SLAC-170

ANNUAL ENVIRONMENTAL MONITORING REPORT

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INTRODUCTION

The Stanford Linear Accelerator Center (SLAC) is located two miles west of the Stanford Campus in San Mateo County, California. Its boundaries include Sand Hill Road on the north and San Francisquito Creek on the south. The land slopes to the south toward San Francisquito Creek. The total length of the accelerator and experimental areas is approximately 3 miles and is oriented almost east-west. Figures 1 and 2 locate SLAC with respect to the surrounding vicinity.

SLAC is a large research laboratory devoted to theoretical and experimental research in high energy physics and to the development of new techniques in high energy accelerator particle detectors. The main tool of the laboratory is a 2 mile long linear accelerator. This accelerator produces beams of electrons with energies up to 22 billion electron volts (22 GeV). It can also accelerate positrons, the "anti-particles" of the electrons, up to 12 GeV. The work is carried out under the sponsorship and financial support of the U.S. Atomic Energy Commission.

Authorization of the project was given by the U.S. Congress in 1961. Construction of the accelerator started in 1962 and was completed in 1966. Research consisting of numerous and varied experiments has been under way since late 1966.

SUMMARY

The SLAC regional surveillance program is intended to assess the contribution from SLAC operations, if any, to the existing radiation environment typically known as "background radiation". The term background radiation includes naturally occurring radioactive elements and man-made radio-elements

usually from past atmospheric weapons' testing. Accordingly, environmental samples are periodically collected and activity levels determined. Airborne radioactivity is measured and recorded continuously at the release point. Continuous physical radiation measurements of neutron and gamma dose is also provided near the site boundary. Environmental and physical radiation monitoring locations are indicated on Fig. 3.

MONITORING TECHNIQUES AND STANDARDS

Concentration Guides for Liquid Effluent

The CG's for unidentified radionuclides that may be produced in water at SLAC and released to the environment is 3×10^{-6} μCi/ml. This is true because the following isotopes are not produced at SLAC: ^{90}Sr, ^{125}I, ^{126}I, ^{129}I, ^{131}I, ^{210}Pb, ^{210}Po, ^{211}At, ^{223}Ra, ^{224}Ra, ^{226}Ra, ^{227}Ac, ^{228}Ra, ^{230}Th, ^{231}Pa, ^{232}Th, ^{248}Cm, ^{254}Cf, ^{256}Fm and natural thorium.[1]

Sample Analysis

All water samples collected are analyzed for gross beta activity and tritium by an independent laboratory. Analysis for alpha emitting radioelements is not performed because we do not produce nor possess in unsealed form significant quantities of this type of radioactivity at SLAC.[2] In addition to routine gross beta analysis, SLAC will examine aliquots of selected specimens by gamma spectroscopy if necessary.

Sample Preparation

When environmental water samples exhibit large amounts of insoluble solids, the solid fraction and filtrate activities are determined separately.

The total volume of each sample is measured and filtered through tarred filters. The original sample bottle is rinsed with the filtrate and the activity in each fraction is determined separately.

For the solid fraction, the filter paper and solid are dried at $\sim 100^{o}C$ and weighed after cooling. A 300 to 500 mg aliquot is counted. If required, self-absorption measurements are made on the dried samples.

The filtrate and water samples exhibiting low solid content are treated the same. An ~200 cc volume is taken from each 500 cc sample and evaporated to a smaller volume in a beaker. It is then transferred to a tarred planchet with dilute acid and water rinses. The sample is evaporated gently, weighed and counted.

Vegetation and soil samples are treated by similar techniques, except that the soil samples are not ashed unless the samples have a high organic content. An aliquot is dried and ashed and a 300-500 mg sample is transferred into a tarred planchet, slurried with water and gently evaporated to dryness. The sample is then cooled, weighed and counted.

Gross Beta

The prepared samples are counted in a low background proportional counter ($\leq$ 1.5 cpm). The results are compared to the efficiency of Cs^{137} for the counting system used.

Some environmental samples require ^{40}K corrections: the total amount of potassium in the sample is determined by flame photometry. The amount of ^{40}K activity can then be calculated based on the percent abundance of this naturally occurring radioelement. This correction is performed on all water supplies whose gross beta activity is $> 1 \times 10^{-7}$ $\mu Ci/ml$.

The data is reported as the single Poisson standard deviation of the counting error.

Tritium

A 2-3 ml aliquot of the filtered solution from the gross beta sample preparation is accurately transferred to a liquid scintillation sample vial. The sample vial is placed in a liquid scintillation counting system. The limit of sensitivity at the 95% confidence level is $\geq 3 \times 10^{-6}$ μCi/ml.

Concentration Guides for Airborne Radioactivity

The Concentration Guides (CG's) for airborne radioactivity appear in Reference 1. They were derived from dose standards which requires that no individual in the general population will be exposed to greater than 500 mrem in one year and that the average dose to a population of suitable size shall not exceed 170 mrem annually from project operations.

Airborne radioactivity produced as the result of operations are short-lived, i.e., the half-lives range from 2 minutes to 1.8 hours and are in gaseous form. These isotopes include the following:

Table 1

Gaseous Radioactivity Released to Atmosphere

Isotope	Half-Life	CG's
^{15}O	2.1 min	5×10^{-8}(a)
^{13}N	9.9 min	5×10^{-8}(a)
^{11}C	20.5 min	5×10^{-8}(a)
^{41}Ar	1.8 hr	4×10^{-8}

(a) Calculated from Reference 3.

Since we do not routinely release airborne radioactivity while the beam is on and usually require a waiting period before turning on the exhausters, the only radioisotope routinely released is ^{41}Ar. By far the greater proportion

of exposure, an individual may receive from the radioelements listed in Table 1, is from whole body immersion. Thus, for an individual to receive a whole body dose of 500 mrem annually requires an exposure to a large cloud of ^{41}Ar whose average concentration is 4×10^{-8} μCi/cc for an entire year.

Analysis Techniques for Airborne Radioactivity

The accelerator and beam switchyard areas are vented by 12 fans: the discharge point is just slightly above roof elevation. The total exhaust rate for the accelerator is 60 m^3/s and the BSY is 40 m^3/s. The accelerator and BSY are not normally vented while the electron beam is on. If personnel entry has to be made during an operating cycle the area is vented for 10 minutes prior to entry and after the electron beam has been shut off. The release of any radioactivity is therefore not continuous and only for brief periods of from 30-60 minutes. The accelerator does not represent a significant source of gaseous or particulate radioactivity due to low activating potential.

Each ventilation fan is interlocked with a radioactive gas detector comprised of a Geiger-Mueller detector, power supply, rate-meter, strip chart recorder and air pump. The electronics are in continuous operation and the recorder and air pump are interlocked with the ventilation fan so that they operate only when the machine is being vented.

The gas monitors for the BSY have been modified to collect particulate samples during venting and have revealed negative results. During this report period, no particulate radioactivity above background levels were detected. This agrees with previous "grab" samples collected in the exhaust stream.

Penetrating Radiation Monitoring Techniques

Seven Peripheral Monitoring Stations (PMS) serve to provide continuously recorded data concerning radiation levels (γ and n) near SLAC boundaries. Their positions are located in Fig. 3.

Radiation information is obtained with a Geiger tube and paraffin-moderated BF_3 neutron detector calibrated with a PuBe neutron source. The resultant sensitivites are such that a γ flux from ^{60}Co exposed to an average value of 1 mR/hr for one hour will be recorded as $\sim 10^4$ counts on the Geiger tube channel, and a neutron flux having an average value for one hour of 1 mrem/hr will be read out as $\sim 10^5$ counts on the BF_3 channel. The hourly printout cycle of the Sodeco register is programmed by the 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.

In connection with the pulse pair resolution limitation of the Sodeco register mentioned above, an important feature of this system involves the pulser which drives the register. It is of the nonparalyzable type. This means that if the instantaneous counting rate (20 counts/sec) is ever exceeded the register will merely not count the pulses in excess of its maximum rate. It can count at this maximum rate continuously (72,000 counts/hr).

MONITORING RESULTS

Penetrating Radiation Monitoring

The measured annual dose to the general population from accelerator operations is from fast neutrons and is characterized as skyshine from SLAC's research area. The total dose measured at each PMS location appears in Table 2. Estimates of individual and general population whole body dose can be calculated based on estimates of distance and population density near SLAC from the PMS data. However, since the "fence post" dose was <1% of the

relevent standard for whole body exposures to individuals in the general population no further extrapolation of the measured values is required.

Environmental Samples

Results of the environmental analysis for radioactivity found in water, soil and vegetation appear in Table 3 and are reported in μCi/ml or μCi/gm for gross beta nonvolatile radioactivity. Analysis of tritium is performed on all water samples but is not reported because all environmental samples analyzed exhibited a tritium content less than the minimum detectable level of 3×10^{-6} μCi/ml.

Some of the peripheral wells (ground water) exhibit higher than normal concentrations of gross beta radioactivity and solids. This activity is due to naturally occurring radioactive potassium-40 and has been verified by flame photometry and gamma spectral analysis. The ^{40}K content in samples from W-1 are typically about 2×10^{-7} μCi/ml accounting for approximately 90% of the gross beta activity present. Only those samples whose concentrations are above 1×10^{-7} μCi/ml are corrected for ^{40}K. One well has exhibited some naturally occurring radioactive daughters of uranium. During dry seasons the concentration has approached 1×10^{-7} μCi/ml.

In addition to the ground and surface water sampling stations previously reported, two composite water sampling stations have been added; these samples are from the sanitary and storm sewers whose daily effluent averages approximately 210 and 260 m^3 respectively. The sampling rate is fixed at 5 ml/min and represents a sampling fraction of approximately 3×10^{-5} of the total effluent volume. At the end of each calendar quarter an aliquot is collected and analyzed for gross beta and tritium radioactivity. Results for 1972 appear in Table 3. There has been no significant increase of radioactivity in environmental samples since SLAC operations began in 1966.

Airborne Monitoring

During 1973, SLAC released 6.1 Ci of short-lived radioactivity in gaseous form. Particulate samplers continue to demonstrate that this form of radioactivity is not present in the atmosphere released from SLAC.

The total volume released and the total time of release was 0.73×10^{6} m^3 and 8.3 hours respectively. This resulted in an on-site average concentration of 8×10^{-6} Ci/m^3 and an average off-site concentration of 3.6×10^{-9} Ci/m^3 during the 8.3 h release period. This release period represents only 0.1% of the total time in one year and the off-site concentration, averaged for an entire year, would therefore be 3.6×10^{-12} Ci/m^3 or $<0.01\%$ of the standard for ^{41}Ar.

Table 2

Annual Penetrating Radiation Dose Measured Near SLAC's Boundaries

1973

PMS NO	Gamma, mrem ± 15%			Neutron, mrem			Total Source	% Standard (b)
	Background + Source	Background	Source	Background + Source	Background	Source		
1	87	89	(a)	11.0	8.1	3.1	3.1	< 1
2	64	64	(a)	9.6	8.1	1.5	1.5	< 1
3	63	60	(a)	11.3	8.1	3.2	3.2	< 1
4(c)	--	--	--	12.0	8.1	3.9	3.9	< 1
5	84	85	(a)	13.0	8.1	4.9	4.9	< 1
6	72	76	(a)	8.1	8.1	0	0	< 1
8	69	68	(a)	12.6	8.1	4.5	4.5	< 1

(a) Difference between gamma background radiation and source contribution falls within normal variation of background values.

(b) Standard from USAEC Manual Chapter 0524.

(c) Station out of service.

Table 3

Measured Radioactivity Content of Environmental Samples
Collected at SLAC from January through December, 1973

Sample	Total Samples	Gross Beta Activity[a]			% Standard[1]
		Minimum	Maximum	Average	
Well Water, μCi/ml	16	5×10^{-9}	1.2×10^{-7}	2.4×10^{-8}	(b)
Surface Water, μCi/ml	4	$\leq 5\times10^{-9}$	3.4×10^{-8}	1.8×10^{-8}	(b)
Sanitary Sewer, μCi/ml	1[c]	---	---	9.2×10^{-8}	(b)
Storm Sewer, μCi/ml	1[c]	---	---	$\leq 4\times10^{-9}$	(b)
Stream Silt as Soil, μCi/gm	3	2.4×10^{-5}	2.8×10^{-5}	2.6×10^{-5}	(b)
Vegetation, μCi/gm	3	2.4×10^{-5}	3.4×10^{-5}	2.9×10^{-5}	(b)

(a) Includes ^{40}K.

(b) Does not apply, all samples revealed background concentrations.

(c) Composite sample.

Table 4

Summary of Maximum Radiation Measurements
by Pathway Near SLAC's Boundaries
1973

Exposure Source	Annual Dose mrem	% of Standard
Penetrating	3.9[a]	0.78
Water and Vegetation	Background	(b)
Airborne	$\leq$ 0.05	$\leq$ 0.01

(a) Maximum measured value at PMS 5.

(b) Does not apply, all samples revealed background concentrations.

APPENDIX A

Atmospheric Dispersion Model

In 1966 an independent evaluation of meteorological regimes at SLAC was performed.[4] 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.

$$\frac{\chi_p}{Q} = \frac{8}{u}\left(\frac{\chi}{2}\right)^{-1.75 + \frac{b(1-C)}{u}}$$

where

χ_p = centerline concentration (Ci/m^3)

Q = source strength (Ci/s)

u = mean wind speed (m/s)

X = distance from source (m)

C = fraction of sky covered by low clouds (use b = +0.5 for night and b = -1.2 for day)

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

For a wind speed of 2m/s atmospheric dilution factors — for determining centerline concentrations — range between 2×10^{-5} and 1.5×10^{-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} is used in the calculation of average concentration at the site boundary.

REFERENCES

1. U.S. Atomic Energy Commission Manual, Chapter 0524, Standards for Radiation Protection.
2. W.R. Nelson, "Radioactive Ground Water Produced in the Vicinity of Beam Dumps," Stanford Linear Accelerator Center Report No. SLAC-TN-65-16 (July 1965).
3. Recommendations of the International Commission on Radiological Protection, Publication 2 (1959) (Pergamon Press, London).
4. J.A. Murray, L.M. Vaughan and R.W. McMullen, Atmospheric Transport and Diffusion Chatacteristics for Selected Daytime Meterological Regimes at SLAC, Memorandum Report No. 326-1, Metronics Aerosol Laboratory, 21 December 1967.

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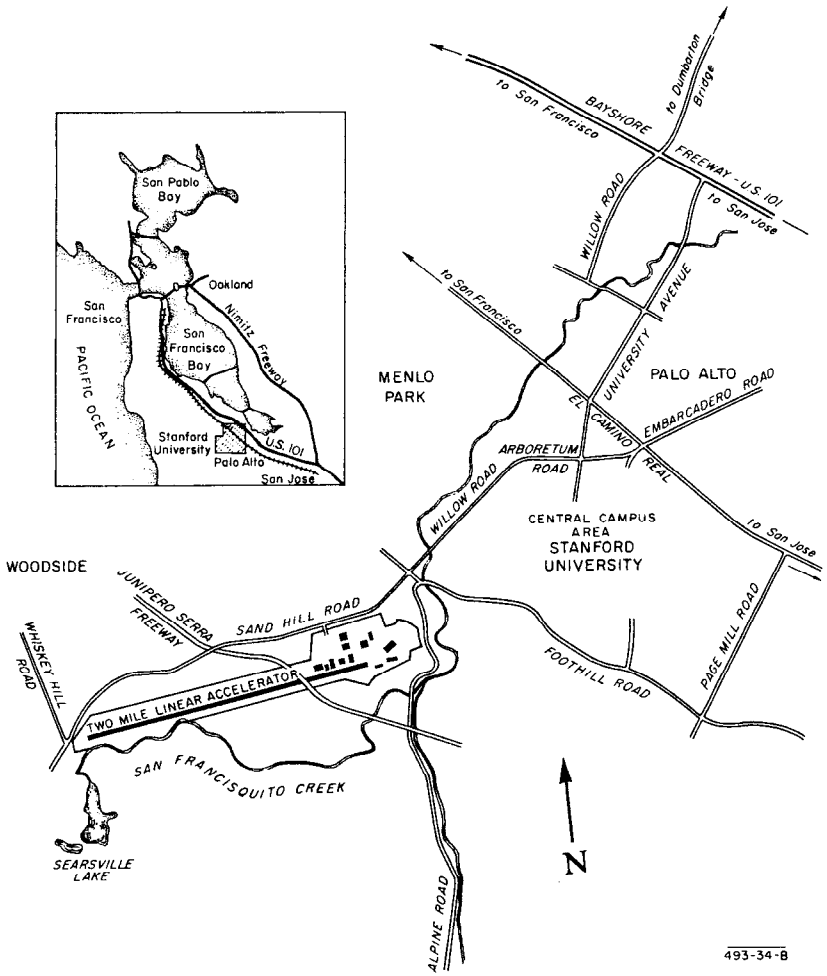


FIG. 1--Site location relative to Stanford University and surrounding communities.

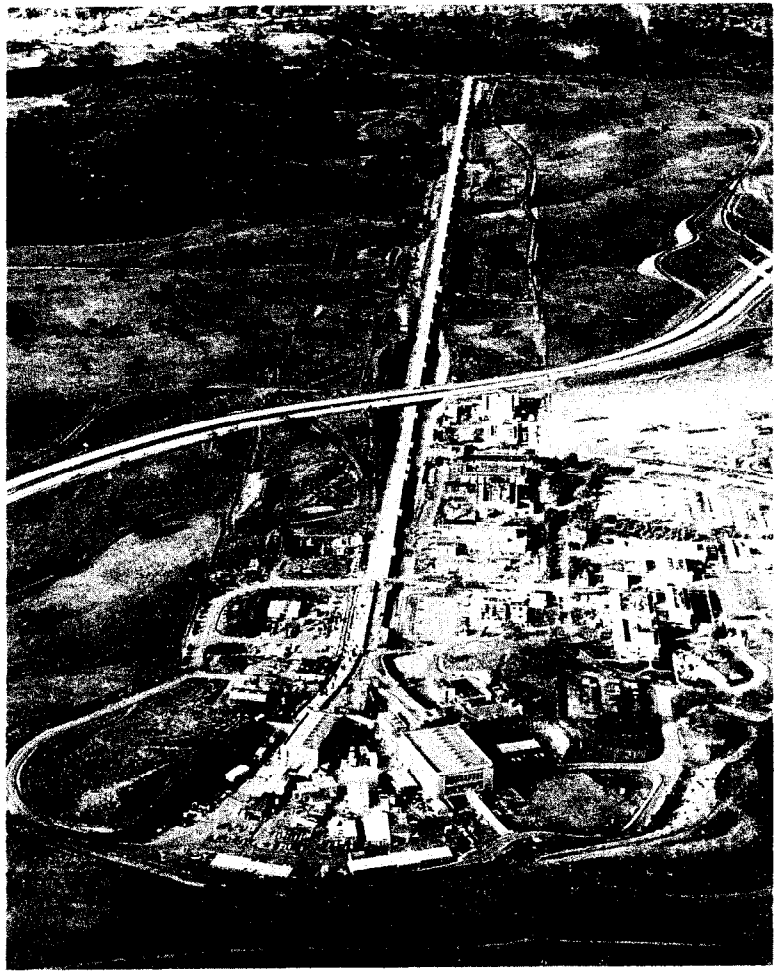
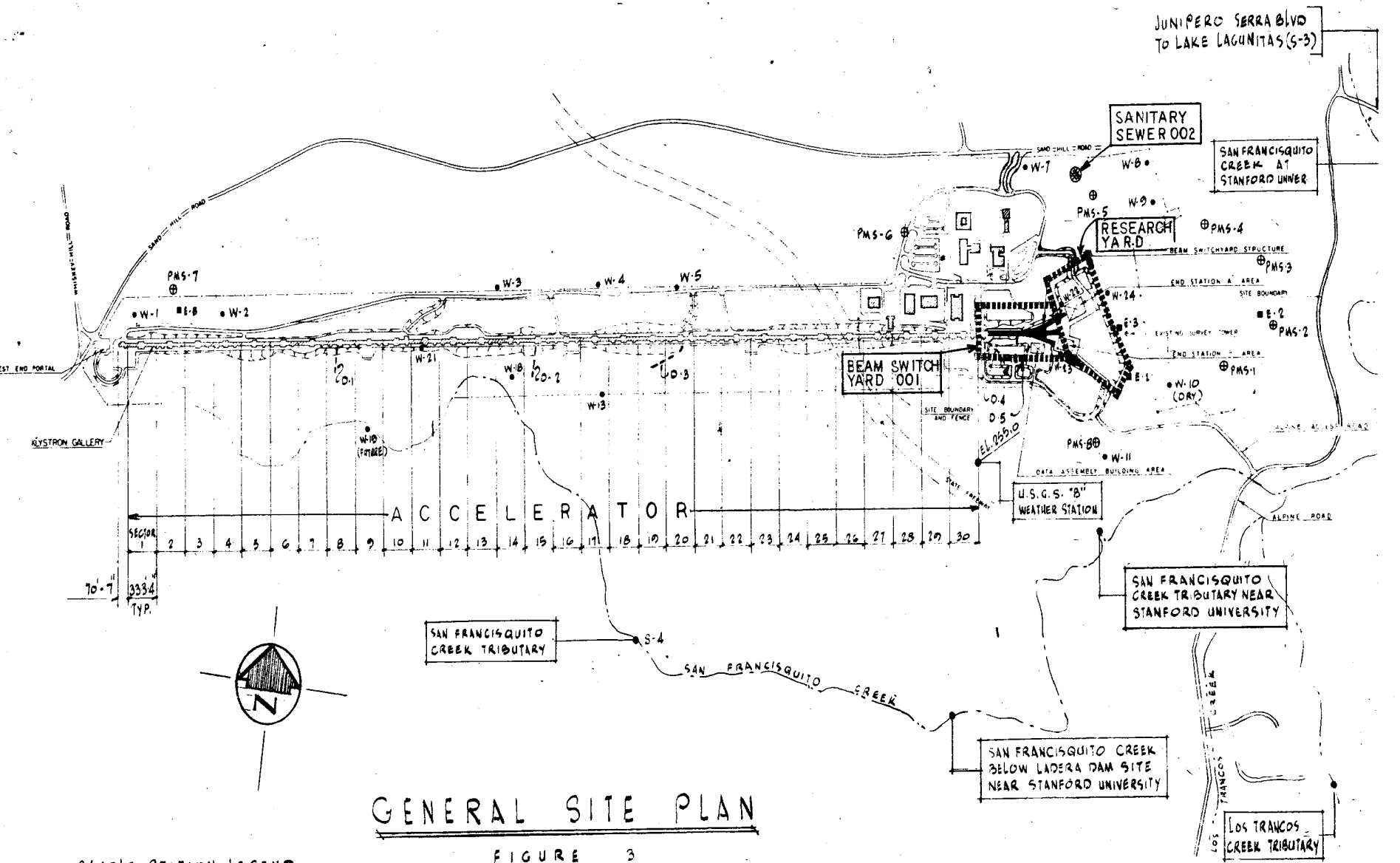


FIG. 2--Air view of SLAC site showing the two-mile accelerator, the research facility, and the principal laboratories and shops.



GENERAL SITE PLAN

FIGURE 3

SAMPLE STATION LEGEND

- •W PERIPHERAL WELLS
- •S SURFACE WATER
- ■E ENVIRONMENTAL PLOTS
- ⊕PMS PERIPHERAL MONITORING STATIONS
- ---D SUBDRAINS

GRAPHIC SCALE

1000' 0 1000' 2000'

SCALE: 1" = 1000'

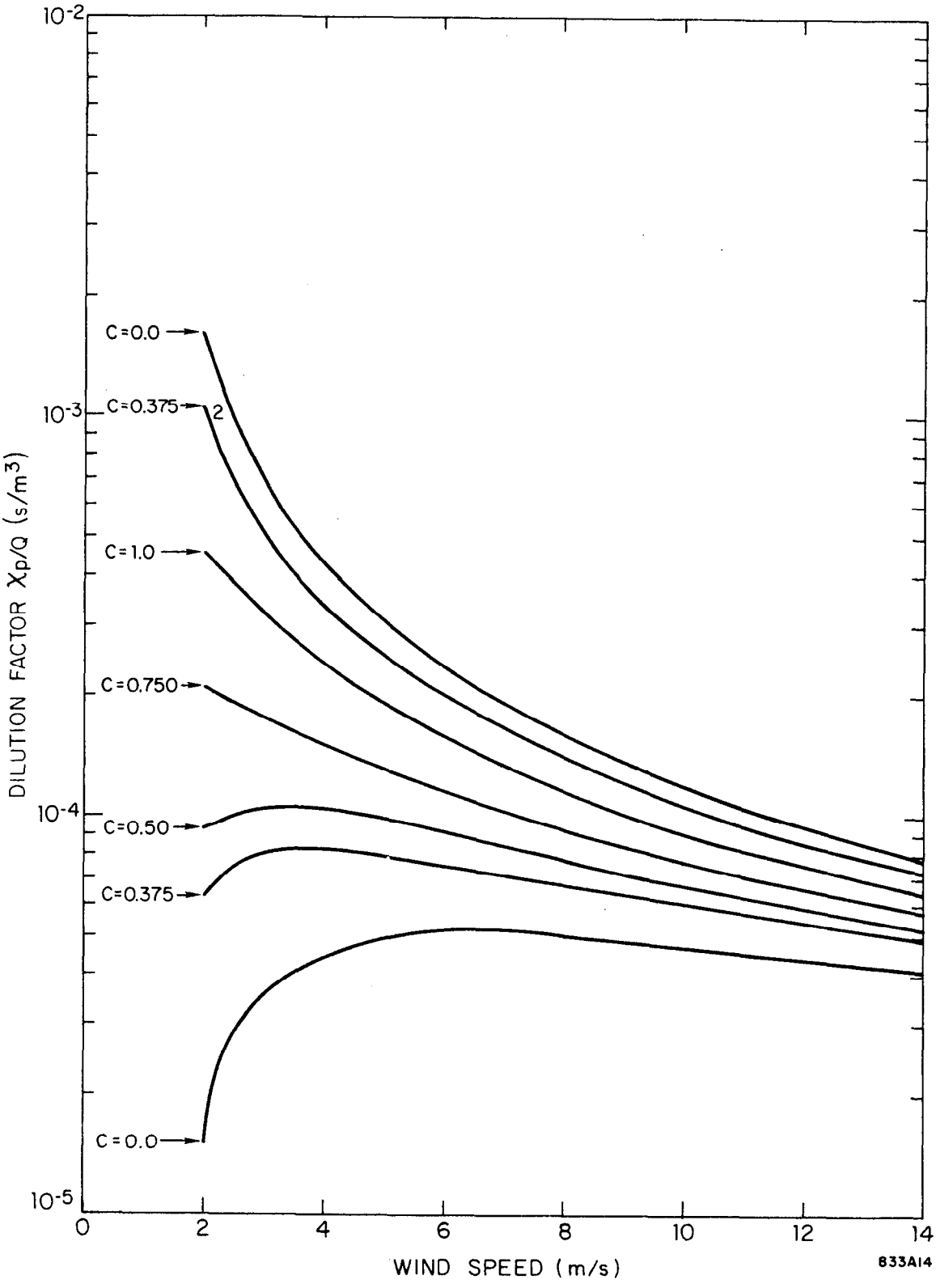

10-2
10-3
10-4
10-5
DILUTION FACTOR Xp/Q (s/m3)
C=0.0
C=0.375
2
C=1.0
C=0.750
C=0.50
C=0.375
C=0.0
0
2
4
6
8
10
12
14
WIND SPEED (m/s)
833A14

Fig. 4