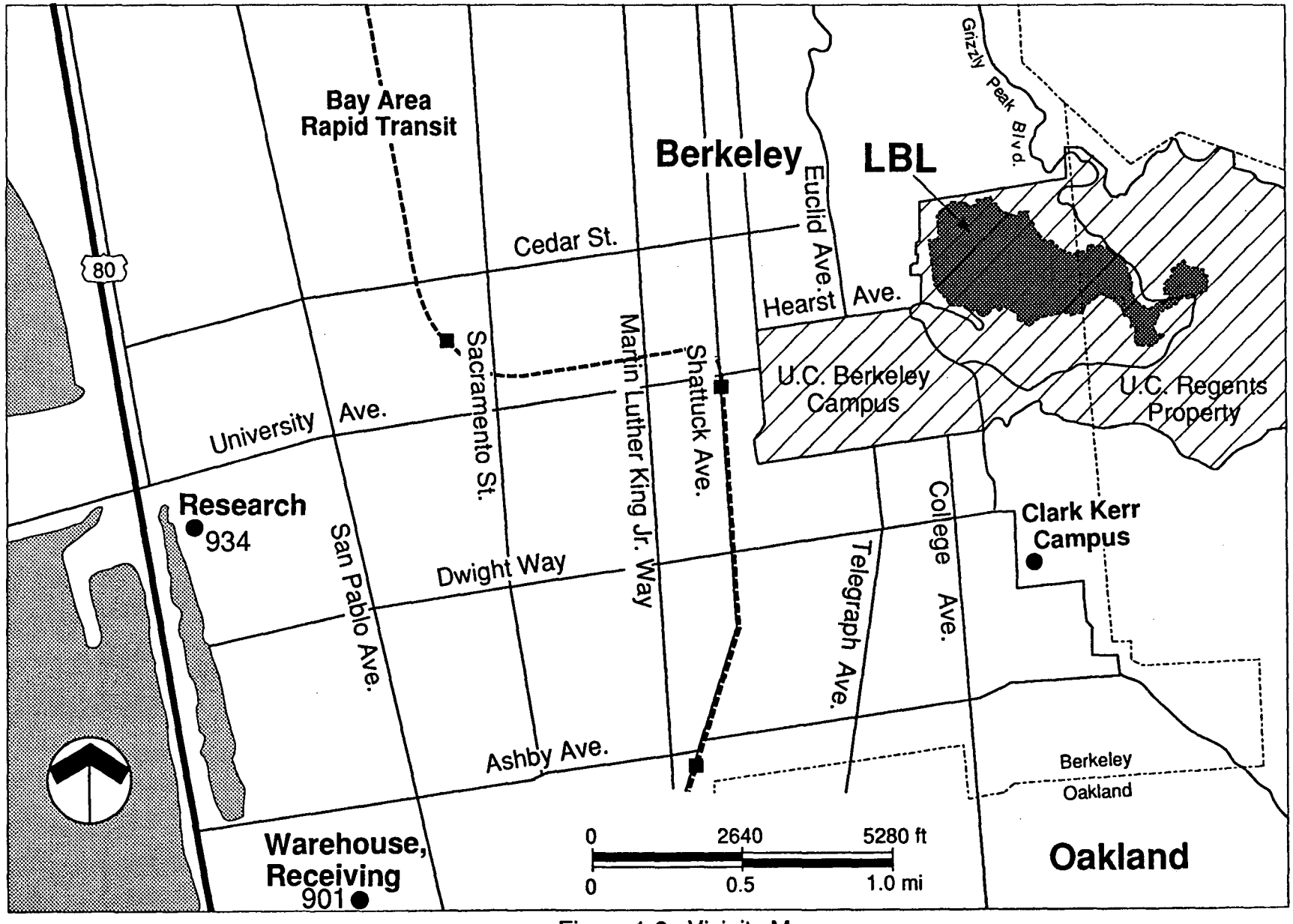

Figure 1-2. Vicinity Map.

The population within an 80-km (50-mi) radius of the Laboratory is approximately 5.1 million (1980 census).[5]

1.5 Land Use

Adjacent land use consists of residential, commercial, business, institutional, and recreation areas (Figure 1-3) Development within the laboratory site is compatible within the surrounding community. The laboratory works with municipal, county, and university planning staffs to coordinate development plans.

1.6 Facilities

LBL research and support activities are conducted at onsite and offsite locations in structures totaling 2.03 million gross square feet (gsf). This includes 80 permanent buildings and 108 trailers and temporary structures on the main LBL site encompassing 1.59 million gsf, 0.11 million gsf on the UC Berkeley Campus, and 0.14 million gsf leased in the East Bay, in the cities of Berkeley and Emeryville (Figures 1-4, 1-5). In 1991, the average age of the main-site buildings was 30 years. The inventory of main-site building space, including current construction, is 1,593,000 gsf.

1.7 Laboratory Population

The Laboratory's employee population consists of 3,330 full- and part-time employees. These employees include 795 staff scientists; 220 faculty scientists; 1,610 technical staff administration staff; and 705 graduate students, undergraduates, and postdoctoral fellows. There are 2,570 full-time equivalent positions. LBL maintains a register of official guests, updated monthly. During 1991, 1,400 registered guests visited the Laboratory. About 610 of these guests are onsite at any one time, so that the total Laboratory population is 3,940. Of this total, 3,055 are located on the main site, 765 are located in UC Berkeley Campus buildings, and 120 are located in offsite leased buildings.

1.8 Meteorology

Located on the east shore of the San Francisco Bay, Berkeley is usually influenced by maritime air masses from the Eastern Pacific Ocean that flow through the Golden Gate. During the spring through autumn months, this flow of marine air is usually generated by the temperature differences between the air over the Pacific Ocean and the interior valleys of California. As the central eastern Pacific is a marine upwelling area, summer fog is commonly observed off shore and often moves on shore summer afternoons.

Because of the cool and moist nature of these air masses, along with their high winds, Berkeley has relatively good air quality compared to most of the Bay Area. During periods of stagnant wind, however, the entire Bay Area, including Berkeley and the LBL site, is influenced by air flow patterns that originate over the warmer and drier interior valleys. This pattern allows for a buildup in pollutant levels over the entire Bay Area, especially ozone. However, a review of air quality data from recent years shows that regions immediately surrounding the northern half of San Francisco Bay seldom exceed either Federal or State air quality standards during these stagnant conditions.

The winter months are climatologically characterized by cycles of Pacific Ocean storms that bring periods of clouds, wind, and rain, followed by stable periods of sunny days with light winds and cool, calm nights. Seasonal temperature variations are small. The mean temperature for the summer is 63°F, while the mean temperature for the winter drops down only slightly to 48°F. Generally, comfortable outdoor conditions prevail year round at the LBL site.

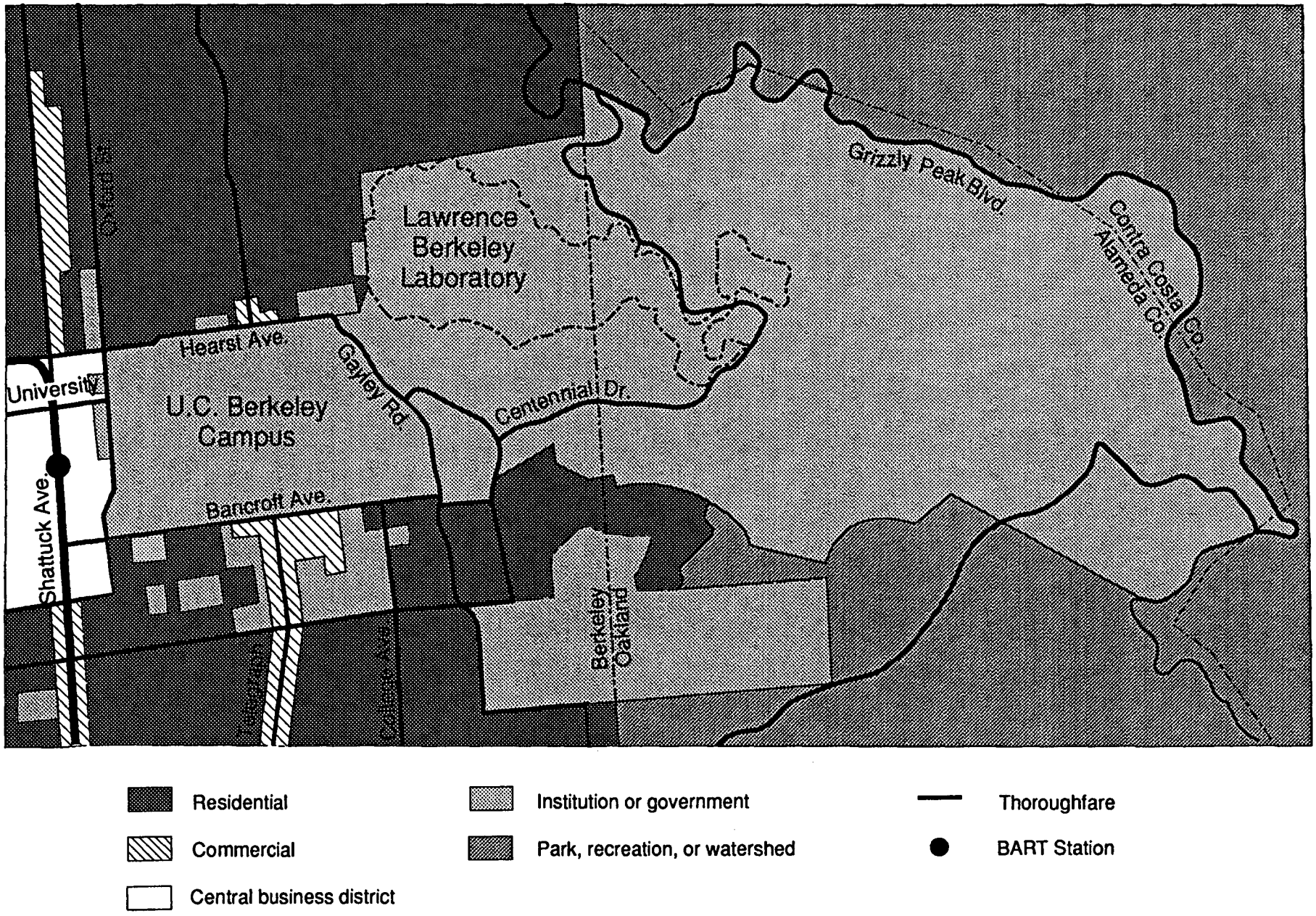

Figure 1-3. Adjacent Land Use Map.

Figure 1-4. Lawrence Berkeley Laboratory buildings.

Bldg. No.	Description
	HILL-SITE BUILDINGS
2	Advanced Materials Laboratory (AML) & Center for X-ray Optics (CXRO)
4	Magnetic Fusion Energy (MFE)
5	Magnetic Fusion Energy (MFE)
*6	Advanced Light Source (ALS)
7	Central Stores & Electronics Shops
10	Cell & Molecular Biology Research & Photography
14	Accelerator & Fusion Research & Earth Sciences
16	Magnetic Fusion Energy Laboratory
17	EH&S/Applied Sciences Lab
25	Mechanical Technology
25A	Electronics Shops
26	Medical Services
27	High Voltage Test Facility & Cable Shop
29	Electronics Engineering, Research Medicine/Radiation Biophysics Offices
31	Chicken Creek Maintenance Bldg.
36	Grizzly Substation Switchgear Bldg.
37	Utilities Service
40	Electronics Development Lab
41	Magnetic Measurements Lab
42	Salvage
43	Compressor Bldg.
44	Indoor Air Pollution Studies
45	Fire Apparatus
46	RTSS, ALS, Accelerator Development
46A	Real Time Systems Section (RTSS)
47	Advanced Accelerator Study
48	Fire Station
50	Physics, Accelerator & Fusion Research & Nuclear Science
50A	Director's Office, Environment & Laboratory Development, Administration Division, Patents
50B	Physics, Computer Center, IRD & ICSD
50C	PID, Physics
50D	MCSD & Nuclear Science
50E	Earth Sciences
50F	Computing Services, IRD
51	Bevalac/Bevatron
51A	Bevatron Experimental Area
51B	External Particle Beam (EPB) Hall
52	Magnetic Fusion Energy Laboratory
53	SuperHILAC Development
54	Cafeteria
55	Research Medicine/Radiation Biophysics
55A	Nuclear Magnetic Resonance (NMR)
56	Cryogenic Facility
58	Accelerator Research & Development
58A	Accelerator Research & Development Addition
60	High Bay Laboratory
61	Standby Propane Plant
62	Materials & Chemical Sciences
63	Accelerator & Fusion Research
64	Accelerator & Fusion Research
65	Data Processing Services
66	Surface Science & Catalysis Lab
68	Upper Pump House
69	Business Services, Materiel Management, Mail Room & Purchasing
70	Nuclear Science, Applied Science & Earth Sciences
70A	Nuclear Science, Materials & Chemical Sciences & Earth Sciences
71	Heavy Ion Linear Accelerator (HILAC)
71A	HILAC Rectifier
71B	HILAC Annex
72	National Center for Electron Microscopy (NCEM)
72A	High Voltage Electron Microscope (HVEM)
72B	Atomic Resolution Microscope (ARM)
72C	ARM Support Laboratory
73	Atmospheric Aerosol Research
74	Research Medicine/Radiation Biophysics, Cell & Molecular Biology Laboratory
74B	Research Medicine/Radiation Biophysics, Cell & Molecular Biology Laboratory Annex
75	Radioisotope Service & National Tritium Facility (NTF)
75A	Compactor, Processing & Storage Facility
76	Construction & Maintenance & Craft Shops
77	Mechanical Shops
77A	Ultra High Vacuum Assembly Facility (UHV)
78	Craft Stores
79	Metal Stores
80	Electronics Engineering
80A	Office Building
81	Liquid Gas Storage
82	Lower Pump House
83	Lab Cell Biology
88	88-Inch Cyclotron
90	Applied Science, Employment, Engineering, Occupational Health, Personnel, Protective Services
	SMALL BUILDINGS AND TRAILERS
B-13A	Environmental Monitoring West of 88
B-13B	Environmental Monitoring West of 90
B-13C	Environmental Monitoring South of UC Recreation Area
B-13D	Environmental Monitoring North of 71
B-13E	Sewer Monitoring Station, Hearst Avenue
B-13F	Sewer Monitoring Station, Strawberry Canyon
B-13G	Waste Monitoring Station, West of 70

*Under construction.

Figure 1-5. Key to LBL Buildings Shown in Figure 1-4

Annually, relative humidity ranges from 85-90 percent in the early morning to 65-75 percent in the afternoon. Annual insolation (incoming solar radiation or sunshine) ranges from 65-75 percent of the theoretically available sunshine, and the average daytime cloudiness is about the same in summer and in winter. The number of annual heating degree-days is about 2,600 and cooling degree-days about 150. Winds are usually light, but the summer afternoon sea breezes range to 20-30 mph; peak winds occur during winter months and usually occur from the south or southwest direction ahead of approaching storms.

About 95 percent of the average annual rainfall of 25 inches at the LBL site occurs from October through April, and intensities are seldom greater than one-half inch per hour. Thunderstorms, hail, and snow are extremely rare. As a general matter, LBL enjoys a Mediterranean-type climate with drought years as well as heavy rainfall years.

1.9 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.

Three major formations have been identified at the LBL site. The western and southern part of LBL are underlain by a moderately to well-consolidated marine Knoxville Formation. This Cretaceous formation consists of shales, siltstones, sandstones, and conglomerates. The upper Miocene or lower Pliocene Orinda Formation occupies most of the laboratory property. It consists of poorly consolidated slaystones, siltsones, sandstones, and conglomerates of relatively low strength and hardness. These rocks are blanketed by clay soils having high shrink-swell characteristics. The volcanic Moraga Formation covers most of the higher elevations of the Laboratory. Although the Moraga Formation overlays the Orinda for most areas at LBL, in some cases Moraga rocks are interbedded with the upper Orinda rocks. The Moraga Formation consists of basalt and andesite flows and pyroclastic tuffs.

Landslide deposits have been encountered in numerous locations within the LBL site. During the past 20 years the Laboratory has carried out a program of slope stabilization to reduce the risk of property damage due to soil movement. The hilly terrain has often required grading and filling to provide suitable building sites. Consequently, landfills up to several tens of feet thick are present in some of the original ravines and depressions.

1.10 Hydrogeology

Highly complex groundwater 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, groundwater levels increase and cause an increase in hydrostatic pressure and a decrease in slope stability. Consequently, the Laboratory has installed an elaborate groundwater detection and drainage system. The drainage system uses both pumped vertical and free-flowing horizontal wells (hydraugers).

Water table depths vary from 10 to over 90 feet across the site (Table 1-1). Because of LBL's hillside location and moderate annual rainfall, surface run-off is a prevalent feature of the site. Two creeks and their tributaries provide natural drainage for the LBL site. Groundwater 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 (Figure 1-6).

Table 1-1. Water Table Depths

Functional Area	Depth (ft[a])
88-Inch Cyclotron Research Area	>40
Central Research and Administration Area	16-30
Bevalac Accelerator Complex	18-50
Light Source Research and Engineering Area	>20
Shops and Support Facilities Area	65-100
Material and Chemistry Research Area	10-15
Life Sciences Research Area	10-30

[a] Depths represented as > X indicate that existing borings have encountered no free water to that depth.

1.11 Water Supply

LBL receives its water from the East Bay Municipal Utility District (EBMUD) at two separate connections (Figure 1-7). The primary connection, which furnishes most of LBL water, is to the EBMUD Shasta Reservoir, which has a 2,000,000 gallon capacity, and the secondary connection is EBMUD Berkeley View tank, which has a 1,000,000 gallon capacity.

Both of the EBMUD facilities are part of the EBMUD system and are backed by many additional reservoirs, pumping facilities, aqueducts, and transmission lines. The EBMUD system has been reliable over the years and has been properly maintained, monitored, and operated.

The LBL system that distributes the EBMUD water within the site consists of an extensive piping layout providing domestic water and fire protection water to all LBL installations. The LBL system also supplies make-up water for cooling towers, irrigation water and water for other miscellaneous uses. The system includes fire hydrants and fire department connections and sprinkler services to almost all buildings.

The LBL system is looped in many areas and is equipped with block valves that can be used to isolate portions of the pipe for repair or replacement while still maintaining full service to most facilities.

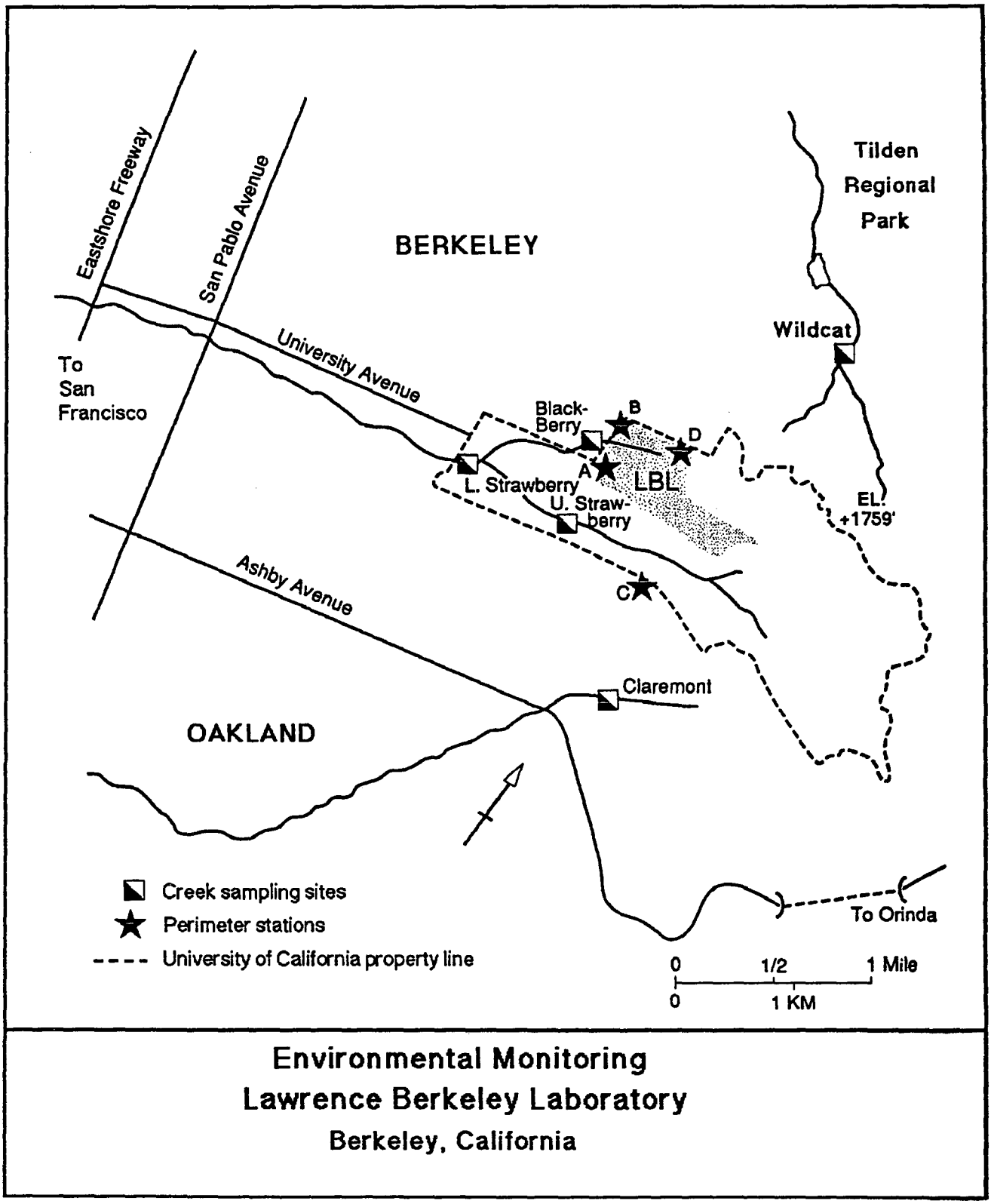

Figure 1-6. Map of LBL perimeter monitoring stations and creek sampling sites.

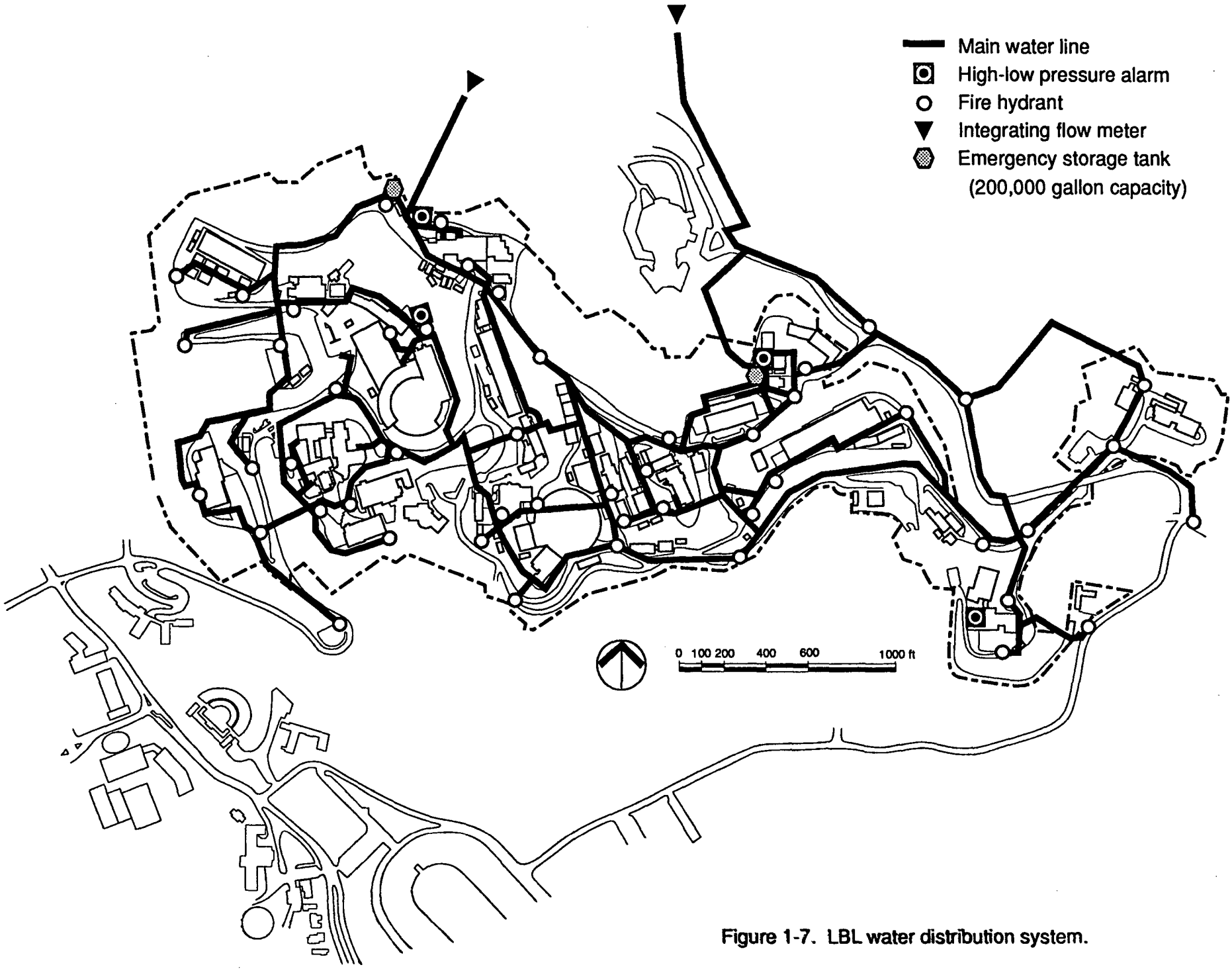

Figure 1-7. LBL water distribution system.

Because of the differences in elevation at the LBL site, there are two main pressure zones that operate at the nominal pressure of about 70 psi. The system is entirely a gravity system, except for the emergency fire protection system described later. Most of the existing pipe is either cement lined and coated steel pipe with welded joints or cast iron and/or ductile iron pressure pipe with mechanical joints. Much of the pipe has been designed and installed to resist forces caused by earth movement due to slides and /or earthquakes. All of the newer lines have been located to avoid potential unstable earth areas.

The LBL emergency fire protection system consists of two 200,000-gallon water storage tanks, one of which is located near Building 75 and the other near Building 71. At each 200,000-gallon tank site there is a diesel-driven fire pump with automatic controls that can pressurize the LBL system if EBMUD service is interrupted. In normal operation, water is slowly circulated from the LBL system through the 200,000-gallon tanks so they are always filled with potable water and the full 400,000 gallons are always available if required. The emergency fire water system was installed in about 1979. An additional 300,000-gallon water storage tank is also being proposed by LBL.

Water usage at LBL during 1985 was 122,872 CCF (CCF equals one hundred cubic feet), or 91,908,256 gallons. Based on an average population at LBL of 2,844 during 1985, this amounts to a per capita use of about 88.5 gallons per calendar day.

By 1990, water usage at LBL had declined to an estimated 105,103 CCF, or a reduction of 14 percent below 1986 levels. This reduction was due to water conservation activities at LBL in response to the five-year drought occurring in the San Francisco Bay Area and Northern California.

The water system at LBL has a high degree of reliability for both domestic use and emergency purposes. This reliability exists by virtue of the two separate connections to EBMUD sources, the two 200,000-gallon storage tanks, and the high quality of both the LBL and EBMUD systems. The system has sufficient capacity to meet the flow rate and duration requirements for fire protection; in the case where EBMUD service is not available , the capacity is limited to 400,000 gallons. There is no present restriction on the volume of water available from EBMUD, except the capacity of the existing pipes.

1.12 Sanitary Sewer Systems

The sanitary sewer system at LBL consists of pipe, manholes, and two monitoring stations (Figure 1-8). Pipe in the system is cast iron or ductile iron. The system is entirely gravity flow and discharges either through a monitoring station in Hearst Avenue or one located adjacent to Centennial Drive in Strawberry Canyon. The Hearst Avenue monitoring system services most of the buildings on the hill, and discharges approximately 60% of the water used at LBL, except those that lie within the South Strawberry Canyon watershed.

Effluent from the Hearst Avenue monitoring station flows to a manhole located above the intersection of Cyclotron Road and Highland, where it enters the City of Berkeley pipe system, which transports it to the EBMUD North Interceptor sewer. The EBMUD North Interceptor carries the effluent to the District's wastewater treatment plant south of the Bay Bridge toll plaza. Here, the wastewater undergoes primary and secondary treatment before it discharges to the San Francisco Bay.

Effluent from the Strawberry Canyon monitoring station flows through a campus sewer that ties to the City of Berkeley system at a manhole near the intersection of Rimway Road and Canyon Road, just south and east of the UC Memorial Stadium. The City system then delivers the sewage to the EBMUD North Interceptor.

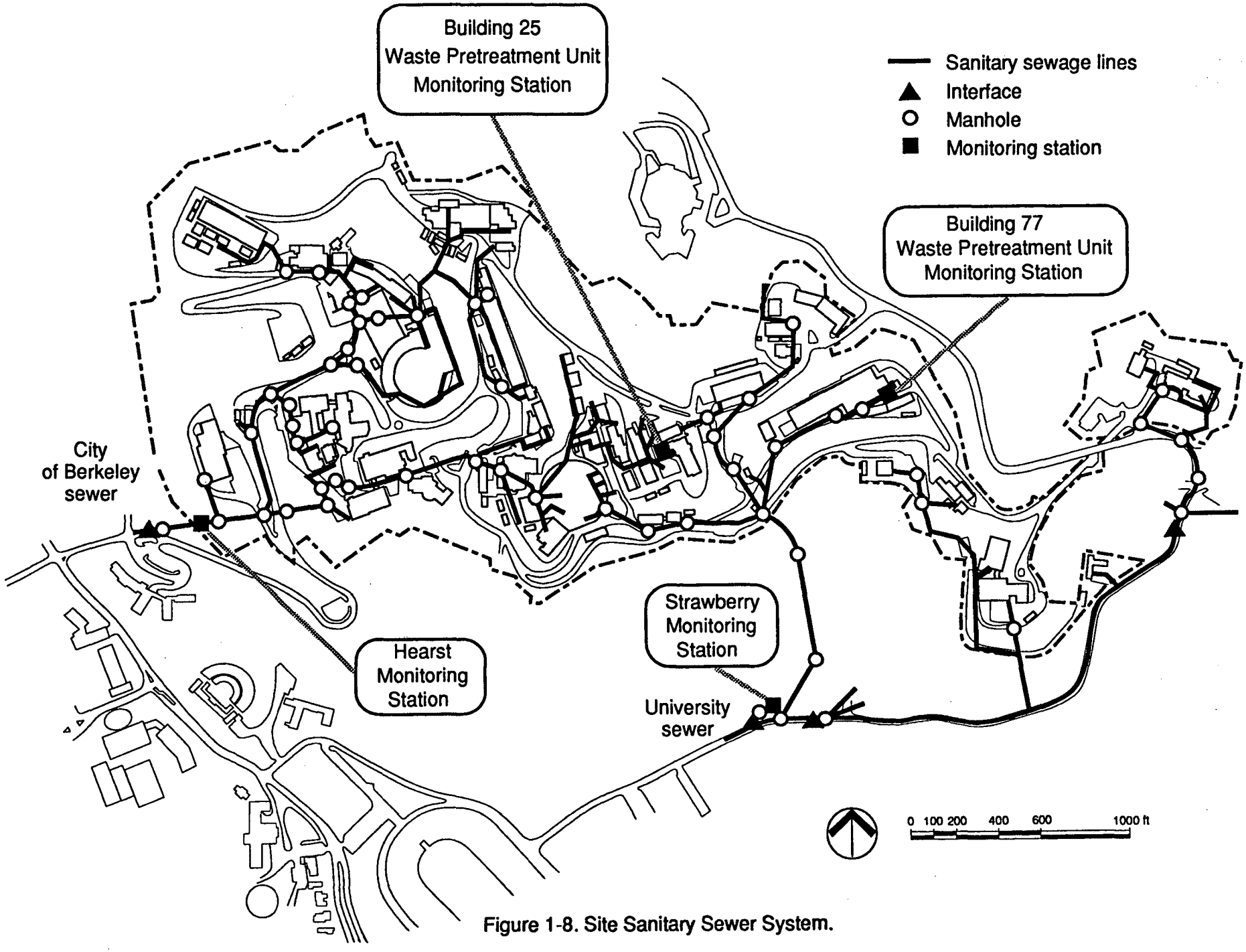

Figure 1-8. Site Sanitary Sewer System.

Several of the main sewer lines have been in service since before 1950, and some are as small as six inches in diameter. However, most of the lines are on a steep gradient and have operated satisfactorily. The monitoring stations measure the volume and the pH of the effluent on a continuous basis. Proportional samples of the sewage are also taken at regular intervals and analyzed for heavy metal content and radioactivity. After the effluent leaves the monitoring stations, it enters the City of Berkeley system, as described above. Part of the effluent flowing through the LBL monitoring stations originates from University of California Berkeley campus facilities, mainly the UC Berkeley Lawrence Hall of Science, the UC Berkeley Lawrence Hall of Science, and the UC Berkeley Space Science Laboratory.

LBL in 1991 initiated a program to check for breaks in its sewer lines and repair them. This program will reduce storm water infiltration and potential releases of sewage to the soil.

The measured wastewater volume for calendar year 1991 at LBL was 212 million liters (56 million gallons). This was approximately 70 percent of water purchased from EBMUD during this period.

A regional sewage project recently has been undertaken in the East Bay. The purpose of the project is to decrease the amount of storm water infiltration into the sanitary sewers and to provide additional transport capacity in sewer lines so that raw sewage will no longer overflow manholes or be discharged into the bay during the rainy season.

1.13 Storm Drainage System

Because of its hillside location and moderate annual rainfall, surface runoff is a prevalent feature at LBL. Consequently, an inclusive storm drain system, designed and installed in the 1960s, discharges into the Blackberry Creek watershed on the north side of LBL and the Strawberry Creek watershed on the south side (Figure 1-9). This system provides for runoff intensities expected in a 25-year maximum-intensity storm.

This watershed also includes other University of California property, public streets of both the cities of Oakland and Berkeley, and private property. The total Strawberry Creek watershed above Gayley Road contains about 874 acres. There are two main creeks in the watershed, namely the North Fork and the South Fork of Strawberry Creek.

Storm water runoff generated from LBL and from the upper parts of the Blackberry Creek watershed discharges into a 60-inch concrete culvert at the head of LeConte Avenue in Berkeley. The drainage facilities in this watershed have proven to be adequate during the heavy rains of the past few years.

Grounds and buildings in the Strawberry Creek watershed area were heavily damaged during storms in October 1962. Subsequent to that time extensive improvements have been made by LBL and UC Berkeley. Current drainage facilities have been able to accommodate all runoff since the improvements have been made. These improvements included additional pipe and culvert capacity, a retention basin, trash racks, and hardening of stream channels.

1.14 Biological Resources

During the 19th and early 20th century, the LBL site was grazing land. Cattle were managed at the site through the 1950s, and the predominant land cover was native and introduced grasses and shrubs. Much of the LBL site is now dominated by introduced trees that have grown in the past 20 to 30 years.

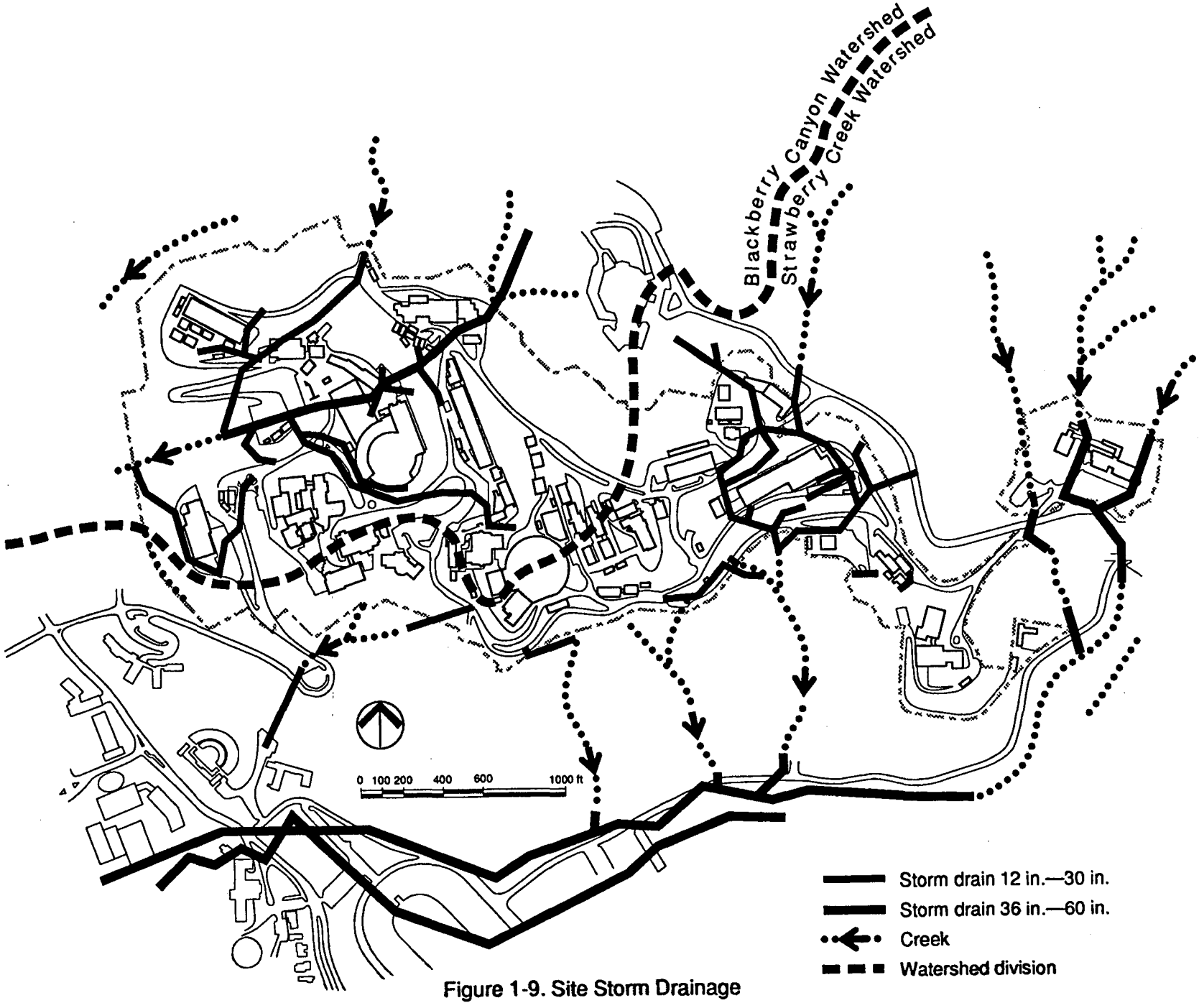

Figure 1-9. Site Storm Drainage

Most of the vegetation remaining within the LBL site is located in zones around the periphery of the site, away from the centrally developed area. Although a herd of deer are maintained on the site, cattle grazing has been eliminated.

Historically, there has been a general successional pattern from grasslands to Baccharis brushlands in areas of the Berkeley Hills where livestock grazing had been eliminated. The oak and bay woodlands in turn would replace the Baccharis brushland/early oak-bay woodland state. This suggests that the site may have been disturbed (burned, cleared, or subject to landslide) at some time within the past 25-75 years.

In general, the LBL site enjoys habitats and associated wildlife that are typical of disturbed portions of the Berkeley-Oakland hills. Approximately 79 species of birds, 20 mammal species, and 19 reptile and amphibian species can be expected to occur on or near the LBL site.

The most significant wildlife habitats within the LBL site occur in Blackberry Canyon and to some extent in the northeasterly edge of the LBL East Site area. The lower portion of Blackberry Canyon supports a relatively intact oak-bay woodland, but is completely surrounded by development. The amount of habitat present is small. The East Site area is rated as important because of the higher interspersion of habitats, and the presence of small areas of modified coastal sagebrush scrub.

The Baccharis brushland provides cover, food, and breeding sites for a variety of common birds and mammals of the region. California quail, brown towhees, white crowned sparrows, song sparrows, and scrub jays are birds typically found in this plant community, and were observed during a field reconnaissance conducted in June 1986. Brush rabbits and mule deer are the dominant mammals of this plant community, and evidence of both was noted during the survey. Nocturnal rodents, most notably deer mice, raccoons, opossum, coyote, and bobcat, are also expected to occur in the less-disturbed brushy areas along the southern perimeter of the site.

Stands of eucalyptus and Monterey pine offer nest sites for many species of birds and are potentially used by red-tailed hawks and great horned owls. Red-tailed hawk and great horned owl nests are used year after year and are noticeable during the non-breeding season. None were located during the field survey. Eucalyptus is also important to hummingbirds and other nectar-eating birds during the flowering season, providing an abundant source of high-energy food.

1.15 Seismicity

The seismically active Hayward fault, a branch of the San Andreas fault system, trends northwest-southeast along the base of the hills below the Laboratory and has the potential to produce an earthquake of approximately Richter magnitude 7.0.

The main part of the San Andreas fault system, which lies about 20 miles west of LBL, offshore beyond the Golden Gate, has a potential for a magnitude-8.3 earthquake. The Calaveras fault, another branch of the San Andreas, lies about 15 miles east of LBL. For an earthquake of given magnitude, the much-closer Hayward fault would produce the most intense ground shaking at the site.

To reduce the potential for damage from seismic activity, the Laboratory has carried out a comprehensive earth-safety program since 1971. All new facilities have been designed and constructed to resist the maximum credible earthquake estimated for the site. All existing LBL buildings were reviewed, and 32 were strengthened to meet current risk criteria.

1.16 Historical and Archaeological Resources

A surface examination of all undeveloped land and proposed building locations within the Lawrence Berkeley Laboratory was completed in preparation of the 1987 Long Range Development Plan Environmental Impact Report.

A check of the data on file with Archaeological Resource Service indicated that no new archaeological sites have been reported since their last review of this literature, performed in 1982.

Three archaeological sites have been identified that are associated with the Strawberry Creek drainage, the main natural drainage channel through the campus. The LBL area lies in the headwaters of Strawberry Creek, in the offshoot called Blackberry Canyon. No prehistoric cultural resources are reported to lie within the Lawrence Berkeley Laboratory, as delineated by the chain link fence which borders the Laboratory area.

On July 14, 1986, a surface reconnaissance was conducted of the proposed building locations at LBL and any other open ground accessible within the fenced LBL area. All reasonably accessible parts of the LBL area were examined. Special attention was given to areas of relatively flat land, or rock outcrops. The steep hillsides were not examined intensively, although transects through accessible areas were made. No indications of historic or prehistoric archaeological resources were encountered in any location within the project area.

As previously indicated, the laboratory is located on a steep hillside with limited amounts of relatively flat land. Those relatively flat areas that do exist are generally covered by buildings or parking areas. Cut and fill operations have been numerous. It appears that all of the LBL areas that might have been suitable for prehistoric occupation and use have been utilized by LBL already. Building 6 (now the Advanced Light Source and formerly the 184-inch Cyclotron) itself occupies what is probably the most likely area to have contained evidence of prehistoric human occupation or use. Thus far, no evidence of any such use has been uncovered.

2.0
Compliance Summary

2.1 1991 Calendar Year

Compliance Status

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

The environmental restoration program continued to investigate the extent of soil and groundwater contamination due to past activities. Low levels of chlorinated hydrocarbon and tritium contamination had been identified on site. The levels of contamination found in the groundwater exceed US/EPA maximum contaminant levels for drinking water; however, there are no known drinking water wells in the area (Details on specific contaminant levels may be found in the groundwater section of this report). These contaminants have not been found off site. More than 240 soil gas samples were taken and 18 monitoring and piezometric wells were installed in 1991.

Resource Conservation and Recovery Act (RCRA)

In July 1991, Cal/EPA conducted a Visual Site Inspection (VSI) as part of a RCRA Facility Assessment. The VSI is part of a comprehensive effort to identify all hazardous waste management units and other areas of concern, and to determine whether the units and areas of concern are, or have been, sources of releases of hazardous waste or hazardous constituents to the environment.

On March 21, 1991, California Department of Health Services (DHS) issued a Report of Violation as a result of an inspection in November and December of the previous year. Seventeen violations of hazardous waste control statues and regulations were found. Violations were found with regards to unpermitted treatment and storage, manifests, labels, facility access, containment, training, planning documents, inspection, and storage. The violations were reviewed and corrected within 30 days in accordance with DHS statues and regulations. Weekly inspections of the relevant areas were instituted to avoid further violations.

National Environmental Policy Act (NEPA)

During 1991, the Laboratory had three NEPA Environmental Assessments (EAs) in various stages of development. The EA for the proposed Hazardous Waste Handling Facility, was reviewed and submitted to DOE Headquarters for final approval. Preliminary arrangements for preparation of an EA for the Human Genome Laboratory were initiated and a first draft of the EA for the Mini Cyclotron - Biomedical Isotope Facility was prepared.

In addition to these larger NEPA projects, the Laboratory instituted procedures and mechanisms to ensure that all Laboratory proposed actions, such as Work for Others, general Plant Engineering projects and Field Task Proposals, received NEPA evaluations.

Clean Air Act (CAA)

The United States Environmental Protection Agency Region IX issued an Administrative Order and Finding of Violation, dated April 19, 1991, for noncompliance with all the requirements of 40 CFR 61 Subpart H, "National Emissions Standard for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities" (NESHAPS). The final rule, passed on December 15, 1989, required compliance with all provisions of the standard by March 15, 1990. Specifically, the Laboratory was found to be not in compliance with monitoring (Section 61.93) and quality assurance (Appendix B, Method 114) provisions

of the Act. The Laboratory is in compliance with the radiation dose limit of 10 mrem per year to an offsite individual. In response, LBL prepared a compliance schedule which included a series of milestones toward full compliance with all elements of NESHAPS. This schedule included three reports which were submitted to the EPA in 1991. On December 9, 1991, EPA submitted a Draft Federal Facilities Compliance Agreement (FFCA) to the DOE San Francisco Operations Office.

Four air quality violations were found by the Bay Area Quality Management District (BAAQMD) in 1991. Two involving vapor degreasers and violations regarding the freeboard ratio requirement, and one involving modification to a permitted source without obtaining an authority to construct were cited in January, 1991. The last violation for 1991, cited on September 27th, was for an illegally constructed underground tank fill pipe. All were corrected and the appropriate documentation was submitted to BAAQMD. As of this writing, the Laboratory awaits the permit paperwork for the above source from BAAQMD.

Clean Water Act (CWA)

On March 13, 1991 the East Bay Municipal Utilities District (EBMUD) identified a discharge permit violation for copper at the Building 25 Printed Circuit Board Shop Treatment Facility. The cause of the violation was determined and mitigation measures adopted to prevent reoccurrences. No other discharge permit violations ocurred at LBL during 1991.

Safe Drinking Water Act (SDWA)

Drinking water is supplied to LBL by the East Bay Municipal Utility District. There are no onsite wells.

Toxic Substances Control Act (TSCA)

On June 29, 1991, representatives of the U.S. EPA, Region IX, conducted a TSCA Section 6 Hexavalent Chromium compliance inspection of comfort cooling towers. No violations of the Federal Hexavalent Chromium regulations, 40 CFR Part 749, were found.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

LBL used registered pesticides in 1991. "Restricted use" pesticides were applied by licensed contractors. LBL personnel apply "general use" pesticides only.

Endangered Species Act (ESA)

The proposed Hazardous Waste Handling Facility (HWHF) Project was reviewed for impacts on the three listed endangered species on the LBL site. A review of endangered and threatened plant and wildlife species, known or suspected to occur within the vicinity of LBL uncovered no endangered or threatened organisms within the boundaries of the proposed HWHF Project. The absence of endangered wildlife species on LBL land was verified by the US Fish and Wildlife Service.

Executive Order 11988, "Floodplain Management"

The Laboratory's main site is not in a floodplain. All offsite projects are reviewed for floodplain management impacts.

Executive Order 11990, "Protection of Wetlands"

There are no wetlands at the Laboratory's main site. All offsite projects are reviewed for protection of wetlands.

Summary of Permits

Hazardous Waste Permits

The Hazardous Waste Handling Facility is operating under a permit issued by DHS for US/EPA, Region IX. On May, 31, 1989 a new permit application was prepared and submitted to DHS. DHS responded to LBL's submittal of the Part B Permit with a Notice of Deficiency (NOD), on December 29, 1989. A revised Part B application incorporating the items requested was submitted to the Department on August 30, 1990. A second Part B application revision in response to verbal comments from DHS was submitted on March 29, 1991. After the State approves the application, it will be submitted to US/EPA, Region IX, for approval.

Permit - By - Rule status is anticipated for five small waste treatment units:

1. Metal finishing wastewater, building 77
2. Metal finishing wastewater, building 25
3. Oil/Water separator wastewater, building 76
4. Acid wastewater, building 2
5. Acid wastewater, building 76A

Wastewater Discharge Permits

The East Bay Municipal Utility District has issued a sitewide permit and two specific permits for metal finishing operations.

Underground Storage Tank Permits

Fifteen operating permits, issued by the City of Berkeley, have been obtained for tanks containing diesel, gasoline, transformer oil, and waste oil.

Air Permits

Twenty eight operating permits, issued by the Bay Area Air Quality Management District (BAAQMD), have been obtained for equipment associated with solvent cleaning, machining, painting, wood dust collection, sandblasting, gasoline dispensing, and sulfur hexafluoride discharges. Seventy nine sources are listed by BAAQMD as exempt from permits.

2.2 Current Issues and Actions

Compliance Status

Resource Conservation and Recovery Act (RCRA)

Cal/EPA conducted a RCRA compliance inspection during February 28 to March 17, 1992. In general, the inspector noted significant improvement compared to the previous inspection. However, violations were found regarding compliance with labelling requirements and with permitted storage conditions.

National Environmental Policy Act (NEPA)

NEPA compliance activities in the first quarter of CY 1992 resulted in continued progress towards initiating the preparation of the EA for the Human Genome Laboratory and completing

the EA for the Mini Cyclotron - Biomedical Isotope Facility. Efforts aimed at expediting the Hazardous Waste Handling Facility EA through DOE Headquarters review also continued.

In response to the California Environmental Quality Act (CEQA) requirements, progress continued towards completing the Initial Study for the Mini Cyclotron - Biomedical Isotope Facility and the Supplemental Environmental Impact Report required for the proposed renewal of the operating contract between the DOE and the University of California. Progress also continued towards initiating the preparation of the EIR for the Human Genome Laboratory.

Clean Air Act (CAA)

The program initiated in 1991 to bring the Laboratory into compliance with the National Emission Standards for Radioactive Emissions, 40 CFR 61 Subpart H continued during the first quarter of 1992. A meeting between DOE/SF, LBL and EPA Region IX technical, legal and compliance staff members was held on February 13, 1992, to discuss monitoring and scheduling issues. These issues will be incorporated into the FFCA which is presently in negotiation.

Executive Order 11988, "Floodplain Management"

On January 15, 1992 a floodplain assessment was performed on a leased warehouse in Emeryville, CA (Building 901). It was determined that there are no floodplain impacts, and no flood risk mitigation measures are required.

Summary of Permits

Air Permits

Six permit applications for an Authority to Construct/Permit to Operate have been submitted to the Bay Area Air Quality Management District. One has been determined to be exempt from the permitting requirements; five are still pending.

Underground Storage Tanks

Application forms were submitted to the City of Berkeley for 15 underground storage tanks as a part of its five year permit renewal program.

Other Ongoing Environmental Activities

A DOE Tiger Team Audit was conducted in January and February 1991. According to the Tiger Team Report, numerous widespread deficiencies were identified; however, no imminent hazards were found. The Team did not recommend the cessation of any operation or the closure of any facility. Nevertheless, the Tigers identified 70 compliance and 16 best-management-practice environmental findings. Key areas of noncompliance were waste management practices, lack of quality assurance/quality control plans, lack of environmental monitoring plans, and lack of effective oversight. A Final Action Plan was accepted by DOE in October. LBL developed 85 tasks with 394 milestones to address the Tiger Team findings. As of March 1992, 19 tasks and 202 milestones have been completed.

An Agreement in Principle (AIP) was entered into between the DOE and the State of California (State) on August 31, 1990. The State's designated lead agency for the purposes of the AIP is the Department of Health Services (DHS). The AIP provides technical and financial support to the State for its activities in environmental oversight, monitoring access, facility emergency preparedness, and initiatives to ensure compliance with applicable Federal, State, and local laws at LBL and five other DOE facilities in California. In 1991 the State collected documentation in the areas of environmental monitoring, radioactive and hazardous waste, laboratory analysis, LBL organizational structures, quality assurance and quality control, and

public relations. Also, informal tours of the hazardous waste yard, monitoring stations, and the on-site analysis lab were given.

On January 7, 1992, the Attorney General for the State of California Department of Justice notified LBL that they were initiating legal action under the provisions of the California hazardous waste control laws. This was being done as a result of violations discovered during an inspection in November and December 1990. LBL is currently engaged in discussions with the state regarding settlement of these violations. On March 24, 1992, as per information package was submitted to Cal/EPA which provided them up-to-date information on LBL's compliance activities.

On February 18, 1992, a Notice of Deficiency was received from Cal/EPA and EPA regarding an RCRA Part B Application for a permit to operate the Hazardous Waste Handling Facility which was submitted on March 29, 1991. This Application was found to be incomplete and a new application was requested by July 1, 1992. LBL was advised that no more NODs will be issued and failure to provide adequate responses may result in a decision to issue a Notice of Decision to Deny the permit.

3.0

Environmental Program Information

3.1 Environmental Program Overview

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

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

DOE Orders

The requirement for the preparation of this report, its format, and the DOE environmental protection guidelines is found in DOE Order 5400.1, "General Environmental Protection Program." Radiation protection guidelines are found in DOE 5400.5, "Radiation Protection of the Public and the Environment."

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

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

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

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

Clean Air Act

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

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

The permit system requires review of equipment design and inspection of the equipment to ensure compliance with the District's requirements. Equipment requires two types of permits: an Authority to Construct, followed by a Permit to Operate. After an Authority to Construct has been issued and construction is complete, District personnel inspect the facility in operation to verify that the equipment performs as required. If it does, the District issues a Permit to Operate, which may contain specific operating conditions for equipment. All permitted sources are renewed and reinspected by the District annually. There are 28 permitted sources at LBL.

Four air quality violations were found by BAAQMD in 1991. Two involved vapor degreasers and violations regarding the freeboard ratio requirement. One involved modification to a permitted source without obtaining an authority to construct. The other was for an illegally constructed underground tank fill pipe. All were corrected and the appropriate documentation was submitted to BAAQMD.

The National Emission Standard for Hazardous Airborne Pollutants (NESHAPS), detailed in the United States Code of Federal Regulations 40 CFR 61 Subpart H, requires that facilities that release radionuclides into the air report those releases to the appropriate regional office of US/EPA in a specific format. See Appendix A for a copy of LBL's report for 1991.

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

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

Two reports were submitted to BAAQMD in 1989:

- An emission inventory plan that identifies the substances that must be reported and provides a plan to estimate the emissions from their sources.
- Emission calculations that were specified in the emission inventory plan.

This information was updated in 1991, and the information was submitted to the District on April 11, 1991.

Clean Water Act

The Clean Water Act (CWA) was established in 1977 as a major amendment to the Federal Water Pollution Control Act of 1972 and was substantially modified by the Water Quality Act of 1987. The Act provides a set of statutes intended to support the restoration and maintenance of water quality in all waters throughout the country. The CWA establishes categories of regulated waters (including surface waters and wetlands), applicable water quality standards and objectives, and permit programs regulating the discharge of facility wastewater to waters. To implement the Act, US/EPA issued pretreatment standards for industrial dischargers as well as general standards controlling toxic pollutants.

US/EPA administers the program generally, but in California, Cal/EPA, including the State Water Resources Board and the various Regional Water Quality Control Boards, administers the Federal permit and enforcement programs for both direct and indirect discharges. LBL is an indirect discharger since its wastewater is discharged to a Public Owned Treatment Works (POTW), which in turn discharges the treated effluent into surface waters. In conformance with both the Federal and state water quality regulating programs, local POTWs must adopt pretreatment standards to ensure that the sewage facility can adequately treat the wastewater it receives.

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

There are two operations that are regulated by the EBMUD pretreatment program and that have wastewater discharge permits:

1) Plating Shop, Building 77
2) Printed Circuit Board Shop, Building 25

Both operations must comply with the Metal Finishing Category Standard (40 CFR 433). In order to meet the standard's discharge requirements, wastewater pretreatment units have been installed at each shop. To ensure compliance with the pretreatment standard, the effluent from the treatment unit is tested periodically. The test methods and schedule are established by the wastewater discharge permit for each operation.

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

On March 13, 1991, EBMUD found a discharge violation for copper at the Building 25 Printed Circuit Board Shop Treatment Facility. Their test result showed a discharge level of 5 milligrams/liter (mg/l). This level exceeded the discharge limit of 3.38 mg/l by approximately 50 percent. Upon notification, the Facility operators performed an extensive evaluation of the treatment processes and procedures, and determined that the onsite test method, which used a Hach Test Kit to determine treatment effectiveness, was flawed. To prevent a recurrence, the treatment procedure was changed by replacing the onsite test method with one that requires all tests to be performed by a certified laboratory using US/EPA standard methods prior to discharge of each batch of treated wastewater. No other violations ocurred at LBL during 1991.

Recent amendments to the CWA require US/EPA to develop a permit system for stormwater runoff that may adversely affect water quality. The permit system is designed to apply facilities (or portions of facilities) where stormwater could intermingle with hazardous materials. In California, this program is being implemented by Cal/EPA through the Regional

Water Quality Control Boards. All "industrial dischargers" must prepare Stormwater Pollution Prevention and Monitoring Plans by October 1, 1992. A Notice of Intent was filed on March 26, 1992, to include LBL in the State of California General Industrial Discharge Permit.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) is a complex body of regulations intended to ensure that hazardous wastes are disposed of in an environmentally safe manner and that facilities treat, store, or dispose of hazardous waste in a way that protects human health and the environment.

RCRA established a "cradle-to-grave" system for regulating hazardous wastes, and prescribes facility standards, waste handling protocols, land disposal restrictions, record keeping, and training requirements. These requirements apply to generators and transporters of hazardous wastes, and to hazardous waste treatment, storage and disposal facilities. Generators who store hazardous waste onsite for 90 days or less must register with US/EPA, obtain an identification number, and comply with hazardous waste record keeping, labelling, training, and other handling requirements. Generators who store waste for longer than 90 days, or who treat or dispose of hazardous wastes onsite, are subject to far more extensive requirements, and must obtain a discretionary permit from US/EPA.

Although RCRA continues to be administered by US/EPA in California, delegation of the basic RCRA program (including all generator requirements) to Cal/EPA is expected in 1992. As a practical matter, Cal/EPA is already administering RCRA requirements, both by agreement with US/EPA and in the course of implementing the more stringent State Hazardous Waste Control Laws (HWCL). Both RCRA and the HWCL govern the disposal of hazardous wastes, including the disposal of mixed radioactive/ hazardous chemical wastes.

Local health departments have entered into Memorandum of Understanding with Cal/EPA [via the Department of Toxic Substance Control (DTSC), Cal/EPA's toxics unit] to administer the RCRA/HWCL requirements for hazardous waste generators. LBL's hazardous waste generator activities are regulated by the City of Berkeley Toxics Program, and the onsite treatment and storage facility is subject to the ongoing jurisdiction of DTSC and US/EPA.

Due to the nature of the research activities conducted at LBL, a large number of waste chemicals classified as hazardous under RCRA are generated; however, most are generated in relatively small quantities. In order to manage hazardous waste before offsite shipment or onsite treatment, LBL operates a RCRA permitted storage facility. This facility was initially permitted in 1983, with an expiration date established for 1988. In 1987, a new RCRA Part B permit application was submitted because of extensive modifications needed to the original permit. However, due to an extremely large workload, DHS was unable to process this revision, and the initial permit was extended pending resolution of the new application. In 1989, the 1987 application was again revised in order to update the application in general, and to add a proposed new Hazardous Waste Handling Facility. This application is currently undergoing a third revision following a series of Notices of Deficiency (NOD). The last NOD, based on an application submitted on March 29, 1991, was received on February 18, 1992. A new Part B application must be submitted by July 1, 1992. Failure to provide adequate responses by the deadline may result in the issuance of a Notice of Decision to Deny the permit.

In an effort to streamline the permitting process for hazardous waste treatment facilities and to ease the regulatory burden associated with obtaining facility permits, DTSC has developed a new procedure enabling some facilities to obtain permits more easily. The DTSC has adopted Permit by Rule (PBR) regulations for specified facilities that would otherwise be required to obtain a full permit. PBR is:

- limited to those facilities that are not required to obtain federal RCRA permits for treatment, and
- limited to the treatment of specified wastes using approved treatment technologies.

There are five wastewater treatment units that will be regulated under PBR. These are:

1) Plating Shop Wastewater, Building 77
2) Printed Circuit Board Shop, Wastewater, Building 25
3) Laboratory acid Wastewater, Building 2
4) Laboratory acid Wastewater, Building 70A
5) Oil/water Separator, Building 76

The wastewater treatment unit at the building 77 Plating Shop is currently operating under a variance that was granted in 1984.

RCRA also includes a program for regulating underground storage tanks (USTs) containing designated hazardous materials; implementing regulations establish UST construction, monitoring, and performance standards; a registration system; release reporting and closure/cleanup requirements; and financial responsibility requirements. This program is directly administered by US/EPA in California. The state UST laws predate the federal UST program, and include regulations that are similar in scope to the Federal program. Regulations implementing the state UST laws are developed by the California State Water Quality Control Board (SWQCB), and local county or fire departments administer the program's permit, inspection, and enforcements requirements. County fire and health departments generally administer the UST program by local ordinance. The City of Berkeley is the local agency designated to permit and inspect USTs and to enforce UST regulations at LBL.

The LBL facility has 15 USTs, all of which contain petroleum products (gasoline, diesel and transformer oil). Eight USTs are new double-walled tanks and seven USTs are existing single-walled tanks (Table 3-2). All of these tanks are routinely monitored for leaks.

Comprehensive Environmental Response, Compensation and Liability Act

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) provides the regulatory framework and funding needed to properly clean up closed and abandoned hazardous waste sites. Under the provisions of CERCLA, facilities are required to collect information on sites that are potentially contaminated by hazardous materials. This information is submitted to US/EPA, and the sites are ranked according to their potentials for impairing human health or damaging the environment. The sites with the highest potentials are placed on the National Priorities List (NPL) and are forced into an environmental cleanup action.

In 1991, Cal/EPA performed a RCRA Facility Assessment (RFA) of LBL for the US/EPA. This was because LBL manages hazardous waste under a RCRA Part B permit. The purpose of the RFA is to determine the potential for, and nature of, releases of hazardous waste or hazardous constituents to the environment, and to provide the scope for investigations and remedial activities to take place if warranted under corrective action permit conditions. The conclusion of the RFA was "No further remedial action planned under CERCLA." As a result, remedial actions will be performed under the RCRA Corrective Action Program.

Superfund Amendments and Reauthorization Act, Title III

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

According to SARA, facilities that handle more than the threshold planning quantities of any extremely hazardous substance are required to submit three distinct planning and inventory reports to the State and local agency. California also adopted a community right to know law called the Hazardous Materials Release Response Plan and Inventory Act (AB 2189). This act provides for the adoption of "business plans" to provide the information and emergency procedures necessary to prevent or mitigate damage to human health and the environment from the release of hazardous material. Each business that handles a hazardous material must adopt a business plan that includes both an inventory of every hazardous material it handles and emergency response plans and procedures it will follow in the event of a release or threatened release of a hazardous material. Business plans must be submitted to local administering agencies for review. This act also requires a business to report a release or threatened release immediately to the local emergency responders, local administering agency, and the State Office of Emergency Services. In California, the reporting requirements of SARA Sections 311 and 312 were incorporated into the requirements of the Hazardous Materials Release Response Plan and Inventory Law. LBL is exempt from the third report, which is required by SARA Section 313, since it applies only to facilities in SIC codes 20 to 39. At LBL, AB 2189 is enforced by the City of Berkeley.

In 1991, LBL conducted a comprehensive inventory of hazardous chemicals. The three reporting thresholds of AB 2189, which are generally smaller than those found in SARA Title III, were used. The following thresholds apply to the entire facility:

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

In addition, an emergency response plan was developed to meet the requirements of AB 2189. The inventory data and emergency response plan were packaged together in a report, called a Business Plan, and submitted to the City of Berkeley on December 22, 1989. An updated Business Plan was submitted in 1990, as required.

Toxic Substances Control Act

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

In 1987, LBL initiated a program to reduce the inventory of PCB-containing equipment. PCB capacitors have been identified and replaced with non-PCB units whenever possible. All utility transformers have been tested. Those with PCB concentrations exceeding 50 parts per million have been replaced or put into a PCB reduction program. Replacement of the high-risk indoor PCB transformers has been completed. Currently, there are no PCB transformers at LBL.

Safe Drinking Water Act

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

The sole source of water supplied to LBL is EBMUD; there are no onsite wells. EBMUD obtains its water from western-slope Sierra Nevada surface waters more than 150 km east of

LBL. Water from this source is piped to a nearby reservoir, where it is stored, treated, filtered, and tested before distribution.

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

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

Federal Insecticide, Fungicide and Rodenticide Act

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

Pollution Prevention Act

The Pollution Prevention Act of 1990 declares that source reduction is a national policy and directs US/EPA to study and encourage source reduction policies. Similarly, under the Hazardous Waste Control Law, Cal/EPA requires that facilities that treat, store, or dispose of hazardous wastes certify that generators sending hazardous wastes to their facilities have established a program to reduce the quantity and/or toxicity of hazardous wastes being generated. In addition, larger generators in California are required to evaluate source reduction opportunities, develop and implement a source reduction plan, prepare a plan summary, and prepare hazardous waste management performance reports

LBL activities in the area of waste minimization are ongoing. LBL has developed and adopted a Waste Minimization and Pollution Prevention Awareness Plan, which serves as a template for future activities in the area of waste minimization. In addition, LBL had actively pursued several waste minimization techniques, including inventory control, material and process substitution, waste segregation, and toxicity reduction. LBL also prepared and submitted to EBMUD a Waste Minimization Opportunities Assessment Report for the metal finishing activities in Buildings 25 and 77.

3.2 Environmental Permits

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

Air Emission Sources

BAAQMD issues operating permits that must be renewed annually. Twenty-eight operating permits, issued by BAAQMD, have been obtained for equipment associated with solvent cleaning, machining, painting, wood dust collection, sandblasting, gasoline dispensing, and sulfur hexafluoride discharges. The current set of permits will expire on July 1, 1992. A list of sources that have operating permits is found in Table 3-1.

Seventy-nine sources are listed by BAAQMD as exempt from permits.

Wastewater Discharges

EBMUD issues wastewater discharge permits annually. The current set will expire on July 8, 1992. LBL has three wastewater discharge permits, as follows:

1) Plating Shop, Building 25 – Permit #776-00025
2) Plating Shop, Building 77 – # 776-00077
3) LBL Site – #066-00791

Hazardous Waste

A RCRA Part A/B application is under preparation for the Hazardous Waste Handling Facility, US/EPA CA Identification Number 4890008986. The current permit is extended until resolution of the new Part B application.

Underground Storage Tanks

The City of Berkeley issues operating permits for underground storage tanks. Fees are paid annually; permits are for a five year period. The current set of permits will be renewed on July 1, 1997. There are currently 15 permitted tanks at LBL which are summarized in Table 3-2.

3.3 Environmental Assessments

During 1991 the Laboratory had three National Environmental Protection Act (NEPA) Environmental Assessments (EAs) in various stages of development. The EA for the proposed Hazardous Waste Handling Facility, originally submitted to DOE Headquarters in 1990, continued through the review process. The EA was revised in response to several iterations of comments and was submitted to DOE Headquarters for final approval. Preliminary arrangements for preparation of an EA for the Human Genome Laboratory were initiated, and a first draft of the EA for the Mini Cyclotron–Biomedical Isotope Facility was prepared.

To satisfy the requirements of the California Environmental Quality Act (CEQA), an Initial Study was prepared for the Mini Cyclotron–Biomedical Isotope Facility, and preliminary arrangements were made for the preparation of an Initial Study for the Human Genome Laboratory. The Laboratory also prepared an Administrative Draft of the Supplemental EIR required for the proposed renewal of the operating contract between the DOE and the University of California.

In addition to these larger NEPA and CEQA projects, the Laboratory proposed actions, such as Work for Others, general Plant Engineering projects, and Field Task Proposals, received NEPA and CEQA evaluations.

Table 3-1. Air Emission Source Operating Permits

Category	BAAQMD Source ID	LBL Building
Cold Solvent Cleaning Equipment		
	S-67	76
	S-72	76
	S-118	934
	S-119	77
Gasoline Dispensing Facility		
	S-76	76
Machine Shop Exhaust Systems		
	S-39	53
	S-46	58
	S-55	70A
	S-68	76
	S-84	77
	S-85	77
	S-89	77
	S-105	79
	S-114	88
	S-115	88
	S-116	79
Paint Drying Oven		
	S-104	77
Paint Spray Booths		
	S-74	76
	S-96	77
Sandblast Exhaust		
	S-97	77
Sawdust Exhaust Systems		
	S-64	76
	S-73	58
Sulfur Hexaflouride Chamber		
	S-124	58
Ultrasonic Degreasers		
	S-38	53
Vapor Degreasers		
	S-22	25
	S-92	77
	S-140	53
	S-141	76

Table 3-2. Underground Storage Tank Operating Permits

Registration Tank ID #	Location (building)	Stored Material	Capacity (gallons)	Construction	Year Installed
Fiberglass Tanks, Double-Walled					
2-1	2	Diesel	1,000	Fiberglass	1988
2-2	2	Diesel	4,000	Fiberglass	1988
Double-Walled Steel with Fiberglass Plastic Corosion Protection					
55-1	55	Diesel	1,000	Glasteel	1986
66-1	66	Diesel	4,000	Glasteel	1987
66-2	66	Diesel	2,000	Glasteel	1987
69-1	69	Waste Oil	2,000	Glasteel	1987
76-1	76	Unleaded Gasoline	10,000	Glasteel	1990
76-2	76	Diesel	10,000	Glasteel	1990
		Single-Walled Tanks			
4	51	Diesel	550	Steel	1968
6	70	Diesel	600	Steel	1953
7	70A	Diesel	1,000	Fiberglass	1975
8	74	Diesel	12,000	Fiberglass	1979
11	58	Transformer oil	2,000	Steel	1978
12	58A	Spill control	2,000	Steel	1978
14	50	Photo solution	550	Steel	1970's

3.4 Environmental Activities

The Air Emission Estimates Report calculates annual average emissions and hourly maximum emissions using mass-balance techniques where possible. Source emissions that could not be calculated will be estimated by source testing or pooled source test data. These values were determined initially in 1990 and will be updated in 1992.

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

An Environmental Monitoring and Remediation Project was initiated in 1989 as a consequence of finding elevated levels of hazardous substances in groundwater and the recognition that the extensive use, handling, and storage of hazardous substances at LBL could potentially contribute to contamination at other locations. Using the limited sampling data and the known chemical usage and handling activities at LBL, a Conceptual Design Report was developed assuming a probable contamination scenario. The preliminary investigations continued through FY 1991 and will provide further results to enhance the understanding of existing conditions. This will be followed by a detailed site characterization planned for 1992, remediation of any impaired areas, and a long-term monitoring program, if necessary.

4.0

Environmental Radiological Program Information

Penetrating Radiation

To determine the radiological impact of LBL accelerator operations, the Laboratory maintains permanent environmental monitoring stations (EMSs) at four points about LBL's perimeter (Figure 1-6).

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.[6] 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. A typical dose equivalent value for a perimeter-monitoring-station neutron detector corresponds to 0.13 mrem/pulse. A gamma-register pulse corresponds to about 1.3 mrem.

The neutron background attributable to cosmic rays measured at LBL exhibits small fluctuations about a mean value of 3.3 mrem/year.[1]

The data from the telemetry system taken during 1991 were insufficiently robust to assess the fence-post exposures attributable to accelerator operation. In spite of the foregoing, LBL has collected sufficient historical beam run vs concomitant fence-post exposures to make a reasonable estimate of the perimeter dose by accelerator beam-run history.

In analyyzing accelerator run histories the following is observed:

The relationship between fence post exposures and 88 inch cyclotron was found to be reasonably well approximated by the expression

$$H_O = 10^{-4} \sum Ae_i \, t_i \qquad (1)$$

Where H_O is the fence-post dose dose in mrem, Ae_i the average 88 inch accelerator beam current in μa-hrs at the extraction radius for the i th beam, and t_i is the beam run duration in hours.

Equation 1 reflects exposures produced during ^3He beam runs in the 88" Cyclotron's cave 2 which accounts for more than 90% of the Cyclotron's annual fence-post exposures.

During 1991 integrated beam current was roughly equal to 600 μa-hrs, and thus the fence-post exposure for 1991 is estimated to have been 600×10^{-4} mrem or 0.06 mrem.

The Bevalac beam schedule during 1991 was roughly comparable to the 1990 schedule, so the 1991 fence-post dose attributable to Bevalac operations is estimated to be equal to the 1990 value of ≤ 2 mrem.

Table 4-1 lists the estimated doses for 1991.

Table 4-1. Fence-post annual effective dose equivalent estimates at the LBL boundary due to accelerator operation, 1991.

	1991 total above background		
Monitoring station	gamma (mrem)	neutrons (mrem)	Total (mrem)
Station 13 A (Bldg. 88)	< 0.06	≤ 0.06	≤ 0.12
Station 13 B (Bldg. 90)	0	0	0
Station 13 C (Panoramic)	0	0	0
Station 13 D (Olympus Gate)	0	< 2	< 2
Standard for comparison	—	—	100[a]
(Dose to individuals at maximum point of exposure)			

(Bounding estimates based on run histories)

[a]Source: Ref. 2.

For some years, two shielded irradiators, a ^{137}Cs unit and a ^{60}Co unit had been stored in the Building 75 waste yard near the perimeter fence. In early 1991, the two units were moved behind a large earth berm to lower potential for worker exposures. The field attributable to the irradiation measured at the perimeter fence nearest to the devices was < 2 μR/hr which predicts an annual "fence post" dose of 17 mrem/year. The perimeter fence at this location is on UC land however, and there are no residences or offsite workplaces in the immediate vicinity. The nearest offsite 40-hour occupancy (The Lawrence Hall of Science) is approximately 270 m from the fence. The nearest home is approximately 500 m away, and both sites are shielded by a hillside. If the shielding by the hillside is ignored, the predicted doses from waste handling facility sources would be ~0.005 mrem/yr at the Lawrence Hall of Science (40-hr/week occupancy) or ~0.007 mrem/yr at the nearest home. The units are clearly marked, barricaded and cordoned off at the ~0.2 mrem/hr isodose line.

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

Airborne Radionuclides

LBL employs a wide variety of radionuclides in its research program, including ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{22}Na, ^{45}Ca, ^{51}Cr, $^{57,60}Co$, $^{68}Ge/Ga$, ^{54}Mn, $^{55,59}Fe$, $^{82,85,90}Sr$, ^{86}Rb, $^{95}Nb/Zr$, ^{99}Mo, ^{99M}Tc, ^{111}In, $^{123,125}I$, ^{123}Te, $^{172,175}Hf$, ^{207}Bi, ^{226}Ra, $^{227}Ac/Th$, $^{228,232}Th$, $^{231,233}Pa$, $^{235,238}U$, DEP-U, ^{237}Np, $^{238,239}Pu$, $^{241,243}Am$, $^{244,246,248}Cm$, ^{249}Bk, $^{249,252}Cf$, and ^{254}Es. Of the foregoing, the most commonly and widely used nuclides are ^{3}H, ^{14}C, ^{32}P, ^{35}S, and ^{125}I. As noted in the environmental program overview section of this report, the principal form in which nuclides are released from LBL stacks is as vapors or gases. Particulate materials are filtered from effluent streams, and

measurable particulate releases are rare. Nuclides in the foregoing list that were released to the atmosphere from LBL stacks during 1991 are ^{3}H as HTO (water vapor), ^{14}C as $^{14}CO_2$, ^{35}S as $^{35}SO_2$, and ^{125}I in various gaseous forms. Both ^{226}Ra and ^{227}Ac produce gaseous radioactive daughters, specifically two isotopes of radon—^{222}Rn and ^{219}Rn, respectively—but the quantities of ^{226}Ra and ^{227}Ac used in LBL research activities are too small to produce any consequential environmental impact. (Both ^{226}Ra and ^{227}Ac are daughters of natural uranium isotopes, ^{238}U and ^{235}U, respectively, which are found, along with their daughters, in most continental rocks and soils in concentrations of a few parts per million.)

Consequential to their operation, LBL accelerators produce air activation radionuclides, specifically, ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar inside their massive vault shields. The vaults are vented to the atmosphere. Since LBL does not yet have active monitors on the accelerator vault vents the air-activation product release estimates listed in Table 2 were calculated using a set of equations developed in Patterson, H.W., and Thomas, R.H., "Accelerator Health Physics", Academic Press, New York, NY, 1973. The model relates air activation production to Accelerator-beam energies and intensities. LBL will have air activation product monitors on all accelerators by mid 1993.

The unidentified alpha-emitter-releases figure in Table 2 is an estimate of the quantity of material that could have been released undetected (below the detection limit) from LBL stacks.

These estimated releases are represented by ^{232}Th. The calculated human exposure from such releases would be less than 0.02 mrem/yr to a maximally exposed offsite individual.

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

Silica-gel HTO samples are changed weekly. Each of the four perimeter environmental monitoring stations contains a tritium sampler, as does the Building 3 site. In addition, the Lawrence Hall of Science (LHS), a facility on UC land north of LBL's perimeter, the UC Mathematical Science Research Institute (MSRI), and an enclosure located at the northeast corner of Building 69A are similarly monitored. These eight locations are identified in Figure 4-1. The stack from the tritium-labeling facility is also monitored for tritium as described above.

Triethylene diamine (TEDA)-doped activated carbon cartridges are used to sample air for radioiodine at the four perimeter stations shown in Figure 1-6. Radioiodines in air, specifically ^{125}I, is assayed by analyzing the activated-carbon cartridges with a sodium iodide detector connected to a multichannel analyzer. The detection limit for ^{125}I is 4×10^{-15} μCi/ml.

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

Gross atmospheric particulate beta and alpha activities are measured by air sampling at the 14 points shown in Figure 4-2.

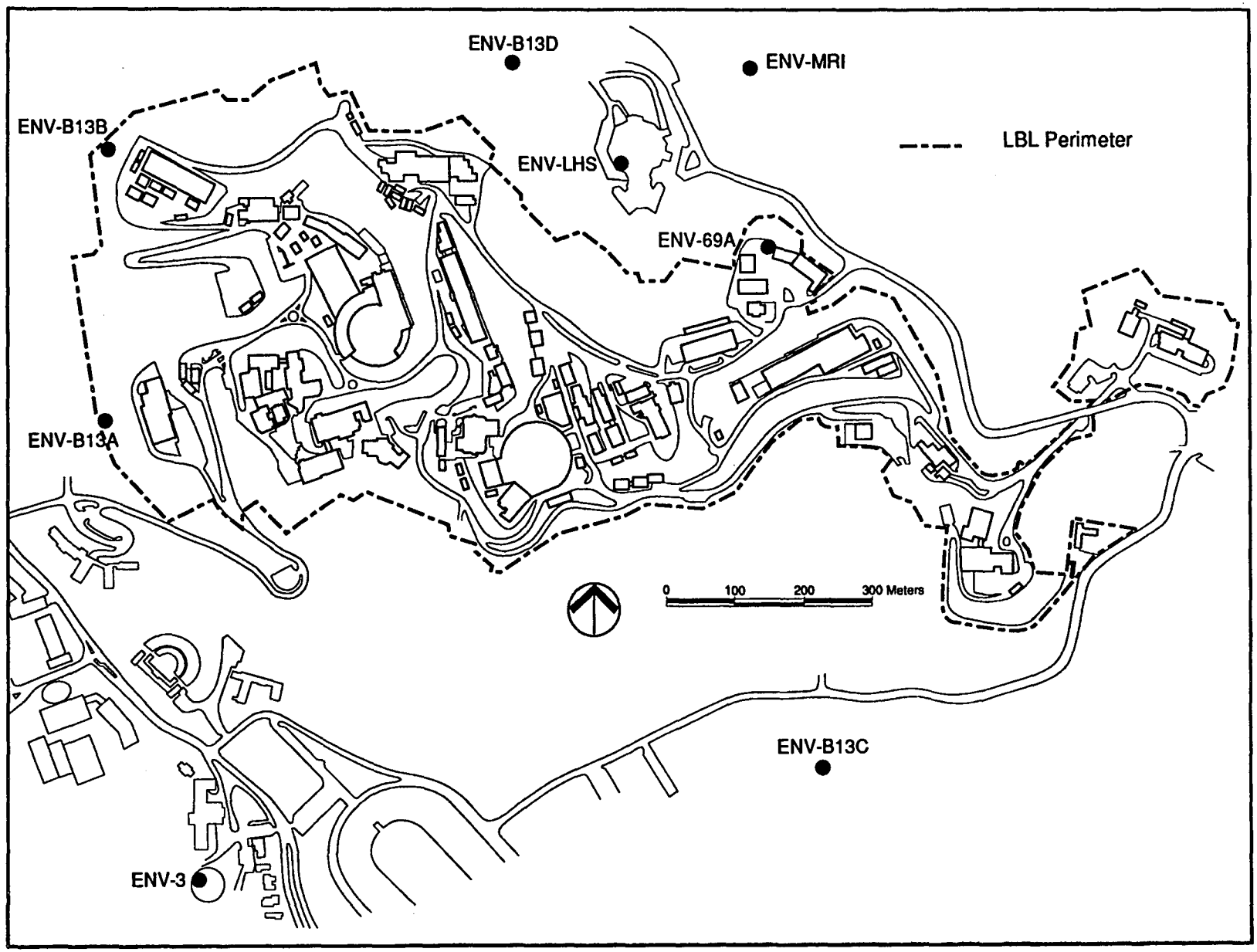

Figure 4-1. Map of airborne environmental tritium sampling sites

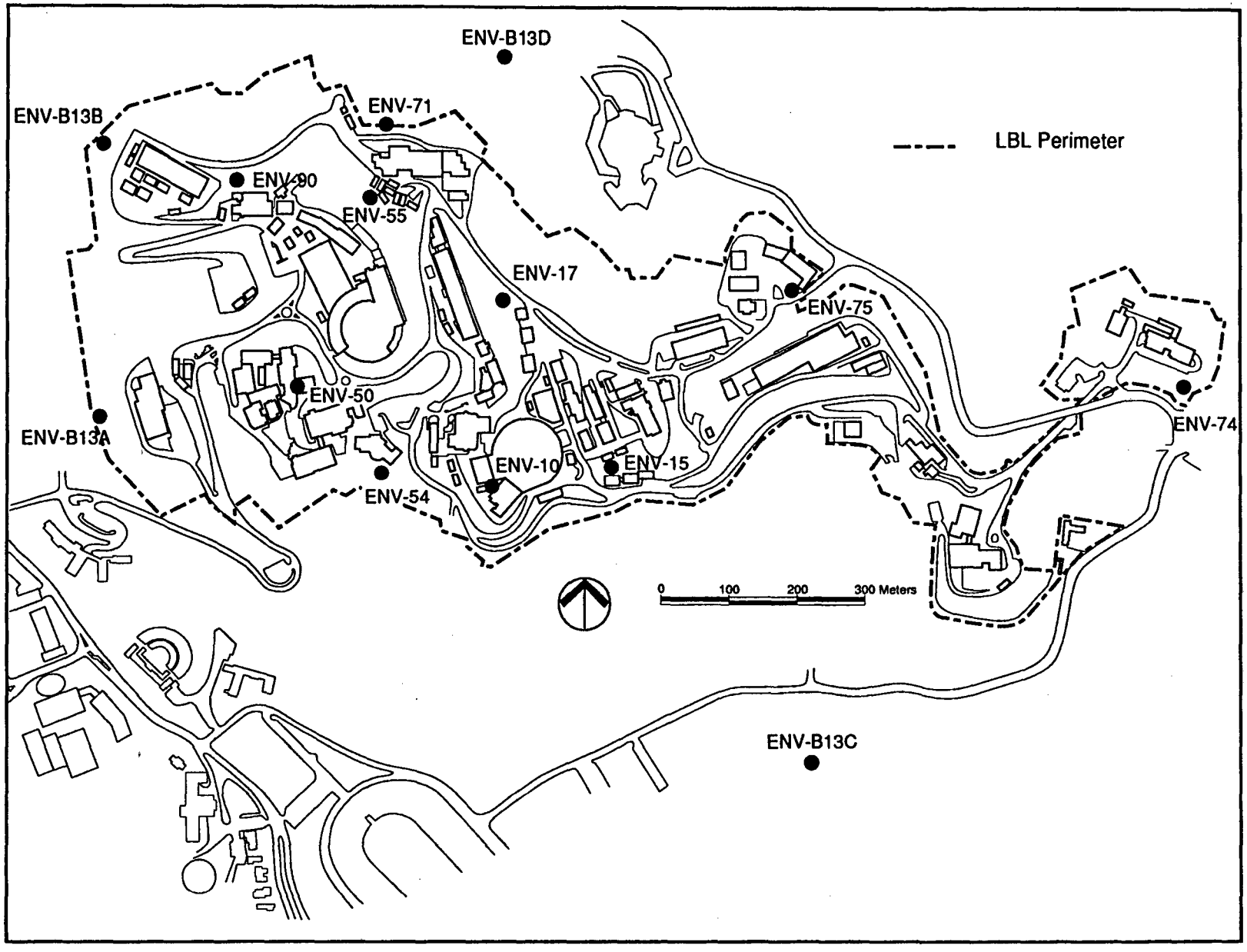

Figure 4-2. Map of airborne radioactive particulate sampling sites

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

Samples are removed weekly. Before they are counted, they are set aside for five days to allow short-lived radon and thorium daughters (naturally occurring airborne radionuclides) to decay. The filters are loaded into an automatic counter that determines gross alpha activity by means 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.

Alan R. Smith of LBL's Low-Background-Counting Facility (LBCF), located in Bldg. 72, aggregated the 14 weekly environmental particulate air samples into sets and analyzed the sets for airborne particulate gamma-emitting nuclides. The sets were allowed to decay for at least two weeks and then analyzed with a large high-purity germanium detector. Each set represented particulates collected from ~14,500 m^3 of air, and was counted for a minimum of 1,000 minutes. The only 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 3.7×10^{-14} to 2.3×10^{-13} μCi/ml and averaged 1.0×10^{-13} μCi/ml, which is < 0.003% of the DCG. The detection limit for ^{7}Be is 2×10^{-16} μCi/ml for a 1,000 minute count. The concentrations of ^{210}Pb from ARS, a natural air contaminant, ranged from 2.9×10^{-15} to 5.5×10^{-14} μCi/ml and averaged 1.3×10^{-14} μCi/ml.

Inasmuch as the DOE Orders[2] make no provision for unidentified radionuclides, throughout this report unidentified radionuclides will be conservatively labeled ^{232}Th if they are alpha-emitting material or ^{90}Sr if beta-emitting material. The assertion of conservatism is made because, although ^{90}Sr and ^{232}Th are used at LBL, they are only in a few LBL laboratories and, for isotopes used at LBL, represent the most restrictive beta and alpha emitters, respectively, listed in Ref. 2. Although ^{227}Ac, which is 4500 times more restrictive a beta emitter than ^{90}Sr, is also used at LBL, its most likely state is in equilibrium with its alpha-emitting daughters, 18-day ^{227}Th and 14-day ^{223}Ra, and it would thus be detected as an alpha emitter.

The total quantities of radionuclides discharged into the atmosphere are summarized in Table 2. Aside from the 1991 tritium release that is 53% of the 1990 value, the figures are similar to those of last year, and the releases resulted in a small collective effective dose equivalent (see Table 1 and the section on Public Doses Resulting from LBL Operations of this report).

One may note that a number of the average values listed in several of the tables in this report (notably Tables 4-2, 4-4, 4-5, 4-7, 4-9, and 4-11) are less than the minimum values listed for individual samples. This occurs whenever the actual average value of a substance measured is less than the detection limit for that substance in an individual sample, and the average represents the arithmetic sum of all measurements divided by the number of measurements taken (as in this report). The uncertainties listed with tabular quantities represent 95% confidence limits of the assay values (or sum of assay values).

Although small quantities of radionuclides (Table 2) were discharged into the atmosphere during 1991, the data from the general environmental air sampling were within the range of historical background values.

The environmental air sampling program for ^{14}C and ^{3}H found detectable concentrations of these nuclides (Tables 4-2 and 4-3). The radioiodine sampling program (Table 4-4) detected no significant ^{125}I in perimeter air during 1991. Essentially, 100% of the tritium released from LBL was discharged from the Building 75 stacks. Table 4-5 summarizes the gross particulate radioactivity measured in LBL air samples during 1991. The Table 4-5 data for 1991 may be compared with data from Table 4-6, which lists LBL perimeter air-sample-data maxima and averages for the period 1982–1991.

Waterborne Radionuclides

Rainwater (see Figure 4-3); creek water (see Figure 1-6); groundwater, which flows from the horizontal wells (hydraugers), whose bores are represented by the heavy dashed lines in Figure 4-4; and sewage from LBL's two sewer outfalls are analyzed for tritium, gross beta, and alpha emitters (see Figure 4-4; the Strawberry Sanitary Sewer is the southern site; Hearst is the western sewer). Additionally, sewer effluent is analyzed for gross halogen (radioiodine) content. (Hydrauger sampling procedures and results are discussed in the Groundwater Protection section of this report.)

The four perimeter environmental monitoring stations have 46-cm-diameter (18-in.) cylindrical rainfall collectors on their roofs. During rainy months (generally October through May), rainwater is collected monthly and analyzed for tritium and for gross alpha and beta activities. During the dry California summer, each collector is rinsed monthly with a quart of tap water, and the rinse is analyzed for "dry deposition." The nine onsite locations shown in Figure 4-3 also contain 46-cm-diameter (18-in.) combination rain/dry deposition collectors, which are sampled on a monthly basis in the same manner as the four perimeter environmental monitoring stations.

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

All measurements of gross alpha and beta activity from atmospheric deposition at outlying perimeter and onsite stations lie within the range of historical normal background measurements; however, tritium exceeding the US/EPA Drinking Water Standards was detected in rainfall collected within the Laboratory boundary near the stack from the Building 75 Tritium Facility (Tables 4-7 and 4-8). The deposition values, adjusted for rainfall, are compared with the Safe Drinking Water Act standards found in drinking-water standards. As mentioned earlier, local drinking water is supplied by EBMUD from sources located more than 150 km east of LBL. EBMUD uses no well water or local surface water as drinking water.

Sewer outfalls are sampled continuously, sample-to-flow ratios are designed to be between 10 and 20 parts per million, and composite samples are taken weekly. The five creek sample points indicated in Figure 1-6 are sampled weekly. A 1-qt grab sample is taken from each site and analyzed for tritium and gross alpha and beta emitters.

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

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

Table 4-9 summarizes the 1991 data from the surface- and tap-water sampling programs. The results are similar to those obtained in past years, and all lie within historical normal range of background activity. Table 4-10 summarizes the surface- and drinking-water samples for 1982–1991.

Table 4-11 summarizes the sewage sampling data for 1991. The average and maximum values listed for sewer beta concentrations reflect the weekly activity found in the more radioactive of the acid or radioiodine planchettes. Table 4-12 summarizes the sewage data for the years 1982–1991.

Table 4-2. Summary of airborne environmental HTO and $^{14}CO_2$ sampling, 1991.

	No. of samples	Concentration (10^{-9} mCi/ml) Avg.	Min.	Max.	Average as % of standard
Samples for Tritium as HTO					
On-Site					
ENV 69A	48	0.2 ± 0.1	≤ 0.7	1.4 ± 0.5	0.2
ENV 3	48	≤ 0.1	≤ 0.7	≤ 0.7	≤ 0.1
Perimeter					
MRI	48	0.2 ± 0.1	≤ 0.7	5 ± 1	0.2
LHS	48	≤ 0.1	≤ 0.7	≤ 0.7	≤ 0.1
B-13A (Bldg 88)[a]	48	≤ 0.1	≤ 0.7	≤ 0.7	≤ 0.1
B-13B (Bldg 90)	48	≤ 0.1	≤ 0.7	≤ 0.7	≤ 0.1
B-13C (Panoramic)	48	< 0.1	≤ 0.7	≤ 0.7	≤ 0.1
B-13D (Olympus)	48	≤ 0.1	≤ 0.7	2 ± 0.7	≤ 0.1
Standard for Comparison[a]	—	100	—		—
Samples for Carbon-14 (as $^{14}CO_2$)					
On-Site					
ENV 3	49	≤ 0.03	≤ 0.2	≤ 0.2	≤ 0.006
Standard for Comparison[a]	—	500	—	—	—

[a]Source: Ref. 2.

Table 4-3. Summary of perimeter airborne environmental HTO and $^{14}CO_2$ sampling, 1982–1991.

Year	No. of Samples	Concentration (10^{-9} mCi/ml) HTO Avg.	HTO Max.	No. of Samples	$^{14}CO_2$ Avg.	$^{14}CO_2$ Max.
1982	102	0.3 ± 0.1	3 ± 1	51	< 0.04	0.3 ± 0.2
1983	101	0.4 ± 0.1	3 ± 1	49	< 0.01	0.3 ± 0.2
1984	97	0.5	7 ± 3	51	0.6	30 ± 10
1985	102	≤ 0.3	5 ± 1	50	≤ 0.1	1.1
1986	100	0.5 ± 0.1	12 ± 3	51	0.07 ± 0.02	0.4 ± 0.1
1987	97	< 0.5	5 ± 1	51	< 0.05	0.4 ± 0.1
1988	144	0.2 ± 0.1	3 ± 1	51	< 0.05	0.2 ± 0.1
1989	142	0.2 ± 0.07	3 ± 1	50	<0.06	<0.3
1990	204	≤ 0.1	3 ± 1	49	≤ 0.03	0.4 ± 0.1
1991	268	≤ 0.1	5 ± 1	49	≤ 0.03	≤ 0.2
Standard for comparison[a]		100		500		

[a]Source: Ref. 2.

Table 4-4. Summary of radioiodine in perimeter air samples, 1991.

Perimeter Station	No. of samples	Concentration (10^{-15} mCi/ml) ^{125}I Avg.	Min.	Max.	Average as % of standard ^{125}I
Bldg. 88	45	8 ± 1	≤ 10	400±80	0.0016
Bldg. 90	45	7 ± 1	≤ 10	300±40	0.0014
Panoramic Way	45	4 ± 1	≤ 10	90±20	0.0008
Olympus Gate	45	8 ± 1	≤ 10	200±30	0.0016
Standard for comparison[a]		5×10^5			

[a]Source: Ref. 2.

Table 4-5. Summary of gross particulate radioactivity in air samples, 1991.

		Concentration (10^{-15} µCi/ml)						Average as % of standard	
		Alpha			Beta				
	No. of samples	Avg.	Min	Max[a]	Avg.	Min.	Max[a]	Alpha	Beta
On-site average of 10 locations	488	0.41±0.11	≤ 2	4 ± 1	12 ± 2	≤ 80	170 ± 30	6	0.1
Perimeter Stations									
Bldg. 88	47	≤ 0.5	≤ 3	4 ± 1	18± 6	≤ 120	180±130	≤ 7	0.2
Bldg. 90	47	≤ 0.5	≤ 3	4 ± 1	≤ 16	≤ 120	≤ 120	≤ 7	≤ 0.2
Panoramic Way	47	≤ 0.5	≤ 3	5 ± 1	≤ 17	≤ 120	≤ 120	≤ 7	≤ 0.2
Olympus Gate	47	≤ 0.5	≤ 3	5 ± 1	≤ 17	≤ 120	180±130	≤ 7	≤ 0.2
Standard for Comparison[b]		7			9,000				

[a]Highest single weekly sample.

[b]Source: Ref. 2—alpha conservatively assumed to be ^{232}Th; beta assumed to be ^{90}Sr.

Table 4-6. Annual gross particulate radioactivity found in LBL perimeter air samples, 1982–1991.

		Concentration (10^{-15} µCi/ml)			
		Alpha		Beta	
Year	No. of Samples	Avg.	Max.	Avg.	Max.
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[a]
1987	191	≤ 0.5	5 ± 3	≤ 16	200 ± 160
1988	197	≤ 0.5	5 ± 3	≤ 16	130 ± 120
1989	191	0.45 ± 0.35	5 ± 3	<16	170 ± 130
1990	204	≤ 1.3	5 ± 3	≤ 16	140 ± 120
1991	188	≤ 0.5	5 ± 2	≤ 16	180 ± 130
Standard for comparison[b]		7		9000	

[a]Chernobyl fire, April 26, 1986.

[b]Source: Ref. 2—alpha conservatively assumed to be ^{232}Th; beta conservatively assumed to be ^{90}Sr.

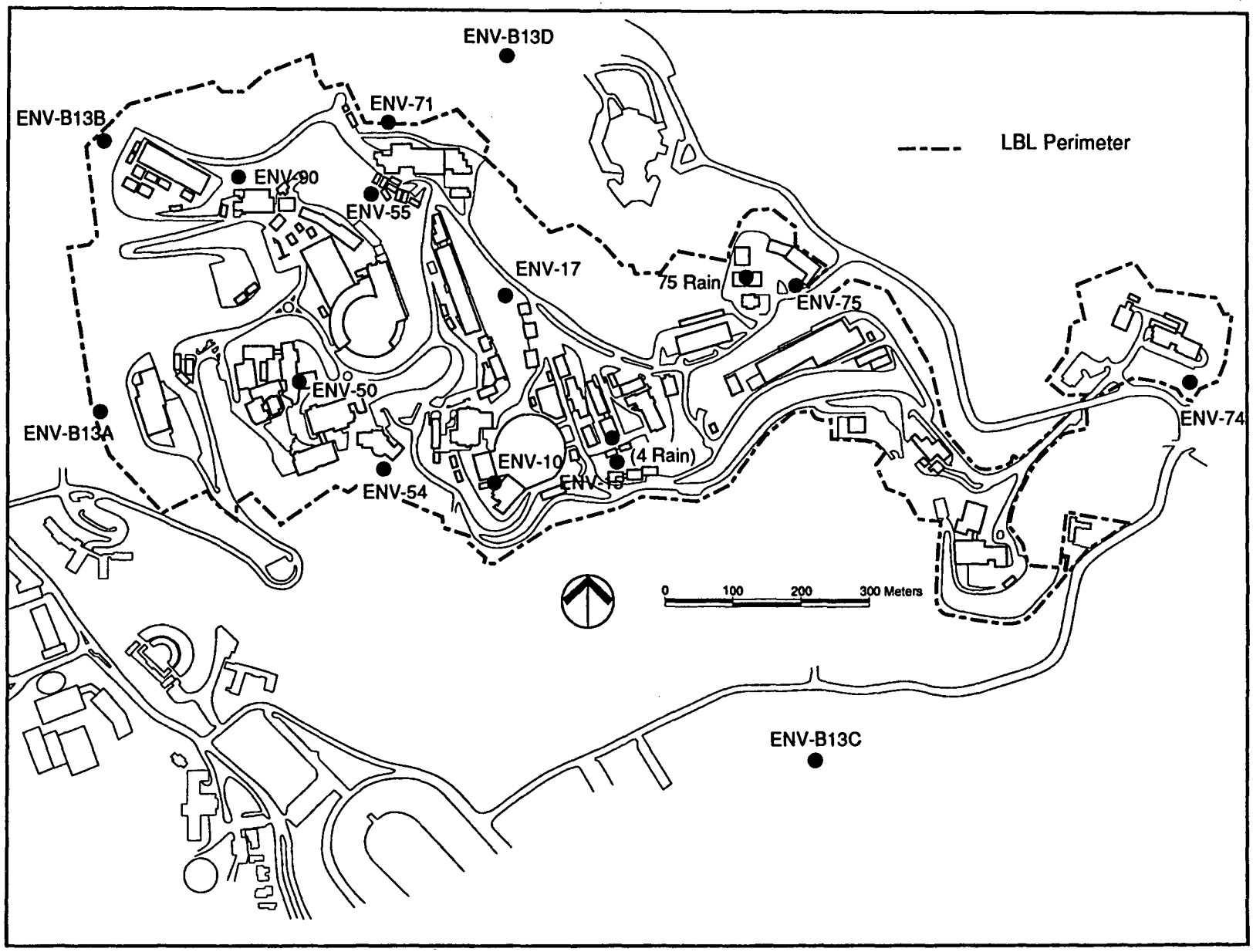

Figure 4-3. Map of rain and dry deposition collectors

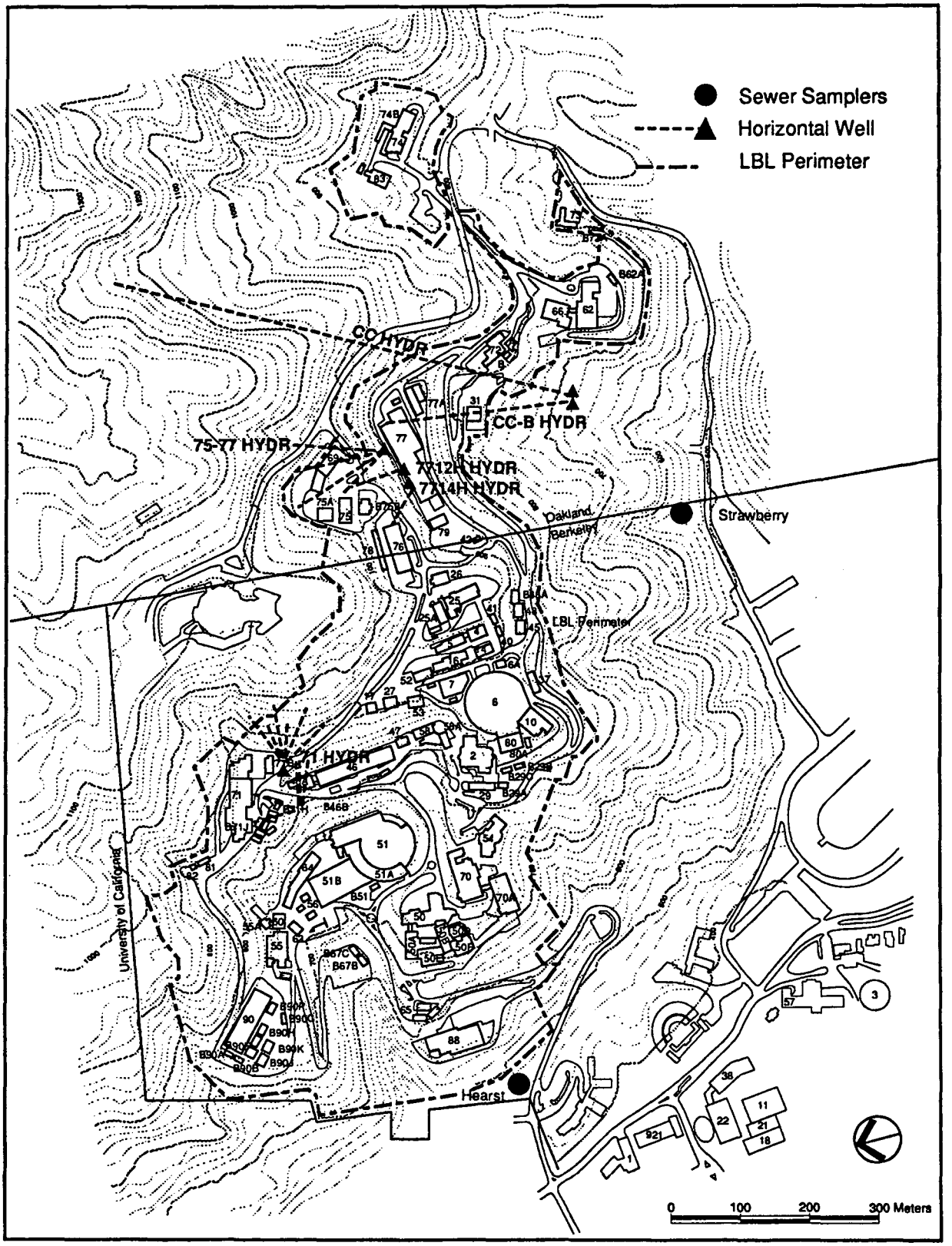

Figure 4-4. Map of LBL hydrauger and sewer smpling sites

Table 4-7. Summary of atmospheric deposition, 1991.

	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 (12 locations)	120	0.06	0.1	0.9	0.07	2.7	160	0.7± 0.2	0.7± 2
Perimeter (4 locations)	48	0.06	0.1	0.8	0.4	1.6	24	≤ 0.01	≤ 0.2
Perimeter Averages as a % of Standards		3		22				< 0.1	
Drinking-water standard × 460[c]		2.30		3.68				9.20	

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

[b]Highest total for any one site.

[c]The standards used for comparison are derived from 40 CFR 141 for alpha and beta (^{90}Sr) values. The deposition represents that quantity of activity found in 459 liters of water (the average quantity of rainfall/m^2 during 1991). Thus, the values used are 469 times the 40 CFR 141 values. [No standards for comparison have been established, so drinking-water standards (radionuclide concentration/l) are used.]

[d]The location of this deposition collector is on the north side of Bldg. 75 (see Fig. 4-3). The average HTO concentration in samples taken from the Bldg. 75 collector was 26 × 10^4 pCi/l, or about 1.3 times the HTO drinking-water standard.

Table 4-8. LBL perimeter station deposition trends, 1982–1991.

			Concentration (10^{-3} mCi/m^2)				(mCi/m^2)		
			Alpha		Beta			HTO	
Year	No. of Samples	Rainfall (cm)	Avg.	Max.	Avg.	Max.	No. of Samples	Avg.	Max.
1982	48	109.0	< 0.01	0.017	1.9	5.2	36	< 0.2	0.3
1983	48	119.4	0.02	0.07	1.6	3.5	36	< 0.2	0.4
1984	48	45.5	0.05	0.08	< 1	3	36	< 0.2	0.2
1985	48	44.5	0.02	0.4	0.7	2	27	< 0.2	0.2
1986	48	81.4	0.03	0.04	0.8 ± 0.2	2	29	0.1	0.3
1987	48	53.4	≤ 0.04	0.06	0.8 ± 0.5	2	24	0.1	0.2
1988	48	45.5	0.03	0.06	0.6	1.4	35	0.6	0.9
1989	48	47.8	0.04	0.04	0.8	1.7	28	0.2	0.6
1990	48	47.4	0.02	0.04	0.6	1.3	36	≤ 0.01	< 0.05
1991	48	46.0	0.06	0.1	0.8	1.6	24	≤ 0.01	≤ 0.2

Public Doses Resulting from LBL Operations

Accelerator-Produced Radiation

The development of LBL's model used to assess the population dose equivalent attributable to penetrating radiation is detailed in Ref. 1. The model used population figures from the 1970 U.S. census.

Although the population within 80 km (50 mi) of LBL increased by 13% during the 1970s[5,8,9] from 4.6 to 5.1 million, the populations of Berkeley and Oakland, the two cities immediately adjacent to LBL, declined. Recomputing the population dose model with population statistics from the 1980 census produced no significant difference in its impact/insult value.

The LBL model developed by Thomas[1] computes population dose equivalent from the maximum measured value of perimeter (fence-post) neutron dose. During 1991 the maximum fence-post dose, estimated at the Olympus Gate Monitoring Station, was ≤ 2 mrem for the year (Table 4-1). The model's expression relating population dose equivalent M (in person-rem) to maximum measured fence-post dose H_o (in rem—a rem is 1000 mrem) is

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

where f = the fraction of the fence-post dose contributed by the 88-Inch Cyclotron and/or the SuperHILAC. For 1991, f = 0 [in Eq. (1) as the telemetry information was not available we must conservatively assign all of the dose to the Bevatron].

Thus the expression becomes

$$M < 10^3\, H_o\ . \qquad (2)$$

Since H_o was ≤ 2.0 mrem (or ≤ 0.002 rem), the collective effective dose equivalent (CEDE) to the 5.1 million people within 50 miles of LBL attributable to penetrating radiation from LBL accelerator operation during 1991 was ≤ 2 person-rem.

Table 4-9. Summary of surface- and drinking-water samples, 1991.

		Concentration (10^{-9} µCi/ml)						Concentration (10^3 pCi/l)					
		Alpha			Beta			Tritium as HTO			Average as % of standard		
	No. of samples	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max	Alpha	Beta	Tritium
On-site streams													
Blackberry	49[a]	≤ 0.4	≤ 0.7	4 ± 3.5	2.4 ± 0.1	0.8 ± 0.7	4 ± 1	0.2 ± 0.04	≤ 0.7	7 ± 1	≤ 8	30	1
Lower Strawberry	49	≤ 0.2	≤ 1.0	4.3 ± 2	2.0 ± 0.1	≤ 0.6	5 ± 1	≤ 0.1	≤ 0.7	3 ± 0.4	≤ 4	25	≤ 0.5
Upper Strawberry	49	≤ 0.6	≤ 0.3	11 ± 6	2.1 ± 0.1	≤ 0.7	6 ± 1	≤ 0.1	≤ 0.7	1 ± 0.4	≤ 12	26	≤ 0.5
Average		≤ 0.4			2.2			≤ 0.2			≤ 8	28	≤ 1
Off-site streams													
Claremont	49	1.1 ±0.4	≤ 0.8	21 ± 8	2.4 ±0.1	≤ 0.6	9 ± 2	0.08±0.04	≤ 0.7	4 ± 0.4	22	30	0.4
Wildcat	49	≤ 0.4	≤ 1	4.2 ± 4.0	1.4 ± 0.1	≤ 0.7	4 ± 1	≤ 0.1	≤ 0.7	2 ± 0.3	≤ 8	18	0.5
Tap Water	49	≤ 0.06	≤ 0.5	1.2 ± 0.7	0.9 ± 0.1	≤ 0.5	2 ± 0.7	0.08±0.04	≤ 0.7	4 ± 1	≤ 1.2	11	0.4
Standard of Comparison[a]		5			8			20					

[a]Only 48 samples are included in the HTO values for Blackberry Creek. One outlier was rejected.
[b]Source: 40 CFR 141.

Table 4-10. Summary of surface- and drinking-water samples, 1982–1991.

	Concentration (10^{-9} µCi/ml)								Concentration (10^{3} pCi/l)			
	Three On-site Streams				Two Off-site Streams				Drinking Water			
	Alpha		Beta		Alpha		Beta		Alpha		Beta	
Year	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
1982	< 0.3	3 ± 2	1.7 ± 0.1	5 ± 1	< 0.3	5 ± 3	1.4 ± 0.1	6 ± 1	< 0.1	1.1 ± 0.5	0.9 ± 0.1	2.2 ± 1
1983	< 0.1	4 ± 2	1.5 ± 0.1	4 ± 1	< 0.3	< 2	1.2 ± 0.1	4 ± 2	< 0.04	1.2 ± 0.5	0.9 ± 0.1	2.3 ± 0.7
1984	< 0.13	< 2	1.6 ± 0.3	3 ± 1	0.6 ± 0.3	3 ± 2	1	8 ± 1	0.03	0.3	0.9 ± 0.1	7 ± 1
1985	< 0.2	< 2	2 ± 0.5	25 ± 2	≤ 0.3	≤ 3	1 ± 0.1	5 ± 1	0.06 ± 0.05	≤ 2	0.9 ± 0.1	2 ± 1
1986	< 0.2	8 ± 5	2.3 ± 0.1	27 ± 2	0.4 ± 0.3	4 ± 3	1.6 ± 0.1	10 ± 2	0.06 ± 0.04	< 0.4	1.1 ± 0.1	6 ± 2
1987	≤ 0.2	7 ± 4	1.7 ± 0.1	13 ± 2	0.4 ± 0.2	≤ 3	1.5 ± 0.2	5 ± 1	< 0.03	< 0.4	0.7 ± 0.1	1.5 ± 0.7
1988	≤ 0.2	6 ± 4	2.9 ± 0.2	110 ± 20	≤ 0.2	3 ± 2	1.0 ± 0.1	9 ± 2	≤ 0.04	≤ 0.5	0.7 ± 0.1	1.7 ± 0.8
1989	≤ 0.3	15 ± 8	2.2 ± 0.2	22 ± 2	≤ 0.4	6 ± 4	1.5 ± 0.1	5 ± 1	≤ 0.07	< 3	0.9 ± 0.1	2.1 ± 0.8
1990	≤ 0.2	< 2	2.1 ± 0.1	5.1 ± 1	≤ 0.2	≤ 3.5	1.7 ± 0.1	6 ± 1	≤ 0.04	≤ 0.5	0.8 ± 0.1	1.4 ± 0.6
1991	≤ 0.4	7 ± 1	2.1 ± 0.1	6 ± 1	≤ 0.7	21 ± 8	1.9 ± 0.1	9 ± 2	≤ 0.06	1.2 ± 0.7	0.9 ± 0.1	2 ± 0.7

Table 4-11a Summary of sewage sampling data, 1991.

	Total quantities discharged			
	Total volume (10^6 liters)	Alpha (μCi)	Beta Emitters	Quantity mCi
Hearst Sewer	140	≤ 5	Gross	3 ± 1
			Tritium	≤ 7
Strawberry Sewer	80		Gross	0.9 ± 0.3
		≤ 2	Tritium	290 ± 50
Standard for comparison[e]		—		1000

[a]California Code of Regulations (CCR) Title 17

Table 4-11b. Summary of sewage sampling data, 1991 (continued).

		Concentration (10^{-9} μCi/ml)							Concentration (10^3 pCi/l)			Average as % of standard		
		Alpha[a,b]			Beta[c]				Tritium			Alpha[b]	Beta[c]	Tritium
	No. of samples	Avg.	Min.	Max.	Avg.	Min.	Max.	No. of samples	Avg.	Min.	Max.	%	%	%
Hearst	93	≤ 0.2		7 ± 3	17 ± 4		60 ± 20		≤ 0.1	≤ 0.7	4 ± 2	≤ 0.4	1.7	0.005
Strawberry	88	≤ 0.3		5± 2	12 ± 3		30 ± 10		4 ± 1	≤ 0.7	18 ± 4	≤ 0.6	1.2	0.2
Overall	181	0.2			15 ± 3				1.2 ± 0.3			≤ 0.4	1.5	0.06
Standard for comparison[e]		50			1000				2000					

[a]The alpha values are based on 47 Hearst and 44 Strawberry samples, respectively.

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

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

[e]Source: Ref. 2.

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

Table 4-12. Sanitary-sewer discharge trends, 1982–1991.

			Concentration (10^{-9} µCi/ml)						Concentration (10^{-9} µCi/ml)			
			Hearst						Strawberry			
		Total	Gross alpha		Gross beta			Total	Gross alpha		Gross beta	
Year	No. of Samples	Flow (10^6l)	Avg.	Max.	Avg.	Max.	No. of Samples	Flow (10^6l)	Avg.	Max.	Avg.	Max.
1982	42	300	0.05	1.1	20	460 ± 20	29	180	0.5	17 ± 12	60	640 ± 40
1983	49	190	0.05	< 5	9	80 ± 7	38	140	< 0.4	< 20	60	640 ± 401
1984	51	170	0.02	< 5	80	1100 ± 50	39	74	0.02	< 2	70	250 ± 10
1985	50	160	< 0.2	< 3	15	90 ± 10	49	120	< 0.2	< 2	140	1600 ± 30
1986	47	200	< 0.1	1 ± 0.3	10 ± 1	50 ± 10	47	110	< 0.1	1.1 ± 0.3	400 ± 10	4200 ± 700
1987	44	140	≤ 0.1	≤ 1.4	11 ± 2	80 ± 20	48	120	≤ 0.1	1.2 ± 1.1	180 ± 40	2200 ± 500
1988	41	160	≤ 0.1	≤ 1.1	9 ± 3	25 ± 5	46	120	≤ 0.1	≤ 4	43 ± 20	1100 ± 300
1989	40	80	≤ 0.2	3 ± 2	13 ± 4	28 ± 10	43	160	≤ 0.2	≤ 2	26 ± 10	190 ± 60
1990	48	160	≤ 0.2	≤ 1.5	32 ± 6	500 ± 100	49	100	≤ 0.2	≤ 1.5	20 ± 4	120 ± 50
1991	45	140	≤ 0.2	7 ± 3	17 ± 4	60 ± 20	44	80	≤ 0.3	5 ± 2	12 ± 3	30 ± 10

Airborne Radionuclides

The dose to the maximally exposed individual and the CEDE resulting from airborne releases of radionuclides are listed in Table 1 in the Executive Summary. They were 0.07 mrem and 3 person-rem, respectively. The US/EPA regulations in 40 CFR 61 Subpart H require that facilities releasing airborne radionuclides compute the impact of such releases using an approved code. In this report, COMPLY, a microcomputer radionuclide dispersion and dose assessment code supplied by US/EPA, was used to compute the effective dose equivalent to a maximally exposed offsite person. The code requires

- radionuclide release data,
- stack height and flow data, and
- distance to the nearest offsite individual.

The data used were as follows: For nuclides other than air activation products from accelerators:

- The released quantities of tritium, ^{14}C, ^{125}I, ^{35}S, and "^{232}Th" are listed in Table 2 in the Executive Summary.
- The stack is 10 m high and 1 m in diameter and has an exhaust velocity of 4.7 m/s.
- The nearest offsite "neighbor," the Lawrence Hall of Science (LHS), is 120 m north of the stack.

For accelerator produced air-activation-products impacts, the following data were used.

Air Activation Nuclides

Annual Estimated Releases (Ci/yr)

	Nuclides				
Accelerator	^{11}C	^{13}N	^{15}O	^{41}Ar	Distance to Receptor (M)
Bevatron	9	10	3	0.09	420
Hilac	8×10^{-5}	1×10^{-4}	5×10^{-5}	5×10^{-6}	120
88" Cyclotron	0.1	0.2	1	0.06	110

The respective modelled maximum individual exposures for 1991 were:

Bevatron	0.02	mrem
Hilac	3×10^{-6}	mrem
88" Cyclotron	0.02	mrem

Since COMPLY cannot compute population dose equivalent, two additional US/EPA-approved computer programs were used. For Laboratory stack releases, a microcomputer version of AIRDOSE-EPA "MICROAIRDOSE"[12] was used, and for accelerator air-activation radionuclide impacts CAP88PC.

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

- radionuclide release data,
- committed dose-equivalent factors for released radionuclides,

- site-specific meteorological data,
- agricultural parameters,
- site-specific food and water source parameters,
- radionuclide-independent parameters, and
- distribution of the population within 80 km (50 mi) of LBL.

The data were obtained from the following sources:

- The released quantities of ^{3}H, ^{14}C, ^{125}I, and ^{35}S listed in Table 2 of this report are used.
- Values are from three sources: values for ^{3}H and ^{14}C are from the original AIRDOSE Report;[11] dose conversion factors for ^{125}I were taken from the US/EPA DARTAB-RADRISK data base for 70-yr dose commitment; the data for ^{35}S and ^{232}Th are from Ref. 14.
- 1960–1964 Oakland Airport five-year average data were used. Although it is most desirable to use onsite meteorology data for the "release year" (1991), the US/EPA Region 9 regional meteorologist indicated that the use of the Oakland Airport five-year average data is, for this application, an acceptable second choice.[13] (LBL expects to collect its own onsite data by the end of 1993.)
- Default parameters provided with the MICROAIRDOSE code were used from Ref. 10.
- Food and water source parameters were compiled by Victor J. Montoya of the ESHC's Environmental Monitoring Section from data provided by the water boards and agricultural commissioners of the 11 San Francisco Bay Area counties. The average values for foodstuffs and water not collected or grown within 80 km (50 mi) of LBL were found to be as follows: 35% of the drinking water is imported; 95% of the produce and leafy vegetables are imported; 25% of the milk is imported; and 90% of the meat is imported. (Imported food and water are assumed to be uncontaminated.)
- Values are from Ref. 15.
- The population distribution about LBL was compiled into 16 compass directions of 10 radial sectors each by Winifred B. Corniea, formerly of ESHC's Environmental Monitoring Section, using data in Ref. 9.

As indicated above, CAP88PC supplied by US/EPA was used to compute the population dose equivalent from accelerator air activation products. In addition to the estimated air activation product releases listed in Table 2, the defaults provided by USA/EPA with the code including the local population distribution and "OAK0319" wind (Oakland Airport winds 1960-64 averages) were used as imput paramaters.

Table 4-13 summarizes the total CEDE due to LBL operations.

Table 4-13. Population effective dose equivalent resulting from LBL operations, 1991.[a]

Contributing factor		Population effective dose equivalent (person-rem)
Penetrating radiation from accelerator operations		≤ 2
Accelerator air activation products		0.16
Radionuclide release		
H-3	≤ 3	
C-14	≤ 0.012	
I-125	≤ 0.007	
S-35	< 0.003	
Unidentified alpha emitters[b]	< 0.02	
Subtotal		≤ 3
Total LBL-produced effective population dose equivalent		≤ 5

[a]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.
[b] ^{232}Th was used as a conservative substitute.

Trends—LBL Environmental Impact

Accelerator-Produced Penetrating Radiation

Figures 4-5 through 4-8 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 1991 maximum estimated perimeter dose equivalent of ≤ 2 mrem (Figure 4-5) remains a fraction of the radiation protection guideline[3] of 100 mrem/yr, reflecting improvements in accelerator beam optics, local shielding, and cave selection.

Airborne and Waterborne Radionuclides

Figure 4-9 shows the annual releases of tritium (as HTO) from the Building 75 Tritium Facility from 1974 through 1991.

The 84 Ci released during routine operations in 1991 is approximately 53% of the 1990 releases and is responsible for approximately 50% of the LBL-produced population-dose equivalent from all sources for 1991. The releases occur during molecular tagging and tritium waste processing.

The NTLF staff presented a five-stage proposal to be phased in over a 14-month period beginning in April of 1990. The design basis of the proposal was to reduce tritium discharges by at least 75% and tritium waste shipments by an equivalent, or greater, percentage. The

proposal was approved by Laboratory management, and the overall reduction in tritium releases from 1989 to 1991 was > 80%. Thus, the improvement exceeded design expectations.

Releases of accelerator - produced air activation nuclide heretofore not specifically listed will be estimated until real-time emission monitors are installed. It is expected that the actual releases of activation products and their concomitant exposures will be well less than calculated values.

Except for high readings from occasional known offsite releases (e.g., atmospheric nuclear weapons tests and the Chernobyl fire), the atmospheric sampling program has yielded data over the past few years that are within the range of historical normal background. Figures 4-10 through 4-12 illustrate atmospheric air and deposition trends.

With historically noted exceptions, the surface-water sampling program has yielded results within the range of historical normal background. Because no substantial changes in the quantities of radionuclides used are anticipated, no changes are expected in these observations. Figure 4-13 shows surface and drinking water trends. Figures 4-14 and 4-15 illustrate annual average radionuclide concentrations in the LBL sewer outfalls. Under the terms of its license, the UCB campus had historically discharged radionuclides into the Strawberry sewer, complicating the analysis of LBL sewer-sampling data. In recent years the University discharges were reduced, and in May 1990 they were eliminated entirely.

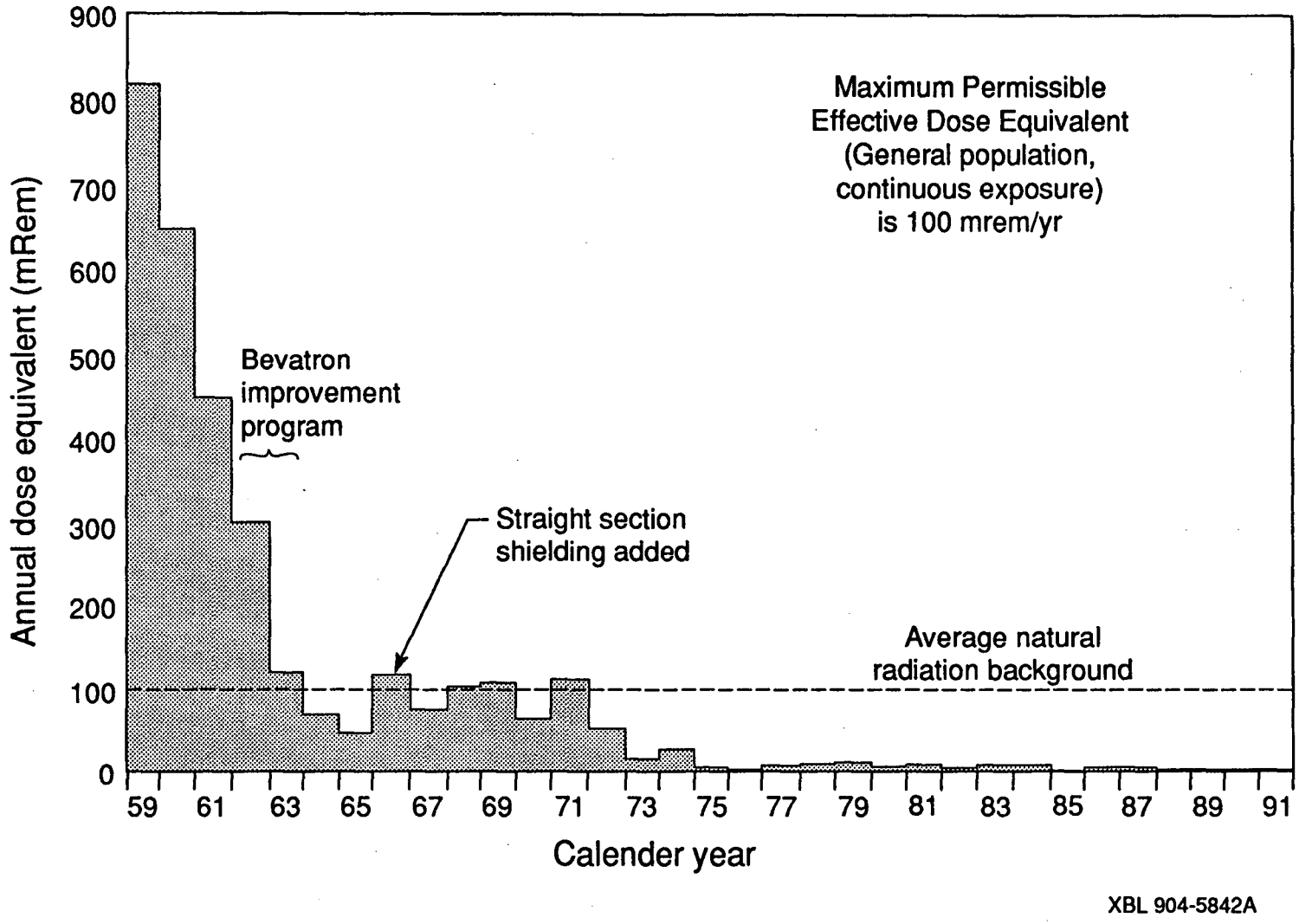

Figure 4-5. Annual accelerator-produced dose equivalent at the Olympus Gate Environmental Monitoring Station, 1959–1991.

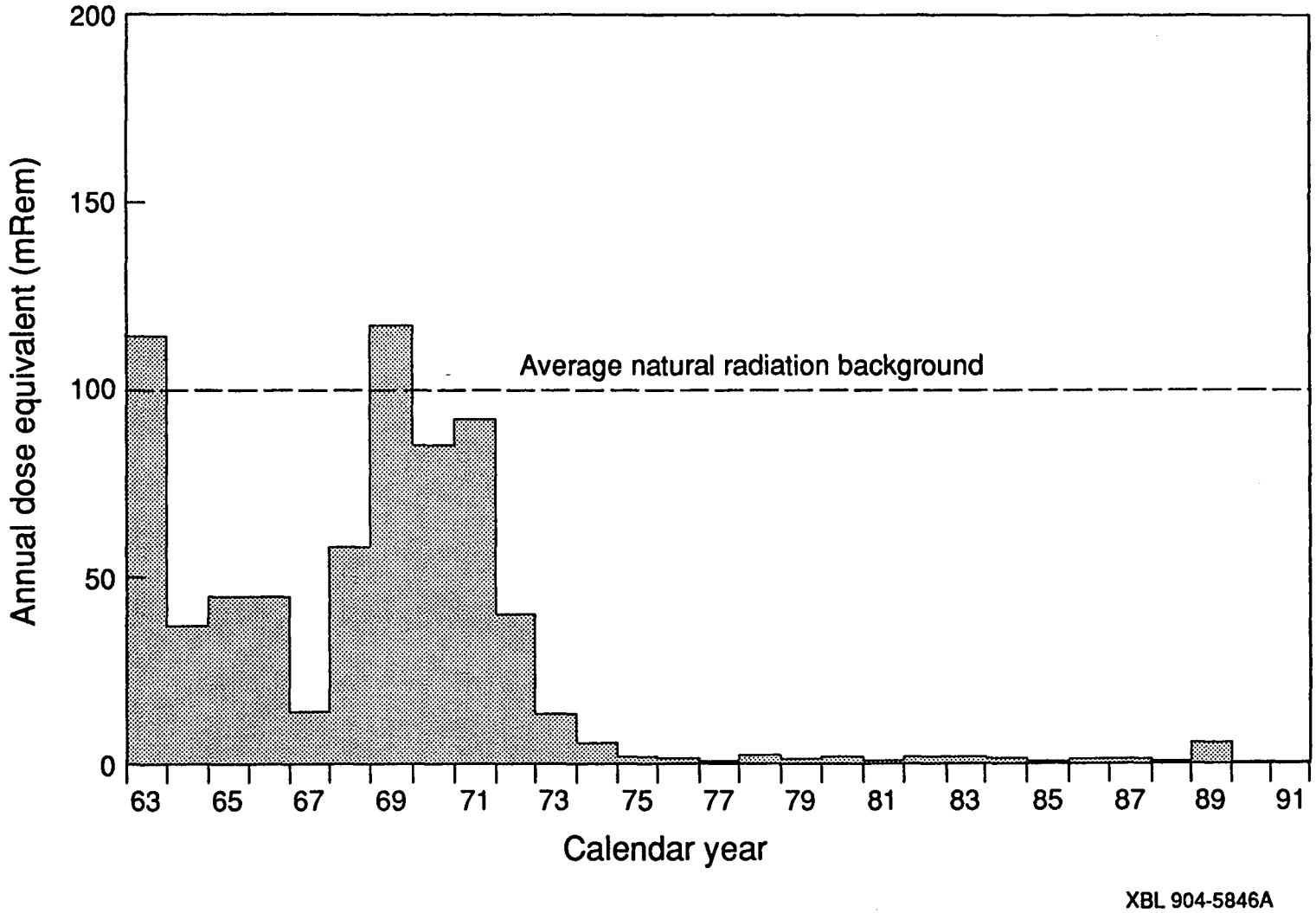

Figure 4-6. Annual accelerator-produced dose equivalent at Building 90 Environmental Monitoring Station, 1962–1991.

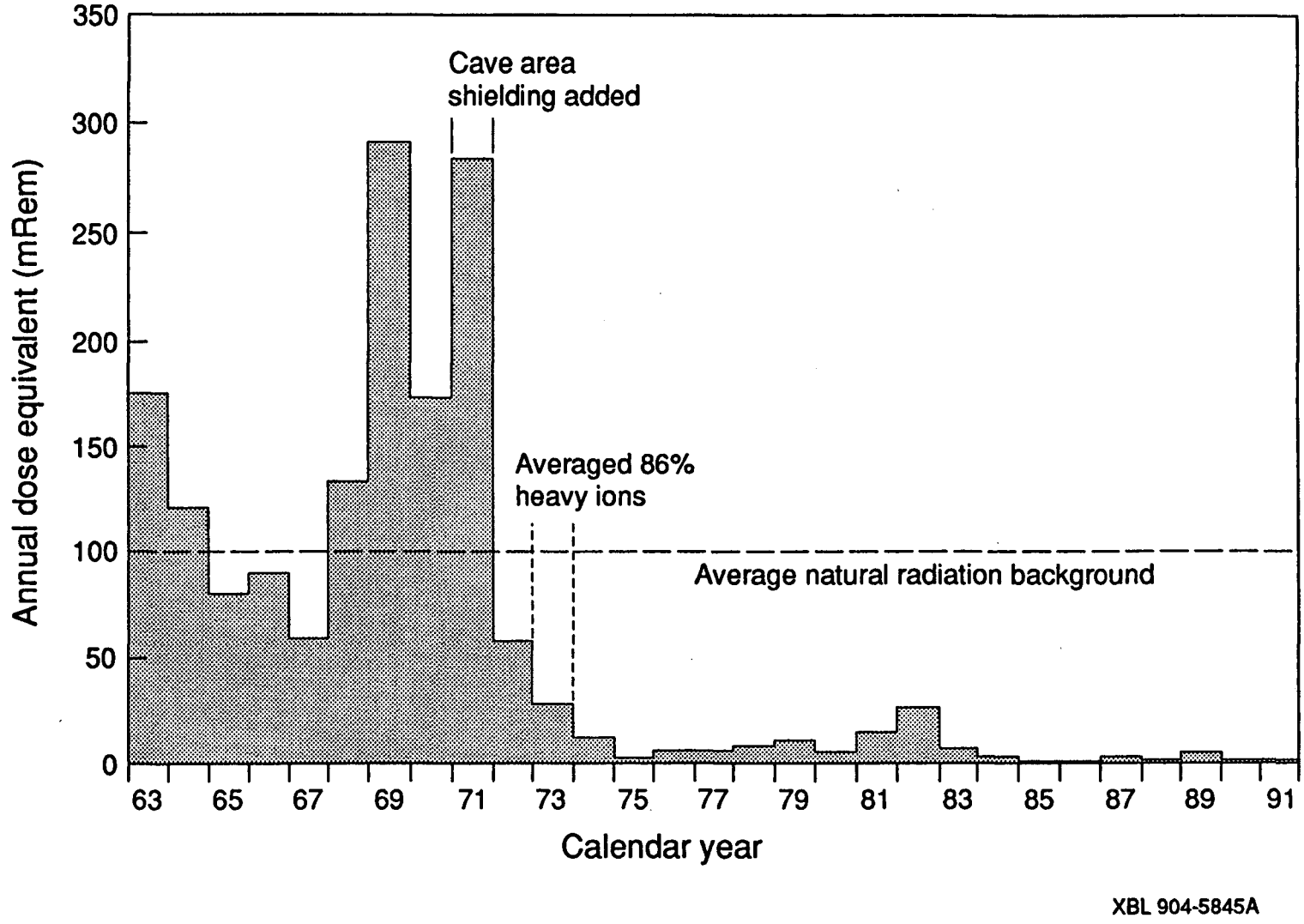

Figure 4-7. Annual accelerator-produced dose equivalent at the 88-Inch Cyclotron Environmental Monitoring, 1963–1991.

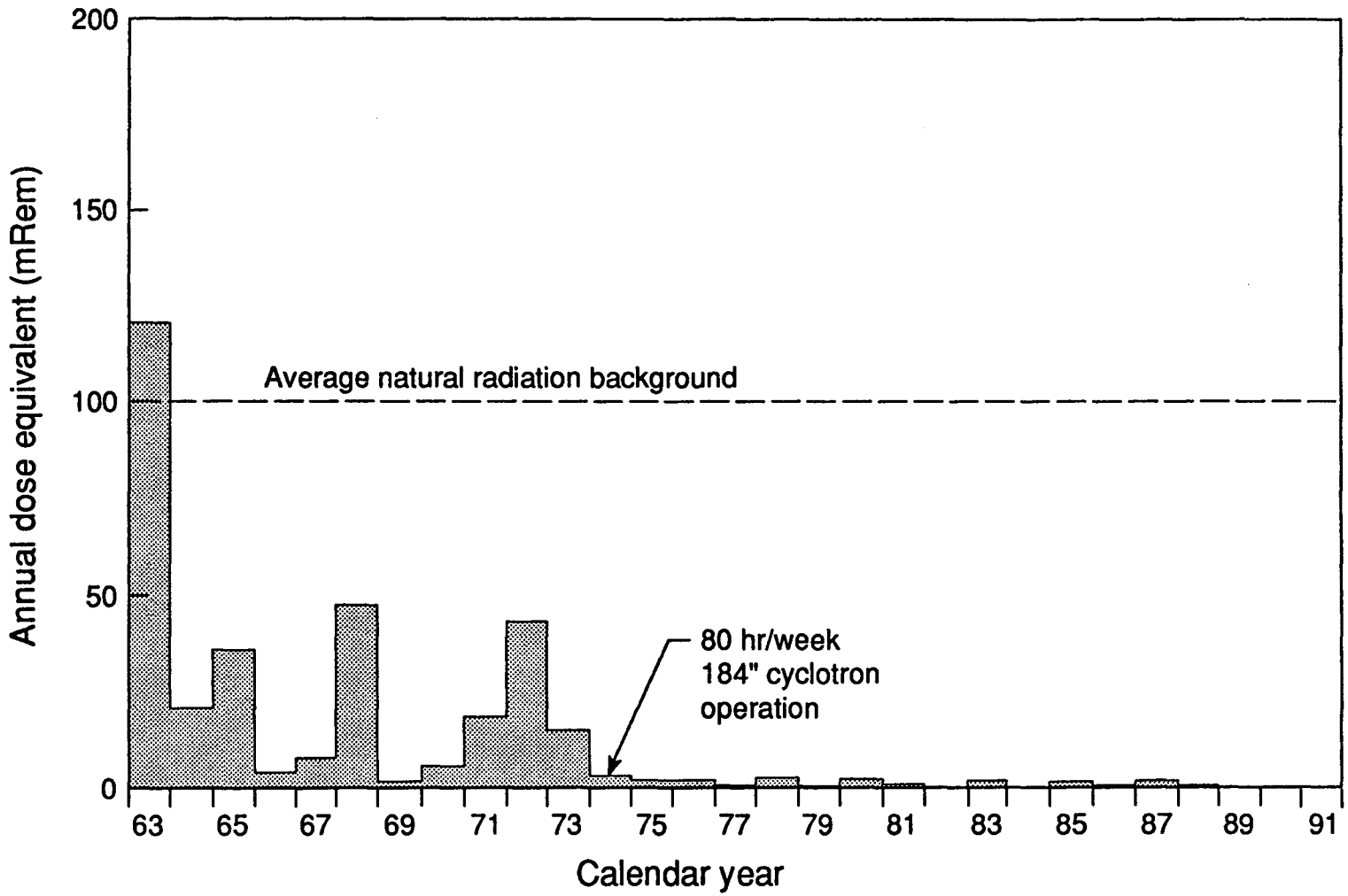

Figure 4-8. Annual accelerator-produced dose equivalent at the Panoramic Way Environmental Monitoring Station, 1963–1991.

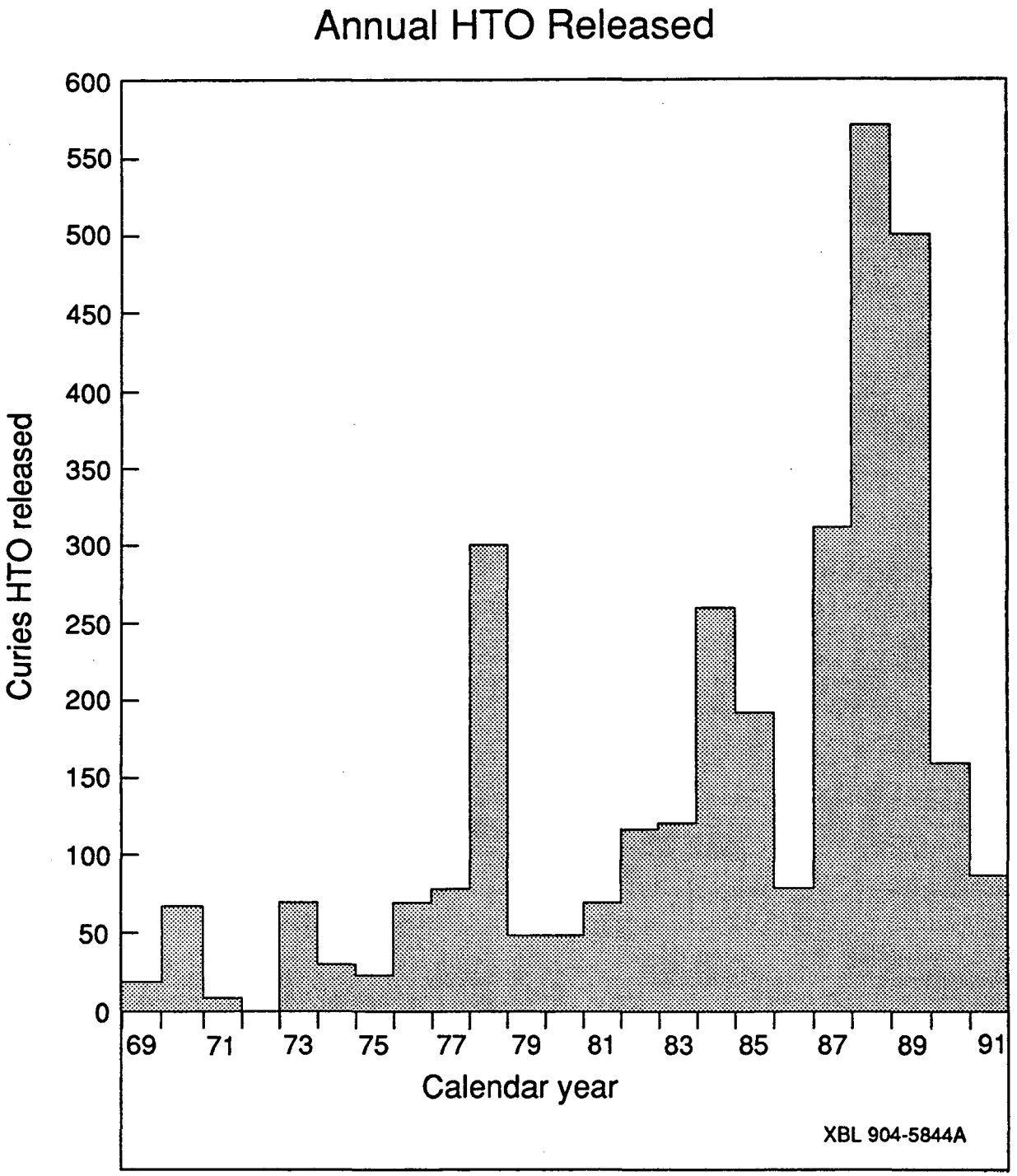

Figure 4-9 Annual releases of tritium (HTO) from the Building 75 Tritium Facility, 1969–1991.

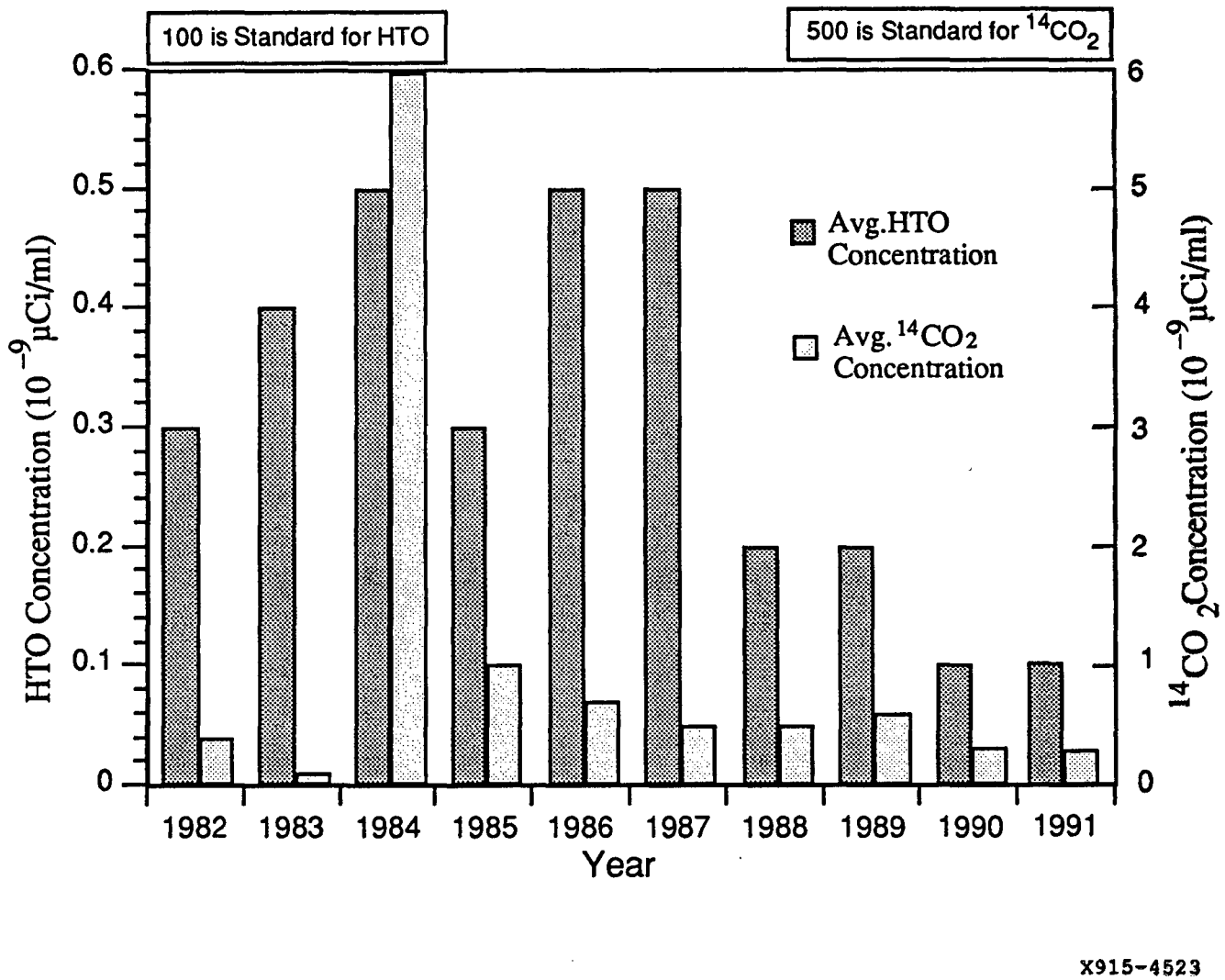

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Figure 4-10. Perimeter airborne environmental HTO and $^{14}CO_2$ trends (Table 4-3 data plotted). Note that the scale for $^{14}CO_2$ concentration is ten times the scale for HTO concentration.

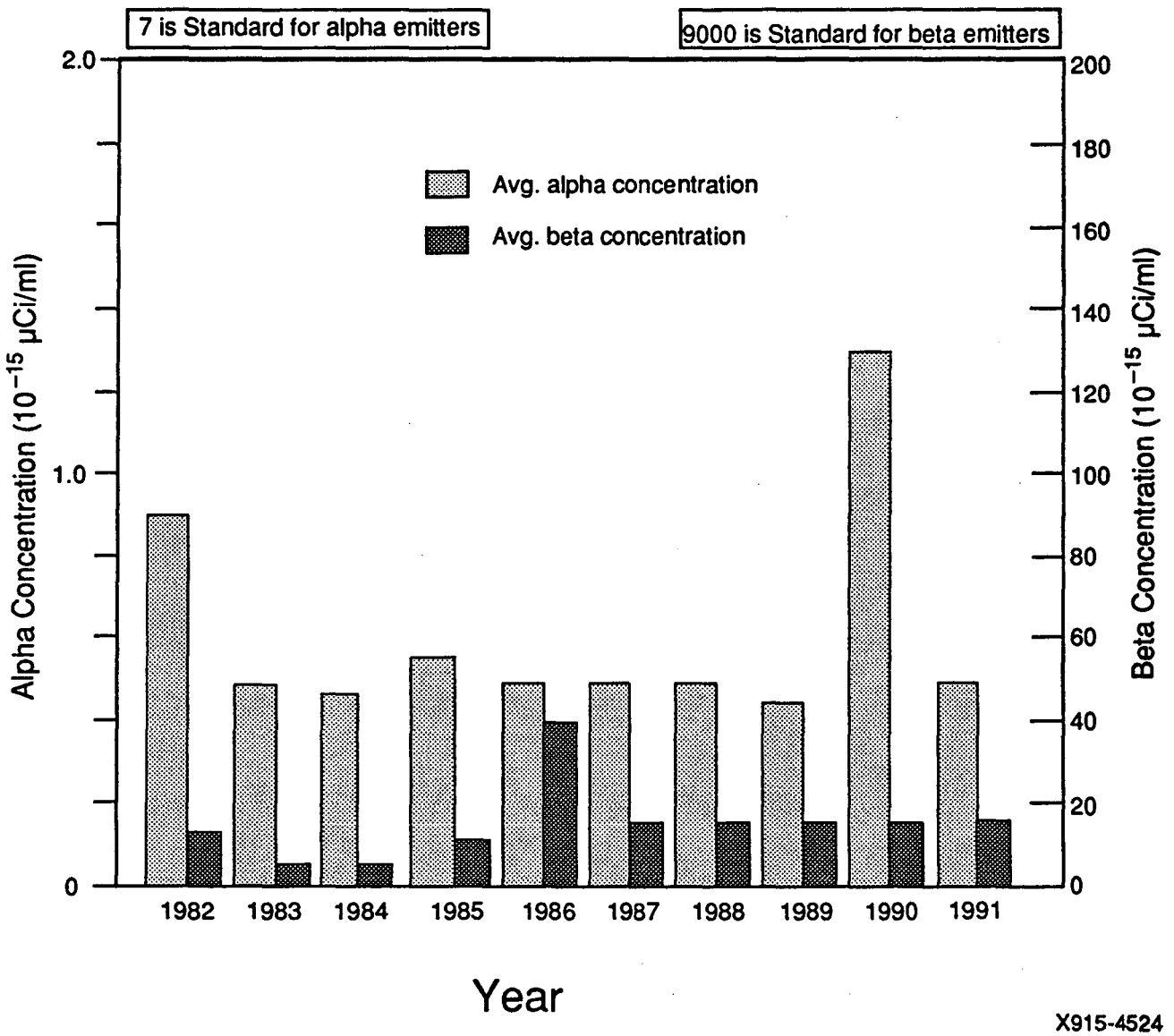


Figure 4-11. Annual average gross alpha and beta particulate radioactivity found in LBL perimeter air samples, 1982–1991 (Table 4-6 data plotted). Note that the scale for beta emitters is one hundred times the scale for alpha emitters.

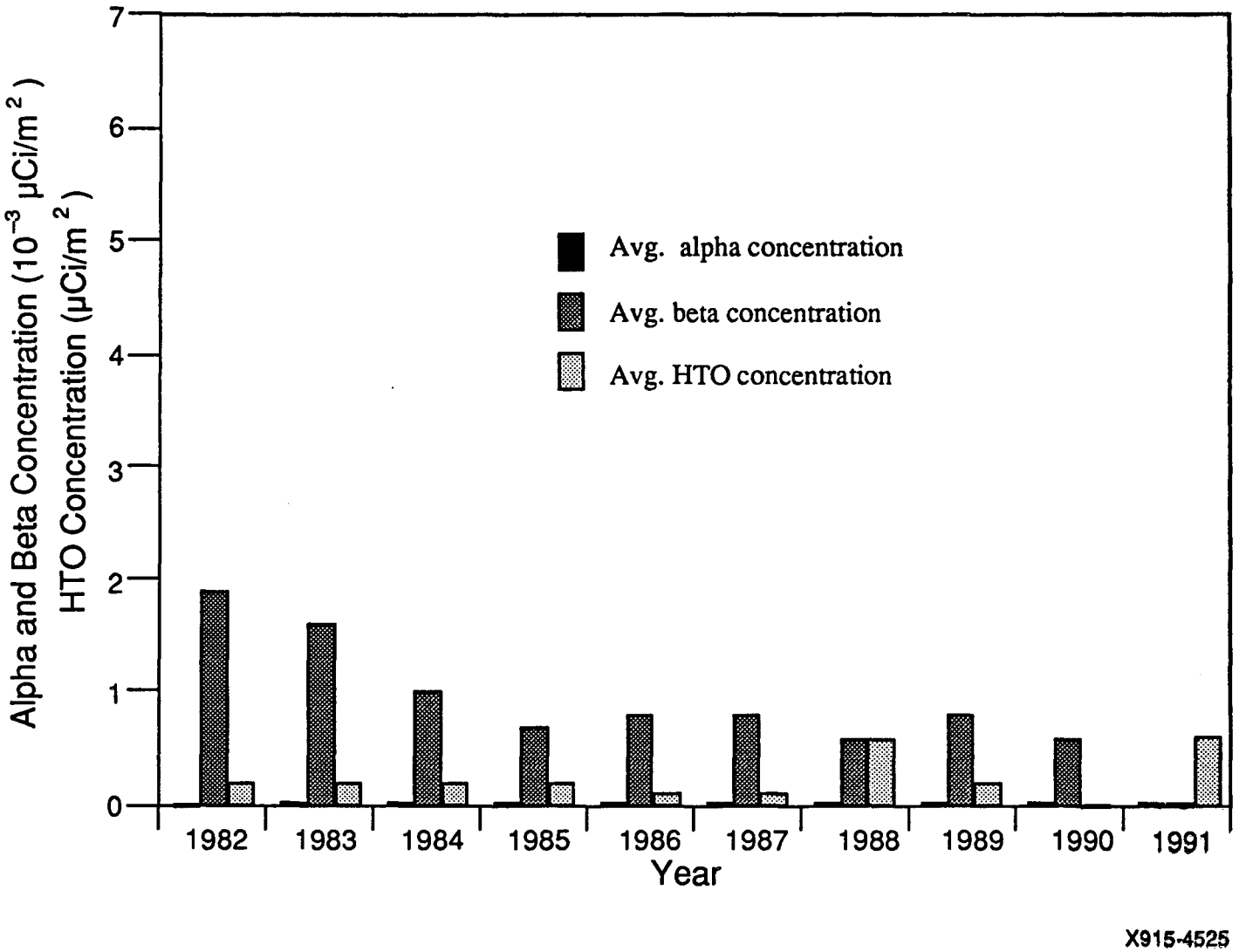


Figure 4-12. Annual alpha and beta emitters and HTO in LBL perimeter deposition samples, 1982–1991 (Table 4-7 data plotted).

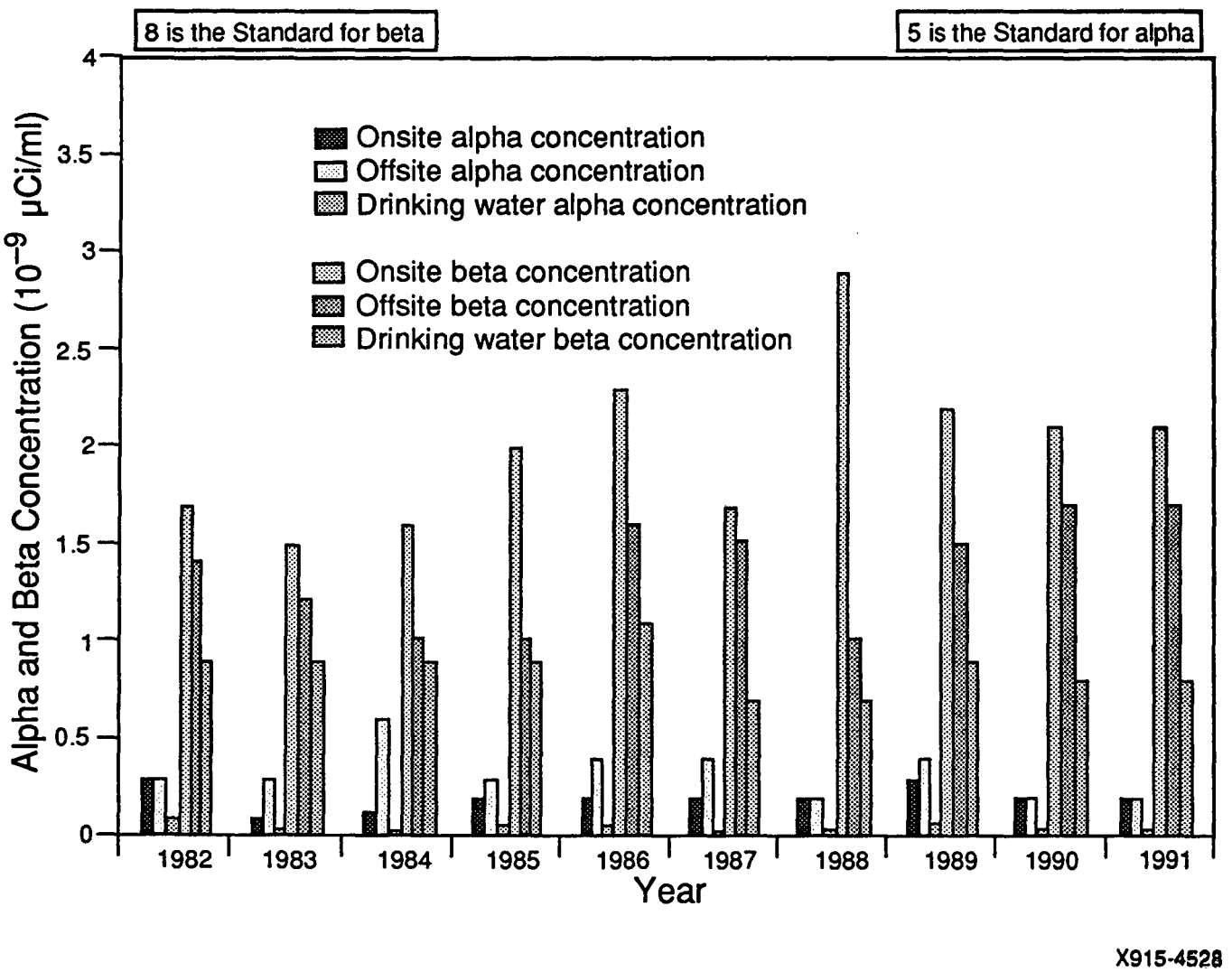


Figure 4-13. Annual average concentrations of alpha and beta emitters in surface and drinking water samples, 1982–1991 (Table 4-10 data plotted).

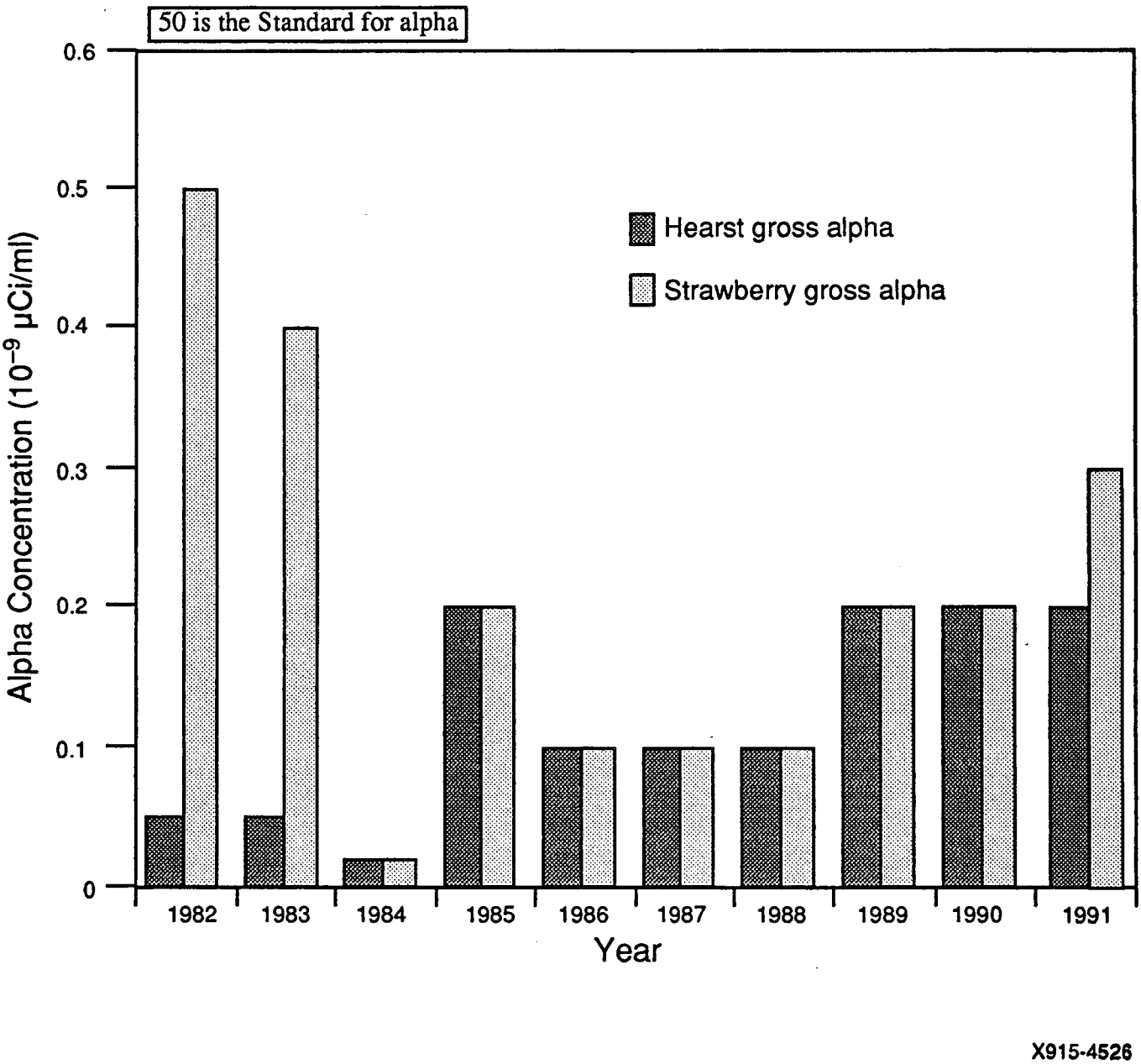


Figure 4-14. Annual average alpha emitter concentrations in LBL sewer effluents, 1982–1991 (Table 4-12 alpha data plotted).

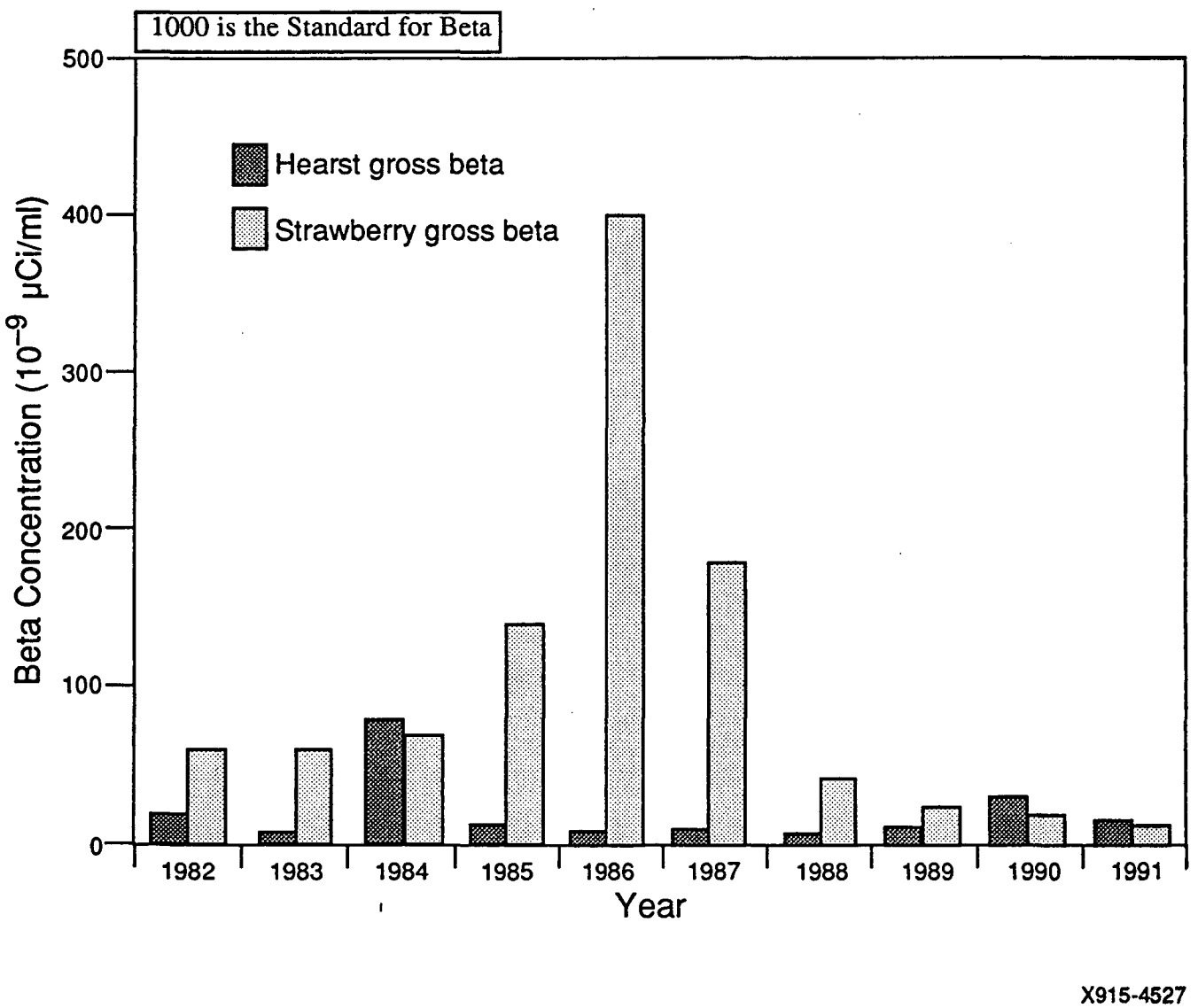


Figure 4-15. Annual average beta emitter concentrations in LBL sewer effluents, 1982–1991 (Table 4-11b beta data plotted).

5.0

Environmental Nonradiological Program Information

5.1 Waterborne Pollutants

Building 25 Plating Shop

As required by EBMUD Wastewater Discharge Permit #775-00025, wastewater samples were taken from the discharge of the Building 25 treatment unit. In addition, EBMUD collected samples during the year and reported their results to LBL. The samples were analyzed for six metals, cyanide, and pH, as specified by the permit.

On March 13, 1991, EBMUD found a discharge violation for copper at the Building 25 Printed Circuit Board Shop Treatment Facility. Their test result showed a discharge level of 5 mg/l. This level exceeded the discharge limit of 3.38 mg/l by approximately 50 percent. Upon notification, the Facility operators performed an extensive evaluation of the treatment processes and procedures, and determined that the onsite test method, which used a Hach Test Kit to determine treatment effectiveness, was flawed. To prevent a recurrence, the treatment procedure was changed by replacing the onsite test method with one that requires all tests to be performed by a certified laboratory using US/EPA standard methods prior to discharge of each batch of treated wastewater. No other violations ocurred at LBL during 1991.

Table 5-1 summarizes the results from the samples taken by LBL and EBMUD.

Table 5-1. Building 25 Treatment Effluent — 1991 Sampling Data

	Cadmium	Chrom.	Copper	Lead	Nickel	Zinc	Cyanide
Number of Samples	4	5	17	14	4	6	2
Minimum Level (mg/L)	0.01	0.01	0.02	0.02	0.13	0.04	0.02
Maximum Level (mg/L)	0.01	0.04	4.30	0.11	0.50	0.15	0.02
Average Level (mg/L)	0.01	0.02	1.18	0.03	0.28	0.07	0.02
Ave % of Limit	0.50	0.90	23.64	1.60	5.60	1.30	0.40
2 x STD Deviation	0.00	0.03	1.84	0.05	0.32	0.09	0.00
Number > Limit	0	0	1	0	0	0	0
Limit (mg/L)	0.69	2.00	3.38	0.69	3.98	2.61	1.2

Building 77 Plating Shop

As required by EBMUD Permit #776-00077, wastewater samples were taken from the discharge for the Building 77 treatment unit. In addition, EBMUD collected samples throughout the year and reported their results to LBL. Samples were analyzed for six metals, volatile organics, and cyanide, as specified by the permit.

There were no violations detected in 1991. Table 5-2 summarizes the results for the samples taken by LBL and EBMUD.

Table 5-2. Building 77 Treatment Effluent — 1991 Sampling Data

	Cadmium	Chrom.	Copper	Lead	Nickel	Zinc	Cyanide	Chlor HCS
Number of Samples	2	3	3	3	3	3	3	2
Minimum Level (mg/L)	0.01	0.60	0.13	0.02	0.14	0.04	0.02	0.01
Maximum Level (mg/L)	0.04	2.00	1.50	0.04	0.84	0.29	0.02	0.41
Average Level (mg/L)	0.01	1.16	0.68	0.03	0.40	0.15	0.02	0.21
Ave % of Limit	2.15	58.17	13.67	1.33	7.93	3.01	0.40	41.60
2x STD Deviation	0.04	1.48	1.44	0.02	0.78	0.25	0.00	0.57
Number > Limit	0	0	0	0	0	0	0	0
Limit (mg/L)	0.69	2.00	3.38	0.69	3.98	2.61	1.20	0.50

Site Wastewater Discharges

There are two sanitary sewer systems serving LBL: the Strawberry Sanitary Sewer and the Hearst Sanitary Sewer. Effluent from each sewer system is monitored at the LBL boundary. Periodic daily sampling is performed to ensure compliance with the site discharge limits mandated by EBMUD Ordinance No. 311.

At both monitoring stations, representative composite and grab samples were collected according to a schedule prescribed by the permit. Composite samples were analyzed for metals; grab samples were analyzed for volatile organic compounds, oil/grease, and cyanide. Tables 5-3 and 5-4 summarize the site wastewater discharge sampling data.

Table 5-3. Strawberry Monitoring Station — 1991 Sampling Data

	Cadmium	Chrom.	Copper	Lead	Mercury	Nickel	Silver	Zinc	Cyanide	Chlor HCS
Number of Samples	6	6	6	6	3	6	5	6	2	1
Minimum Level (mg/L)	0.01	0.02	0.04	0.02	0.00	0.01	0.02	0.07	0.02	0.02
Maximum Level (mg/L)	0.04	0.41	0.51	0.03	0.00	0.44	0.03	0.65	0.02	0.02
Average Level (mg/L)	0.02	0.14	0.26	0.02	0.00	0.17	0.02	0.22	0.02	0.02
Ave % of Limit	1.62	7.00	5.20	1.17	1.33	3.33	2.00	4.43	0.40	4.60
2x STD Deviation	0.03	0.30	0.43	0.01	0.00	0.42	0.00	0.43	0.00	0.00
Number > Limit	0	0	0	0	0	0	0	0	0	0
Limit (mg/L)	1	2	5	0.6	0.05	5	1	5	5	0.50

Table 5-4. Hearst Monitoring Station — 1991 Sampling Data

	Cadmium	Chrom.	Copper	Lead	Mercury	Nickel	Silver	Zinc	Cyanide	Chlor HCS
Number of Samples	6	6	6	6	3	6	5	6	2	2
Minimum Level (mg/L)	0.00	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.02	0.03
Maximum Level (mg/L)	0.01	0.03	0.13	0.03	0.00	0.01	0.10	0.23	0.02	0.09
Average Level (mg/L)	0.01	0.02	0.10	0.02	0.00	0.01	0.04	0.15	0.02	0.06
Ave % of Limit	0.59	0.92	1.58	1.17	2.20	0.20	4.40	3.07	0.40	12.20
2x STD Deviation	0.01	0.02	0.09	0.01	0.00	0.00	0.08	0.16	0.00	0.08
Number > Limit	0	0	0	0	0	0	0	0	0	0
Limit (mg/L)	1	2	5	0.6	0.05	5	1	5	5	0.5

There were no wastewater discharge violations at either the Strawberry or Hearst Monitoring Stations in 1991. Five-year average trends are shown in Figures 5-1, 5-2, and 5-3.

5.2 Airborne Pollutants

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

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

Table 5-5 summarizes the emission estimates determined in 1989. This report will be updated in 1992.

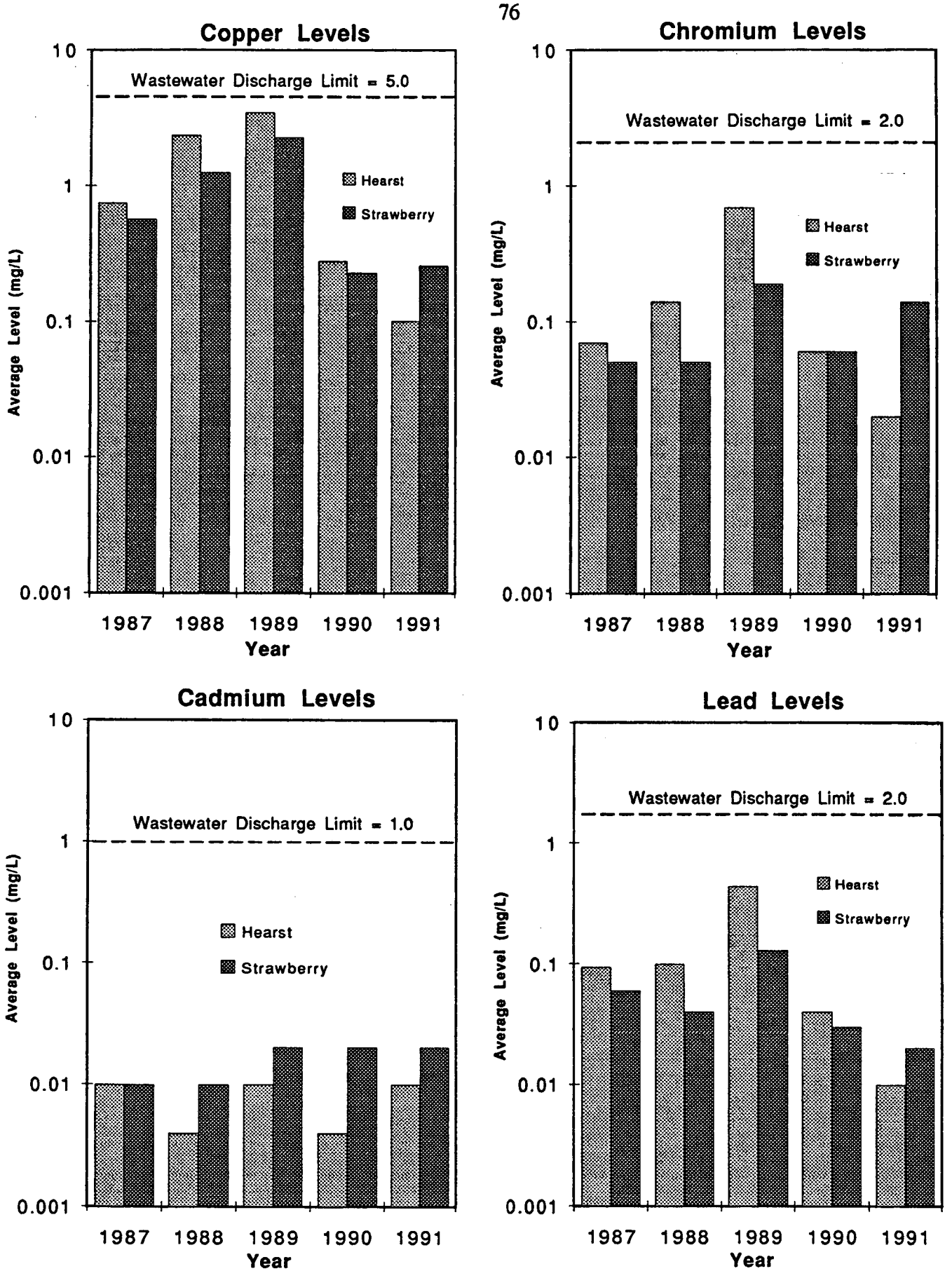


Figure 5-1. Hearst and Strawberry Monitoring Stations: Effluent Trends for Copper, Chromium, Cadmium, and Lead

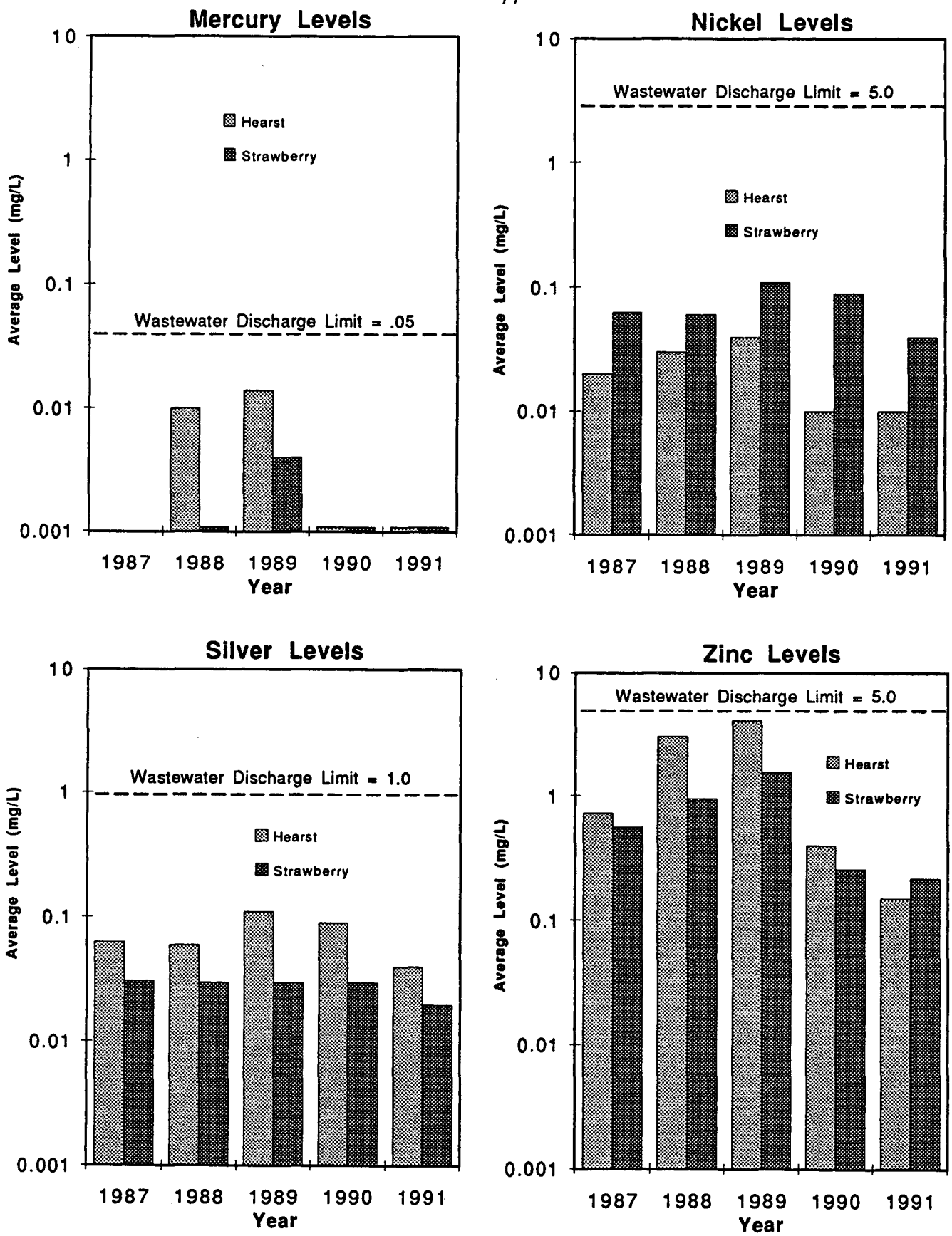


Figure 5-2. Hearst and Strawberry Monitoring Stations: Effluent Trends for Mercury, Nickel, Silver, and Zinc

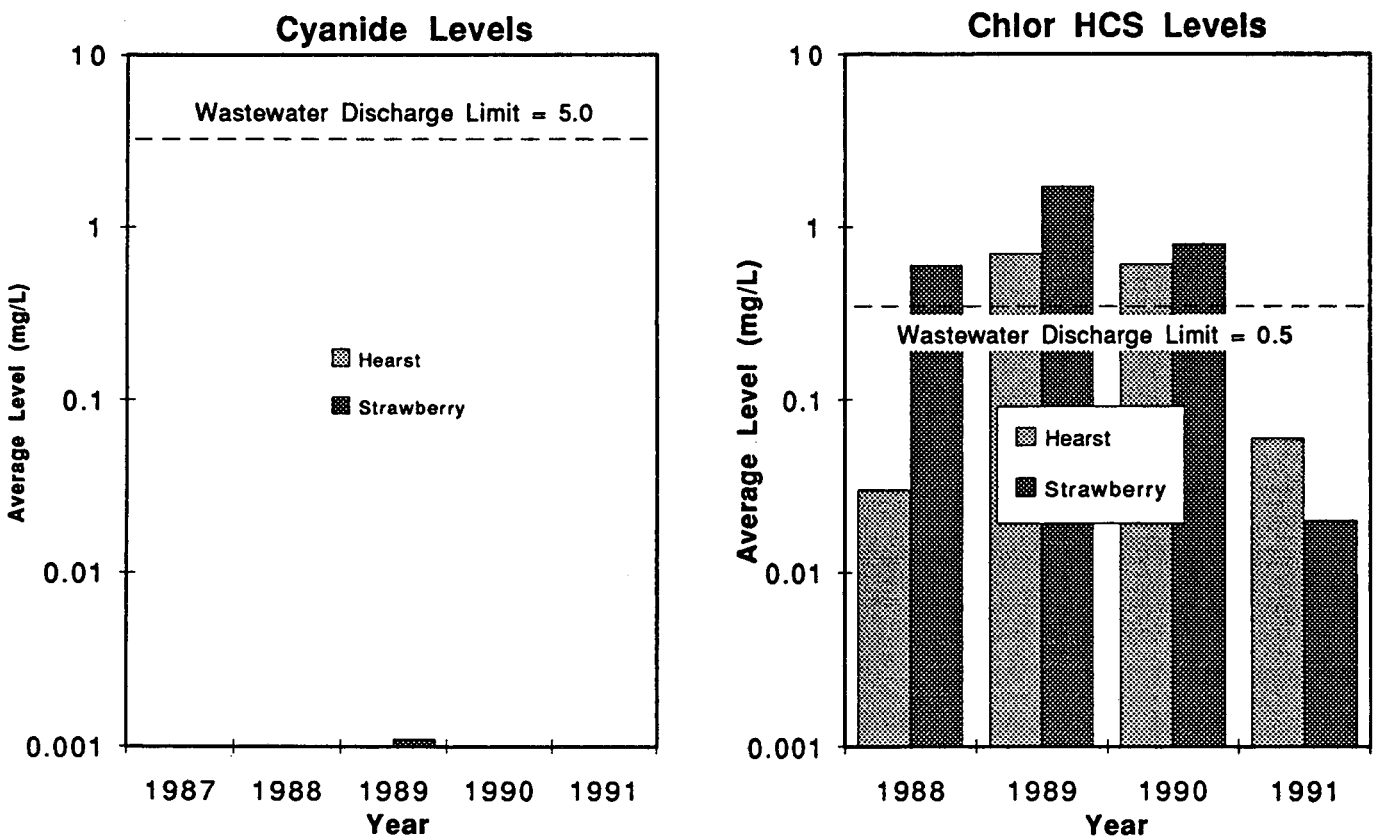


Figure 5-3. Hearst and Strawberry Monitoring Stations: Effluent Trends for Cyanide and Chlorinated Hydrocarbons

Table 5-5. Air toxics emission estimates.

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

6.0

Groundwater Protection

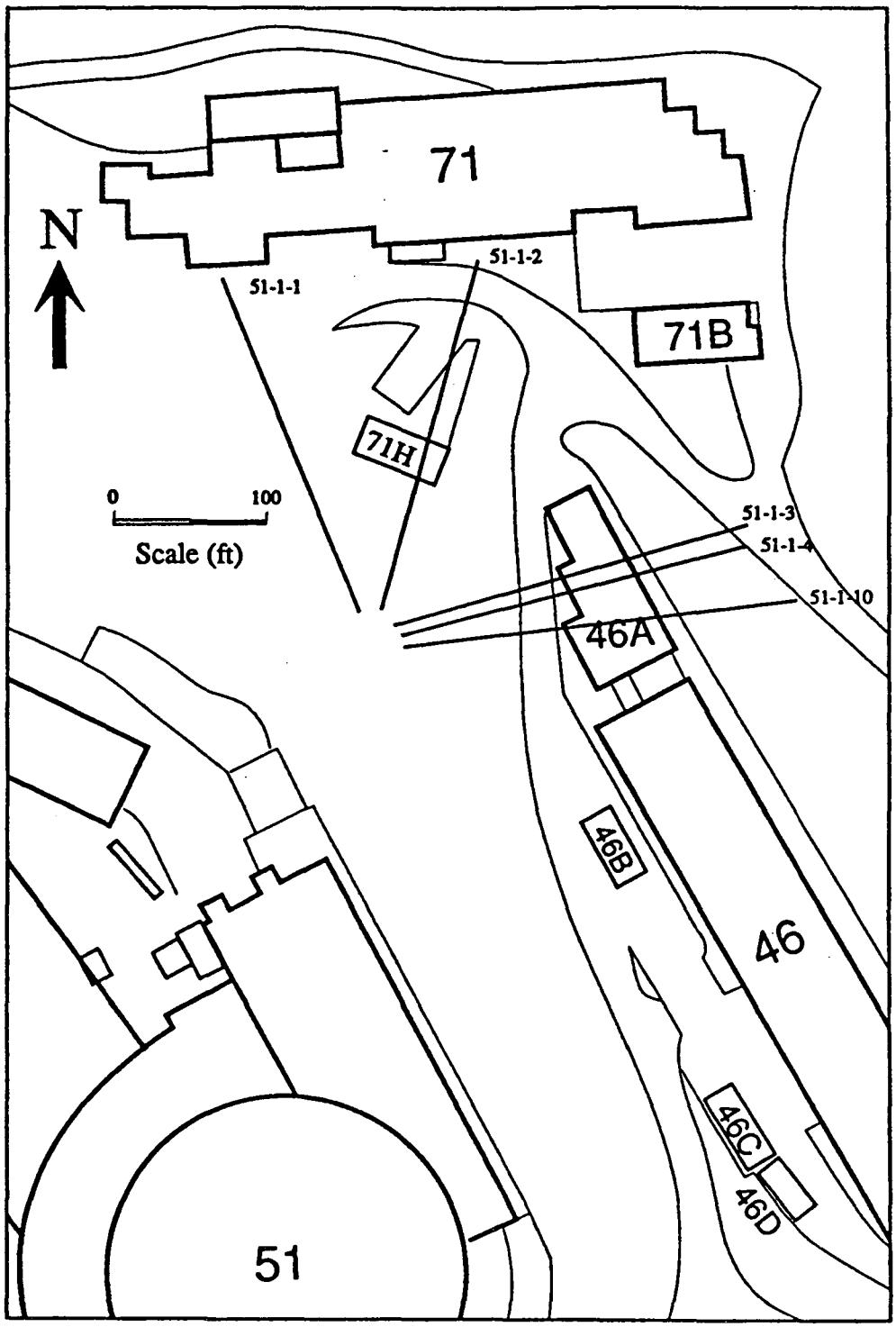
Previous Studies

In the summer of 1986, as a part of the environmental baseline study for the development of the East Canyon area within the site, LBL staff collected several samples of soil, groundwater, surface water, and vegetation from within the property's boundary, as well as from adjacent areas. Groundwater samples were collected from a few flowing horizontal drains (hydraugers). Chemical analysis of water samples from two adjacent hydraugers (51-1-3 and 51-1-4) east of Building 51 (see Figure 6-1) showed low levels of solvents (chlorinated hydrocarbons). Flow rates from these hydraugers are of the order of one or two liters per minute. Because of the persistence of these levels of chemical contamination in the effluent water from these two hydraugers and the observation of contamination elsewhere on the site, in 1989 LBL submitted a proposal to DOE for a sitewide environmental characterization and monitoring program. Meanwhile, during Fiscal Year 1990, LBL carried out a preliminary investigation. This investigation essentially concentrated on three areas as shown in Figure 6-2. The three areas chosen for further study are regions where historical geotechnical studies indicated the presence of subsurface contaminants, or previous "practices" or activities made the areas suspect. (e.g. former motorpool or salvage yard sites). Groundwaters in these areas are believed to be confined to three different hydrologic sub-basins. The results of this investigation are summarized below.

Contaminated groundwater being discharged through hydraugers 51-1-3 and 51-1-4 comes from a plume of contamination present in a narrow aquifer formed along the bed of the main branch of the original Blackberry Canyon Creek. The general direction of groundwater flow in this aquifer is shown in Figure 6-3. Contaminants present in this aquifer are mainly perchloroethylene (PCE), trichloroethylene (TCE), cis-1,2-dichloroethylene (cis-1,2-DCE) and Freon 113. The total concentration of PCE, TCE, and cis-1,2-DCE measured from water samples collected during 1990 from the monitoring well 90-3 (see Figure 6-4) and the hydraugers did not exceed 0.11 mg/L. The Freon 113 concentration measured in Hydrauger 51-1-1 effluent was below 1 mg/L. To investigate the extent of contamination, three new monitoring wells (90-4, 90-5, and 90-6) were constructed downstream from the observed position of the contaminant plume. Locations of these wells are also shown in Figure 6-4. Chemical analyses of water samples from these wells indicated that the plume of contamination was contained in an area up-gradient from these three wells.

Chemical analysis of "grabbed" water samples from a few wells and slope indicators in the "old town" area (Buildings 7, 52, and 53) showed chlorinated hydrocarbon concentrations ranging up to 2 mg/L. Contaminants present in groundwater in this area include PCE, TCE, cis-1,2-DCE, vinyl chloride, and carbon tetrachloride.

Chemical analysis of water samples collected from three closely spaced wells in the Corporation Yard (Building 69-75 area) showed low concentrations of chlorinated solvents (less than 0.1 mg/L). Figure 6-5 shows a piezometric map of this area.



ESD-9010-0039B

Figure 6-1. Approximate position of some of the Hydraugers east of Building 51.

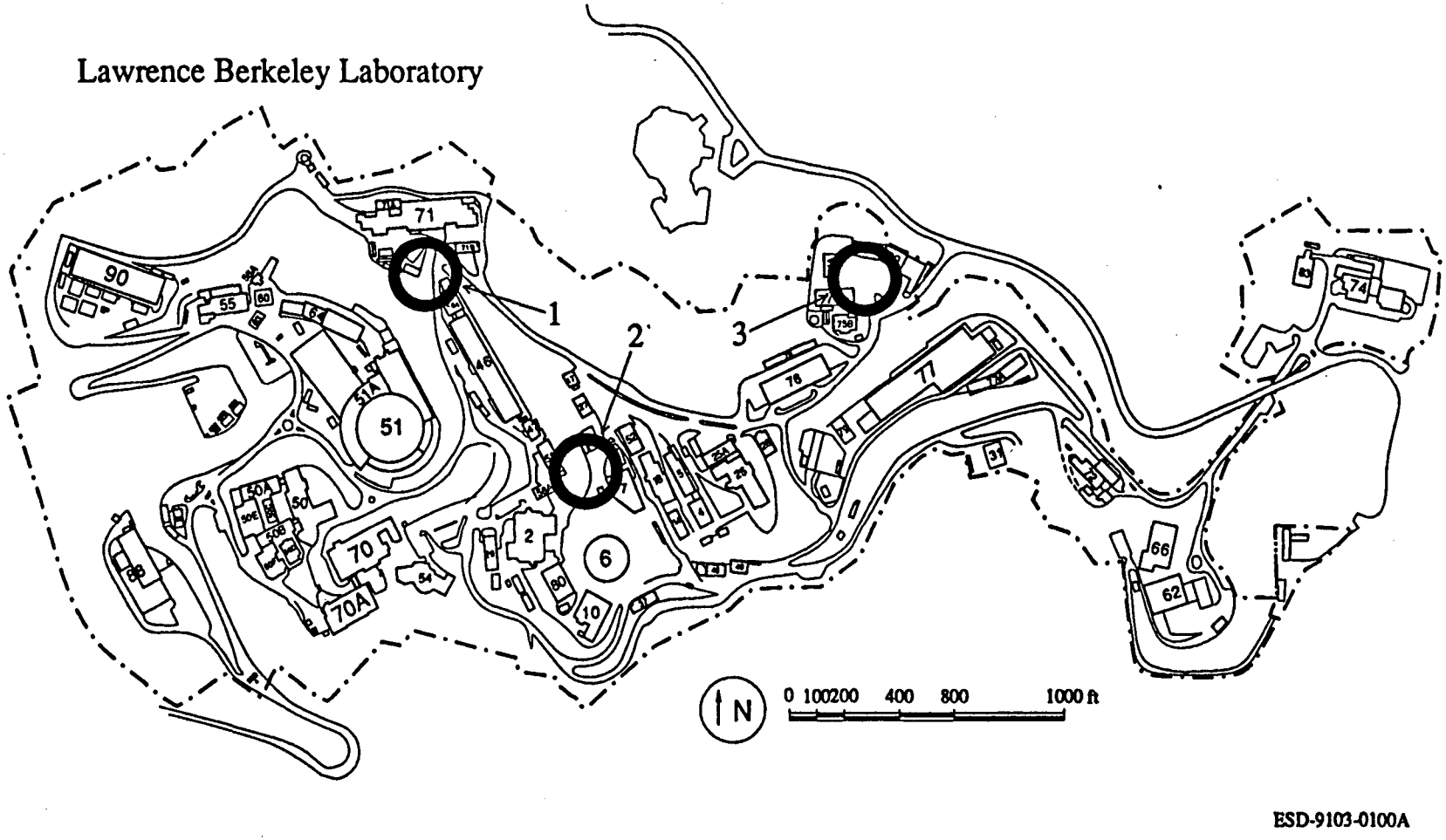
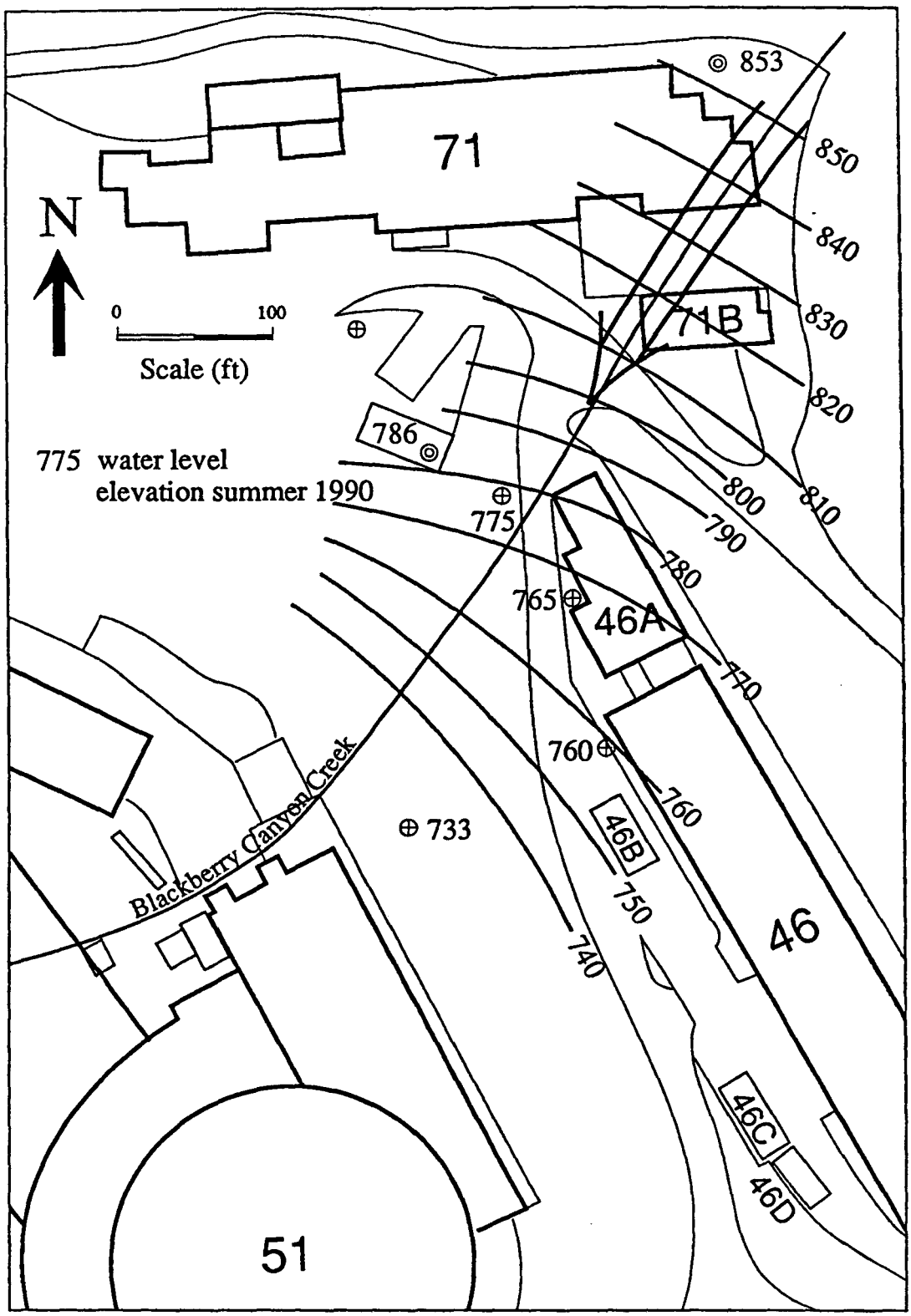
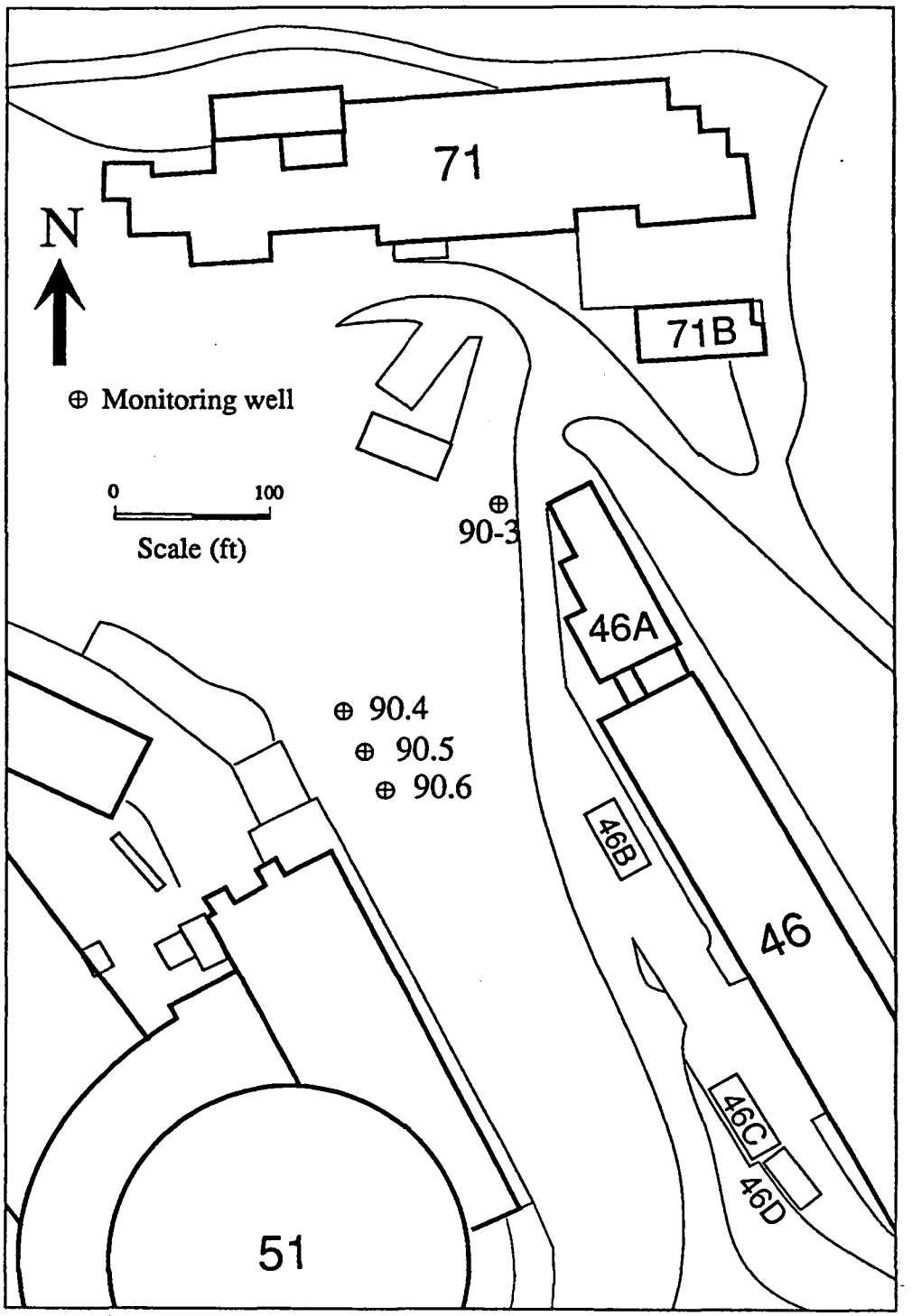


Figure 6-2. Location of three sites where environmental investigations were carried out in 1990.



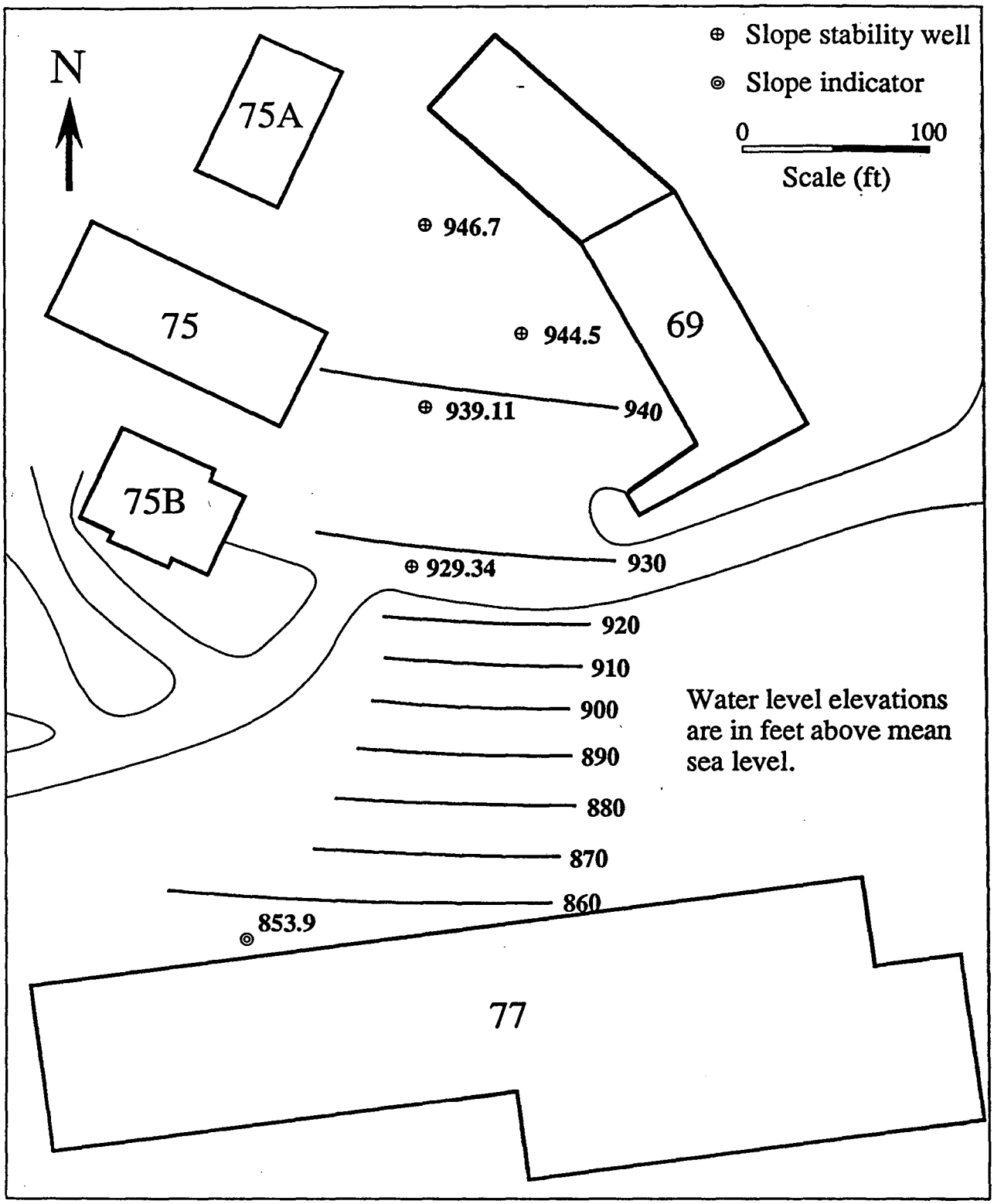
ESD-9011-0041

Figure 6-3. Piezometric map of groundwater in the vicinity of Bldgs. 46, 51 and 71, during the summer of 1990. Elevations are in feet above mean sea level.



ESD-9101-0085B

Figure 6-4. Location of monitoring wells in the vicinity of Buildings 46, 51, and 71.



ESD-9011-0043

Figure 6-5. Piezometric map of groundwater in November 1990.

6.2 Groundwater Studies During 1991

To monitor the quality of groundwater leaving the western and southern boundaries of the LBL property, a total of nine peripheral monitoring wells were installed at strategic locations, as shown in Figure 6-6. The depths of these wells vary from 35 to 109 ft. Water samples from these wells were collected and initially tested for volatile organic compounds (VOC) and 17 metals according to the EPA method 8240 and California Code of Regulations, respectively. A water sample from a monitoring well downgradient of the plating shop (Building 77) was also tested for hexavalent chromium. Only one of these wells, namely MW-P7, contained measurable levels of contamination (24 µg/L of TCE). The monitoring well MW-P7 is located close to the southeast corner of Building 37, about 130 feet north of the LBL property line.

All of the nine wells are sampled quarterly and tested for VOCs. The TCE contamination found in monitoring well MW-P7 was approximately the same in water samples collected throughout the year.

Water samples from all of the flowing hydraugers were collected and tested for VOCs. The concentration variations of contaminants in effluents from hydraugers 51-1-1 and 51-1-3 east of Building 51 are shown in Figures 6-7 and 6-8. Discharges from all flowing hydraugers in this area are collected and treated by granulated activated carbon (GAC) systems. Treated water is then added to the cooling tower in that area. The treatment system consists of a series of filters followed by two GAC drums. Water samples from a port between two GAC drums are collected every month and tested for VOCs. The first drum is replaced as soon as a breakthrough of VOCs is detected.

LBL had installed four monitoring wells downgradient from the previously decommissioned or removed underground storage tanks. Figure 6-9 shows the location of these four wells. Quarterly water samples are collected from these wells and tested for VOCs (EPA method 8240/8260). Figure 6-10 shows time variation of contaminants in well MW 76-1, which is located downgradient from the previously removed underground storage tanks at the Motor Pool. Concentration variations of contaminants in well MW 7-1, located downgradient from the previously decommissioned waste-oil storage tank under B52-B, are shown in Figure 6-11. Analyses of water samples collected from two other monitoring wells, namely 62-B1A, and 62-B2, located at the site and downgradient from a previously removed underground storage tank, did not show any detectable contaminants.

To investigate groundwater contamination in the Corporation Yard (Building 69-75 area), two monitoring wells where installed in this area. Furthermore, two other monitoring wells were constructed south of Building 77, directly downslope of the Corporation Yard. Figure 6-12 shows the location of these wells. Water samples from these wells and all previously available slope stability facilities (wells and slope indicators) were collected and tested for tritium. Figure 6-13 shows tritium concentrations detected in water samples collected from these wells and slope indicators. Tritium concentrations in all new wells that are properly constructed are below 1000 pCi/L. The only well that shows tritium above drinking water maximum contaminant level of 20,000 pCi/L is a slope stability well, 13-130, which is located east of Building 75 (see the ongoing radiological hydrauger monitoring section later in this report for additional Tritium in groundwater data). Water samples from the newly constructed monitoring wells in this area, namely, 91-1, 91-2, 91-3, and 91-5, have been tested for VOCs and 17 metals. No significant contaminants were detected in these wells.

To investigate the groundwater contamination in the "old town" area, three new monitoring wells were constructed as shown in Figure 6-14. Quarterly water samples were collected from these wells and tested for VOCs. Water samples from well 1-220 were essentially clean. However, groundwater at the location of 90-2 and 91-7 was found to be

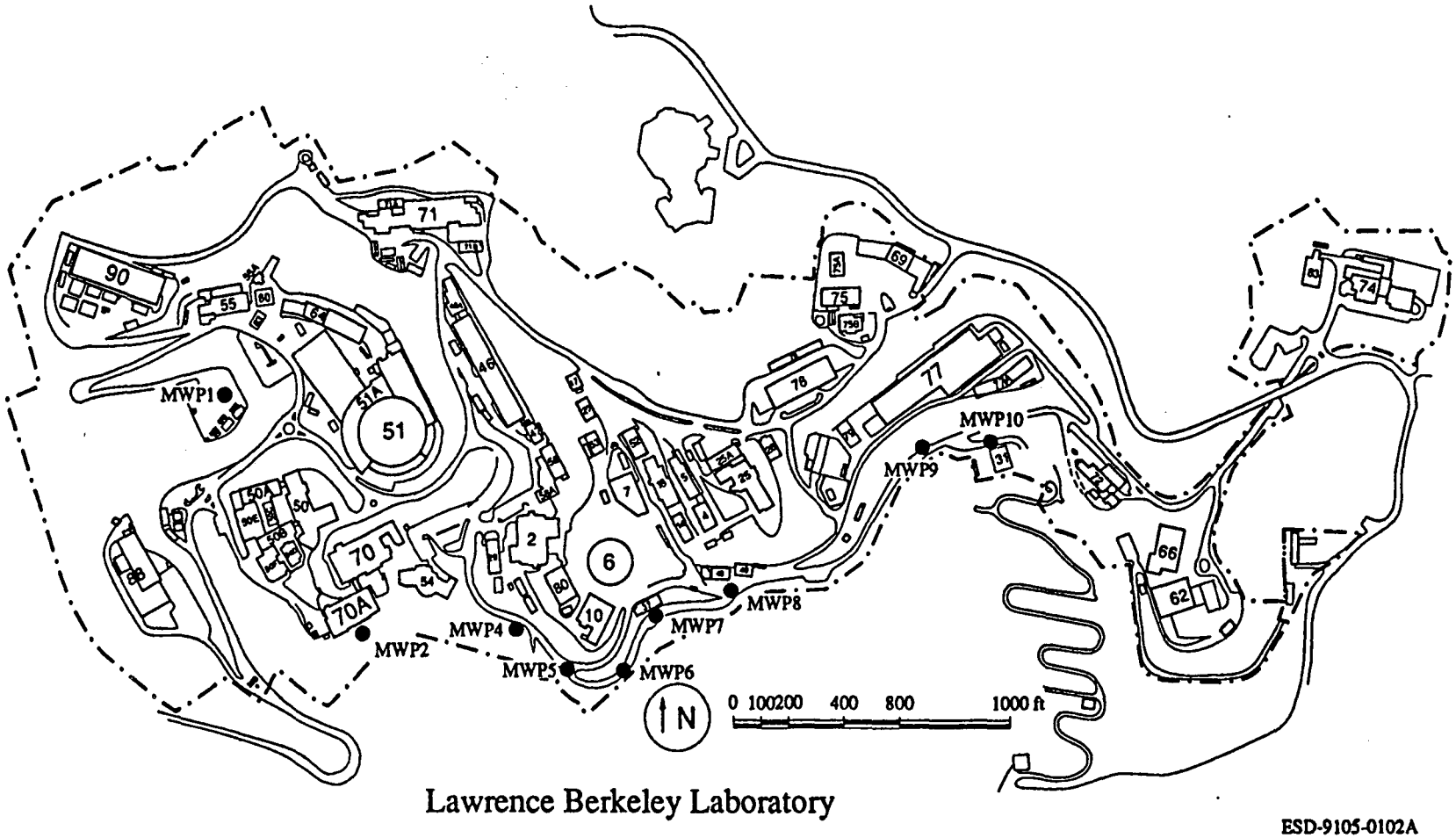


Figure 6-6. Approximate locations of peripheral monitoring wells.

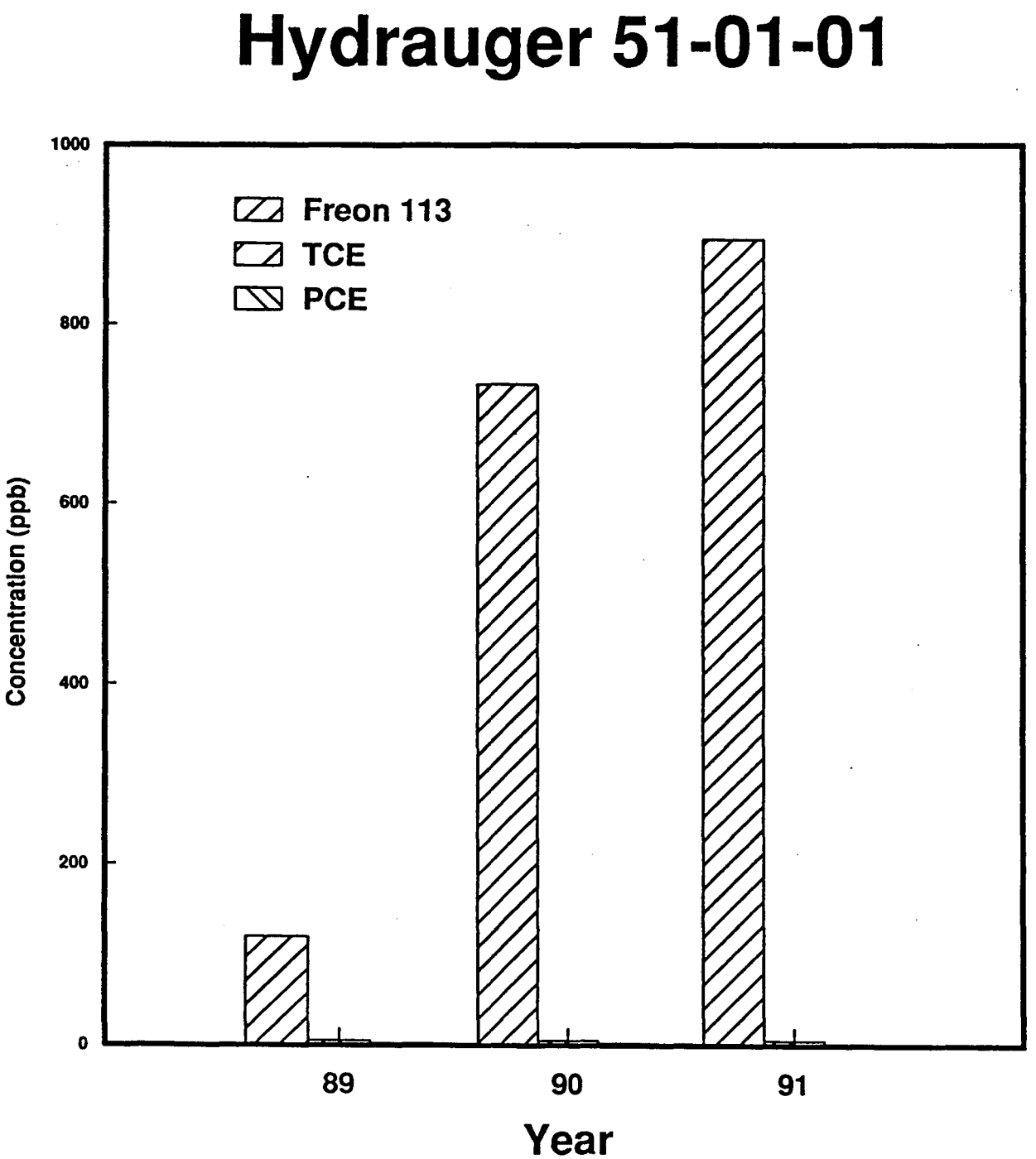


Figure 6-7. Time variation of contaminant concentrations in Hydrauger 51-1-1.

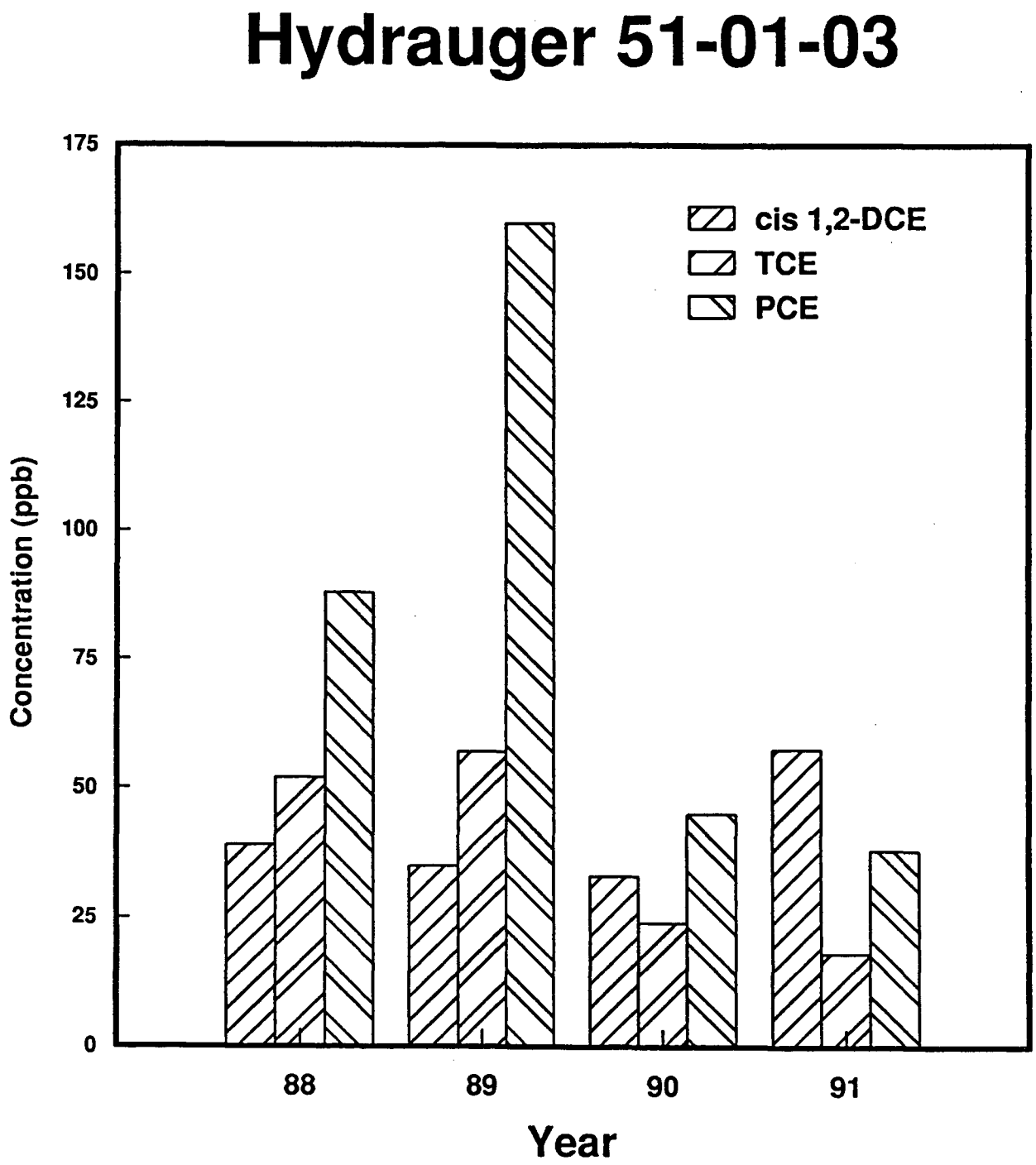


Figure 6-8. Time variation of contaminant concentrations in Hydrauger 51-1-3.

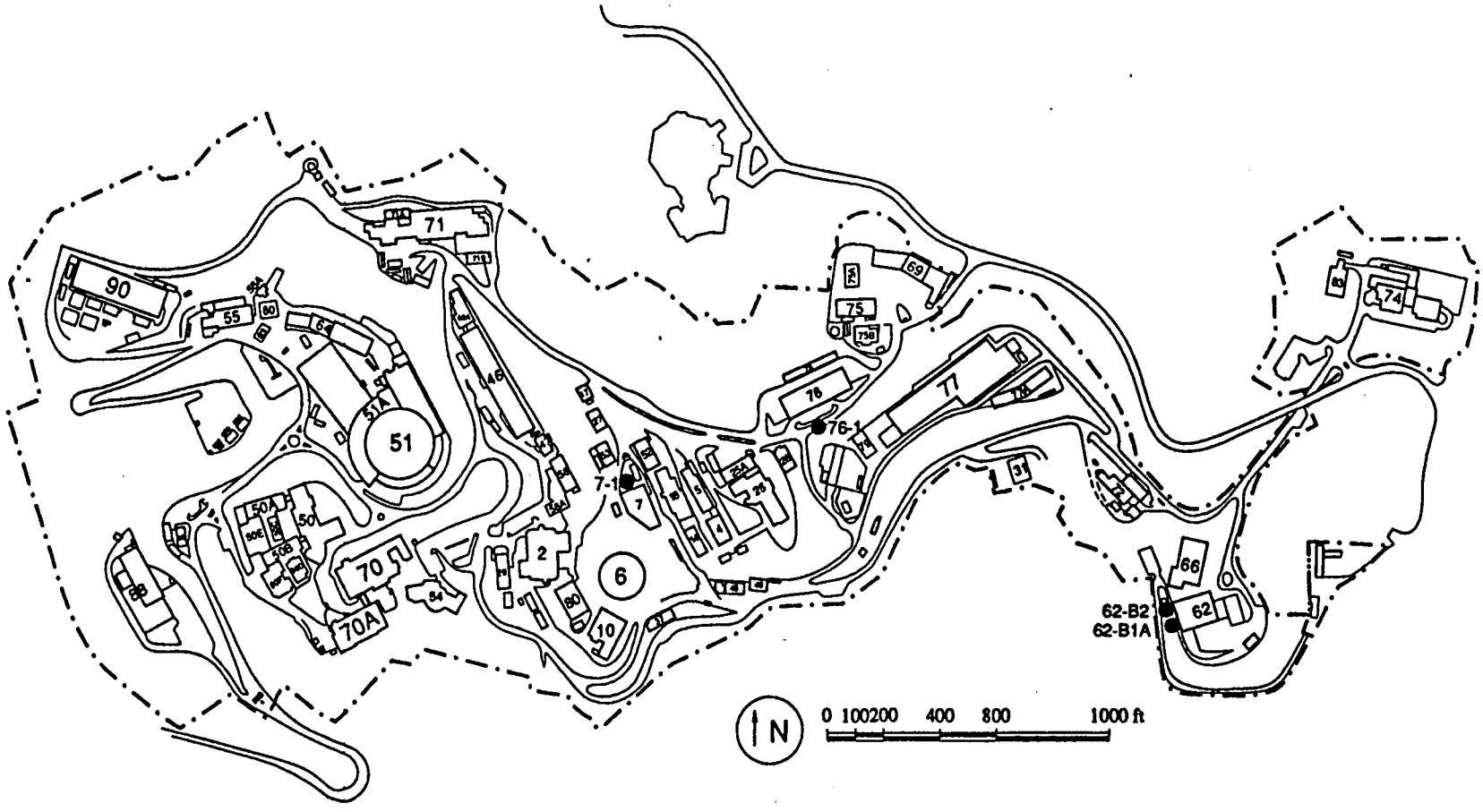


Figure 6-9. Locations of interior monitoring wells (July 1991).

ESD-9107-0127A

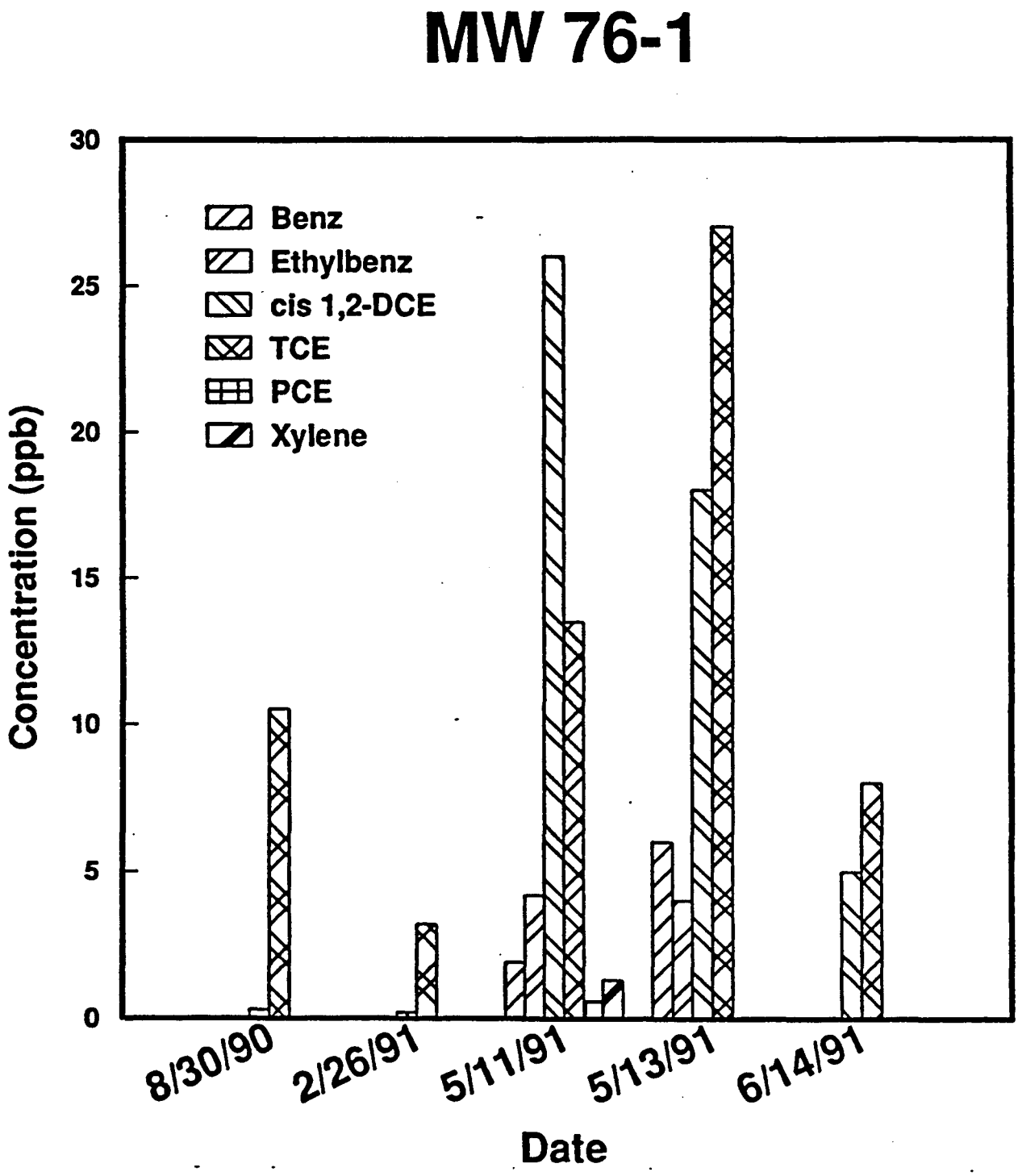


Figure 6-10. Time variation of contaminant concentrations in monitoring well MW 76-1.

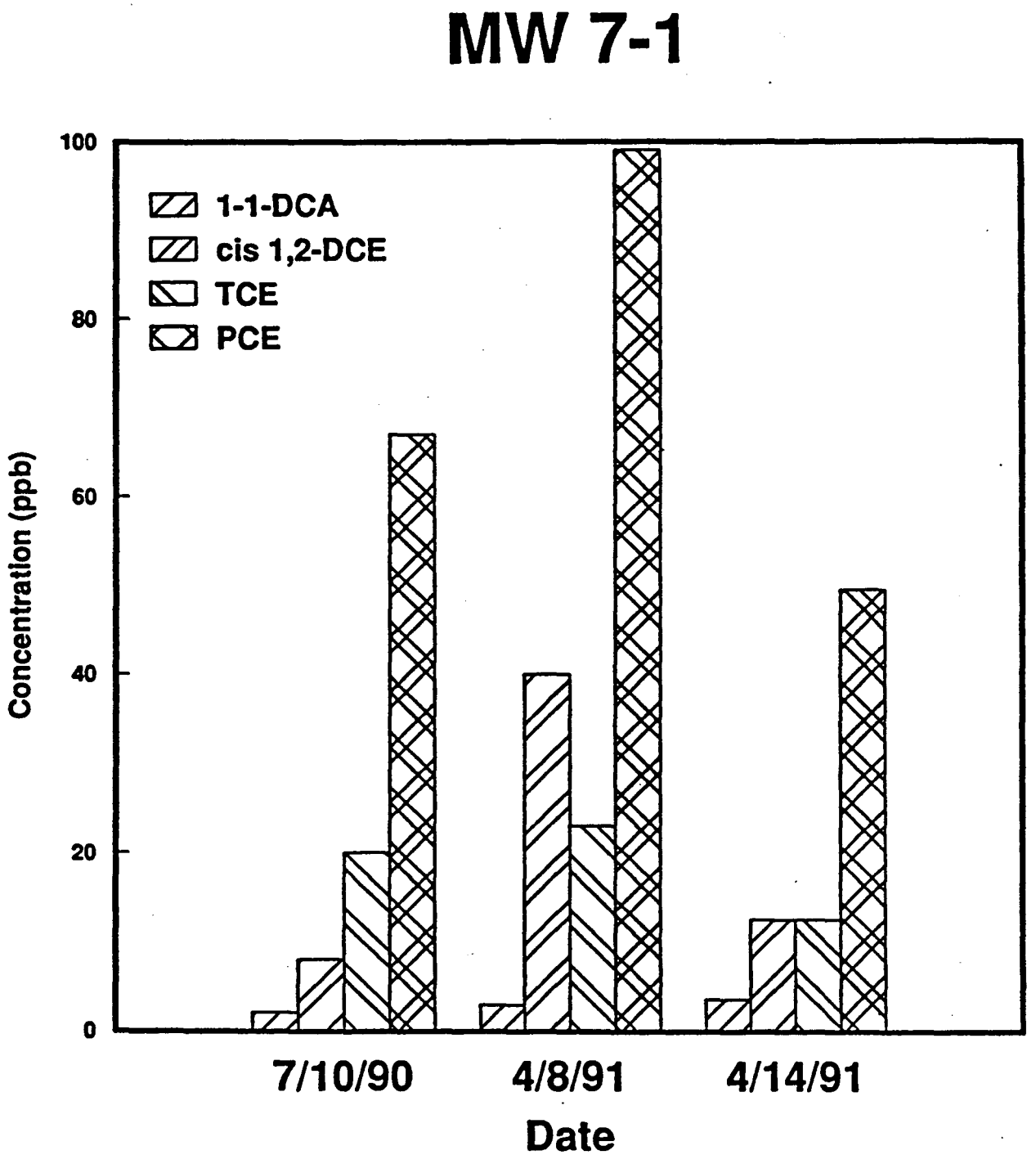
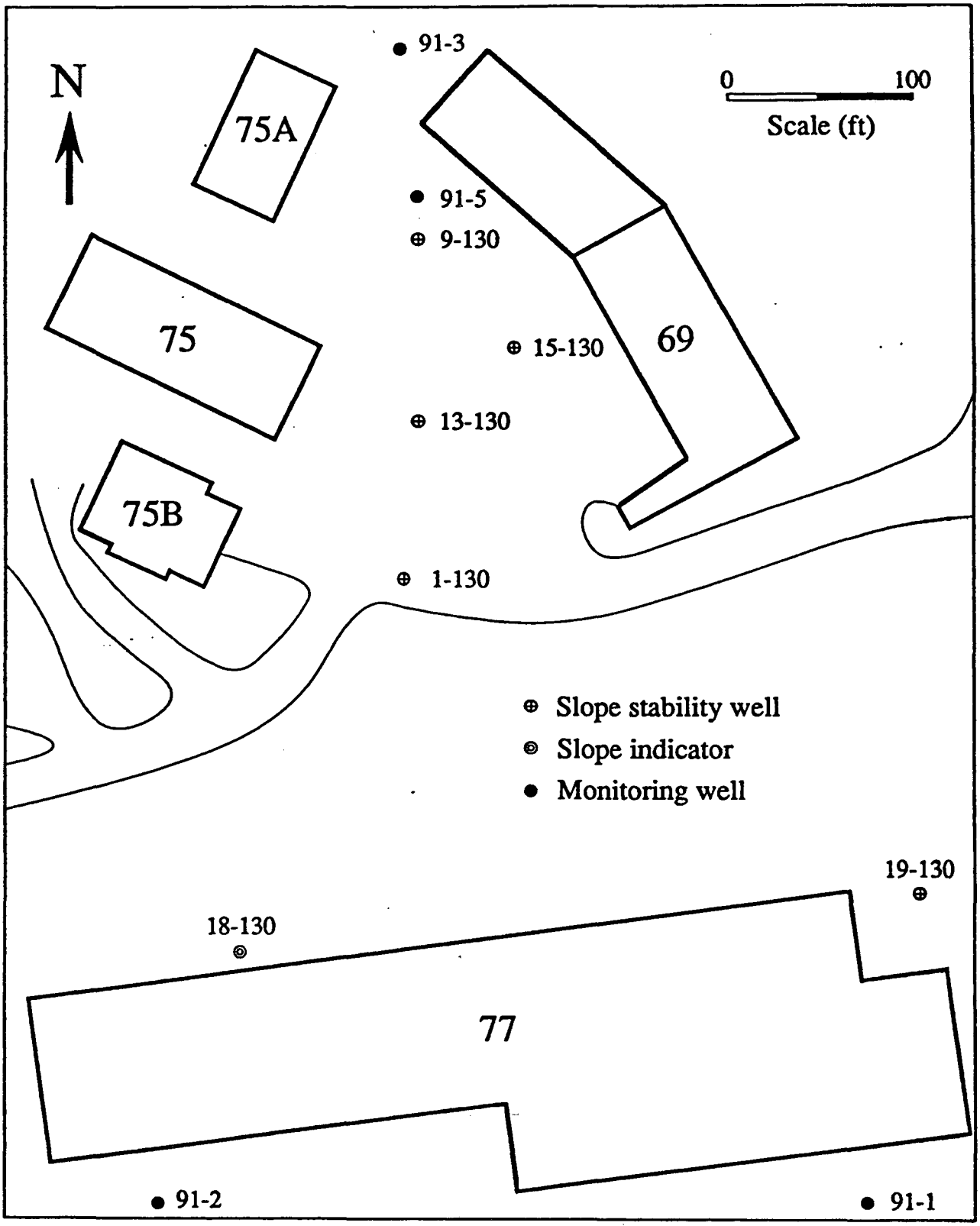
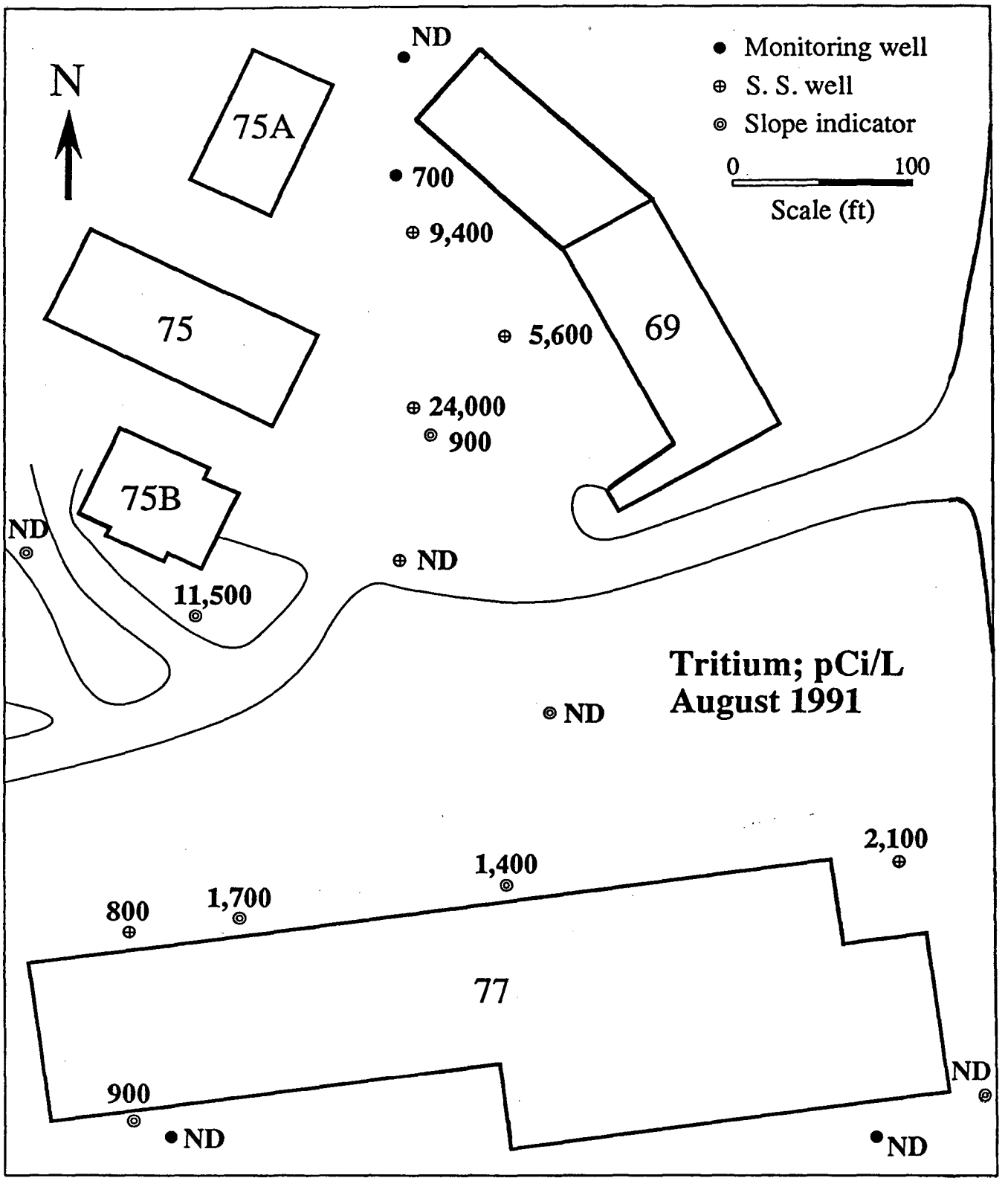


Figure 6-11. Time variation of contaminant concentrations in monitoring well MW7-1.



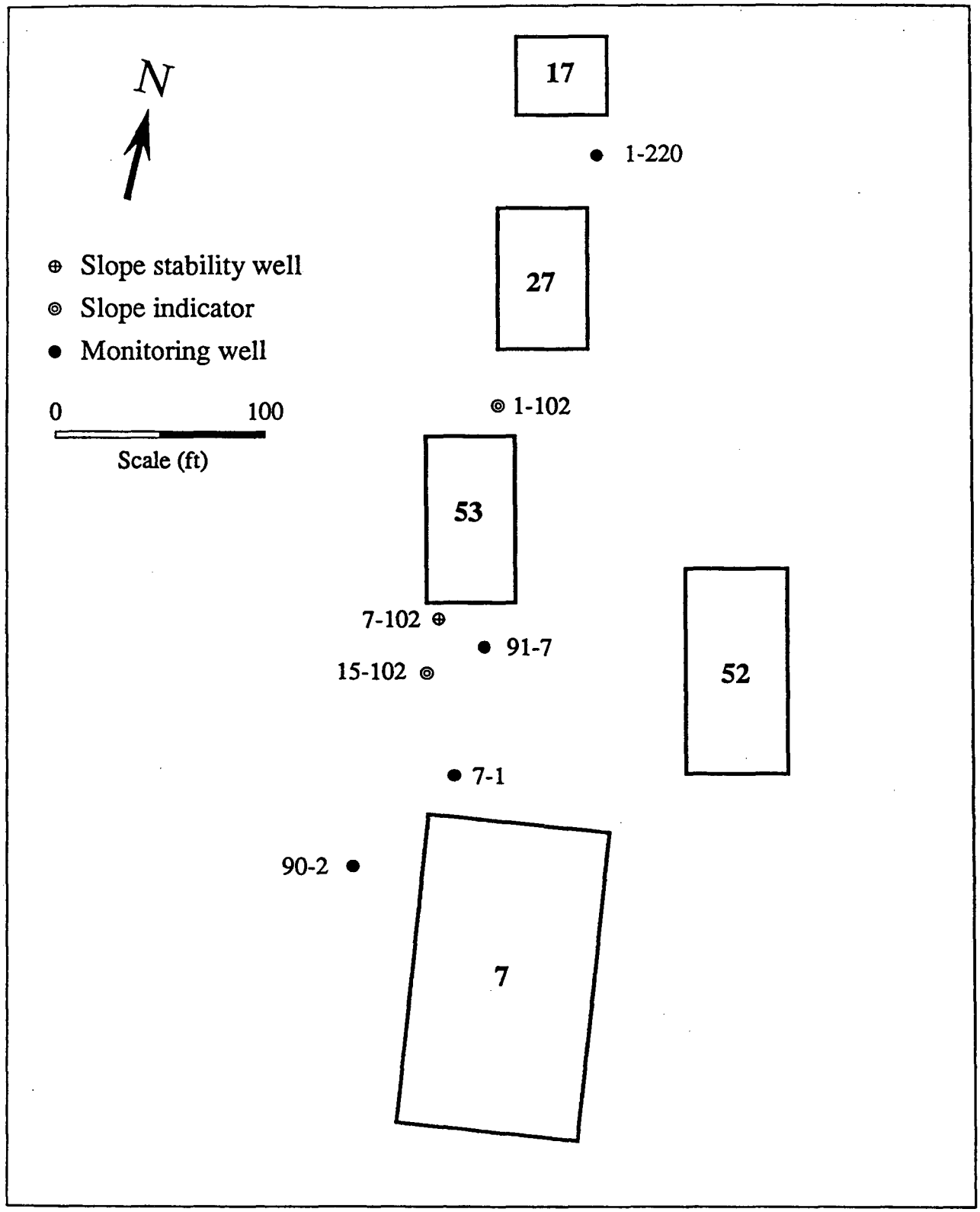
ESD-9105-0104A

Figure 6-12. Approximate location of new monitoring wells and old slope stability facilities.



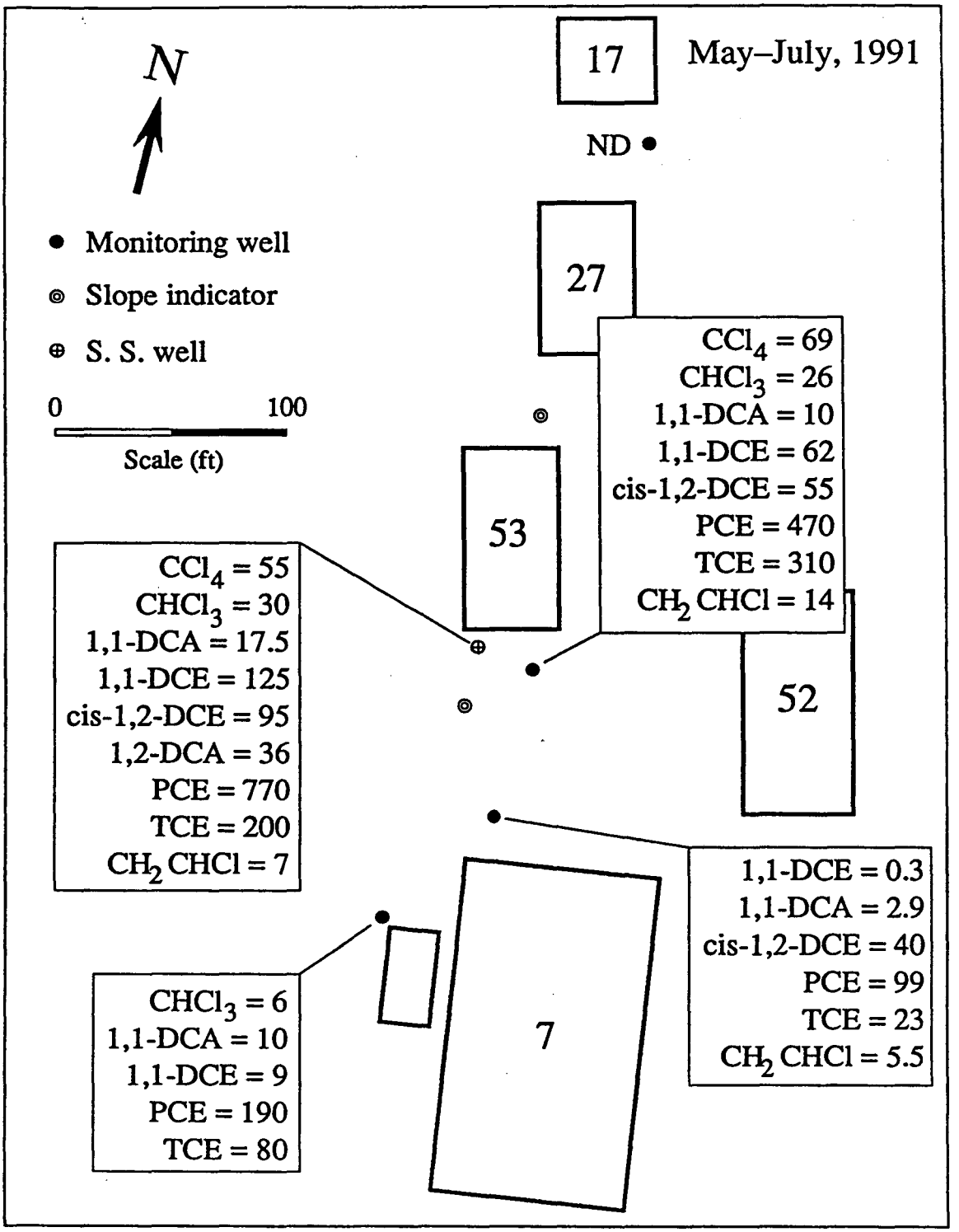
ESD-9108-0145

Figure 6-13. Tritium concentrations measured in water samples from various wells and slope indicators.



ESD-9105-0103A

Figure 6-14. Approximate locations of monitoring wells and slope stability facilities in the "Old Town".



ESD-9108-0154

Figure 6-15. Concentration of contaminants detected in wells and slope indicators in µg/L, in "Old Town" area.

highly contaminated. Contaminants and their concentrations detected in this area are shown in Figure 6-15.

Based on the present information, it is believed that a plume of contamination consisting of several chlorinated solvents is present in a perched aquifer at the contact of volcanic and sedimentary rocks. This plume extends from at least west of Building 7 (north of ALS) to north of Building 53.

Well inventory

A comprehensive inventory of all known cased borings at LBL was carried out during 1991. A total of 32 slope stability wells, 17 observation wells, and 25 slope indicators were located, all constructed during the last thirty years. The purpose of these facilities is to allow monitoring and to control the movement of unstable slopes at LBL. As a result, their constructions are not compatible with the requirements of monitoring well design. Many of these wells and slope indicators are gravel packed all the way to the ground surface. This will obviously provide a fast path for potential contaminants to reach the groundwater. LBL is currently working with the slope stability consultants to take appropriate actions to protect the groundwater. That may mean to properly abandon some of these wells or replace them with new wells that will protect the groundwater.

Ongoing Radiological Hydrauger Monitoring

As part of the ongoing environmental monitoring program, six of LBL's many hydraugers were sampled monthly. Samples taken were counted for tritium and gross alpha and beta activity. One sampling point, designated 75–77 hydr, collects water from a group of four 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 Figure 4-4) for the approximate "fan out" of the hydrauger bores). The second hydrauger, designated CC hydr, is an approximately 750-m-long horizontal bore from the Chicken Creek access road into Little Grizzly Peak (see Figure 4-4). The hydrauger designated CC-B hydr is a 150-m bore. The hydrauger designated 7712H hydr is approximately 64 m long, begins under the east end of LBL Building 76, and drains through the retaining wall north of Building 77. The hydrauger designated 7714H hydr is approximately 68 m long and runs approximately north-south from its origin in the earth lens on which Building 75 was constructed 10 m southeast of Building 75 to the retaining wall north of Building 77. The hydrauger designated 71 hydr is a manifolded group of six bores that fan easterly into the hillside south and east of Building 71. All sampled hydraugers except 7714H continued to flow throughout 1991. The flow from 7714H stopped in March. 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 4-7). The CC hydrauger is the deepest hydrauger (below grade) at LBL and is sampled so that the deepest available groundwater can be assayed. The 71 hydrauger group is sampled because it drains groundwater from the western side of the hill on which the tritium stack is located. The 7712H and 7714H hydraugers are sampled because their bores begin closest to the tritium facility.

Table 6-1 summarizes the hydrauger data for 1991. Significant concentrations of tritium were found in three of the hydraugers sampled. Indeed, the average tritium concentration of 26,000 pCi/l found in the 7712H hydrauger exceeded the US/EPA 40 CFR 141 limit of 20,000 pCi/l of tritium in community drinking water. It should be noted that the flow from 7712H is low (on the order of 0.2 l/min) and that the local surface and groundwater does not serve as a source of drinking water. The waters that flow from the 7712H and 14H hydraugers and the 75–77 hydrauger system are heavily mineralized. The gross radioactivity found in those three hydraugers is typical of such waters. There is no reason to attribute any of the radioactivity found in the hydraugers (aside from tritium) to LBL activities.

Table 6-1. Summary of groundwater samples, 1991.

Hydrauger Designation	No. of Samples	Concentration (10^{-9} µCi/ml) Alpha Avg.	Alpha Min.	Alpha Max.	Beta Avg.	Beta Min.	Beta Max.	Concentration (10^3 pCi/l) Tritium as HTO Avg.	Tritium Min.	Tritium Max.	Average as % of drinking-water standard Alpha %	Beta %	Tritium %
CC Hydr.	12	≤ 1.2	≤ 2.	5.8±5.4	0.8 ± 0.3	0.8 ± 0.7	1.7 ± 0.8	≤ 0.1	≤ 0.7	1.3 ± 0.3	≤ 24	10	≤ 0.5
CC-B Hydr.	12[a]	3.3 ± 2	≤ 4	12 ± 7	1.3 ± 0.3	≤ 0.8	3 ± 1	≤ 0.1	≤ 0.7	0.8 ± 0.7	66	16	≤ 0.5
71 Hydr.	12[a]	≤ 0.8	≤ 1.4	3.9± 3.6	1.5 ± 0.2	≤ 0.7	3 ± 1	≤ 0.1	≤ 0.7	2 ± 0.5	≤ 16	19	≤ 0.5
75–77 Hydr.	12	≤ 2.8	≤ 5	10 ± 8	3.8 ± 0.4	≤ 0.6	6 ± 2	5 ± 1	1 ± 0.3	9 ± 1	≤ 56	48	25
77 12H Hydr.	12	≤ 3	≤ 4	30 ± 15	3.6 ± 0.4	2 ± 1	6 ± 2	26 ± 3	19 ± 2	32 ± 4	≤ 60	45	130[d]
77 14H Hydr.	2[b]	≤ 5	≤ 4	≤ 7	≤ 2	≤ 2	≤ 2	4.4 ± 0.3	4.0 ± 0.4	4.7 ± 0.4	≤ 100	≤ 25	22
Drinking-water standard[c]		5			8			20					

[a]Only 11 samples were used in the HTO assessments of CC-B and 71 Hydrauger as each sample group contained 1 outlier
[b]The 7714 H Hydrauger only flowed for 2 months during 1991.
[c]40 CFR 141, beta assumed to be ^{90}Sr.
[d]During 1990 the Department of Energy officially adopted the Environmental Protection Agency's (EPA) values for community drinking-water standards. The EPA Standard for tritium in drinking water is 20×10^{-6} µCi/ml. Thus, the average tritum concentration in hydrauger 77 12H exceeded the EPA limit. The hydrauger does not deliver water to or from any community drinking water supply.

7.0

Quality Assurance

In response to LBLs self-assessment and the 1991 Tiger Team findings LBL committed to a major upgrade of the Laboratory's institutional and programmatic Quality Assurance programs.

As part of the LBL Environmental Protection Department Quality Assurance Upgrade, the Radioanalytical Lab will apply for California State Certification in three radioanalytical methods in 1992.

During 1991, in addition to the quality-assurance procedures described in the body of this report, samples that were blind-spiked with tritium were analyzed along with each group of environmental samples assayed for HTO.

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

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

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

The LBL Environmental Monitoring Section analyzed DOE's Environmental Measurements Laboratory (EML) QAPXXXIV and QAPXXXV water samples for tritium, as well as air and water samples for several gamma emitting nuclides. The results, as reported in Refs. 16 and 17, are tabulated in Table 7-1.

During 1991 the Section began analyzing United States Environmental Protection Agency (US/EPA) Intercomparison Studies Program Samples in preparation for California State Certification of the radioanalytical laboratory. The 1991 results are tabulated in Table 7-2.

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

Table 7-1. LBL QAP sample results, 1991.

QAP Sample #	Date	Medium	Nuclide	Reported LBL Results[a] (± percent)	EML Value	Ratio LBL/EML
XXXIV	3/91	Air	^{7}Be	$5.80 \times 10^{1} \pm 31$	5.30×10^{1}	1.09
		Air	^{54}Mn	$5.00 \times 10^{0} \pm 20$	4.80×10^{0}	1.04
		Air	^{57}Co	$6.00 \times 10^{0} \pm 33$	5.82×10^{0}	1.03
		Air	^{60}Co	$6.00 \times 10^{0} \pm 33$	5.14×10^{0}	1.17
		Air	^{137}Cs	$6.00 \times 10^{0} \pm 33$	4.53×10^{0}	1.32
		Air	^{144}Ce	$5.20 \times 10^{1} \pm 30$	5.22×10^{1}	1.00
		Water	^{3}H	$1.50 \times 10^{2} \pm 20$	3.61×10^{2}	0.42[b]
		Water	^{54}Mn	$1.69 \times 10^{2} \pm 30$	2.13×10^{2}	0.79
		Water	^{57}Co	$1.99 \times 10^{2} \pm 30$	2.30×10^{2}	0.87
		Water	^{60}Co	$1.81 \times 10^{2} \pm 29$	2.01×10^{2}	0.90
		Water	^{137}Cs	$1.57 \times 10^{2} \pm 29$	1.69×10^{2}	0.93
		Water	^{144}Ce	$5.10 \times 10^{1} \pm 31$	3.51×10^{1}	1.45
XXXV	9/91	Air	^{90}Sr	$6.90 \times 10^{-1} \pm 13$	6.63×10^{-1}	1.04
		Vegetn	^{90}Sr	$3.60 \times 10^{2} \pm 22$	4.39×10^{2}	0.82
		Water	^{3}H	$8.00 \times 10^{1} \pm 25$	1.00×10^{2}	0.80
		Water	^{90}Sr	$9.80 \times 10^{0} \pm 18$	1.01×10^{1}	0.97

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

[b]The 3/91 ^{3}H result reported was erroneously divided by 2.22.

Table 7-2. Summary of Performance in EPA intercomparison study samples, 1991.

Date Received	Analysis	Media	LBL Results (pCi/L)*			Mean	EPA Value (pCi/L)*	Passed
4/16/91	Gross α	Water	44	41	39	41.3	54 ± 24.3	Yes
	Gross β	Water	96	92	99	95.7	115 ± 28.5	Yes
	^{89}Si	Water	16	14	13	14.3	28 ± 8.7	No
	^{90}Sr	Water	17	14	15	15.3	26 ± 8.7	No
	^{137}Sr	Water	34	31	28	31	25 ± 8.7	Yes
5/10/91	^{89}Si	Water	34	37	34	35	39 ± 8.7	Yes
	^{90}Sr	Water	25	25	26	25.3	24 ± 8.7	Yes
5/17/91	Gross α	Water	22	22	24	23	24 ± 10.4	Yes
	Gross β	Water	45	46	46	45.7	46 ± 8.7	Yes
6/21/91	^{3}H	Water	10343	10732	10741	10605	12480 ± 2165.2	Yes
8/30/91	Gross α	Filter	17	19	16	17.3	25 ± 10.4	Yes
	Gross β	Filter	73	70	72	71.7	92 ± 17.3	No
	^{90}Sr	Filter	20	19	19	19.3	30 ± 8.7	No
	^{137}Cs	Filter	26	27	24	25.7	30 ± 8.7	Yes
9/13/91	^{89}Si	Water	57	56	51	54.7	49 ± 8.7	Yes
	^{90}Sr	Water	24	24	23	23.7	25 ± 8.7	Yes
10/18/91	^{3}H	Water	1431	1453	1430	1438	2454 ± 610.7	No
10/22/91	Gross α	Water	86	87	83	85.3	82 ± 36.4	Yes
	Gross β	Water	51	53	55	53	65 ± 17	Yes
	^{89}Si	Water	7	7	8	7.3	10 ± 8.7	Yes
	^{90}Sr	Water	10	9	11	10	10 ± 8.7	Yes
	^{60}Co	Water	16	15	15	15.3	20 ± 8.7	Yes
	^{134}Cs	Water	8	11	11	10	10 ± 8.7	Yes
	^{137}Cs	Water	10	16	13	13	11 ± 8.7	Yes

*The filter results were pCi/Filter.

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Appendix A
U.S. Department of Energy
Radionuclide Air Emission Annual Report
(Subpart H, 40 CFR 61.94)
Calendar Year 1991

Site Name: Lawrence Berkeley Laboratory

Operations Office Information

Office:	San Francisco Field Office		
Address:	1333 Broadway		
	Oakland, CA 94612		
Contact:	Steven Lasell	Phone:	(510) 273-7417

Site Information

Operator:	University of California		
Address:	1 Cyclotron Road		
	Berkeley, CA 94720		
Contractor Contact:	Gary Schleimer	Phone:	(510) 486-7623
DOE Site Contact:	Carl Schwab, 50B-3238	Phone:	(510) 486-6412

Section I. Facility Information

Site Description:

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 research that is appropriate for an energy research laboratory. LBL, birthplace of the cyclotron, was founded by the late Nobel Laureate Ernest Orlando Lawrence in 1931.

The Laboratory also supports nationwide university-based research by providing national facilities, including the National Center for Electron Microscopy, three large accelerators, several small accelerators, a number of radiochemical laboratories, several small gamma irradiators, and a tritium (^3H) labeling laboratory. Figure 1 illustrates the LBL site.

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

The Site

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

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

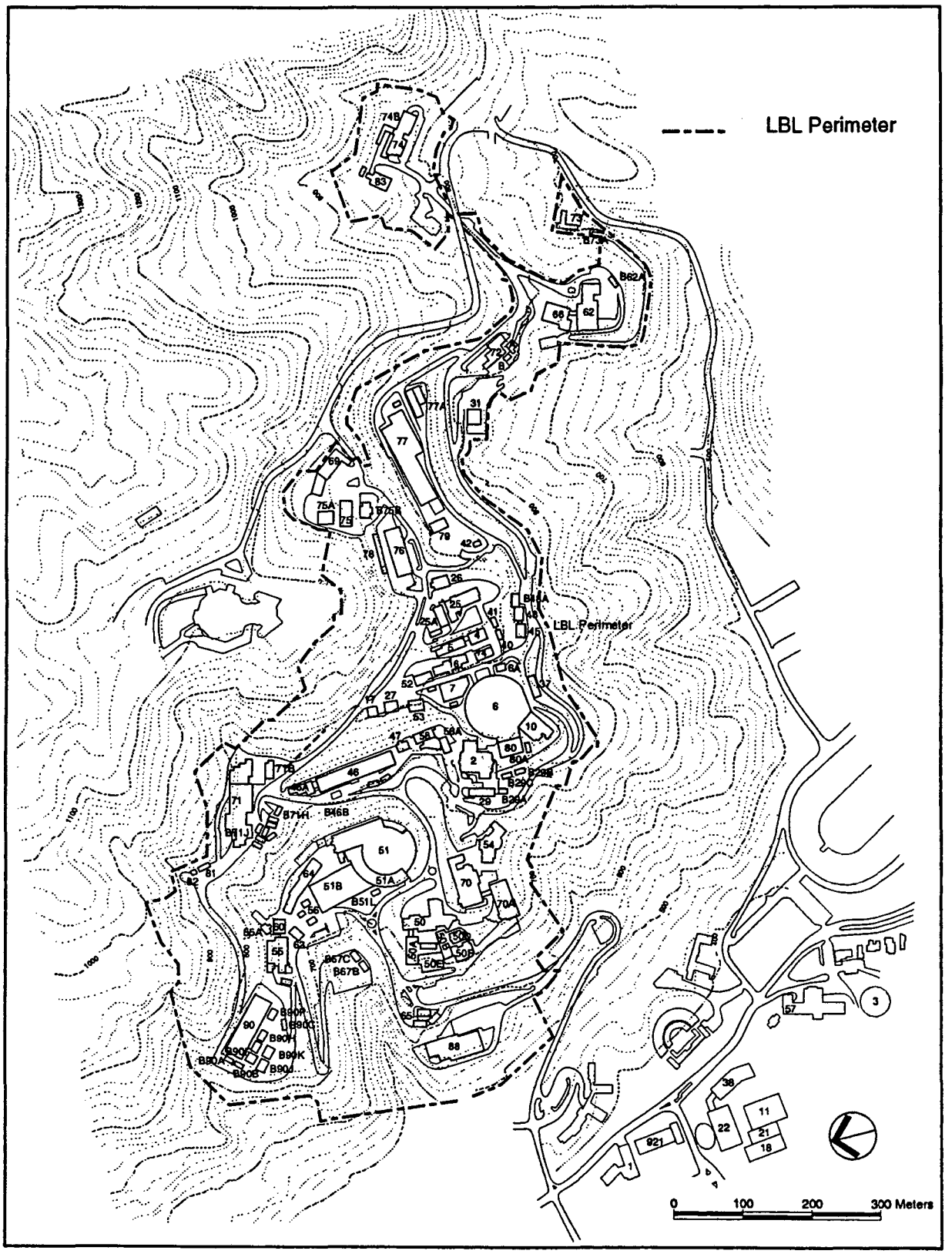

Figure 1. Lawrence Berkeley Laboratory buildings.

Bldg. No.	Description
	HILL-SITE BUILDINGS
2	Advanced Materials Laboratory (AML) & Center for X-ray Optics (CXRO)
4	Magnetic Fusion Energy (MFE)
5	Magnetic Fusion Energy (MFE)
*6	Advanced Light Source (ALS)
7	Central Stores & Electronics Shops
10	Cell & Molecular Biology Research & Photography
14	Accelerator & Fusion Research & Earth Sciences
16	Magnetic Fusion Energy Laboratory
17	EH&S/Applied Sciences Lab
25	Mechanical Technology
25A	Electronics Shops
26	Medical Services
27	High Voltage Test Facility & Cable Shop
29	Electronics Engineering, Research Medicine/Radiation Biophysics Offices
31	Chicken Creek Maintenance Bldg.
36	Grizzly Substation Switchgear Bldg.
37	Utilities Service
40	Electronics Development Lab
41	Magnetic Measurements Lab
42	Salvage
43	Compressor Bldg.
44	Indoor Air Pollution Studies
45	Fire Apparatus
46	RTSS, ALS, Accelerator Development
46A	Real Time Systems Section (RTSS)
47	Advanced Accelerator Study
48	Fire Station
50	Physics, Accelerator & Fusion Research & Nuclear Science
50A	Director's Office, Environment & Laboratory Development, Administration Division, Patents
50B	Physics, Computer Center, IRD & ICSD
50C	PID, Physics
50D	MCSD & Nuclear Science
50E	Earth Sciences
50F	Computing Services, IRD
51	Bevalac/Bevatron
51A	Bevatron Experimental Area
51B	External Particle Beam (EPB) Hall
52	Magnetic Fusion Energy Laboratory
53	SuperHILAC Development
54	Cafeteria
55	Research Medicine/Radiation Biophysics
55A	Nuclear Magnetic Resonance (NMR)
56	Cryogenic Facility
58	Accelerator Research & Development
58A	Accelerator Research & Development Addition
60	High Bay Laboratory
61	Standby Propane Plant
62	Materials & Chemical Sciences
63	Accelerator & Fusion Research
64	Accelerator & Fusion Research
65	Data Processing Services
66	Surface Science & Catalysis Lab
68	Upper Pump House
69	Business Services, Materiel Management, Mail Room & Purchasing
70	Nuclear Science, Applied Science & Earth Sciences
70A	Nuclear Science, Materials & Chemical Sciences & Earth Sciences
71	Heavy Ion Linear Accelerator (HILAC)
71A	HILAC Rectifier
71B	HILAC Annex
72	National Center for Electron Microscopy (NCEM)
72A	High Voltage Electron Microscope (HVEM)
72B	Atomic Resolution Microscope (ARM)
72C	ARM Support Laboratory
73	Atmospheric Aerosol Research
74	Research Medicine/Radiation Biophysics, Cell & Molecular Biology Laboratory
74B	Research Medicine/Radiation Biophysics, Cell & Molecular Biology Laboratory Annex
75	Radioisotope Service & National Tritium Facility (NTF)
75A	Compactor, Processing & Storage Facility
76	Construction & Maintenance & Craft Shops
77	Mechanical Shops
77A	Ultra High Vacuum Assembly Facility (UHV)
78	Craft Stores
79	Metal Stores
80	Electronics Engineering
80A	Office Building
81	Liquid Gas Storage
82	Lower Pump House
83	Lab Cell Biology
88	88-Inch Cyclotron
90	Applied Science, Employment, Engineering, Occupational Health, Personnel, Protective Services
	SMALL BUILDINGS AND TRAILERS
B-13A	Environmental Monitoring West of 88
B-13B	Environmental Monitoring West of 90
B-13C	Environmental Monitoring South of UC Recreation Area
B-13D	Environmental Monitoring North of 71
B-13E	Sewer Monitoring Station, Hearst Avenue
B-13F	Sewer Monitoring Station, Strawberry Canyon
B-13G	Waste Monitoring Station, West of 70

*Under construction.

8/27/92 Table 1. Key to LBL Buildings Shown in Figure 1

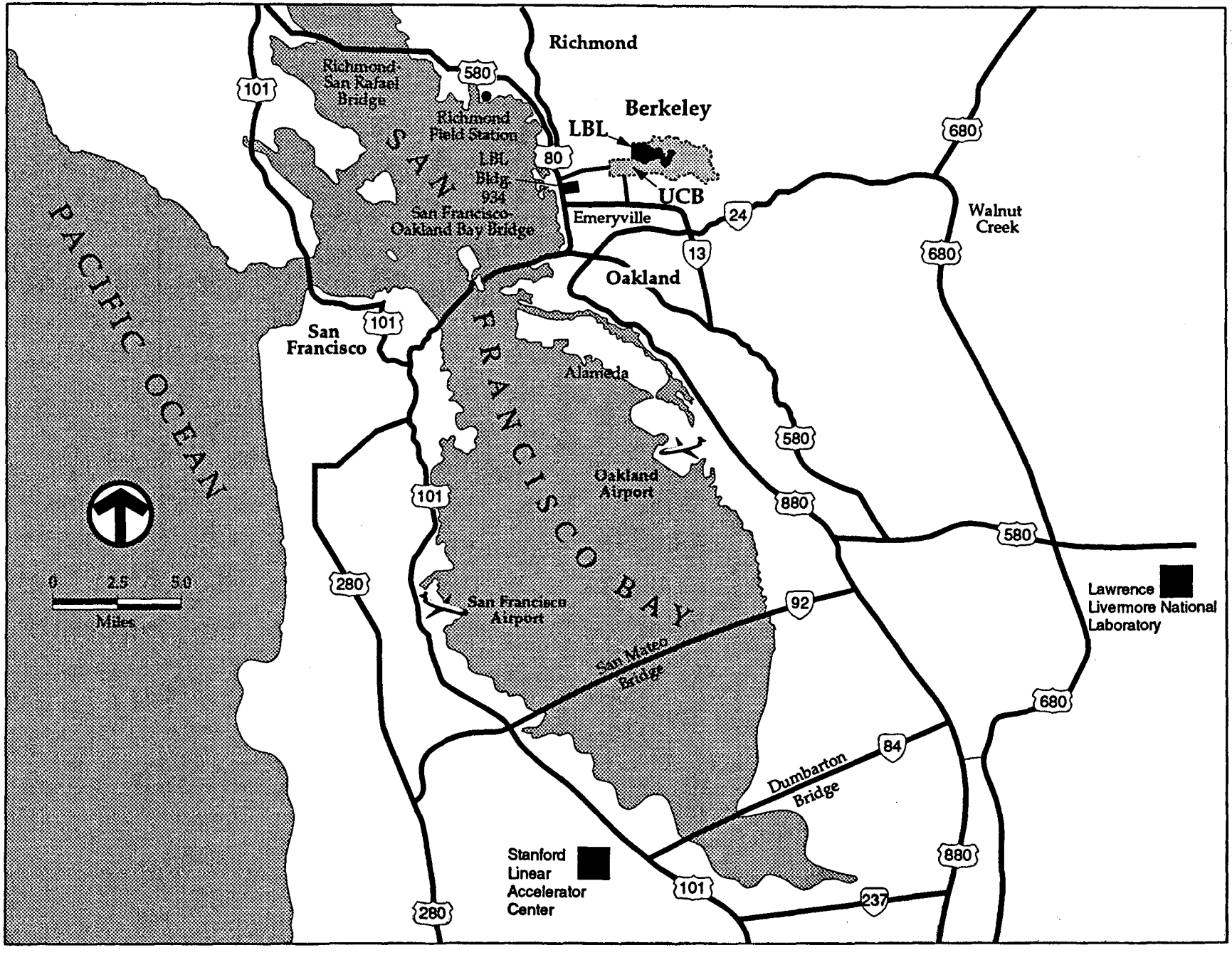

Figure 2. San Francisco Bay Area Map.

The Laboratory's activities are located on site and off site. There are 81 buildings on the LBL hillside site, plus additional facilities located on the University campus, notably the Donner Laboratory of Biology and Medicine and the Melvin Calvin Laboratory. The on-site space consists of 1,350,000 gross square feet (gsf) in about 60 buildings: 1,307,000 in DOE buildings and trailers, and 43,000 in University-owned buildings. Off-site space utilized by LBL consists of 260,000 gsf in various University buildings on the UC at Berkeley (UCB) campus and 130,000 gsf in leased facilities in Emeryville and Berkeley. (See Figure 2 for the location of LBL Building 934.)

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

The Climate

The climate of the LBL site is greatly influenced by its nearness to the Pacific Ocean and its exposure to the maritime air that flows in from San Francisco Bay. Seasonal temperature variations are small, with a mean temperature difference between the summer 17°C (63°F) and winter 9°C (48F) of only 8.5°C (15°F). Relative humidity ranges from 85-90% in the early morning to 65-75% in the afternoon. The average annual rainfall is 64 cm. About 95% of the rainfall occurs from October through April, and intensities are seldom greater than 1.3 cm/hr. Thunderstorms and hail and snow are extremely rare. Winds are usually light, but summer sea breezes range up to 9-13m/s (20-30 mph). Winter storm winds from the south or southwest have somewhat lesser velocities.

Source Description:

LBL employs a wide variety of radionuclides in its research program, including ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{22}Na, ^{45}Ca, ^{51}Cr, $^{55,59}Fe$, $^{57,60}Co$, $^{68}Ge/Ga$, ^{54}Mn, $^{82,85,90}Sr$, ^{86}Rb, $^{95}Nb/Zr$, ^{99}Mo, ^{99}MTc, ^{111}In, ^{125}I, ^{207}Bi, ^{226}Ra, $^{227}Ac/Th$, $^{231,233}Pa$, $^{235,238}U$, DEP-U, ^{237}Np, $^{238,239}Pu$, $^{241,243}Am$, $^{244,246,248}Cm$, ^{249}Bk, $^{249,252}Cf$, and ^{254}Es.

Of the foregoing, the most commonly and widely used nuclides are: ^{3}H, ^{14}C, ^{32}P, ^{35}S, and ^{125}I.

Compliance Status of Lawrence Berkeley Laboratory :

On April 23, 1991, the Laboratory received a Finding of Violation (FOV) dated April 18, 1991, numbered document 9-91-18B, from Region IX of the United States Environmental Protection Agency. The finding orders the laboratory to "evaluate *all* radionuclide release points and determine the monitoring requirements at LBL in accordance with Section 61.93 of the Clean Air Act and demonstrate compliance with Section 61.92 of the Act within 30 days of the order." LBL is in compliance with the basic standard of 10 mrem to a maximally exposed offsite individual. The laboratory is not in compliance with the monitoring requirements of the regulation and is negotiating an FFCA with Region IX of the EPA. During 1991 LBL identified all actual and potential sources of dispersible radionuclides, evaluated all release point discharges, and proposed monitoring methods for each stack or vent.

Sources Description:

LBL carries on operations which have the potential to emit radionuclides into the atmosphere in 17 laboratory buildings. All of LBL's source are "small sources"; i.e., the effective dose equivalent (EDE) from each source is < 0.1 mrem, and no collection of sources imposed an EDE of greater than ≥ 0.1 mrem to an offsite individual in 1991.

At present, discharge points with the most significant potential for routine or accidental release are continuously sampled. The categorical exception to the foregoing are the air activation product discharges from accelerators, which we have not historically monitored. The 1991 discharges from LBL accelerators were computed using a bounding calculation method developed in Patterson, H.W., and Thomas, R.H., *Accelerator Health Physics*, Academic Press, New York, NY, 1973, pp 519-531. Very small sources, that is, sources with potential for routine annual offsite impacts of < 0.005 mrem are, in general, not sampled continuously. The program LBL proposed to Region IX formalizes the foregoing process and includes a graded strategy for performing the "periodic confirmatory monitoring" called for in Section 61.93 (b)(4)(i) of the Clean Air Act.

Activities with low potential impact (< 0.01 mrem in a year) are carried out in unfiltered fume hoods. Activities with higher potential impact are performed in systems with appropriate exhaust filters or absorbers in place.

In addition to being small sources, many of LBL release points qualify as "grouped sources." The following criteria were used:

1. The sum of the EDEs attributable to all stacks in the group must be < 0.1 mrem.

2. Sources must be in close proximity (same or nearby building), and/or similar operations with similar nuclides are carried out in the facilities.

3. Sources grouped in the description section may not be grouped in the dose assessment section if the critical receptors are not the same (see Attachment II).

Building 75 houses LBL's National Tritium Labeling Facility (NTLF), in which a wide variety of molecules used in chemical, biochemical, and radiopharmaceutical studies are labeled with tritium and purified for further use. There are two stack release points for these activities, both of which are continuously sampled. The radionuclide releases are in the form of gaseous tritium (HT) or tritiated water (HTO). More than 95% of the 84 Ci of HTO released during 1991 operations was released from the stack located up the northern hillside from Bldg. 75 , The closest discharge point to offsite individuals. The other discharge point from the NTLF, located on the roof of Building 75, is further from offsite individuals and released < 5% of the 1991 discharges. The EDE to a maximally exposed individual from these stacks was 0.07 mrem, and represented the largest exposures to offsite individuals in 1991.

The LBL radiological waste handling facility, also located in Bldg. 75 (and 75A), processed no waste during all of 1991, so there were no stack discharges attributable to waste handling.

Building 88 contains an 88" sector focused cyclotron used in a wide variety of research applications. Beams of ions from H+ through uranium are accelerated onto targets used for nuclear studies. The primary airborne impact to an offsite individual from this facility is attributable to air activation radionuclides produced in the cyclotron vault during the fraction of the beam year when intense light ions are run (less than 5% of the beam year during 1991). There is presently no active stack monitor on this source, but the LBL stack monitoring upgrade project includes installation of a real time system on the vault vent stack. As there is no practical mechanism to do so, there are no controls on the release of air activation products. The quantity of activation products is controlled by the fraction of the beam year spent running light ions, and limits on circulating beam current. For 1991, the EDE from the 88 inch cyclotron discharges was modeled at 0.02 mrem.

Buildings 71 and 51, "the Bevalac." These two buildings house a large linear accelerator (71) and a heavy ion synchrotron (51). The machines are used to accelerate ions from helium to uranium in order to carry on nuclear studies and radiotherapy. Releases from these machines are air activation products produced by beam loss. Venting is diffuse (from building ventilators along the buildings' roof lines). The estimated EDE to an offsite individual from Bevalac

airborne releases is estimated at 0.02 mrem for 1991. There are no emission controls on these sources.

Buildings 70 and 70A are nuclear science and chemical science facilities programs. They include super heavy nuclear studies, waste migration studies (tracer amounts) and nuclear chemical studies. There is also a cell survival study group in 70A. The radioactive work is carried out by four research groups in twelve of the many laboratories in the two buildings. Emissions are released through 20 stacks, 19 of which are sampled continuously. Discharges from the stack from the Cell Survival Study Group Lab are too small to require sampling. There is also a pit storage room where radionuclides are stored in a fireproof pit in closed containers. Aside from the release of 1 mCi of ^{14}C as CO_2 from, the pit storage room, releases from the facility were below the detection limit which is $<1 \times 10^{-6}$ Ci of alpha activity from all 19 stacks. The EDE from such releases would be < 0.02 mrem.

Buildings 1 and 3, "Donner Laboratory" and "Calvin Laboratory." Cell and molecular biology studies are performed in both facilities. The buildings are located on the University of California campus. The predominant nuclides used are ^{3}H, ^{32}P, ^{35}S, and ^{14}C as labeled amino acids and DNA precursors. $^{14}CO_2$ is also used in Bldg. 3 as an "incubant." Bldg. 1 has non-LBL employees who work in the building, but Bldg. 3 is wholly occupied by LBL personnel. Work is done on benchtops and in hoods in both buildings. Releases are from building vents and hoods (11 stacks in Bldg. 1 and 5 in Bldg. 3). Five Stacks in Bldg. 1 and four in Bldg. 3 are sampled. The respective EDEs from Buildings 1 and 3 are 0.009 mrem and 0.03 mrem.

Buildings 74, 74B, and 83 include a wide variety of cell biology, virology, research medicine, and human genome projects. Releases from 74 and 74B come from hoods and stacks that vent individual workplaces. Bldg. 83 vents are through HEPA-filtered biological cabinets. In laboratories where >10 mCi/yr of ^{125}I is used, the material is worked up in Tetraethylene Diamine (TEDA) -doped activated-carbon-filtered enclosures. Eleven stacks in 74, three stacks in 74B, and one stack from Bldg. 83 (a total of 14) are sampled. The EDE from this group of stacks was 0.003 mrem for 1991.

LBL Buildings 25, 26, and 62. There is a single user of radionuclides in each of the 3 listed buildings. Vacuum deposition of natural Th and uranium (mg-quantities) is done in Bldg. 25. The LBL bioassay laboratory is in Bldg. 26. (Trace quantities of a variety of nuclides are used in sample spiking and standards preparation.) A thorium aerosol study with mg quantities of 0.1μ thorium spheres is performed in one lab in Building 62. All of the aforementioned operations are carried out in enclosures whose exhaust streams are HEPA filtered. The 62 stack is sampled. The EDE from Building 62 for 1991 was 5×10^{-6} mrem. The EDE modeled from Building 25 and 26 release estimates are 3×10^{-7} mrem and 2×10^{-6} mrem, respectively.

Building 55, Research Medicine. The primary radiological activities carried out in Bldg. 55 are positron emission tomography (PET) and metabolic studies. The studies are carried out on human patients. The radiological activities take place in 2 laboratories and a (PET) camera room. As > 200 mCi of radioiodine is worked up in the facility annually, operations with radioiodine are done in a HEPA and TEDA-doped carbon-filtered enclosure. Two radiation hoods and the radioiodine box stacks are sampled continuously. The EDE from this facility's releases was 0.001 mrem for 1991.

Building 934 is located off site roughly 3 air miles from LBL. The radiological activities include cell and molecular biology research. Also, forensic DNA investigations are carried out by a group from the California Department of Justice. The research employs RNA and DNA precursors and amino acids labeled with ^{3}H, ^{14}C, ^{32}P, and ^{35}S. Metabolism of ^{35}S amino acids produces $^{35}SO_2$, which is released to the atmosphere. Our studies indicate that < 0.01% of the activity incubated is available for release. No stacks are sampled at this location. The offsite EDE modeled from 934 release estimates is 4×10^{-5} mrem.

Section II. Air Emissions Data

Point Source	# of Stacks	Type Control	Efficiency (%)	Distance to Nearest Receptor
*88 Vault	1	None (1)	0	110 m (residence)
*71 Vault	1	None (1)	0	120 m (residence)
*51 Vault	1	None (1)	0	410 m (residence)

Grouped Source	# Stacks	Type Control	Efficiency (%)	Distance to Receptor
Building 75 National Tritium Labeling Facility	2	Silica gel(2)	>99	130 m (school)
Building 75A Storage Box	1	T-DAC(3) HEPA	>75 >99	200 m (workplace)
Buildings 74, 74B& 83 Stacks	14	T-DAC(3) NONE(4)	>75 0	200 m (residence)
Building 55 Stacks	5	HEPA T-DAC(3)	>99 >75	270 m (residence)
Building 3 Stacks	3	NONE(4)	0	50 m (workplace)
Buildings 70 & 70A(5) Stacks	20	HEPA (Manifolds) NONE (Hood)	>99 0	330 m (residence)
*Building 934 Stacks	9	NONE(4)	0	12 m (residence)
Building 1 Stacks	11	NONE(4)	0	10 m (same bldg)
*Buildings 25 & 26	2	HEPA	>99	240 m (workplace)
Building 62	1	HEPA	>99	240 m (workplace)

*Not monitored, emissions estimated.

Quantities of nuclides released from LBL stacks contributing ≥ 10% of the EDE from a release point

Radionuclide	Annual Quantity (Ci)
H-3	84
C-14	1.2×10^{-2}
S-35	7×10^{-4}
I-125	3×10^{-4}
Unidentified Alpha Emitters	$<1 \times 10^{-6}$
C-11	9 (E)
N-13	10 (E)
O-15	4 (E)

(E) Estimated

---

1 The Radionuclides released from the accelerators are air activation products which are impractical to control. (The maximum offsite EDE from an LBL accelerator in 1991 was ≤ 0.02 mrem.)

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

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

4 The uncontrolled releases are from LBL fume hoods which are unfiltered.

5 The stacks included in this group source vent a number of laboratories whose research employs μCi and mCi quantities of a number of actinides. The estimated release is the sum of the product of the lower detection limit times the annual flow for each stack over the 20 stacks. ^{232}Th was used as a conservative dose-equivalent representative of the actinides used.

Section III. Dose Assessments

Description of Dose Model

COMPLY was used to compute maximum offsite effective dose equivalent for all stacks and stack groups.

Summary of Input Parameters
(See Attachment II for a list by stack group.)

All nearest receptors were assumed to grow all vegetables and produce at home if a residence or at the nearest residence to the receptor if a workplace or school.

The nearest farm where milk and meat is produced is >2000 meters from any "maximum offsite receptor." The meteorology used with COMPLY was reformatted data from the AIRDOS PC OAK 0319.wnd file, as onsite meteorology was not available. LBL completed a preliminary study of meteorological monitoring, siting, equipment, and quality assurance requirements during 1991. Equipment will be in place, and collecting data, on or before September of 1993

Compliance Assessment

Effective Dose Equivalent: 0.07 mrem to an offsite individual 130 meters north of the NTLF Stack.

Additions or Modifications

There were no new sources constructed or modifications to LBL radiological release points during 1991.

Certification

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

Name:_____

Associate Laboratory Director for Operations

Signature:_____Date:_____

(Original signed by Klaus H. Berkner)

Name:_____

Assistant Manager for Energy Programs
DOE Field Office
San Francisco

Signature:_____Date:_____

(Original signed by Martin J. Domagala)

IV. Supplemental Information

Provide an estimate of collective effective dose equivalent (person-rem/yr) for 1991 releases.

The estimated collective effective dose equivalent (CEDE) to persons living within 80 km of LBL is 3 man-rem attributable to LBL airborne releases.

Report any unplanned releases of radionuclides to the atmosphere, the date of release and the resulting EDE to the public. Describe the incident and the corrective action taken.

There were no unplanned airborne releases to the atmosphere from LBL during 1991.

Estimate release levels (Curies) from unmonitored sources and describe the methods used in the assessment. Determine the EDE to the public form each source.

The total release to the atmosphere of unmonitored sources from LBL is estimated at 23 Ci of produced air activation products ($T1/2 \leq 1.8$ hr) and 10^{-5} Ci of nuclides released from laboratory stacks. The air activation product release values are based on air activation modeling (See the descriptions of Bldgs. 51, 71, and 88 discharges in the sources and emissions data section of this report). The laboratory stack releases from small unmonitored sources are computed from quantities used multiplied by typical release fractions (based on LBL measurements and NRC literature values).

Identify and describe sources of diffuse emissions (e.g., large area sources of radionuclides) and estimate the emission levels in Ci/yr and EDE to the public. Describe the method used to determine the values reported.

Fugitive emissions from stored tritium waste are estimate at < 0.2 Ci. The maximum effective dose equivalent (EDE) to a member of the public from such releases would be < 0.0002 mrem.

The fugitive release estimate is the product of the annual average workplace HTO concentration where the tritium waste is packaged and stored, times the number of air changes in the storage building per year. The EDE estimate from the releases was determined by comparison with the National Tritium Labeling Facility stack releases and the concomitant offsite EDE.

If pertinent, estimate dose (air pathway) to the critical receptor from DOE activities based on environmental monitoring and surveillance data.

The maximum offsite average concentration was 0.2 ± 0.1 μCi/m^3 of HTO at an offsite workplace. The EDE to a occupant of the facility would have been ≤ 0.07 mrem.

Provide information on the status of compliance with Subparts Q and T of 40 CFR Part 61 if applicable.

Although exempt form Subpart H, provide information on Rn-220 emission from sources containing U-232 and Th-232 where emissions potentially can exceed 0.1 mrem/yr to the public or 10% of the non-radon dose to the public.

Provide information on non-disposal/non-storage sources of Rn-222 emissions where emissions potentially can exceed 0.1 mrem/yr to the public or 10% of the non-radon dose to the public.

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

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

LBL has identified 7 points subject to the continuous monitoring requirements of 40 CFR subpart H, Section 61.93(b). During 1991 only 2 of the 7 points produced discharges and one point was continuously monitored (sampled). LBL has identified: a) all emission points and evaluated releases, b) categorized stacks by EDE, and c) suggested suitable monitoring methodology for each point. The information developed in a - c above was sent to EPA region IX during 1991. The cost to upgrade all monitoring systems to satisfy 40CFR subpart H requirements is approximately $1.2 x 10^6 (funding approved).

LBL presented Region IX a proposal for a graded approach to periodic confirmed monitoring. The proposal separates stacks into four categories graded by EDE:

1. For sources whose EDE is <0.001 mrem, LBL will verify that established annual use limits are not exceeded.
2. For stacks with 0.001 EDE < 0.01, LBL will sample during a typical two week work cycle annually.

3. For stacks with $0.01 \leq EDE < 0.05$, LBL will sample continuously and change and analyze samples monthly.*
4. For stacks $0.05 \leq EDE < 0.1$ LBL will sample continuously and change and analyze samples weekly.

* For species with T 1/2 < 100 hours, a continuous emission monitor will be employed. At LBL the only nuclides routinely used or produced during 1991 whose T 1/2 were < 100 hours (parent species) were accelerator-produced air activation products. (Any future programs employing short-lived nuclides will be evaluated on a case-by-case basis.)

Under its Tiger Team action plan, LBL is upgrading all monitoring and analytical QA. The program will meet or exceed all provisions contained in Appendix B method 114.

LBL NESHAPS REPORT "COMPLY" INPUT PARAMETER AND MODELED DOSE INFORMATION - 1991

Source (LBL Facility or Bldg	Number of Stacks grouped	Control (s)	Efficiency (%)	Nuclides	Release (Ci)	Receptor	Distances To Receptor	Distances To Produce	-(M) To Meat and Milk	Stack Height (M)	Bldg. Height (M)	Bldg. Width (M)	Effective Dose Equivalent (EDE) (mrem)
75 NTLF	2	Silica GeL	>99(1)	H-3 (HTO)	84	School	130	500	2000	10	0	0	0.07
88 VAULT	1	NONE	0	C-11 N-13 0-15 AR-41	0.1 (E) 0.2 (E) 0.9 (E) 0.01 (E)	Residence	110	NA	NA	12	10	85	0.02
75A STORAGE BOX	2	T-DAC (2) HEPA	>75% >99%	I-125	3 x 10-7	Workplace	200	500	2000	8	6	24	2 x 10-6
74,74B & 83 STACKS	5	T-DAC(2) NONE	>75%	I-125 S-35	2 x 10-4 7 x 10-4	Residence	200	200	2000	7	5	60	0.003
BLDG 55 STACKS	3	HEPA T-DAC(2)	>99% >75%	I-125	1 x 10-4	Residence	270	270	2000	9	7	40	0.001
BLDG 3 STACKS	5	NONE		C-14 AS CO2	1 x 10-2	Workplace	60	270	2000	15	14	33	0.03
BLDG 70 & 70A STACKS	20	HEPA (MANIFOLDS)	>99%	"TH-232" (3)	<1 x 10-6	Residence	330	330	2500	13	11	60	<0.02
BLDG 62	1	HEPA	>99%	TH-232	2 x 10-8	Workplace	240	400	2000	13	11	70	5 x 10-6
51 VAULT	BV	NONE	0	C-11 N-13 0-15 AR-41	9 (E) 10 (E) 3 (E) 0.1 (E)	Residence		NA	NA	15	15	100	0.02
71 VAULT	BV	NONE	0	AS ABOVE	<10-3 (E)	Residence	150	NA	NA	10	10	130	3 x 10-6
934	9	NONE	0	S-35	5 x 10-6	Business	12	400	5600	4	4	20	4 x 10-5
1	11	NONE	0	S-35	1 x 10-5	School	10	400	3000	9	9	55	0.009

(1) Silica Gel traps are >99% efficient traps for HTO as long as they are changed before breakthrough.
NTLF Personnel routinely change traps when working in the facility.
(2) TEDA-doped activated carbon traps.
(3) The "Th-232" value is the "effective" release from all 20 stacks in the listed group assuming continuous release at the lower limit of detection.
Th-232 was conservatively chosen to represent the alpha-emitting nuclides used at the facilities.
(BV) Building Vents.
(E) Estimated.
(4) The maximum EDE is 0.07 MREM, not the sum of all terms, as the NTLF, 88, 51, Bldg 3, and 70/70A maximally exposed individuals are in different places.

Appendix B
Acronyms and Other Initialisms

ALS	Advanced Light Source
BAAQMD	Bay Area Air Quality Management District
Cal/EPA	California Environmental Protection Agency
CCF	100 cubic feet
CEDE	collective effective dose equivalent
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
DCG	derived concentration guide
DCE	dichloroethylene
DHS	California Department of Health Services
DOE	U.S. Department of Energy
DTSC	Department of Toxic Substances Control (part of Cal/EPA)
EA	Environmental Assessment
EBMUD	East Bay Municipal Utility District
EIR	Environmental Impact Report
EMS	Environmental Monitoring Station
ERDA	U.S. Energy Research and Development Agency
ESA	Endangered Species Act
FFCA	Federal Facilities Compliance Agreement
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
GAC	granulated activated carbon
gsf	gross square feet
HEPA	high-efficiency particulate air (filter)
HTO	tritiated water
HWCL	Hazardous Waste Control Laws (State of California)
HWHF	Hazardous Waste Handling Facility (at LBL)
LBCF	Low-Background-Counting Facility
LBL	Lawrence Berkeley Laboratory
LHS	Lawrence Hall of Science

MS	monitoring station
MSRI	UC Mathematical Sciences Research Institute
MW	monitoring well
NCRP	National Commission on Radiation Protection and Measurements
NEPA	National Environmental Protection Act
NESHAPs	National Emission Standard for Hazardous Airborne Pollutants
NIST	National Institute of Standards and Technology
NOD	Notice of Deficiency
NPL	National Priorities List
NTLF	National Tritium Labeling Facility
PBR	Permit by Rule
PCB	polychlorinated biphenyls
PCE	perchloroethylene
POTW	Public Owned Treatment Works
RCRA	Resource Conservation and Recovery Act
RPG	radiation protection guidelines
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SIC	Standard Industrial Classification
SWQCB	State Water Quality Control Board
TCE	trichloroethylene
TEDA	tetraethylene diamine
TSCA	Toxic Substances Control Act
UC	University of California
UCB	University of California at Berkeley
UST	underground storage tanks
US/EPA	U.S. Environmental Protection Agency
VSI	Visual Site Inspection
VOC	volatile organic compounds

Appendix C
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