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Environmental Monitoring Report

For Calendar Year 1978

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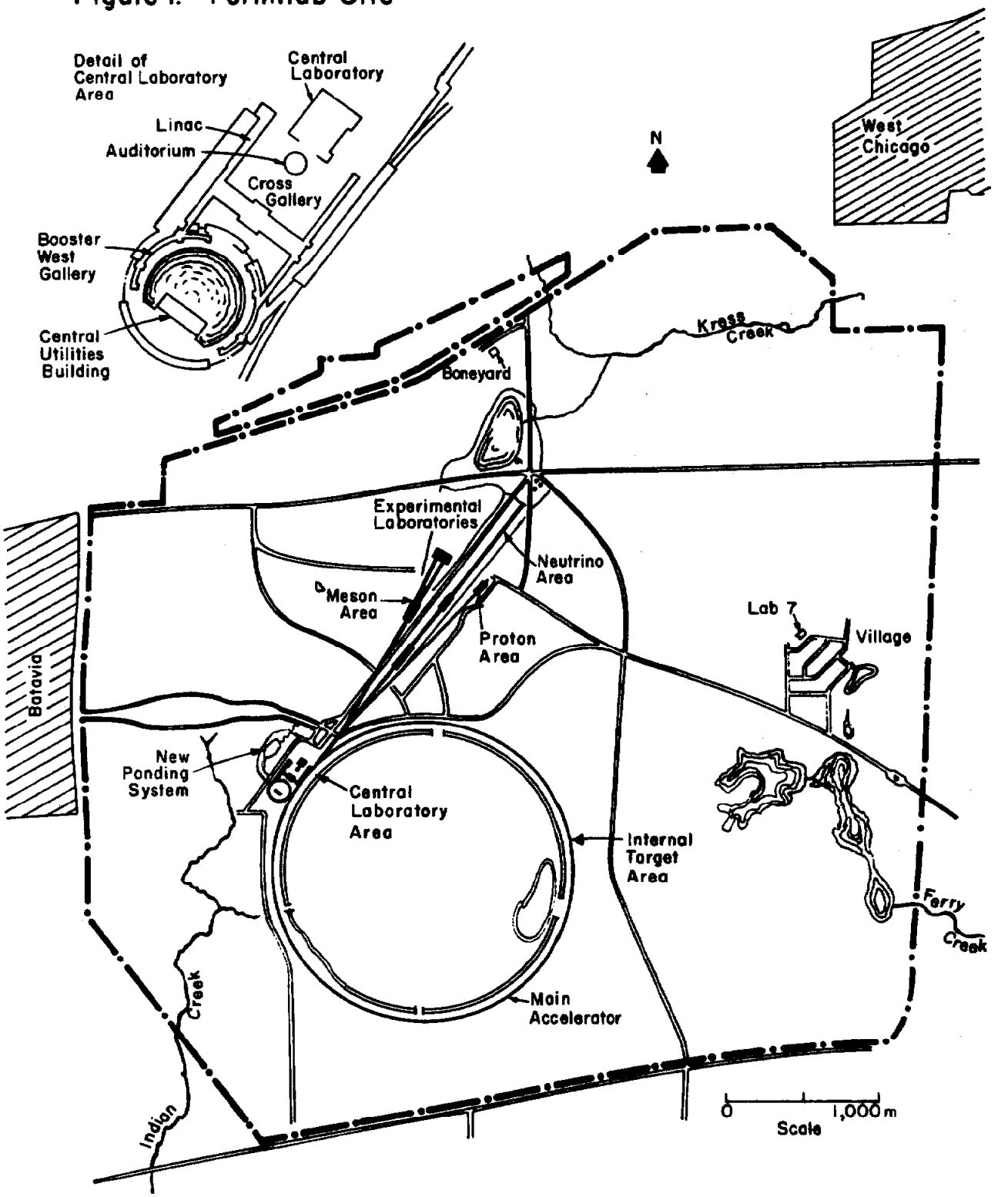
1. Introduction

This report gives the results of the environmental monitoring program at Fermi National Accelerator Laboratory (Fermilab) for Calendar Year (CY-) 1978. The Fermilab Facility is a proton synchrotron with a design energy of 200 GeV (billion electron volts); however, the energy reached 500 GeV in 1976 and operation at 400 GeV is now routine. The primary purpose of the installation is fundamental research in high energy physics. In addition, cancer patients are being treated using neutrons released by interaction with protons from the accelerator.

The proton beam extracted from the 2 km (1.2 mi) diameter main accelerator is taken to three different experimental areas on site (Meson, Neutrino, and Proton Areas in Fig. 1). All three of these areas received proton beams for the first time in 1972. Radioactivity is produced as a result of the interaction of the accelerated protons with matter. Operation of the accelerator produces some radiation which penetrates the shielding material as well as some airborne radioactivity. Also, some radioactivation of the water used to cool radioactive components and of the soil occurs. Since the Fermilab site is open to the public, this free access necessitates a thorough evaluation of our on-site discharges as well as our potential for off-site releases of radioactive effluents. Thus, an extensive monitoring program tailored to these needs is being maintained.

Figure I. - Fermilab Site



Monitoring results are also reported for nonradioactive pollutants. Included as pollutants are pesticides and copper used in weed, insect, rodent and algae control.

Also, a corrosion inhibitor containing zinc and chromium (as chromate) was formerly used in one of the water systems. Discharge underground and subsequent surfacing required monitoring and that monitoring continued in CY-1978. The CY-1978 results are reported as well as those from monitoring the performance of the two sewage treatment plants on site.

Fermilab is located in the greater Chicago area (Fig. 2) on a 27.5 km^2 (10.6 sq mi) tract of land in an area which is rapidly changing from farming to residential use. There are many municipalities in the vicinity, resulting in a distinct pattern of high population concentration. Within a 3 km (2 mi) distance from the Laboratory boundaries, Batavia (pop. 9,000*), Warrenville (pop. 3,000*) and West Chicago (pop. 10,000*) can be found.

The two major environmental features near the Laboratory are the Fox River to the west, which flows south through Batavia with an average of 1900 million liters (500 million gallons) per day, and the west branch of the DuPage River which passes east of the site flowing south with an average of 265 million liters (70 million gallons) per day through

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*1970 U. S. Census.

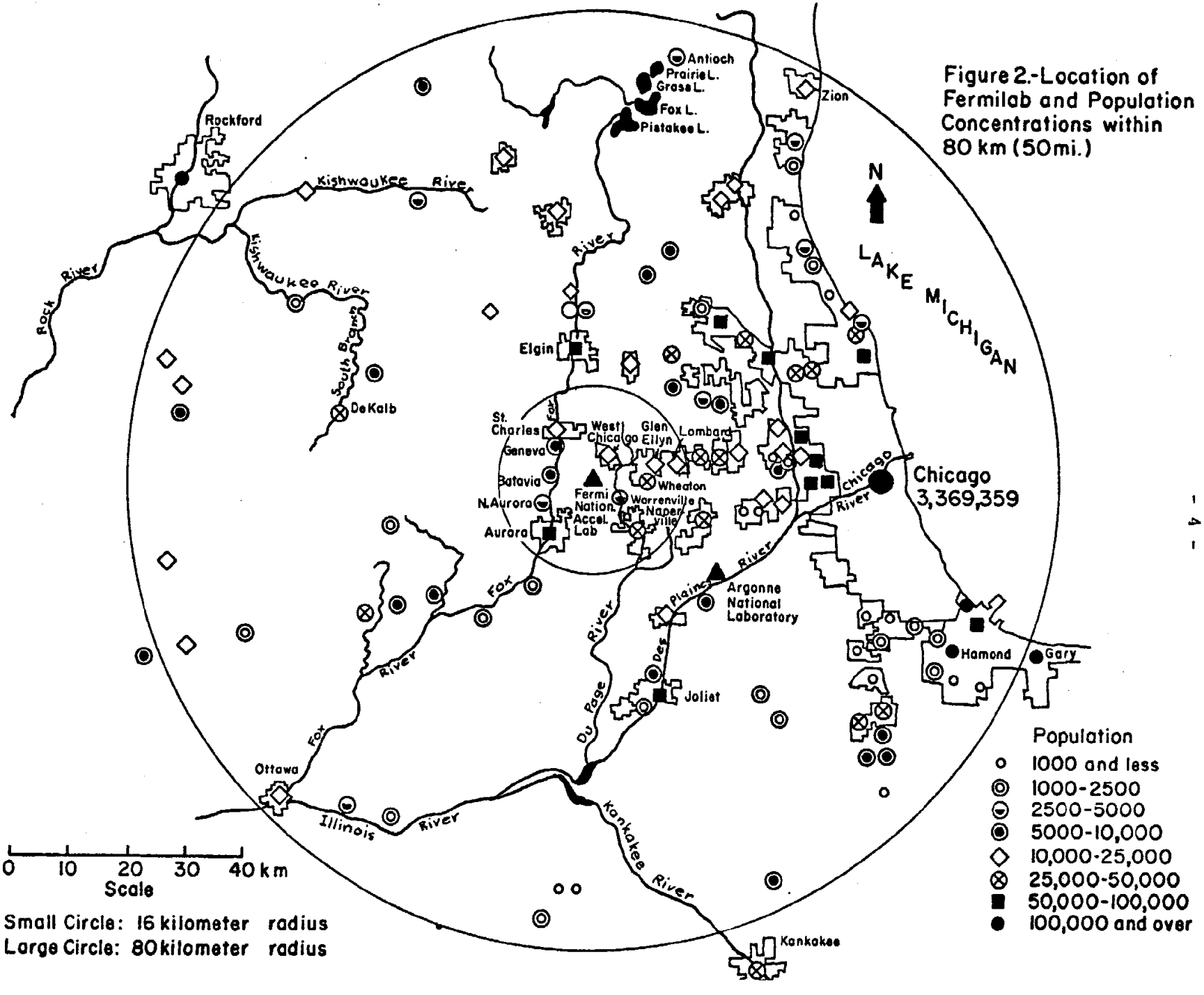

Figure 2.-Location of Fermilab and Population Concentrations within 80 km (50 mi.)

Warrenville. The rainfall on site during 1978 was 103 cm (40 in).[1] The land on the site is relatively flat with a high area, elevation 244 m (800 ft) above sea level (ASL), near the western boundary and low point, elevation 218 m (715 ft), ASL, toward the southeast. The drainage of the ground water and most of the surface water is toward the southeastern corner of the Laboratory, toward the DuPage River. A somewhat smaller amount drains to the southwest, toward the Fox River. The drinking water in many of the surrounding communities comes from deep wells usually drilled 1,200 feet deep into the Cambrian Ordovician aquifer system.[2]

The mean wind speed for the 15-year period from 1950-1964 was 3.4 m/sec (7.6 mi/hr) at Argonne National Laboratory (ANL).[3] The direction is quite variable with the observation of more southwesterly winds than from any other direction. The mean wind speed was 3.6 m/sec (8.1 mi/hr) in CY-1978 with more southwesterly winds.[3] Fermilab is about 30 km (19 mi) from ANL and the terrain is relatively flat, so similar wind conditions would be expected. Detections of radioactive gas plumes here have been strongly correlated with wind directions obtained from strip-chart recordings made at ANL during our releases.

2. Summary

The accelerator operated routinely at 400 GeV during CY-1978 with about the same number of protons during CY-1978 as in CY-1977. The total number of protons accelerated in 1978 was 2.1×10^{19}. The maximum number of protons accelerated at one time exceeded half of the planned or design intensity of 5×10^{13} protons per acceleration cycle and typical operation was at about 40 percent of the design intensity. Thus, environmental monitoring in CY-1978 was done under operation conditions not grossly different from those expected in the future.

During CY-1978 there was one abnormal occurrence which had an impact on the facility and its operation. On September 13 a rainfall of 15.5 cm (6.1 in) occurred with the bulk of it falling in less than three hours before dawn. An associated lengthy and extensive power outage resulted in inoperative sump pumps which led to the flooding of some underground enclosures. The damage estimate was $140,000, primarily for repair of magnets, transformers and other electrical equipment.

A new ponding system[4] was in operation throughout CY-1978, eliminating the use of chromates. The concentration of chromates in on-site waters was negligible in CY-1978. Copper from regeneration of resins at the B0 Water Treatement Plant continues to surface.[4] The surfacing was at a reduced rate

in CY-1978 and the copper concentration in the C4 pond which receives this discharge was well below the State of Illinois Standard for waters in general use. The B0 Water Treatment Plant is being moved to the Central Utilities Building. Completion of the move is expected before May 1, 1979. The drain pipe will be capped, eliminating any waste disposal in the B0 perforated pipe field; and a holding tank will be used for precipitation of the copper compounds. The releases of copper and chromate have had little or no off-site impact.

The total potential radiation exposures at the point of highest dose rate at the site boundary and to the general off-site population from Fermilab operations during CY-1978 were 11 mrem and 5 man-rem, respectively, compared to 7 mrem and 3 man-rem,* respectively, last year. The site boundary dose rate is higher because the experimental area produced more off-site muons this year.[4] The potential dose at the site boundary corresponds to 2.2 percent of the standard of 500 mrem for an individual who is not a radiation worker. It is primarily from muons.

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* Reported as 1 man-rem in Environmental Monitoring Report for CY-1977. See Section 4.

Airborne radioactivity was released across the site boundary in small amounts throughout the year from the stacks ventilating a Neutrino Area enclosure where the beam struck a target. The radioactive gas was primarilly ^{11}C, total quantity released was 2.4 kCi, and the maximum dose at the site boundary was 0.7 mrem for 1978. The average concentration at site boundary based on measurements at the stack was 0.1 percent of the Concentration Guide (Sections 3.2 and 4). There was also a controlled release of tritium produced in helium gas near another target. The total amount of tritium released was 370 mCi. Tritium was released continuously from January 1, 1978 through September 6, 1978, with an average concentration at the site boundary of 0.00001 percent of the Concentration Guide (Sections 3.2 and 4), resulting in a negligible off-site exposure. No accelerator-produced radioactivity was detected in the ground water and off-site releases of tritium of surface water totaled 125 mCi, about the same as last year's release.

3. Monitoring, Data Collection, Analysis and Evaluation

The three types of accelerator-produced radiation chosen for environmental monitoring are discussed below. These radiations have direct pathways to the off-site population. Other more indirect pathways, such as through the food chain, have received little attention to date. The decision on what to monitor is based on the type of operation, radionuclides released and monitoring results from this and other high energy physics laboratories.

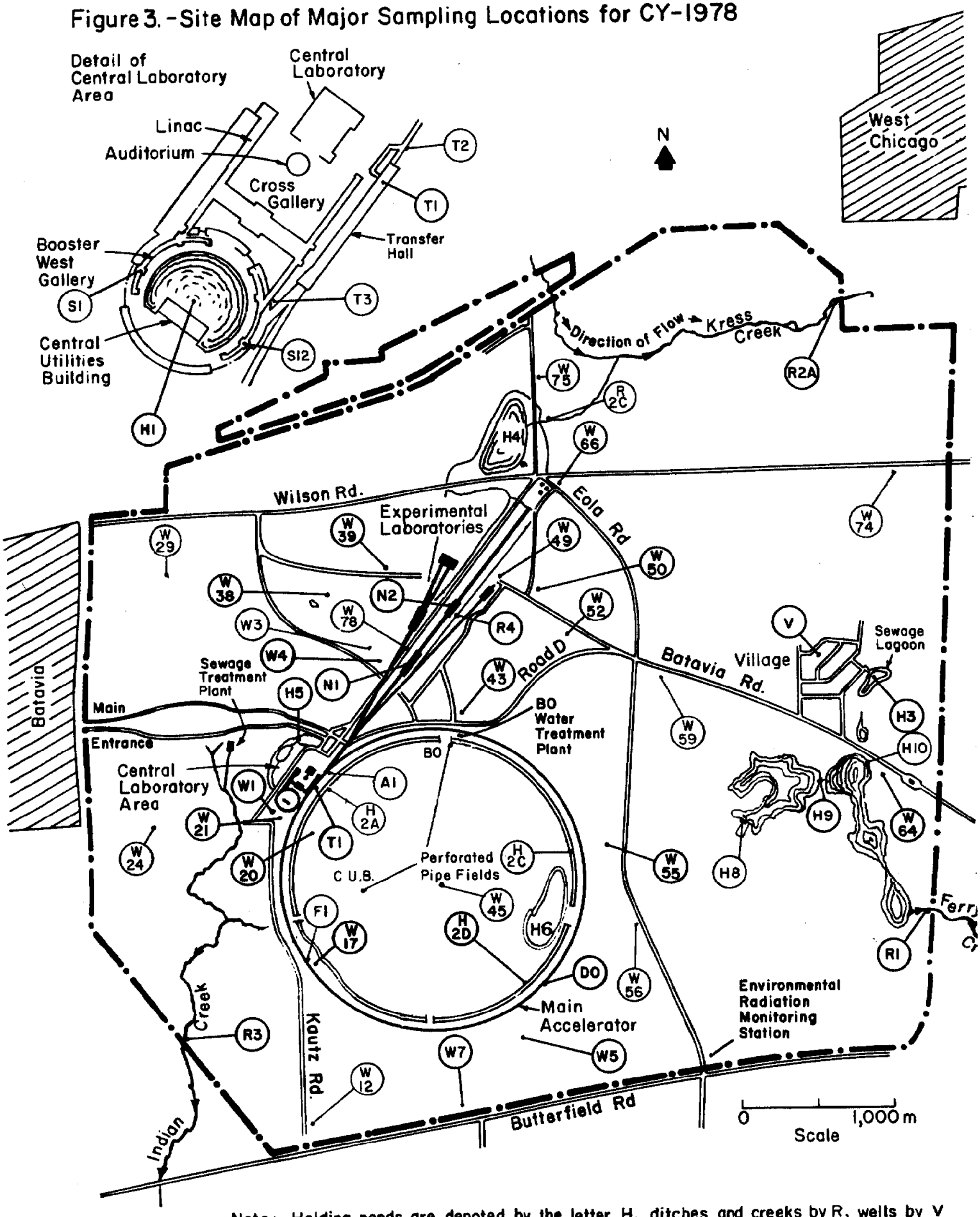
3.1 Penetrating Radiation

Operation of the accelerator at current energies and intensities results in production of some penetrating radiation (primarily muons and neutrons) outside the shielding. Although the shielding has been designed to be adequate for this operation, monitoring for purposes of determining actual radiation levels both on and off the site is necessary.

A large network of detectors was used to monitor penetrating radiation. At the end of CY-1978 there were approximately 200 detectors deployed around the site for the main purpose of protecting on-site personnel. The majority of these detectors were connected to a data logger which automatically recorded the radiation levels for subsequent examination.[5] Approximately ten detectors were used primarily for environmental radiation monitoring. Most of these were deployed at the ends of the paths traveled by the protons or near the site boundary. Of the latter, seven were large volume, 110 liter, ionization chambers for gamma-ray and charged particle detection.

For several years a special radiation monitoring station with gamma-ray, charged particle and neutron detectors of high sensitivity was maintained near the site boundary (Fig. 3).[6] This station detected no accelerator-produced radiation. In CY-1977 all detectors except one gamma-ray scintillation counter were removed for use else-

Figure 3. - Site Map of Major Sampling Locations for CY-1978



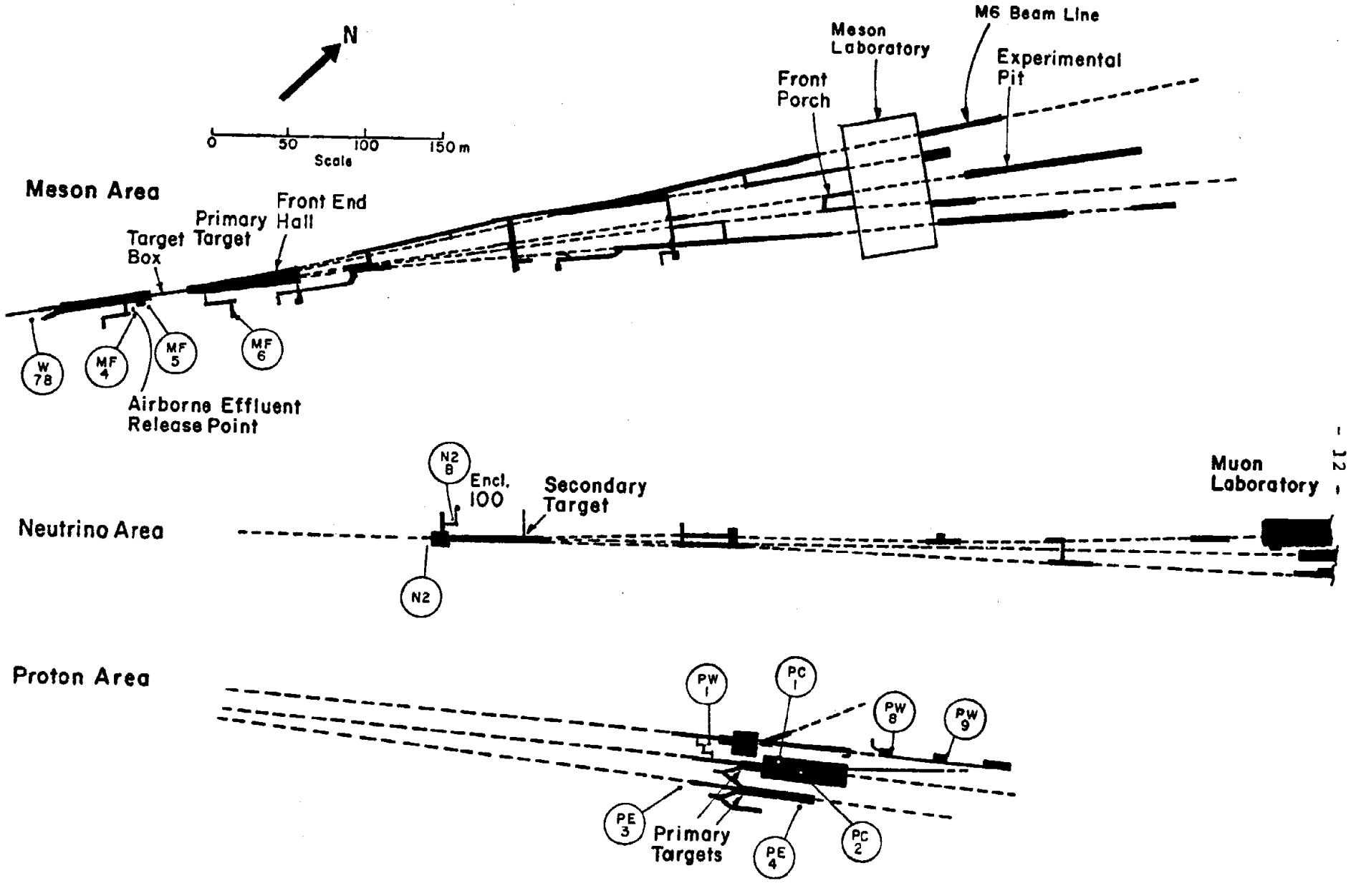
Note: Holding ponds are denoted by the letter H, ditches and creeks by R, wells by V and W, and sumps by other letters.

where on site. The remaining gamma-ray detector is identical to one used near the experimental areas (W43 in Fig. 3) to detect ^{11}C in the Neutrino Area radioactive gas releases. It provides background levels for comparison to those levels of ^{11}C and also to levels detected by the Mobile Environmental Radiation Laboratory (MERL). The MERL is a four-wheel-drive vehicle equipped with detectors of high sensitivity for finding penetrating radiations and measuring levels at different distances for determining dose rates at the site boundaries. The long distances to the site boundaries and the low levels of radiation there compared to natural background levels make it necessary to measure levels closer to the shielding.

3.1.1 Muons

The MERL was used for determining the exposure levels at the site boundary and for locating the source of the penetrating radiation discovered behind the Muon Laboratory, a facility in the Neutrino Area (Fig. 4).[4,7,8] The MERL was equipped with two 26 cm x 26 cm (8" x 8") scintillation counters, one behind the other, with associated electronics to verify that the penetrating radiation (the individual muons) came through both counters. These counters were used to determine the direction and radiation level of the penetrating radiation. Dose measurements were made at the site boundary with the scintillation counters

Figure 4 - Sampling Locations in External Experimental Areas



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while recording the number of counts from one of the 110 liter ionization chambers placed in the path of the muons much closer to the source. The counts from that ionization chamber were recorded for the entire year through the data logger to determine the annual dose at the site boundary. The operation with muons in CY-1978 resulted in radiation capable of delivering a total dose of 10 mrem over a region of about 50 m (160 feet) wide at the site boundary.

3.1.2 Neutrons

Neutrons were detected outside the shielding in the Proton Area (Fig. 4) in CY-1978. The location where neutrons were detected was so far from site boundaries that the annual dose at site boundary from neutrons was negligible.

3.1.3 Gamma Rays

In May 1977 E G & G, Inc., under ERDA (now DOE) contract, conducted an aerial radiological survey of Fermilab and surrounding area.[4,9] The detection system used consisted of 20 NaI(Tℓ) scintillation counters each 12.7 cm diameter by 5.1 cm thick (5" x 2") mounted in a helicopter. Data were recorded on magnetic tape and analyzed with aid of computer techniques.

Flight paths were 100 m (300 ft) apart at an altitude of 100 m (300 ft) with location determined by referencing to radio beacons placed on nearby water towers. The area covered was approximately 6 km by 6 km (4 mi x 4 mi)

with the Laboratory in the center. The results indicated three areas where radiation was significantly higher than natural background.[4] All three of these were locations where radioactive materials were stored. One of these, the Fitzgerald Barn, has been razed and the material moved to the Lundy Barn just south of the Boneyard (Fig. 1). This building was constructed of shielding blocks, hence it reduced the environmental radiation levels. The second of the three areas is Lab 7 in the Village (Fig. 1). Most of the radioactive material has been removed from Lab 7 and sent off site for burial. The exposure based on 24-hour occupancy throughout CY-1978 in two of the three houses nearby would have been 3 mrem compared to 23 mrem in CY-1977, and in the third it would have been 2 mrem instead of 17 mrem. These are both less than one percent of the standard of 500 mrem for an individual who is not a radiation worker.

The third of the three areas detected during the aerial survey is the primary radioactive waste disposal storage area on site - the Boneyard. As shown in Fig. 1, this area lies close to the site boundary. On the north side there is an earth berm to prevent any direct radiation from leaving the site. Radiation scattered by the air, i.e., "skyshine", was responsible for a dose of 3 mrem at the nearest site boundary for the entire year of 1978. Much of the inventory was shipped to an approved off-site burial ground during CY-1978, and in August, when shielding was put over the top of the most radioactive material, the radiation levels at the site boundary were reduced to background levels.

3.2 Airborne Radioactivity

Radioactivation of air in measurable concentrations will occur wherever the proton beam or the spray of secondary particles resulting from its interactions with matter passes through the air. Along most proton beam lines (paths of the protons from the accelerator) the protons travel inside evacuated pipes. Thus, radioactivation of air is now usually caused by secondary particles. Monitoring of such activation is carried out for purposes of personnel exposure control. Under no circumstances is the off-site concentration of airborne radioactivity expected to approach the limits for uncontrolled areas set forth in the Department of Energy Manual, Chapter 0524 (DOE Manual 0524).

Radioactive gas, parimarily ^{11}C, was produced by interaction of secondary particles with air. Monitoring was carried out by detecting the beta particles emitted in the radioactive decay.[6] A release of 2.4 kCi occurred from the stacks (Fig. 5) in the Neutrino Area during 1978. From measurements made at the stack and calculations based on a Gaussian plume diffusion model,[4,10] the expected dose at the site boundary for 1978 was 0.7 mrem, which corresponds to 0.14 percent of the applicable Concentration Guide[11] (Section 4).

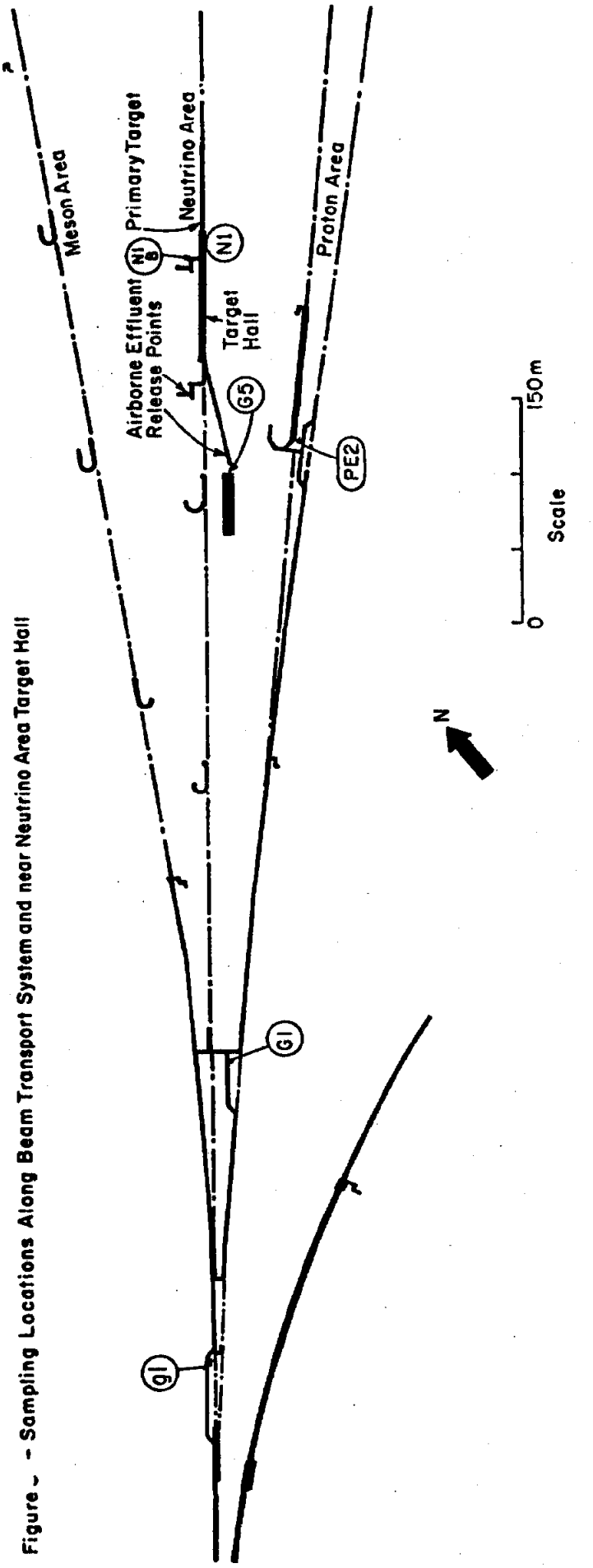


Figure - Sampling Locations Along Beam Transport System and near Neutrino Area Target Hall

Tritiated helium was released continuously as the tritium was produced from January 1, 1978 through September 6, 1978 from the Meson Area Target Box. The Meson Area then had a scheduled shutdown period extending beyond the end of CY-1978. The total activity released for the year was 370 mCi of ^{3}H. A small amount, 1.6 mCi, of ^{3}H was released from the Neutrino Area stacks. The Gaussian plume diffusion model[10] was used with neutral wind conditions to calculate the site boundary ^{3}H concentration. The average site boundary concentration for the release was less than 2×10^{-14} $\mu Ci/m\ell$ or a negligible percentage (0.00001 percent) of the applicable Concentration Guide given in the DOE Manual Chapter 0524.

3.3 Waterborne Radioactivity

During accelerator operations, some radioactivation of the soil will occur.[12,13] Leaching of these radionuclides into the ground water provides a possible mechanism for transport of Fermilab-produced radionuclides into the surface run-off waters and aquifer. Hence, a broad program of ground water monitoring for radioactivity is maintained. Measurements are also made of on-site concentrations of radionuclides in our surface waters and in closed loop (recirculating) cooling systems which are sources of potential off-site releases.

Water samples are collected periodically on site and in surface waters off site. They are analyzed for the presence of those radionuclides which are produced in and

leachable from Fermilab soils in measurable quantities.[12] This group of radionuclides also includes those produced in water directly. Analyses are made for ^{3}H, ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn and ^{60}Co. The latter is hardly leachable (approximately 0.1 percent); however it has been detected in discharges during regeneration of water treatment resin.

Water samples were collected from the following types of wells on site:

1. Farm Wells - Approximately 30 m Deep - 41 Samples
2. Fermilab Water Supplies - Approximately 70 m Deep - 4 Samples
3. Fermilab Deep Well Emergency Supply - 436 m Deep - 2 Samples

Water samples were also collected from sumps, creeks, and rivers. Samples were analyzed by Eberline Instrument Corporation, Midwest Facility, West Chicago, Illinois, during CY-1978. Each monthly shipment included one sample containing known amounts of several of the accelerator produced radionuclides to check the accuracy of the assays.

The agreement of the reported concentration with known concentrations of radionuclides in control samples provided verification that the analyses were meeting the specifications agreed upon in the contract. In addition to Fermilab samples, Eberline also analyzed samples

received from the DOE Environmental Measurements Laboratory (EML) as part of a quality assurance program. The results obtained by Eberline for EML samples are shown in Table 1. Also included are results obtained by EML and by Fermilab.[14] Fermilab has no liquid scintillation counting apparatus, hence no tritium determinations in water were performed here.

3.3.1 Results of Analyses

The Fermilab CY-1978 water sampling locations for detection of accelerator-produced activity are shown in Figs. 3, 4 and 6. No accelerator-produced radionuclides were reported in water samples taken from the three creeks leaving the site (Fig. 2). Four samples were obtained from Kress Creek and three each from Ferry and Indian. River water samples were obtained once during CY-1978 from the Fox River in Aurora and from the west branch of the DuPage River in Warrenville. Neither river is utilized as a drinking water supply. No evidence for accelerator-produced radionuclides was found.

3.3.1.1 Tritium

The results for on-site tritium measurements yeilding detectable levels in surface waters are given in Table 2. All other sampling points were essentially at background levels. The total off-site release in surface waters was 125 mCi of tritium this year compared with 128 mCi last year.

Table 1

Comparison of Water Analyses

Sample Date	Radio-nuclide	Environmental Measurements Laboratory Results (μCi/mℓ) (x 10^{-6})	Percentage of Concentration Guide for Surface Waters (μCi/mℓ) (x 10^{-6})	Fermilab Results (μCi/mℓ) (x 10^{-6})	Eberline Result (μCi/mℓ) (x 10^{-6})	Mean Value for all Participants In Quality Assurance Program
01/78	^{3}H	21.5	2		25.6	25.1
04/78		21.2	2		21.0	22.8
04/78		21.2			22.9	22.8
07/78		365	37		385	356
10/78		12.6	1		14.7	14.0
10/78	^{22}Na	0.90	9	0.89	0.65	0.84
01/78	^{54}Mn	1.27	4		0.6	1.42
04/78		1.04	3	0.91	1.0	1.00
10/78		0.90	3	1.01	0.8	0.94
01/78	^{60}Co	3.92	39		3.0	4.4
04/78		3.79	38	4.5	4.3	4.1
07/78		0.24	2		0.28	0.24
10/78		0.90	9	0.84	0.70	0.85

TABLE 2

Results of On-Site Water Sample Analyses

Collection Point	Number of Samples Collected	Tritium Concentration C (μCi/mℓ)*			Percentage of Relevant Standard
		C max	C min	C mean	
MF4 Sump	2	2.2×10^{-5}	1.6×10^{-5}	1.9×10^{-5}	0.6
MF5 Sump	6	2.2×10^{-3}†	8.0×10^{-6}	3.9×10^{-4}	13.0
MF6 Sump	1	3.0×10^{-6}	3.0×10^{-6}	3.0×10^{-6}	0.1
N1 Sump	7	7.0×10^{-5}	5.0×10^{-6}	2.8×10^{-5}	0.9
N2 Sump	16	1.5×10^{-4}	1.0×10^{-5}	3.9×10^{-5}	1.3
N2B Sump	3	2.5×10^{-5}	1.0×10^{-5}	1.7×10^{-5}	0.6
PC1 Sump	3	2.2×10^{-5}	1.0×10^{-5}	1.6×10^{-5}	0.5
PC2 Sump	3	7.6×10^{-5}	$< 3 \times 10^{-6}$	3.0×10^{-5}	1.0
PE4 Sump	6	9.4×10^{-5}†	$< 3 \times 10^{-6}$	2.2×10^{-5}	0.7
PW1 Sump	2	3.0×10^{-6}	3.0×10^{-6}	3.0×10^{-6}	0.1
PW9 Sump	1	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	1.7

*C max is the highest concentration detected in any sample from that location and C min is the lowest. C mean is the average for all samples from one location.

†Measured during a one-day release in July when water was going to Casey's Pond.

The release occurred at less than 0.3 percent of the Concentration Guide (Section 4 below) and made a negligible contribution to the potential off-site dose. A leak in the Meson Area Target Box closed loop on July 17, 1978, coupled with a failure to replace the plug in the retention pit following a test, resulted in a tritium concentration of 2.2×10^{-3} μCi/mℓ in the MF5 sump discharge (Fig. 4). Water was flowing into Casey's Pond at the time and no off-site release occurred. Tritium concentration in the ditch at the discharge point was less than the Concentration Guide of 1×10^{-3} μCi/mℓ for surface waters (Section 4).

Eberline Instrument Corporation reported tritium levels above the detection limit of 3×10^{-6} μCi/mℓ for one sample from the well at Site 20 (W20 in Fig. 3) and one sample from our deep well (W4 in Fig. 3). For the well at Site 20 the concentration was 4×10^{-6} μCi/mℓ and for the deep well it was 9×10^{-6} μCi/mℓ . The analyses were repeated and the tritium in each sample was below the detection limit. The Environmental Protection Agency (EPA) limit for community water systems is 2×10^{-5} μCi/mℓ for tritium (Section 4).

3.3.1.2 Beryllium

Concurrent with the production of ^{3}H with 12 year half-life is the production of ^{7}Be with 53 day half-life in the closed cooling water systems. The ^{7}Be is chemically active and is easily removed from the water by the resins used to maintain water purity. These resins are regenerated at two locations on site (Central Utilities Building and B0 Water Treatment Plant, Fig. 3) and the discharge containing ^{7}Be is released into the soil in perforated pipe fields six feet below the surface inside the main accelerator. The short half-life of the ^{7}Be and its strong chemical affinity with the soil ensure that the release will place no burden on the environment. Sampling, where some of the effluent discharged into the perforated pipe field is surfacing, has yielded only small amounts of ^{7}Be and none has been detected in nearby wells.

There continued to be some surfacing of this water containing ^{7}Be in both perforated pipe fields during CY-1978 (Fig. 3). At B0 the surfacing occurs at the entrance to the field. There the concentration of ^{7}Be in the silt was only 6 pCi/g in CY-1978. The surfacing near the beginning of the CUB perforated pipe field became worse in CY-1978. The peak concentration of ^{7}Be rose to 350 pCi/g from only 1 pCi/g in CY-1977. In addition, ^{54}Mn, ^{60}Co, and ^{172}Hf were detected in peak concentrations of 5, 3, and 77 pCi/g,

respectively. The ^{60}CO and ^{172}Hf originated from regeneration of resins contaminated with tungsten spallation products.[4] The remaining 20 resin tanks have been disposed of in an off-site licensed radioactive waste burial ground.

In September 1978 clay pipe was laid in limestone and covered with soil in the CUB field to replace the deteriorated perforated metal pipe. This change should increase the capacity of the field and thus, reduce the potential for surfacing of radionuclides.

The B0 Water Treatment Plant is being moved to the Central Utilities Building to allow future use of the B0 area for colliding beam experiments. The move should be completed by May 1, 1979. The new arrangement includes a 15,000ℓ (4000 gal) settling tank for removing copper from the regeneration effluent. Since the concentration of ^{7}Be is a maximum at the same time the copper appears in the discharge, most of the ^{7}Be should be removed with the copper.

A silt sample taken at the discharge of a sump in the Switchyard (T2 in Fig. 3) gave a ^{7}Be concentration of 7 pCi/g. Traces of ^{22}Na, ^{54}Mn, and ^{60}Co were also found. This sump is located in Enclosure B, an enclosure containing components for splitting the proton beam and sending portions to the Meson and Proton Areas, in addition to the Neutrino Area (Fig. 6). At times the pumping

frequency of the sump pump is high enough to bring short half-life radionuclides such as ^{15}O and ^{11}C (two and 20 minute half-life, respectively) to the surface. These radionuclides are easily detected with a radiation survey meter (typically approximately 0.3 mrem/hr at 5 cm (2 in) from the water).

Silt samples taken in our three creeks near the site boundary and at the effluent release point and three downstream locations for the Central Laboratory Sewage Treatment Plant showed no ^{7}Be or other radionuclides. The purpose of the samples associated with the sewage treatment plant was to verify that no radionuclides were being released into the sewage treatment plant. Water samples were also taken and showed no accelerator produced radionuclides above the detection limits for surface waters. No radionuclides were expected since the sewage treatment plant system is separate from the ditches which receive low levels of radionuclides.

3.3.2 Vegetation Sampling

In CY-1978 a vegetation sampling program was initiated. Samples were taken at the points where surfacing of radionuclides has been occurring in the Main Ring perforated pipe fields, and around the two exhaust fan stacks where large volumes of radioactive gas have been vented in the Neutrino Area (N1 in Fig. 3). In addition, samples were taken in the

sump discharge path near the Neutrino Target Hall (also N1 in Fig. 3). This sump collects water from under the primary target impervious membrane (bathtub). The silt in the sump discharge area has reached a peak ^{7}Be concentration of 54 pCi/g and a peak ^{54}Mn concentration of 32 pCi/g. The strong affinity of ^{7}Be for soils makes it also unlikely that the activity seen is from leaching of soil. The radionuclide from leaching of soil we would expect to be picked up[12] by silt is ^{22}Na. This was present but with a peak concentration of less than 1 pCi/g. Thus, it is likely that the contamination resulted from radioactivity which entered the sump directly, from operations in the Target Hall rather than from the underdrains. A cover has been placed over the sump to reduce the potential for such an occurrence in the future.

The results of the vegetation sampling are given in Table 3. The peak concentrations given are based on the weight of the unprocessed sample. The samples were scrubbed to remove surface contamination. The samples (mostly crownvetch, Coronilla varia) from the vicinity of the stacks had collected only surface contamination (^{7}Be) while the sample from the sump discharge area (cattails, Typha sp.) indicated that activity (^{54}Mn) had been incorporated into the plants.

TABLE 3

Vegetation Sampling Results

Location	Radionuclide	Peak Concentration (pCi/g) Uptake	Surface Contamination
N1 Sump Discharge Area	^{54}Mn	96	0
N1 Spur Track Stack	^{7}Be	0	50
N1 Labyrinth Stack	^{7}Be	0	30
B0 Perforated Pipe Field	None	0	0
CUB Perforated Pipe Field	None	0	0

3.3.3 Soil Activation

Since the percolation rates for water in Fermilab soils are calculated to be very low - less than 1 m (3 ft) per year[15] - analyses of well waters do not provide the early warning desired for detection of accelerator-produced radioactivity in the ground water.* To provide such a warning we have taken soil samples from the vicinity of targets

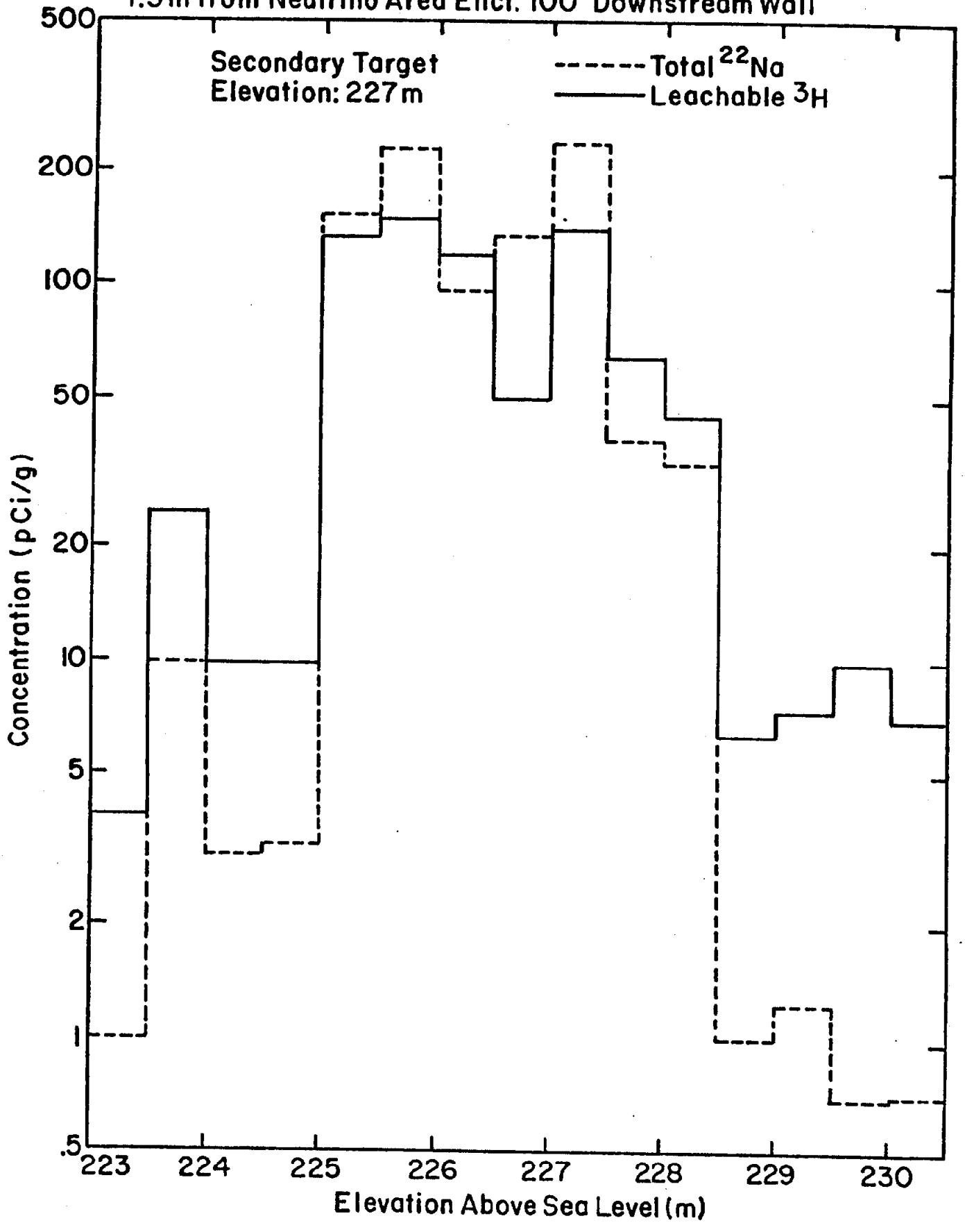
*Measurements were made at former AEC Site A's burial ground (called Plot M) 40 km (25 mi) from Fermilab where the soil is similar to that at Fermilab. Some tritium was found in the aquifer, giving a lower limit of 1.2 m (4 ft) per year for the velocity. Most of the tritium was found at shallower depths, which probably corresponds to a slower movement of around 0.6 m (2 ft) per year.[16]

and other locations where proton interactions result in some radioactivation of the soil. Many radionuclides were detected but since the major long-lived ones leachable from Fermilab soils were ^{3}H and ^{22}Na, quantitative measurements were made only on those.[12] The results have been presented elsewhere.[4,17]

In CY-1978 soil borings were made near Neutrino Area Enclosure 100. Samples were taken 1.5 m (5 ft) downstream (in the direction of motion of the protons) from the north wall of the enclosure. The hole was bored 12.6 m (41.5 ft) from the top of the earth-shielding berm to an elevation 223 m (732.5 ft) above sea level. This depth was 3.8 m (12.5 ft) below the proton beam. Continuous sampling occurred the last 7 m (23 ft). The samples were analyzed for leachable ^{3}H and total ^{22}Na with the results shown in Fig. 6. The measurements of total ^{22}Na were done at Fermilab. The leaching and ^{3}H analyses were done by Eberline Instrument Corporation. The pattern is similar to that found in holes bored at 0.6 m and 2.7 m from the wall in late 1974; however the new boring hole was drilled deeper and many more samples were analyzed.[17]

The basic patterns for total ^{22}Na and leachable ^{3}H are similar. Since the percentage of ^{22}Na leachable is at most about 20 percent from Fermilab soils,[12] the total ^{22}Na measurement gives a good indication of soil activation. Comparing the ^{3}H distribution and concentration with the ^{22}Na distribution and concentrations reveals any natural leaching and movement of ^{3}H from where it was produced. If one assumes that ^{22}Na and ^{3}H are produced in the same ratio everywhere, then the figure indicates a movement of ^{3}H both upward and downward from where it was produced - a diffusion rather than a leaching. There is no evidence that a large fraction of the leachable ^{3}H has been removed from the activation region.

Figure 6. Soil Activation Measurements
1.5 m from Neutrino Area Encl. 100 Downstream Wall



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3.4 Nonradioactive Pollutants

3.4.1 Water Utilization

The domestic water supply at Fermilab is provided essentially by two wells approximately 70 m (220 ft) deep. One (W1 in Fig. 3) is located in the Central Laboratory Area and the other (V in Fig. 3) is in the Village. In cases of low pressure, a third 70 m (220 ft) deep well (near W4 in Fig. 3) is used to supply the additional water in the Central Laboratory Area. The average use from these three wells is approximately 816,000 ℓ/day (216,000 gal/day).

3.4.2 Test for Pollutants in Water Leaving the Site

Our water laboratory tests the quality of water leaving the site by sampling each of the three creeks. Measurement of pH, DO (dissolved oxygen) BOD5 (biochemical oxygen demand for 5 days) and suspended solids are made semi-annually while coliform tests are conducted monthly. These test results are included in Table 4 and sampling locations are shown in Fig. 3 (R1, R2A, R3).

Authorization permits to discharge under the National Pollutant Discharge Elimination System (NPDES) have been obtained for both sewage plants.

The Central Laboratory sewage plant exceeded its maximum limits during two periods for BOD5 (limit 10 mg/ℓ) and suspended solids (limit 12 mg/ℓ). The first excursion resulted from extremely excessive flow of rain water into the system making it necessary to bypass a portion of the sewage to

TABLE 4

SITE WIDE WATER QUALITY REPORT FOR CY-1978

	pH	DO mg/ℓ	BOD5 mg/ℓ	Susp. Solids mg/ℓ	Chlorine Residual mg/ℓ	Fecal Coliform # per 100 mℓ
Ferry Creek	Max. 8.5 Ave. 8.3 Min. 8.1	9.0 8.8 8.5	7.0 6.6 6.2	49 39 29		112 24 0
Indian Creek	Max. 7.7 Ave. 7.6 Min. 7.5	8.1 8.0 7.8	2.6 2.6 2.6	11 9.5 8		210 76 0
Kress Creek	Max. 7.7 Ave. 7.6 Min. 7.6	8.9 8.8 8.8	3.8 2.6 1.4	24 15 7		342 142 33
Main Ring	Max. 8.6 Ave. 8.5 Min. 8.3					4 2 0
Central Lab. Sewage	Max. 8.0 Ave. 7.6 Min. 7.3	12.0 7.8 5.8	72(1) 3.5 .57	59(2) 2.1 0	.75 .60 .20	20 2 0
Village Sewage Lagoon	Max. 9.2 Ave. 8.2 Min. 7.9	15.0 9.7 4.3	23.0 3.7 .7	51(3) 8 1	.75 .56 .20	1 .09 0

(1) During non-compliance, March, 1978.

(2) During non-compliance, March, 1978.

(3) During non-compliance, April, 1978.

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prevent flooding of the plant. This bypassed sewage overwhelmed the diversion dam intended to cycle effluent into the main ring pond system,[4] allowing some untreated sewage into Indian Creek near the RF building. To prevent a recurrence, more than 550,000 ℓ (144,000 gal) of untreated sewage was trucked from the Central Laboratory Plant to the Village system over eight days. Plant Management personnel inspected 55 manholes for infiltration and chemical grouting of 11 was accomplished by a subcontractor. Infiltration has been reduced. The second excursion resulted from a petroleum loading from an unknown source which produced a severe kill of bacteria. It again was necessary to haul liquid to the Village system until the plant had recovered. Negotiations have been completed with the City of Batavia to hook up the main site sewage system to their municipal treatment plant. The existing Central Laboratory Plant will be put on standby and the problems associated with this small plant will be eliminated. This construction contract has been signed and the work should be accomplished in 1979.

The Village system exceeded its maximum limit for suspended solids once during CY-1978 due to an unusual algae growth which occurred under the ice. Holes were cut in the ice, the oxidation pond was treated with aquazine, and the system recovered.

3.4.3 Chemical Treatment of Water Systems

Some chemical treatment of our various water systems was necessary to control algae and weed growth during CY-1978.

3.4.3.1 Copper Sulfate and Diquat

Copper sulfate and Diquat were used in the Main Ring ponds and C4 Pond (H6 in Fig. 3) for algae and weed control. This type of chemical treatment is used only in the Main Ring since these waters are off limits to the public and no fishing is allowed. The Illinois limit on copper in effluent is 1 mg/ℓ (Section 4) and this limit was not exceeded (Table 5). In fact, the limit for water in general use (0.02 mg/ℓ) was not exceeded.

3.4.3.2 Aquazine

The new ponding system functions as follows: Water is pumped from the Booster Pond into a ditch in which it runs by way of the small West Pond into Swan Lake. The water is then returned to the Booster Pond by a return ditch. A diversion dam in the return ditch allows control of the water level in Swan Lake, the overflow going to Indian Creek. These waters were treated with aquazine which is an acceptable pesticide per EPA registration No. 100-437, as follows: Booster Pond, 18 kg (40 lb); Swan Lake, 104 kg (229 lb), and return ditch, 4.5 kg (10 lb).

TABLE 5

Heavy Metal Analyses CY-1978

Sample Date	Sample Location	Chromium Hex. mg/ℓ	Copper mg/ℓ	Zinc mg/ℓ
Oct. 10, 1978	C4 Main Ring Pond @ H2C	< 0.01	0.007	0.008
	C4 Pond @ H6	< 0.01	< 0.001	0.007
	Casey's Pond @ H4	< 0.01	< 0.001	0.014
	Swan Lake @ H5	< 0.01	0.011	0.017
	Village Lagoon @ H3	< 0.01	0.109	0.015
	Ephemeral Lake @ H10	< 0.01	0.003	0.008
	Ephemeral Lake @ R1	< 0.01	0.001	0.011
	Lake Law @ H3	< 0.01	0.003	0.006
	Lake Law @ H9	< 0.01	0.002	0.006
	Well 1 @ Central Utilities Building	< 0.01	0.013	3.63
	Well 17	< 0.01	< 0.001	0.566
	Well 20	< 0.01	< 0.001	0.314
	Well 21	< 0.01	0.007	0.065
	Well 43	< 0.01	0.001	0.110
	Well 45	< 0.01	0.002	0.076
	Well 55	< 0.01	< 0.001	0.733
	Well 56	< 0.01	< 0.001	0.353
Oct. 26, 1978	Well 1 @ Well			0.010
Nov. 15, 1978	X-Gallery*			0.336
	Site 38*			0.061
	Lab A*			0.461
	Central Laboratory 7E*			0.257
	Reservoir @ Well 1			0.018
	Central Utilities Building*			0.527
	Well #3			0.068

*Supplied by Well 1.

In addition to the ponding system, the following were also treated with aquazine: The two reflecting ponds north of the Central Laboratory: East Pond, 10 kg (22 lb); Center Pond, 16 kg (35 lb); the Village Oxidation Pond, 68 kg (150 lb) and the Phillips Farm Pond, 3.6 kg (8 lb). The Phillips Farm Pond is a small pond approximately 150 m west of Well 38 (W38 in Fig. 3). This product manufactured by Ciba Geiger, is an acceptable pesticide per EPA registration No. 100-437.

3.4.3.3 Chromate

The success of the cooling pond system in eliminating the need for chromate compounds was demonstrated during CY-1978. Although it was necessary, during the warmer summer months, to use the cooling towers in conjunction with the ponds, it was not necessary to treat the towers and thus no chromate compounds were pumped into the Main Ring tile field.

Sampling for chromates was included in our routine testing for heavy metals and no concentrations above the detection limit were found in site surface waters as wells tested (Table 5). The wells tested were those in the vicinity of the CUB perforated pipe field where the effluent had surfaced.

3.4.3.4 Zinc

During routine analysis of various waters for heavy metals, an unusually high level of zinc was found in water from Well #1 (3.63 mg/ℓ) which normally supplies drinking water for the main site. Shortly before this sample was taken in the Central Utility Building (CUB), this portion of the system had been shutdown and water supplied from Well #3 so that repair work could be done to the water main between the CUB and Well #1. This temporarily high level must be attributed to internal corrosion and the disturbance caused by the repair work since later sampling from the same point was well within the limit of 1.0 mg/ℓ established by the State of Illinois (Section 4). See Table 5.

3.4.4 Applications of Pesticides

Few changes were made for CY-1978 in the Fermilab pest control plan.[18] A total of 9 kg (20 lb) of ABATE was used to control mosquito larvae in CY-1978 and 208 liters (55 gal) of Malathion was used for the control of adult mosquitos.

The services of an exterminator was retained during CY-1978 for the control of miscellaneous pests. This subcontractor, licensed by the State of Illinois, used small quantities of approved materials as follows: Diazinon for the control of insects, Eatons AC50, Pro Cide and Herb

Stat M7 for the control of mice and rodents in buildings not occupied by children, and Vapora roach spray.

3.4.5 Application of Herbicides

In addition to those materials used in water treatment, 378.5 liters (100 gallons) of Pramitol was used to kill weeds in parking lots and power stations.

To maintain good relationships with neighboring farmers and voluntarily comply with local weed commission requests, noxious weeds, primarily Canadian and sow thistle, have been controlled. In 1978 a total of approximately 2271 ℓ (600 gal) of 2-4D (low volatility Amine form) was used at 1% strength in water applied to approximately 9.7 km^2 (3.7 sq mi) on site.

Corn was planted on approximately 25% of the site by licensees who agreed to apply only herbicides and fertilizers on an approved list compiled for the Laboratory by an outside consultant. In addition, the rate of application and total amounts applied had to be approved before application, and these were checked at the time of application by Fermilab.

The materials applied are given in Table 6.

TABLE 6

Corn Field Applications

Herbicides	Total
Aatrex 80W (Ciba Giegy) @ 448 kg/km^2 (4 k/acre)	3425 kg (7556 lb)
Sutan Plus (Stauffer) @ 470 ℓ/km^2 (2 qt/acre)	3570 ℓ (3778 qt)
Insecticide	
Counter 15G (Am. Cyanimid) @ 1112 kg/km^2 (10 lb/acre)	8495 kg (18,890 lb

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3.5 Environmental Impact

3.5.1 Assessment of Potential Radiation Dose to the Public

Fermi National Accelerator Laboratory is located in the densely populated Chicago Area. The distribution of population in different directions from the center of the main accelerator is shown in Table 7 based on the 1970 census.[19] Note that there are about eight million people living within 80 km (50 mi) of the site. There are only about 2000 within 5 km (3 mi), but the number of people living close to the Laboratory is rapidly increasing as a result of housing construction now in progress to the east and west of the site. The dose rates at the site boundary were highest from penetrating muons, resulting in a

large contribution to the total off-site potential dose. The direction of the muons was northeast toward West Chicago where the increase has not been as rapid. The projected population for West Chicago in 1977 was 12,000 or approximately 20 percent higher than the 1970 census.[20] The population distribution obtained from the 1970 census was used to evaluate the potential exposure to the public for CY-1978 and the man-rem dose obtained using the 1970 census was increased by 20 percent to reflect the increase in population.

The radiation exposure to the general population from operation of Fermilab in CY-1978 was about 5 man-rem. Approximately 3.0 man-rem was from muons and 1.6 man-rem from airborne radioactivity (^{11}C). The exposures are given in detail in Table 7.

The exposure from muons was determined by starting with the dose to an individual at the site boundary and calculating dose versus distance from the point on site where the penetrating radiation (Section 3.1) originated to 80 km (50 miles) from the site using the inverse square of the distance and summing over the appropriate numbers of individuals from Table 8. The region that was considered contained approximately 100,000 people.

The exposure from airborne releases was calculated starting with the 0.7 mrem per year dose rate at the site boundary obtained using the Gaussian plume diffusion model and determining dose versus distances out to 80 km (50 mi) from the site including ^{11}C decay. Since most of the exposure occurred within 16 km (10 mi) from the site, the result based on the 1970 census was increased by 35 percent to reflect the growth in this region since 1970.[20]

Several of the closed loop cooling systems are reaching levels where off-site releases, from these loops, should they occur, would be detectable but not hazardous. Some off-site release of radioactive water occurred while Casey's Pond (H4 in Fig. 3) the reservoir receiving water from discharges in the three external areas to which protons are delivered was full. The mean concentration of tritium during the period of release was less than one percent of the Concentration Guide for uncontrolled areas. Also, drinking water in the area is taken from wells rather than from the creek receiving the discharge. Hence, the dose from the release is expected to be neglibible.

Table 7

Summary of Population Exposures for CY-1978

Source	Contribution to Population Exposures (man-rem)
Penetrating Muons From Neutrino Area	3.0
Airborne Radioactivity From Neutrino Area	1.6
Gamma Rays From Boneyard	0.01
Gamma Rays From Lab 7*	0.03
Total	4.6

*On-site exposure to individual members of the general population assuming 24 hour per day occupancy.

A trace amount of tritium reported in two of 47 samples of water from on-site wells pumped in CY-1978. The tritium concentration reported for one of these wells (W20 in Fig. 3) was 4.4×10^{-6} μCi/mℓ. Our detection limit is 3×10^{-6} μCi/mℓ (Section 4). The well at Site 20 is near the sectors of the main ring where the proton beam is accelerated and extracted. However, the amount of soil activation at that point would not lead us to expect any tritium in the well water. The analysis was repeated on that sample and no tritium was found. The other sample was from our deep well (W4 in Fig. 3). The tritium concentration reported was 9×10^{-6} μCi/mℓ.

Table 8

INCREMENTAL POPULATION DATA IN VICINTY OF FERMILAB, 1970

DISTANCE, KILOMETERS FROM CENTER OF MAIN RING DISTANCE, MILES / DIRECTION	0-3.2 0-2	3.2-5 2-3	5-6.4 3-4	6.4-8 4-5	8-16 5-10	16-32 10-20	32-48 20-30	48-64 30-40	64-80 40-50	80-97 50-60	97-113 60-70
N	97	0	0	73	607	72549	59787	48373	28900	29156	25212
NNE	0	0	2306	1338	3728	75631	77070	108837	131661	102076	129086
NE	0	0	2692	4815	10321	63960	306836	123882	0	0	0
ENE	23	0	1587	20	44882	211107	864920	649681	0	0	0
E	0	0	0	0	11567	185533	1144118	1061396	0	0	13634
ESE	0	0	1998	2403	11764	74815	304494	629984	385309	193880	59602
SE	0	0	1657	0	22797	30689	39084	106622	30481	25141	10666
SSE	0	33	0	0	0	29540	124447	4559	15496	67239	11479
S	0	316	0	0	1338	4201	9058	10815	10829	8939	3087
SSW	0	45	1326	7579	44014	5063	1470	13488	6673	26103	15946
SW	0	0	3053	1009	34667	10155	14275	4543	27436	37847	10946
WSW	0	0	1671	3172	1733	4569	6054	5271	10716	6700	12863
W	0	0	3732	0	0	4059	2320	4039	11657	8043	29325
WNW	0	1143	5987	55	184	3109	48301	4087	11213	44197	11807
NW	69	0	890	3585	7003	1232	7547	3978	46860	165281	68082
NNW	0	0	362	3353	14633	20243	7256	23393	10634	28732	10542
TOTAL	189	1537	27261	27402	209288	796455	3017047	2802948	728965	743334	412277
CUMULATIVE TOTAL	189	1726	28987	56389	265677	1062132	4079179	6882127	7611092	8354426	8766703

Repeated analyses gave irreproducible results. One result was 0.8×10^{-6} μCi/mℓ. Something besides tritium, perhaps an impurity in the acid used to treat the sample, was producing the scintillation first ascribed to tritium.

Thus, the potential radiation dose to the public from the operation of Fermilab in CY-1978 remained small.

3.5.2 Evaluation of Nonradioactive Pollutant Releases

Although it was necessary to chemically treat some waters to control the growth of algae and weeds during CY-1978, these treatments have been kept as low as possible in order to protect wildlife and fish. These levels, well within guidelines established by the State of Illinois, could have had no deleterious effects on off-site waters. Further, sampling the waters leaving the site confirmed that no Laboratory activity affected those waters in any way that might harm the off-site environment (Tables 5 and 6).

The new ponding system (Section 3.4.3.3) has been successful in eliminating the need for chromate treatment and subsequent disposal.

There was one release of a nonradioactive pollutant during CY-1978. On May 13, 1978, an unknown quantity of an unidentified petroleum product killed a portion of the bacteria in the Central Laboratory sewage plant. The source of this petroleum product was never determined. It was

necessary to haul raw sewage to the Village Sewage Lagoon until the plant recovered two weeks later. There was little or no environmental impact.

There were no activities during CY-1978 which created problems with respect to nonradioactive airborne effluents. Heating is accomplished by use of natural gas, liquified propane gas, or electricity. The bulk of the heating is supplied by natural gas fired boilers located in the Central Utilities Building. The effluents from these boilers are analyzed annually to maintain proper combustion efficienty.

3.5.3 Potential Impact of Other Toxic Substances

Passage of the Toxic Substances Control Act mandates the control of substances which might be harmful to the environment.[21] A program was initiated during CY-1978 to identify materials used at the Laboratory which might be harmful and to evaluate their impact. Of particular concern are polychlorinated biphenyls (PCB's) used in some large transformers and large capacitors. Those objects containing more than 500 parts per million (ppm) must be labeled, records must be maintained and great care taken to prevent spills. Spill control curbing has been installed around all those transformers in service which are filled with PCB insulating liquids.

Disposal of PCB materials is governed by strict EPA regulation. A unique problem exists with respect to a number of capacitors removed from service in the Booster. These capacitors are slightly radioactive as well as containing PCB's, and are being stored until an approved disposal method is available.

4. References

The Concentration Guides used in the analyses of the water samples for radioactivity were taken from the DOE Manua, Chapter 0524, Annex A, Table II, Column 2 (Water in Uncontrolled Areas) and reduced by a factor of three where appropriate for a suitable sample of exposed population. The smaller of the values given for soluble and insoluble forms has been used in each case. The specifications are given in Table 9. The Concentration Guides for airborne activity were taken from the same source, Table II, Column 1 (Concentrations in Air in Uncontrolled Areas), and divided by a factor of three for determining the total off-site potential dose to the public. For tritium the Concentration Guide from Table II, Column 1, is 2×10^{-7} μCi/mℓ. For ^{11}C the Concentration Guide, 2×10^{-8} μCi/mℓ, was taken from the calculation by Yamaguchi.[11]

Table 9

SPECIFICATIONS FOR THE ANALYSES

OF RADIONUCLIDES IN WATER

RADIONUCLIDE	CONCENTRATION GUIDE FOR POPULATION Individual (μCi/mℓ)	Suitable Sample (μCi/mℓ)	Community Water System	SPECIFIED* SENSITIVITY (μCi/ml)	SPECIFIED* PRECISION (μCi/ml)
^{3}H	3×10^{-3}	1×10^{-3}	2×10^{-5}	3×10^{-6}	3×10^{-6}
^{7}Be	2×10^{-3}	6.7×10^{-4}	1.3×10^{-5}	5×10^{-7}	5×10^{-7}
^{22}Na	3×10^{-5}	1×10^{-5}	2×10^{-7}	3×10^{-7}	3×10^{-7}
^{45}Ca	9×10^{-6}	3×10^{-6}	6×10^{-8}	3×10^{-7}	3×10^{-7}
^{54}Mn	1×10^{-4}	3.3×10^{-5}	6.7×10^{-7}	5×10^{-8}	5×10^{-8}
^{60}Co	3×10^{-5}	1×10^{-5}	2×10^{-7}	1×10^{-7}	1×10^{-7}

* The precision and sensitivity are stated for the 68% confidence level (one standard deviation). The precision required is the value specified or ± 10 per cent, whichever is the lesser precision. The sensitivity is taken to be the minimum concentration which can be detected within the 68 per cent confidence level. The detection limit for ^{3}H is lower than the specified sensitivity; however, the specified sensitivity is still only 0.3 per cent of the lower Concentration Guide, and the number of spurious detections of ^{3}H is reduced. Note that for ^{22}Na and ^{45}Ca the present specified sensitivity is higher than the Concentration Guide for community water systems. All sensitivity and precision requirements were lowered for our one community water system, our Village well (V in Fig. 3), in CY-1978 and will be lowered for all ground water samples in CY-1979.

It has been pointed out by P. Gollon that this Concentration Guide has been incorrectly reported in previous Fermilab environmental monitoring reports.[22] In fact, although this value was not the one used in determining dose rate, the exposure has been incorrectly reported, as well. For CY-1977 the population exposure due to airborne radioactivity should have been 2.0 man-rem rather than the 0.5 man-rem reported. The confusion resulted from the difference between ^{11}C exposure inside and outside an enclosure. For ^{11}C produced and remaining inside a typical Fermilab enclosure the Concentration Guide is higher because there are no gamma-rays coming from long distances, i.e., from outside of the enclosure. For ^{11}C in the atmosphere the annihilation gamma rays coming from long distances in the plume contribute significantly to the dose reducing the Concentration Guide for the general population.

The appropriate Radiation Protection Standard for penetrating radiation applied to individuals in uncontrolled areas was taken from the DOE Manual, Chapter 0524, Paragraph II.A. The annual dose for whole-body exposure is 0.5 rem when applied to a suitable sample of the exposed population.

The Water Pollution Standards for nonradioactive pollutants were taken from Chapters 2 and 3 of the State of Illinois Pollution Control Board Rules and Regulations. The waters on site were considered to be in the "general use" category. The values for total hexavalent chromium for general water quality is 0.05 mg/ℓ. The Standards for total copper at the discharge point and for general water quality are 1.0 and 0.02 mg/ℓ respectively, and for zinc are both 1.0 mg/ℓ for surface water and for well water. The Air Quality Standards limit the releases of SO_2 oxides of nitrogen to 816 g (1.8 lbs) and 136 g (0.3 lbs) respectively, per 252 million calories (per million btu's) of actual heat input in any one hour.

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