Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

Fermilab 89/63
1104.100
UC-41

Site Environmental Report

For Calendar Year 1988

May 1, 1989

Samuel I. Baker

Operated by Universities Research Association, Inc.
Under Contract with the United States Department of Energy,
Chicago Operations Office, Batavia Area Office

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by
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Laboratory Work and Measurements
by
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1. Introduction

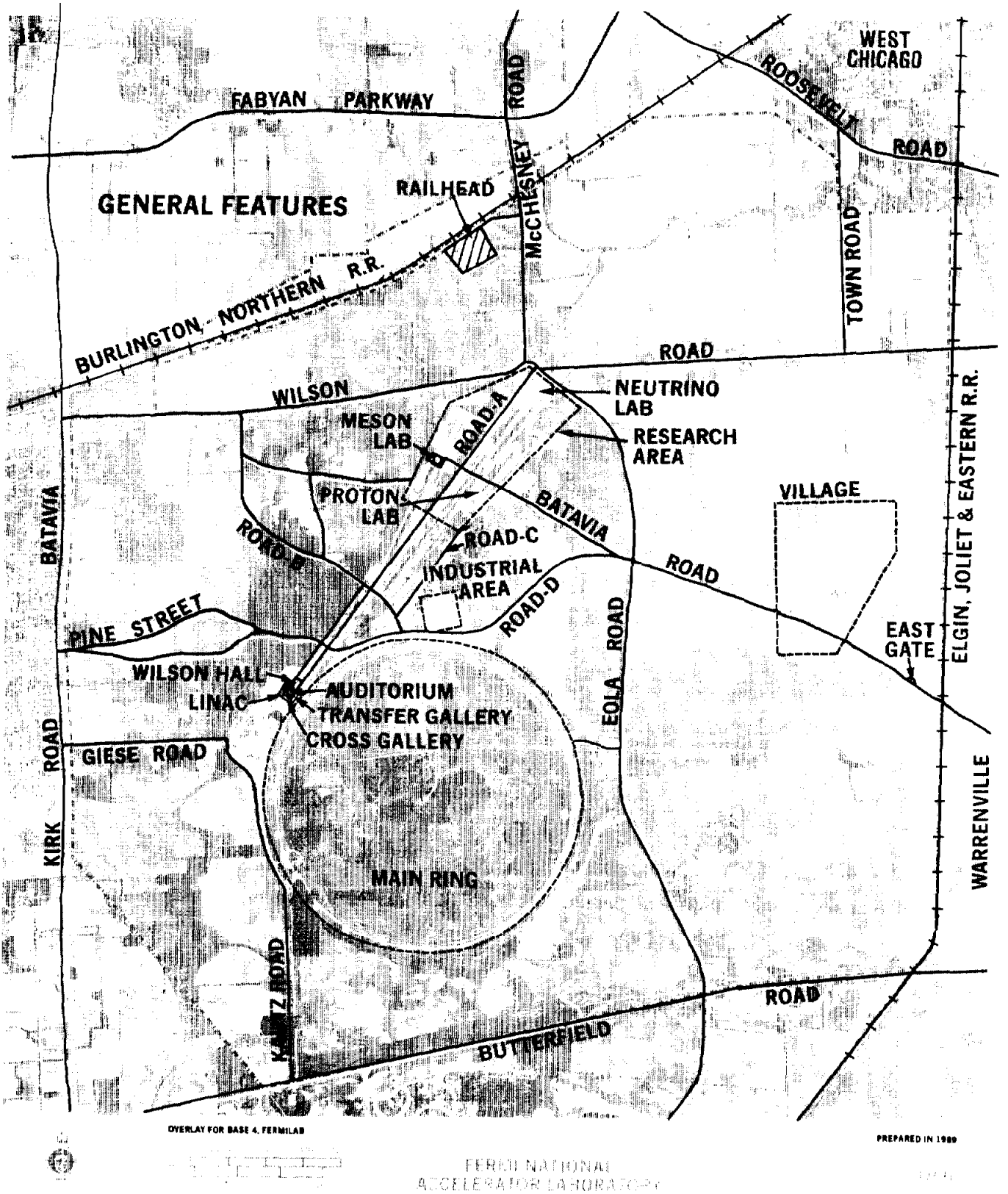
This report summarizes the environmental activities and their results at Fermi National Accelerator Laboratory (Fermilab) for Calendar Year (CY-) 1988.

The facility consists of a series of proton accelerators which became operational in 1972, producing higher energy protons than any other accelerator. As a result of accelerator improvements, the original design energy of 200 GeV (billion electron volts) was gradually raised and operation at 400 GeV was routine between 1976 and 1982 using conventional magnets. Then a ring of superconducting magnets was added which doubled the energy while using less electrical power.

The primary purpose of the installation is fundamental research in high-energy physics. Up to 1986 this research was performed by extracting protons from the final accelerator (now a synchrotron using superconducting magnets). These protons were directed onto fixed targets after being extracted from the superconducting synchrotron called the TEVATRON. Colliding beam studies, collisions of protons and antiprotons each having 900 GeV, were conducted for the first time in 1987. These collisions were detected at four locations inside the TEVATRON. In addition, cancer patients are being treated using neutrons released by the interactions of 66 MeV protons from the Linac (linear accelerator), the second stage of the series of accelerators.

When the proton beam is extracted for fixed target physics from the 2 km (1.2 mi) diameter main accelerator, the protons are delivered to three different experimental areas on-site. These are the Meson, Neutrino and Proton Labs located in the Research Area (Fig. 1). These three areas received proton beams for the first time in 1972 when extraction of protons from the accelerator was achieved. For colliding beam studies, antiprotons are produced by extracting 120 GeV protons from the ring of conventional magnets inside the main accelerator tunnel. These protons strike a fixed target and the negatively charged antiprotons are collected. Radioactivity is produced as a result of the interaction of the accelerated protons with matter. Operation of the accelerator produces some airborne radioactivity as well as some radiation which penetrates the shielding material. Also, some radioactivation occurs in the water used to

Figure 1


GENERAL FEATURES
FABYAN PARKWAY
RAILHEAD
McCHESNEY ROAD
WEST CHICAGO
ROOSEVELT ROAD
TOWN ROAD
BURLINGTON NORTHERN R.R.
ROAD
WILSON
NEUTRINO LAB
MESON LAB
ROAD-A
RESEARCH AREA
PROTON LAB
BATAVIA ROAD
VILLAGE
ROAD-B
ROAD-C
INDUSTRIAL AREA
ROAD
ROAD-D
EOLA ROAD
PINE STREET
EAST GATE
ELGIN, JOLIET & EASTERN R.R.
WILSON HALL
LINAC
AUDITORIUM
TRANSFER GALLERY
CROSS GALLERY
GIESE ROAD
KIRK ROAD
MAIN RING
WARRENVILLE
KAUTZ ROAD
ROAD
BUTTERFIELD
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1989
FERMI NATIONAL ACCELERATOR LABORATORY

cool beam components and in the soil around the accelerator tunnel and external beam lines. A thorough evaluation has been made of the on-site discharges as well as the potential for off-site releases of radioactive and nonradioactive effluents. An extensive monitoring program is being carried out to verify that radiation exposures as well as nonradioactive releases are far below the permissible limits.

Fermilab is located in the greater Chicago area (Fig. 2) on a 27.5 km^2 (10.6 mi^2) 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 increasing population concentration eastward toward Chicago (Fig. 3). Within a 3 km (2 mi) distance from the Laboratory boundaries, Batavia (pop. 14,651),[1] Warrenville (pop. 9,852),[2] and West Chicago (pop. 14,412)[2] can be found (Fig. 2).

The two major environmental features near the Laboratory are the Fox River to the west, and the west branch of the DuPage River which passes east of the site. The Fox River flows south through Batavia with an average of 2236 million liters (591 million gallons) per day from October 1, 1987 through September 30, 1988. The west branch of the DuPage River flows south with an average of 207 million liters (55 million gallons) per day for the same period through Warrenville (Fig. 2).[3] The rainfall on-site during 1988 was 80 cm (31.3 in).[4] The land on the site is relatively flat as a result of past glacial action. The highest area, with an elevation of 244 m (800 ft) above mean sea level (MSL) is near the western boundary. The lowest point, with an elevation of 218 m (715 ft) above MSL is toward the southeast. The drainage of the groundwater 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 360 m (1200 ft) deep into the Cambrian/Ordovician aquifer system.[5] Also, there are many individual private wells drilled into the shallow silurian aquifer system around 30 m (100 ft) below the surface.

The primary source of drinking water on the Fermilab site the shallow Silurian dolomite aquifer.[5] Wells 1 and 3 (Fig. 4) are the main wells and collect water from 20 to 70 m (65 to 220 ft) below the surface. Water for the

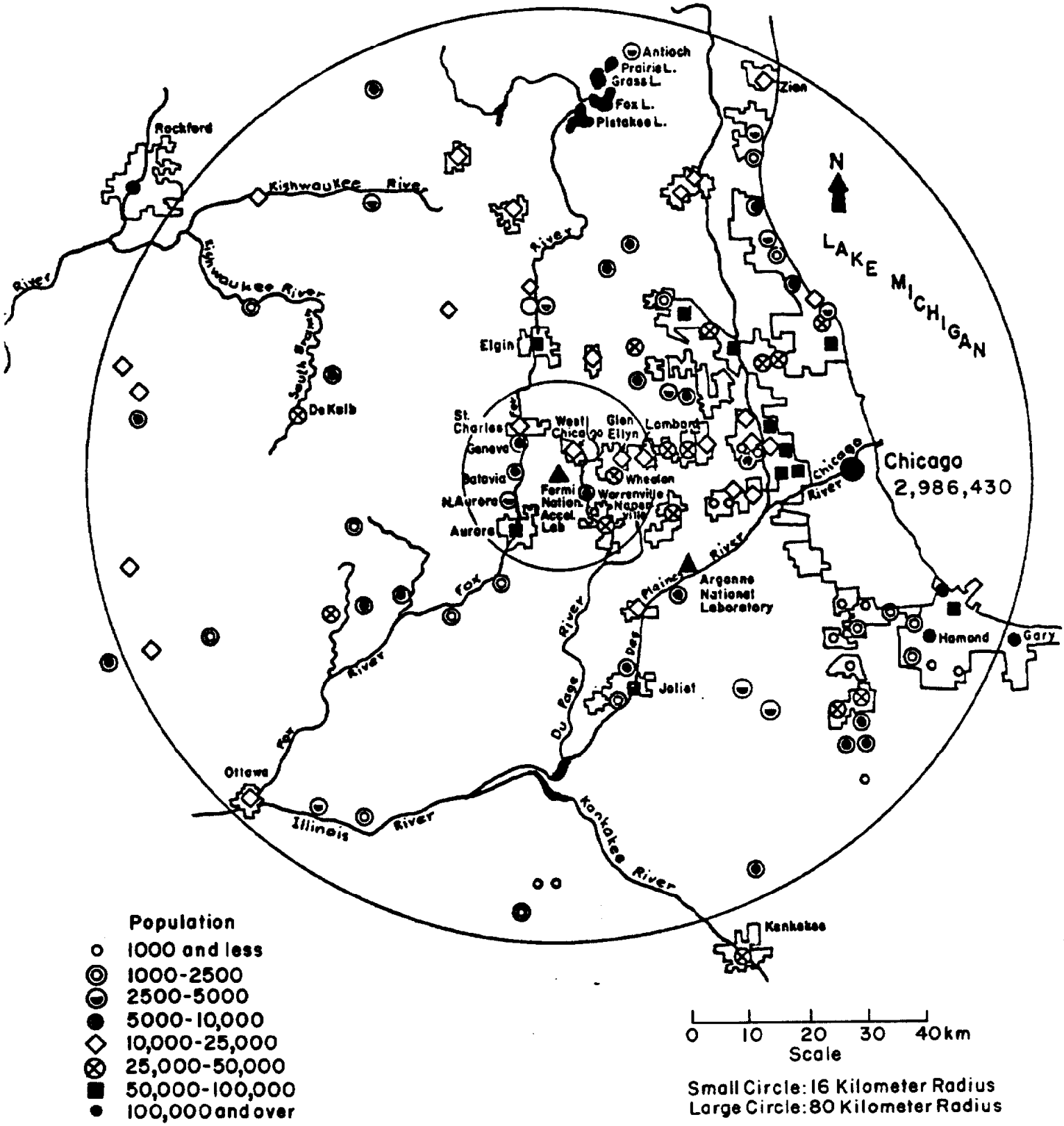
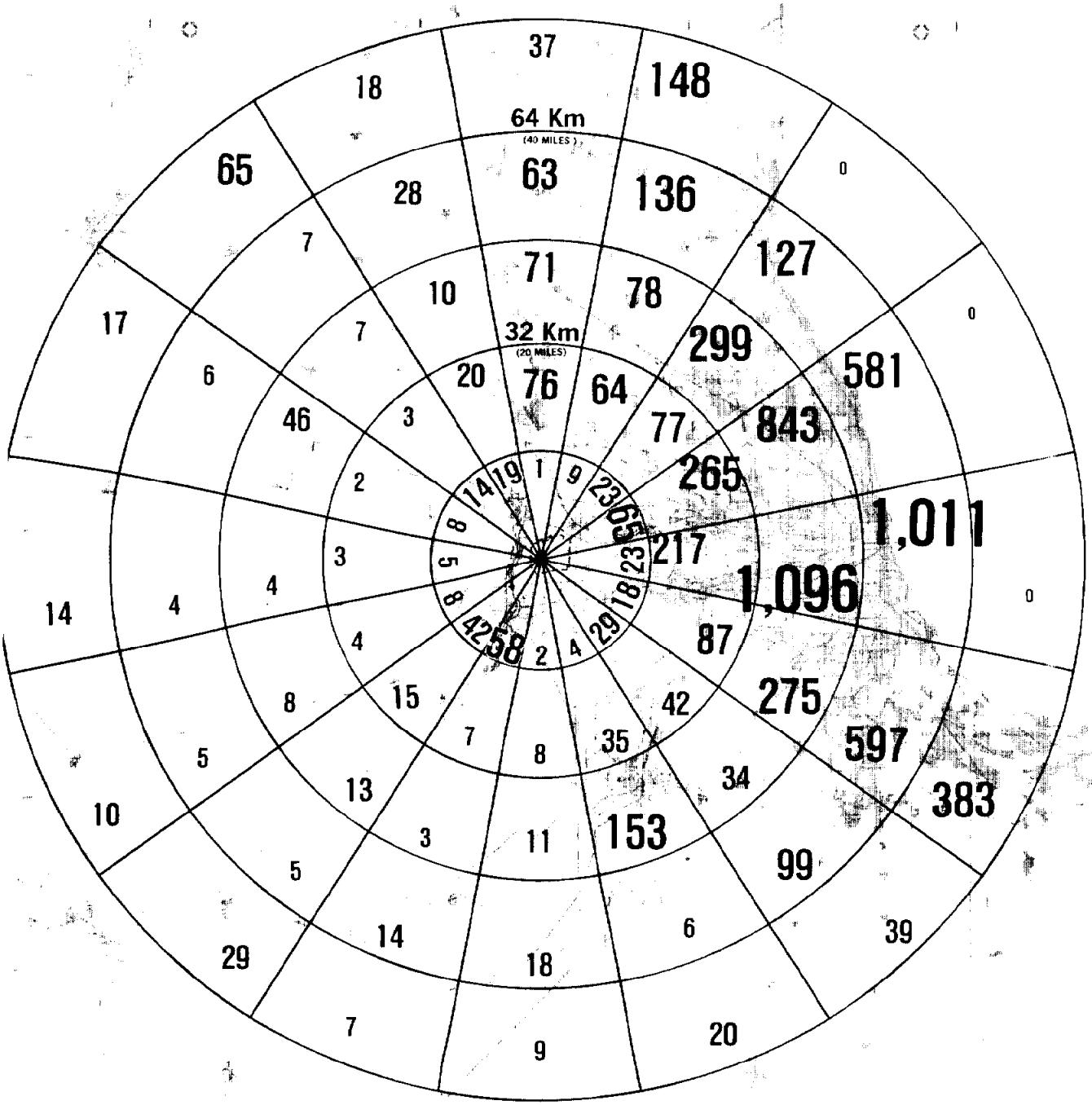


Figure 2 - Location of Fermilab and Population Concentrations within 80 km (50 mi.)

1988

Figure 3



NOTE: NUMBERS REPRESENT NEAREST 1000.

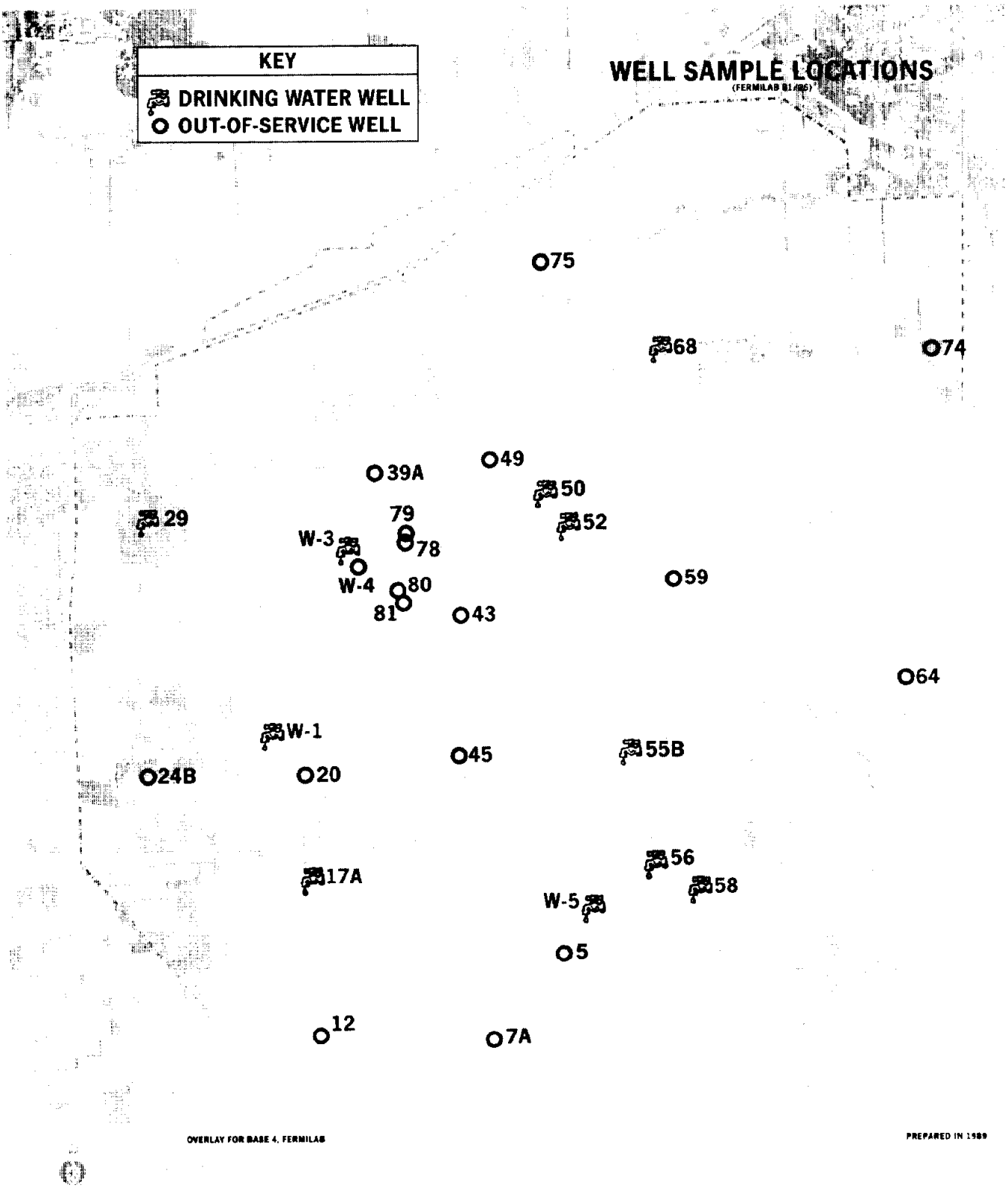
POPULATION DISTRIBUTION - 1980
(1980 CENSUS)

OVERLAY FOR BASE 1, FERMILAB

REGIONAL AREA SURROUNDING FERMI NATIONAL ACCELERATOR LABORATORY

PREPARED IN 1982
DOE

Figure 4


KEY
DRINKING WATER WELL
OUT-OF-SERVICE WELL
WELL SAMPLE LOCATIONS
(FERMILAB 81486)
75
68
74
49
39A
50
29
79
52
W-3
78
59
W-4
80
81
43
64
W-1
45
55B
24B
20
56
17A
58
W-5
5
12
7A
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1989

Village (Fig. 1) was obtained from Warrenville to the east beginning in January 1987 and service from Well 62 in the Village (Fig. 5) was terminated at that time. A new well (W-5 in Fig. 4) went into service the end of November 1988, supplying drinking water to the new colliding beam facility under construction at D0. The rainfall collected in ponds on the site are used for cooling the accelerator and some experimental area facilities through heat exchangers. The surface cooling water supply is augmented as necessary by pumping water from the nearby Fox River.

The land within the site boundary was primarily farm land before the State of Illinois acquired it for the DOE Fermilab site although the small village of Weston (population 380 at that time) was located on the eastern side (Fig. 1). Much of the land, approximately 9.3 km^2 (2300 acres), has remained in crop production, primarily corn. A total of 2.26 km^2 (559 acres) has been planted in native prairie vegetation to date. The village of Weston has provided residences for visiting scientists as well as support facilities for the research program.

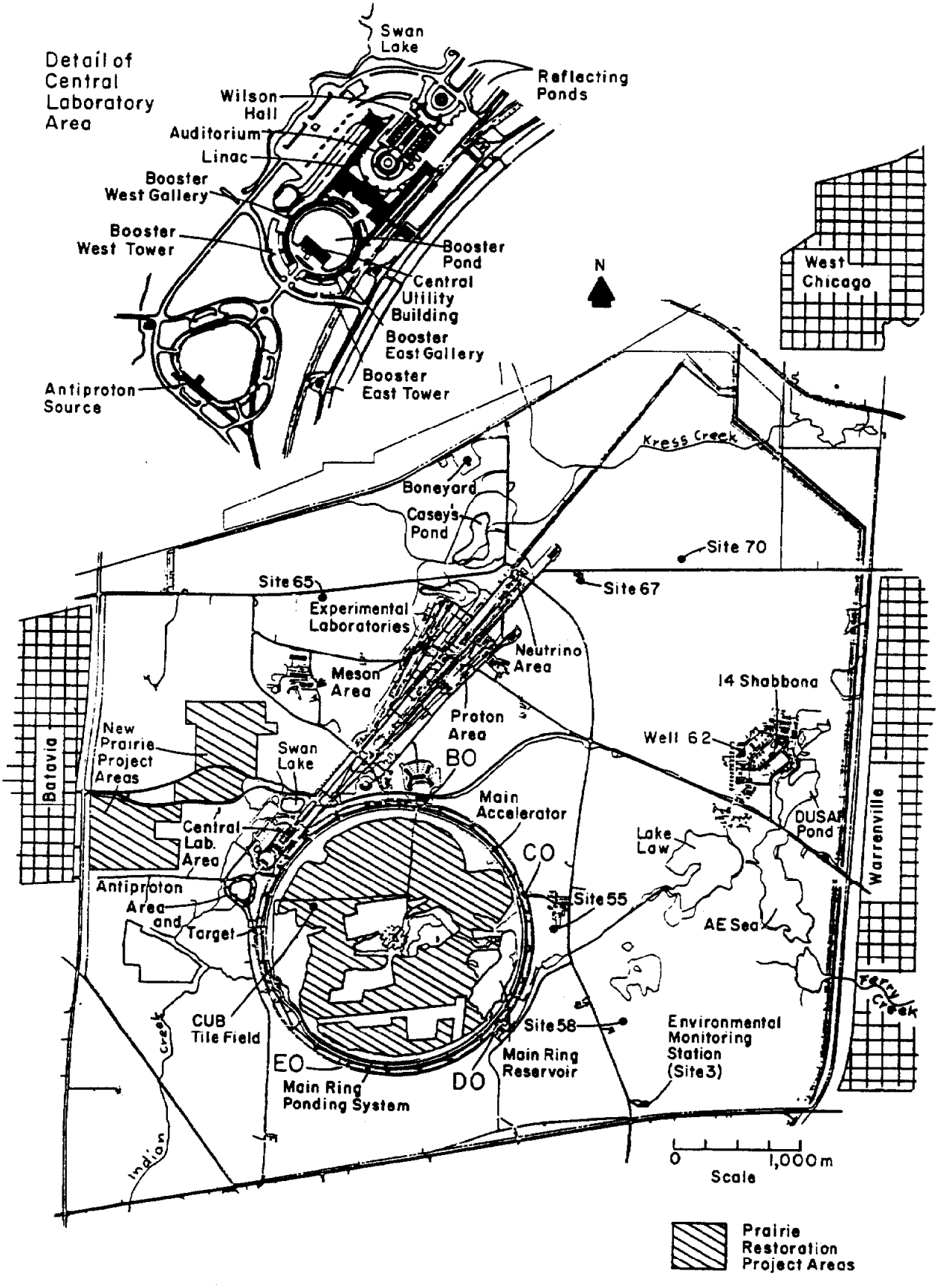
2. Summary

The 800 GeV fixed target run, begun in June 1987, was completed in February 1988. Then the large Collider Detector Facility (CDF) detector was re-installed in the main accelerator tunnel at B0 and smaller detectors installed at C0, D0 and E0 (Fig. 5). The proton energy was increased to 900 GeV and colliding beam experiments continued for the remainder of 1988.

During the fixed target run a total of 2.2×10^{18} protons were accelerated. Approximately 0.5×10^{18} protons were delivered to fixed targets in 1988. The latter caused the release of 6.6 curies of ^{11}C and ^{13}N from the Neutrino Area stack (near Neutrino Area Primary Target in Fig. 6) in 1988. During the colliding beams run a total of 101 curies of ^{11}C, ^{13}N, ^{39}Cl and ^{41}Ar were released from the Antiproton Source stack (near Antiproton Target in Fig. 5). The total of 108 Ci is greater than the 81 Ci released in 1987 because more radioactive gas is released during Antiproton Source operations.

In November 1987 a magnet was installed to bend muons downward into the ground. That markedly decreased the site boundary muon dose rate in 1988 from

Figure 5 - Fermilab Site



the Muon Laboratory. Based on 1987 operations without the magnet the dose for 1988 would have been 7.8 millirem (mrem). With the magnet operating the dose was only 0.5 mrem. The highest dose in CY 1988 came from the Meson Area. This dose was 1.2 mrem at the site boundary from the Meson West beam line compared to 13 mrem from the Muon Laboratory in CY 1987. There was negligible off-site exposure from penetrating radiation during the colliding beams experiments. However, the site boundary dose rate (fence line assuming 24 hr/day exposure) from the radioactive material stored at the Railhead (Fig. 1) was 1.6 mrem for CY 1988. Since the Railhead is so close to the site boundary, this is one case where the maximum individual potential radiation exposure is lower - only 0.3 mrem - than the site boundary value. Thus, the muons from the Meson West beam line resulted in a higher maximum individual potential radiation exposure - still approximately 1.2 mrem - than that from the residual radioactivity at the Railhead.

The total potential radiation exposure to the general off-site population from Fermilab operations during CY-1988 was 3.3 person-rem, or about 40% higher than the average of 2.4 person-rem per year from previous operations. Since the exposure is from penetrating radiation, the 50 year dose commitment from operations in 1988 will be the same as the exposure received in 1988.

A summary of off-site releases of radioactive effluents in CY-1988 is given in Table 1. The total release of airborne radioactivity was 108 Ci from venting of air containing short half-life radionuclides. The off-site release of tritium (^3H) in surface water totaled approximately 336 mCi, somewhat more than last year's release of 266 mCi.[6] The increase was the result of more water leaving the site during CY-1988. Water left the site via the Kress Creek spillway for 51% of the year in 1988 compared with 38% the year before. The amount of rainfall was a little below average in 1988; however the rainfall was less during the summer when hot weather reduces the overflow to Kress Creek. The primary source of tritium in water reaching Casey's Pond from drainage ditches in the Research Area was tritiated water discharging from an underdrain system beneath a target and beam dump system. The target was the primary target in the Neutrino Area. The target received most of the protons accelerated by Fermilab. After the CY-1982 operating period ended, the target was moved to a new location with a

different underdrain system. Thus, the tritium released in CY-1988 was essentially from operations before CY-1983.

Table 1

Summary of Radioactivity Released to the Off-Site Environment in CY-1988

Release Point	Radionuclide	Pathway	Release in Curies
N01 Enclosure	$^{11}C, ^{13}N$	Air	6.6
AP0 Enclosure	$^{11}C, ^{13}N, ^{41}Ar$	Air	101
Debonding Oven	^{3}H	Air	0.003
Kress Creek Spillway	^{3}H	Water	0.336

There were no abnormal occurrences which had an impact on the facility and its operations in CY-1988. In order to comply with an October 1988 date for polychlorinated biphenyl (PCB) control, Fermilab has removed large PCB capacitors from the Booster accelerator tunnel (Fig. 5) and from the Capacitor Tree adjacent to the Master Substation (northwest corner of intersection of Roads A and B in Fig. 1). The total number remaining on the site is only 106 compared to over 2000 when the PCB regulations were promulgated in 1979.

3. Environmental Program Information

3.1 Environmental Program Description

The National Environmental Policy Act of 1969 as amended mandates the Federal Policy to restore and enhance the environment and to attain the widest range of beneficial use without degradation. Since its inception, Fermilab has endeavored to protect and enhance the environment. For over ten years a prairie restoration project has been in progress on the 1.57 km^2 (388 acre) plot inside the main accelerator ring (Main Ring in Fig. 1). In the past several years the prairie project has been expanded to include areas outside the ring (Fig. 5). The total outside is 0.69 km^2 (171 acres). In another effort to enhance the environment, farm houses were moved from their original locations to a site at the south end of the Village (Fig. 1) and renovated to provide housing for scientists performing experiments at Fermilab rather than abandoned and allowed to deteriorate. Some farm wells were maintained for monitoring and others were properly sealed to prevent inadvertent contamination of the aquifer. Ponds and lakes were created to control surface run-off and provide cooling water for the

accelerator and experimental areas. Over 40,000 trees have been planted to improve the environment. In addition, strong emphasis has been placed on the control of chemical and radioactive materials as potential sources of environmental pollution. Adequate shielding has been provided for preventing exposure from penetrating radiation.

The Fermilab environmental and effluent radiological monitoring program follows, in general, the guidance given in the Department of Energy (DOE) Order 5400.1, draft Order 5400.XY, and in the reports A Guide for Environmental Radiological Surveillance at DOE Installations[7] and A Guide for Effluent Radiological Measurements at DOE Installations.[8] This includes adherence to the standards given in other existing DOE orders, in particular, DOE Order 5480.1A, chapter XI, which pertains to permissible doses due to radioactive releases, and gives guidance on maintaining exposures to as low as reasonably achievable (ALARA).[9]

The emphasis has been placed on potential environmental exposure path-ways appropriate to high-energy physics laboratories. These pathways include external exposure and internal exposure. The external exposure is from direct penetrating radiation and airborne short-lived ^{11}C, ^{13}N, and ^{41}Ar. The internal exposure is from ^{3}H and ^{22}Na in water, primarily potential drinking water. There is one unique characteristic at Fermilab which requires consideration. That is the use of large volumes of sand and gravel in two locations to assist in stopping the high-energy protons and secondary particles. Although the groundwater beneath these two areas is protected by membranes impervious to water and by underdrain systems to collect the water, radiological monitoring of soil and water is done to ensure that no radioactivity reaches drinking water supplies. See Section 4.4.4. Monitoring results are also reported for nonradioactive pollutants. Included as pollutants are pesticides used in weed, insect, rodent, and algae control.

3.2 Summary of Environmental Monitoring Performed in CY-1988

Fermilab performed extensive environmental monitoring in CY-1988, while the colliding beam and fixed target research programs were in progress, on three types of accelerator-produced radiation: penetrating, airborne, and waterborne.

The largest sources of penetrating radiation were muons and gamma rays. Neutrons were also monitored. The airborne radionuclides ^{11}C, ^{13}N and ^{41}Ar as well as the waterborne radionuclides ^{3}H (tritium) and ^{22}Na were monitored. The Department of Energy (DOE) regulations requiring this monitoring are found in DOE Order 5480.1A, Chapter XI. The penetrating radiation measurements were made primarily using a mobile environmental radiation laboratory (MERL) that was developed by Fermilab. The MERL is a motor vehicle with special directional detection equipment. A network of 120 fixed detectors with continuous data recording was also used.

For airborne effluents continuously operating stack monitors recorded the concentration released from the two stacks emitting essentially all of the radioactivity. For waterborne effluents meters recorded the volume of water discharged. Monthly water samples were analyzed to determine concentrations of tritium and other radionuclides. The fraction of the year the water left the site was determined by weekly inspections of the spillway.

The data on radioactive effluents was reported to the Department of Energy via the Effluent and On-Site Discharge Information Systems operated for the Department of Energy by EG&G, Idaho.

Additional monitoring for radionuclides in sediment and vegetation on the site has been done to investigate other possible pathways to the off-site environment.

The results during the full year of operations in CY-1988 were much better than the applicable standards in every case. In particular, the highest site boundary penetration radiation level was 1.5% of the relevant standard in CY-1985, negligible in CY-1986, 13% in CY-1987 and 1.6% in CY-1988. Operation of the New Muon Laboratory in 1987 produced a cone of muons which resulted in the higher radiation level over a narrow portion of the site boundary. However, installation of a magnet in November 1987 to bend the muons downward made the site boundary (fence line) radiation level higher from stored radioactive material at the Railhead than from muons in CY-1988. Airborne radionuclide concentrations and waterborne concentrations were below detection limits. See Section 7 for applicable standards.

Monitoring for chemical pollutants in drinking water systems on the site is done periodically. Thirteen wells and three distribution systems were sampled in CY-1985. The results indicated good water quality in all the wells sampled. The only parameters which were worse than the standard in any sample were iron, total dissolved solids, and in one well, sulfate. The iron is believed to be an indication of rust in the plumbing in those cases rather than iron in the aquifer.

On January 28, 1987, the source of drinking water for the Village (Fig. 1) was switched from the Village well (62 in Fig. 5) to the Warrenville community water supply. In 1988 a new well (W-5 in Fig. 4) was drilled at D0 to provide water for the new colliding beams facility being constructed there. Chlorine concentrations were tested every workday by Fermilab in the Village and in D0 as well as in the Main Site supply (W-1 and W-3 in Fig. 4). Monthly samples for fecal coliform were sent to the Illinois Environmental Protection Agency (IEPA) for analysis. All tests showed satisfactory levels of coliform and chlorine in 1988.

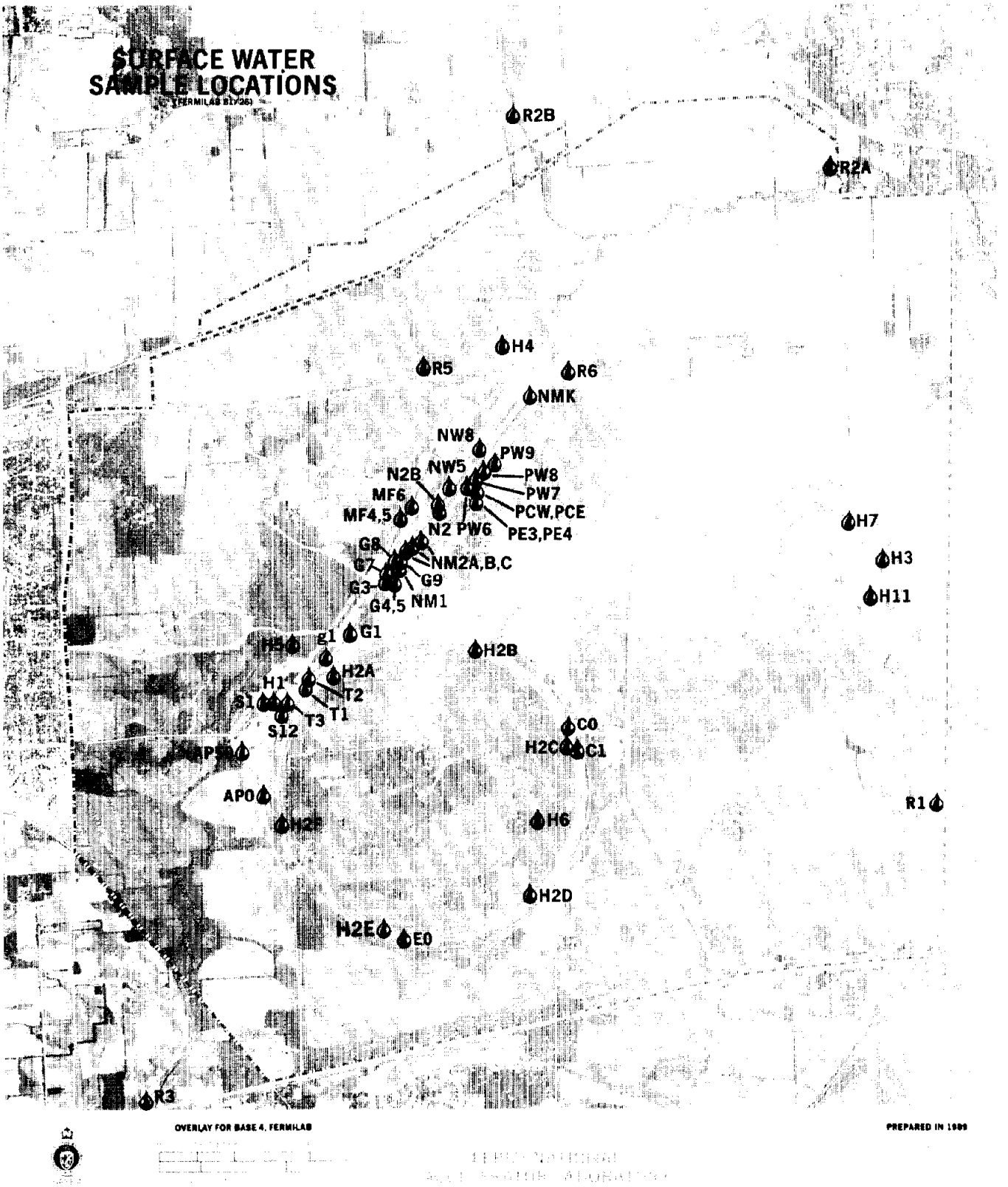
The Laboratory performs coliform tests on unchlorinated well water supplies on the site. When greater than four colonies per 100 ml are found in a sample, the well is chlorinated and subsequently retested. No fecal coliform was found in these unchlorinated supplies and none was chlorinated in CY-1988.

Creeks and ponds are sampled semiannually for pH, dissolved oxygen, biochemical oxygen demand, suspended solids, and fecal coliform (Figs. 5 and 6). Results met standards for waters in general use in CY-1988 except for high fecal coliform readings in Kress Creek and Indian Creek in October 1988 and high pH readings in Ferry Creek in April 1988 and in Casey's Pond in October 1988.

3.3 Environmental Permits

The magnet debonding oven (Section 3.3.2) has an Illinois Environmental Protection Agency permit (I.D. No. 043807AAI, Application No. 79070012) which expires March 5, 1994. There have been no cases of noncompliance.

Figure 6


SURFACE WATER
SAMPLE LOCATIONS
R2B
R2A
H4
R5
R6
NMK
NW8
PW9
N2B
NW5
PW8
PW7
MF6
PCW,PCE
MF4,5
N2
PW6
PE3,PE4
G8
NM2A,B,C
G7
G9
G3
G4,5
NM1
H7
H3
H11
H5
g1
G1
H2B
H2A
H1
T2
S1
T1
T3
S12
C0
H2C
C1
P5
APO
R1
H2F
H6
H2D
H2E
E0
R3
OVERLAY FOR BASE 4, FERMILAB
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Fermilab has interim status under the Resource Conservation and Recovery Act (RCRA) (USEPA I.D. No. IL6890030046) to operate a hazardous waste storage facility. This status will continue until the Illinois Environmental Protection Agency has processed Fermilab's Part B application. The facility is in compliance with the RCRA regulations. Regulated chemical wastes are stored in the facility as well as a limited amount of mixed waste. Typical regulated chemical wastes are hazardous wastes, polychlorinated biphenyls (PCBs), and used oil. The mixed waste is ^{241}Am and lead debris from a fire in 1987. Only wastes generated by Fermilab are stored at the facility for proper disposal elsewhere in the future.

Emco Wheaton coaxial vapor recovery systems have been installed on all gasoline dispensing equipment at Fermilab under a permit (I.D. No. 043807AAI, Application No. 86020057) issued by the Illinois Environmental Protection Agency (IEPA). The permit expires on February 13, 1991. There have been no compliance problems with the systems.

Fermilab has an IEPA permit (I.D. No. 043807AAI, Application No. 87110096) for three natural gas boilers at the Central Utility Building (Fig. 5), two natural gas boilers at the Wide Band Lab in the Proton Area (Fig. 5), and one propane gas boiler at Industrial Building #2 in the Industrial Area (Fig. 1). A grit blast operation at Industrial Building #2 is also included on that permit. Fermilab has received a permit (I.D. No. 043807AAI, Application No. 88010042) for operation of a vapor degreaser at Industrial Building #3 in the Industrial Area. No permit was needed for the new septic field installed near DO (north of W-5 in Fig. 4). It was classified as a Class 5 injection well in CY-1988. The CUB tile field (Fig. 5) is also a Class 5 injection well.

Fermilab had open burning permits in 1988 from IEPA for prairie management fires and for research in fire protection. The research was to determine if fires propagate in bundles of electrical cables in horizontal cable trays. Propagation occurred in one type of cable-hardline coaxial cable, which is used for signal and communication links rather than power distribution.[10]

3.4 Assessments and Impact Statements

No formal environmental assessments and no environmental impact statements were prepared in either draft or final form during the year at Fermilab. However, there is an on-going program in place to routinely evaluate new projects and modifications to existing operations and facilities to determine if there is a significant potential for impact. Also, see Section 6 for the evaluation of operations conducted in CY-1988.

3.5 Summary of Significant Environmental Activities

In the early 1970's Fermilab began a prairie restoration project on the 1.57 km^2 (388 acre) plot inside the main accelerator (Fig. 5). In CY-1984 some Fermilab land (0.11 km^2 or 28 acres) outside this plot was plowed and seeded with prairie plants. Since then additional prairie planting has been done (Fig. 5), resulting in a total of 0.69 km (171 acres) outside the main accelerator.

There are very few remnants of the original prairie left. In CY-1986 a small remnant was found along the Burlington Northern Railroad tracks near the northern site boundary. In CY-1988 another remnant was found near the eastern site boundary north of Batavia Road. This remnant is near the Elgin, Joliet, and Eastern Railroad tracks. The occasional fires in the past along the railroad right-of-ways probably were responsible for the preservation of the remnants.

The Fermilab restoration is one of the largest prairie sites in the country. The harvesting of seeds is done by volunteers and by the Roads and Grounds group of the Business Services Section and the environmental aspects receive the attention of a prairie committee consisting of laboratory personnel and outside university representatives. In CY-1987 mechanical harvesting yielded about 4000 kg (9000 lbs) of uncleaned prairie seeds, the largest harvest to date. An additional 2000 kg (approximately 4400 lbs) of seeds was harvested in CY-1988. Fermilab conducts routine burning of the prairie restoration areas with assistance from the prairie committee and volunteers.

In CY-1986 an archaeologist, R. Jeske, was hired to update the status of Fermilab's American Indian sites. The work done in 1970-71 by A. Early was

validated and one additional site identified. Since that time the archaeological work has continued under the direction of R. Lurie. The remaining 15% of the property was surveyed and one more site found, bringing the total to 26. Phase II testing was completed on twelve sites, one of which is believed eligible for the National Register of Historic Places. This site has cultural material below the plow zone which is unusual for sites in northeastern Illinois. The Fermilab sites are basically hunting camps occupied for relatively short periods of time rather than villages. Most of the land was prairie and marsh adjacent to a forest on the west side of the Laboratory. The forest stretched to the Fox River when the Indians camped here. Some sites were occupied 3000 years ago.

Six archaeological sites in areas being farmed were evaluated in CY-1987 and CY-1988. No significant findings resulted but the archaeologists recommended that two be taken out of agricultural production to preserve the cultural material. The Laboratory has removed that land in the southwestern corner of the site as well as some marginally productive land in the northeastern corner of the property from the list of tracts which will be placed in production.

Characterizations of the site continued in other areas covered under the National Environmental Policy Act. A bird survey at Fermilab during 1987 and 1988 identified 227 of the 314 species observed in the entire state. Of the 43 birds threatened or endangered in Illinois 26 have been seen at the Laboratory. The wide range of habitats and the sheltered conditions, e.g., no hunting allowed on the site, have made breeding successful - 63 species raised young during this period. Insect surveys of the prairie and characterizations of the woodlands have also been completed.

The Laboratory has continued its aggressive program to remove large PCB capacitors rather than supply the containment and security necessary to keep them in service as required by October 1, 1988. As a result the initial inventory of over 2000 large PCB capacitors was reduced to 106 by the end of CY-1988. The large PCB capacitors which were radioactive had all decayed to exempt quantities in 1988 and were disposed of by incineration in a PCB incinerator approved by the U.S. Environmental Protection Agency (EPA).

The U. S. Department of Energy Environmental Survey for Fermi National Accelerator Laboratory was conducted from September 14 to September 25, 1987. The purpose of this effort was to identify, via baseline surveys, existing environmental problems and areas of environmental risk at Fermilab. This survey was part of a larger effort to rank the findings on a DOE-wide basis and establish priorities for addressing the environmental problems found. The Survey team consisted of two members from the DOE Headquarters in Washington, D.C., and seven independent specialists with expertise in dealing with different types of environmental problems.

The Survey team found that the missing mineral oil from the T82A transformer spill[11] in 1985 could have potentially been as high as 22,710 l (6000 gal). During the Survey approximately 475 l (125 gal) was located in a vault under the Capacitor Tree near the Master Substation. This oil entered the vault by flowing down an open electrical cable duct on the transformer pad the night the spill occurred. Oil also is collecting in a sump in an underground enclosure about 7.5 m (25 ft) east of the transformer pad. The sump collects water near the footings of the enclosure about 6 m (20 ft) below the ground surface. In CY-1986 about 190 l (50 gal) of oil was collected. In CY-1987 about 208 l (55 gal) more was collected and in CY-1988 an additional 38 l (10 gal) was collected.

In CY-1988 six holes were drilled near the spill location to search for additional oil. An oil stain was found on one of the soil samples from the hole closest to the transformer pad. There was also a thin oil layer on top of the perched water table at that point. Thus, there is evidence for oil above the clay layer which starts at about 5 m (16 ft) below the surface.

Three monitoring wells were installed for future water sampling at different depths below the surface. The deepest extends to 12 m (40 ft). In addition, soil samples will be analyzed to determine the extent of the oil migration and obtain an estimate of the volume.

The Survey team found that discharges of chromates[12] from 1974 to 1976 to the old CUB perforated pipe field may be a source of soil and groundwater contamination. They found no evidence of contamination, but felt that more

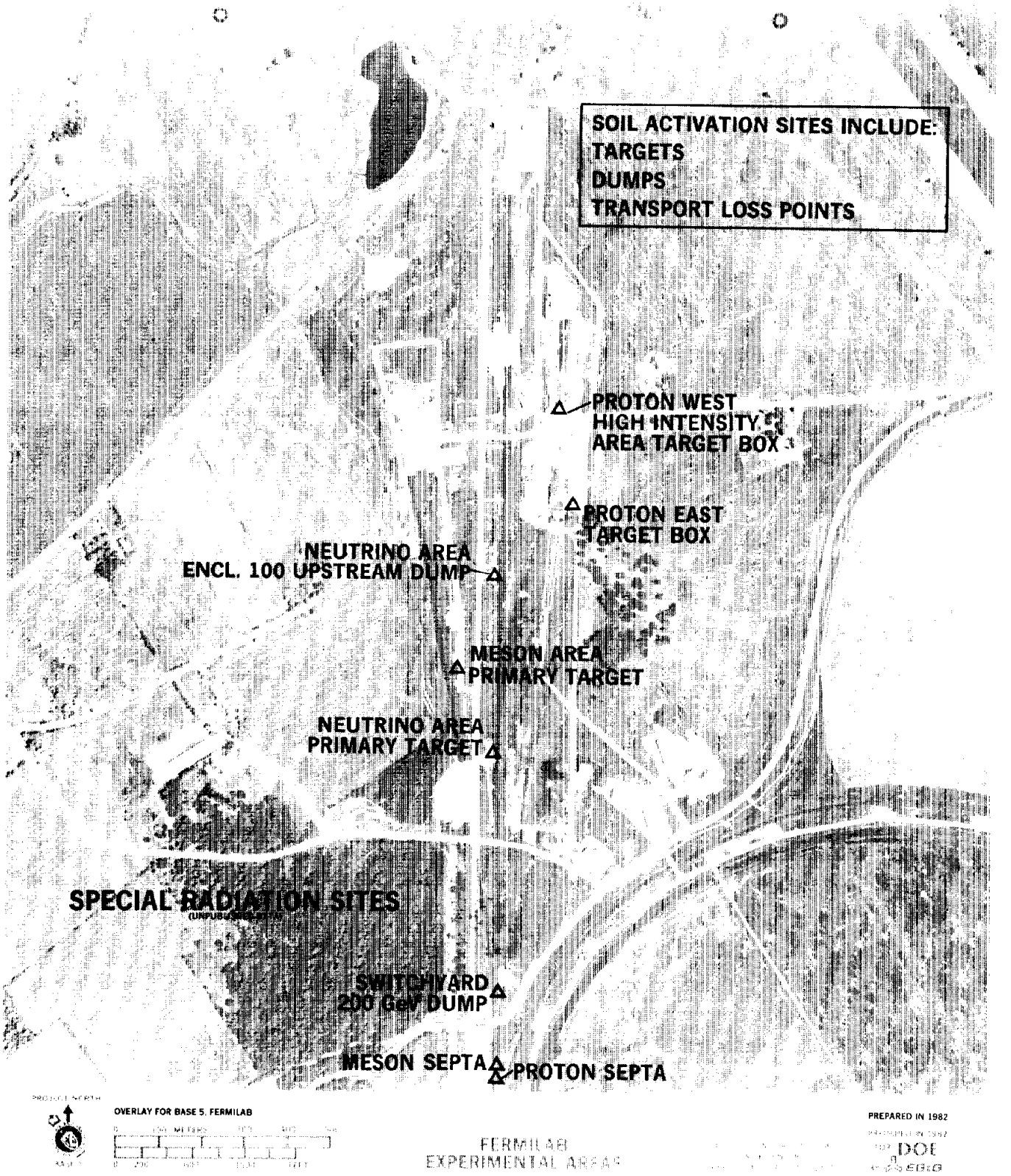
sampling was needed. In 1988 five shallow (4.6 m or 15 ft) sampling holes and two deeper (11.6 m or 38 ft) holes were drilled in the perforated pipe field to search for chromates. The soil samples were analyzed for chlorides and total chromium. Sodium chloride from regeneration of resins has been discharged continually into that area since 1972 and provides a good tracer.[13] A distinct chloride plume was found showing migration along the top of the low permeability clay layer (Yorkville till) toward the southeast. The only chromium level above background was near the surface and that sample did not have hexavalent chromium above the detection limit of 10 mg/kg.

One boring hole was made downstream of the chloride plume. Samples from that hole did not contain any elevated chromium levels. Thus, there is no evidence for chromate in advance of the chloride plume. The holes were cased and water from them will be sampled in the future to monitor for chromate. In addition, samples were taken from inside and around the perforated pipe. Some hexavalent chromium was found inside the pipe. Also, total chromium levels were elevated in and around the pipe but only a small percentage of the zinc chromate added to the cooling water was found.

Some PCB spills occurred during removal of the capacitors from the Capacitor Tree and some PCB contamination remains from earlier leaks. Cleanup work was already in progress at the time of the Survey. The team listed that contamination in their findings. The total amount of PCB spilled is estimated to be below the reportable quantity of 4.54 kg (10 lbs).[14] Three cleanup efforts were made in CY-1988. The sampling at the end of each cleanup indicated residuals above 10 parts per million (ppm) PCB. One spot in the soil within the original cleanup area still has not been satisfactorily cleaned up, although the metal structure is now clean. There is also an additional area outside the drip line of the Tree where contamination has been found. More characterization will be made in an effort to achieve cleanup on the next attempt.

Soil radioactivation has occurred and continued to occur in CY-1988 near the N01 and M01 target areas (Neutrino Area and Meson Area primary targets in Fig. 7) and the NW4 beam dump (Neutrino Area Encl. 100 Upstream Dump in Fig. 7) as a result of fixed target experiments. The team was not satisfied with the characterization of the soils beneath the underdrains. They felt that the

Figure 7


SOIL ACTIVATION SITES INCLUDE:
TARGETS
DUMPS
TRANSPORT LOSS POINTS
PROTON WEST
HIGH INTENSITY
AREA TARGET BOX
PROTON EAST
TARGET BOX
NEUTRINO AREA
ENCL. 100 UPSTREAM DUMP
MESON AREA
PRIMARY TARGET
NEUTRINO AREA
PRIMARY TARGET
SPECIAL RADIATION SITES
SWITCHYARD
200 GeV DUMP
MESON SEPTA
PROTON SEPTA
OVERLAY FOR BASE 5, FERMILAB
FERMILAB
EXPERIMENTAL AREAS
PREPARED IN 1982
DOE

groundwater monitoring system in these areas as well needed improvement. Six 45° sampling holes were made beneath the target areas and beam dump in CY-1988 for three purposes:

(a) To sample the soil for ^{3}H and ^{22}Na.

(b) To search for a high permeability sand and gravel layer which could shunt radioactivity laterally away from wells sampling the deeper lying aquifer nearby.

(c) To install monitoring wells for future shallow water sampling at these locations.

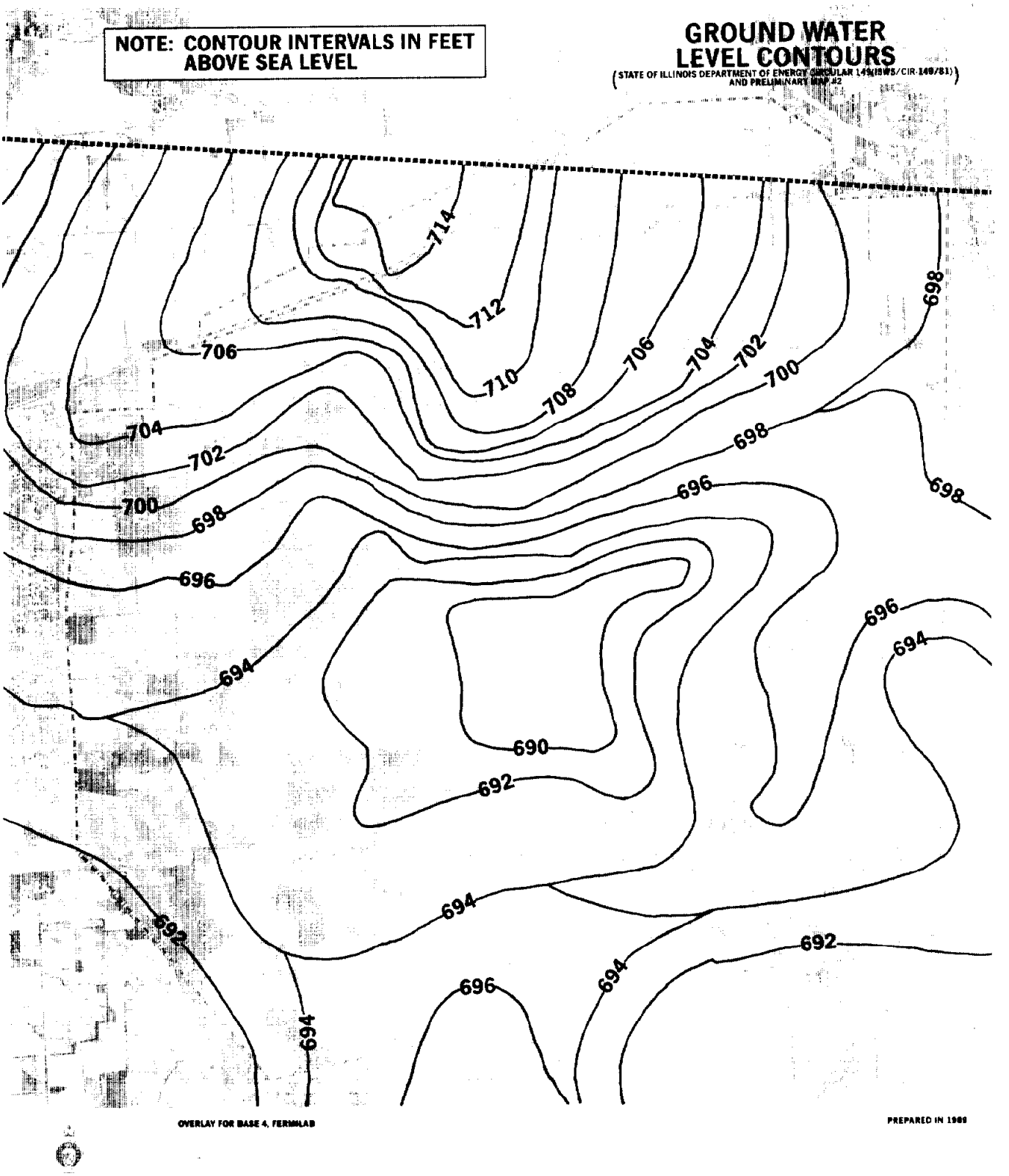
The holes extended approximately 18 m (60 ft). This corresponded to approximately 13 m (42 ft) vertically to elevation 215 m (705 ft) above sea level. The water table is located at 212 to 213 m (696 to 700 ft) and bedrock starts at 206 m (677 ft). Thus, presence of radionuclides in samples of soil from these holes should indicate some downward movement from the target or dump above. Only samples from one hole, north of the N01 target contained positive indications: ^{3}H was reported by the first analytical laboratory at a fraction of the drinking water standard. The remaining half of the split sample was processed at Fermilab and then sent to a different vendor. These results were higher than the standard. Water samples taken from the hole also showed ^{3}H concentrations above the drinking water standard. See Section 4.4.4.

No sand and gravel layer was found below the N01 target. Thus, there is no highly permeable layer present to carry radionuclides away horizontally as they move down toward the aquifer. There was evidence for sand and gravel around elevation 218 m (715 ft) near the M01 target and around 217 (712 ft) near the NW4 beam dump. Thus, there is evidence for a horizontal sand and gravel layer at a number of places on-site but it is not a continuous layer everywhere. Whether or not it could provide a path for radionuclides to the site boundary is not clear.

Monitoring wells were installed at the six locations by placing plastic casings in the 45° holes. In addition, three new vertical wells were drilled 3 m (10 ft) into the bedrock down gradient from these soil activation areas (Wells 79, 80, and 81 in Fig. 4). The groundwater contours are shown in Fig. 8. A summary of hydrogeology follows.

1989

Figure 8


NOTE: CONTOUR INTERVALS IN FEET ABOVE SEA LEVEL
GROUND WATER LEVEL CONTOURS
(STATE OF ILLINOIS DEPARTMENT OF ENERGY CIRCULAR 149 (ISWS/CIR-149/81) AND PRELIMINARY MAP #2)
714
712
710
708
706
704
702
700
698
696
694
692
690
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1988

3.6 Summary of Hydrogeology

The Fermilab site has thick glacial till consisting primarily of low permeability clay.[15] This clay forms a barrier to the downward percolation of any water containing radioactivity. Beneath the clay the first layer of rock is a dolomite of Silurian age.[5] Its fractured upper 3 m (10 ft) and the saturated sand and gravel immediately above it in most places carry sufficient water for individual farm needs. The water level contours for this aquifer are shown in Fig. 8. Note that the water from the Research Area flows toward Well 1, the primary on-site drinking water supply (Fig. 2). Groundwater leaves the site and flows southwest toward the Fox River and southeast toward the West Branch of the DuPage River.

Beneath the silurian dolomite are older formations laid down by sedimentation during the Cambrian and Ordovician periods when the region was under sea water. These consist of dolomite and sandstone with perhaps some shale. The sandstone aquifer at approximately 300 m (1000 ft) below the surface provides sufficient volumes of water for local municipal water supplies.

The spillways should be noted as shown on the map of surface water drainage (Fig. 9). In the event of an accidental spill, backup efforts will be concentrated at those points to stop the flow of any hazardous substance if it cannot be contained closer to the discharge point.

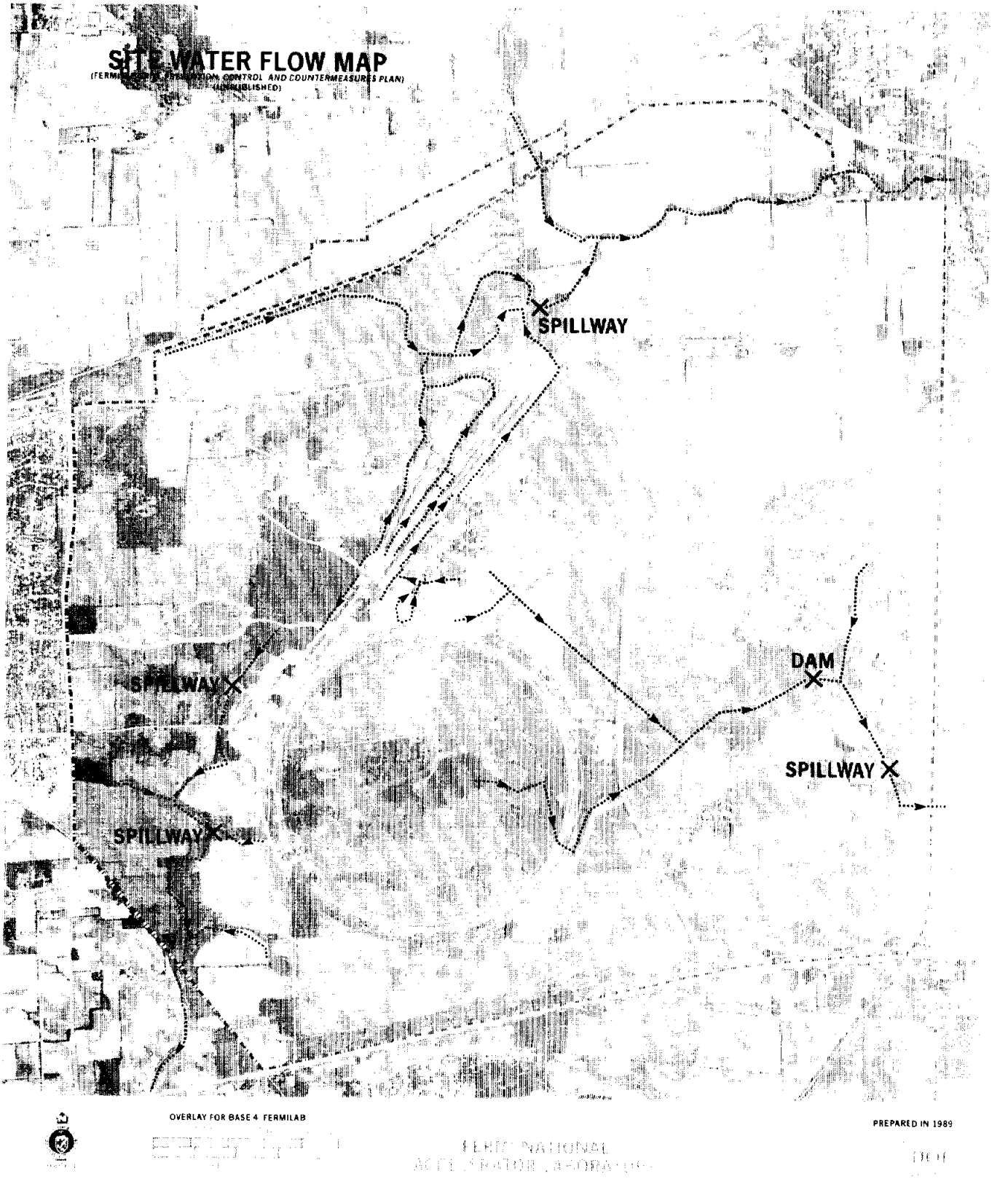
4. Environmental Radiological Program Information

4.1 Environmental Radiation Monitoring

Three types of accelerator-produced radiation are monitored - penetrating radiation, airborne radioactivity, and waterborne radioactivity. These radiations usually have direct pathways to the off-site population. Other more indirect pathways, such as through the food chain, have received much less attention to date. The decision on what to monitor is based on the type of operation, radionuclides released, potential hazard, and monitoring results from this and other high-energy physics laboratories.

1988

Figure 9


SITE WATER FLOW MAP
(FERMILAB EROSION/SEDIMENTATION CONTROL AND COUNTERMEASURES PLAN)
(UNPUBLISHED)
SPILLWAY
SPILLWAY
SPILLWAY
DAM
SPILLWAY
OVERLAY FOR BASE 4 FERMILAB
PREPARED IN 1989

4.2 Penetrating Radiation

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

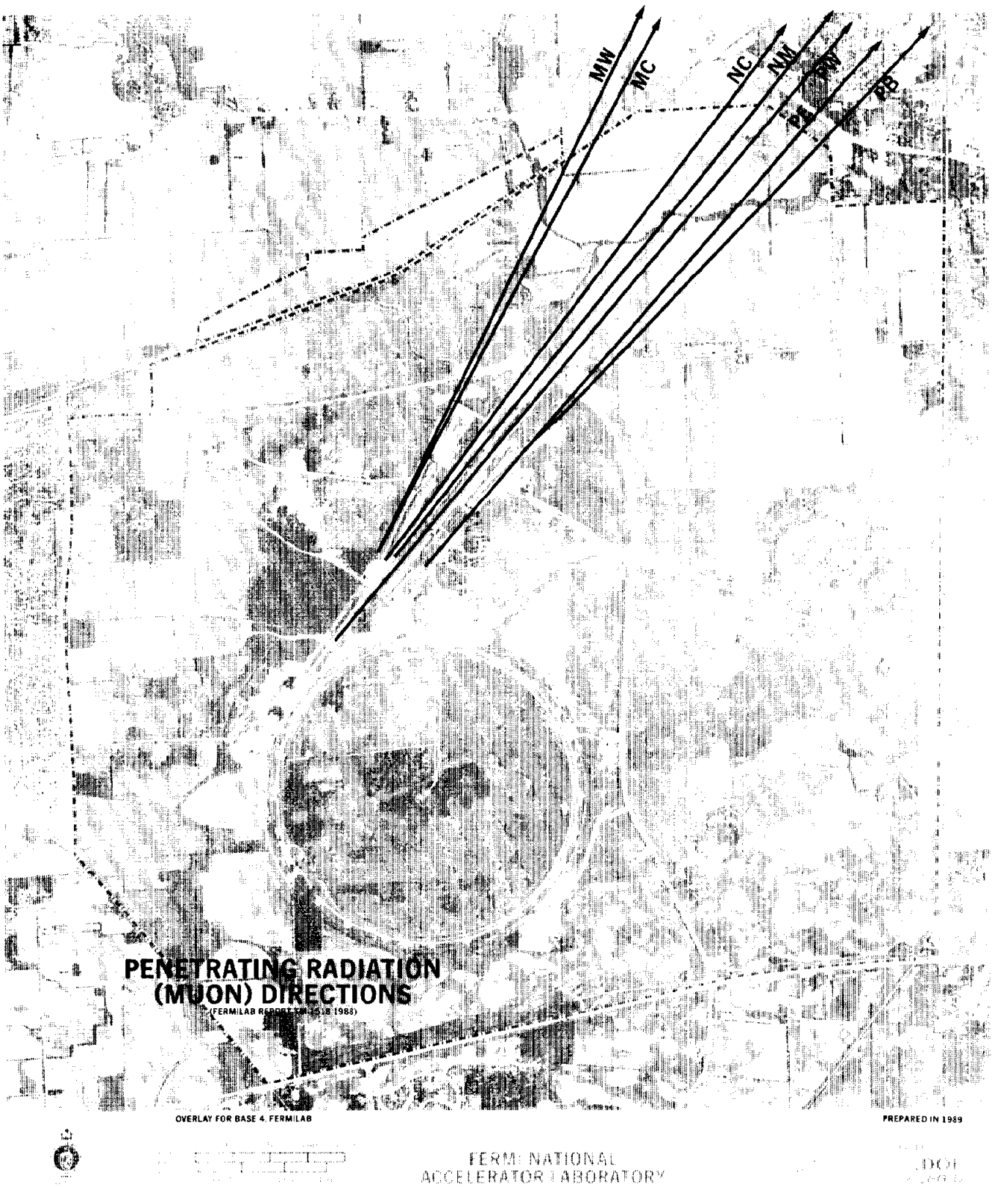
A network of detectors was used to monitor penetrating radiation. At the end of CY-1988 there were approximately 120 detectors deployed around the site with the primary purpose of controlling on-site radiation. The majority of these detectors were connected to a data logger which automatically recorded the radiation levels for subsequent examination.[16] In CY-1988 only three detectors were used primarily for environmental radiation monitoring. One was a large volume, 110 liter, ionization chamber (called a Hippo) for gamma ray and charged particle detection. It was located near the Boneyard at the Railhead (Fig. 5). Another was a large scintillation counter. It was located near the site boundary (Environmental Monitoring Station in Fig. 5). The last was a tissue-equivalent ion chamber located at 14 Shabbona in the Village (Fig. 5).

The Mobile Environmental Radiation Laboratory (MERL) was used in CY-1988 for determining the exposure levels at the site boundary and for locating the source and direction of penetrating radiation such as muons and neutrons.[17,18,19,20] The MERL is a four-wheel-drive vehicle equipped with two 20 cm x 20 cm (8 in x 8 in) scintillation counters, one approximately 15 cm (6 in) behind the other, for muon detection. It also has a DePangher "long counter" for neutron detection.[21]

4.2.1 Muons

Measurements of muons from the Meson, Neutrino, and Proton Areas were made in CY-1988 while the accelerator was delivering 800 GeV protons.[22] The directions of the penetrating muons are shown in Fig. 10. A new beam line, the NM line in Fig. 10, was placed in operation in CY-1987. This line produced a beam of muons for studying their interactions with matter. The line was located

Figure 10


MW
MC
NC
NM
PW
PB
PENETRATING RADIATION
(MUON) DIRECTIONS
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1989
FERMI NATIONAL
ACCELERATOR LABORATORY

3.7 m (12 ft) below the surface at the Muon Laboratory just north of Wilson Road (just north of the Neutrino Lab in Fig. 1).

The muons which penetrate the earth shielding can travel beyond the site boundary through the air before stopping. Therefore, measurements were made both on and off the site. Muons travel farther than protons because they do not interact strongly with matter. Muons are the cosmic rays of natural background radiation. The muon is basically a heavy electron and hence has the same biological effect (the same quality factor of 1) as electrons or gamma rays. Just as electrons and positrons have negative and positive charges, muons can be positive and negative but not neutral in charge. This gives one the possibility of deflecting a beam of muons downward to reduce the number which go off-site at ground level. This was done in November 1987 with the muon beam at the Muon Laboratory. As a result the exposures in CY-1988 were greatly reduced (about 15 times less).

The site boundary dose rates for CY-1988 were determined from the numbers of protons incident on the targets and the muon dose rates per incident proton obtained by measurements using the MERL (Section 4.2 above). The maximum fence line annual dose based on 24 hour per day occupancy was 1.2 mrem for CY-1988. This exposure was the result of muons from the MW (Meson West) line rather than from the NM line (Muon Laboratory). The NM line site boundary dose was 0.5 mrem for CY-1988 rather than 7.8 mrem which would have resulted without the operation of the deflecting magnet.

4.2.2 Neutrons

Neutrons penetrated the shielding in the most easterly of the external experimental areas (Proton East line in Fig. 5) in the Proton Area in CY-1981 and CY-1982.[20,23,24] However, in CY-1983 additional shielding was added to this area resulting in site boundary dose rates from neutrons since that time which are much less than the 0.4 mrem neutron dose rate for CY-1981.

1989

4.2.3 Gamma Rays

The primary radioactive waste storage area on-site - the Boneyard - is also the primary source of off-site gamma radiation. Activated accelerator components and shielding, primarily iron and concrete, are stored in the Boneyard at the Railhead (Fig. 1) for future disposal or reuse following radioactive decay. As shown in Fig. 5, the Boneyard, which is a secure area, lies close to the site boundary. In 1987 radioactive material was moved into a new cave constructed at the southwest corner of the Boneyard. In addition, there was an area nearby designated for radioactive material storage for future use. A large amount of low-level radioactive material was placed in that area. The site boundary dose for CY-1988 was determined using thermoluminescent dosimeters (TLDs), the large volume ion chamber (Hippo), and a hand held NaI (Tl) scintillator (to measure the rate of decrease with distance). The radiation level at the nearest site boundary was 1.6 mrem for CY-1988. The maximum exposure to the individual living closest to that point on the site boundary would have been 0.3 mrem for 1988, assuming 24 hour per day occupancy and a dose rate inversely proportional to the square of the distance from the source. The distance from the site boundary to the residence was 550 m (1800 ft). Thus, the dose to a member of the public in CY-1988 from the Boneyard was lower than the site boundary (fence line) dose.

4.3 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.

During the first two months of CY-1988 the fixed target program was in operation. During that period 800 GeV protons were sent to the Research Area (Fig. 1). More protons were delivered to the Neutrino Area primary target than to any other target. This target has less shielding around it inside the

1988

enclosure and produces primarily ^{11}C (70% ^{11}C and 30% ^{13}N). The total release was 6.6 Ci from the neutrino Area stack (fixed target operation).

During the last six months of CY-1988 the Antiproton Source was in operation and 120 GeV protons were focused onto a target (Antiproton target in Fig. 5) to produce antiprotons. This target was a source of radioactive gas resulting from interaction in air of secondary particles leaving this target. Because this target is heavily shielded and the air volume is small, there are many thermal neutrons also radioactivating the air. The result is a mixture of primarily ^{11}C and ^{41}Ar with smaller amounts of ^{13}N, ^{38}Cl, and ^{39}Cl in air. The ^{41}Ar has a half-life of 1.8 hours and is produced by neutron capture in ^{40}Ar. Air contains about 1% argon which is essentially ^{40}Ar. Interaction of high-energy secondary particles with nitrogen and oxygen in the air produces 20 minute half-life ^{11}C and 10 minute half-life ^{13}N. Interaction of high energy neutrons with argon in the air is probably the source of 37 minute half-life ^{38}Cl and 58 minute half-life ^{39}Cl. The total release was 101 Ci from the Antiproton Area Stack (colliding beam operation).

The site boundary concentrations were calculated using the computer program AIRDOSE-EPA[25,26] (a gaussian plume diffusion model). Wind conditions for O'Hare Airport about 43 km (27 mi) away were used as input. The terrain between Fermilab and the airport is relatively flat. The maximum dose to an individual member of the general population for CY-1988, found by summing the contributions from the two sources, was 0.03 mrem.

A debonding oven was placed in operation during CY-1979 in the Industrial Area (Fig. 1). Its purpose is to debond magnets by decomposing the epoxy adhesives at high temperatures. Most of these conventional magnets are radioactive and have failed after years of accelerator operation in the Main Ring tunnel. The gaseous effluent was measured during the acceptance test on June 8, 1979, conducted for the Illinois EPA and contained only ^{3}H at very low-levels. The tests were primarily performed to measure nonradioactive emissions. The test utilized a typical 6 m (20 ft) long magnet reading 0.8 mrem/hr at 0.3 m (1 ft) from the surface and 8 mrem/hr in the bore tube where the protons traveled. The total amount of ^{3}H released from this magnet was 160 μCi at a stack concentration of 1.3×10^{-8} μCi/ml or about seven percent of

the Derived Concentration Guide (Section 7). The stack is approximately 10 m (30 ft) high. Using the computer program AIRDOSE-EPA gives a negligible percentage of the applicable Concentration Guide at the site boundary.

The number of radioactive magnets debonded in CY-1988 was 11 corresponding to a total release of 3 mCi of ^{3}H into the air. The radioactivity in the magnets was similar to that in the 1979 test, thus the 1979 data are still valid. In CY-1988 the wind conditions were similar to those in past years.

4.4 Waterborne Radioactivity

During accelerator operations, radioactivation of the soil occurs in some places.[27,28] Leaching of these radionuclides into the groundwater provides a possible mechanism for transport of Fermilab-produced radionuclides into the surface run-off waters and aquifer. Hence, a broad program of groundwater monitoring for radioactivity is maintained. Measurements are also made of on-site concentrations of radionuclides in Fermilab 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 from 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.[22] 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 resins. These ion exchange resins are used to remove impurities from water in closed loop systems.

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

1. Farm and Monitoring Wells - Approximately 30 m Deep - 51 Samples

2. Fermilab Water Supplies - Approximately 70 m Deep - 5 Samples

1988

The wells routinely sampled are shown in Fig. 4. Water samples were also collected from sumps, creeks, and rivers. All surface and groundwater samples collected were analyzed by International Technology Corporation (IT Corporation), 1550 Bear Creek Road, Oak Ridge, Tennessee 37831. Each monthly shipment included at least one sample containing accelerator-produced radionuclides in known amounts to check the accuracy of the assays. See Section 7 on quality assurance.

4.4.1 Water Sample Collection

To obtain water samples from wells not in regular use, the wells are pumped for a sufficient length of time to insure that the water standing in the pipe has been pumped out before a sample is taken. The water in the pipe could conceivably have been there since the last time a sample was taken. Normally, the pipe volume is pumped several times before sampling. Water samples from creeks and other surface waters are normally collected by dipping a sampler well below the surface. Sumps inside enclosures are sampled by portable peristaltic pumps. Also, in CY-1984 meters were added to some sumps which pump radioactive water to record their operating times.

The water sampling schedule is based on the following rationale:

1. Wells 39, 43, 45, 49, 59, and 78 are sampled quarterly because they are closest to the areas of maximum soil activation (near targets and dumps) and/or are in the direction the water is expected to flow in the aquifer.

2. Wells W-1, 5, W-5, 17A, 20, 24B, 29 and 55B are sampled semiannually because they are near the accelerator.

3. The remaining wells are sampled annually because they are near the site boundary or serve as backups to more frequently sampled wells or as drinking water supplies.

4. The one deep well, W4, is sampled normally annually to look for long-term trends or changes in percolation down to that level. No sample was obtained in CY-1988.

5. Sumps closest to the areas of maximum soil activation are sampled frequently. The number of samples per year is dependent on the concentration seen in the water. In CY-1988 N1 sump and N2 sump were each sampled five times. The MF5 sump was sampled six times, the MF4 sump and the PW8 sump were sampled twice. In 1987, radioactivity was seen for the first time in a sump near the NM2B enclosure. This sump, designated NM2B, was sampled quarterly. The enclosure is adjacent to the target location which received most of the protons in the past. During CY-1986 the N1 sump which pumps out the water from under that target was not pumping automatically. Since the NM2B sump is lower, it is believed that radioactive water flowed down to it from the vicinity of the target. In CY-1987 the N1 sump pump controls were repaired and it is now pumping automatically. As a result the concentration of tritium in the NM2B sump has decreased to background levels.

6. The N1 retention pit was sampled five times and the retention pit nearby in the south addition to the Neutrino Target Hall was sampled six times during CY-1988. Discharge does not occur automatically from them. The water from these pits is monitored and disposed of properly by solidification and burial as radioactive waste, if necessary.

7. The other sumps are sampled less often with the frequency based on the tritium concentration found there in the past.

8. The creeks are routinely sampled three times a year and Kress Creek is sampled at least monthly whenever water from the Laboratory flows over the spillway into the creek. Ferry Creek and Indian Creek were sampled three times and Kress Creek was sampled sixteen times in CY-1988.

9. Ponds and ditches with a potential for receiving radioactive water are sampled annually.

10. The Fox River and west branch of the DuPage River which receive run-off from Fermilab are sampled semiannually upstream and downstream from the creek mouths.

11. The closed loop cooling systems which cool targets and dumps are sampled with a frequency which depends on the level of radioactivity. Operating systems having concentrations greater than 0.01 μCi/ml are sampled quarterly (500% of the Derived Concentration Guide in Section 4). Those having concentrations between 0.001 and 0.01 μCi/ml are sampled annually. The total number of closed loop samples was seven in CY-1988. This is down considerably from previous years because many systems were drained and have not reached high concentrations since 800 GeV operations commenced.

12. The ion exchange resin regeneration systems are routinely sampled for analysis on-site. Samples are analyzed on-site at the Nuclear Counting Laboratory. The regeneration systems remove radionuclides such as, ^{7}Be, ^{54}Mn, and ^{60}Co as well as calcium and other nonradioactive impurities from the resins which function to keep conductivity of closed loop water systems low. Throughout CY-1988 effluent containing radioactivity from the regenerations went to a settling tank rather than to the Central Utility Building (CUB) tile field inside the Main Ring. After the salt (essentially NaCl), had precipitated, carrying the radionuclides out of solution with it, the water was drained off the top and sent to the tile field. The pH was adjusted before discharge to ensure that it was not a hazardous waste.

    Throughout 1988 the salt was pressed to remove water and then dried. It is being stored until approval for disposal as radioactive waste is received.

13. In the past several samples were collected annually to look for radioactivity leached from activated steel. Only one sample was collected in CY-1988.

4.4.2 Results of Analyses

All current Fermilab water sampling locations for detection of accelerator-produced activity are shown in Figs. 4 and 6. Not all locations need to be sampled every year. See Section 4.4.1 above. No accelerator-produced radionuclides were reported in three water samples taken from Ferry and Indian Creeks (R2A in Fig. 6) or the sixteen samples from Kress Creek. No accelerator-

produced radionuclides have ever been detected in the water from the creeks and rivers. Thus, the results are not included in Table 2. All water samples with detected activity are reported in Table 2. Two sets of river water samples were obtained during CY-1988 from the Fox River in Aurora upstream and downstream from the mouth of Indian Creek. Also, two sets of three samples were obtained from the west branch of the DuPage River in Warrenville (Fig. 2) upstream and downstream from the mouth of Kress Creek and farther downstream past the mouth of Ferry Creek. Neither river is utilized as a drinking water supply downstream from the creek entrances.

4.4.2.1 Tritium

The results for on-site tritium samples yielding detectable levels in surface waters (Fig. 6) are given in Table 2. All other sampling points were at background levels. Water collected from around footings of buildings and underground enclosures and discharged from sumps is considered surface water. Water in aquifers is called groundwater. The total off-site release in surface waters was 336 mCi of tritium this year, this is about a 25% increase over CY-1987. This increase resulted primarily from an increase in the volume of sump water that left the site via Kress Creek. The radioactivity released off the site was at such a low concentration that it could not be detected. Detailed reports of off-site effluent releases and on-site discharges are made via the Department of Energy Effluent and On-Site Discharge Information Systems, EG&G, Idaho.

The surface water from the experimental areas (Fig. 5) flows into Casey's Pond except during wet seasons. During these seasons, the pond fills up (68 million l or 18 million gal capacity) and barricades are placed at the two entrances to the pond to keep the water from flooding the pump room. When these barriers, called stop logs, are in place, the water bypasses the pond and leaves the site via Kress Creek (Figs. 5 and 9). This was the case for approximately 51% of the year in CY-1988, compared to 38% in CY-1987. There were no discharges of radioactivity totaling greater than 1 mCi from a closed loop water system leak in CY-1988.

Table 2

Tritium Detected in On-Site Water Samples
Tritium Concentration C (μCi/ml)*

Collection Point	Number of Samples	C Max	C Max Error	C Min	C Min Error	C Mean	Percentage of Standard
AP0	2	1.9×10^{-5}	1.5×10^{-6}	9.0×10^{-6}	2.0×10^{-6}	1.4×10^{-5}	0.69
G4	4	7.8×10^{-5}	1.1×10^{-5}	$<3.0\times10^{-6}$	---	4.0×10^{-5}	2.0
G5	4	1.3×10^{-5}	2.0×10^{-6}	$<3.0\times10^{-6}$	---	5.7×10^{-6}	.29
G8	2	4.9×10^{-6}	1.2×10^{-6}	$<3.0\times10^{-6}$	---	4.0×10^{-6}	.20
N1 (G9 in Fig. 6)	6	1.1×10^{-4}	1.6×10^{-5}	5.5×10^{-5}	8.0×10^{-6}	8.6×10^{-5}	4.3
MF4	2	1.1×10^{-5}	1.9×10^{-6}	$<3.0\times10^{-6}$	---	6.9×10^{-6}	.35
MF5	6	7.4×10^{-5}	1.1×10^{-5}	2.6×10^{-5}	4.0×10^{-6}	6.0×10^{-5}	3.0
NM1	2	8.9×10^{-6}	1.7×10^{-6}	4.2×10^{-6}	1.2×10^{-6}	6.6×10^{-6}	.33
N2	5	2.1×10^{-4}	3.1×10^{-5}	4.5×10^{-5}	6.7×10^{-6}	1.3×10^{-4}	6.4
NW8	2	3.6×10^{-6}	1.0×10^{-6}	$<3.0\times10^{-6}$	---	3.3×10^{-6}	.17
PW8	2	9.9×10^{-6}	1.8×10^{-6}	$<3.0\times10^{-6}$	---	6.4×10^{-6}	.32
PW9	2	4.5×10^{-6}	1.2×10^{-6}	4.4×10^{-6}	1.1×10^{-6}	4.4×10^{-6}	.22

* 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.

4.4.2.2 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. The tritium remains in the cooling water system. These resins are regenerated in two separate systems located at the Central Utility Building (Fig. 5). The effluent from these two systems is sent to a settling tank for removal of almost all of the radioactivity before it is sent to a clay tile field inside the Main Ring (Fig. 5). There it percolates into the soil about 60 cm (2 ft) below the surface. The short half-life of ^{7}Be and its strong chemical affinity with the soil ensure that any residual radioactivity released will place no burden on the environment. The amount of ^{7}Be discharged to the tile field in CY-1988 was very small; however trace amounts were detected in the sediment and vegetation. See Section 4.4.3 below.

4.4.3 Sediment and Vegetation Sampling

Sediment and vegetation samples were taken near discharge points for radioactive effluents. The results for sediment samples are given in Table 3. The vegetation results are given in Table 4. The samples were taken of the top centimeter of sediment in the ditches. Dry weights were obtained by weighing the samples after baking in an oven for at least 24 hours at 115°C.

The presence of ^{137}Cs (Table 3) indicates fallout from previous atmospheric nuclear testing. The ^{60}Co could be from fallout or accelerator-produced, but appears to be all accelerator-produced based on the locations. The ^{7}Be could be from cosmic ray production or accelerator-produced. The radionuclides ^{22}Na and ^{54}Mn are only accelerator-produced. Note that ^{7}Be and ^{60}Co are elevated in the sample from the CUB Tile Field, even when compared to sump discharge sediment results. This indicates accumulation is occurring even though the bulk of the radioactivity settles out with the precipitating salt. The water drained off is sent to the tile field. Some welling up of that water is bringing radionuclides to the surface.

An annual vegetation sampling program was initiated in CY-1978. Vegetation samples were taken near the radioactive gas exhausts in the Neutrino Area (G9 in Fig. 6) and Antiproton source (Antiproton target in Fig. 5) in addition to vegetation samples in areas with waterborne radioactivity. See Table 4.

Table 3

CY-1988 Sediment Sampling Results

Location	Concentration (pCi/g dry weight)				
	^{7}Be	^{22}Na	^{54}Mn	^{60}Co	^{137}Cs
Ferry Creek	---	---	---	---	0.51±0.04
Indian Creek	2.9±0.6	---	---	---	0.21±0.03
Kress Creek	0.54±0.45	0.04±0.02	---	---	0.18±0.02
APO Sump	2.0±0.5	---	---	---	0.13±0.02
C1 Sump	1.06±0.43	---	---	---	0.17±0.02
MF5 Sump	4.5±1.9	0.68±0.06	0.29±0.04	0.07±0.03	0.11±0.02
N1 (G9) Sump	1.1±0.5	0.71±0.06	0.24±0.03	0.52±0.04	0.06±0.02
N2 Sump	---	0.06±0.02	---	---	0.03±0.02
NM2B Sump	1.3±0.5	0.03±0.02	---	---	---
PW8 Sump	2.6±0.5	0.09±0.02	---	---	---
T3 Sump	---	---	---	---	---
CUB Tile Field	59.9±4.4	0.05±0.3	0.31±0.04	0.90±0.09	0.09±0.02
Site 12*	---	---	---	---	0.27±0.03
APO Stack (0m)	4.9±0.4	---	---	---	---
APO Stack (1m)	1.5±0.6	0.04±0.02	---	---	0.06±0.02
APO Stack (10m)	1.6±0.6	0.03±0.02	---	---	0.08±0.02
N01 Stack (0m)	0.74±0.20	0.11±0.02	---	---	---
N01 Stack (3m)	---	0.11±0.03	---	---	0.08±0.02
N01 Stack (10m)	0.89±0.56	0.03±0.02	---	---	0.07±0.02
N01 Stack (100m)	0.76±0.50	0.09±0.02	---	---	0.06±0.02

*Background levels expected - no radiation sources nearby.

The peak concentrations for vegetation sampling are based on the dry weight of the sample except for ^{3}H which is measured in the water extracted. The results from the analyses of the vegetation samples indicated small concentrations of radionuclides similar to those seen in the past.[24] In other samples based on previous results[29] the radionuclide ^{7}Be is expected to be present as surface contamination from air while other radionuclides are most likely incorporated into the plants. The vegetation contained small quantities of accelerator-produced radionuclides. The amounts of radioactivity are so low that consumption of the vegetation by animals in the human food chain would be permissible. The concentrations of ^{7}Be below 20 pCi/g are unlikely to be accelerator-produced because of the short half-life and correlation to CY-1987

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data.[6] The ^{3}H concentrations are taken adjacent to the low (1 to 3 m or 3 to 10 ft) stacks. Thus, some ^{3}H is being emitted from the stacks, but it is masked by the much higher concentrations of ^{11}C (>10^{6} times higher by calculation).

Table 4

CY-1988 Vegetation Sampling Results

Location	Concentration				
	^{3}H (pCi/ml Vegetation Moisture)	^{7}Be (pCi/g Dry Weight)	^{22}Na (pCi/g Dry Weight)	^{54}Mn (pCi/g Dry Weight)	^{60}Co (pCi/g Dry Weight)
Ferry Creek		12.6±1.9	0.43±0.10	---	---
Indian Creek		14.2±2.1	0.15±0.08	---	---
Kress Creek		11.3±2.2	---	---	---
APO Sump		24.7±2.1	0.29±0.08	---	---
C1 Sump		14.2±2.9	0.25±0.11	---	---
MF5 Sump		15.5±4.5	0.77±0.23	---	---
N1 (G9) Sump		12.1±3.0	---	---	---
N2 Sump		10.0±1.7	0.20±0.07	---	---
NM2B Sump		12.2±1.7	0.30±0.08	---	---
PW8 Sump		13.4±2.2	---	---	---
T3 Sump		9.4±1.3	0.15±0.07	---	---
CUB Tile Field		25.4±2.4	0.09±0.06	---	---
Site 12*		6.9±1.0	---	---	---
APO Stack (0m)	232±23	309±19	---	0.26±0.05	---
APO Stack (1m)	170±17	143±9	---	0.15±0.05	---
APO Stack (10m)	11.4±1.2	---	---	---	
APO Stack (100m)	9.1±1.0				
NO1 Stack (0m)	57±6	8.5±1.1	0.08±0.05	---	---
NO1 Stack (3m)	18.6±1.9	5.9±0.8	---	---	---
NO1 Stack (10m)	6.5±0.7	---	---	---	
NO1 Stack (100m	4.0±0.5	---	---	---	

*Background levels expected - no radiation sources nearby.

4.4.4 Soil Activation

Because the percolation rates for water in Fermilab soils are calculated to be very low - less than 1 m (3 ft) per year[30] - analyses of well waters do not provide the early warning desired for detection of accelerator-produced radioactivity in the groundwater. To provide such a warning soil samples were taken from the vicinity of targets and other locations where proton interactions

result in some radioactivation of the soil. Because the major long-lived radionuclides leachable from Fermilab soils are ^{3}H and ^{22}Na, quantitative measurements were made only on those.[27] Most of the soil activation occurred around the Neutrino Area primary target located in the Target Tube until 1982. Between 1982 and 1988 the target was located in a new enclosure 300 ft south of the Target Tube. At the end of February 1988 the neutrino production program was completed and such targeting is not expected in either of these locations in the future.

Six 45° bore holes were made in CY-1988 beneath the primary targets and beam dumps in use in the Meson and Neutrino Areas (Fig. 7) between 1972 and 1982. These targets and dumps had sand and gravel "bathtubs" (impervious liners or membranes filled with sand and gravel) beneath them. Soil was sampled outside and beneath the bathtubs to a depth of more than 6 m (20 ft) below the lowest underdrains. The Neutrino Area holes were drilled at the north (downstream) end of the Target Tube and under the retention pit in the N01 Enclosure just south (upstream) of the Target Tube.

Soil samples were analyzed for ^{22}Na and ^{3}H by Controls for Environmental Pollution, Inc. (CEP), P.O. Box 5351, Santa Fe, NM 87502. No ^{22}Na was detected (<0.01 pCi/g). The only samples containing detectable levels of ^{3}H are reported in Table 5. The detection limit is 0.2 pCi/ml of soil moisture. The one report of 0.2 ± 0.1 pCi/ml for the sample from the bottom of hole S-1062 in the Meson Area is believed to be a false positive. All other samples were from hole S-1059 at the north end of the Neutrino Area Target Tube. Note that the concentrations are all well below the limit of 20 pCi/ml for community drinking water supplies. Also, the first indication of ^{3}H occurs at the level of the underdrains beneath the bathtub (Fig. 11). It is surprising that the levels are not higher at that point since the concentrations in the discharged water are much higher (N1 Sump in Table 2): Average 86 x 10^{-6} μCi/ml or 86 pCi/ml. Also, one would expect some gradient in concentration rather than the observed fluctuations. To verify the positive results, Fermilab heated three of the split samples and collected the soil moisture. Analyses by IT Corporation gave much higher results: 135 to 309 pCi/ml. See Table 5. Since these results were so much higher than the earlier assays, water samples were obtained from the cased hole. To check for contamination from higher elevations the standing water was sampled. Then the

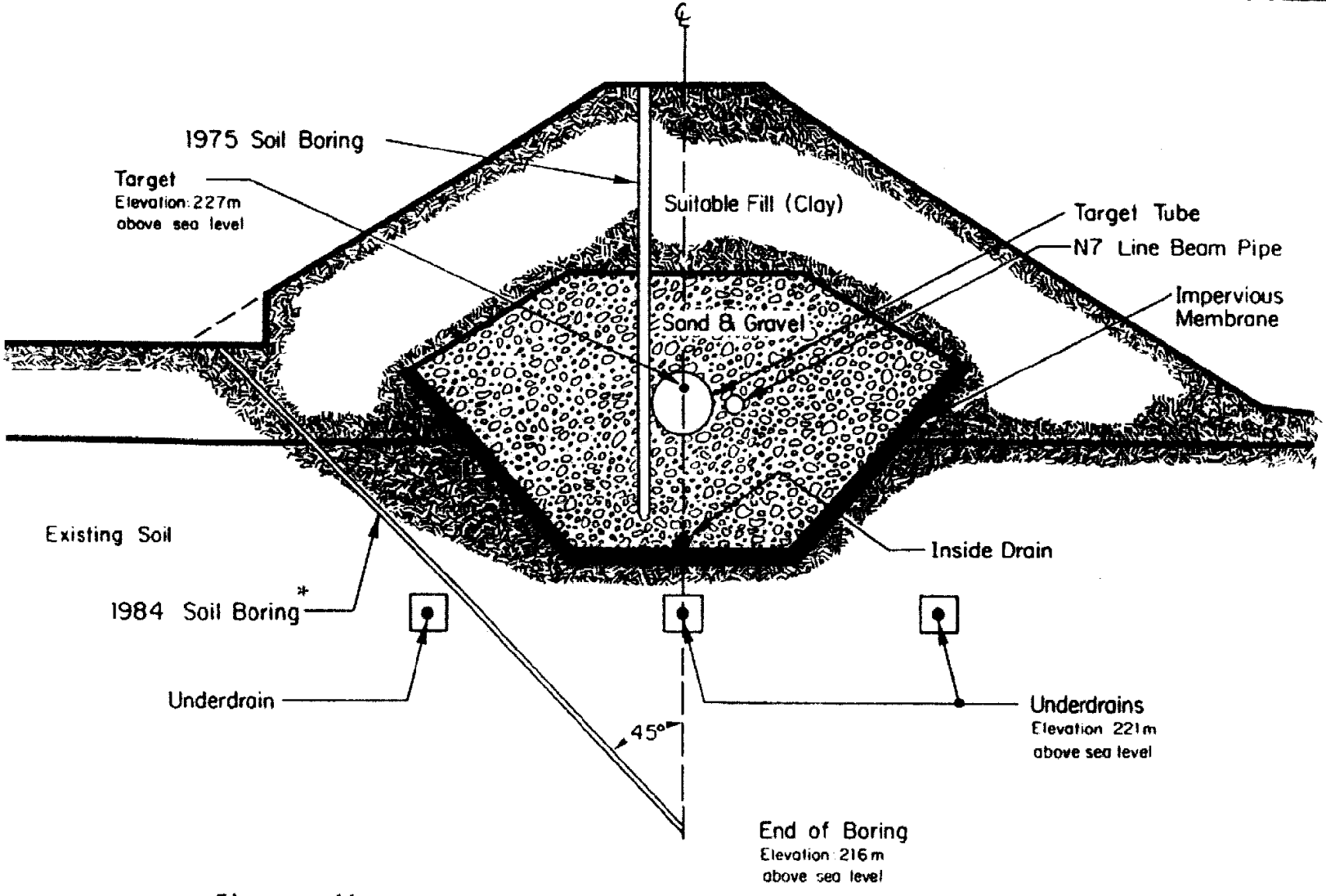

Figure: 11 Cross Sectional View at Neutrino Area Primary Target

*1988 Soil Boring Parallel to
This One and 78 m (255 ft) Away.

Table 5

Tritium Detected in Soil From 45° Bore Holes

Bore Hole Number	Location	Depth in Hole (m)	Depth in Hole (ft)	Elevation Above Sea Level (m)	Elevation Above Sea Level (ft)	Concentration In Soil Moisture (pCi/ml) CEP Result	Concentration In Soil Moisture (pCi/ml) IT Corp. Result
S-1059	Neutrino Area Target Tube North End	8.1-8.8	26.5-29	221.1-221.7	725.4-727.2	0.7±0.1	
		8.8-9.4	29-31	220.7-221.1	724.0-725.4	6.3±0.2	
		9.8-10.1	32-33	220.1-220.5	722.6-723.3	8.1±0.2	264±26
		10.1-10.8	33-35.5	219.7-220.2	720.8-722.6	5.3±0.2	
		10.8-11.6	35.5-5-38	219.2-219.7	719.1-720.8	2.3±0.1	
		11.6-12.2	38-40	218.7-219.2	717.6-719.1	8.1±0.2	
		12.2-13.1	40-43	218.1-218.7	715.5-717.6	2.3±0.2	
		13.1-13.9	43-45.5	217.5-218.1	713.7-715.5	5.0±0.2	135±14
		13.9-14.6	45.5-48	217.0-217.5	712.0-713.7	1.3±0.1	
		14.6-15.4	48-50.5	216.5-217.0	710.2-712.0	2.3±0.1	
		15.4-16.2	50.5-53	215.9-216.5	708.4-710.2	0.8±0.1	
		16.2-16.9	53-55.5	215.4-215.9	706.7-708.4	1.8±0.1	
		16.9-17.7	55.5-58	214.9-215.4	704.9-706.7	0.5±0.1	
		17.7-18.3	58-60	214.4-214.9	703.5-704.9	6.6±0.2	309±39
S-1063	Meson Area Target Box North End	3.0-3.7	10-12	226.7-227.2	743.9-745.3	0.2±0.1	

hole was pumped dry and allowed to recharge. Water entered from slits in the bottom five feet of the casing. The results were as follows:

Table 6

Tritium Detected in Water From 45° Bore Hole

Sample Description	Location	Depth in Hole (m)	Concentration (pCi/ml) IT Corp. Result
S-1059 Standing Water	Neutrino Area Target Tube North End	17.7-18.3	29
S-1059 Recharge Water	Neutrino Area Target Tube North End	17.7-18.3	134

These results indicate that tritiated water has been found 6.7 m (22 ft) below the underdrains.

In CY-1983 a new target and dump system was put into operation to abort any errant protons inside the Main Ring tunnel. The well shielded dump was placed just outside the tunnel (near C1 in Fig. 6). It was provided with a sampling underdrain which normally is not pumped.[11,31] The drains adjacent to the Main Ring tunnel lead to sump pits equipped with pumps, hence water in the region around the tunnel and above the underdrains is normally kept free of standing water. The region below the Main Ring drains is not.

The abort dump itself is sealed watertight. Drains inside have remained dry. The part of the dump below the Main Ring tunnel drains sits in water, permitting leaching of tritium produced in the sand and gravel surrounding the dump. Water samples from the underdrain beneath the dump contain tritium and ^{22}Na. The concentrations are below the DOE Concentration Guides for release to surface waters (Section 8). We have begun a program of pumping water from the sampling underdrain periodically to keep the concentration low. During CY-1988 a test was begun to pump water from the sump at 150 l (40 gal) each day to compare the amount of activity pumped out in one year with that calculated.

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5. Environmental Monitoring for Nonradioactive Pollutants

5.1 Domestic Water Supplies

The primary drinking water supply at Fermilab in CY-1988 was provided by a well pumping from an aquifer approximately 70 m (220 ft) deep. This well (W1 in Fig. 4) is located in the Central Laboratory Area. A second well (W3 in Fig. 4) pumps from the same aquifer and supplies water to the Main Site system when demand exceeds the capacity of the Central Laboratory well (W1 in Fig. 4). On January 28, 1987, the Village system was connected to the supply from Warrenville, the neighboring community to the east. The Village well was totally removed from the system. A new well (W5 in Fig. 4) was installed in 1988 to supply water to a colliding beams experiment under construction at D0. The new water system became operational the end of November 1988.

The Main Site system is chlorinated at the Central Utility Building when Well #1 is providing water. The alternate supply source, Well #3, has its own reservoir and chlorinator. Our water laboratory conducts tests for pH and fecal coliform monthly. Tests of the Village system are also conducted monthly. Monthly samples for total coliform per 100 ml were sent to IEPA for analysis for both systems. No fecal coliform was found and pH conformed to Illinois standards during 1988. The new system at D0 is also a chlorinated system but used sodium hypochlorite rather than chlorine gas. The chlorine level in these chlorinated drinking water supplies is tested each workday. The average use from Well #1 and Well #3 combined was approximately 443,000 l/day (117,000 gal/day) during 1988, approximately the same as reported last year.[6]

The water supply wells, other potable wells, and out of service wells are monitored periodically to see if water meets the State of Illinois standards even in cases where the standards are not mandatory.[32] Eleven potable water wells (Fig. 4), two out of service wells (20 and 45 in Fig. 4) near the CUB tile field (Fig. 5), and one out of service well near the Industrial Area (43 in Fig. 4) were sampled directly in CY-1985.[11] Also, samples were taken from the water taps of the distribution systems of three of these 14 wells. The water from all wells except the one in the industrial area was analyzed for nine metals including chromium, iron, lead, mercury, and zinc. Most of the samples were also analyzed for sodium. Total dissolved solids, chloride, fluoride, sulfate, and nitrate

plus nitrite were also measured as well as pH and cyanide. Water from the chlorinated systems was analyzed for trihalomethanes: chloroform, dichlorobromomethane, dibromochloromethane and bromoform. Water from the industrial area well and other wells in areas where solvents are used were analyzed for ammonium, trichloroethane, trichloroethylene, and total organic carbon. Also, a few wells were sampled for benzene and gasoline. The analyses were performed by Aqualab, Inc. (now NET Midwest), 850 W. Bartlett Road, Bartlett, Illinois 60103.

Several wells were above the standard for iron. This is probably from the plumbing. One well, W3, was above the standards for manganese and total dissolved solids as well as iron. However, all these wells are exempt from the standards for iron and manganese. These standards only apply to community water supplies serving larger populations.[32] Water for the Village system is obtained from Warrenville. The Fermilab Main Site supply (Well W-1 and Well W-3), the new well (W-5) at D0, and the well (55B) at Site 55 are currently the only site non-transient, non-community supplies and will need to meet the new regulations for these systems.[33]

The water laboratory performs coliform tests on unchlorinated well water systems on the site. When coliform levels exceed four colonies per 100 ml, the well is chlorinated and retested. No wells needed chlorination in CY-1988.

Well #29 has a high sulfate concentration and ion exchange resins are used to treat the water. Several other wells are just above the standard for total dissolved solids. Well #50 has a high total organic carbon value compared to other wells. This might indicate organic infiltration. This well is behind a former farm house. There is evidence for a dug well east of the existing well. Thus, there is a potential pathway for organic pollutants to reach the well.

New drinking water regulations were promulgated in CY-1988 regarding concentrations of lead in drinking water.[33] Community water suppliers were required to notify users of the limits and sources of lead. The Village receives its water from Warrenville which is a community supply. Besides notification the Laboratory sampled all the residences in the Village. In every case the concentrations were less than the 50 parts per billion limit. In addition,

samples were taken from the Main Site supply and residences at Site 29 and Site 58 (Fig. 4). These samples were also in compliance.

5.2 Industrial Water Ponding Systems

There are several water systems used for cooling magnets and for fire protection:

The Industrial Cooling Water (ICW) System consists of Casey's Pond (Fig. 5) at the end of the Neutrino Beam Line and underground mains to fire hydrants and sprinkler systems throughout the Central Laboratory Area and Experimental Areas. Casey's Pond is supplied by surface drainage and can be supplied by pumping from the Fox River. The pond holds 68,000,000 l (18,000,000 gal).

The Swan Lake/Booster Pond System (Fig. 5) is used for cooling purposes at the Central Utility Building (CUB). Water is pumped from the Booster Pond into a ditch in which it runs by way of a small West Pond into Swan Lake. The water is then returned to the Booster Pond by a return ditch. Water is also pumped from Swan Lake to NS1 Service Building (G9 in Fig. 6) for cooling purposes, from which it returns by a surface ditch. This system can be supplied water from the ICW System and it overflows into Indian Creek (Figs. 5 and 9).

The Main Ring Ponding System consists of a series of interconnecting canals completely encircling the interior of the Main Ring with a large reservoir pond inside the Main Ring Ponding System (Fig. 5). This water is used in heat exchangers at the service buildings for cooling the Main Ring magnets. The system is generally supplied by surface drainage, although make-up water can be pumped from Casey's Pond. The system overflows into Lake Law (Figs. 5 and 9).

5.3 Other Lakes and Ponds

Surface drainage from the eastern portion of the site flows into Lake Law, DUSAF Pond and the AE Sea (Figs. 5 and 9). These lakes and ponds are accessible to the public, and they are the head waters of Ferry Creek.

Semiannual tests are made of water samples taken where the three creeks leave the site (R1, R2A, and R3 in Fig. 6), as well as from Casey's Pond and the Fox River. Results of the tests for pH, dissolved oxygen, five-day biochemical oxygen demand, (BOD5), suspended solids, and fecal coliform for 1988 are found in Table 7. Tests for fecal coliform bacteria are made monthly in our water laboratory. Levels above 200 were found in Indian Creek and Kress Creek in CY-1988. The explanations for the high readings have not been found. Fecal coliform bacteria are found in recent deposits of fecal material from warm-blooded animals. They serve as an indicator for pathogens which can multiply under similar conditions. Thus, the Laboratory will continue to check the levels, search for the sources of nutrients, and look for any effects. Results for pH were above the standard of 9.0 for water in general use for Ferry Creek in April 1988, for the Fox River in April and October 1988 and for Casey's Pond in October. There were no adverse effects noted in Casey's Pond.

5.4 Sewage Treatment

On December 22, 1986, the Village sewage collection system was connected to the City of Warrenville system and has been delivering sewage to the Naperville Springbrook Treatment Plant via that system since then. The Naperville plant is a modern sewage treatment system with ample capacity. The Main Site sewer system was connected to the City of Batavia system June 26, 1979, and has been delivering sewage to the Batavia sewage treatment plant since that time. The IEPA terminated the NPDES permit for the Village Oxidation Pond on May 12, 1987, at the Department of Energy's request.

5.5 Chemical Treatment of Water Systems

Some chemical treatment of our various water systems is required each year to control the growth of algae and aquatic weeds. Only EPA registered chemical agents are used. These are applied by trained personnel licensed by the State of Illinois and following the manufacturer's directions.

Table 7

Site Wide Water Quality Report for CY-1988

	pH		D0 mg/l		BOD5 mg/l		Susp. Solids mg/l		Fecal Coliform mg/l	
	April	Oct	April	Oct	April	Oct	April	Oct	April	Oct
Ferry Creek	9.5	Dry	10.3	Dry	8.3	Dry	34	Dry	4	Dry
Kress Creek	8.3	8.3	8.6	5.2	1.0	1.9	0	31	88	700
Indian Creek	8.5	8.8	10.2	5.2	0.7	3.7	2	55	56	600
Casey's Pond	8.9	9.5	7.4	5.9	1.1	1.3	2	38	0	100
Fox River	9.2	9.1	7.9	6.1	4.6	3.8	13	30	108	100
General Standards[28]	6.9 -	9.0	Not less than 5.0 at any time		*		*		Mean of 200	

* There are standards for effluent from treatment works or waste water sources, but no general standards.

5.5.1 Chlorine

In addition to the routine chlorination of the Main Site water system and the swimming pool, a chlorination system for the Swan Lake cooling pond system has proved successful in helping to eliminate the need for chromate treatment of the cooling towers. Chlorine is added to the cooling water for a period of 30 minutes four times a day at a rate which results in a chlorine concentration of 0.5 ppm as the cooling water leaves the equipment. Only one piece of equipment within the plant is chlorinated at a time. Consequently the concentration of chlorine entering the Swan Lake system is significantly reduced from 0.5 ppm.

Bromine was used for the first time in 1987 for water treatment at Fermilab. Water pumped from Casey's Pond was treated with a 1-Bromo-3chloro-5,5-dimethyl hydantoin chemical in a pellet form. This chemical, Nalco 85WT-037/7343, is supplied by Nalco Chemical Company, One Nalco Center, Naperville, Illinois 60566. The bromamines formed when the chemical reacts with agricultural based amines are more effective biocides than chloramines. Thus, better control of biological growth in the heat exchangers in the Research Area is expected using this treatment instead of chlorination. No treatment has been done in the past because air towers rather than industrial water heat exchangers were used. A comprehensive monitoring program to minimize the amount of chemical required has been initiated. The total available halogen was adjusted to be 0.2 mg/l or less in the water as it leaves the heat exchangers. The total amount of Nalco 85WT-037 used in CY-1988 was only 160 kg (350 lbs).

5.5.2 Aquazine

The Village Oxidation Pond was treated three times in CY-1988 in an attempt to control algae growth and reduce suspended solids. The total applied quantity of Aquazine, containing 80% simazine: 2-chloro-4, 6-bis (ethylamino)-s-triazine, was 218 kg (480 lbs). Aquazine was also used to treat the Main Ring Ponding System, the Swan Lake/Booster Pond System, and the reflecting ponds by Wilson Hall in CY-1988 (Fig. 5). Approximately 1633 kg (3600 lbs) of Aquazine was applied to the Main Ring Ponding System, 558 kg (1230 lbs) was applied to the

Swan Lake/Booster Pond System, and 84 kg (186 lbs) was applied to the reflecting ponds.

5.5.3 Heavy Metals and Other Toxic Materials

No heavy metals were used for water treatment of the cooling towers. The chlorinated Swan Lake cooling pond water was passed through the cooling system and a biodispersant, Nalco 7349, was added which lifted deposits from the metal surfaces so they could be oxidized by the chlorine. The biodispersant was fed intermittently with the rate of application adjusted to maintain a peak concentration of 20 mg/l. Nalco 7349 is a polyglycol manufactured by Nalco Chemical Company. Another Nalco product, Nalco 7387, was applied continuously to maintain less than 1 mg/l with a peak total phosphorus concentration of 1.3 mg/l. Nalco 7387 is an organophosphorus compound which prevents scale information. It does not have the toxic properties of organic phosphorus esters found in some restricted-use pesticides.[34] A total of 977 kg (21,500 lb) of Nalco 7387 was used and about 10% that much Nalco 7349.

Trace amounts of heavy metals and copious quantities of sodium chloride have been discharged into the CUB Tile Field (tile field in Fig. 5) inside the Main Ring in the past. Copper is the primary heavy metal. It is an impurity removed by the ion exchange resins used to keep the conductivity of closed loop water systems low. These mixed-bed resins are regenerated using hydrochloric acid and sodium hydroxide. When the two chemicals combine after traversing the resins, salt•(NaCl) is formed. Trace amounts of ^{7}Be are also removed (Section 4.4.2.2). A settling tank was used beginning in CY-1986 to remove salt and ^{7}Be from the effluent from resin regeneration. The salt is being stored to allow ^{7}Be levels to decrease by radioactive decay. Concentration of the radionuclides by reducing the water content with a press and then drying the salt in an oven has resulted in detection of ^{60}Co in the salt. Disposal methods are being investigated.

6. Evaluation of Environmental Impacts

6.1 Assessments of Potential Radiation Dose to the Public

Fermi National Accelerator Laboratory is located in the densely populated Chicago area. There are about eight million people living within 80 km (50 mi) of the site (Fig. 3).[35] There are 326,645 people within 16 km (10 mi) of the center of the main accelerator based on the 1980 census results compared to 265,677 counted in the 1970 census.[36] The detailed distribution of population as a function of distance and direction from Fermilab is given in Table 8.[36] The population distribution close to Fermilab is shown in Fig. 12. The estimated increase in population from 1980 to 1988 is 13.6% within 16 km (10 mi) of Fermilab based on county and local city population estimates.[1,2]

The dose rate at the site boundary in CY-1988 from Fermilab operations was primarily from muons from the Research Area (Fig. 1). The total dose to the individual receiving the maximum from Fermilab operations was 1.2 mrem for CY-1988. The point where that exposure occurred is along the northeastern site boundary. This is approximately 1% of the background radiation dose.[37] The dose rate at the site boundary from the Boneyard was 1.6 mrem but decreased to only 0.3 mrem at the nearest residence.

The radiation exposure to the general population from operation of Fermilab in CY-1988 was approximately 3.3 person-rem (Table 9). This exposure was primarily from penetrating radiation (muons and gamma rays). This total is to be compared with a total of approximately one million person-rem to the population within 80 km (50 mi) from natural background radioactivity.[36,37] Based on typical United States radiation exposures from diagnostic x-rays, medical treatments, and other artificial sources an additional 500,000 person-rem would be expected for the population in the Chicago area with 80 km (50 mi) of Fermilab in CY-1988.[38]

The magnet debonding oven was used to debond 11 radioactive magnets in CY-1988. The resulting ^{3}H release from the debonding oven stack had negligible impact.

Table 8

Incremental Population Data in Vicinity of Fermilab, 1980

LATITUDE = 41.832 LONGITUDE = 88.251

DISTANCE, KILOMETERS FROM CENTER OF MAIN RING	0-8	8-16	16-32	32-48	48-64	64-80	80-97	97-113	113-128
DISTANCE, MILES DIRECTION	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80
N	198	1110	77247	75658	63188	37183	30696	28459	149892
NNE	3455	5821	68274	76075	120930	145415	100858	173092	87495
NE	9836	12718	78701	292724	139718	0	0	0	0
ENE	1445	63784	263526	840460	551913	0	0	0	0
E	4472	18423	218631	1107254	924752	0	0	33317	56442
ESE	3081	15075	92242	268040	597113	379986	196888	78056	17600
SE	2655	25167	37956	34405	106938	38944	24651	11963	10027
SSE	339	3262	44203	148699	7962	21154	70503	10828	13195
S	841	1336	8604	10301	17011	11089	6640	4354	11967
SSW	7855	49656	8635	3492	17420	6373	25217	24588	10469
SW	6344	35851	13598	15566	5317	30917	36362	13671	13226
WSW	5830	2205	5578	6322	4509	10930	8474	11704	12175
W	3641	971	2941	5339	5111	13693	8445	28768	49103
WNW	7595	851	3018	42762	6723	21231	40449	13891	37012
NW	4641	9607	3297	7974	7358	65288	157549	71682	28229
NNW	3428	15152	22722	10674	29830	17952	29399	24276	58430
TOTAL	65656	260989	949173	2945745	2605793	800155	736131	528649	555262
CUMULATIVE TOTAL	65656	326645	1275818	4221563	6827356	7627511	8363642	8892291	9447553

Figure 12

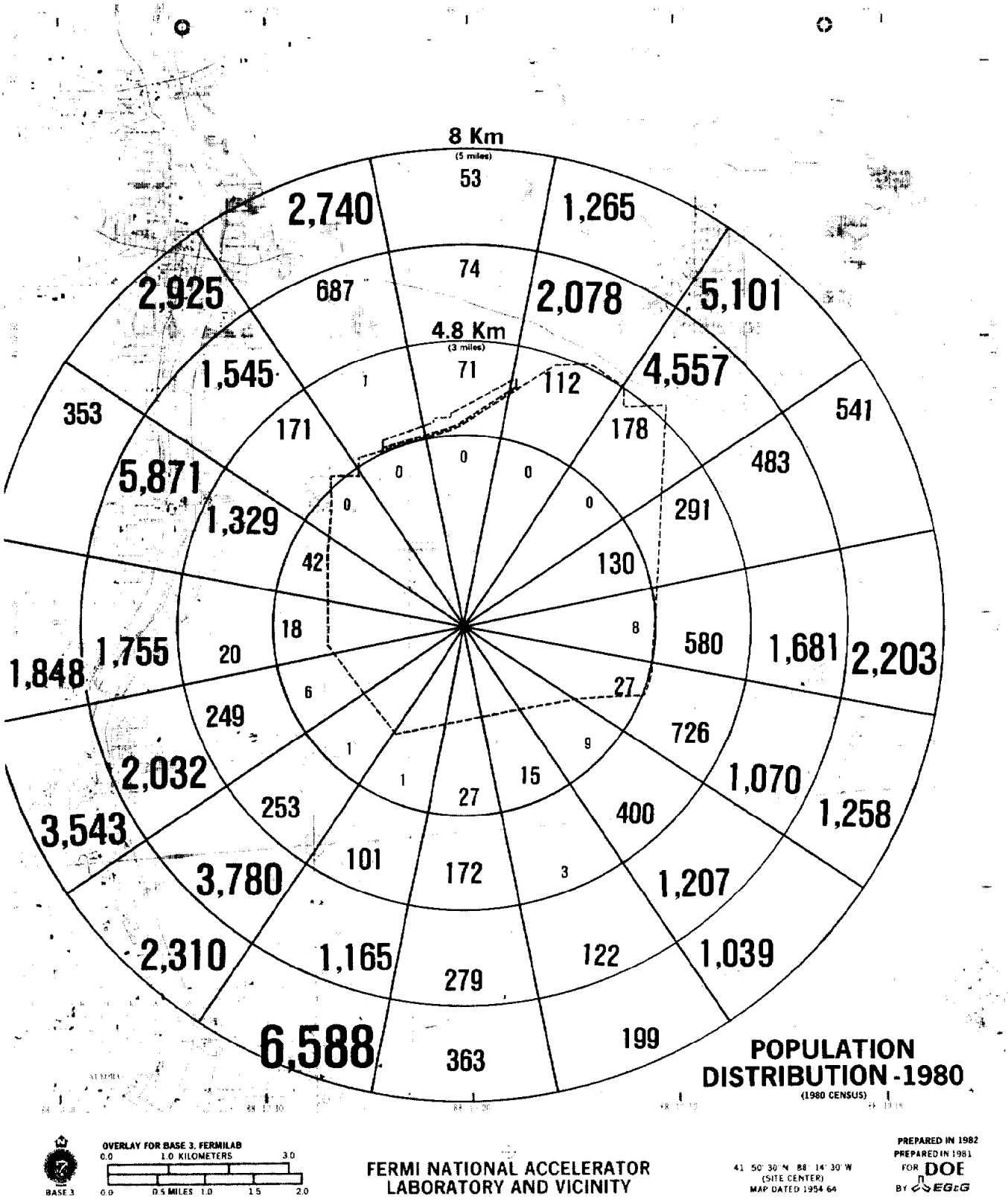
8 Km
(5 miles)
4.8 Km
(3 miles)
53
74
71
112
2,740
1,265
2,925
687
2,078
5,101
1,545
4,557
353
171
178
541
5,871
483
1,329
291
42
130
18
8
580
1,681
2,203
1,848
1,755
20
6
27
249
726
2,032
1
9
1,070
1
15
1,258
3,543
253
27
400
101
172
3
1,207
3,780
2,310
1,165
122
1,039
279
199
6,588
363
POPULATION
DISTRIBUTION - 1980
(1980 CENSUS)
OVERLAY FOR BASE 3, FERMILAB
0.0 1.0 KILOMETERS 3.0
0.0 0.5 MILES 1.0 1.5 2.0
BASE 3
FERMI NATIONAL ACCELERATOR
LABORATORY AND VICINITY
41° 50' 30" N 88° 14' 30" W
(SITE CENTER)
MAP DATED 1954 64
PREPARED IN 1982
PREPARED IN 1981
FOR DOE
BY EG&G

Table 9

Summary of Population Exposures for CY-1988
Within a 80 km (50 mi) Radius of Fermilab

Sources	Contributions to Population Exposures (person-rem)
Penetrating radiation (muons) from the Research Area	0.6
Penetrating radiation (gamma rays) from the Boneyard	1.8
Airborne radioactivity from the Antiproton Area	0.9
Airborne radioactivity from the Neutrino Area	0.0
TOTAL	3.3

Some releases of radioactive water occurred from sumps collecting water from under areas where protons interacted. About 51% of this volume of water left the site while Casey's Pond (Fig. 4), 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 Derived Concentration Guide for prolonged exposure to the general population. Also, drinking water in the area is taken from wells rather than from the creek receiving the discharge. Hence, the dose from the release was negligible.

Between April and July 1987, a radon survey was conducted at Fermilab. The survey included Village residences, office areas and beam tunnels. The charcoal canister method[39] was used. A total of 41 canisters were used in this study. Four locations had results greater than the EPA residential standard of 4 pCi/l (Section 8). None of these locations has a high occupancy factor. The highest result was 8.0 pCi/l and the geometric mean was 1.4 x+ 2.3 pCi/l.

The results of the survey do not indicate a need for remedial action in any area. Based on measurements covering a large portion of the site, it appears that the site is a normal radon concentration area.

6.2 Assessment of Nonradioactive Pollutant Releases

Although it was necessary to chemically treat some waters with aquazine to control the growth of algae and weeds during CY-1988, efforts were made to keep these treatments as low as possible in order to protect wildlife and fish. Aquazine is biodegradable and no environmental impact is expected. There is a program to look for persistent chemicals in the Fermilab environment periodically.

There were no activities during CY-1988 which created problems with respect to nonradioactive airborne effluents. Heating is accomplished by use of natural gas, liquefied propane gas, or electricity. The bulk of the heating is supplied by natural gas fired boilers located in the Central Utility Building. These boilers are adjusted annually to maintain proper combustion efficiency.

6.3 Potential Impact of Other Toxic Substances

6.3.1 Pesticides

In addition to the water treatments mentioned in Section 5.5, the following EPA registered herbicides, insecticides and rodenticides were applied by trained personnel following the manufacturer's instructions:

For broad leaf noxious weed control of the bison pasture 114 l (30 gal) of 2,4-D Amine was applied to 32 hectares (80 acres) in 1988. In addition, Trimec herbicide containing 27.6% 2,4-D, 13.9% 2-(2-methyl-4chlorophenoxy) proponic acid (MCPP), and 2.8% 3,6-dichloro-o-anisic acid (Dicamba), was applied to turf areas to control broad leaf weeds in the Village and Sauk Circle just south of the Village (Fig. 1), around Wilson Hall, the east reflecting pond, Swan Lake, West Pond (near Swan Lake in Fig. 5), Sites 29, 38, 50, 52, 58 (Fig. 5), the Experimental Areas Operations Center, Master Substation, New Muon Lab, Proton Assembly Building and Pioneer Cemetery in the Experimental Areas or Research Area (Fig. 1), Neutrino Area bubble chamber area (Fig. 1), the Industrial Area, Central Helium Liquefier (near the Industrial Area in Fig. 1), and main accelerator area. Also, turf at various locations along Pine Street, Wilson Road, and Roads A, B, and D (Fig. 1) were treated. Approximately 379 l (100 gal) was applied in 1988.

Roundup, containing 40% isopropylamine salt of N-(phosphonomethyl) glycine, and 40.4% Surflan A.S., containing Oryzalin (3,5-dinitro-N4,N4-dipropylsulfanilamide) were applied in equal amounts around bases of trees, fire hydrants, sign posts, foundations, and liquified petroleum gas tanks to control annual and perennial grasses and weeds. The rate of application was approximately two liters (one-half gal) each per 0.4 hectare (acre). The weeds and grasses treated were in the Village and Sauk Circle just south of the Village (Fig. 1), along major Fermilab roads, around Wilson Hall, Collider Detector Facility near the Industrial Area, Industrial Area, new Muon Laboratory, Neutrino Area bubble chamber, Experimental Areas Operations Center and Sites 38, 50, 52, 56, 58, and 64 (Figs. 4 and 5).

Spike 80W, a non-selective herbicide containing tebuthiuron, was applied to 0.008 km^2 (2 acres) to control vegetation in areas of the Bubble Chamber yard and 19 monitoring well sites, on gravel in the Proton Area, and along barn foundations at Sites 3, 12, 50, 65, 67, and 70 (Figs. 4 and 5).

Corn was planted by licensees in CY-1988 on 7.91 km^2 (1955 acres). Licensees are persons who pay the Laboratory for use of a portion of the land on the site for agricultural purposes. Pesticides were applied as follows:

5881 l (1554 gal) Lasso-atrazine herbicide, containing 27.2% alachlor [2-chloro-2'6'-diethyl-N-(Methoxymethyl)acetanilide] and 15.5% atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)s-triazine], applied to 5.03 km^2 (1243 acres).

4905 kg (10814 lbs) Counter insecticide, containing 15% terbufos (S-{[(1,1-dimethylethyl)thio] methyl}0, 0-diethyl phosphorodithioate) applied to 5.03 km^2 (1243 acres).

1602 l (423 gal) Bicep-6L herbicide, containing 27.4% atrazine, 1.5% atrazine related compounds, and 36.1% metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide], applied to 2.74 km^2 (677 acres).

2673 kg (5893 lbs) Lorsban 15G insecticide, containing 15% chlorpyrifos [0,0-diethyl 0-(3,5,6-trichloro-2-pyridyl)phosphorothioate] was applied to 2.74 km^2 (677 acres) at planting time to control soil insects. Approximately 38 l (10 gal) of Lorsban was applied to 0.16 km^2 (40 acres) of alfalfa north of Batavia Road. The treatment was for control of alfalfa weevil (Hypera postica).

A helicopter spray operation became necessary in July 1988 for control of western and northern corn rootworm beetles (Diabrotica virgifera virgifera and Diabrotica longicornis barberi). Sevin brand XLR plus carbaryl insecticide, containing 1-Naphthyl N-methylcarbamate 43% by weight, was applied to 1.5 km^2 (371 acres) of corn in the northeastern section of the Laboratory. Approximately 88 l (23 gal) was sprayed after stationing ground-based observers to ascertain that the pesticide was applied properly.

Soybeans were planted by licensees in CY-1988 on 0.81 km^2 (200 acres). The following pesticides were applied to this land:

1.09 kg (2.4 lbs) Sencor DF herbicide, containing metribuzen: 4-Amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4 triazin-5(4H)-one 75%, applied to 0.16 km^2 (40 acres).

42.6 l (11.3 gal) Dual 8E herbicide, containing metolachlor: 2-chloro-n (2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide 86.4%, applied to 0.16 km^2 (40 acres).

186 l (40 gal) of Basagran herbicide, containing 42% bentazon (3-(1methylethyl)-1H-2,1,3-benzothiadiazin-4-(3H)-one 2.2-dioxide applied to 0.79 km^2 (194 acres).

24 l (6 gal) of Fusilade 2000 herbicide containing 13% fluazitop-p-butyl: butyl 2-(4.5-trifluoromethyl-2-pyridi/oxy) phenoxyproprionate applied to 0.14 km^2 (34 acres).

For mosquito control, an ultra low volume application of CYTHION Premium Grade Malathion insecticide was performed at only two different times.

Approximately 11 l (2.8 gal) of CYTHION were used in each application at Sites 29 and 58 (Figs. 4 and 5).

Contrac Rat and Mouse Bait, EPA #12455-36, a rodenticide containing 0.005% 3-[3-(4'Bromo-[1,1'-biphenyl]-4-yl)-3-hydroxy-1-phenylpropyl]-4-hydroxy-2H-1-benzopyran-2-one was placed in pan-type feeders inside approximately 40 outdoor electrical substations to reduce rodent nesting in this high voltage equipment. Approximately 11.3 kg (25 lbs) was used in CY-1988.

Approximately 100 trees on the site were treated with Dipel, containing bacillus thuringiensis, for killing eastern tent caterpillars (Malacosoma sp.). Approximately 0.23 kg (0.5 pounds) was applied diluted in 379 l (100 gal) of water.

Several walnut trees at Site 58 (south of 55 in Fig. 4) were treated with 0.15 kg (0.33 lb) of Orthene 75 S, containing acephate (O.S-Dimethyl acetylphosphoramidothioate) 75% to remove aphids and scale.

The services of a contract exterminator, licensed by the State of Illinois and using EPA registered pesticides, was retained during CY-1988 for the control of miscellaneous pests found in kitchens, laboratories and living areas throughout the site.

6.3.2 Polychlorinated Biphenyls

An inventory of polychlorinated biphenyls (PCBs) still on the site is maintained. PCB inspections are performed and reports made to the U. S. Environmental Protection Agency as called for in the regulations.[40] The PCB Status Report as of January 1, 1988, listed 51 PCB transformers in use, in storage for use, or in storage for disposal. The inventory of large PCB capacitors in use, in storage for use or in storage for disposal was reduced from 1718 to 106 in CY-1988. The capacitors were disposed of by incineration in an off-site EPA-approved incinerator. Efforts are being made to obtain non-PCB substitutes for those few still in service.

6.3.3 Hazardous Wastes

Responsibility for disposal of hazardous waste was assigned to the Safety Section in CY-1979 and a hazardous waste handling and storage facility was developed at Site 55 (Fig. 5). This facility is roofed and fenced, and has a hardstand and three concrete containment areas. An additional facility with concrete containment area for PCBs was developed at Site 3 where the Environmental Monitoring Station is located (Fig. 5). This facility is for inside storage of hazardous materials which are for future use. In CY-1982 a PCB storage building was constructed at Site 55 which is much farther from the site boundary than Site 3. Off-site impact from a potential airborne release of PCBs was greatly reduced when most of the PCB items were removed from Site 3. In CY-1984 a heated chemical waste storage building was added at Site 55. This facility was completed in 1985 and has a hood and an indoor shower and eyewash. It also has indoor containment areas to segregate acids and bases. Typical wastes are solvents, oils, laboratory chemicals, asbestos, acids, and bases.

Over the years it has been the practice to deposit excess materials such as lumber, concrete, building materials and earth on the Meson Area shielding hill (north of the Meson Lab, Fig. 1) to scatter muons and provide some additional shielding. To assure that none of these materials is hazardous to the environment and none will contribute to the contamination of surface or groundwaters, a program to control such deposition was developed during 1979. Rules have been promulgated and responsibility for access and control has been assigned to the Roads and Grounds group. The Safety Section monitors this program. In 1982 burial of wood, paper and other wood products on the hill was halted.

6.3.4 Heavy Metals

Copper sulfate is no longer used to treat the ponding systems. Copper solution from the etching of printed circuit boards was disposed of as hazardous waste or recycled. Chromate treatment of the cooling towers has been replaced by biodegradable treatments. All residences on the site were sampled for lead in drinking water. All were in compliance with new regulations. Thus, the environmental impact from heavy metals is and should continue to be negligible.

6.3.5 Chlorides

The potential environmental impact of release of chlorides from the resin regeneration process into the CUB clay tile field (Fig. 6) has been evaluated. The process uses sodium hydroxide and hydrochloric acid, yielding sodium chloride (salt) and water. Assuming the salt released in one year (before CY-1986) all ends up in the nearest drinking water well (W1 in Fig. 4) and is diluted in the water normally pumped from the well for one year, the concentration would be less than 25% of the applicable limit of 250 mg/l. See Section 8. Thus, the environmental impact should be minimal. A similar result was found for the impact from salt applied to Fermilab roads in the winter. Disposal of large volumes of salt in the CUB Tile Field was halted in CY-1986.

6.3.6 Ethylene Glycol

Ethylene glycol is used in closed loop low conductivity water systems which might freeze in the winter. One such system in the Neutrino Area (near R4 in Fig. 6) developed a leak underground in late 1987. The leak continued until the end of the fixed target running period in February 1988. The amount released in CY-1988 was 2530 l (668 gal). Some of it was detected in the water discharged from a sump. That concentration was about 10,000 mg/l which is at the level where fish can be affected. By the time the water reached Casey's Pond, dilution was sufficient to result in no adverse environmental impact.

6.3.7 Chlorofluorocarbons

A mixture of chlorofluorocarbons (Freon® 115 and 116) having high vapor pressure became contaminated with oil (about 10% by volume) when a bubble chamber piston seal failed. The mixture was placed in a propane gas storage tank awaiting disposal. During early CY-1988 a leaking valve was discovered on the propane tank. Approximately 520 l (137 gal) of chlorofluorocarbons had vented. This material has the potential for an adverse environmental impact on the ozone layer.

1988

7. Quality Assurance in CY-1988

7.1 Quality Control

Water samples collected in CY-1988 were analyzed by International Technology (IT) Corporation, 1550 Bear Creek Road, Oak Ridge, Tennessee 37831. In addition, such samples were counted at the Fermilab Nuclear Counting Laboratory. All ^{45}Ca and ^{3}H analyses were done by IT Corporation. Chemical separations have been found necessary for ^{45}Ca assay in the presence of ^{22}Na and other radionuclides. Each shipment to IT included at least one sample prepared at Fermilab containing known amounts of several of the accelerator-produced radionuclides. Known concentrations of tritium were included in every shipment.

7.1.1 Analytical Procedures at IT Corporation

IT Corporation analyzes water samples using similar procedures to those described previously.[41] Liquid scintillation counting is done using the scintillator "Pico-FluorLLT" and a counting system, both of which were manufactured by Packard Instrument Co., Inc., 2200 Warrenville Road, Downers Grove, Illinois 60515. Gamma spectroscopy is done with intrinsic germanium semiconductor detectors with efficiencies 20% to 30% that of a 7.6 cm dia. x 7.6 cm high NaI (Tl) scintillator. Alpha detection is done using a scintillation counter after whatever specific chemical separation is required. Screening for ^{45}Ca is done by liquid scintillation counting. Any necessary chemical separation of ^{45}Ca is followed by beta counting using gas-flow proportional counters.[42]

The samples were subjected to the appropriate one of the following analyses:

Type 1a: Test for ^{3}H (tritium), ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn, and ^{60}Co at surface water sensitivities. See Table 10.

Type 2a: Test for all of the above at groundwater sensitivity plus total radium (the sum of ^{223}Ra, ^{224}Ra, and ^{226}Ra) and total thorium (the sum of ^{228}Th and ^{232}Th).

Table 10

Specifications for the Analyses of Accelerator-Produced Radionuclides in Water

Radionuclide	CONCENTRATION GUIDE FOR POPULATION (μCi/ml) Prolonged Period of Exposure	Community Water System	SPECIFIED SENSITIVITY AND PRECISION* (μCi/ml) Surface Water	Groundwater
^{3}H	2×10^{-3}	2×10^{-5}	3×10^{-6}	1×10^{-6}
^{7}Be	1×10^{-3}	4×10^{-5}	5×10^{-7}	5×10^{-7}
^{22}Na	1×10^{-5}	4×10^{-7}	3×10^{-7}	2×10^{-8}
^{45}Ca	5×10^{-5}	2×10^{-6}	3×10^{-7}	6×10^{-9}
^{54}Mn	5×10^{-5}	2×10^{-6}	1×10^{-7}	7×10^{-8}
^{60}Co	5×10^{-6}	2×10^{-7}	1×10^{-7}	2×10^{-8}

* The precision and sensitivity are stated for the 95% confidence level (approximately two standard deviations). The precision required is the value specified or ±10 percent, whichever is the lesser precision. The sensitivity is taken to be the minimum concentration which can be detected within the 68 percent confidence level.

Type 3a: Chemical separation of ^{45}Ca before its determination; otherwise the same as Type 1a.

Type 4a: ^{3}H only, at surface water sensitivity.

Type 5a: Chemical separation of ^{45}Ca and analysis for ^{45}Ca only, using surface water sensitivity.

Type 6a: The same as Type 1a except at groundwater sensitivity.

Type 7a: The same as Type 4a except at groundwater sensitivity following distillation.

Type 8a: Test for gross alpha, gross beta, ^{3}H, ^{131}I, and ^{134}Cs at groundwater sensitivity. This analysis is performed on drinking water systems on-site which supply water to more than 25 people during the workday.

Type 9a: Test for Sr-90 only, at groundwater sensitivity.

Separate analyses of two aliquots from the same sample bottle is indicated by changing the letter "a" to the letter "b" on the Type designation.

The specifications for the above analyses are given in Table 10.

7.1.2 Quality Assurance Samples

During CY-1988 Fermilab and IT Corporation participated in the DOE Environmental Measurements Laboratory (EML) quality assurance program.[43] Results are given in Tables 11 and 12. Note problems with Fermilab's performance on ^{3}H analysis. All ^{3}H samples were done by the vendor in CY-1988 (Section 4.4). Other results were comparable. Also, Fermilab sent quality assurance samples monthly to IT Corporation, who analyzed Fermilab water samples independently. See Table 13. IT Corporation is reporting values for ^{45}Ca which are consistently lower than the amounts in the samples prepared by Fermilab. Since ^{45}Ca is reabsorbed almost immediately after being leached from the soil,[26] ^{45}Ca is not expected to be present in Fermilab water samples.

Table 11

EML Quality Assurance Program Results for Fermilab*

Sample Date	Radio-Nuclide	Percentage of Concentration Guide for Surface Waters**	Prepared Concentration	Ratio of Fermilab Result to Prepared Concentration
3/88	^{3}H	1.04	2.07×10^{-5} µCi/ml	1.42
	^{54}Mn	14.0	7.00×10^{-6} µCi/ml	1.03
	^{60}Co	38.2	1.91×10^{-6} µCi/ml	0.94
	^{7}Be	+	4.73×10^{-3} µCi	1.08
	^{54}Mn	+	3.63×10^{-4} µCi	1.05
	^{60}Co	+	2.82×10^{-4} µCi	0.99
9/88	^{3}H	0.53	1.06×10^{-5} µCi/ml	3.01
	^{54}Mn	3.0	1.52×10^{-6} µCi/ml	1.08
	^{60}Co	73.6	3.68×10^{-6} µCi/ml	1.08
	^{7}Be	+	2.16×10^{-3} µCi	0.99
	^{54}Mn	+	1.85×10^{-4} µCi	1.01
	^{60}Co	+	3.74×10^{-4} µCi	0.89

*Samples prepared by Environmental Measurements Laboratory
**Prolonged Exposure (Table 10)
+Air Filter

Table 12

EML Quality Assurance Program Results for IT Corporation*

Sample Date	Radio-Nuclide	Percentage of Concentration Guide for Surface Waters**	Prepared Concentration	Ratio of IT Corp. Result to Prepared Concentration
3/88	^{3}H	1.04	2.07×10^{-5} µCi/ml	0.98
	^{54}Mn	14.0	7.00×10^{-6} µCi/ml	1.07
	^{60}Co	38.2	1.91×10^{-6} µCi/ml	1.04
	^{7}Be	+	4.73×10^{-3} µCi	0.92
9/88	^{3}H	0.53	1.06×10^{-5} µCi/ml	0.97
	^{54}Mn	3.0	1.52×10^{-6} µCi/ml	1.09
	^{60}Co	73.6	3.68×10^{-6} µCi	1.13
	^{7}Be	+	2.16×10^{-3} µCi	1.10
	^{54}Mn	+	1.85×10^{-4} µCi	1.14
	^{60}Co	+	3.74×10^{-4} µCi	0.99

*Samples prepared by Environmental Measurements Laboratory
**Prolonged Exposure (Table 10)
+Air Filter

Table 13
Fermilab Quality Assurance Program Results for IT Corporation*

Sample Number	Radio-Nuclide	Percentage of Concentration Guide for Surface Waters**	Prepared Concentration (μCi/ml)	Ratio of IT Corp. Result to Prepared Concentration
8802	^{3}H	6.0	1.20×10^{-4}	0.94
8803	^{3}H	0.2	3.00×10^{-6}	$0.33,^{+}1.13$
	^{7}Be	0.1	1.20×10^{-6}	1.26
	^{22}Na	9.0	9.00×10^{-7}	1.15
	^{45}Ca	0.8	4.00×10^{-7}	0.32
	^{54}Mn	0.8	4.20×10^{-7}	0.89
	^{60}Co	25.0	1.30×10^{-6}	0.99
8804	^{3}H	0.6	1.20×10^{-5}	$.86^{+},.75$
8805	^{3}H	0.3	6.00×10^{-6}	1.25
	^{7}Be	0.03	2.50×10^{-7}	1.98
	^{22}Na	6.6	6.60×10^{-7}	1.14
	^{45}Ca	1.4	6.90×10^{-7}	0.12^{++}
	^{54}Mn	2.1	1.03×10^{-6}	0.91
	^{60}Co	50.0	2.50×10^{-6}	1.56^{++}
8806	^{3}H	6.0	1.20×10^{-4}	0.96
8807	^{3}H	0.3	5.90×10^{-6}	16.49†
	^{7}Be	0.0	0.00	Ok
	^{22}Na	42.0	4.20×10^{-6}	1.17^{++}
	^{45}Ca	1.1	5.30×10^{-7}	0.19^{++}
	^{54}Mn	86.8	4.30×10^{-5}	1.05
	^{60}Co	24.2	1.20×10^{-6}	9.74†
8808	^{3}H	119.0	2.40×10^{-3}	$.93^{+},1.15^{++}$
8809	^{3}H	0.0	0.00	OK††
8810	^{3}H	4.8	9.60×10^{-5}	1.21^{++}
	^{7}Be	1.3	1.3×10^{-5}	0.98
	^{22}Na	81.0	8.20×10^{-6}	0.95
	^{45}Ca	120.0	6.00×10^{-5}	0.57^{++}
	^{54}Mn	17.7	8.80×10^{-6}	0.99
	^{60}Co	406.0	2.03×10^{-5}	1.03
8811	^{3}H	0.5	9.27×10^{-6}	0.76
8812	^{3}H	47.8	9.57×10^{-4}	1.01
	^{7}Be	1.5	1.48×10^{-5}	1.03
	^{22}Na	7.9	7.91×10^{-7}	1.01
	^{45}Ca	9.8	4.90×10^{-6}	0.37^{++}
	^{54}Mn	0.8	3.97×10^{-7}	0.87
	^{60}Co	78.8	3.94×10^{-6}	0.94

*Samples prepared by Fermilab and sent with shipments of environmental samples.

**Prolonged Exposure (Table 10).

Ok = means vendor reported results correctly as less than the required sensitivity.

$^{+}$Prepared sample was split for a second analysis.

$^{++}$Vendor reported results do not meet specifications.

†Fermilab recount confirmed that the discrepancy was due to sample preparation error.

††Blank analyzed for all six radionuclides.

7.2 Additional Quality Assurance Efforts

The scope of the environmental protection program at Fermilab has broadened over the years. The Laboratory has doubled in personnel from the number employed when the first proton beam was extracted from the main accelerator in 1972. Regulations have changed. Much more emphasis is now being placed on control of hazardous wastes and other nonradioactive pollutants.

As the inventory of radionuclides with potential for release to the environment has grown, the environmental monitoring program has expanded. More remote pathways have been explored and additional sampling points have been added. Special investigations have been made to measure concentrations and to detect any unexpected movement of radionuclides. These investigations would provide any necessary early warnings, giving time to take action before an off-site problem occurs.

Fermilab has a number of closed water systems which build up inventories of radionuclides, primarily tritium. These are sampled periodically to provide information useful for spill control. The precautions taken are imposed based upon the potential environmental impact. Once the concentration exceeds that which can be released according to DOE regulations (Section 8), then a spill plan is written and becomes part of the Laboratory's Spill Prevention, Control, and Countermeasures Plan (SPCC Plan).

When spills occur from closed loop cooling systems, sump pumps are shut off in the vicinity and samples taken to determine whether or not the water in the sump pits can be released. One of the lessons learned from spills is that a leak of water into a vacuum system in a radiation area can result in much higher tritium concentrations in the water pumped out than expected. The water vapor removes tritium from components. Other radionuclides are not removed, so a gamma ray survey meter does not detect the problem.

The Laboratory has strengthened its environmental review program. All new projects requiring project directives and/or affecting land management on the site receive a comprehensive environmental review. The review program includes considerations, such as threatened and endangered species, cultural resources,

wetlands, and flood plains, specifically addressed in the National Environmental Policy Act (NEPA).

Groundwater protection from organic chemicals has become a concern throughout the nation in recent years. Testing for several of these has been added to our sampling and analysis program. In addition, the Laboratory has strengthened its waste collection and auditing programs. Hazardous waste generators on the site are now required by regulation[44] to have a waste minimization program. The Laboratory documents these efforts in an annual report to the State of Illinois. This report also gives the quantities and types of hazardous waste generated, stored on-site, and disposed of off the site. The Laboratory does not have an on-site hazardous waste disposal facility.

Some radioactive water solidified in CY-1986 and some low-level radioactive scrap metal which normally have been declared waste and shipped off-site for burial were recycled by using them in the construction of shielding blocks in CY-1987 and CY-1988. These blocks are being used for reducing the exposure from higher level radioactive materials at the Boneyard (Fig. 5). The composition and radioactivity inside these blocks have been recorded in the Decontamination and Decommissioning File.

8. References

The appropriate Radiation Protection Standard for penetrating radiation applied to individuals in uncontrolled areas was taken from the DOE Order 5480.1A, Chapter XI.7. The annual dose for whole body exposure is 500 mrem when applied to occasional exposures such as might occur during an accident. The appropriate standard for a prolonged period of exposure of the general population is 100 mrem/yr including exposures from drinking water and airborne radioactivity. Exposures to the public from routine Fermilab operations must meet the regulations corresponding to prolonged periods.

The Concentration Guides used in the analyses of the surface water samples for radioactivity were taken from the draft DOE Order 5400.XY and DOE Order 5480.1, Chapter XI, (replacing Table II, Column 2), Derived Concentration Guides (DCG) - Concentrations of Radionuclides in Water and Air that could be

Continuously Consumed or Inhaled, Respectively, and Not Exceed an Effective Dose Equivalent of 100 mrem/year. The specifications are given in Table 10. These Derived Concentration Guides are based on guidance given in International Commission on Radiological Protection (ICRP) Publications 23, 26, and 30, Pergamon Press, New York. For tritium the Derived Concentration Guide is 2×10^{-7} μCi/ml. For ^{11}C the Derived Concentration Guide, for prolonged exposures, is 2×10^{-8} μCi/ml because submersion dose must be included for ^{11}C. Of the 100 mrem/year for prolonged exposure, a maximum of only 25 mrem/year per person is allowed from airborne radioactivity. This regulation is imposed by the United States Environmental Protection Agency (EPA) and is found in the U. S. Code of Federal Regulations 40 CFR 61. The source for EPA guidance on radon exposure is document EPA-OPA-86-004, issued in August 1986. The recommended residential limit is 4 pCi/l.

The Concentration Guide used in the analyses of groundwater samples for tritium was taken from the U. S. Environmental Protection Agency regulations for community drinking water systems.[11] The maximum contamination level permitted for tritium is 2×10^{-5} μCi/ml and corresponds to an annual exposure of 4 mrem if one uses the supply as one's sole drinking water source. Thus, of the 100 mrem/yr permitted for prolonged exposure of the general population, only 4 mrem is allowed from drinking water. The proposed EPA regulation based on ICRP-30 lists 9×10^{-5} μCi/ml for ^{3}H. The Concentration Guides for the other radionuclides in Fermilab's analyses of groundwater samples have been determined by dividing the Derived Concentration Guides (DCG) in the draft DOE Order 5400.XY by 25 (Table 10). These agree well with the proposed EPA regulations. The specified sensitivity and precision of the analyses have been reduced to well below these Concentration Guides (to at most 10% of the Guide).

The Air and Water Pollution Standards for nonradioactive pollutants were taken from Chapters 2 and 3 of the State of Illinois Pollution Control Board Rules and Regulations.[45] The waters on-site were considered to be in the "general use" category. The value for total hexavalent chromium for general water quality of 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, for silver are 0.1 and 0.005 mg/l respectively, and for cyanide are 0.025 mg/l for both. The maximum contaminant level for chloride in water for general use is

500 mg/l and the level of total dissolved solids is 1000 mg/l. In public drinking water the standards for chloride and total dissolved solids are 250 mg/l and 500 mg/l, respectively.[46] The Air Quality Standards limit the release for oxides of nitrogen to 136 g (0.3 lbs) per 252 million calories (per million btu's) of actual heat input in any one hour. Release of sulfur doxide shall not exceed 2000 ppm.[45]

The appropriate regulations for PCBs and hazardous wastes are found in the U. S. Code of Federal Regulations 40 CFR 761 and 40 CFR 260-265, respectively. The concentration limit is 2 ppm for human consumption of fish.[47]

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