SLAC–341

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ENVIRONMENT AND SAFETY OFFICE
STANFORD LINEAR ACCELERATOR CENTER
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I. Introduction

A. General

The Stanford Linear Accelerator Center (SLAC) is a national facility operated by Stanford University under contract with the U. S. Department of Energy (DOE). It is located on the San Francisco Peninsula, about halfway between San Francisco and San Jose, California. The site area is in a belt of low rolling foothills, lying between the alluvial plain bordering San Francisco Bay on the east and the Santa Cruz Mountains on the west. The accelerator site varies in elevation from 53 to 114 meters (m) above sea level, whereas the alluvial plain to the east around the Bay lies less than 46 m above sea level; the mountains to the west rise abruptly to over 610 m. The SLAC site occupies 170 hectare of land owned by Stanford University and leased for fifty years in 1962 to the DOE (then AEC) for purposes of research in the basic properties of matter. The lands are part of Stanford's "academic reserve," and are located west of the University and the City of Palo Alto. The site is located in an unincorporated portion of San Mateo County. It is bordered on the north by Sand Hill Road, and on the south by the San Francisquito Creek. The accelerator is sited on a roughly 300 m-wide parcel, 3.2 kilometers (km) long, running in an east-west direction. The width of the parcel expands to about 910 m at the target (east) end to allow space for buildings and experimental facilities.

The SLAC staff currently numbers roughly 1,550 employees; there are about 1,200 full-time people, 200 part-time and 150 visiting scientists. Approximately one-quarter of the staff is professional, composed of physicists, engineers, programmers and other scientific-related personnel. The balance of the staff composition is support personnel including technicians, crafts personnel, lab assistants, clerical and administrative employees.

B. Accelerators in Perspective

Accelerators are simply tools of research enabling physicists to explore and understand the fundamental behavior of the subatomic environment.

Some accelerators are linear, as is SLAC's; others are circular in geometry as are cyclotrons, synchrocyclotrons, betatrons and synchrotrons. All conventional accelerators accelerate subatomic particles (electrons, protons, positrons, alpha particles) to a high energy and bombard a target nucleus. Physicists then study the effects of the collisions in an attempt to understand precisely what happens and thereby understand the nature of the atomic nucleus. Because of the very strong forces which bind the nucleus and its constituents together, physicists need greater and greater energies in order to delve constantly deeper. Consequently, accelerators have grown in size and complexity.

One of the important components of the U. S. high energy physics program is the 3.2 km-long electron accelerator at SLAC. This machine is now capable of accelerating electrons to 50 billion electron volts (GeV), and positrons will soon achieve the same energy. These particle beams are utilized by an array of experimental fixed target installations, two colliding beam storage rings and the SLAC Linear Collider (SLC).

The Positron Electron Project (PEP) storage ring is a special extension of the SLAC accelerator and poses no greater environmental problems than does the existing linac. The center-of-mass energy achieved by colliding beam particles together is vastly more efficient than having a single beam strike a stationary target. In a colliding-beam storage machine, the beam particles are truly "recycled," *i.e.,* the same bunches of beam particles are brought into collision over and over again, rather than striking a target only once. For this reason, colliding-beam devices, in a fundamental way, produce very much less radiation and residual radioactivity than do conventional accelerators.

The PEP facility, completed in 1980, is a large storage ring housed in an underground tunnel at depths varying from 6–30 m and in which beams of electrons and their antimatter equivalent, positrons, circulate in opposite directions at energies up to 15 GeV. The underground ring has a diameter of about 700 m and is located at the eastern extremity of the SLAC site.

When particles of matter and antimatter meet head-on at high velocity, both are completely converted into energy. According to the formulations of Albert Einstein, energy can be transformed into matter and vice versa. In the electron-positron collisions some of the resulting energy is immediately transformed back into matter, producing a variety of particles of immense interest to physicists. Many of the design details of the PEP facility are based on the design and experience of a small existing storage ring at SLAC called the Stanford Positron Electron Asymmetric Ring (SPEAR). The SPEAR facility came into operation and began performing colliding-beam experiments in 1972. The SPEAR machine is about one-eighth the size and is capable of about one-quarter the energy of the PEP facility. Although the high energy physics usefulness of SPEAR will be fully exploited in the 1980's, its success has established the feasibility and served as a prototype for PEP. It also serves as a strong source of synchrotron light for the Stanford Synchrotron Radiation Laboratory (SSRL).

In addition to the aforementioned facilities, SLAC has built a new machine, the SLC. The SLC project was proposed in 1980 and finished in 1987. When fully operational SLC will provide electron-positron collisions at 100 GeV energy (center-of-mass).[1] This new project will not have any additional significant environmental impact. It is housed in a 3 km underground tunnel having a single interaction region at the eastern end of the site.

C. Local Climate

The climate in the SLAC area is Mediterranean. Winters are warm and moist, and summers are mostly cool and dry. Long term weather data describing conditions in the area have been assembled from official and unofficial weather records at Palo Alto, 4.8 km to the east. The SLAC site is 60 to 120 m higher than the Palo Alto station and is free of the moderating influence of the city; temperatures therefore average about two degrees lower than those of Palo Alto. Daily mean temperatures are seldom below 0 degrees Centigrade or above 30 degrees Centigrade.

Rainfall averages about 560 millimeters (mm) per year. The distribution of precipitation is highly seasonal. About 75% of the precipitation, including most of the major storms, occur during the four month period December through March. Most winter storm periods are from two days to as much as a week in duration. The storm centers are usually characterized by relatively heavy rainfall and high winds. The combination of topography and air movement produces short fluctuations in intensity which can be best characterized as a series of storm cells following one another so as to produce the heavy precipitation for periods of five to fifteen minutes with lulls in-between.

D. Site Geology

The entire SLAC site is underlain by sandstone and claystone. In general the bedrock on which the western half of the accelerator rests is of Eocene age (over 50 million years old) and that under the eastern half is of Miocene age (over ten million years old). On top of this bedrock at various places along the accelerator alignment are found alluvial deposits of sand and gravel generally of Pleistocene age (one million years old). At the surface is a soil overburden of unconsolidated earth materials averaging from 1 to 1.5 m in depth.

E. Site Water Usage

Use of water by SLAC is about equally divided between accelerator and equipment cooling, and domestic uses such as landscape irrigation, sanitary sewer and drinking water. The "pre-PEP" (circa 1979) consumption amounted to about 340,000 cubic meters per year (930 cubic meters per day, on the average).

Since half of the water is necessary for machine cooling, the daily consumption of this component varies directly with the accelerator running schedule and hence also varies directly with electric power demand (the domestic water usage is relatively constant and is insensitive to the accelerator schedule). The relationship between power and water consumption can be appreciated if one considers that 85% of the power used in linac operation is finally dissipated by water evaporation in the ratio of about 630 kilowatt–hours (kWh) per cubic meter of water. SLAC now employs four cooling water towers comprising a total cooling capacity of 73 MW to dissipate the heat generated by the linear accelerator and other experimental apparatus.

Power consuming devices are directly cooled by a recycling closed-loop system of low conductivity water (LCW). The LCW is piped from the accelerator or other devices to be cooled, to the cooling towers where the heat is exchanged from the closed system to the domestic water in the towers. A portion of the tower water is ultimately evaporated into the atmosphere. Because of this constant evaporation during operation, the mineral content of the remaining water gradually increases and eventually must be discarded as "blowdown."

The SLAC domestic water is furnished via the Menlo Park Municipal Water Department (MPWD) whose source is the City of San Francisco-operated Hetch Hetchy aqueduct system from reservoirs in the Sierra Nevada. SLAC and its neighboring Sharon Heights development, including the shopping center, receive water service from a separate independent system (called "Zone 3") within the MPWD. This separate system taps the Hetch Hetchy aqueduct and pumps water up to a 7600 cubic meter reservoir west on Sand Hill Road. The Zone 3 system was constructed in 1962 under special agreements among the City of Menlo Park, the developer of Sharon Heights, Stanford University, and the DOE. The cost of construction including reservoir, pump station and transmission lines was shared among the various parties; each party has a vested interest in, and is entitled to, certain capacity rights in accordance with these agreements.

During current operations roughly 45% of the water consumed by the laboratory is rejected by evaporation from the four cooling towers. The remaining 55% is disposed of as follows:

- 26% is runoff to the San Francisquito Creek via the storm drains;
- 20% is waste domestic and process water discharged via the sanitary sewers connected to the Menlo Park Sanitary District; and
- 9% is absorbed into the ground from irrigation.

F. Land Use

San Mateo County has the ultimate planning responsibility with respect to University lands which are within the county but not within an incorporated city. The San Mateo County General Plan is the primary land use regulatory tool with respect to such lands. Adherence will be made to all applicable federal, state and local regulations including chemical and sanitary discharges which might adversely affect, directly or indirectly, the environmental quality.

The Board of Trustees of Stanford University has the responsibility of preserving and protecting Stanford's land endowment for the use of present and future generations of students and faculty. While financial and political influences on land use policy are taken into account, the dominant and prevailing consideration is the appropriateness of those policies in the furtherance of the University's academic mission. Board policies are designed to encourage land uses consistent with the institutional characteristics and purposes of Stanford and to discourage those uses or claims which do not relate to or support the mainstream of the University. Certainly this project falls into the former category.

The purpose of the Stanford land endowment is to provide adequate land for facilities and space for the instructional and research activities of the University. The use of lands is planned in a manner consistent with the characteristics of Stanford as a residential teaching and research university, and provides flexibility for unanticipated changes in academic needs. Cooperation with adjoining communities is important, and the concerns of neighboring jurisdictions are considered in the planning process.

G. Demography

Menlo Park is the closest incorporated city to SLAC. According to the 1980 census the City of Menlo Park has a land area of 43.8 km^2, a population of 26,369 and a population density of 602 persons per km^2. This population has decreased by 1.7% since the 1970 census.

In 1974 a population estimate within 1.6 km of SLAC was determined by aerial photographs and type of structures revealed. The populated area surrounding SLAC is a mix of offices, schools, condominium, apartments, single family housing and pasture land. Occupancy factors of .1–1.0 were assumed, depending on the type of structure. The populated area is about 1.5 km^2 or about 1,000 people from the 1980 census population density. The total area including open lands is 8 km^2.[2]

II. 1988 Summary

A. Nonradioactive

1. Underground Storage Tanks

Four underground tanks at the Central Utility Building were emptied of diesel oil and cleaned. These tanks now contain chilled water. Two underground tanks containing gasoline and diesel were removed in compliance with state and local regulations. There are now no underground tanks at SLAC containing hazardous materials.

2. Environmental Survey

The DOE Environmental Survey Team identified areas that may require additional investigation and procedures that should be written. A total of 27 findings identified by the Team have been addressed in a Draft Action Plan submitted in September by SLAC and DOE–SAN. Estimated cost for the Draft Action Plan is $4.6 million.

3. Remediation/Cleanup Projects

Three sites have been sampled and remediated. These areas, Salvage Yards 1 and 2 and the Magnet Yard/Radioactive Storage Area were sampled statistically to determine the amount of cleanup. After soil removal, sampling was performed to ensure cleanup levels had been obtained. Sampling and remediation is continuing at the Master Substation and the Casting Pad. Other areas have been targeted for sampling.

4. Spill Prevention Control

A Spill Prevention Control and Countermeasures (SPCC) Plan has been approved by SLAC management. Deficiencies in the program have been noted and will be corrected. The SPCC Plan includes consolidating waste accumulation areas, installing berms and writing operating procedures to prevent spills and releases.

B. Radioactive

1. Neutron Radiation

Neutron radiation dose near SLAC's boundaries was not measurable for 1988 because of SLC testing at low power levels $\leq 5\%$ of design.

2. Effluent Monitoring (Air and Water)

Effluent monitoring revealed that SLAC did not release measurable gaseous radioactivity during 1988. There were no releases to the sanitary sewer during 1988.

C. SLAC Linear Collider Project (SLC)

A major new construction project was started in 1984. This project is described in DOE/ER (No. 0154), Environmental Assessment, September 1982. The project comprises two primary structures (see Fig. 2):

1. An underground tunnel system approximately 3 km in circumference constructed beneath existing facilities, and,

2. A research hall located midway around the tunnel near PEP's Region 2.

The new machine is designed to collide high-energy beams of electrons and positrons (50 GeV each) provided by the 3.2 km-long linear accelerator. It is now operational.

III. Environmental Program Information

A. Environmental Monitoring Summary

1. General

Environmental monitoring is required by a variety of local, state and federal agencies. Samples of air and water effluents are analyzed for nonradioactive and radioactive elements and chemical compounds. Collected samples are analyzed by State of California certified laboratories. Some "in-house" analyses are performed for process control. In addition to liquid effluent monitoring, continuous air monitoring for radioactive gaseous emissions and external penetrating neutron radiation dose rate are performed.

2. Nonradioactive Effluent—Wastewater

Wastewater from SLAC is discharged in three ways:

- The sanitary sewer flows to a local treatment facility with eventual discharge to San Francisco Bay.
- Cooling tower blowdowns are discharged to natural open ditches. Eventual discharge is to San Francisquito Creek by surface flow or seepage.
- Storm sewer effluent is released to natural open ditches or the city/county storm sewer system. The ditches also carry the cooling tower blowdowns and any groundwater pumped from the linac or subsurface storage rings and sumps. The city/county storm sewer system empties into San Francisquito Creek.

Typical amounts are 42,000 m^3/year to the sanitary sewer; 150,000 m^3/year to the storm drains; and 150,000 m^3/year evaporated, for a total of 340,000 m^3/year. In addition, an average of 900,000 m^3/year falls as rain on the 170 hectare site, also flowing to the creek.

About 20% of SLAC's domestic water supply is released to the sanitary sewer; the remaining 80% leaves the site by evaporation or by storm drains and natural ditches to San Francisquito Creek. The sanitary sewer outlet at the northeast corner of the site carries sanitary wastes and treated plating shop effluents through West Bay Sanitary District lines to the South Bay System Authority treatment plant (DOE Contract E(04–3)–480).

The South Bayside System Authority (SBSA) monitors the treatment facility effluent for compliance with metal finishing pretreatment standards (Table III–1). SBSA monitors the total sewer discharge limits for SLAC as well. Total sanitary sewer discharge limits are shown in Table III–2.

Wastewater discharged through the storm drain system includes a combination of water runoff and miscellaneous sources, such as once-through cooling water and pumped groundwater from sumps in the storage rings. Groundwater from the last third of the linac drains into this storm drain system. Rainwater runoff from the Campus Area drains into the city storm sewer system. Runoff from the rest of SLAC is collected and discharged with the cooling tower blowdowns to two oil-water separators. The separators collect oil runoff from parking lot areas prior to discharge to the drainage ditches and San Francisquito Creek.

The National Pollutant Discharge Elimination System (NPDES) permit covers discharges from cooling tower blowdowns. This permit is administered by the California Regional Water Quality Control Board, San Francisco Bay Region. As part of the permit requirements, samples of the cooling tower blowdowns and creek (upstream and downstream of SLAC's discharges) are taken twice a week. A toxicity bioassay using salmonids for each cooling tower effluent is taken monthly. Table III–3 shows the type and frequency of sampling required by the NPDES permit. Table III–4 summarizes the NPDES for 1988.

Table III–1

Standards for Treatment Facility

Species	Daily max. mg/l	Avg. last 4 samples mg/l
Cadmium	0.69	0.055
Chromium (total)	2.77	1.11
Copper	3.38	0.24
Cyanide (total)	1.20	0.37
Lead	0.69	0.05
Nickel	3.98	0.18
Silver	0.43	—
Zinc	2.61	0.057
Total toxic organics	2.13	0.0729(1)

(1) One sample only

Table III–2

Sanitary Sewer Standards

Species	mg/l
Arsenic	0.1
Cadmium	0.2
Chromium (total)	0.5
Copper	2.0
Cyanide (total)	1.0
Lead	1.0
Mercury	0.01
Nickel	1.0
Silver	4.0
Sulfides dissolved	0.1
Zinc	3.0
Oil or grease, animal or vegetable origin	300
Oil or grease, mineral or petroleum origin	100
Chlorinated hydrocarbons	0.02
Phenolic compounds	1.0
Temperature	$< 65°C$
pH	> 6.0

Table III–3

NPDES Sampling Requirements

Sampling Stations	E-001,	E-002,	E-003	C-R, C-1(2)	Limit
Type sample	Obs	Cont	Grab	Grab	
Flow rate (gal/day)		M			
Settleable matter (ml/l/hr)			W(1)	W(1)	0.1
Oil and grease (mg/l)			2/W	W(1)	5
Total phosphate (mg/l)			2/W	2/W	<20
Total suspended solids (mg/l)			2/W	2/W	
Total dissolved solids (mg/l)			2/W	2/W	
pH (units)			M	M	6.5–8.5
Temperature (C)			M	M	
Toxicity (% survival)			M(1)		90
All applicable standard observations	M				
Cooling water chemicals (type and lbs/mo added)	M				

<u>Type of Sample</u>

Obs = observation
Cont = continuous sample
Grab = grab sample

<u>Frequency of Sampling</u>

W = once each week
M = once each month
Q = once each quarter
2/W = twice a week

(1) To be sampled on days coincident with effluent sampling.

(2) San Francisquito Creek upstream and downstream of discharge points.

Table III–4

1988 Summary of NPDES Monitoring Results

Parameter	Value	E-1	E-2	E-3
Daily flowrate (gal/day)	Minimum	0	0	0
	Maximum	5400	9100	74020
Settleable matter: (ml/l/hr)		<0.1 to <1		
Oil and grease (mg/l)		Range <1 to 10.2 (1)		
Total phosphate (mg/l)		Range <.03 to 31.37 (2)		
Total suspended solids (mg/l) 30-day avg		Range <1 to 47		
Total dissolved solids (mg/l) 30-day avg		Range 104 to 2784		
Toxicity (% survival)		85–100		
pH		Range 7.2 to 8.6		

(1) Oil and grease values over 5 mg/l are normally seen at the beginning and during the rainy season as storm drains pick up oil and grease from vehicle parking areas.

(2) Excursion over 20 mg/l limit within cooling tower due to equipment failure.

A biosurvey of San Francisquito Creek has been completed to determine the effects of increased blowdown volume on the creek.[3] The findings of the biosurvey show that the creek is nitrate dependent and that the increased loading of phosphates from cooling tower discharges with SLC operation will not promote algae bloom and eutrophication. Water temperature modeling predicts no significant change in San Francisquito Creek temperatures from the proposed discharge increases. All reports on this study have been submitted to the California Regional Water Quality Control Board, San Francisco Bay Region, and California Department of Fish and Game.

A second sewer connection serves PEP IR–4, 6, 8, the Magnet Factory, and SLC Collider Hall. This connection carries only small amounts of ordinary human wastes; no cooling or process water is discharged through this line. No monitoring of this sewer connection is performed.

3. Nonradioactive Effluent—Airborne

Monitoring for nonradioactive airborne effluents is not required. SLAC has been issued permits from the Bay Area Air Quality Management District (BAAQMD) for boilers, paint spray booths, sandblasting booths, degreasers and other miscellaneous point sources of particulates, organics, nitrogen oxides, sulphur dioxide and carbon monoxide. This agency has not required air monitoring. A list of sources and annual average emission is shown in Table III–5.

Table III–5

BAAQMD Permits and Emissions

S#	Source description	Annual Average lbs/day PART	ORG	NO_x	SO_2	CO
1	Boiler	-	-	20	7	5
2	Boiler	-	-	7	2	2
3	Degreaser	-	9	-	-	-
4	Degreaser	-	28	-	-	-
5	Spray Booth		7	-	-	-
6	Boiler	-	-	4	16	1
7	Sandblasting Booth	-	-	-	-	-
8	Sandblast Room	-	-	-	-	-
9	Degreaser	-	4	-	-	-
10	Woodworking Operations	-	-	-	-	-
11	Metal Cutting Operations	-	-	-	-	-
13	Metal Grinding Operations	-	-	-	-	-
14	Sandblast Booth	-	-	-	-	-
16	Sandblast Booth	-	-	-	-	-
17	Metal & Epoxy Glass Grinding	-	-	-	-	-
18	Refrigerated Vapor Degreaser	-	3	-	-	-
19	Fume Hood	-	-	-	-	-
20	Printed Circuit Board Etchant	-	-	-	-	-
21	Anodizing, Pickling & Bright Dip Oper.	-	-	-	-	-
22	Vapor Degreaser	-	2	-	-	-
23	Cold Cleaner	-	-	-	-	-
24	Cold Cleaner	-	-	-	-	-
25	Cold Cleaner	-	-	-	-	-
26	Cold Cleaner	-	-	-	-	-
27	Cold Cleaner	-	-	-	-	-
28	Cold Cleaner	-	-	-	-	-
29	Cold Cleaner	-	-	-	-	-
30	Sludge Dryer	-	-	-	-	-
31	Cold Cleaner	-	-	-	-	-
32	Cold Cleaner	-	-	-	-	-
33	Cold Cleaner	-	-	-	-	-
34	Cold Cleaner	-	-	-	-	-

PART = Particulates; ORG = Organics; NO_x = Nitrogen oxides; SO_2 = Sulfur dioxide; CO = Carbon monoxide

4. Radioactive Effluent—Airborne

Airborne radionuclides are produced in the air volume surrounding major electron beam absorbers such as beam dumps, collimators and targets. The degree of activation is dependent upon the beam power absorbed and the composition of the parent elements. The composition of air is well known, consisting of nitrogen, oxygen and trace quantities of carbon dioxide and argon. Induced radioactivity produced at high energies are short-lived such as oxygen-15 and carbon-11, having half-lives of 2 minutes and 20 minutes, respectively. Nitrogen-13, having a half-life of 10 minutes, is also produced but in much lower concentrations. As a consequence of water cooling and concrete shielding, both containing large quantities of hydrogen, the thermal neutron reaction with stable argon produces argon-41, which has a half-life of 1.8 hours.

We have not detected any other radionuclides including particulates in the airborne effluent exhausted from SLAC.

The accelerator, PEP, SPEAR and experimental areas are designed to transport (not absorb) high-energy electrons and positrons. Radioactive gas concentrations are therefore not produced in measurable quantities. The Beam Switch Yard (BSY) represents the only portion of SLAC designed to absorb high-energy particles and is the only source of detectable gaseous radioactive emissions. The BSY is not vented continuously. It is vented only for emergencies and at the end of each experimental cycle for brief periods of one hour or less.

The Derived Concentration Guides (DCG's) for airborne radioactivity appear in Ref. 4. They were derived from dose standards which require that no individual in the general population be exposed to greater than 25 mrem in one year.

Airborne radioactivity produced as the result of operations is short-lived; *i.e.*, the half-lives range from 2.1 minutes to 1.8 hours and are in gaseous (not particulate) form. These isotopes include the following:

Table III–6

Radioactive Gases

Isotope	Half–Life	μCi/cm^3
^{15}0	2.1 minutes	2.5×10^{-9} (*)
^{13}N	9.9 minutes	2.5×10^{-9} (*)
^{11}C	20.5 minutes	2.5×10^{-9} (*)
^{41}Ar	1.8 hours	2.5×10^{-9}

(*) Calculated from Ref. 5, assuming total submersion.

Since we do not routinely release airborne radioactivity while the beam is on, and require a waiting period before turning on the exhaustors, the only radioisotope released is argon-41. By far the greater proportion of exposure an individual may receive, under any circumstances, from the radioelements listed in Table III–6 is from whole body immersion. Thus, for an individual to receive a whole body dose of 25 mrem annually requires a continuous exposure to a large cloud whose average concentration equals 2.5×10^{-9} μCi/cm^3 (Ci/m^3) for an entire year.

The BSY areas are vented by a total of five fans: the discharge point is just slightly above roof elevation. The total exhaust rate for the accelerator is 60 m^3/min, and for the BSY 40 m^3/min. Venting of PEP and its Interaction Regions (IR's) is accomplished by a total of 14 exhaust fans which vent just above grade level, with a total exhaust rate of 50 m^3/min. PEP is the only facility that is vented while the beam is on.

Each BSY ventilation fan is provided with a radioactive gas detector. A Geiger–Mueller (GM) detector, power supply, rate meter, strip chart recorder and air pump are interlocked with the ventilation fan so that they operate only when the machine is vented.

The gas monitors for the BSY collect particulate samples during venting and have revealed negative results; during this monitoring period particulate radioactivity above background was not detected.

5. Radioactive Effluent—Wastewater

Wastewater containing radioactivity is not routinely released from the site. The only possible sources of liquid radioactive effluents are from primary cooling water systems in the BSY. In the event of leaks from the systems, water is collected in stainless- steel-lined sumps sized to contain the entire water volume. When necessary, the contents of the sumps are pumped to a mobile holding tank. The tank is then moved to the nearest sanitary sewer inlet and drained into the sewer after analysis is received.

As discussed in Section III A–2–4, the only source of induced radioactivity is where the electron/positron beam is absorbed. Since water is composed of hydrogen and oxygen, the only radioisotopes produced are the short-lived oxygen-15 and carbon-11, beryllium-7 (54d) and tritium (12.3y). Oxygen-15 and Carbon-11 are too short-lived to present an environmental problem and the beryllium-7 is removed by the resin beds required to maintain the electrical conductivity of the water at a low level. Therefore, tritium is the only radioactive element present in the water that is of environmental importance.

Water that leaks from these systems is disposed of via the sanitary sewer. The concentration of tritium released is less than the Concentration Guides as specified by DOE Order 5400.XX, Requirements for Radiation Protection for Public, without using the sewer effluent for dilution. SLAC is also bound by the provision in a contract for service, with the West Bay Sanitary District and DOE Contract E(04–3)–480.

6. Penetrating Radiation Monitoring

Six Peripheral Monitoring Stations (PMS) provide continuously-recorded data from radiation monitors located near SLAC boundaries. Their positions are located in Fig. 3.

The measured annual dose to the general population coming from accelerator operations is almost entirely from fast neutrons and is characterized as skyshine from SLAC's research area. Estimates of individual and general population whole body doses can be calculated from the PMS data, based on estimates of distance and population density near SLAC. PMS–1 is located at the most sensitive location. Historically this station has always been used to calculate population dose since it records the maximum dose near our site boundary.

From demographic information and the measured radiation dose near the site boundary, we can estimate both the average individual dose and the population dose from SLAC operations. From 1974 data, we used a population of 2,040 persons who are included in the pool exposed to 1 mrem or more for any calendar year. A shift in the experimental program to low intensity experiments, including storage ring experiments, is the primary reason for the decrease in site boundary measurements, calculated population dose and population number.

Radiation information is obtained with a GM tube for the ionizing component, and a paraffin-moderated BF_3 neutron detector calibrated with a Pu-Be neutron source. The resultant sensitivities are such that a gamma exposure of 1 mR from a radioactive ^{60}Co source would be recorded as 10^4 counts on the GM tube channel, and a neutron dose-equivalent of 1 mrem would be recorded as 10^5 counts on the BF_3 channel.

The hourly printout cycle of the Sodeco register is programmed by two clock motors with cam actuated switches and associated electronic circuitry. This programmer automatically interrupts data acquisition, generates a print command, resets the digits in parallel, and reverts to the normal condition of serial counting of incoming data pulses. Dead time per printout cycle is less than 20 seconds per hour, so that the related corrections would be negligible and are not made.

B. Environmental Permits, Orders and Notices

1. Permits

In addition to DOE Orders, the following regulatory permits or contracts have been issued to SLAC:

California Regional Water Quality Control Board
San Francisco Bay Region
NPDES permit: CA0028398, Order #87–044
Waste discharge requirements: Order #85–88

Bay Area Air Quality Management District
Plant No. 556, 32 permits

West Bay Sanitary District
DOE Contract E(04–3)–480
MPSD Resolution 779

2. Notices of Violations

SLAC received no notices of violations from regulatory agencies in 1988.

C. Environmental Activities

1. Underground Storage Tanks

The four underground tanks at the Central Utility Building were emptied of diesel. The lines and tank were then cleaned using detergents. All waste waters were transported offsite as hazardous wastes. The tanks now contain chilled domestic water that will be used for air conditioning.

The two tanks at the Palo Alto Fire Station contained leaded gasoline and diesel. Both tanks were removed and the surrounding soil sampled to ensure no spills or leaks had occurred. Permits for tank removals and approval for sampling procedures were obtained from the San Mateo County Environmental Health. No soil contamination was found at either tank.

2. Environmental Survey

The DOE Environmental Survey Team visited SLAC from February 29 to March 4, 1988. The 27 findings identified by the Team have been addressed in a Draft Action Plan submitted by SLAC and DOE–SAN. Most of the findings deal with potential contamination from possible spills. The areas under remediation were noted by the Survey. Additional documentation in the form of standard operating procedures and records were identified as areas that needed improvement.

3. Remediation/Cleanup Projects

ESO has identified areas that need to be investigated for potential contamination. Three areas, Salvage Yards 1 and 2, and the Magnet Yard/Radioactive Storage Area, have been sampled, remediated and closed out. Reports on each cleanup have been sent to the DOE and San Mateo County Environmental Health Services.

Salvage Yard 1 was used for the storage of material and equipment to be salvaged, including oil-filled equipment. Sampling was initially for PCBs and lead. Preliminary sampling of the surface and soil showed a maximum PCB contamination of 120 ppm and lead in excess of 4,000 ppm. The high lead level was suspected to be due to lead pellets and shot that had not been sieved from the sample prior to analysis. A total of 90 cubic yards of soil and asphalt was removed and disposed at an off-site facility.

Applicable cleanup levels, based on California state standards, were determined to be 5 ppm for PCBs. Lead has a limit of 500 ppm (total threshold limit value, TTLC) and 5 ppm (soluble threshold limit concentration, STLC). Sampling after remediation showed PCB concentrations less than 5 ppm; the soluble threshold limit concentration (STLC) for a composite sample (using three random soil 8 ppm, above the STLC limit of 5 ppm for lead. Concerns that volatile hydrocarbons, the organic compounds most likely to have been present at Salvage Yard 1, prompted sampling for organics. No volatile halocarbon contamination was found at a depth of 2 feet. This area was capped with asphalt and sealed to prevent leaching of any soluble lead to groundwater.

Salvage Yard 2 stored surplus equipment. The area was partially covered with asphalt. Hazardous constituents that may have been stored in the area were PCBs and halocarbons. Sampling showed no halocarbon contamination and the maximum PCB concentration to be 40 ppm. About 52 cubic yards of dirt and asphalt were removed. Sampling after cleanup showed a high PCB concentration of 1.4 ppm with an average of 0.73 ppm. The area has been capped with asphalt, sealed and bermed.

The Magnet Yard/Radioactive Storage Area was an area where radioactive materials were stored. A set of trailers near this area housed supplies and equipment for the Craft Shop. Steps had already been taken to remove the trailers and expand the Radioactive Storage Area when the Environmental Survey Team arrived. This area was sited as a potential contaminated area. Sampling for radioactive isotopes, halocarbons and chlordane showed no contamination at the surface nor down to a depth of 3 feet. This area has been asphalted, bermed and fenced.

The Casting Pad was sited by the Survey Team as a contaminated area. Oil stains were evident from past spills and it was decided that all visible stains would be removed. Sampling by an outside contractor showed no contamination of halocarbons or chlordane to a depth of 3 feet. Soil removal will start once plans for the area have been finalized.

The Master Substation contains the primary power transformers and electrical equipment for SLAC. This area also served as the main storage area for pumps and lines used in the transfer of transformer oil. The area has been divided into three parts. Sampling of the first third showed PCB contamination, primarily in drainage along the Substation, up to 480 ppm. No contamination was detected in the drainage ten feet from the Master Substation. Maximum contamination in the Substation proper was 40 ppm. Soil removal and sampling will continue.

4. Spill Prevention Control

A Spill Prevention Control and Countermeasure (SPCC) Plan has been approved by SLAC management. The Plan noted deficiencies in spill prevention or control. These items should be corrected this year. The SPCC Plan will be updated yearly or as often as necessary to reflect changes at SLAC.

D. Radioactive Effluent Monitoring Summary

1. Liquid

As stated in Section III–A–5, water containing radioactivity is not routinely released from the site. However, water from the BSY sumps must be pumped occasionally because of the accumulation of water from small leaks or drainage due to modification or repair of the cooling systems. Samples from these sumps are collected and sent to a certified analytical laboratory for analysis. The water is pumped to a holding or transfer tank and released to the sanitary sewer after analysis is received. There were no releases during 1988. Because of heavy construction the sewer sampling station has been out of service. This station was reestablished late in 1988. Samples will be submitted for analysis each quarter in 1989.

2. Airborne

During 1988 no measurable quantities of radioactive gas were released from the BSY. This is because of continued SLC linac upgrading.

E. Dose Assessment from Neutron Monitoring

Four PM stations have been out of service for the entire year (see Table III–7). PMS–1 has been operational. Also, the gamma sensor at PMS–1 has been modified to test a neutron counter that may permit a more precise evaluation of neutron dose from SLAC skyshine. This unit is being tested under actual environmental conditions.

Table III–7

Annual Penetrating Radiation Dose Measured

Near SLAC Boundaries for 1988

PMS	Gamma (mrem)			Neutron (mrem)		
No.	Total	Background	Net	Total	Background	Net
1	OS	OS		12	12	0
2	OS	OS		OS	OS	
3	OS	OS		OS	OS	
4	OS	OS		OS	OS	
5	OS	OS		OS	OS	
6	OS	OS		OS	OS	

OS = Out of service.

F. Ground Water Monitoring

1. Nonradioactive

There are presently no local, state or federal regulations requiring ground water monitoring at SLAC for nonradioactive compounds or elements. There are eight wells associated with the Plant Maintenance and Services tank study that are measured monthly for water levels. Samples are analyzed quarterly for volatile and semivolatile organics (EPA Methods 8010 and 8020).

The nearest wells offsite are located about 0.7 miles from the accelerator. These wells are located on the south side of San Francisquito Creek. No groundwater is used on the north side of the creek. Indications are that the groundwater underlying SLAC is perched and contains high levels of total dissolved solids (TDS).

2. Radioactive

SLAC instituted a ground water monitoring program in 1965. Some of the wells used to define geological formations for construction purposes were used to sample well water to document a background level. Since that time, many of these wells have been abandoned. We have maintained three wells near major beam absorbers to document that induced radioactivity or leakage of radioactive water is not a problem. Because of SLC machine testing at low power, samples were not analyzed during 1988. We have not been able to resume sampling because of SLC schedule changes. In any case the high energy e^-/e^+ beam was not run in these areas during 1988.

G. Quality Assurance

1. Nonradioactive

All nonradioactive laboratory analyses are performed offsite by certified (state or EPA) laboratories. These labs maintain their own quality assurance and quality control (QA/QC) programs as required by their certification. EPA or state approved methods are specified for each analyses. A chain-of-custody is maintained by SLAC and the lab.

Appendix A

Atmospheric Dispersion Model

In 1966, an independent evaluation of meteorological regimes at SLAC was performed.[6] From this study, an empirical mathematical model was developed. The model that is used predicts the centerline concentration very well, but overestimates the total dosage values.

$$\frac{\chi P}{Q} = \frac{G}{u} \left(\frac{X}{X_0}\right)^{-1.75+[b(1-c)/u]}$$

where

χP	=	centerline concentration (Ci/m^3)
Q	=	source strength (Ci/s)
G	=	8 m^{-2}
u	=	mean wind speed (m/s)
X	=	distance from source (m)
X_0	=	2 m
C	=	fraction of sky covered by low clouds
b	=	0.5 m/s day; $b = -1.2$ m/s night

Figure 4 summarizes peak concentration per unit source strength as a function of wind speed and atmospheric stability at a fixed distance of 400 m (roughly the distance from the source to SLAC's boundaries). To characterize atmospheric stability, the degree of cloud cover is indicated for day and night time regimes. This method is based upon Pasquill's data for cloud expansion for various stability categories.

For a wind speed of 2 m/s atmospheric dilution factors—for determining centerline concentrations—range between 2×10^{-5} and 1.5×10^{-3} sec/m^3. For purposes of estimating radiation dose at the site boundary, neutral conditions are assumed and a generally conservative dilution factor of 4.5×10^{-4} sec/m^3 is used to calculate average concentration at the site boundary (see Fig. 4, curve 1.0).

Because of recent regulatory requirements, DOE has required the use of a computer program called AIRDOSE for calculating population dose from airborne radioactive emissions. We have not yet implemented the model because radioactive emissions for 1988 were not detectable and the model is therefore unnecessary. This new requirement will be implemented when normal experimental schedules are resumed and if gas releases are detectable.

Appendix B

Model For Potential Dose Assessment

According to Department of Energy orders, an assessment of whole body man-rem dose to the general population near SLAC is required where appropriate. Our site boundary dose due to accelerator operation has generally been less than 10 mrem per year from penetrating radiation. We have estimated the population size to include individual annual doses down to 1 mrem, which corresponds to a distance of approximately 1.6 km from a central point representative of the source of neutrons. The 1 mrem value is approximately 1% of the total natural background dose, and 1% of the technical standards for the general population (DOE Order 5480.11).

There are three major pathways leading to human exposure from ionizing radiation: (1) airborne, (2) food chain and (3) direct exposure to penetrating radiation. Of these three major pathways, only direct exposure to penetrating radiation is of any measurable significance from SLAC operations. The source of this exposure is from neutrons resulting from the absorption of high-energy electrons and photons in the experimental areas creating energetic particles, some of which escape from the heavily shielded enclosures.

In order to make an accurate and realistic assessment of radiation exposure to the public at low doses, it is necessary that exposure from the natural radiation environment be known. This is true because the instruments used respond to natural radiation sources as well as man-made sources, and the portion due to natural radiation must be subtracted from the total measurement. The population exposure assessments appearing in this document are, in all cases, overstatements of the true impact. Hence, the resulting values are representative of an upper limit of the possible range.

While the annual neutron dose from accelerator operations at the site boundary has generally been measurable, it has always amounted to less than 10% of the total annual individual dose from natural background radiation. According to an EPA report, the average dose from cosmic, terrestrial and internal radiation in California is 125 mrem. For purposes of comparison, we have rounded this number to 100 mrem.[7]

Another quantity of interest is the population dose in units of man-rem. This is simply the product of average individual dose and the total population exposed. For example, if 1,000 people are exposed to an average annual background dose of 0.1 rem (100 mrem), then the population dose is 0.1×1000, or 100 man-rem from natural background radiation. The annual variation of exposure to natural background radiation may vary by ±20%, largely caused by the difference of naturally occurring uranium, thorium and potassium present in the ground and in building materials where people live and work.

Two major problems associated with this dose assessment affect overall accuracy of the measurement. First, the conversion of neutron flux to dose requires that the spectrum of neutrons at the measurement point be known because the quality factor (QF) is a function of neutron energy. Because of the very low neutron fluences at the SLAC boundary and beyond, it is impossible to measure the energy spectrum. Therefore we have selected a QF of 10 as a conservative choice. We feel that this choice leads to an overestimate of the neutron dose-equivalent by a factor of approximately 2. Until a useful experiment can be performed with neutron yields of sufficient intensity, the quality factor cannot be determined with any better precision.

A second problem is the behavior of neutrons at large distances. Most of the high energy accelerator laboratories have made measurements. They are unique to each facility because of design differences, type of machine and surrounding topography. Here again, we have chosen a conservative formula for calculating the dose at distances other than the point of measurement. Lindenbaum[8] gave a method for evaluating skyshine neutrons which was later verified by Ladu et al.[9] using Monte Carlo techniques. Lindenbaum approximated the falloff by $(e^{-}R/\lambda)/R$ where R is distance in meters from the source and $\lambda = 250$ m. This equation fits the SLAC data fairly well, and is the one used to predict doses beyond our measuring station (Fig. 4). We feel that the methods used and reported in this document may overestimate the true population dose by at least an additional factor of 2.

The population activity close to SLAC, *i.e.*, within 1.6 km, is a mixture of commerce and residential dwellings. The occupancy factor—the proportion of time throughout the year that these structures are occupied—is assumed to be .25 for business activities, and 1.0 for private dwellings. The number of people is estimated for each type of structure, multiplied by the occupancy factor and summed to estimate the total population that might be continuously present.

According to the 1980 census the City of Menlo Park has an average population density of 602 persons per square kilometer (km^2). The populated area impacted by this source term is 1.5 km^2. Therefore the population total is 920 people. Previous estimates have resulted in a larger number by a factor of 2 which is a function of the analytical model used. For purposes of estimating the population dose we have rounded the calculated number to 1,000 people.

Appendix C

Calibration and Quality Assurance Procedures

The natural background radiation provides continuous verification that the monitoring equipment is connected and functioning properly. During accelerator downtime and any interrupted operation background radiation provides a calibration baseline as well.

A regular calibration procedure was initiated in 1984 using two small radioactive sources. The sources are placed at a measured distance to produce a known dose equivalent rate. The equipment is kept in normal operation during these checks. The printer is marked so the calibration data is not confused with normal measurements. This procedure will be repeated twice each year and following equipment repair or maintenance. Also, response to natural background radiation provides proof that the instruments are operating properly.

<u>Airborne Radioactive Monitoring Equipment</u>

Dose-equivalent from gaseous radioactivity reaching the site boundary, if large enough, would be detected by the PMS, which has its own quality assurance procedures.

The separate radioactive gas monitors for each ventilation fan are inspected and calibrated at the beginning of each accelerator cycle. They are calibrated with a small radioactive source. During operation, the natural background radiation response assures that they are operating properly.

All water samples are analyzed by certified analytical laboratories which have their own documented quality assurance procedures.

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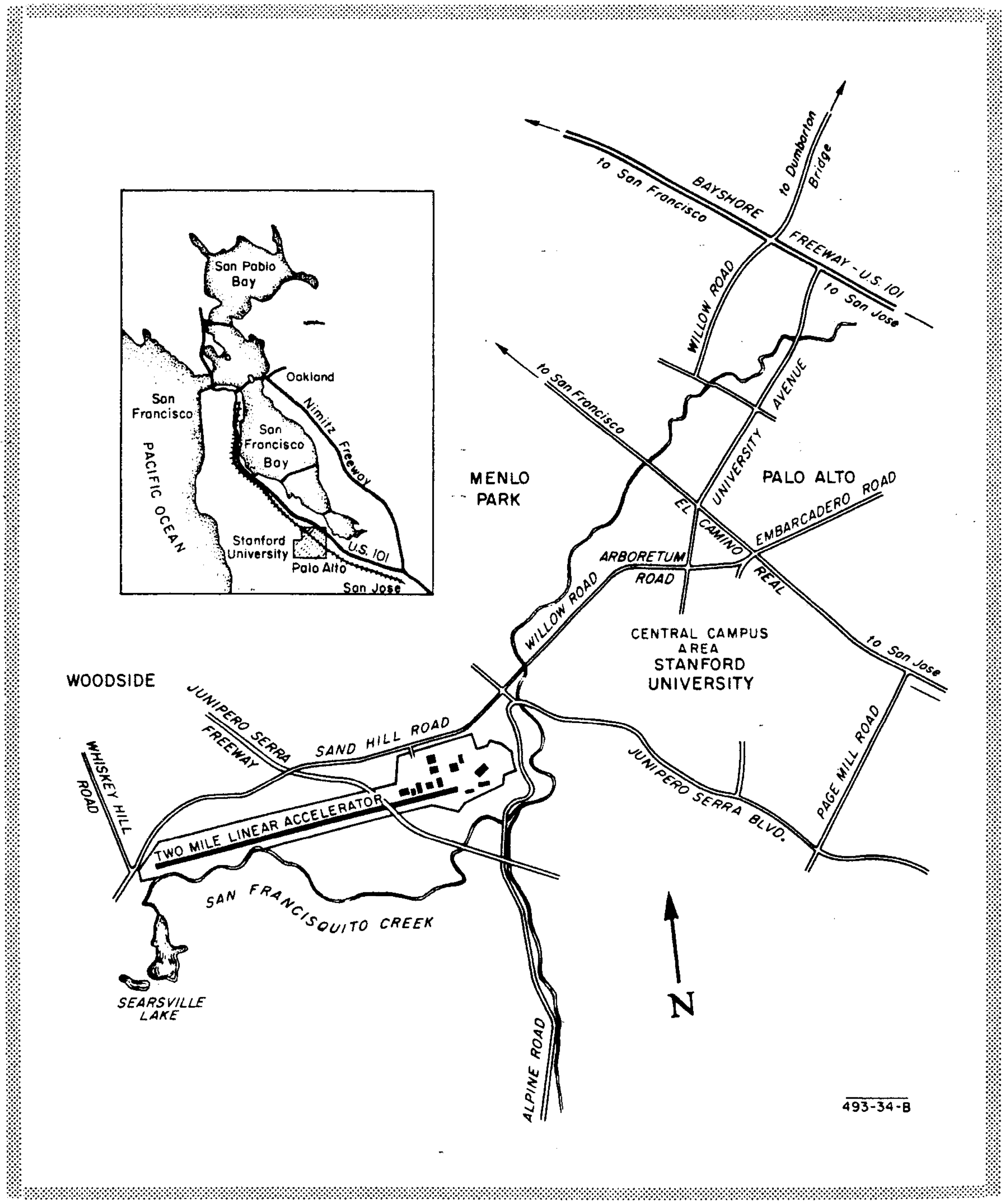

Fig. 1. SLAC Site Location.

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Fig. 2. Air view of SLAC site showing the two mile accelerator, the research facility, and the principal laboratories and shops. In the foreground the PEP Interaction Regions can be seen, connected by the circumferential road. Also shown is the SLAC Linear Collider, currently under construction (dotted line).

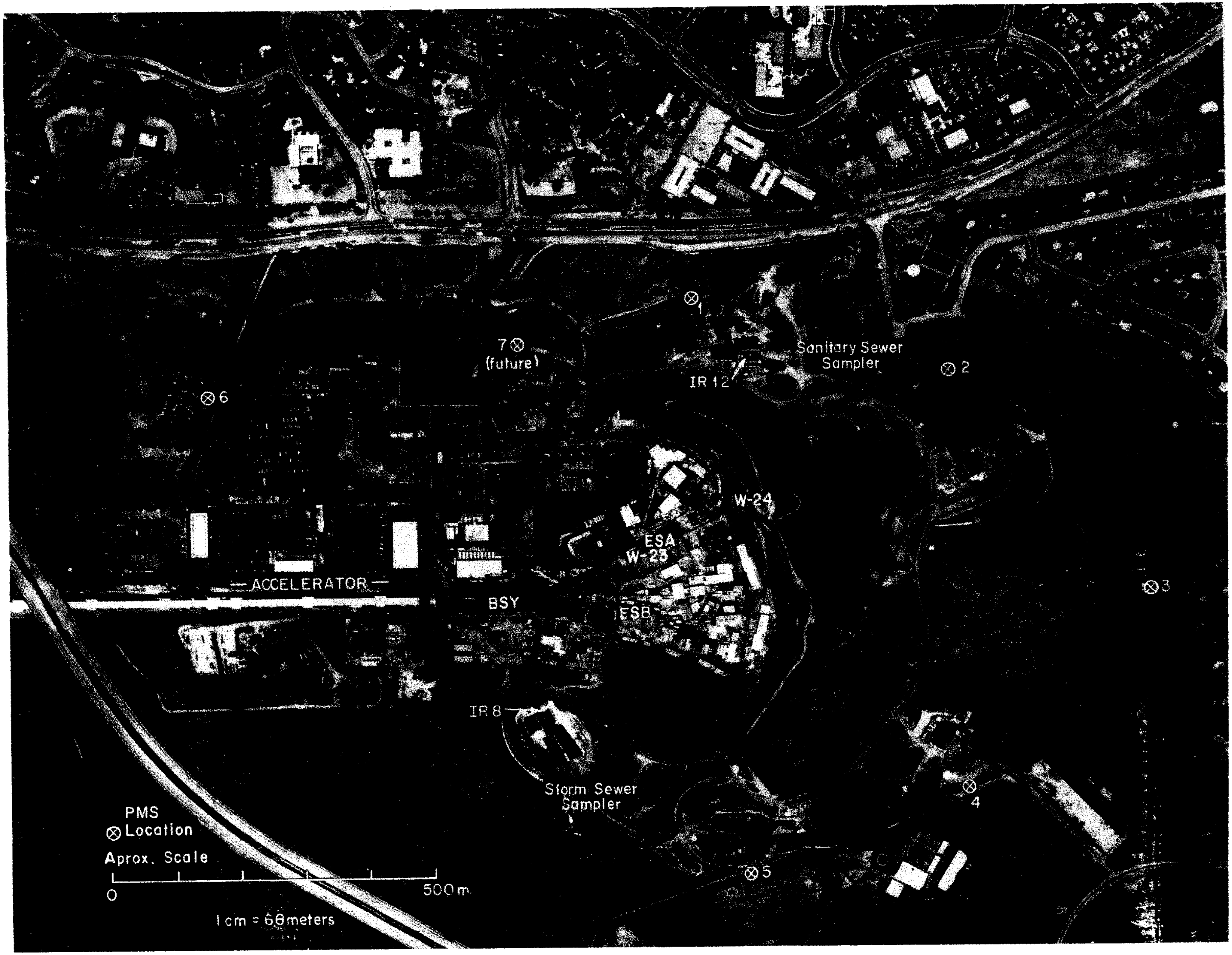

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Fig. 3. SLAC research yard and surrounding community.

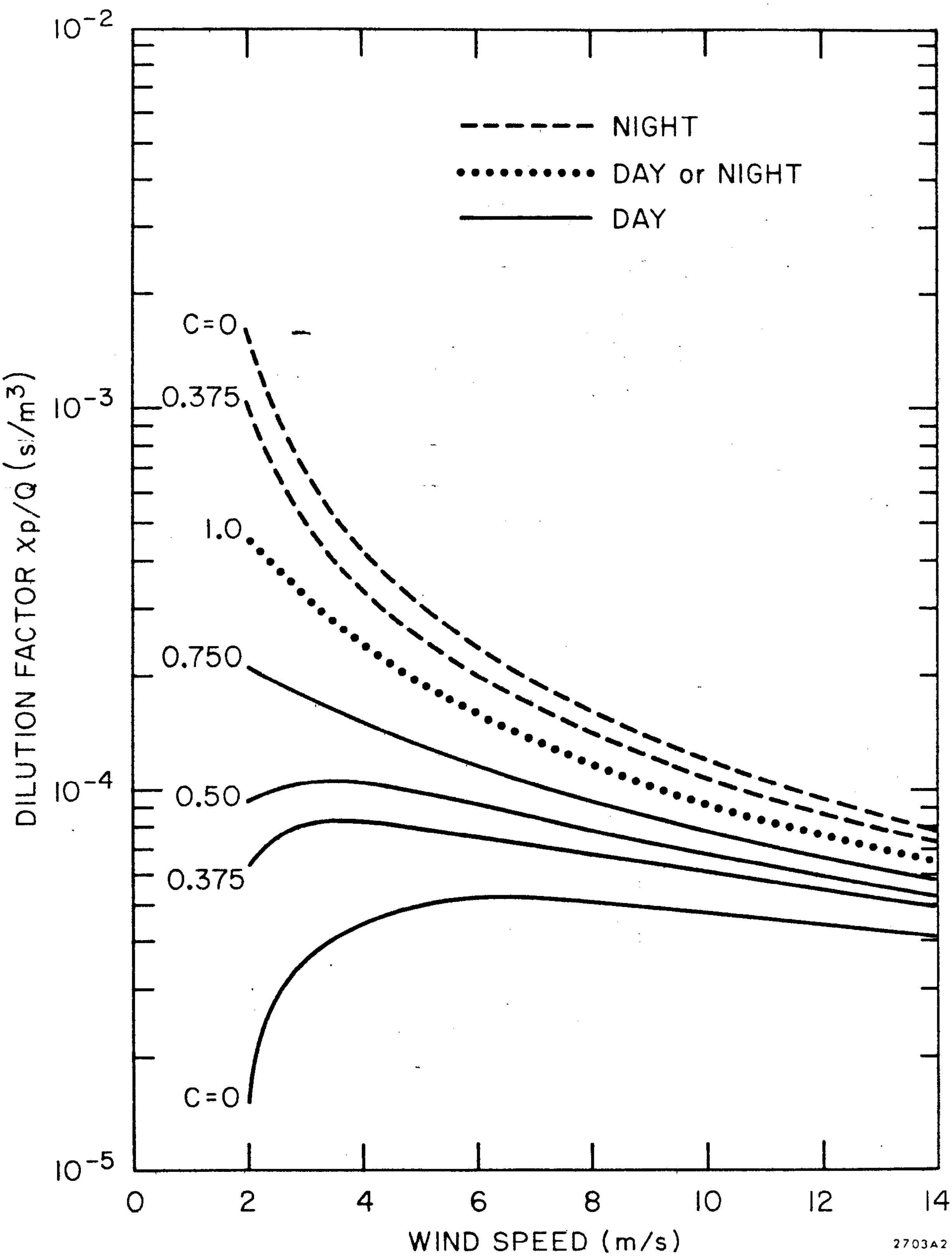

Fig. 4. Centerline dilution factor for various atmospheric conditions as a function of wind speed.

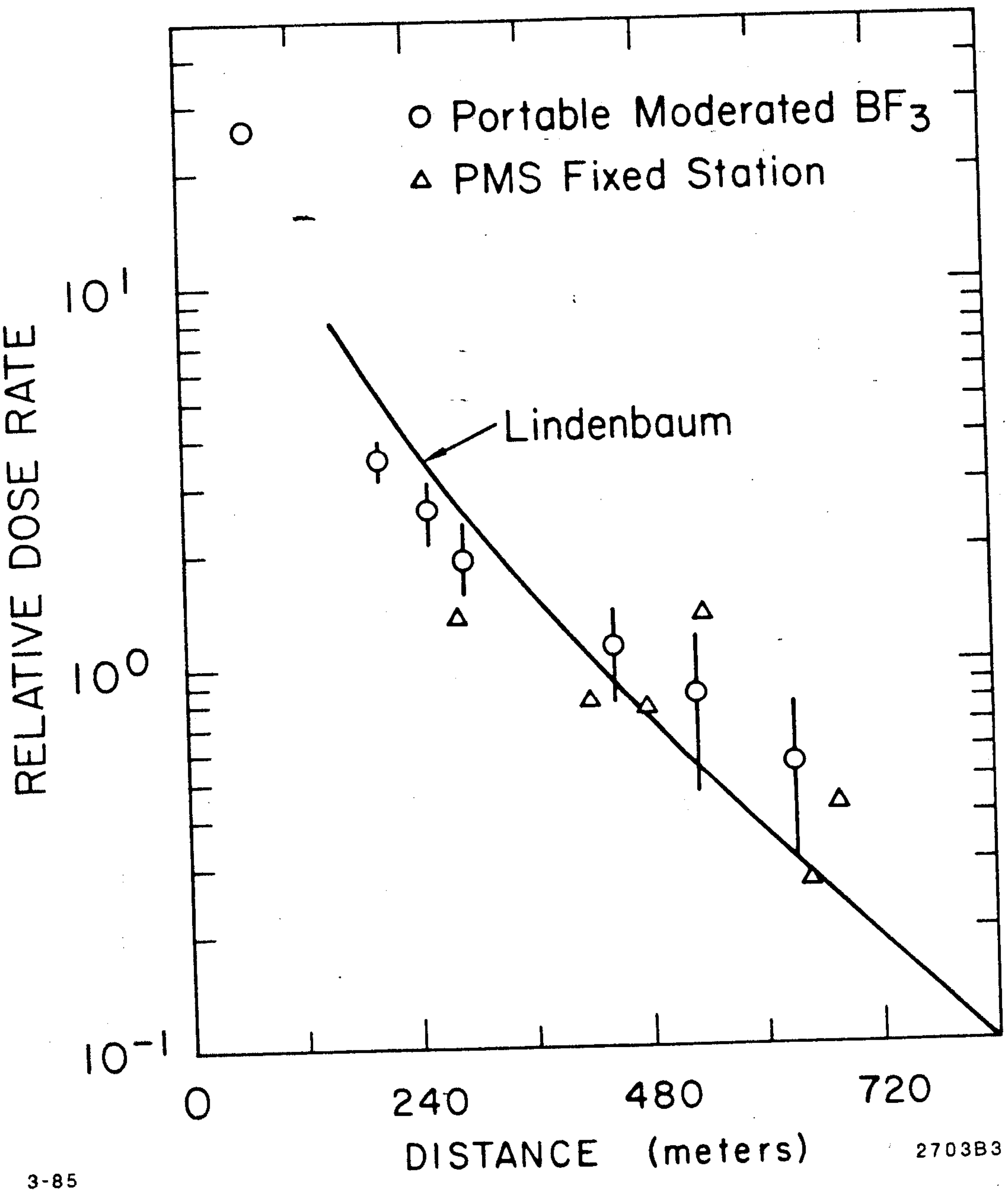

Fig. 5. Measurements made along a line between ESA and site boundary.