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FEED MATERIALS PRODUCTION CENTER ENVIRONMENTAL MONITORING ANNUAL REPORT FOR 1988

06/01/89

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WMCO/DOE-ORO
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REPORT

FEED MATERIALS PRODUCTION CENTER

FMPC-2173
Special
UC-707

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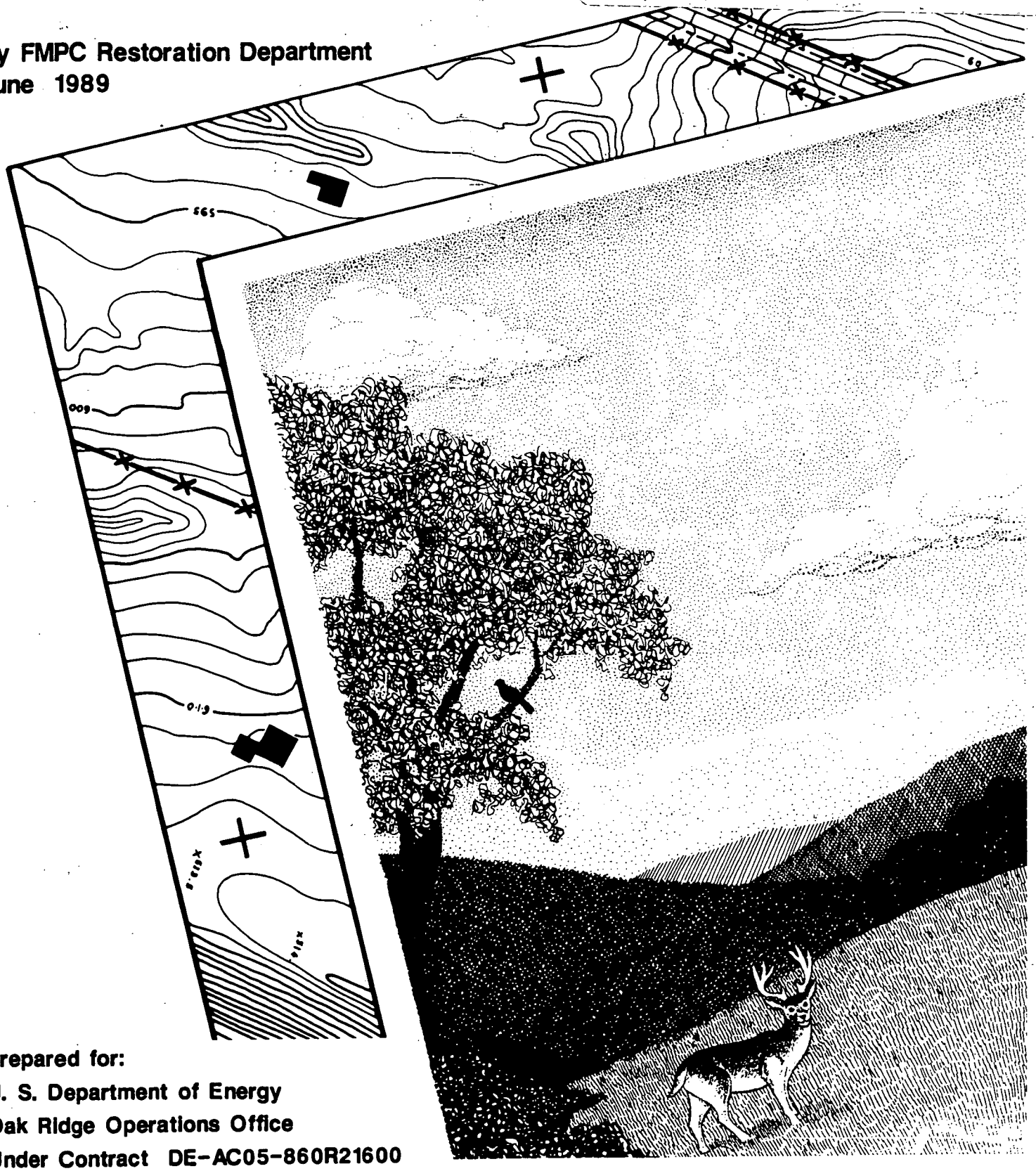
ENVIRONMENTAL MONITORING ANNUAL REPORT FOR 1988

By FMPC Restoration Department

June 1989



Prepared for:
U. S. Department of Energy
Oak Ridge Operations Office
Under Contract DE-AC05-860R21600

Westinghouse Materials Company of Ohio P.O. Box 398704 Cincinnati, Ohio 45239-8704

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Environmental Monitoring Annual Report for 1988

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FMPC Restoration

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Approved:

W.A. Weinreich, Vice President
FMPC Restoration

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Conversion Table

Traditional radiological units (curie, roentgen, rad and rem) are used throughout this report. Wherever possible, the more scientifically acceptable Systeme Internationale (S.I.) units (becquerel, coulomb/kg, gray and sievert) are also presented in parentheses. The metric system of units of measurement is the primary system used for nonradiological parameters. The English system equivalent units are frequently presented in parentheses.

To facilitate conversion of data from one system to another, the table below may be useful.

1 centimeter (cm)	=	0.3937 inch (in)
1 meter (m)	=	39.37 inches (in)
1 kilometer (km)	=	0.62 mile (mi)
1 milliliter (ml)	=	0.0338 ounce (oz)
	=	0.061 cubic inch (in^3)
	=	1 cubic centimeter (cm^3)
1 liter (l)	=	1.057 quart (qt)
	=	61.02 cubic inches (in^3)
1 gram (g)	=	0.0353 ounce (oz)
	=	0.0022 pound (lb)
1 kilogram (kg)	=	2.2 pounds (lb)
1 curie (Ci)	=	3.7×10^{10} disintegrations per second (d/s)
1 becquerel (Bq)	=	1 disintegration per second (d/s)
	=	27 picocuries (pCi)
1 millicurie (mCi)	=	0.001 curie (Ci)
1 microcurie (μCi)	=	0.000001 curie (Ci)
1 picocurie (pCi)	=	1×10^{-12} curie (Ci)
	=	2.22 disintegrations per minute (d/m)
	=	0.037 Bq
1 roentgen (R)	=	2.58×10^{-4} coulombs per kilogram of air (C/kg)
1 rad	=	0.01 gray (Gy)
1 rem	=	0.01 sievert (Sv)
1 millirem (mrem)	=	0.001 rem

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Acronyms

AHF	Anydrous Hydrogen Fluoride
AMS	Air Monitoring Station
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BAT	Best Available Technology
BDN	Biodenitrification
BOD_5	Five Day Biochemical Oxygen Demand
BMP	Best Management Practices
BSL	Biodenitrification Surge Lagoon
BTU	British Thermal Units
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
D&D	Decontamination & Decommissioning
DHF	Dilute Hydrogen Fluoride
DOE	Department of Energy
EA	Environmental Assessment
EDL	Economic Discard Limit
EIS	Environmental Impact Statement
EML	Environmental Measurements Laboratory
EMR	Environmental Monitoring Report
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center

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Acronyms (Continued)

FS	Feasibility Study
ICRP	International Commission on Radiological Protection
NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
OAC	Ohio Administrative Code
ODH	Ohio Department of Health
OEPA	Ohio Environmental Protection Agency
OAC	Ohio Administrative Code
ODH	Ohio Department of Health
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
PCB	Polychlorinated biphenyls
PET	Proficiency Environmental Testing
PTI	Permit To Install
PTO	Permit To Operate

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Acronyms (Continued)

QA	Quality Assurance
QF	Quality Factor
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation and Feasibility Study
RI	Remedial Investigation
SAQA	Site Analytical Quality Assurance
SASF	South Ammonia Storage Facility
SWRB	Stormwater Retention Basin
TLD	Thermoluminescent Dosimeter
TOC	Total Organic Carbon
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
USEPA	U. S. Environmental Protection Agency
WMCO	Westinghouse Materials Company of Ohio

Executive Summary

The Department of Energy's (DOE) Feed Materials Production Center (FMPC) is involved in the reprocessing of uranium for the nation's defense program. The FMPC also manages the storage of some radioactive and hazardous materials. As a part of its operations, the FMPC continuously monitors the environment to determine that it is operating within federal and state standards regarding emission of radiological and nonradiological materials. Data collected from the FMPC monitoring program are used to calculate estimates of radiation dose for residents surrounding the FMPC. For 1988, the estimate of dose due to FMPC operations indicated that people in the area were exposed to less than 3% of the DOE standard established to protect the public from radiation exposure. Indeed, the dose from FMPC operations during 1988 was less than 1% of what is considered the average dose each resident in the Greater Cincinnati area receives each year from naturally-occurring radiation. This annual report is a summary of the FMPC's environmental performance during 1988. An addendum to this report detailing the status of chemical releases at the FMPC will be issued later this year.

Scope of this Report

The Environmental Monitoring Annual Report describes the ways in which emissions from the site can reach the surrounding environment, what media are sampled, includes data from the ongoing FMPC Environmental Monitoring Program, explains how the FMPC estimates the maximum doses an individual could receive from activities at the site, and presents estimated doses due to operations during 1988. This report also includes information on quality assurance practices that are an integral part of a reliable environmental sampling and monitoring program, and describes waste management activities at the site as well as work being performed to address the effects of past operations and to protect the environment.

Following Environmental Standards

Because it is not possible to prevent entirely the release of all radiological and nonradiological materials from any manufacturing or production facility, the United States Environmental Protection Agency (USEPA) and the Department of Energy establish standards for emission levels that ensure public safety. These standards are based upon recommendations by the National Council on Radiation Protection (NCRP), the USEPA, the International Commission on Radiological Protection (ICRP), and other scientific and government agencies. The Ohio Environmental Protection Agency (OEPA) and USEPA establish standards for acceptable levels of nonradiological pollutants. In those instances where standards do not exist, the FMPC compares the sampling results with comparable data from previous years, with control data from

data from previous years, with control data from samples taken at areas unaffected by FMPC activities, and with published data for the concentrations of elements as found in nature.

Estimating Radiation Doses to the Public

Each year, the FMPC estimates the radiation doses generated by operations at the site. The largest overall potential source of radiation exposure to the public from the operation of the FMPC is through the air pathway, the critical pathway. The air pathway will provide, for a specific radionuclide, the greatest dose to a population, or to a specific group of the population.

As previously stated, the estimate of dose due to FMPC operations during 1988 indicated that people in the surrounding area were exposed to a maximum committed effective dose of less than 3% of the DOE standard of 100 millirem (mrem). This dose takes into account total airborne emissions, population distribution, and meteorological data. The FMPC also calculated doses the public could receive from the liquid pathway, the indirect pathways of eating produce or fish from the area, and from external radiation produced by materials stored at the site. The terminology, methodology, and results for all dose calculations are described in Chapter 2 of this report.

The calculated maximum committed effective dose a resident could receive from operations at the FMPC during 1988 was 2.9 mrem. This is a very conservative estimate because to receive that dose, the resident would have to remain outside of his home 100% of the time for an entire year.

Furthermore, as a hypothetical example, if that same resident drank 2.0 liters (2.1 quarts) of water per day from the offsite well with the highest uranium concentration in 1988 (that well is not used for drinking water), ate 4.4 kg (9.7 lb) of fish caught in the Great Miami River at the point where the FMPC effluent enters the river, and ate 38.1 kg (84 lb) of potatoes grown on a farm near the FMPC, that resident could receive a committed effective dose of 35 mrem. Of that dose, 32 mrem would be attributed to drinking water from the contaminated well.

These doses can be compared to the average radiation dose of 360 mrem that each U. S. resident is exposed to each year. About 300 mrem come from radon and other natural sources, including cosmic rays. Other contributors include medical X-rays and consumer products like televisions and smoke detectors.

The effective dose due to natural background radiation for the entire population within 80 km (50 mi) of the FMPC was 900,000 person-rem. For the same population group, the committed effective dose due to 1988 airborne emissions from the FMPC was 59 person-rem.

Environmental Monitoring and Sampling

To obtain the data for the dose calculations, and to estimate the impact of FMPC operations on the health and safety of nearby residents, the FMPC continued its ongoing program to monitor and sample the environment. Chapter 3 of this report details the monitoring and sampling program.

The Air Pathway

Since the air pathway is the critical pathway by which contaminants can reach the environment and members of the community, the FMPC samples the air, soil, vegetation, produce, and milk to determine the extent of any contamination.

The average concentrations of uranium at the 12 air monitoring stations located along the FMPC boundary and offsite were all less than 4% of the DOE standard. Average total suspended particulate concentrations collected from the fenceline and onsite air monitoring stations were within National Ambient Air Quality Standards. Uranium emissions to the air totaled 108 kg (237 lb) for 1988.

No standards exist for uranium concentrations in soil or in vegetation. The FMPC compared soil data collected during 1988 to published values

for naturally-occurring uranium for Ohio soils. All offsite samples were within the background range for Ohio soils except for three specific areas that had slightly above-background concentrations. In general, uranium concentrations found in soil and in vegetation near the FMPC were no different than the concentrations found some distance from the site.

The FMPC sampled produce from farms and gardens within 3 km (about one and one-half miles) of the site, and also, as a control measure, from farms located between 3 km to 24 km (15 mi) from the site. The majority of produce that was collected exhibited uranium concentrations that were at levels too low to detect by the independent laboratory's analyses.

The FMPC collected monthly samples of milk from the dairy located next to the site, and from a control dairy located about 35 km (22 mi) west of the FMPC. The average uranium concentration present in the milk samples from both locations was below the laboratory's minimum detectable level.

The Liquid Pathway

The FMPC carefully samples and monitors the components of the liquid pathway that radiological and nonradiological materials from the site could take to reach the surrounding environment. The first component of this pathway is through the groundwater. The FMPC's groundwater monitoring program has grown significantly during the last year with the addition of more than 110 monitoring wells both on the FMPC site and, with the cooperation of FMPC neighbors, in the immediate vicinity of the site.

The groundwater data collected indicated that uranium concentrations for onsite wells were significantly below the drinking water standard for groundwater tentatively proposed by USEPA and used by DOE. All offsite wells, except for the three wells that were identified several years ago as having uranium concentrations above the tentative drinking water standard, had uranium concentrations considerably below the drinking water standard. Generally, the average uranium concentrations were in the background range for groundwater in this area.

Additional components of the liquid pathway for contaminants from the FMPC reaching the environment were the discharge of FMPC effluent (which is sampled continuously) to the Great Miami River, and from the overflow of stormwater runoff from the Stormwater Retention Basin to Paddy's Run.

The total amount of uranium in the FMPC effluent to the Great Miami River was 858 kg (1,892 lb). The average uranium concentrations at the sampling locations in the Great Miami River (downstream of the discharge line and at the outfall itself) were less than 0.3% of the DOE guideline.

Stormwater runoff from the production area, administration area, and the parking lot collected in the Stormwater Retention Basin (SWRB). There was one overflow of the SWRB in 1988; about 1.6 million gallons of stormwater was discharged into the Storm-Sewer Outfall Ditch. This overflow, which was monitored and sampled, contained 5.4 kg (11.9 lb) of uranium. This amount was significantly lower than in the years before the SWRB was in operation. Under normal conditions, the water in the SWRB was pumped to the effluent discharge line where it was monitored and sampled before it was discharged into the Great Miami River.

Some stormwater does drain from the waste pit area into Paddy's Run along the western boundary of the site. There, the highest average uranium concentration found in Paddy's Run was about 7% of the DOE standard. The average concentrations for the nonradiological parameters of nitrate-nitrogen and fluoride sampled at all surface water locations were less than OEPA standards, as they have been for several years.

The FMPC met the discharge limits for National Pollutant Discharge Elimination System (NPDES) parameters more than 88% of the time in 1988. The majority of violations were at the Sewage Treatment Plant, which cannot adequately handle five-day biochemical oxygen demand and total suspended solids. Future plans include improving the overall wastewater treatment system at the site to reduce stress on the Sewage Treatment Plant and to continue to improve the NPDES compliance rate.

Uranium concentrations in some sediment samples taken from the Storm-Sewer Outfall Ditch near the SWRB were above the background range for Ohio soils. However, sediment samples from the Great Miami River and Paddy's Run, including samples from below the Storm-Sewer Outfall Ditch, were within the natural-background range.

The uranium concentrations in fish sampled in 1988 were higher than in previous years. The analyses are being rechecked. Even using the suspect data, the maximum committed effective dose from eating these fish would be only 0.31% of the DOE standard. The highest component of that dose, the dose to the bone, could be 0.1% of the DOE standard.

Waste Management Activities

The FMPC continues to make notable progress in reducing the amount of waste stored at the site. The amount of backlog waste has been reduced by more than 40% since October 1986, and a waste minimization program is now in place. These actions have significantly reduced the potential for environmental problems related to waste management activities.

Special Studies and Significant Events

In addition to the ongoing routine data collection and analysis performed as part of the FMPC environmental monitoring program, several additional environmental studies were initiated or completed during 1988.

Through the comprehensive Remedial Investigation and Feasibility Study (RI/FS), the FMPC is investigating the nature and extent of potential environmental impacts from past and current operations at the site. Based upon the results of this investigation, the RI/FS will then develop and evaluate engineering alternatives to mitigate the identified environmental concerns. The study is being completed for DOE in cooperation with USEPA and OEPA.

Work continues on the task of stabilizing the K-65 Silos, which contain waste residues from the Manhattan Project of World War II. Some of the tasks completed during 1988 included videotaping the interior of the silos, monitoring the interior pressure of the silos, continuing the radon monitoring program, and issuing the FMPC Emergency Plan that provides a detailed response procedure in the event of an unplanned release from the silos.

The FMPC has developed a comprehensive plan to improve the conditions for the temporary storage of thorium materials. All thorium has been removed from an elevated silo and bins, packaged in special drums, inventoried, and stored in warehouses onsite. All thorium materials stored outside in drums and in old warehouses will be repackaged. This will greatly reduce the possibility of any thorium being released to the environment.

Among the tasks undertaken to enable the site to comply with air emission standards, the FMPC tested ten production stacks. Particulate emissions from all the stacks tested during 1988 complied with OEPA regulations. In addition, the FMPC tested the wet scrubbers in Plant 8, the Scrap Recovery Plant, to update emission factors and to establish significant databases for emissions resulting from several wet exhausts processes. These capabilities have been used to track the emissions of uranium.

The FMPC onsite meteorological system operated satisfactorily for 330 days during 1988, and provided much of the data needed for the calculations to determine radiation doses to the public. When lightning strikes disrupted data collection on three separate occasions, the FMPC was able to obtain data from the Greater Cincinnati International Airport, located about 27 km (17 mi) south of the site.

In October 1988, the OEPA approved the Best Management Practices (BMP) Plan submitted by FMPC to protect the surface waters surrounding the site from any significant release of toxic or hazardous substances. By observing the best management practices presented in the plan, FMPC employees will reduce the likelihood of a spill, and will know how to respond quickly if a spill does occur.

Other significant water improvement projects in 1988 included the expansion of the Stormwater Retention Basin, upgrading the Biodenitrification Surge Lagoon, and upgrading the effluent sampling and monitoring capabilities. These projects enable the FMPC to better protect and monitor the groundwater and surface water surrounding the site from pollutants originating from the FMPC.

Oak Ridge National Laboratory is preparing an Environmental Impact Statement (EIS) for the FMPC to address and evaluate the cumulative environmental impacts of activities and operations at the site. The draft EIS is expected to be released to the public, cooperating agencies, and Congress during 1989.

The FMPC removed stores of anhydrous hydrogen fluoride and anhydrous ammonia from the site in early 1989, thus eliminating a significant risk at the FMPC. In addition, several new chemical storage facilities using the best available technology have been built to store remaining chemicals.

The Ohio Department of Health (ODH) completed a three-year testing program that has confirmed that uranium contamination of groundwater wells near the FMPC is confined to three wells located just south of the facility. Furthermore, the ODH survey found no serious contamination of soil in offsite areas, and found only slightly elevated concentrations of uranium in soil samples collected northeast of the FMPC.

In addition to the water and soil testing, ODH measured radon levels in 25 homes and 16 other locations near the FMPC. The ODH concluded that the source of radon in homes was the soil and rock beneath the homes themselves.

According to the ODH report, external radiation measurements taken at 31 locations near the FMPC detected no levels which would represent a threat to the health and safety of nearby residents.

During November 1988, the OEPA sampled drinking water from 17 public water supplies which draw from wells within 16 km (10 mi) of the FMPC. The OEPA tests showed no abnormal amount of radioactivity.

Unusual Events

During 1988, three events occurred that posed potential facility safety problems. These were a release of about 66 kg (145 lb) of uranium from Plant 2/3 gulping operations during June, the release of uranyl nitrate from Plant 2/3 in January that included 18 kg (40 lb) of uranium, and a uranium-metal chip fire in October. There was no offsite environmental impact from either of the latter two events, and a maximum predicted dose of less than 1 millirem from the Plant 2/3 release in June. These events are discussed in Chapter 6.

Summary

Significant progress has been made during 1988 in reducing emissions of uranium and other pollutants to the environment. As remedial efforts increased at the FMPC, programs for environmental monitoring and sampling are in place to ensure that emissions of both radiological and nonradiological pollutants meet all standards and are kept to levels as low as reasonably achievable. There were no measurable effects to the public due to the FMPC's daily operations during 1988 or due to the expanded remedial work underway at the site.

Chapter One — Introduction

Shortly after the end of World War II, the United States government recognized the need for improved facilities to produce uranium metal. Existing facilities, developed for the war effort, were overburdened and unable to meet increasing demands. The Atomic Energy Commission wanted to improve control and increase the safety of production operations, as well as increase the quality and quantity of uranium metal production.

After careful study, the government selected Fernald, Ohio as the site for one of its new uranium-production facilities in 1951. The major portion of construction at the Feed Materials Production Center (FMPC) was completed in 1954. Figure 1 presents a detailed overview of the FMPC site as it exists today.

The FMPC is located approximately 32 km (20 mi) northwest of downtown Cincinnati, Ohio. The primary activity of the FMPC is the manufacture of purified uranium-metal products for use at several Department of Energy (DOE) sites. These products have been an integral part of the United States' defense program. However, the FMPC neither produces nor stores explosive weaponry, devices or highly radioactive materials. Since January 1, 1986, Westinghouse Materials Company of Ohio (WMCO) has managed the FMPC under its contract with the DOE.

As part of its ongoing efforts to protect the health and safety of nearby residents, the FMPC engages in a broad range of activities related to environmental monitoring and sampling, waste management, and overall site remediation. The activities of site remediation are designed to correct the effects of past operations at the site, and to guard against the potential for future damage.

The FMPC strives to determine the amount of radioactive and nonradioactive materials that leave the FMPC site and enter the surrounding environment. These materials include such things as chemicals, metals, and gases which the FMPC looks for by sampling various media, including air, water, soil, vegetation, and milk.

The overall monitoring and sampling effort has three purposes:

- To ensure that the FMPC can detect any release of materials as quickly as possible so that corrective actions can be implemented immediately
- To estimate the radiation dose that area residents may be exposed to as a result of any release of materials
- To measure progress in correcting problems from past operations and in implementing improved environmental management practices.

The FMPC waste management activities are directed at disposal, elimination, and safe storage of both liquid and solid wastes in compliance with all applicable regulations.

Finally, in addition to the Environmental Monitoring Program, the FMPC is engaged in several environmental areas, including remedial activities and day-to-day operations that center

(1A) BUILDING IDENTIFICATION

Building I.D. No.	Grid Coordinates	Title
00	**	General
1a	C-3	Preparation Plant
1b	C-3	Plant 1 Storage Building
2a	B-3	Ore Refinery Plant
2b	B-3	Lime Handling Building
2c	B-3	Bulk Lime Handling Building
2d	C-3	Metal Dissolver Building
2e	C-3	NFS Storage and Pump House
3a	B-3	Maintenance Building
3b	B-3	Ozone Building
3c	B-3	Control House
3d	B-3	NAR Towers
3e	B-3	Hot Raffinate Building
3f	B-3	Digestion Fume Recovery
3g	B-3	Refrigeration Building
3h	B-3	Refinery Sump
4a	B-4	Green Salt Plant
4b	B-4	Plant 4 Warehouse
4c	B-4	Plant 4 Maintenance Building
5	B-4	Metals Production Plant
6	B-5	Metals Fabricating Plant
7	B-4	Plant 7
8a	B-3	Recovery Plant
8b	B-3	Maintenance Building
9	C-5	Special Products Plant
10a	D-4	Boiler Plant
10b	D-4	Boiler House Maintenance Building
11	A-4	Service Building
12a	C-4	Maintenance Building (Main)
12b	C-4	Cylinder Storage Building
12c	C-4	Lumber Storage Building
13a	A-3	Pilot Plant Wet Side
13b	A-3	Pilot Plant Maintenance Building
13c	A-3	Sump Pump House
14	A-4	Administration Building
15	A-3	Laboratories
16	A-5	Main Electrical Substation
18a	C-2	Surge Lagoon
18b	B-3	General Sump
18c	C-4	Coal Pile Runoff Basin
18d	B-3	Biodenitrification Towers
18e	*	Storm Water Retention Basin
18f	D-1	Pit 5 Sluice Gate
18g	C-1	Clearwell Pump House
19a	C-4	Metal Tank Farm
19b	A-3	Pilot Plant Ammonia Tank Farm
20a	C-4	Valve/Control Building
20b	D-4	Filter/Chemical Building
20c	C-4	Cooling Towers
20d	B-5	Elevated Storage Tank (Potable H_2O)
20e	B-3	Well House
20f	B-3	Well House
20g	A-3	Well House
20h	D-4	Process Water Storage Tank
20j	B-2	Lime Slurry Pits
22a	B-5	Gas Meter Building
22b	A-3	Storm Sewer Lift Station
22c	A-5	Truck Scale
23	*	Meteorological Tower
24a	D-3	Railroad Scale House
24b	C-4	Railroad Engine Building
25a	*	Chlorination House
25b	*	MH #175
25c	A-5	Sewage Lift Station Building
25d	*	U.V. Disinfection Building
25e	*	Digester Control House
26a	B-3	Pump House - H.P. Fire Protection
26b	B-3	Fire Protection Storage Tank
28a	A-4	Security Building
28b	A-4	Human Resources Building
30a	C-3	Chemical Warehouse
30b	C-3	Drum Storage Warehouse
31	A-5	Engine House - Garage
32	D-5	Magnesium Storage
34a	B-1	K-65 Storage Tank - North
34b	B-1	K-65 Storage Tank - South
35a	C-1	Metal Oxide Storage Tank - North
35b	B-1	Metal Oxide Storage Tank - South
37	A-3	Pilot Plant Annex
38	D-4	Propane Storage
39a	B-3	Incinerator Building
39b	B-3	Warehouse
39c	B-3	Incinerator Bulding Sprinkler Riser House
44a	A-5	Trailer Complex - 6-Plex - East
44b	A-4	Trailer Complex - 3-Plex
44c	A-3	Trailer Complex - 7-Plex - South
44d	A-3	Trailer Complex - 7-Plex - North
44e	A-4	Trailer Complex - 10-Plex
45	B-3	Building 45
46	A-5	Heavy Equipment Garage
51	A-2	UF_6 to UF_4 Reduction Facility II
53a	A-4	Health, Safety & Production Control Building
53b	A-4	In-Vivo Building
54a	A-3	UF_6 to UF_4 Reduction Facility I
54b	A-3	Warehouse/Weather Shelter
55a	B-4	Slag Recycling Plant
55b	B-4	Slag Recycling Pit/Elevator
56	D-3	CP Storage Warehouse
60	D-3	Quonset Number 1
61	D-3	Quonset Number 2
62	D-3	Quonset Number 3
63	D-4	KC-2 Warehouse
64	D-5	Plant 9 Warehouse
65	D-5	Plant 5 Warehouse
66	C-3	Drum Reconditioning Building
67	C-3	Plant 1 Storage Building
68	A-3	Pilot Plant Warehouse
69	D-5	Decontamination Building
71	C-3	General In-Process Storage Warehouse
72	C-3	Drum Storage Building
73	*	Fire Brigade Training Center Building
77	C-5	Finished Products Warehouse
78	*	New D&D Facility (On Hold)
79	B-5	Plant 6 Warehouse
80	B-3	Plant 8 Warehouse
81	C-5	Plant 9 Warehouse
82	B-5	Receiving & Incoming Materials Inspection Area

* Outside of Perimeter Security Fence

**NOTE: Any Unidentified Area is Referred to as 00 General

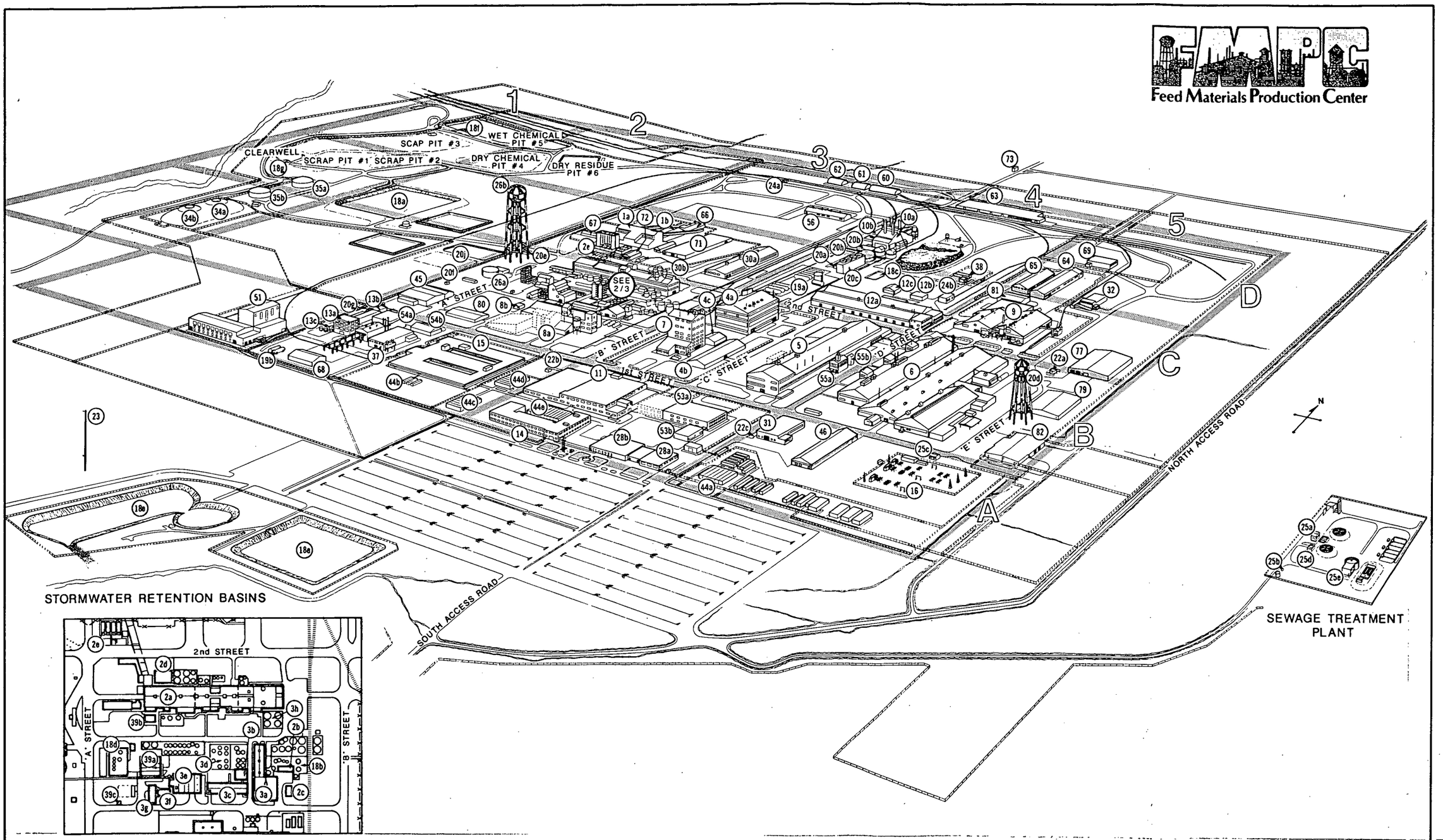

Figure 1. FMPC Site Overview

on helping the site meet all applicable environmental standards, and responding to unexpected events that have the potential to affect the environment.

This Environmental Monitoring Report (EMR) describes the results of the FMPC monitoring, sampling, waste management, and remedial activities during 1988 according to requirements stated in DOE Order 5400.1.[1] To help readers understand the material presented in the rest of the report, this chapter provides background information on the following topics:

- Physical and ecological characteristics of the FMPC site
- Leading economic activities in the Fernald area
- Production and storage operations at the FMPC
- Radiation and its potential effects on human health
- Exposure pathways to humans
- The environmental standards with which the FMPC must comply
- The FMPC Environmental Monitoring and Sampling Program.

Physical and Ecological Characteristics of the Site

The FMPC is situated on a relatively level plain, about 177 m (580 ft) above sea level. The land rises to 213 m (698 ft) at the northern boundary and slopes downward to 168 m (551 ft) at Paddy's Run on the western boundary.

Soil Types

At the FMPC, nearly 15 m (49 ft) of clay-rich till, generally described as silty clay loam, overlies sand and gravel deposits left by a retreating glacier. The deposits are about 5 km (3 mi) wide and 46 m (151 ft) deep, and fill the remains of an ancient river valley that was cut into the bedrock. The Great Miami River, which runs in a southerly direction about one km (0.6 mi) east and south of the FMPC, presently cuts through these deposits. Sand and gravel deposits often hold water; in fact, the area under the FMPC and vicinity is part of a large aquifer system in southwestern Ohio (Figure 2). This aquifer is a major source of fresh water for industries and residences in or near Cincinnati. More than 60 m (200 ft) below the surface of the FMPC lies bedrock consisting of alternating layers of limestone and shale.

Vegetation and Wildlife

The vegetation at the FMPC is typical for this region, consisting of grassland, brushland, woodland, and wetland areas. The area north of the production area is moderately wooded with a variety of deciduous hardwoods. Similar wooded areas are also found along natural watersheds on the western area of the site; grassland and brushland are the primary vegetation in the waste storage area. Several acres immediately north of the production area were planted in pine as part of an environmental improvement project in 1973. Most of the remainder of the site is leased to local dairy producers whose cattle graze on a variety of pasture grasses.

This diversity provides abundant forage (browse, fruits, seeds, and buds) and cover for wildlife, including eastern cottontails, woodchucks and pheasants. The pine plantation provides thermal cover for deer and other animals by easing the effects of air temperature, radiant heat loss, and insulation. It also provides nesting areas for various species of birds, such as song sparrows, blue jays, cardinals, robins, and the tufted titmouse. Logs and tree cavities also provide moist microclimatic conditions for wildlife.

White-tailed deer, bobwhite quail, scattered waterfowl, and other game species have been observed onsite. Paddy's Run provides refuge for at least 23 species of fish, including minnows, darters, and shiners. There were no endangered species at the FMPC.[2]

Precipitation for 1988

The total rainfall for this area in 1988 was the same as the average rainfall for the years 1958 through 1987: 102 cm (40.0 in). The wettest month during 1988 was July when 17.4 cm (6.9 in)

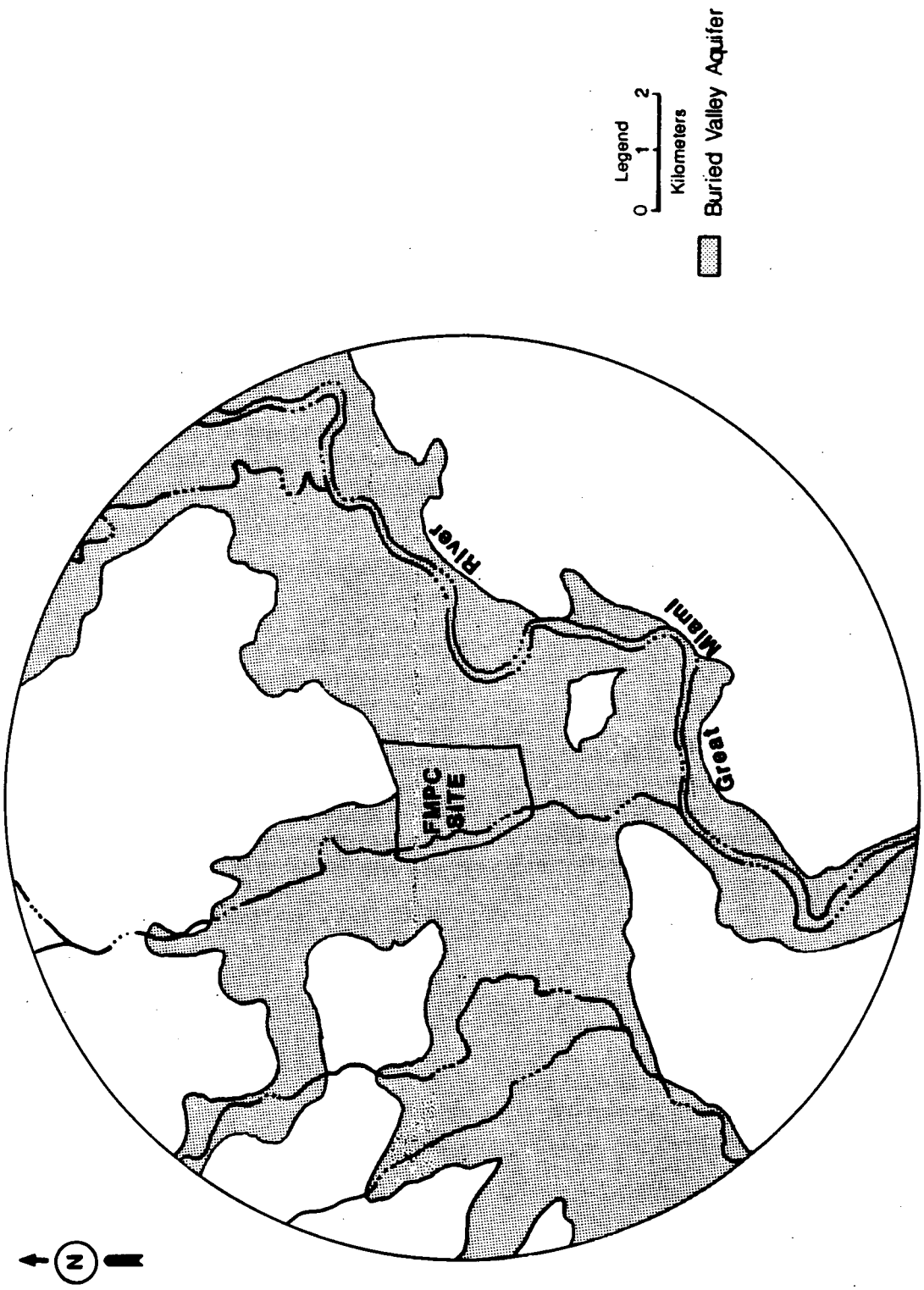

Figure 2. Buried Valley Aquifer Underlying the FMPC Site and Vicinity

fell, most during two thunderstorms. By contrast, the least precipitation was recorded in June when 3.02 cm (1.2 in) fell. These figures were obtained from the Greater Cincinnati International Airport, located about 27 km (17 mi) south of the site. Precipitation data for the entire year were not available from the FMPC meteorological tower because of damage caused by lightning strikes (discussed in Chapter 6).

Leading Economic Activities in the Fernald Area

The major economic activities in the area are farming and raising dairy and beef cattle. These activities also account for the majority of the land use in the area around the FMPC. Major crops include sweet corn, field corn, soybeans, and winter wheat. Several nearby farms also sell garden produce locally or in nearby urban markets. The FMPC is a major employer and source of income for the local area as well.

Other important commercial products from the area include sand, gravel, and water from the aquifer. Many gravel-pit operations exist along the Great Miami River and in the floodplain some distance inland. In addition, a water company located 2 km (1.25 mi) upstream of the FMPC outfall (this is where the FMPC liquid effluent is discharged into the river) began operating just prior to the construction of the FMPC. Presently, this company pumps nearly 20 million gallons of groundwater per day, which it sells chiefly to industries in Greater Cincinnati.

Upstream of the FMPC on the Great Miami River lie the communities of Fairfield, Hamilton, Middletown, and Dayton (Figure 3). Downstream areas are sparsely populated and have a few small and scattered industries. The Great Miami River flows into the Ohio River about 29 km (18 mi) south of the FMPC.

Production and Storage Operations at the FMPC

The Environmental Monitoring Program is an essential part of FMPC daily operations because both radiological and nonradiological hazardous materials are used in production and are stored at the site. Through careful handling and monitoring, the FMPC strives to assure there is minimal impact from these production and storage activities on the surrounding environment and on the economic activities in the surrounding areas. The production and storage operations are described in this section.

An Overview of Production Operations

The basic processes used at the FMPC to produce uranium metal have remained fairly consistent over the years, although details have varied. The site reprocesses uranium scrap metal and uranium trioxide (UO_3) powder, called orange oxide, from other DOE sites. In addition, the FMPC heats materials such as floor sweepings and dust collector and production residues that contain uranium to remove moisture and some impurities. These remaining materials then undergo a series of chemical reactions which extract the uranium, leading to the formation of orange oxide.

The orange oxide from these sources is either stored or converted to "green salt," uranium tetrafluoride (UF_4). The FMPC receives green salt from other DOE sites, and also produces green salt by reducing uranium hexafluoride (UF_6) received from other DOE sites.

The green salt is blended with magnesium granules and placed in a closed reduction pot lined with magnesium fluoride. The reduction pot is heated in a furnace until the contents react to produce uranium metal shaped in a form called a derby. Some derbies are sent directly to other DOE sites, while the remainder are melted, along with uranium scrap-metal recovered from earlier production and fabrications, in a vacuum induction furnace. When the molten uranium metal reaches the proper temperature, it is poured into a graphite mold to form ingots. Ingots vary in weight, size, and shape according to how they will be used at other DOE sites.

Most of the final products at the FMPC are depleted uranium, that is, they contain a smaller percentage of uranium-235 than does naturally-occurring uranium - less than 0.71% U-235. There

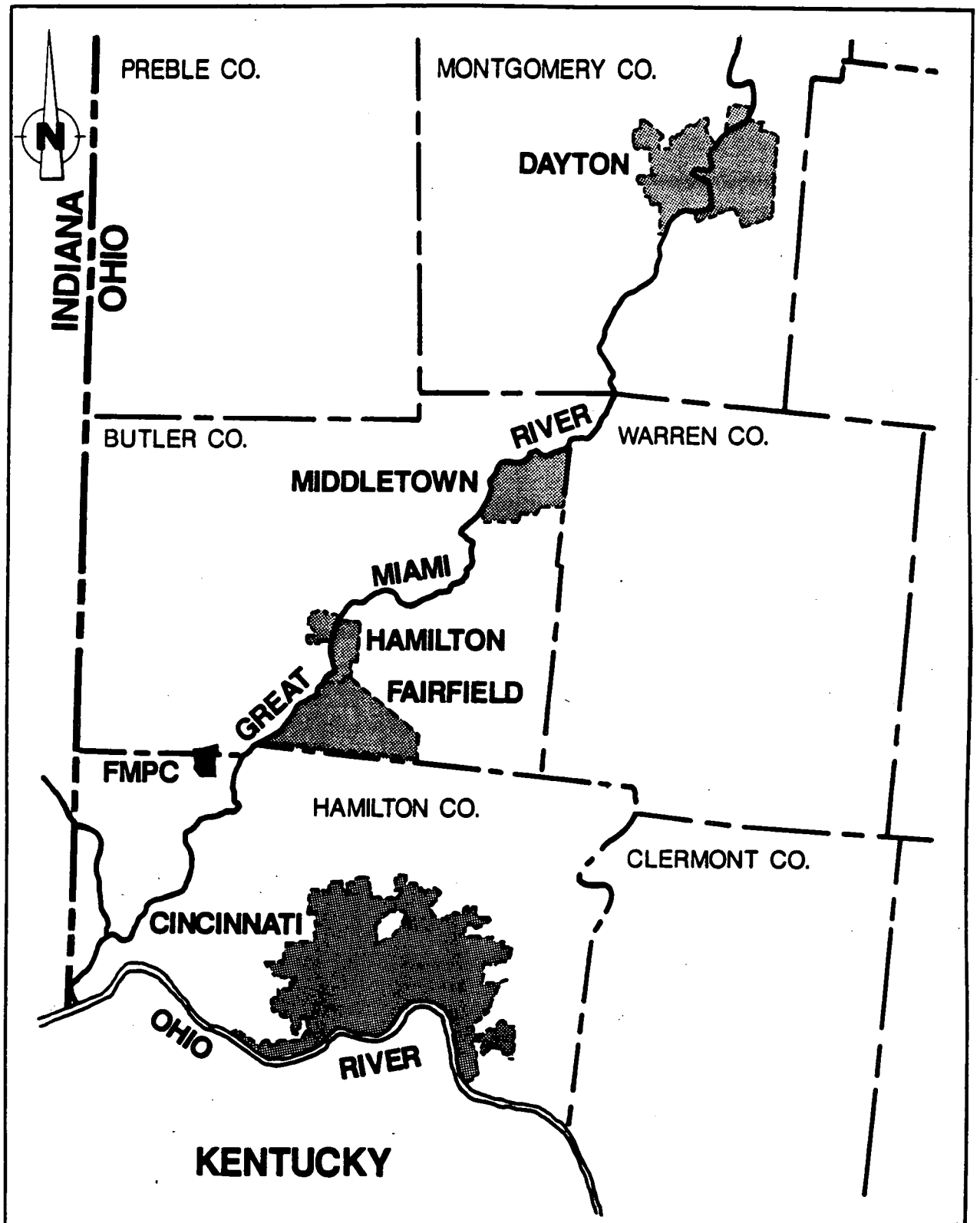

Figure 3. Communities Upstream of the FMPC

is some amount of slightly enriched products (greater than 0.71% uranium-235) stored onsite. Most of this inventory is enriched to no more than 1.25% uranium-235.

Handling and Storing Radioactive and Hazardous Materials at the FMPC

The FMPC follows a rigorous safety program to ensure the safe handling and storing of hazardous and radioactive materials. Extensive safety reviews are performed on facilities and handling procedures, as well as on projects to add new storage facilities and to remove those materials no longer needed for production. The safety reviews consider the hazards, and periodically update the analyses to reflect process changes, modifications, or additions.

Large quantities of radioactive and hazardous materials handled or stored in approved facilities during 1988 included:

Radioactive

- Pitchblende ore residues containing radium stored in the K-65 silos
- Thorium and thorium compounds stored in several locations within the production area
- Uranium metal
- Uranium compounds
- Contaminated magnesium fluoride (MgF_2)
- Contaminated scrap metal

Hazardous

- Anhydrous hydrogen fluoride (AHF)
- Anhydrous ammonia (NH_3)
- Nitric acid
- Sodium hydroxide
- Potassium hydroxide
- Magnesium metal
- Process waste, including wastes regulated by the Resource Conservation and Recovery Act (RCRA).

The FMPC has projects underway to improve the way it stores thorium and, wherever possible, to remove hazardous materials from the site. The thorium previously has been stored in a silo, bins, and warehouses; work continues on repackaging the thorium into containers suitable for long-term storage or shipment to an offsite location. In light of reduced production requirements during 1988, the FMPC began selling its inventory of AHF and NH_3. In January 1989, the FMPC completed the sale of AHF, thereby eliminating a principal hazardous material from the site. The ammonia was removed from the site in April 1989. Thorium repackaging and eliminating the AHF and ammonia inventories are discussed in detail in Chapter 6, Significant Events and Special Studies.

Radiation and Its Potential Effects on Human Health

Because the FMPC works with radioactive materials, an understanding of the environmental monitoring program requires some understanding of radiation and its potential health effects.

Radioactivity is a process in which a nucleus of an atom spontaneously disintegrates, or decays. Radiation refers to the energy that is released in the form of particles or waves when the disintegration or decay of the nucleus occurs. This section explains the different forms radiation takes, the decay process, its effect on the decaying atom, and the result of the interaction of radiation with other atoms.

Forms of Radiation

Radiation produced by radioactive decay takes one of three main forms: alpha particles, beta particles, or gamma rays.

Alpha Particles. Alpha particles consist of two protons and two neutrons (the same as a helium nucleus) and have a positive charge. Because they are charged, they interact with other atoms and lose energy. Moreover, because of their large size, alpha particles do not travel very far (one to eight centimeters in air) when released. They are unable to penetrate any solid material, such as paper or skin, to any depth. However, if alpha particles are released inside the body, they can damage the soft internal tissues. Radioactive uranium releases alpha particles, so that, if uranium particles are

inhaled or swallowed, biological effects may occur.

Beta Particles. Beta particles are electrons and carry a negative electrical charge. They are much smaller than alpha particles. Because of their small size and the fact that they travel at close to the speed of light, they can travel for longer distances in air and can penetrate solid materials more readily than alpha particles. Beta particles have the same effect as alpha particles, but since they are smaller than alpha particles, they cause less damage when ingested. Radioactive thorium-234, the first decay product of uranium-238, releases beta particles. Other radionuclides present at the FMPC (thorium-228, -230, -232) decay by emitting alpha particles.

Gamma Rays. Gamma rays are bundles of electromagnetic energy which behave as though they were particles. These pseudo particles can be thought of as a bundle of energy called a photon. They are similar to visible light, but of a much higher energy. X-rays are another type of high-energy electromagnetic radiation, and excessive exposure to X-rays can damage the body. Gamma rays are even more energetic than X-rays. They can travel long distances and can penetrate not only skin, but substantial distances into solid materials such as cement or steel. Gamma rays are often released during radioactive decay along with alpha and beta particles. Potassium-40 is an example of a naturally-occurring radionuclide found in all human tissue that decays by emitting a very high-energy gamma ray.

Processes and Effects of Radioactive Decay

There are two basic processes by which an atom decays. One process occurs when a neutron changes into a proton and an electron. The electron is then emitted as a high-speed beta particle and the proton remains in the nucleus, thereby increasing the atomic number of the nucleus (the number of protons in the nucleus) by one, and consequently, altering its chemical properties. The second process involves the ejection of an alpha particle from the nucleus of the atom. By removing two protons from the nucleus, it reduces the atomic number by two. This also creates an atom with different chemical properties. During either type of decay, gamma rays can also be emitted.

When radiation interacts with another material, it affects the atoms of that material principally by knocking negatively charged electrons out of orbit. This causes the atom to lose its electrical neutrality and become positively charged. An atom that is charged, either positively or negatively, is called an ion. Anything that creates an ion is said to be ionizing.

The biological effects on humans of high levels of ionizing radiation - levels thousands of times higher than those found every day in nature - can include vomiting, nausea, hemorrhaging, injury to the thyroid and central nervous system, cancer, genetic mutation or death. Most people receive such a low-level of radiation that the effects, if present at all, are so small that they cannot be measured.

Units of Measurement

The units often used when discussing radiation can be categorized into measurements of activity, absorbed dose, and dose equivalent. Figure 4 gives a summary of these units.

Activity. The number of nuclear transformations in a material, that is, the disintegrations or decays of one element into another occurring per unit of time is called its activity. Activity is generally expressed in curies. One curie (Ci) is equal to 37 billion transformations or disintegrations per second (3.7×10^{10} d/s). For example, a radionuclide may have an activity or strength of 1,000 Ci, which means that the transformation rate is $1{,}000 \times (3.7 \times 10^{10}$ d/s) = 3.7×10^{13} d/s.

A picocurie (pCi) is one-trillionth (10^{-12}) of a curie. It is equal to 2.22 disintegrations per minute (2.22 d/m).

A becquerel is also a unit of activity. One becquerel equals one disintegration per second.

Absorbed Dose. When we measure energy, we use a unit called electron volts (eV). To understand an eV, imagine a one-volt battery

Unit (Abbr)	What it Represents	Conversion
curie (Ci)	activity	37 billion nuclear disintegrations per second. (3.7×10^{10} d/s).
picocurie (pCi)	activity	one-trillionth of a curie. 1×10^{-12} Ci; 2.22 d/m.
becquerel (Bq)	activity	1 nuclear disintegration per second (1 d/s).
electon volt (eV)	energy	see explanation below.
rad	absorbed dose	100 ergs per gram of tissue.
gray (Gy)	absorbed dose	100 rads or 1 joule/kg of tissue.
Quality Factor (QF)	the relative tissue damage inflicted by different types of radiation of the same energy.	The greater the damage, the higher the QF. Beta and gamma QF=1; alpha QF=20.
rem	dose equivalent	absorbed dose in rads times quality factor.
sievert (Sv)	dose equivalent	100 rems.

Figure 4: Units of Measurement

connected to two plates, one positively charged and one negatively charged. If a particle with a charge of ± 1 electron goes between the two plates, it is given energy equal to one eV. One kilowatt-hour of energy, the amount used by a 1,000-watt appliance in an hour, is equal to 2.25×10^{25} eV. Because an eV is such a small quantity of energy, one generally refers to million electron volts or MeV. For example, if a beta particle is released from strontium-90, it could have as much as 546,000 eV, or 0.546 MeV (million electron volts). Another example is the gamma-ray from naturally-occurring potassium-40 which has an energy of 1,461,000 eV or 1.461 MeV.

The absorbed dose is the amount of energy imparted to matter. This energy is measured in rads (radiation absorbed dose). A rad is equal to 62.5×10^6 MeV imparted to a gram of tissue.

Dose Equivalent. Some particles produce greater biological effects than other particles for the same amount of energy imparted. Alpha particles, for example, are much larger and have twice the charge of beta particles, so they have a greater effect on a substance with which they come in contact. In order to compare the biological effect of different types of radiation, a unit called the dose equivalent was defined, and is measured in rems. (A sievert is also used to measure the dose equivalent. One sievert equals 100 rems.) A rem is found by multiplying the absorbed dose (rads) by a quality factor (QF). The quality factor for beta particles, gamma

rays, and X-rays is just one. In contrast, the quality factor for alpha particles is twenty.

The term "dose" is frequently substituted for the term "dose equivalent"; that convention will be used in this report. When referring to absorbed dose, the short version will not be used.

To estimate various potential radiation doses to the public, the FMPC used data collected as part of the Environmental Monitoring Program, along with information about the pathways radioactive materials take to reach the surrounding environment and populations. These estimated doses are discussed in Chapter 2, and the next section describes the concept of pathways.

Exposure Pathways to Humans

Exposure pathways define the means by which people may become exposed to both radioactive and nonradioactive materials. This section centers on the radiological pathways.

The major pathways of interest are those which could cause the highest calculated dose to the public. These pathways are determined from the type and amount of radioactivity released, the environmental transport mechanism, and how the land near a site is used.

The environmental transport mechanism includes physical factors, such as the hydrological (water flow) and meteorological (wind speed and wind direction at the time of the release) characteristics of the area. This information is used to evaluate how the radionuclides will be distributed in the area. The most important factor in evaluating the exposure pathways is the use of the environment. Many factors are considered such as dietary intake of residents, whether the land is used for recreation or farming for example, and the location of homes in the area.

Figure 5 represents the many liquid pathways radiological materials can take from their point of release (such as air emissions from stacks or the discharge of liquids into a river) through the environment to a human.[3] The segment of the liquid pathway of primary interest at the FMPC is ingestion - drinking the water and eating fish from the river or eating produce that has been irrigated with potentially contaminated groundwater.

For the air pathway, Figure 6, the primary routes are inhalation of airborne contaminants (gases or particulates) and the ingestion of food products that could be contaminated from airborne deposition of radionuclides (either directly or through the soil-roots-plant pathway).[3] Accordingly, the FMPC conducts extensive monitoring and sampling of the various segments of the pathways to determine if the contaminants are present, in what amounts, and if they pose a health hazard.

Although radionuclides can reach humans by many different pathways, some are more important than others. The pathway of greatest concern is termed the critical pathway, that is, the exposure pathway which will provide, for a specific radionuclide, the greatest dose to a population, or to a specific group of the population.

Once radionuclides move through a pathway and reach a person, the material deposited in the body remains there until it is removed by biological processes or until it decays away. Most materials entering the body tend to concentrate in specific organs. Ingested uranium, for example, may tend to concentrate in the bone. Once in the bone, it takes years for the uranium (which decays at a slow rate) to be removed by natural processes. As a result, the bones of a person who ingests uranium will absorb more energy (and receive more damage) than other parts of the body.

Exposure to Natural Radiation

We are constantly exposed to low levels of radiation. Most of it is background radiation – the radiation we receive from nature. In the United States, the average total annual exposure to an individual from all sources of radiation is 360 mrem.[4] Of this amount, about 300 mrem can be attributed to radon and other natural sources, while man-made radionuclides contained in medical sources and consumer products account for the remainder. Background radiation includes

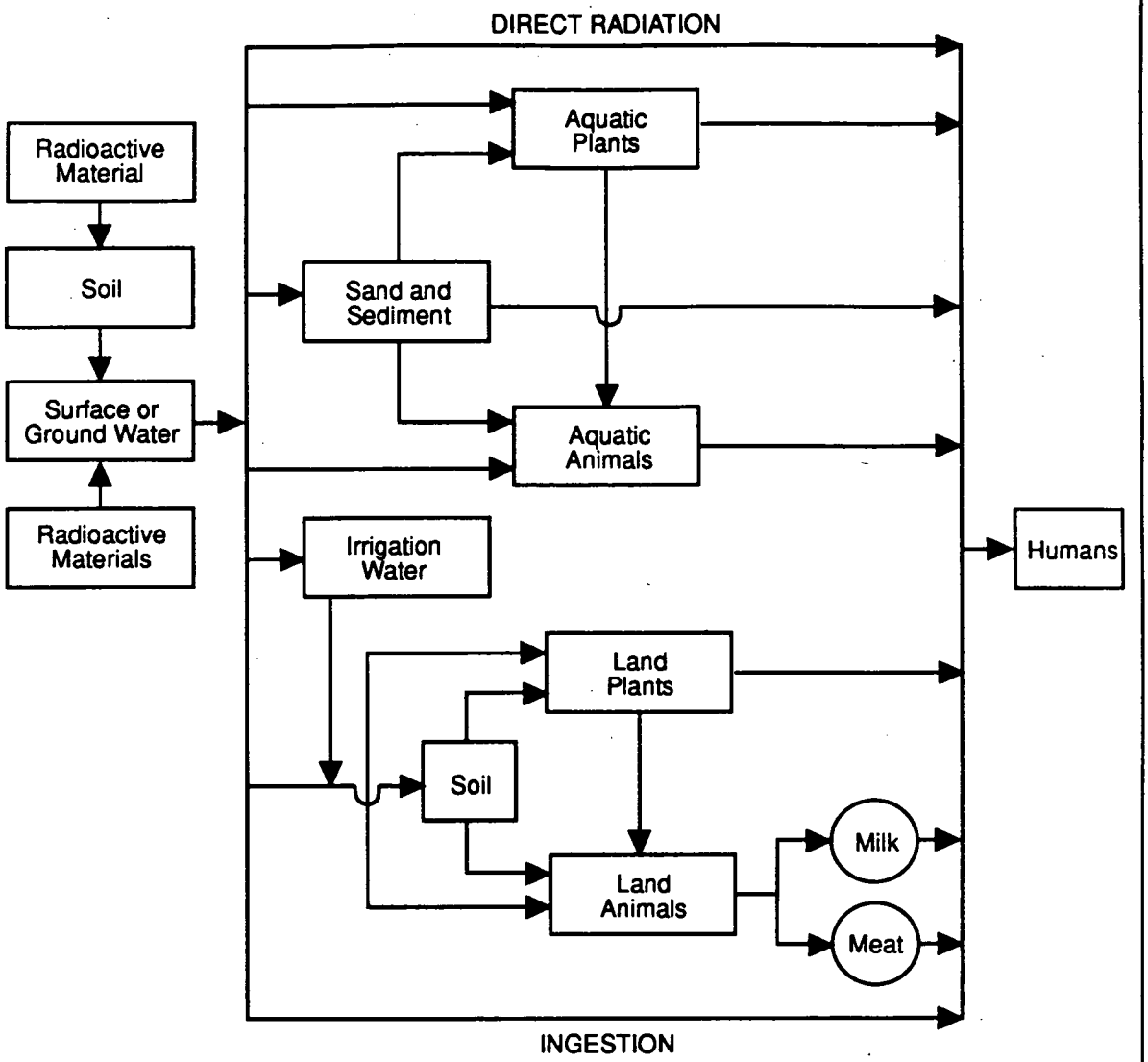

Figure 5: General Liquid Pathways to Humans

cosmic rays, the disintegration of radioactive elements in the earth's crust (principally radon), and naturally-occurring radioactive isotopes in the human body. We are also exposed to radiation from medical procedures, man-made fertilizers, nuclear reactor effluents, and household appliances such as smoke detectors and televisions.[5]

In this report, the radiation levels measured at the FMPC and in the surrounding environment are compared to the radiation levels at locations unaffected by FMPC operations. An important component of the Environmental Monitoring Program is the frequent monitoring and sampling of these kinds of background locations (such as sampling milk from a dairy in Indiana, or sampling water and sediment from the Great Miami River upstream of the FMPC discharge point). The data from these background locations, also referred to as control locations, enable the FMPC to assess the impact of operations on the environment. In those instances where control data are not available, the FMPC

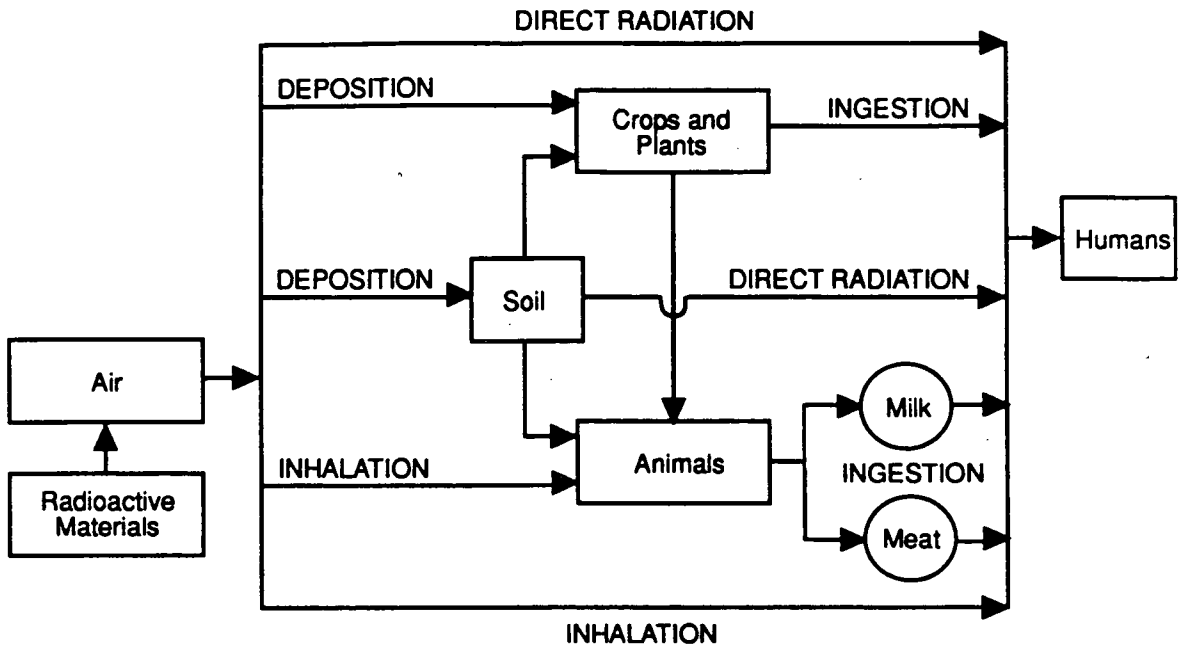

Figure 6: General Air Pathways to Humans

compares sampling and monitoring data to published values for specific radionuclides. Another reason the results of sample analyses are compared with results from control locations and also with data from previous years is that the concentration of radioactivity present in the environment will change due to factors such as weather or variations in the collection and analysis programs. The next section provides information on the effects of low-level radiation, whether it is naturally occurring or originates from a facility like the FMPC.

Effects of Low-level Radiation

The effects of radiation on humans are divided into two categories, somatic and genetic. Somatic effects are those that develop in the directly exposed individual, including a developing fetus. Genetic effects are those that are observed in the offspring of the exposed person.

Because we are constantly exposed to both natural and man-made sources of radiation, and because the body has the capacity to repair damage from low levels of radiation, it is difficult to determine the effects at low-levels. This section explains why this is true and how genetic effects may occur.

Somatic Effects. A dose of 1,000 rems of radiation delivered instantaneously will most probably kill a human. A dose of 600 to 1,000 rems causes severe sickness, but there is some chance for recovery. A dose of 200 to 600 rems causes some sickness with a very good chance for recovery. A dose of 100 to 200 rems could possibly cause some vomiting, but probably no demonstrable long-lasting effects.[6]

Significant clinical symptoms of radiation probably won't be seen in individuals who have been exposed to less than 100 rems.[7] Some scientists believe that there are no directly observable radiation effects on human beings exposed to less than 10 rems.[8] This may or may not be true. The uncertainty is caused by the fact that biological damage created by this level of radiation is too small to be detectable.

For example, someone with cancer may have developed it from man-made radiation, background radiation, or some other source not

related to radiation. Because all illnesses caused by low-level radiation can also be caused by other factors, it is presently impossible to determine individual health effects of low-level radiation. However, there are a few groups of people that are studied because they have been exposed to higher levels of radiation. These include the survivors of Hiroshima and Nagasaki, uranium miners in the United States and eastern Europe, a group of about 40 workers who used paint containing radium, early users of X-ray machines, some Department of Energy employees working in the defense facilities, and people suffering from illnesses where radioactive material was used for treatment.

Even after studying the health effects of radiation on these groups, scientists are still not able to determine with certainty how much cancer may have been caused by low-level radiation.

Those exposed to high levels of radiation are undoubtedly at greater risk. We know this because we see that the number of radiation effects increases as the level of radiation dose increases. This is represented in Figure 7.

This relationship is not so obvious when dealing with low-level radiation. Scientists have not been able to determine if there is an increase in the number of radiation effects when there is an increase in low-level radiation.[5] In other words, we do not know if there is a certain radiation level, or threshold, below which humans can be exposed without causing medical problems. If there is a threshold, the graph of the effect of radiation would look like Figure 8.

Estimates on the value of the threshold level for radiation, if it exists, vary significantly. As mentioned earlier, some scientists believe it could be as high as 10 rem.[6] Others insist there is no threshold level below which radiation exposure is safe.[8] They feel there is always a direct relation between the amount of radiation to which people are exposed and the number of related radiation effects. Figure 9 graphically represents the "no threshold" view.

Certain somatic effects have been documented only at high radiation levels. These include opacification, or clouding, of the lens of the eye, the impairment of fertility and the reduction of the number of white blood cells in the blood. Problems caused by radiation seen in the development of the embryo apparently result from large doses, not the low levels characteristic of natural background radiation. Therefore, the most likely somatic effect of low-level radiation is believed to be some increased risk of cancer.[5]

Genetic Effects. A single ionizing event has the potential to cause a genetic effect. To understand why this is true, it is helpful to look at the structure of a human cell.

Human cells normally contain 46 chromosomes; 23 transmitted from the mother, and 23 from the father. These 46 chromosomes contain about 10,000 genes, which are passed on to the next generation and which determine many physical and psychological characteristics of the individual.

Radiation can cause physical changes or mutations in these genes. Chromosome fibers can break and rearrange causing interference with the normal cell division of chromosomes, affecting the number and structure. A cell can rejoin the ends of a broken chromosome but, if there are two breaks close enough together in space and time, the broken ends from one break may join incorrectly with those from another. This can cause translocations, inversions, rings, and other types of structural rearrangement.[5]

The mutated genes can then be passed on to offspring. They typically have no effect on the offspring as long as the genes from the other parent are not mutated in the same way. However, the genes stay in the body of the offspring and are passed on to following generations. They can accumulate in number until they become so numerous that they meet similar genes when reproducing. They would then become present in the characteristics of the offspring.[6]

There is no evidence that there are radiation levels below which chromosomes are not affected, but the number of occurrences drops dramatically at lower levels of radiation.[9]

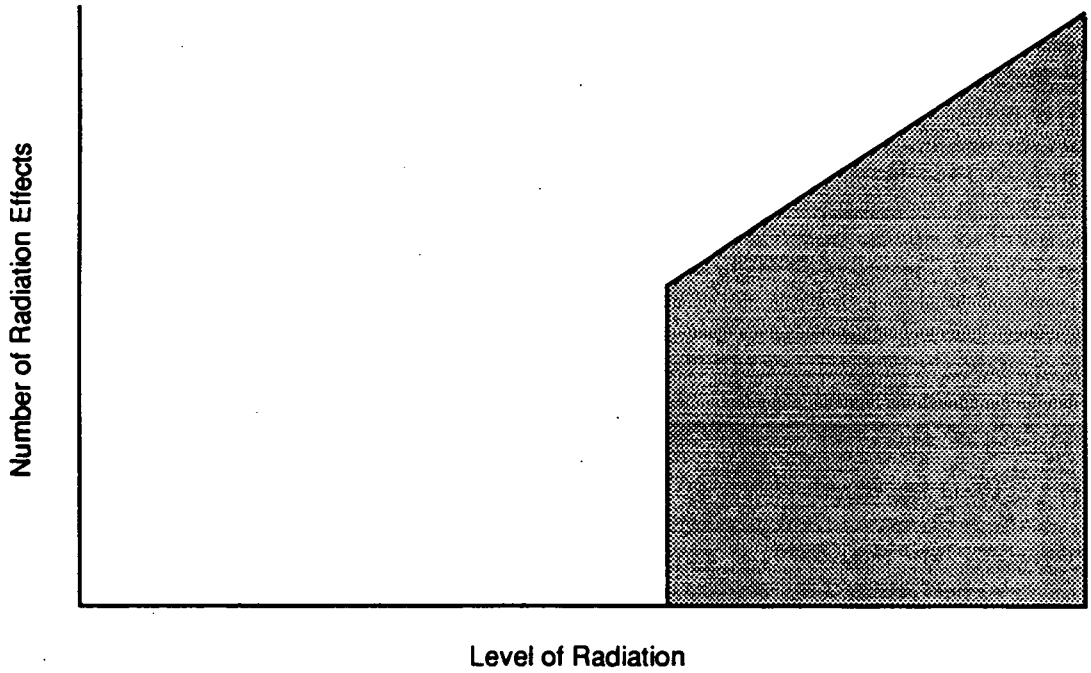

Figure 7. Number of Radiation Effects vs. Level of Radiation

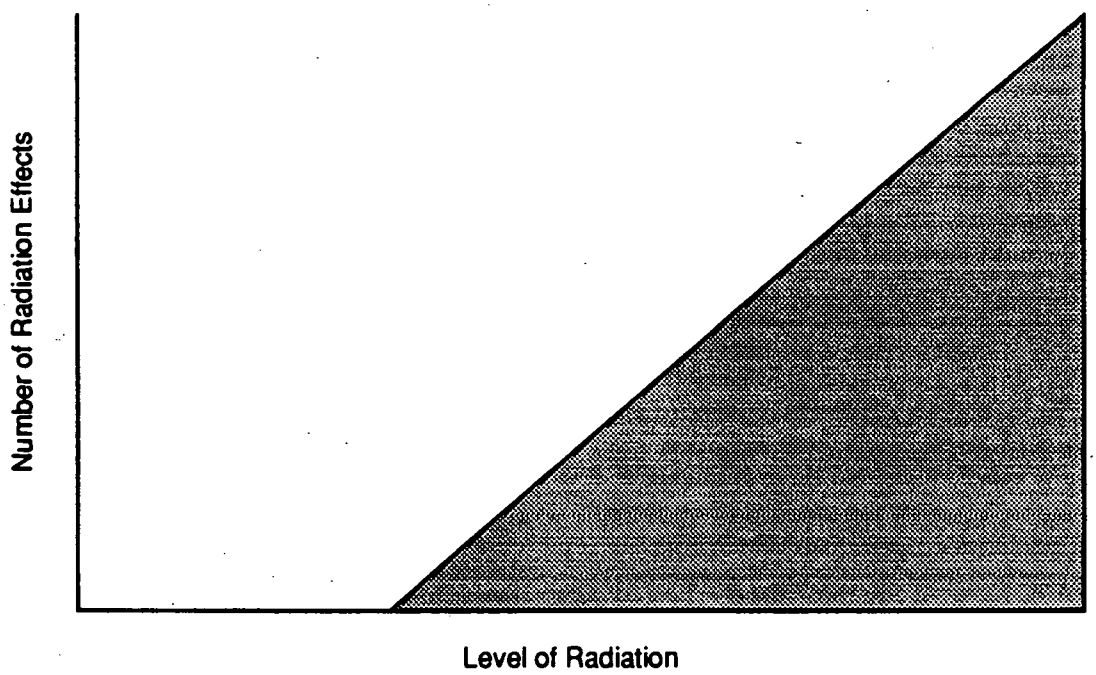

Figure 8. Threshold of Radiation

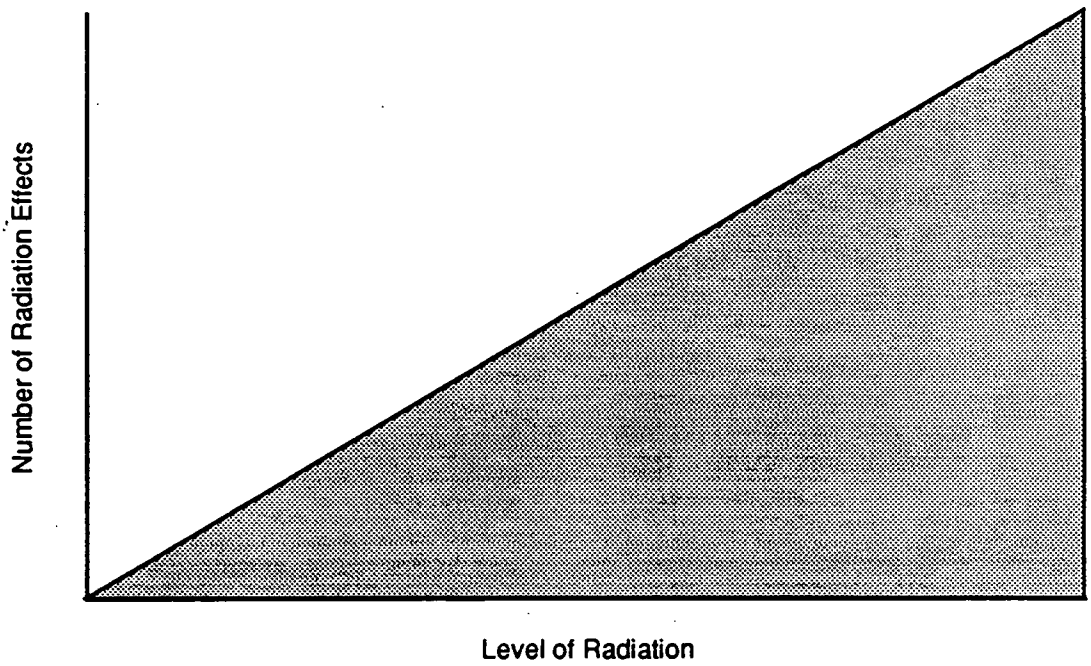

Figure 9. No Threshold of Radiation

Environmental Standards and Limits

The effects of radiological and nonradiological materials and how they move through the many pathways in the environment to humans have been examined by numerous national and international scientific and governmental groups, including USEPA, National Council on Radiation Protection (NCRP), International Commission for Radiological Protection (ICRP), and DOE. Organizations such as these have established many standards and guidelines to ensure that employees, people in the surrounding communities, and the environment are protected. The FMPC follows these standards and guidelines in its daily operations. The following paragraphs describe some of the standards that apply to the operation of the FMPC.

Department of Energy publications define the standards for radiation exposure to the public from discharges to the water and air. These standards are included in DOE Order 5400.xx, "Radiation Protection of the Public and the Environment."[10] The FMPC must not exceed these standards, which have been adopted by DOE based upon recommendations of ICRP.[11]

The standards state that the individual exposed to the greatest amount of radiation, the maximally-exposed individual, be subject to no more than 100 mrem (one mSv) per year effective dose. The standard further states that no individual organ can receive more than 5 rem (0.05 Sv) per year.

The maximally-exposed individual is that member of the community calculated to receive the highest effective dose based on the location of his or her home, weather conditions, and the critical pathway.

Throughout this report, specific standards for various pollutants are stated for comparison to the results of the FMPC Environmental Monitoring Program. There are some pollutants, or parameters, for which standards have not yet been established. Furthermore, there are instances where standards do not exist for parameters in specific media, such as uranium in

soil, vegetation, produce, or fish. However, these data are included in the calculations used to determine dose. This is discussed in Chapter 2. In the absence of standards, results are compared with control data from areas unaffected by the FMPC activities. 1988 results are also compared with results of previous years to establish trends.

The Environmental Monitoring and Sampling Program

To define a comprehensive environmental monitoring program, a facility must consider many factors, including the production process, the wastes and byproducts of production, the physical characteristics of the surrounding environment, how the contaminants move through the environment, and the standards and limits established by the government and regulatory agencies. After considering these kinds of factors, the FMPC designed a comprehensive, year-round program to evaluate the impact of its operations and remedial activities on the environment. By collecting data on the region's groundwater, surface water, air, soil, sediment, vegetation, milk, and fish, the FMPC is able to estimate the radiation dose to humans.

Monitoring and Sampling Emissions

The FMPC conducts routine monitoring and sampling of the environment for hazardous, radioactive and chemical materials both onsite and offsite. Environmental monitoring refers to continuous observations and data recording. For example, the FMPC has installed continuous samplers at liquid discharge points to monitor the content of wastewater. Sampling corresponds to the collection of a physical sample and the chemical analysis of that sample in a laboratory. This could be soil, sediment, or water samples. Generally, monitoring enables a facility to distinguish trends and deviations from background concentrations of constituents more quickly than sampling does because monitoring results are readily available. Sampling, on the other hand, requires time for analyses so results are not as readily available as from monitoring. However, sampling furnishes more sensitive data than monitoring and provides quantitative estimates of the parameter of interest.

The decisions as to what types of samples to collect were made after considering the pathways for the transfer of radionuclides through the environment to humans. Sampling locations were determined based on sample availability, local meteorology, local water characteristics, local population characteristics, and land uses. The sampling frequencies for the various media were based on the radionuclides of interest, their half-lives (the amount of time required for one-half of the material to decay; half-lives vary from millionths of a second to millions of years), and their behavior in the environment.

Within this report, annual summaries of monitoring and sampling data are presented in the text, figures (usually as bar charts), and in tables. The summary tables display the sampling location, number of samples collected, minimum, maximum and average concentrations of the parameter(s) of interest, and the percent of standard. The 95% confidence levels about the average are calculated where possible.

Because no two samples of a material will normally yield precisely the same results, and because of variability in the laboratory analysis of a material, there is always some degree of uncertainty as to a true, or exact value of a sample. The reader can interpret the 95% confidence level to mean that "we are 95% confident that the true average value lies between the average minus the confidence level and the average plus the confidence level." For example, in Table 9 of this report *Radionuclides in Air*, an average value for each radionuclide is followed by a "±" and a number. This number represents the 95% confidence level. All data for the Environmental Monitoring Program are in the tables included in Appendix A.

History of the FMPC Environmental Monitoring Program

Environmental Monitoring Reports for the FMPC have been issued regularly for the past 30 years. Format and content have changed greatly in that time.

The first FMPC Environmental Monitoring Report was published May 1, 1960 and covered calendar year 1959. The report contained two pages of text, two tables and two figures that summarized analytical results for air and water samples collected at the following locations:

- Air - sampling stations located at the four corners of the production area fenceline
- Water - where the FMPC effluent enters the Great Miami River and at upstream and downstream locations in the river (Ross and New Baltimore, Ohio).

Over the years, changes were made in the time periods covered by each report. For 1960 and 1961, quarterly reports were issued with an annual summary in the fourth quarter report. From 1962 to mid-1970, semiannual reports were issued with an annual summary in the second half report. A semiannual report was issued for first half of 1971 and an annual report was issued for the entire year. Only annual reports were issued thereafter.

Report content also underwent a considerable change. The brief quarterly reports of the early 1960's evolved into more extensive documents which contain data for many radionuclides in samples collected at several hundred locations. Many additions to the report are a consequence of the requests that the public and governmental agencies should be provided with information that compare actual site discharges against regulatory standards and guidelines.

Structure of the Monitoring Program

Since air and liquid effluents are the primary pathways by which pollutants from the FMPC can reach surrounding populations and the environment, the FMPC Environmental Monitoring Program is organized into two major sections: monitoring and sampling for the effects of air emissions, and monitoring and sampling for the effects of liquid effluents.

The primary source of FMPC emissions for the air pathway are the furnaces, milling machines, and other types of production machinery in the plants. Fugitive dust particles from the production area and the waste pit area also contribute to overall air emissions. Fugitive dust is dust that is not vented through a production stack; for example, dust from construction activities.

The FMPC also collects soil, vegetation, produce and milk samples to investigate the extent to which pollutants are transported from the FMPC via the air pathway.

The primary component of the liquid pathway to humans is the FMPC effluent discharge point (the outfall) on the Great Miami River. The Great Miami River is not a source of public drinking water between the FMPC and the Ohio River. Some people do fish in the Great Miami River, but the river is considered unsafe for swimming due to the turbulence of the water. Nonetheless, the FMPC continuously monitors and samples all wastewater effluent before it is discharged through the outfall into the river. In addition, the FMPC conducts routine surface water and sediment sampling in the Great Miami River and Paddy's Run, and annually samples fish near the FMPC outfall.

A second component of the liquid pathway is the possible contamination of the groundwater through runoff from the production area and the waste storage area. The FMPC has installed over 110 groundwater monitoring wells during 1988 as part of the ongoing Remedial Investigation and Feasibility Study (RI/FS). The data collected as part of the RI/FS, as well as the data collected as part of the ongoing Environmental Monitoring Program, enable the site to identify the extent of any contamination in the groundwater and to develop plans to rectify the situation. The RI/FS program is discussed in Chapter 6.

Topics Discussed in this Report

The next chapter, Chapter 2, describes how some of the data from the sampling program are used in computer models and in calculations to estimate effects of radiation exposures to individuals and population groups near the FMPC.

Chapter 3 details the sampling and monitoring program; Chapter 4 centers on data verification and quality assurance procedures. The ongoing and expanding waste management activities are described in Chapter 5, and Chapter 6 covers several additional topics:

- The Remedial Investigation/Feasibility Study
- Water compliance activities, including projects to improve the control of effluent
- Air compliance activities, including stack sampling
- Additional studies and improvements, including a discussion on the Environmental Impact Statement, improvements in the storage of production chemicals at the site, and the results of independent tests of drinking water in the vicinity of the site
- Unusual events during 1988 such as the Plant 2/3 gulping emissions.

Chapter Two
Estimated Radiation Doses for 1988

One of the chief public concerns about any facility that handles radioactive materials is that people in the area will be exposed to harmful amounts of radiation. This chapter provides estimates of the radiation doses generated by the FMPC during 1988. Overall these estimates indicate that people in the area surrounding the FMPC were exposed to a committed effective dose of less than 3% of the DOE standard defining radiation protection of the public and the environment (Table 1). This dose takes into account all contributors to the air pathway, which is the critical pathway for the FMPC.

This chapter explains how the FMPC estimates the maximum dose an individual in the public could receive through the air pathway from FMPC operations during 1988. Similarly, dose calculations are made for the liquid pathway and external radiation based on data from the sampling and monitoring conducted throughout the year for these media. The next section describes the terms used in the dose calculations for this report.

Defining Dose Terms

In the field of radiation protection, several terms are used to describe the types of doses an individual or group of individuals may receive from a facility like the FMPC. To aid the general reader's understanding of the data and the conclusions drawn from the analysis, some of the general terms are described in the following paragraphs. Additional terms are included in the glossary to this report.

Dose equivalent is an expression of the effect of radiation on the body. This dose measurement takes into account the type and energy of the radiation as well as its effect on human tissue. The term "dose equivalent" is frequently shortened to dose, which is the term used in this context in this report.

Whole body dose equivalent results from a uniform irradiation of the whole body. For the vast majority of radionuclides emitted from the FMPC, a whole body dose is due to radionuclides external to the body (as opposed to radionuclides entering the body through ingestion and inhalation). The whole body refers to all human organs or tissue excluding the skin and the lens of the eye. The whole body dose is reported for comparison with the National Emission Standards for Hazardous Air Pollutants (NESHAP) guideline of 25 mrem (0.25 mSv) per year.[12]

Organ doses are also reported to verify compliance with NESHAP, which sets the annual exposure limit from airborne emissions of 75 mrem (0.75 mSv) to specific organs.[12] The organ of interest is the particular organ or tissue that is likely to be of greatest importance when

more than one organ is exposed. Several factors influence the selection of this organ, including the amount of dose received, the chemistry of the radionuclide, the sensitivity of that organ to the particular form of radiation, and the importance to the overall health of the person resulting from damage to that organ. Organs of primary interest for the radionuclides found in FMPC discharges and processes are the lung, kidneys, and bone surfaces.

Effective dose equivalent represents a weighted average of doses to specific organs as defined by ICRP.[11] The effective dose incorporates exposures from inhalation and ingestion as well as from external exposure. It can be used to estimate the health effects risk of the exposed individual. A weighting factor for each organ is applied in calculating the effective dose equivalent. The weighting factor is the ratio of the random risk of any health effect arising from a dose to a specific tissue to the total risk of possible health effects when the whole body is irradiated uniformly. To calculate the effective dose equivalent, all of the organ doses (multiplied by their respective weighting factors) are summed. This is the dose most often cited for comparisons to standards.

Committed effective dose equivalent is the effective dose that will be accumulated by a specific organ over a specified period (often 50 years) following initial intake, retention by the body, and continued decay of the absorbed radioactive substance.

How Estimates of Dose Are Determined

In order to arrive at the most accurate estimate of radiation doses, the FMPC uses data gathered from monitoring and sampling efforts along with an understanding of the air and liquid pathways, information about the site, and the surrounding community.

To estimate the doses a person could receive through the air pathway from FMPC operations, airborne data are provided as input to a sophisticated mathematical modeling program referred to as AIRDOS. It is a USEPA requirement that the FMPC use AIRDOS to demonstrate that the site complied with the Clean Air Act (CAA). AIRDOS was developed by Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. The FMPC worked with ORNL and used the AIRDOS code to compute the dispersion of airborne radionuclides and the doses due to airborne releases of radionuclides through all inhalation, ingestion, and direct radiation pathways, and estimates the committed radiation dose an individual could receive over the next 50 years due to FMPC releases during 1988. Calculations follow the standards established by ICRP Reports 26 and 30, with some modifications recommended by the USEPA.[11]

Maximum Doses to an Individual in the Public as Calculated using AIRDOS

The following maximum doses from FMPC air emissions to the individual were calculated using the AIRDOS model:

- 19 mrem (0.19 mSv) to the pulmonary tissue
- 14 mrem (0.14 mSv) to the bone surface
- 2.9 mrem (0.029 mSv) committed effective dose
- 0.00089 mrem (8.9×10^{-6} mSv) external whole body dose (Table 1).

The calculated doses are well below DOE standards.

For the 1988 dose calculations, the FMPC and ORNL included data such as source terms (source terms are the annual emissions of radionuclides listed in Table 2), population distribution data, and site-specific meteorological data. In 1988, for the first time, the FMPC used annual average meteorological data from a 60-meter instrument tower located onsite just west of the Stormwater Retention Basin for all AIRDOS calculations (Figure 1). In the past, the FMPC used a five-year average of meteorological parameters from Greater Cincinnati International Airport, located about 27 km (17 mi) south of the site. The site meteorological data are considered much more representative of meteorological conditions

than data obtained from the airport, which has somewhat different topographical features.

The 1988 estimated airborne releases included not only discharges from monitored stacks and the Plant 8 scrubbers that were included in the 1987 dose calculations, but for the first time included accidental releases of radionuclides, estimates of releases from unmonitored stacks, building ventilation systems, and fugitive emissions such as resuspended materials from contaminated areas and the waste pits.

During 1988, an exhaustive review of possible contributors to FMPC airborne emissions was conducted following discovery in June of airborne emissions from a refinery stack that had not previously been considered as a potential emitter of uranium. This led to an examination of every unmonitored stack at the FMPC. Where actual emissions could not be measured, conservative emission estimates were made.

The estimated total airborne uranium release during 1988 was 108 kg (237 lb), which included a discharge from all process stacks of 28 kg (62 lb) after correcting for round-off errors; a release of 66 kg (146 lb) from Plant 2/3 during a three-week period in June; a total of 0.9 kg (2 lb) from a chip fire in October; and an estimate of 13 kg (29 lb) from fugitive dust releases from the waste storage area during the year.

The 0.9 kg of uranium from the chip fire was included as an accidental release for the AIRDOS model even though a review of the event concluded that there was no uranium loss offsite to the atmosphere and/or to the ground.[13] The 0.9 kg loss was based on an inventory difference before and after the chip fire, and was included in AIRDOS as a worst-case assumption.

The 1987 airborne emissions were also recalculated. Largely due to unmonitored discharges from denitration gulping operations (200 kg; 441 lb), the 1987 estimate was revised to 302 kg (664 lb). The estimated 1988 releases were, therefore, 36% of the revised 1987 estimates.

The 1988 airborne emission data compiled by the FMPC were entered into AIRDOS, along with information about the area surrounding the FMPC. The area was divided into 16 wind sectors (Figure 10 is a typical example of wind sectors) and the residence closest to the FMPC in each sector identified. All potential sources of airborne radionuclides were considered, and where the actual release was not measured, conservative assumptions were made. An additional important conservative assumption was that an individual at each location in the 16 wind sectors remained outside his home 100% of the time for the entire year.

Dose calculations were made for each of the 16 residents. Even though the predominant wind direction at the FMPC is from the southwest (Figure 11 includes a wind rose), the resident who received the maximum dose during 1988 lives 1,340 meters (0.83 mi) west-northwest of the center of the FMPC production area. This is the result of the very conservative source terms that were calculated for fugitive dust emissions from the waste storage area, which is located in the northwest sector of the site.

Although uranium processing decreased in 1988, the inclusion of conservative emission estimates for sources previously assumed to have no airborne contribution resulted in an increased estimate of dose to the maximally-exposed individual via the air pathway. Nevertheless, the maximum committed effective dose of 2.9 mrem (0.029 mSv) was less than 3% of the DOE standard for protection of the public, and 25% of the USEPA NESHAP standard for annual exposure to specific organs.

Calculating Other Doses via the Air Pathway

In addition to calculating the maximum dose to an individual, the FMPC used AIRDOS to calculate the cumulative radiation dose over the next 50 years to the human population living within 80 km (50 mi) of the FMPC resulting from 1988 emissions (Table 3). The dose was negligible compared to the background radiation the same population received over the same time period. The FMPC also used AIRDOS to calculate the doses a person could receive if he were at an air monitoring station (AMS) 100% of the time for an entire year. The locations of the air monitoring stations are shown in Figure 11; the summary

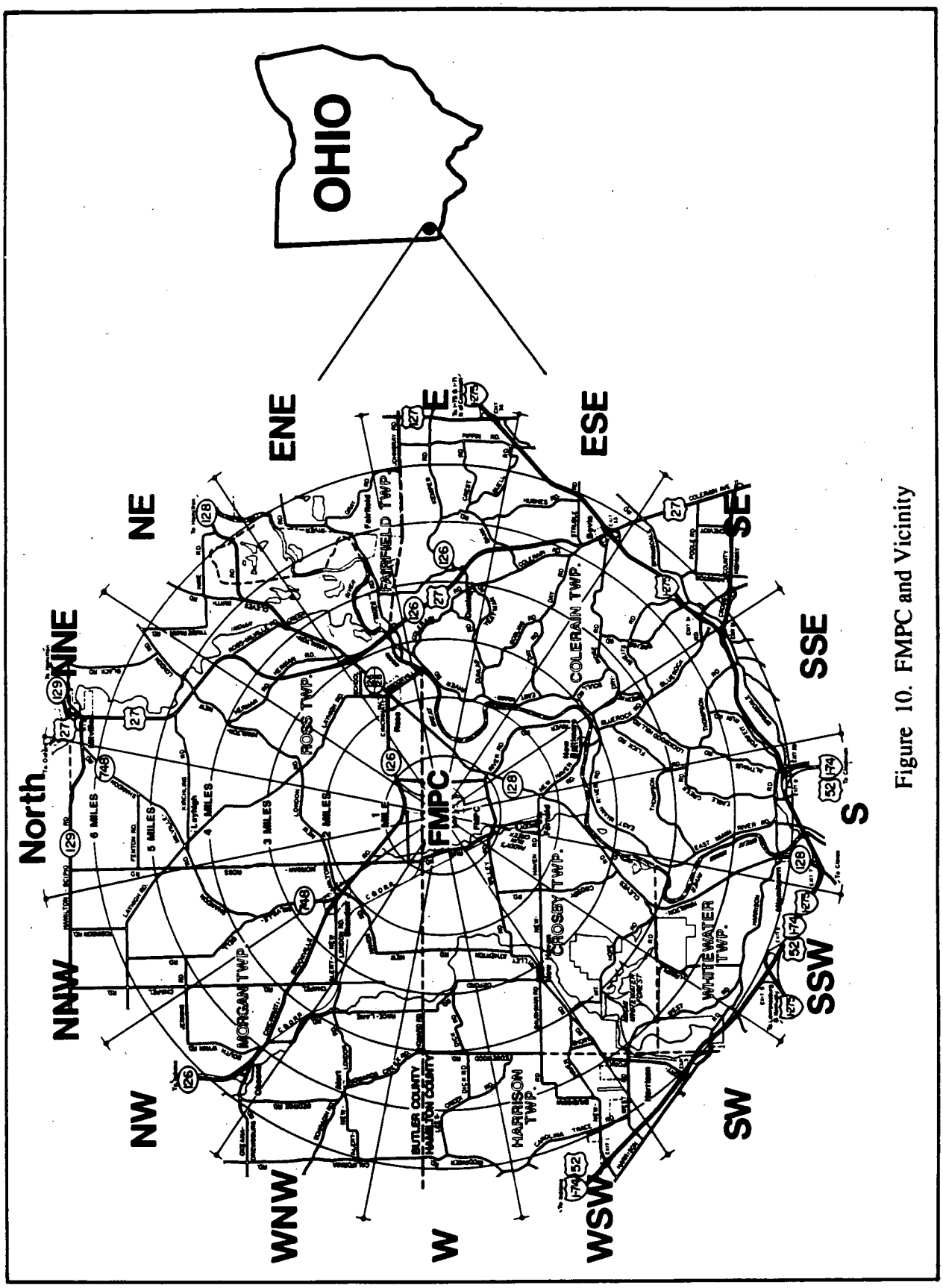

Figure 10. FMPC and Vicinity

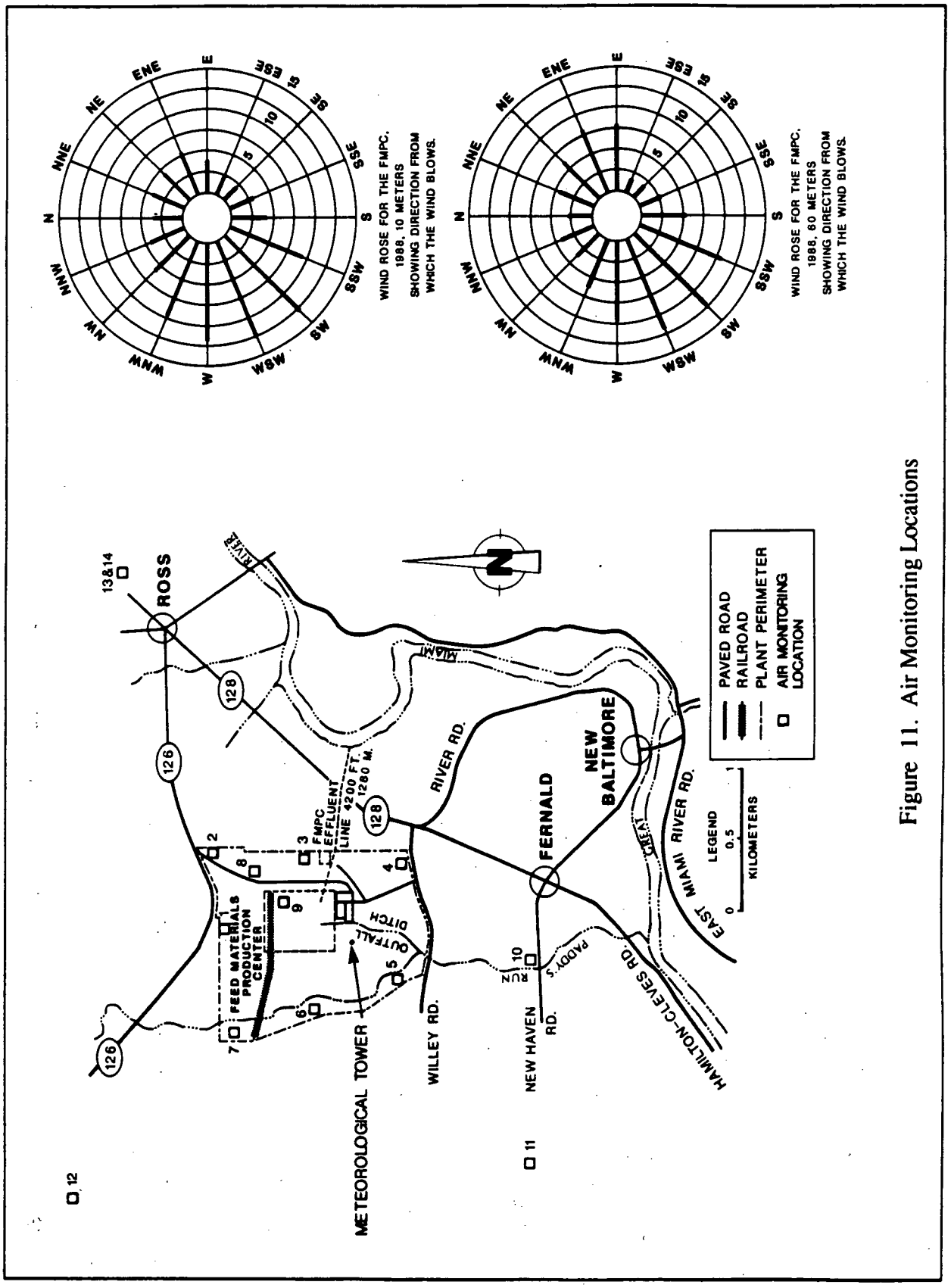

Figure 11. Air Monitoring Locations

included in Table 4 shows that the calculated doses are well within the NESHAP standards. Lastly, the FMPC calculated the estimated committed effective dose over 50 years that an individual could receive from eating produce grown near the FMPC. This dose was also insignificant (Table 1). The following paragraphs explain how the FMPC determined these values.

Estimated Population Dose

AIRDOS was used to calculate the cumulative radiation doses over the next 50 years - these doses are the committed doses - to every person within 80 km (50 mi) of the FMPC resulting from 1988 emissions. The committed effective dose due to 1988 airborne emissions was 59 person-rem (0.59 person-Sv). A person-rem is the collective dose to a population group. For example, a dose of one rem to ten people results in a collective dose of ten person-rem. As a comparison, the effective dose due to natural radiation per year for the same population group is 900,000 person-rem (9,000 person-Sv). The total whole body dose for the 80 km (50 mi) population was 0.066 person-rem (6.6×10^{-4} person-Sv) due to 1988 airborne emissions.

To calculate doses at any given location, the AIRDOS model uses airborne emission data, thus the model is a very effective way to compare annual doses to the population over a very wide area. Since the FMPC measures uranium and other radionuclide concentrations at the air monitoring stations, AIRDOS can calculate doses at those locations, including along the FMPC fenceline where the public has closest access to the site.

Estimated Doses at the Air Monitoring Stations

Average air concentrations of uranium and other radionuclides at air monitoring stations 1 through 14 were entered into AIRDOS. Table 4 presents the estimated lung doses and effective doses that could be accumulated for the next 50 years for a person breathing the air at one of the stations 100% of the time during 1988.

The results showed that the 1988 average committed effective dose at air monitoring stations 1-7 was 2.0 mrem (0.020 mSv). AMS 3 had the maximum committed effective dose of 4.0 mrem (0.040 mSv), while AMS 7 had the minimum committed effective dose of 0.7 mrem (0.070 mSv). The maximum calculated fenceline pulmonary dose at AMS 3 (32 mrem, 0.032 mSv) was 43% of the NESHAP standard for organ dose.

The calculated average offsite committed effective doses at AMS 10 through 14 were 0.6 mrem (0.006 mSv), with the maximum of 1.1 mrem (0.011 mSv) at AMS 13 and the minimum of 0.4 mrem (0.004 mSv) at AMS 12. These were a small fraction of the annual average background radiation dose of 360 mrem received by individuals living in this area, and were comparable to 1987 doses (Table 4).

Even though the public does not have access to the onsite locations, AMS 8 & 9, the FMPC calculated the committed effective doses at those locations as well. The results were 5.2 mrem (0.052 mSv) and 7.5 mrem (0.075 mSv) respectively.

As in 1987, the highest estimated doses were calculated at the two onsite stations and at the fenceline station AMS 3. Also as in 1987, the lowest doses were at the offsite locations AMS 10, 11 and 12.

By comparing doses at AMS 8 & 9 with the fenceline and offsite stations, one can see how quickly the values drop as the distance from the FMPC increases. For example, the committed effective dose decreased 59% from AMS 9 to AMS 2, and decreased an additional 64% from AMS 2 to AMS 13. The committed effective dose decreased 85% from AMS 9 to AMS 13. These air monitoring stations are in line sequentially outward from the process area in the prevailing wind direction, as shown in Figure 11.

This decrease occurs in part because the particles of uranium in the air emissions are relatively heavy (uranium is a heavy metal - about 19 times as heavy as water and more than 50% heavier than lead). The uranium particles tend not to disperse as far or as uniformly as lighter particles might under similar conditions. Therefore, it would be expected that as distance

from the FMPC process area increases, the concentration of uranium isotopes in the air would decrease rapidly. This expectation is supported by data collected at air monitoring stations 9, 8, 2 and 13, and by soil samples collected near these stations. Data on uranium concentrations in air and in soil are provided in Chapter 3 and Appendix A.

Estimated Dose from Eating Produce Grown Near the FMPC

Since there are many private stands that sell produce grown on farms near the FMPC, this report estimated the committed effective dose an individual could receive over 50 years from ingesting uranium in the produce grown on those farms during 1988. The calculated committed effective dose of 0.025 mrem (2.5×10^{-4} mSv) is considered insignificant.

To calculate this dose, the FMPC collected samples of the local produce and analyzed them for uranium. The dose calculations were based on a person eating about 38 kg (84 lb) of potatoes during 1988. Potatoes were chosen since, as a tuber, they tend to take up any available uranium in the soil more readily than other types of produce would under similar conditions. Therefore, an individual eating produce grown on nearby farms would not receive a significant radiation dose.

Liquid Pathway Dose Calculations

Even though the liquid pathway is not the critical pathway for the FMPC, doses were calculated for a person drinking only water from either the offsite well with the highest uranium concentration, or from the Great Miami River at the FMPC outfall. These sources were used for dose calculations even though neither was actually used for drinking water. The FMPC also sampled and analyzed fish from the Great Miami River, and calculated a dose from eating fish. The results are discussed in the following paragraphs.

Estimated Dose from Drinking Groundwater from Well 15

Well 15, which is located just south of the site and is not used as a source of drinking water, had the highest offsite uranium concentration in 1988. The committed effective dose an individual could receive over a 50-year period from drinking 2.0 liters (2.1 quarts) of water per day from well 15 during 1988 was calculated to be 32 mrem (0.32 mSv), which is 32% of the DOE standard, and 515 mrem (5.15 mSv) to the bone surface, which is 10.3% of the DOE standard (Table 1).

Estimated Dose from Drinking Great Miami River Water

Although the Great Miami River is not designated as a public water supply by the OEPA, the FMPC estimated the radiation dose over a period of 50 years to an individual if, during the year 1988, that person drank only the water from the river at the FMPC effluent discharge point. A daily intake of 2.0 liters (2.1 quarts) could result in a dose of 1.1 mrem (0.011 mSv) to the bone surface, and a committed effective dose of 0.072 mrem (0.00072 mSv) for average river flow during 1988.[14] The bone dose from drinking river water containing FMPC effluents would be less than 30% of the USEPA standard for drinking water. The USEPA has not established an effective dose standard for drinking water. The doses (which are calculated using measured radionuclide concentrations in the effluent line) could vary due to fluctuations in flow rates of both the Great Miami River and the FMPC effluent line. These dose calculations assumed drinking river water that was mixed with FMPC effluent, and were based on average FMPC discharge and river flow rates.

Estimated Dose from Eating Fish from the Great Miami River

As part of the ongoing monitoring and sampling program, fish from the Great Miami River were sampled in September 1988 and analyzed for total uranium. The data indicated an increased level of uranium above background levels in the

fish collected at all three sampling locations. There is currently no explanation for the apparent increase in uranium concentration, although a different contract laboratory analyzed the fish for the FMPC this year. The fish sampling program is discussed in Chapter 3.

Continuous monitoring of uranium discharged into the Great Miami River during 1988 showed a small increase over the amount discharged in 1987 (858 kg vs 770 kg). Also, measurements of uranium in river sediment indicated only background concentrations at all sampling locations. The laboratory is rechecking its analyses to verify the results, and a resampling effort is being undertaken to check for sampling biases and to better define the cause and extent of the increase.

Using the available, albeit suspect, uranium concentration data, the FMPC calculated the increased dose a person could receive from consuming 4.4 kg (9.7 lb) of this fish caught by the FMPC outfall to the Great Miami River. That person could receive an estimated committed effective dose of 0.31 mrem (0.0031 mSv), and a maximum organ dose of 4.9 mrem (0.049 mSv) to the bone surface. While higher than those calculated from 1987 data, these doses were well below DOE standards.

External Radiation Pathway

There are many sources of external gamma radiation at the FMPC, but the primary source of concern to the public is the K-65 Silos. The FMPC calculated a dose for exposure to gamma radiation using thermoluminescent dosimeters (TLD) located at each air monitoring station. TLD's are small devices which store radiation dose information for several months or even longer. This provides an excellent method to measure the dose received over long periods of time. The maximum annual gamma exposure of 15.3 µR/hr (15.3 µrem/hr) was measured at AMS-6, the station closest to the K-65 Silos on the west side of the site (Table 5).

To assess doses from direct radiation to individuals living near the site, the FMPC used a pressurized ionization chamber to collect data at various locations around the FMPC. Several measurements were taken at control locations to obtain an average background gamma dose rate from natural sources. This value was determined to be 65 mrem (0.65 mSv) per year. One should note that this was not the total background dose for this area, as shown in Table 1. The conservative estimate of the annual external gamma dose to the resident living closest to the K-65 Silos was 16 mrem (0.16 mSv) above background, which is less than 16% of the DOE standard. Again, this dose included the conservative assumption that the resident remained outside his home 100% of the time during 1988.

Radon

The largest contributor to the average annual effective dose to individuals in the U.S. population is from natural background concentrations of radon and its decay products. At an average of 200 mrem/yr (2 mSv/yr), naturally-occurring radon accounts for 56% of the 360 mrem/yr (3.6 mSv/yr) background dose in the U.S.[11] Although the FMPC is not currently required under NESHAP to calculate the dose due to radon, DOE standards specify that emissions of radon to uncontrolled areas must be at average concentrations less than 3.0 pCi/l (0.11 Bq/l).

The net radon concentration of 0.60 ± 0.60 pCi/l (0.022 ± 0.022 Bq/l) indicated that the concentrations measured at the FMPC fenceline were not statistically distinguishable from background radon concentrations, and were within DOE guidelines.

The Origin of Radon

Radon originates from the natural, radioactive decay of uranium. When an uranium atom decays, it begins a long series of transformations from one radioactive chemical form to another, until finally a stable (nonradioactive) atom of lead is produced. Each of the various radioactive atoms (radionuclides) created during the transformations has its own natural rate of decay. The sequence of different atoms that

result during the decay process is called the decay chain.

There are two distinct isotopes (isotopes are atoms which have the same number of protons but different numbers of neutrons) of radon that are of concern. The first, commonly called radon, results from the radioactive decay of uranium-238. The second, commonly called thoron, results from the radioactive decay of thorium-232. Neither of these isotopes of radon is found in significant quantities in the materials processed at the FMPC. Before delivery to the site, the recycled feed materials undergo a chemical process which removes the materials that decay to radon and thoron. Because of the very long radioactive half-lives of uranium-238 and thorium-232, little radon and thoron have been produced by their decay during the 38 years of FMPC operations.

However, the FMPC does store materials that produce radon and thoron. Radium-226, the immediate precursor of radon, is a constituent of the material stored in the K-65 Silos. Thorium-228, a precursor of thoron, is found in the material that is stored in the thorium warehouses. Radon, which has a half-life of 3.8 days, has a greater potential for contributing to offsite radiation exposure than thoron, which has a half-life of less than one minute.

The FMPC Radon Monitoring Program

Because of the increased awareness about radon concentrations, the FMPC collected radon data by monitoring 21 locations along the FMPC fenceline during 1988. In addition, there were 16 radon monitoring locations immediately adjacent to the K-65 Silos, four monitoring locations onsite at various distances from the silos, and nine offsite locations (Figure 12).

The nine offsite locations are classified as follows: four at offsite air monitoring stations; three positioned outdoors at nearby residences; and two locations more than 20 km (12.4 mi) from the FMPC in the two least prevalent wind directions. These last two locations were monitored in order to measure background concentrations of radon. The program also includes real-time continuous radon monitors which were installed at four locations along the K-65 exclusion fence. These monitors are not used for perimeter fenceline dose calculations, but are expected to provide data for estimating occupational doses near the K-65 Silos.

Each fenceline location contains two, three, or six alpha-track-type radon detectors in a weatherproof housing. An alpha-track radon detector is a passive, long-term device for integrating radon concentrations in air by permanently recording the tracks of alpha particles being emitted from radon and its decay products. The detectors are changed quarterly by FMPC personnel, who then send the detectors to the company which provided them for analysis. A summary of results is presented in Table 6. The 1988 results are not significantly different from those obtained in 1987.

Two background locations were discontinued in 1988 and replaced with locations more distant from the FMPC in the two least prevalent wind directions. Radon detectors at air monitoring station locations AMS 3 and AMS 5 were also removed (the air monitoring stations continue to operate) because radon detectors at FMPC-E and FMPC-I were in the same location along the fenceline (Figure 13).

For each quarter of the year, the average radon concentration at each location was computed from the results for all of the detectors at that location. At year's end, the average of the four quarterly concentrations was computed; these annual averages are presented in Table 6.

Also presented in Table 6 is the average of all 21 fenceline monitoring locations for 1988, the average of the two background locations for 1988, and the average net radon concentration at the fenceline for 1988. Included with this data are the standard deviations at the 68% confidence level. The net concentration of 0.60 ± 0.60 pCi/l (0.022 ± 0.022 Bq/l) indicated that the concentrations measured at the fenceline (and, therefore, the doses) were not statistically distinguishable from background concentrations, and were within DOE guidelines. The DOE required that radon concentrations in uncontrolled areas (such as the FMPC fenceline) be maintained at less than 3 pCi/l (0.11 Bq/l) above background. The average fenceline

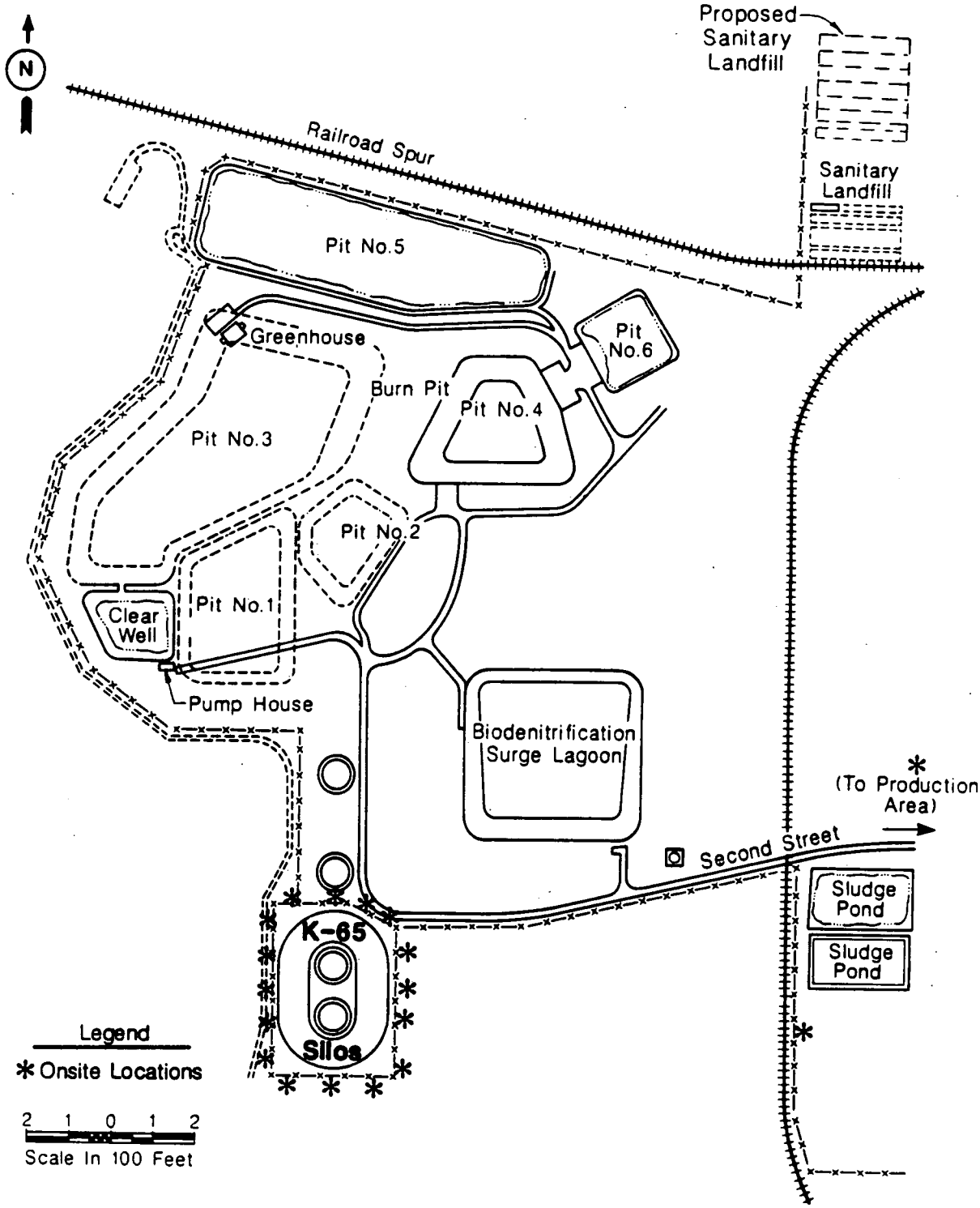

Figure 12. Onsite Radon Monitoring Locations - Waste Storage Area

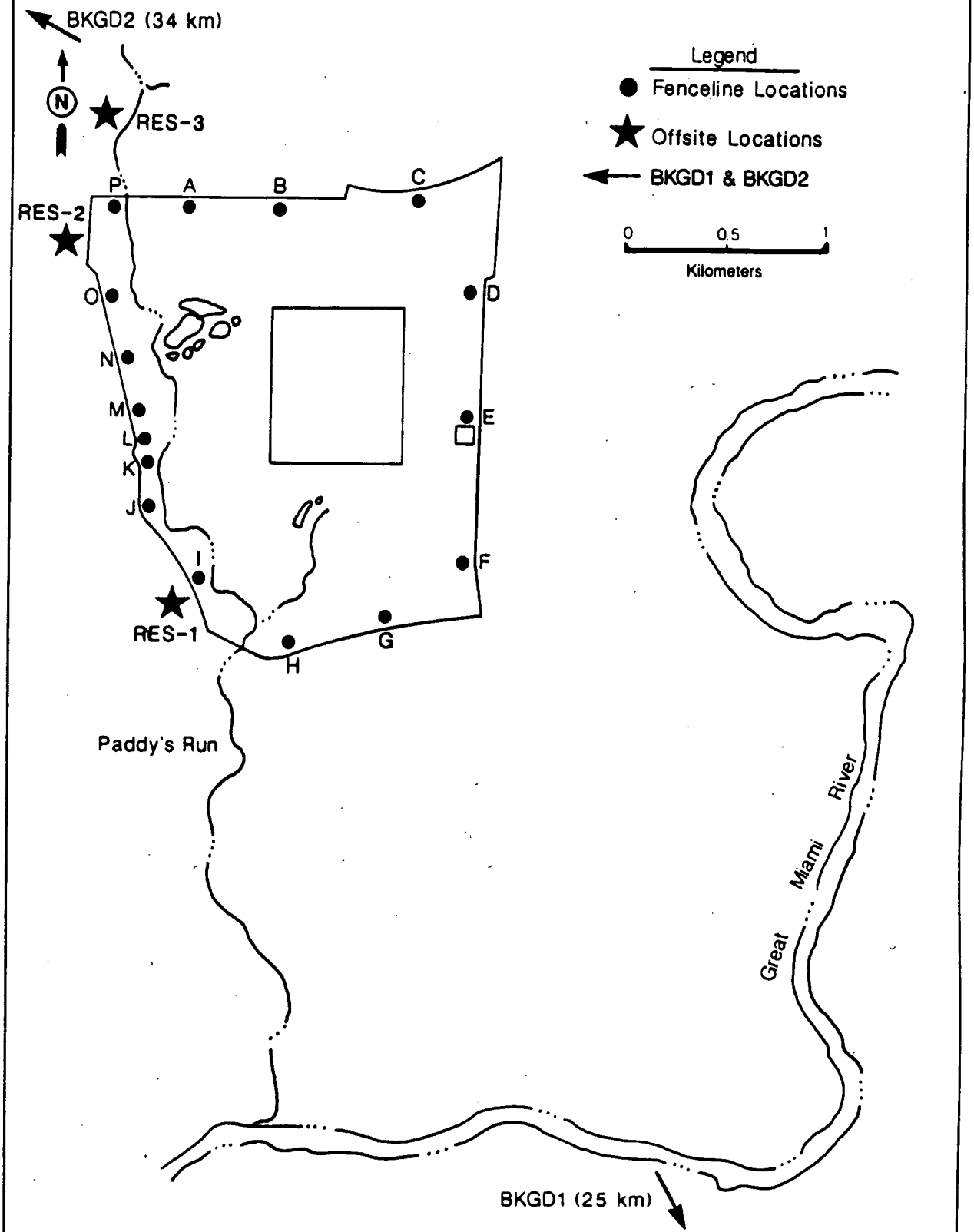

Figure 13. Offsite and Fenceline Radon Monitoring Locations

concentration can also be compared to the action level of 4 pCi/l (0.15 Bq/l) recommended by the USEPA for indoor radon concentrations.

As a quality control measure, five detectors of the same type were placed at the same location each quarter. The average standard deviation of the results from this location in 1988 was ± 33%, which was an improvement over 1987 results and which compared closely with the standard deviation of the 21 fenceline locations in 1988 (± 34%).

If only the six fenceline locations along Paddy's Run Road closest to the K-65 Silos (FMPC-J through O in Figure 13) were averaged for the year, the average radon concentration at those locations, 1.4 ± 0.6 pCi/l (0.052 ± 0.021 Bq/l), would fall within the DOE guidelines. The average net above-background radon concentration at these locations was 0.8 pCi/l (0.030 Bq/l), which was 27% of the DOE guideline. It can be concluded that, at the FMPC fenceline, radon concentrations were well within DOE guidelines of 3 pCi/l above background.

Although the data indicated that the west fenceline concentrations were slightly above background, those concentrations did not represent a health concern and were less than the average indoor radon concentration for houses in the United States as reported by the USEPA.

The same conclusion was reached by the Ohio Department of Health (ODH) in a study of radon concentrations in homes and the environment near the FMPC.[15] Only background or slightly above-background levels of radon were detected in the environment, and the source of radon levels detected in homes was determined to be the soil and rock beneath these homes.

Summary

Radiation doses generated by the FMPC during 1988 were a small fraction of the background dose a person receives each year from natural sources. As such, the doses could not be measured directly but had to be inferred from careful measurements of various environmental parameters such as air, water, milk, fish, and vegetables. From these measurements, and by making conservative assumptions to ensure the doses would not be underestimated, the FMPC used sophisticated computer modelling and made additional calculations to estimate possible doses to people living in the vicinity of the FMPC. The results of these calculations indicated that the radiation dose to our neighbors as a result of FMPC operations was a very small fraction of the natural background radiation dose - an average increase of less than 1% for the maximally-exposed individual.

Chapter Three
Results of the FMPC Monitoring and Sampling Program for 1988

In order to gain a detailed understanding of the effects of its production and storage operations on the surrounding environment, the FMPC measures the amounts of various radiological and nonradiological materials that leave the site. The results of some of these measurements were used in determining the estimated radiation doses described in the preceding chapter. All of the measurements were of value in assessing the FMPC's impact on surrounding areas.

Overall, these measurements indicated that the amounts or concentrations of radiological and nonradiological materials present in the surrounding environment were well below all applicable standards established by federal and state laws.

This chapter presents the methodology used for making these measurements as well as the data collected during 1988. Oftentimes data from 1987 and 1986 are presented for comparison to 1988 data.

Sampling Procedures

Sampling procedures must be comprehensive so that one is certain that the samples collected are representative of the media being investigated. Since quality assurance is critical in collecting valid samples, the environmental sampling procedures include the following:

- Representative sampling sites
- Proper collection techniques and chain-of-custody procedures
- Maps, diagrams, and forms used in sampling
- Special precautions to prevent contamination in sampling
- Sample preservation methods
- Equipment calibration procedures
- Record-keeping procedures
- Data review and verification
- Field and analytical quality control checks (provisions for collecting and analyzing blanks, spikes, duplicates, equipment rinse samples).

Air Pathways

As discussed in the previous chapters, the largest overall potential source of radiation exposure to the public from the operation of the FMPC is via the air pathway. In addition to the inhalation pathway, other pathways of radiation exposure can be through airborne contaminants which are introduced to the human food chain through soil, vegetation, farm and garden produce, and milk. This section describes the various sampling programs which were implemented at the FMPC to monitor these media for radiological and nonradiological parameters.

Sampling the Air

FMPC production operations generate airborne radioactive particulates. Ventilation and air-filtration systems such as dust collectors reduce employee exposure to these particles and reduce their release into the environment.

In order to provide accurate information about particulate concentrations in ambient air, the FMPC operates 14 continuous, high-volume air monitoring stations. The locations for the air monitoring stations, as shown in Figure 11, were selected for several reasons: locations one through seven provided average particulate concentration data at the FMPC fenceline because this was where the public has closest access to the site. Since the prevailing winds at the FMPC are from the southwest, the FMPC added two stations in 1986 to the northeast in the production area (AMS 8 & 9). Their locations were selected based on a computer-modelled prediction of the areas where the highest ground-level concentrations of airborne uranium from FMPC operations would be found. Two offsite monitoring stations are also located in the northeast quadrant in Ross, Ohio (AMS 13 & 14). AMS 14 was added in the third quarter of 1988 to comply with USEPA guidelines on siting of air monitoring stations for particulates. The three remaining offsite stations are located at an industrial site south of the FMPC near the community of Fernald (AMS 10), southwest of the site on New Haven Road west of Crosby Road (AMS 11), and northwest of the site on Chapel Road south of Route 126 (AMS 12).

The filters from the air monitoring stations were collected and analyzed at weekly intervals during 1988. At each AMS, air was drawn through a 20 cm by 25 cm (8 in by 10 in) filter at a rate of approximately 1 m^3/min (about 35 ft^3/min). Any changes in flow rate over the sampling period were accounted for by inspecting charts which continuously recorded flow data.

The filters, which were weighed before and after sample collection to obtain the weight of the collected particulates, were carefully handled so as not to disturb or lose any deposited particulates. At the laboratory, technicians stored the filters for at least three days after collection to allow for the decay of naturally-occurring short-lived radionuclides. Next, they were dissolved in acid and the solutions were analyzed for uranium content, beta activity, and total suspended particulates. A portion of each of these solutions was retained to provide a yearly composite, which was then analyzed for trace radionuclides, such as isotopes of radium, neptunium, plutonium, and thorium. The next section discusses the results for the monitoring of radiological parameters.

Radiological Parameters. The average concentrations of uranium at the seven fenceline and five offsite air monitoring stations were all less than 4% of the DOE standard. In fact, the DOE lowered the limits for uranium by a factor of 20 in 1988. Table 7 compares the results of the air monitoring program in 1988 to 1987 data for uranium concentrations and beta activity from various radionuclides, and for average particulate concentrations. Figures 14, 15, and 16 compare concentrations of these parameters for 1986 through 1988. Except for AMS 1 and AMS 2, where average uranium concentrations increased slightly, all air monitoring stations during 1988 recorded lower average airborne uranium concentrations than in 1987.

Although some reported concentrations of trace radionuclides were higher in 1988 than in 1987, the highest concentration as reported in Table 8 was less than 1% of the DOE guideline. Concentrations of all airborne trace radionuclides in 1988 were well within the applicable DOE guidelines (Figures 17 through 21). Thorium-228, thorium-232, and plutonium-238 concentrations were generally lower. Plutonium-239/240 concentrations were somewhat higher in 1988. However, as shown in Figure 18, the thorium-230 concentrations were significantly higher at the onsite and most fenceline locations compared to previous years. This may be due to the increased processing in the Scrap Recovery Plant of waste materials that have been stored onsite for several years. During 1988, a greater proportion of stored materials was processed than in 1987, leading to the observed increase in thorium-230 air concentrations at the air monitoring stations. However, even with the observed increase in thorium-230 air concentrations, the levels recorded were well below applicable standards.

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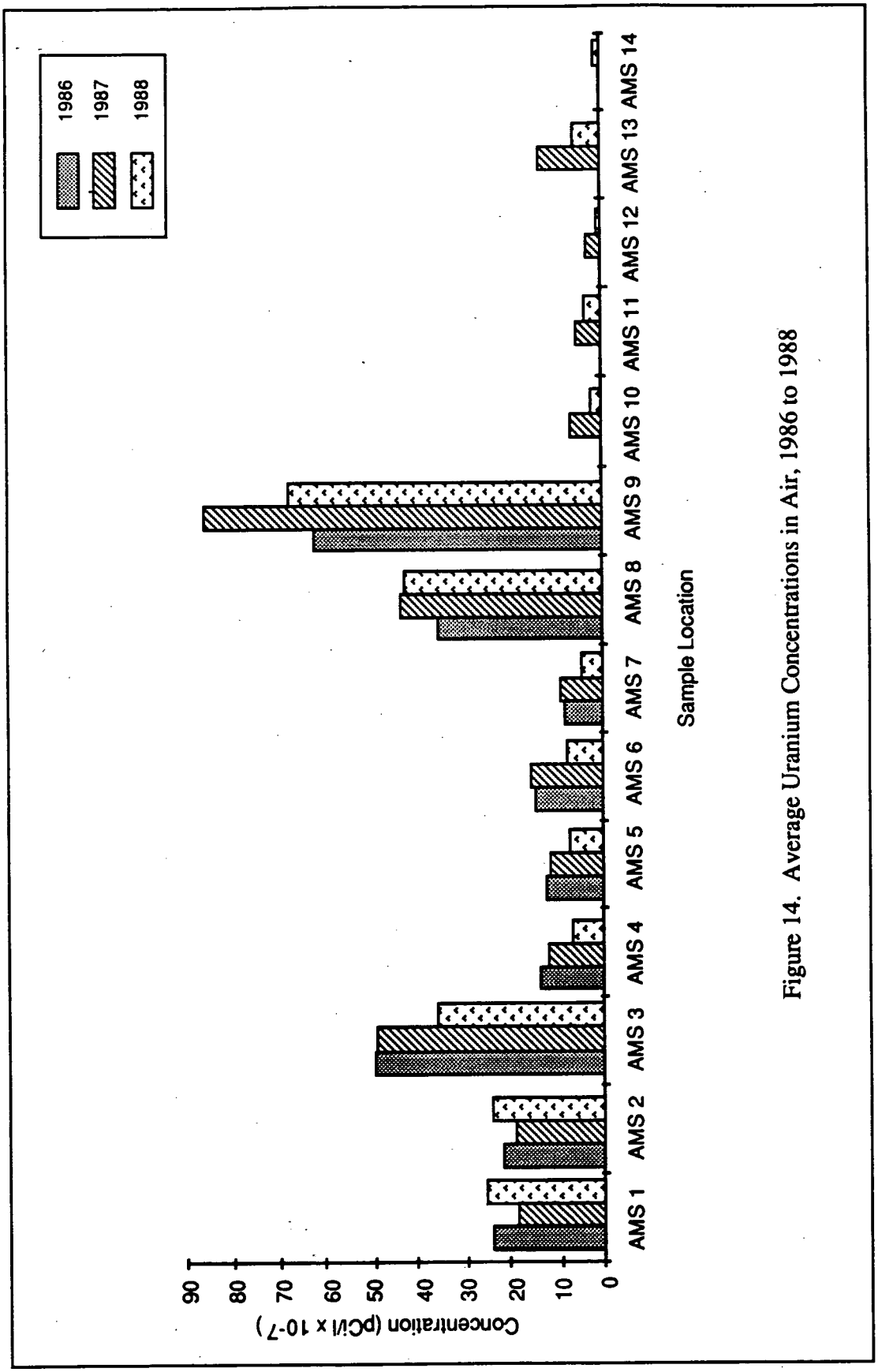

Figure 14. Average Uranium Concentrations in Air, 1986 to 1988

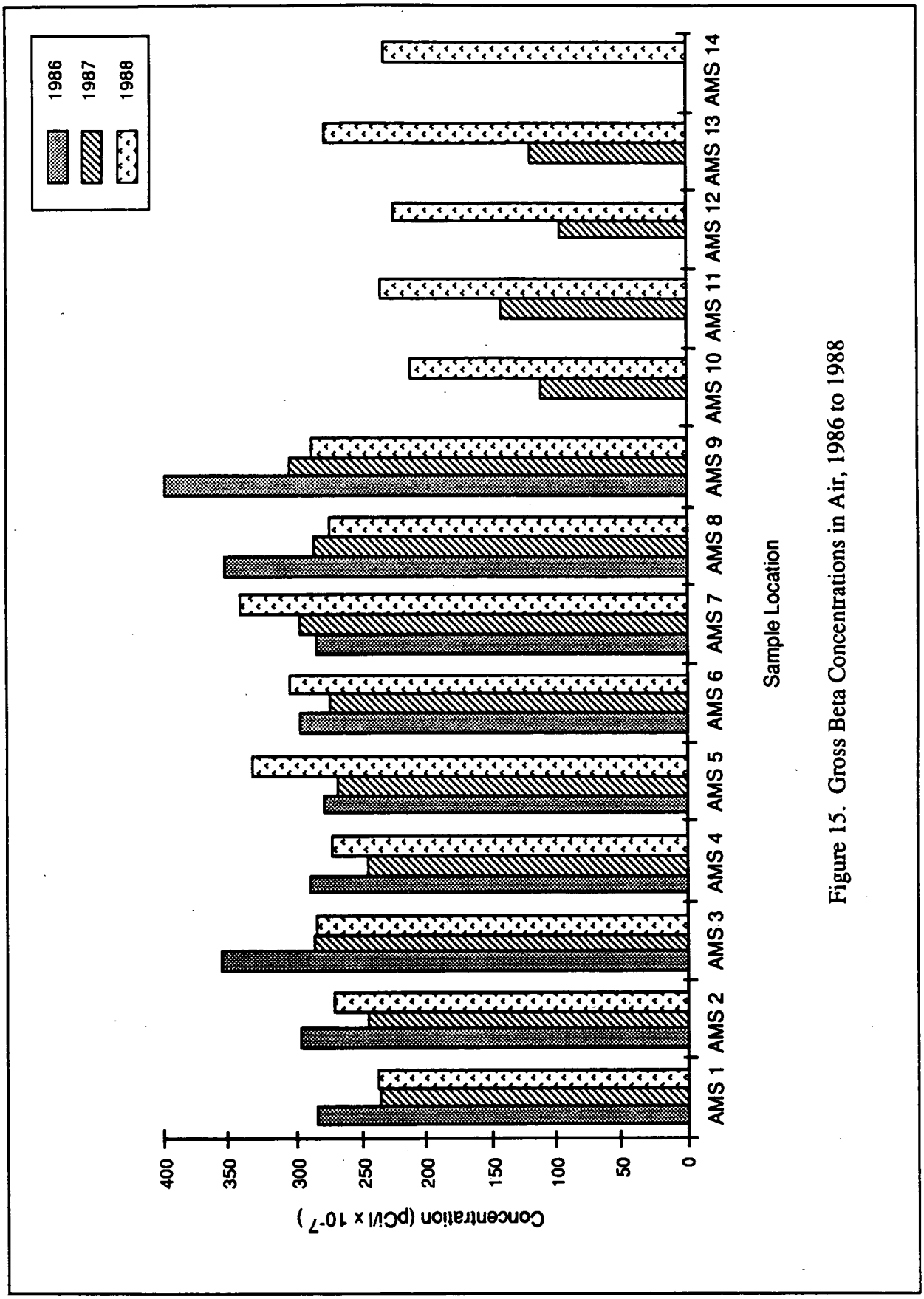

Figure 15. Gross Beta Concentrations in Air, 1986 to 1988

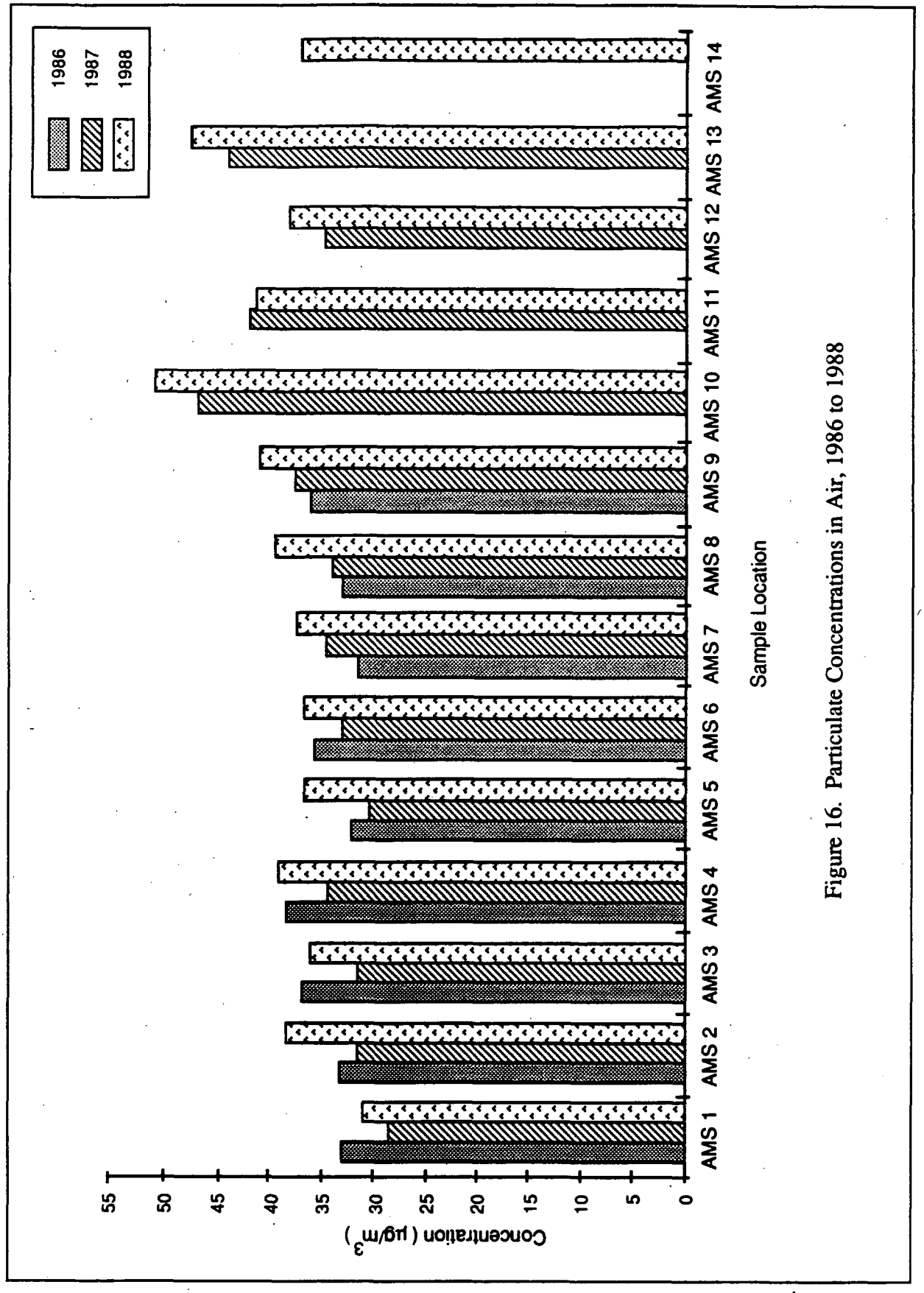

Figure 16. Particulate Concentrations in Air, 1986 to 1988

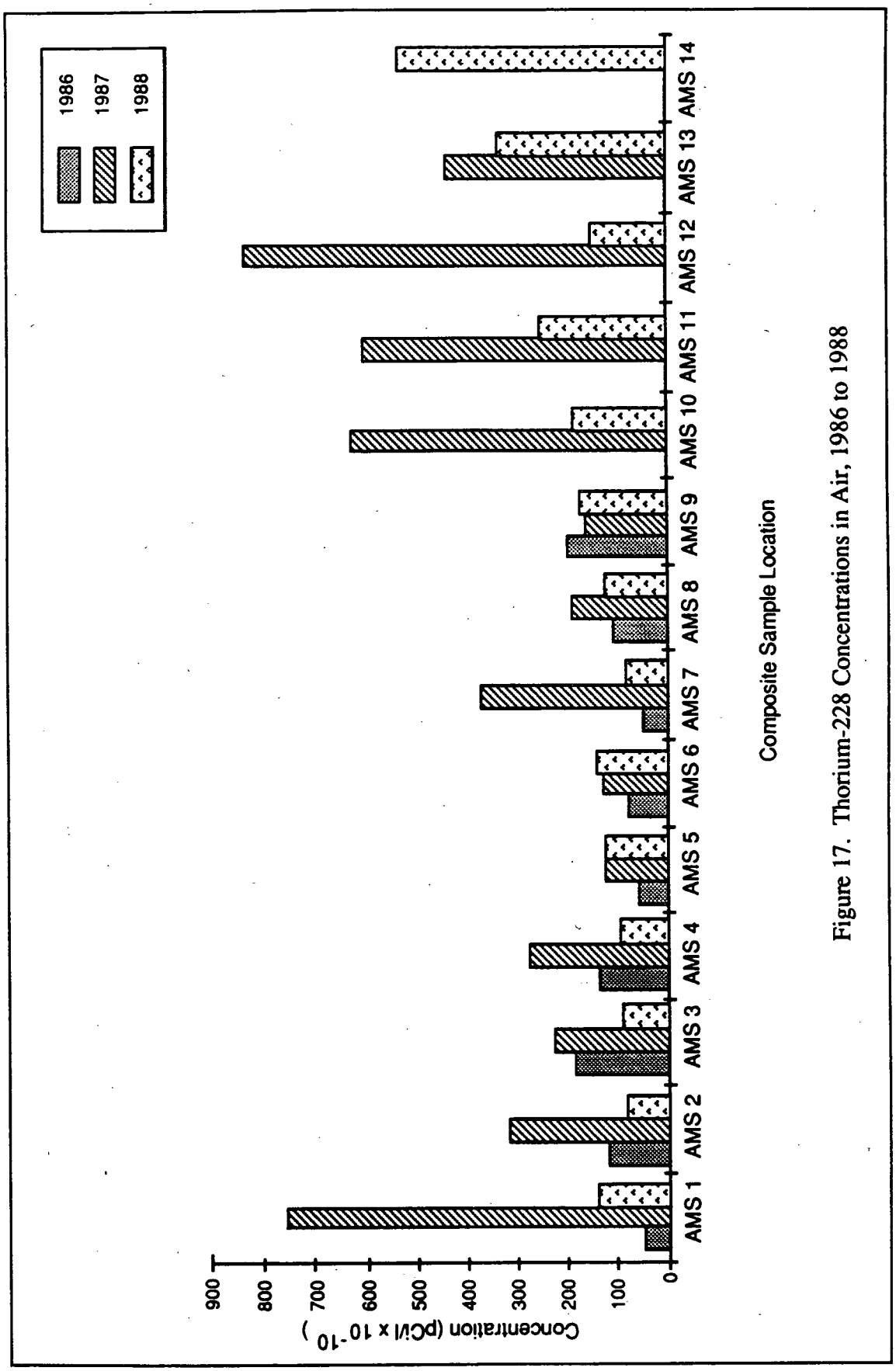

Figure 17. Thorium-228 Concentrations in Air, 1986 to 1988

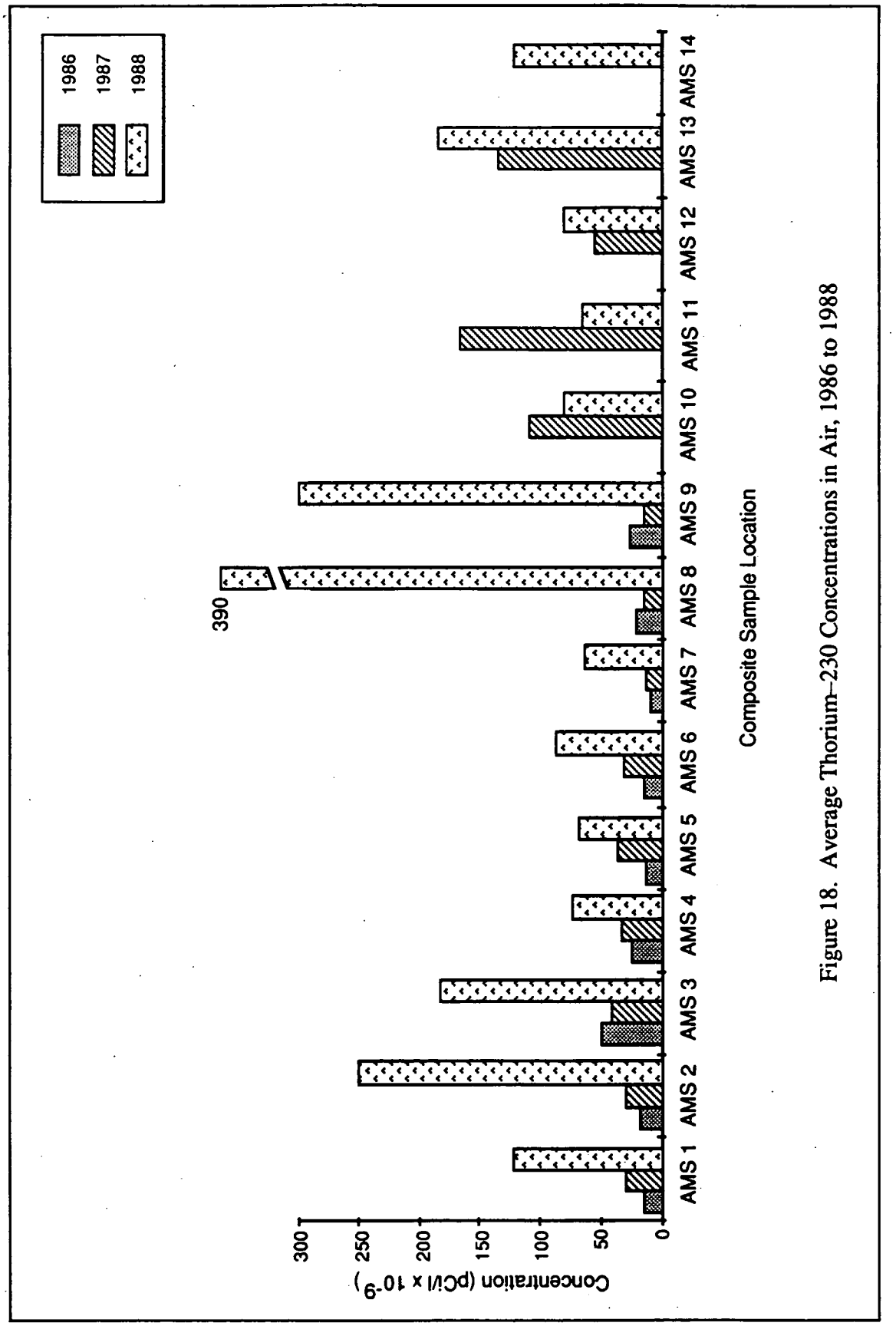

Figure 18. Average Thorium–230 Concentrations in Air, 1986 to 1988

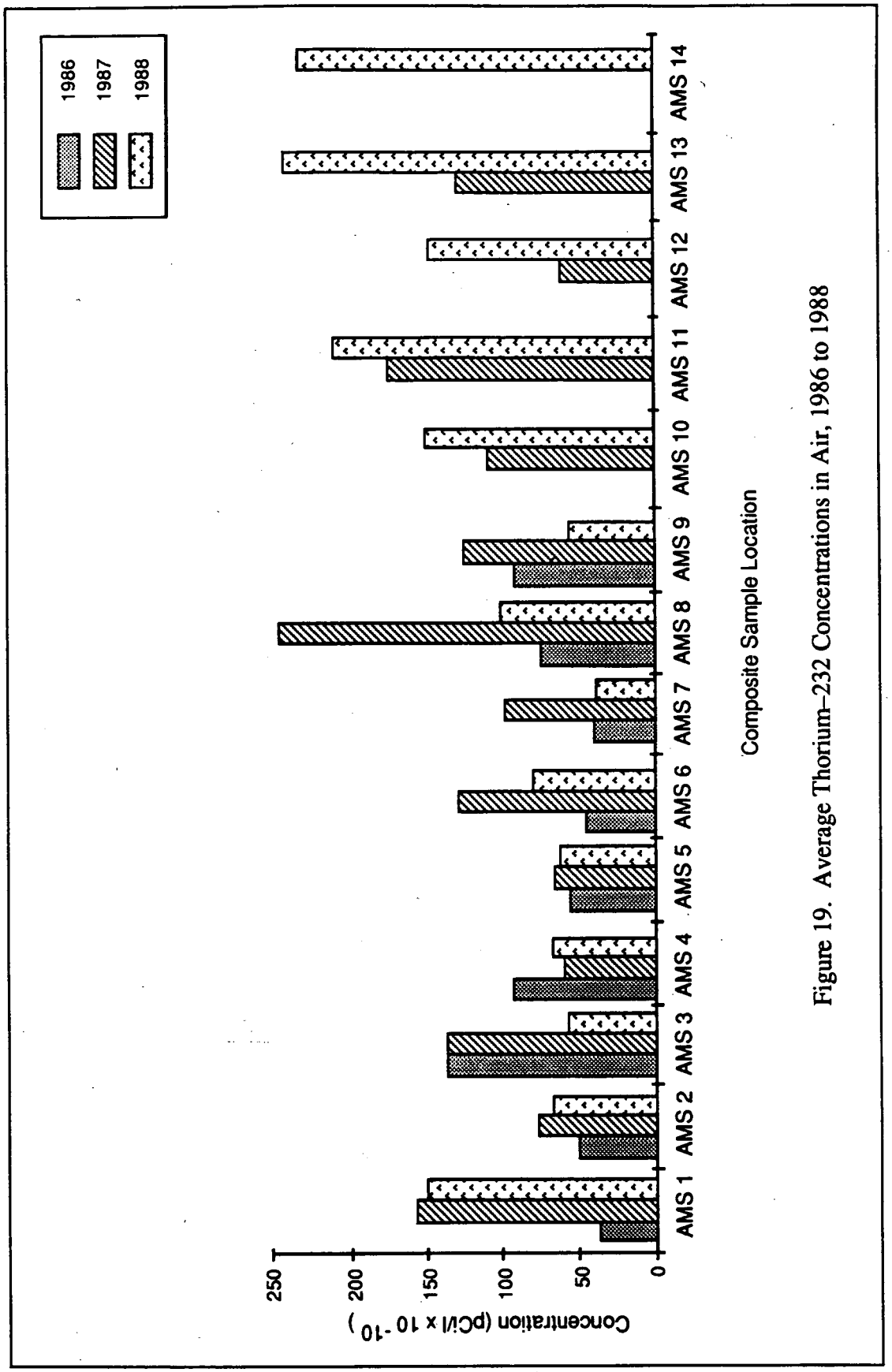

Figure 19. Average Thorium–232 Concentrations in Air, 1986 to 1988

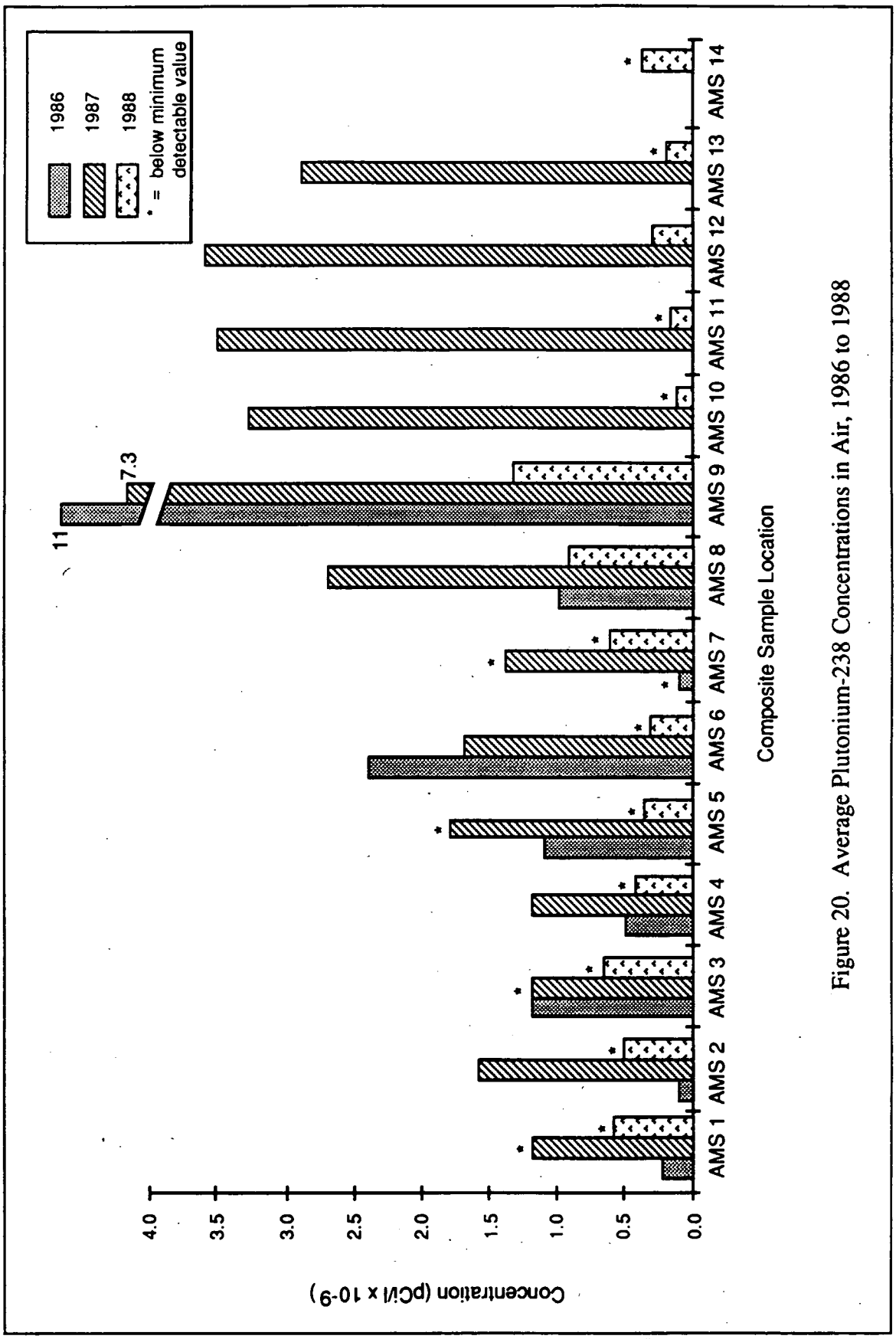

Figure 20. Average Plutonium-238 Concentrations in Air, 1986 to 1988

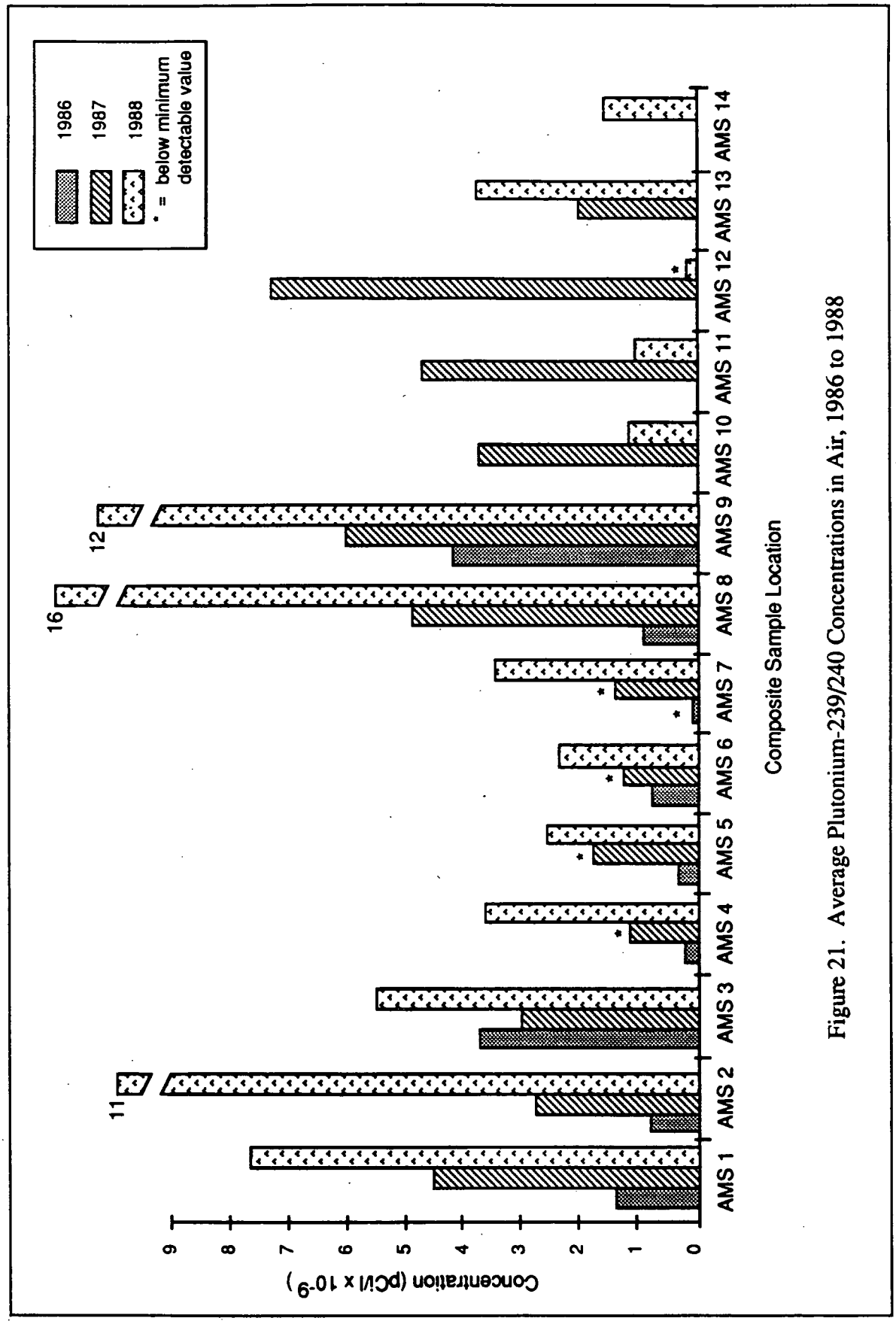

Figure 21. Average Plutonium-239/240 Concentrations in Air, 1986 to 1988

As discussed in Chapter 2, the FMPC reassessed its historical uranium discharges to the air, revising the 1987 total upward to 302 kg (664 lb). The estimated 1988 total was 108 kg (237 lb); therefore, the estimated 1988 totals were 36% of the revised 1987 estimates.

Chapter 2, in the section on direct radiation, discussed how the FMPC monitors gamma radiation, which is another component of the air pathway. These data are provided in Table 5.

Nonradiological Parameters. In addition to monitoring airborne radiological parameters, the FMPC monitored production processes for nonradiological pollutants including total suspended solids (or airborne dust), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and the opacity of emissions from the coal-fired boilers. The opacity, the shade or density of particulate emissions, is a measure of how much light is blocked by the particulate emissions.

The 1988 results of the analysis of average total suspended particulate concentrations from air monitoring stations one through seven ranged from 31.6 $\mu g/m^3$ at AMS 1, to 39.4 $\mu g/m^3$ at AMS 4 (Table 7; Figure 16). These results, though 13% higher on average than in 1987, were still well within National Ambient Air Quality Standards (NAAQS) limits.[16,17] Elevated concentrations at all stations were probably due to the extremely dry summer in 1988, as well as the expanded construction activity at the site that increased dust.

At the FMPC, electrostatic precipitators maintained particulate emissions from the steam-generation plant below the limit of 0.06 kg (0.14 lb) per million British Thermal Units (BTU) input, as listed in the most recent Permits to Operate (PTO) for the boilers. Furthermore, visible emissions from the two FMPC coal-fired boilers were continuously monitored by instruments designed to measure opacity. The measurements show that the FMPC complied with these requirements.

Sulfur dioxide emissions may not exceed 0.9 kg (2.0 lb) per million BTU input for each of the two coal-fired boilers at the FMPC.[18] The FMPC analyzed samples of coal on a regular basis for sulfur content and heat content. SO_2 emissions were calculated according to methods and procedures in OAC rules.[19] This limit could be exceeded if the FMPC used coal containing 1.3% or greater sulfur. Therefore, the FMPC used coal containing less than one percent sulfur.

The State of Ohio has not established NO_x emission limits for FMPC industrial process sources since the site is located in a region of the state which is exempt from such limits. During 1988, the FMPC maintained NO_x emissions at 100 ppm or less for monitored process sources. This standard was maintained by ventilating most potential sources of NO_x to a bubblecap tower where they were scrubbed before they are released into the atmosphere. Some of the smaller sources of potential NO_x emissions at the FMPC were not ventilated through a scrubber system. Efforts are continuing to develop systems to reduce emissions from these facilities.

Sampling Soil and Vegetation

Soil and vegetation sampling provided a method to assess the radionuclides and nonradiological materials which have been deposited on the ground from the atmosphere. Many naturally-occurring radionuclides as well as radionuclides in the fallout from world-wide nuclear weapons' testing can be expected in the samples. The FMPC also analyzed vegetation samples for fluoride because the production process had used anhydrous hydrogen fluoride in the past.

During 1988, the routine soil sampling and parallel soil and vegetation sampling programs were reviewed. Routine soil sampling means that only soil is sampled at a location; all vegetation is excluded. Parallel soil and vegetation sampling simply means that samples of both soil and vegetation are taken at the same location at the same time. It was found that many of the sampling locations of both programs were situated very close to one another. To increase sampling efficiency and effectiveness, the programs were combined, reducing the number of sampling locations to 29 from 38. The locations were chosen according to the prevailing wind direction and distance from the site (Figure 22). In addition, care was taken to avoid areas that were fertilized because some fertilizers have high concentrations of uranium that would bias sample results.

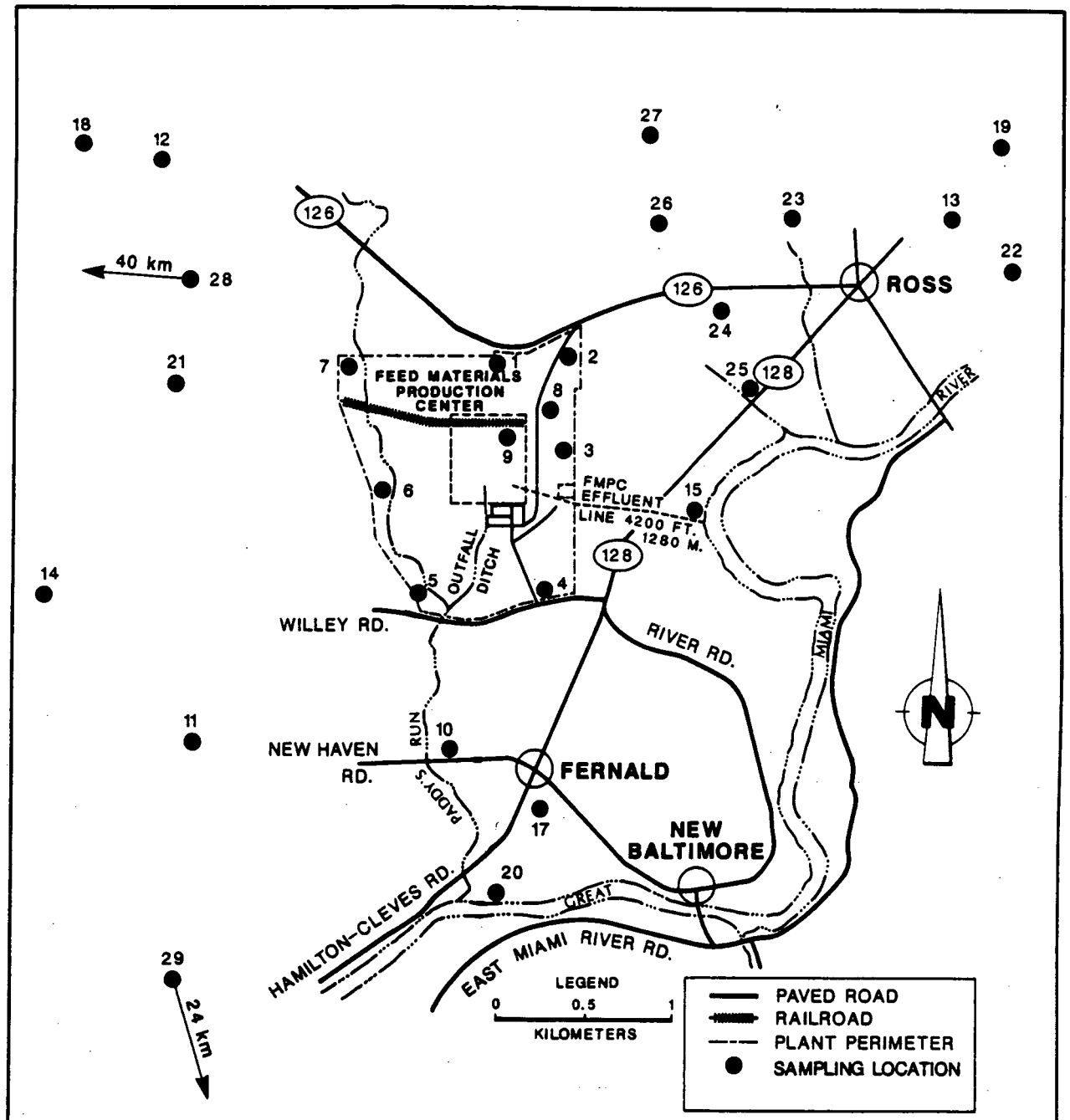

Figure 22. Soil and Vegetation Sampling Locations

As a result of combining the two programs, thirteen of the sampling locations had never been sampled prior to 1988. Four locations from the 1987 parallel soil and vegetation program and twelve locations from the 1987 routine soil monitoring program were chosen as 1988 sampling points. Table 9 lists the 1988 sampling locations and their corresponding identification numbers that were selected from the 1987 programs.

Samples were taken from non-cultivated plots to provide characteristic measurements of uranium concentrations that had been deposited from the atmosphere. Since the elements that make up soil are usually not evenly distributed in a given plot, several samples were collected at each plot to ensure that a representative sample was taken. Each soil sample was made up of a composite of ten cores 2 cm (about 1 inch) in diameter and 5 cm (about 2 inches) deep. Care was taken to exclude vegetation from the sample. The cores were taken at two depths, 0-5 cm (0-2 in) and 5-10 cm (2-4 in), within the soil profile, and were obtained from each corner and the center of two 1 m^2 (about 11 ft^2) grids.

No DOE or USEPA standards have been established for most soil radionuclide levels. For purposes of comparison, naturally-occurring uranium-238 concentrations in Ohio range from 0.76 pCi/g (0.02 Bq/g) to 2.2 pCi/g (0.08 Bq/g).[20] Total natural uranium is approximately twice this concentration since the two major isotopes of uranium (U-238 and U-234) occur together naturally in about the same activity in the soil. The Nuclear Regulatory Commission (NRC) established a concentration of 35 pCi (1.3 Bq) of natural uranium per gram (=50 ppm) of soils, which is the level generally used as an interim guideline for allowing the public to use the land.

The concentrations for onsite samples ranged from 2.8 to 73 pCi/g dry wt (0.10 to 2.7 Bq/g dry wt). The concentrations for offsite samples ranged from 1.4 to 6.1 pCi/g dry wt (0.05 to 0.23 Bq/g dry wt) (Table 10). In 1988, sampling locations one through seven exhibited average uranium concentrations slightly higher than the range considered background in Ohio. Location 3 displayed the highest uranium concentration in the soil. This is most likely attributable to the past operation and subsequent demolition of an incinerator adjacent to the sewage treatment plant. Elevated uranium concentrations have been observed at this location for the past several years. The remaining two onsite locations (8 and 9) displayed higher than background uranium concentrations. These sampling sites are located in the prevalent wind direction, and the results reflect fallout from air emissions at the site.

All offsite soil sampling locations except for 18, 24, and 27 displayed uranium concentrations that fell within the range considered background for Ohio. Although the uranium concentrations for these three locations were slightly higher than the reported background range for Ohio soils, other samples taken near each location were within the background range.

The vegetation samples collected along with the soil during 1988 had uranium concentrations ranging from 0.002 to 5.6 pCi/g dry wt or 0.0001 to 0.21 Bq/g dry wt, respectively (Table 10). Although standards have not been established for uranium in vegetation, the data for 1988 generally showed uranium concentrations in vegetation near the FMPC were basically the same as the concentrations found in vegetation at some distance from the FMPC.

Each vegetation sample of about 500 g (wet weight) was a composite of a number of subsamples. Each subsample consisted of all above-ground plant material (principally grass) which was clipped near ground level from a 0.5 m (1.5 ft) diameter circle. Five of these subsamples equalled 1 m^2 (11 ft^2) of ground cover. After the vegetation samples were collected, each was air-dried and then analyzed for uranium and fluoride.

Fluoride concentrations in vegetation ranged from less than 0.02 to 15 µg/g (ppm) in 1988. Since the state of Ohio does not have a standard for fluoride in vegetation, the Kentucky standard of 80 ppm was used for comparison (Table 10). The average fluoride concentration in vegetation was 5.6 ppm in 1988, which is 7% of the Kentucky standard. Again, the fluoride concentrations in vegetation near the FMPC were basically the same as the concentrations found in vegetation at some distance from the FMPC.

Sampling Farm and Garden Produce

As another way to monitor the movement of uranium through the air pathway, the FMPC sampled produce grown on five farms and gardens within 3 km (1.8 mi) of the site. As a control measure, the FMPC also sampled produce from five farms and gardens located between 3 km and 24 km (15 mi) from the site (Figure 23). Radionuclides that occur naturally or are deposited in the soil by airborne dust may be taken up by plants through their root systems and incorporated in their edible portions, and then ingested by humans or animals which eat them.

Many of the locations that were sampled in 1987 could not be sampled in 1988 due to the drought conditions in the early summer that limited area crops. Locations 1, 2, 5, and 6 were the only sites sampled both in 1987 and 1988. The remaining six sites sampled in 1988 were new locations.

Based on limited data, uranium concentrations in leafy vegetables, roots and stems, and fruits were approximately the same in 1987 and 1988. Uranium concentrations in vegetables were generally lower than those found in vegetation samples. In fact, the majority of vegetables exhibited concentrations of uranium that were less than detectable levels. There appeared to be no correlation between uranium concentration, distance from the FMPC, vegetable type, or farm from which the vegetables were grown (Table 11).

Sampling Milk

Another way by which radiation can reach humans is through the ingestion of radionuclides in the air-to-grass-to-cow-to-milk pathway. Potentially, milk is a significant pathway to humans for some radionuclides because of the relatively large surface area that a cow can graze every day, the rapid transfer of milk from producer to the consumer, and the importance of milk in the diet. Furthermore, cows graze on land immediately adjacent to the FMPC. Therefore, the milk is collected and analyzed routinely, even though uranium is not a radionuclide that one would normally expect to be concentrated in cow's milk.

In 1988, the FMPC conducted monthly sampling of milk produced by cows grazing on the FMPC land adjacent to the site and at a background (control) dairy in Indiana, about 35 km (22 mi) west of the FMPC. The average uranium concentration present in the milk samples was below the laboratory's minimum detectable level of 0.7 pCi/l (0.03 Bq/l), and did not vary between the two locations.

In addition to total uranium, one of the monthly milk samples was analyzed for a number of radionuclides (Table 12). Results for all nuclides (where they were detectable) were in the range of a fraction of a picocurie per liter with the exception of naturally-occurring potassium-40. All nuclide concentrations were within the range expected in background milk samples.

During 1988, the FMPC sent six samples of milk that contained known amounts of uranium to the contract laboratory to test the lab's ability to detect high levels of uranium in the milk. The FMPC lab deliberately added the uranium to the milk. This is known as "spiking" the sample and is an accepted quality assurance procedure. The lab detected uranium in all six samples, at the average concentration of 7.0 pCi/l. The actual average uranium spike was 8.3 pCi/l. This indicates that the laboratory did an adequate job of analyzing uranium in milk at environmental levels.

Water Pathways

Radionuclides may be present in the Great Miami River from many sources, including atmospheric deposition, runoff and soil erosion, or from liquid effluents. Radionuclides from the FMPC could reach the river by any one of four liquid pathways. The first of these is by direct discharge into the Great Miami River. By far the greatest volume of liquid effluent from the FMPC is the approximately one-half million gallons per day released at Outfall 001 that empties into the Great Miami River. This water was sampled continuously before it was discharged to the river and was analyzed for uranium and all other nuclides that could be in

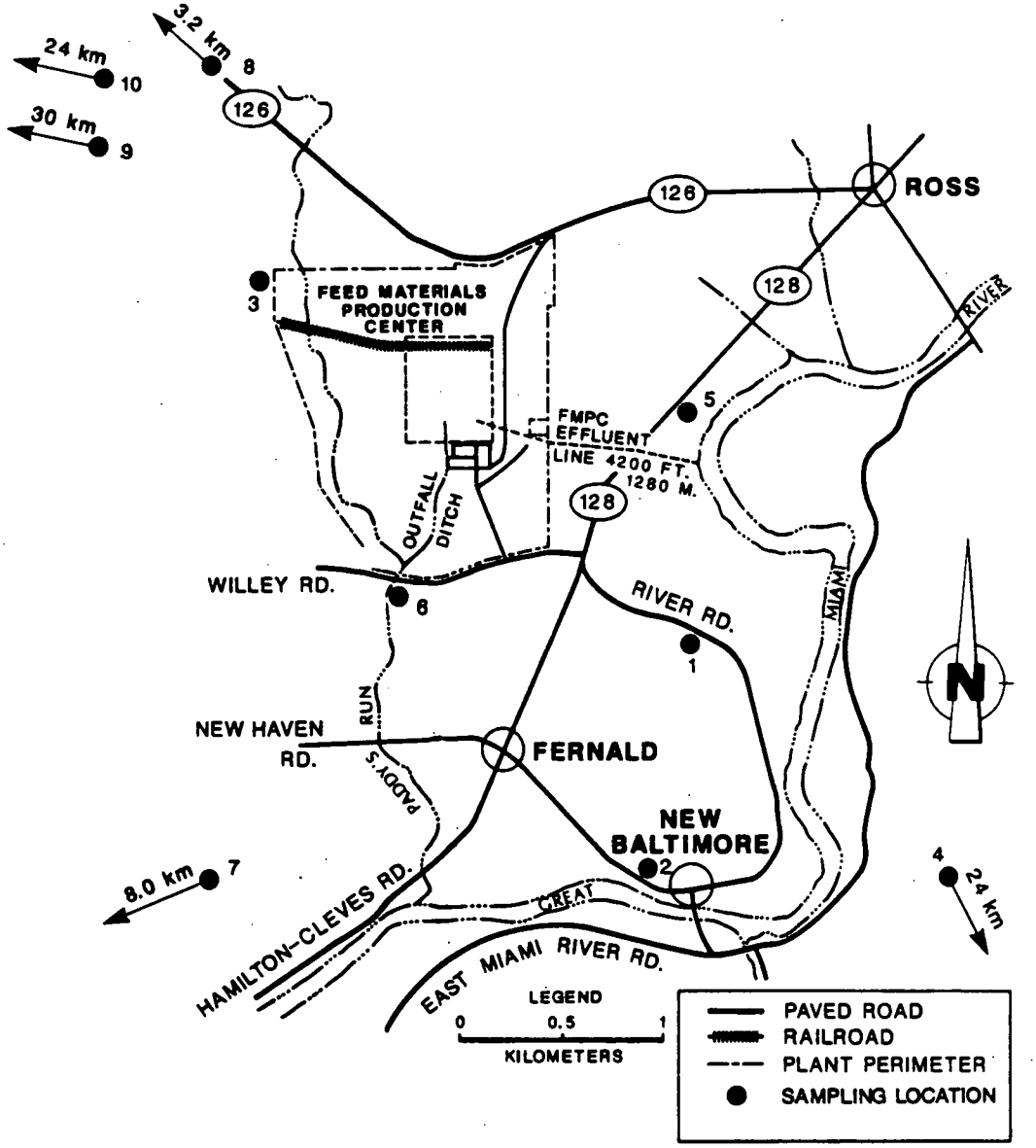

Figure 23. Farm and Garden Produce Sampling Locations

FMPC effluent. Daily grab samples (a grab sample is a single sample taken over a short time period) were taken from the Great Miami River both upstream and downstream from the point where the FMPC effluent enters the river.

A second possible pathway is via stormwater runoff directly to Paddy's Run from the outlying areas of the FMPC. Paddy's Run water was sampled weekly at six locations both above and below the FMPC.

A third possible pathway is the overflow of the Stormwater Retention Basin. If there is a very large storm, or a series of smaller storms, the SWRB could reach capacity. Additional water would be discharged to Paddy's Run via the Storm-Sewer Outfall Ditch. In 1988, there was one such event - 1.6 million gallons - during which samples of the overflow were taken six to 12 times per day.

Groundwater, the fourth pathway, is the most difficult to define and quantify. In addition to routine groundwater sampling as part of the Environmental Monitoring Program, the RI/FS is currently reviewing results from over 200 wells both onsite and offsite to better define and document contributions to groundwater contamination from FMPC operations.

The FMPC groundwater monitoring and sampling program has evolved during the history of the site. Beginning with five production wells drilled during the construction of the site, monitoring wells were added during the 1950's through the early 1980's in the waste storage area to observe groundwater quality. These thirteen wells, including three of the original production wells, continue to be sampled on a regular basis for radiological and nonradiological parameters as part of the ongoing Environmental Monitoring Program. Their locations are shown in Figure 24.

In late 1981, the State of Ohio and FMPC sampled several wells in the Fernald area to determine the cause of elevated beta activity found in one well. The FMPC reported to the State of Ohio in November 1981 that the site had discovered uranium in two offsite wells. This prompted an expansion of groundwater monitoring at the FMPC. Twenty-three new wells were drilled onsite to identify the cause and extent of the contamination. Also as a result of the report to the state, the FMPC expanded its groundwater sampling program to include existing offsite wells owned by residents and businesses near the site. Year-by-year, wells have been added to the Environmental Monitoring Program.

Today, there are three primary groundwater programs at the FMPC: RCRA, RI/FS, and the Environmental Monitoring Program. Most of the wells drilled after the report to the state have been included in at least one of the groundwater programs at the FMPC. For example, a series of wells were installed in the waste pit area as part of the RCRA program, which is discussed in Chapter 5. The ongoing RI/FS program, discussed in Chapter 6, has resulted in the drilling of over 110 wells during 1988 both onsite and offsite. Each program has specific goals, but the overall reason for the various sampling programs is the same - to identify areas of contamination, to compare levels of contamination with previous years, and to track the movement of contaminants through the aquifer. This chapter centers on the wells that comprise the Environmental Monitoring Program.

A technique used to map and characterize groundwater is to drill what are called cluster wells. A cluster well is a grouping of two or more wells at different depths at the same location which are used to sample different waterbearing zones within the groundwater. Environmental Monitoring wells 301 and 401 are cluster wells, as are 308 and 408.

The depth of the well and the waterbearing zone the monitoring well extends into is denoted by the first digit of the number. Figure 25 is a geologic cross section which shows the four waterbearing zones within the buried aquifer which underlies the FMPC. Wells extending into the perched aquifer within the shallow-silty-clay-till (approximately 35 feet deep) are denoted as 100-series. Wells extending into the upper portion of the sand and gravel aquifer (about 70 feet deep) are denoted as 200-series wells. The 300-series wells are placed within the lower portion of the upper sand and gravel aquifer, approximately 120 feet deep. The 400-series wells are installed in the sand and gravel

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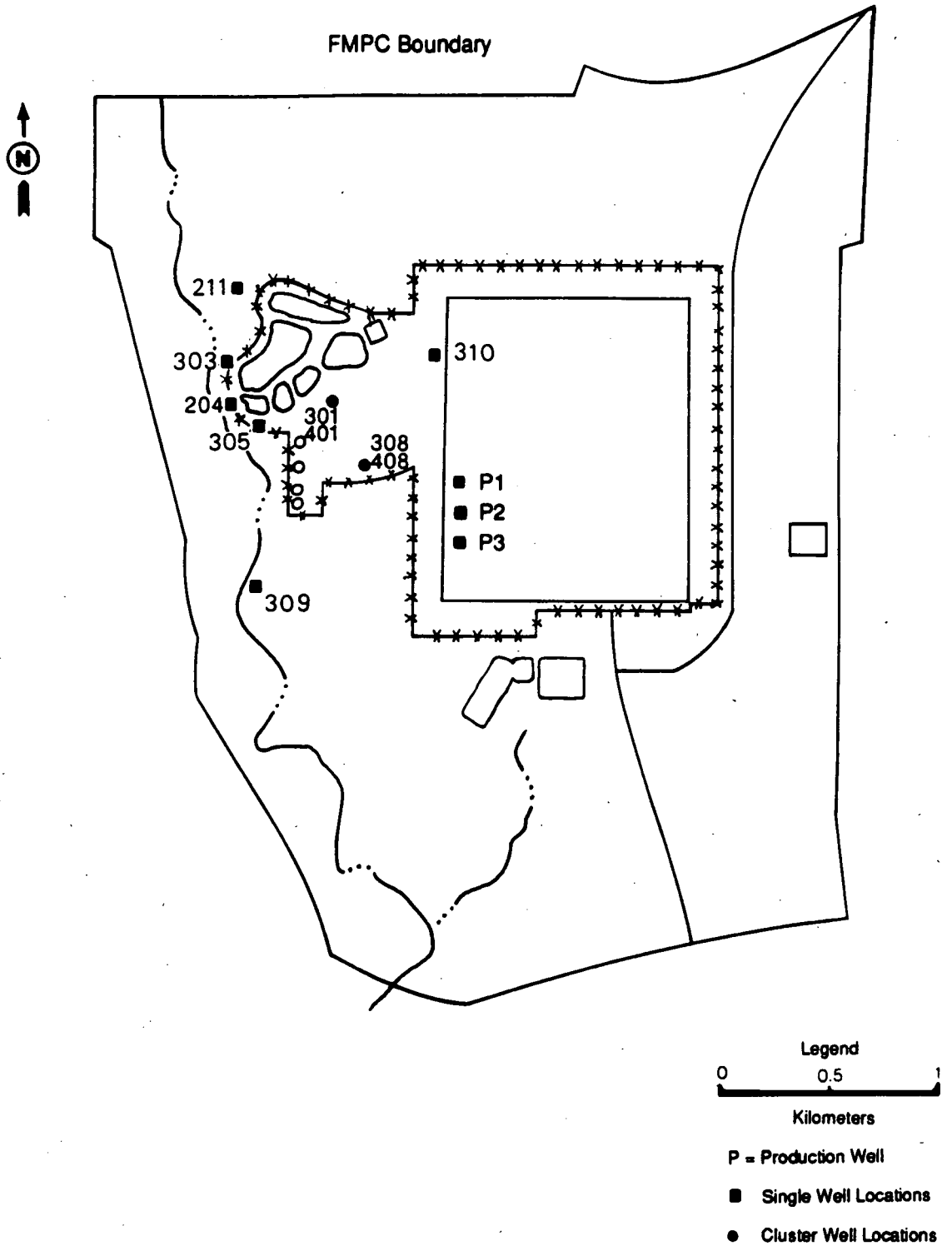

Figure 24. Onsite Monitoring Wells Locations

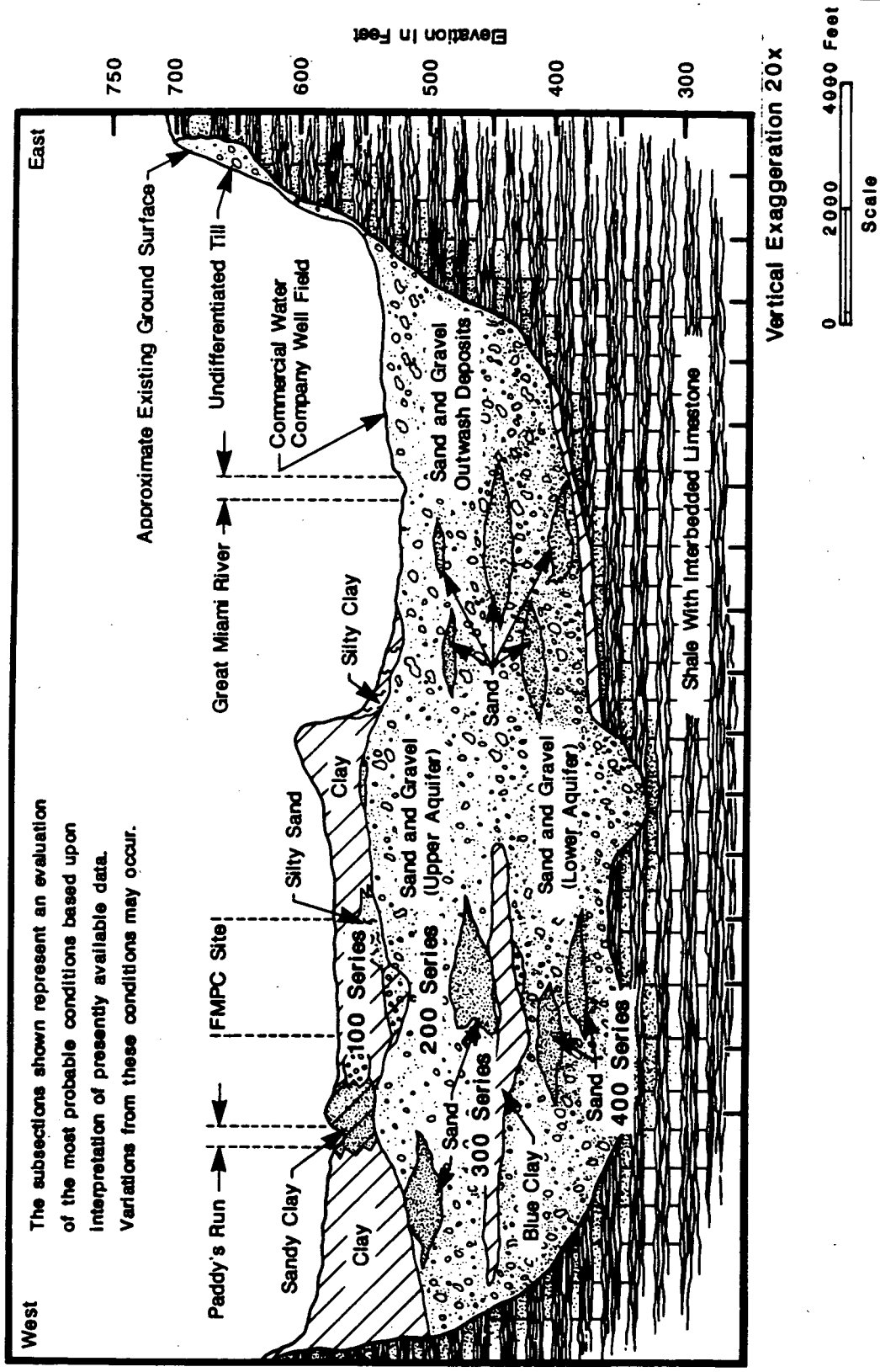

Figure 25. Cross Section of the Great Miami River Valley

aquifer which underlies the "blue clay" layer. Wells P-1, P-2, and P-3, the FMPC production wells which supply potable water for the site, draw water from under the blue clay layer of the aquifer.

The following sections describe the various sampling programs at the FMPC which monitor the liquid pathways (this includes sediment and fish sampling) for radiological and nonradiological parameters.

Sampling Groundwater

Groundwater is a vital element in our ecosystem. Consequently, the FMPC carefully monitors the groundwater in and around the site to see what contaminants may be present, and to track the movement of any contamination found in the aquifer. This enables the FMPC to better define the steps the site should take to control present contamination and to prevent additional contamination from occurring.

The groundwater sampling program is organized into onsite wells and offsite wells. The wells in each group are sampled according to specific schedules (monthly and quarterly), and the samples are analyzed for specific parameters (radiological, nonradiological).

Under normal conditions, the onsite monitoring wells were sampled monthly for uranium and quarterly for alpha, beta, pH, chloride, nitrogen-nitrate, and sulfate. However, due to well refurbishing and associated problems in 1988, many of the wells were sampled only once. The frequencies are listed in Tables 13 to 19. Well refurbishing included replacing faulty pumps, pump motors, electrical wiring, and locking-cap covers. The soil around the wells was graded to direct water away from well casings to prevent rain and surface water runoff from entering and possibly contaminating the wells.

Onsite Monitoring Wells, Radiological Parameters. The onsite monitoring wells were sampled and analyzed for uranium concentrations and gross alpha and beta concentrations (Tables 13 - 15). All concentrations of uranium in the onsite monitoring wells were well within the USEPA drinking water standard of 40 pCi/l (1.5 Bq/l). Gross alpha and beta measurements are used as indicators to identify areas where further analysis of specific isotopes is warranted.

Results of all groundwater sampling were compared to National Primary and Secondary Drinking Water Regulations as well as the DOE guidelines for radiation protection. A study by the U.S. Geological Survey states that natural background levels for uranium in groundwater in most areas in the U.S. range from 0.068 to 6.8 pCi/l (0.0025 to 0.25 Bq/l).[21] USEPA drinking water standards apply only to the production wells. The standards do not apply to the remainder of the onsite wells because they are not used as a public water source; they are used for monitoring purposes only. Nevertheless, the data from these wells are compared to the standards for reference purposes.

Figure 26 displays average uranium concentrations from 1986 to 1988 for the onsite wells. Differences in average uranium concentrations between 1987 and 1988 showed no trends, except for well 309 near Paddy's Run in which the average uranium concentration increased, and for wells 303 and 308, which decreased significantly during 1988.

A gross alpha measurement is a different type of measurement than a uranium measurement, which is a quantitative measurement of X-ray fluorescence from a water sample. The gross alpha measurement, on the other hand, is a measurement of alpha particles released from the evaporated water sample and is a more qualitative measurement. Gross alpha is principally used as a screening test or an indicator parameter that would trigger more specific tests. It is reported, as is the gross beta measurement, because the measurements are taken and there are USEPA drinking water standards to compare against for these parameters.

Figures 27 and 28 show the average gross alpha concentrations and gross beta concentrations, respectively, in onsite wells from 1986 through 1988. All average gross alpha concentrations were well below the standard of 15 pCi/l, and the average gross beta concentrations were below

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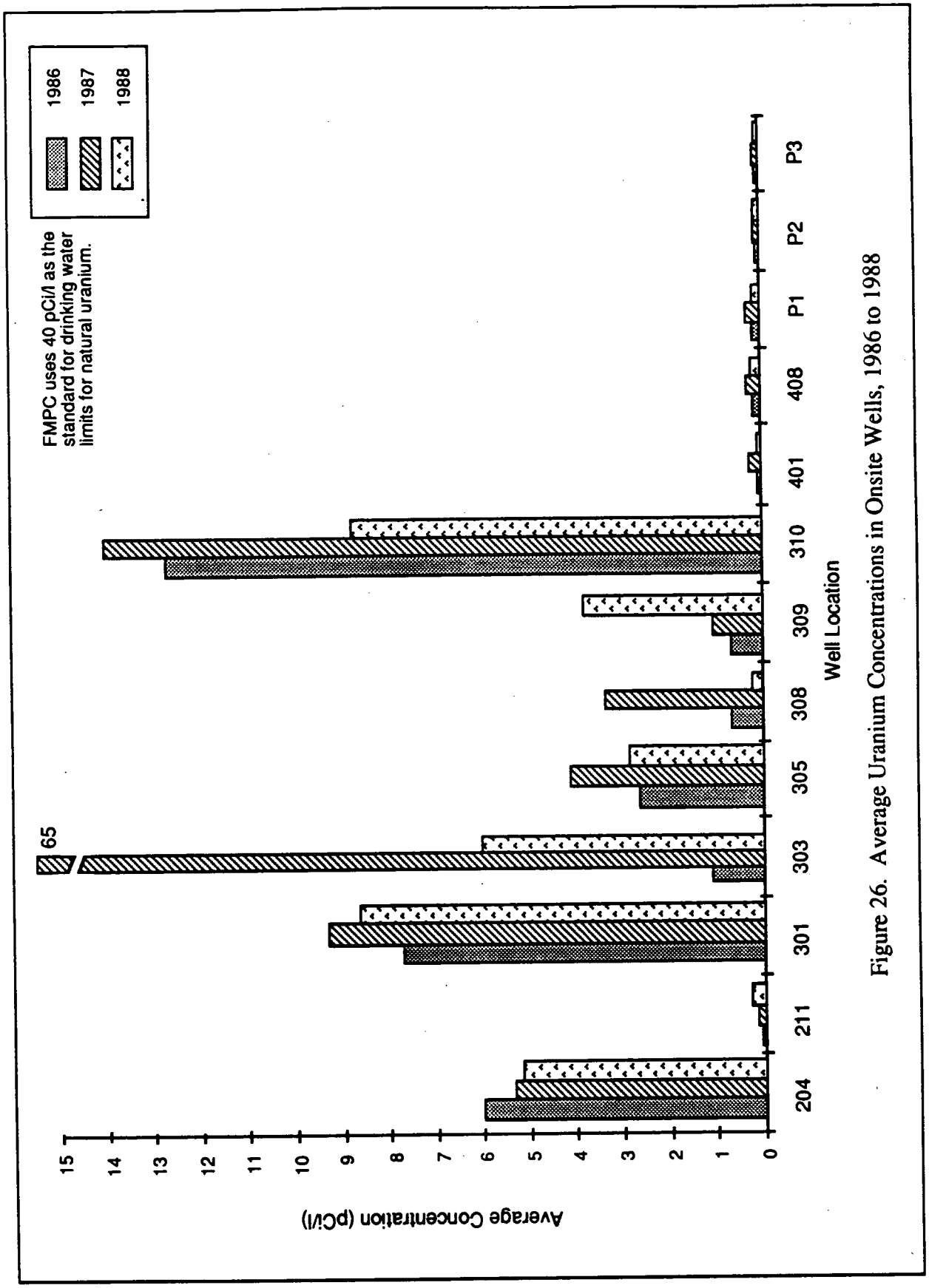

Figure 26. Average Uranium Concentrations in Onsite Wells, 1986 to 1988

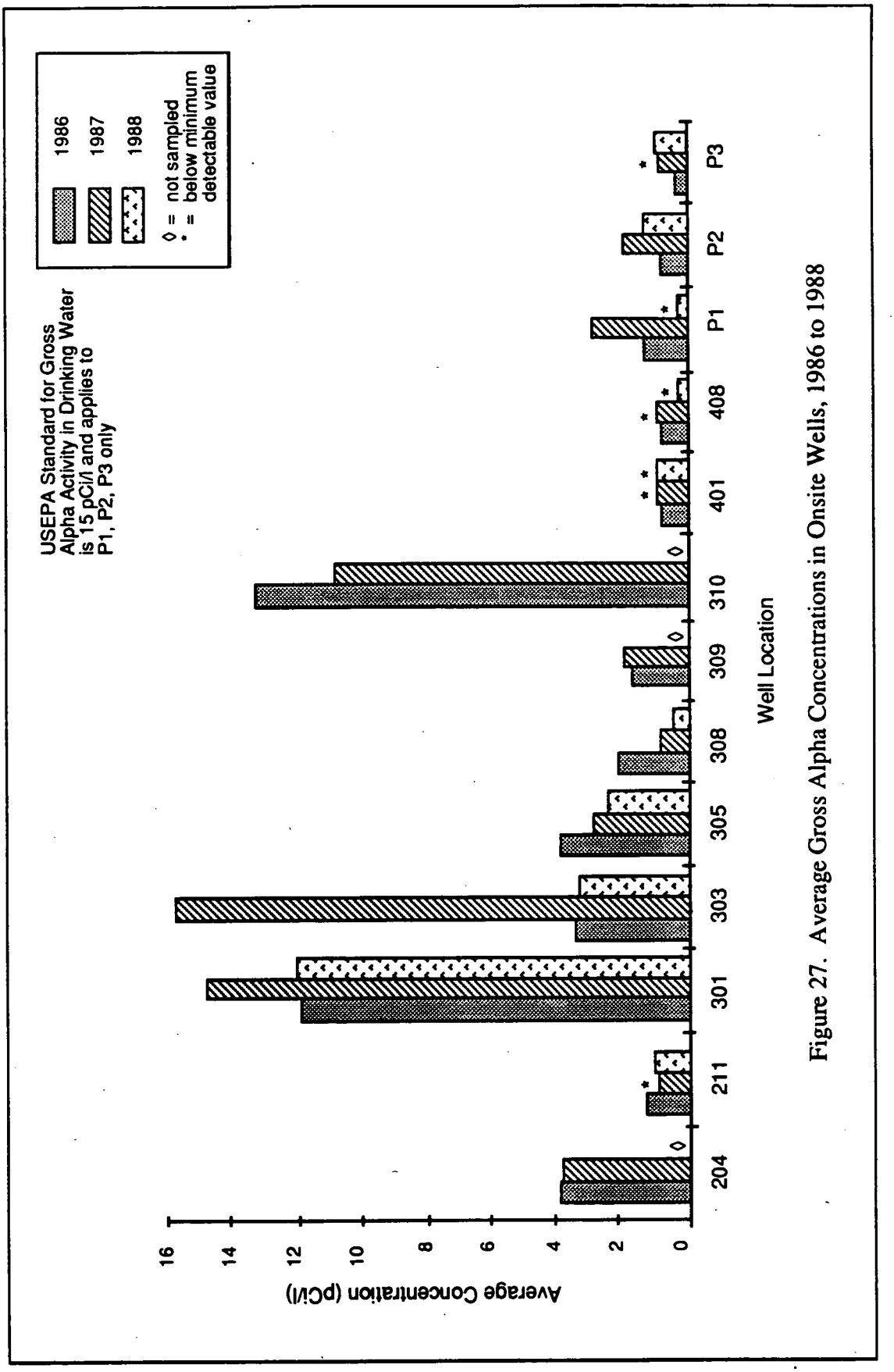

Figure 27. Average Gross Alpha Concentrations in Onsite Wells, 1986 to 1988

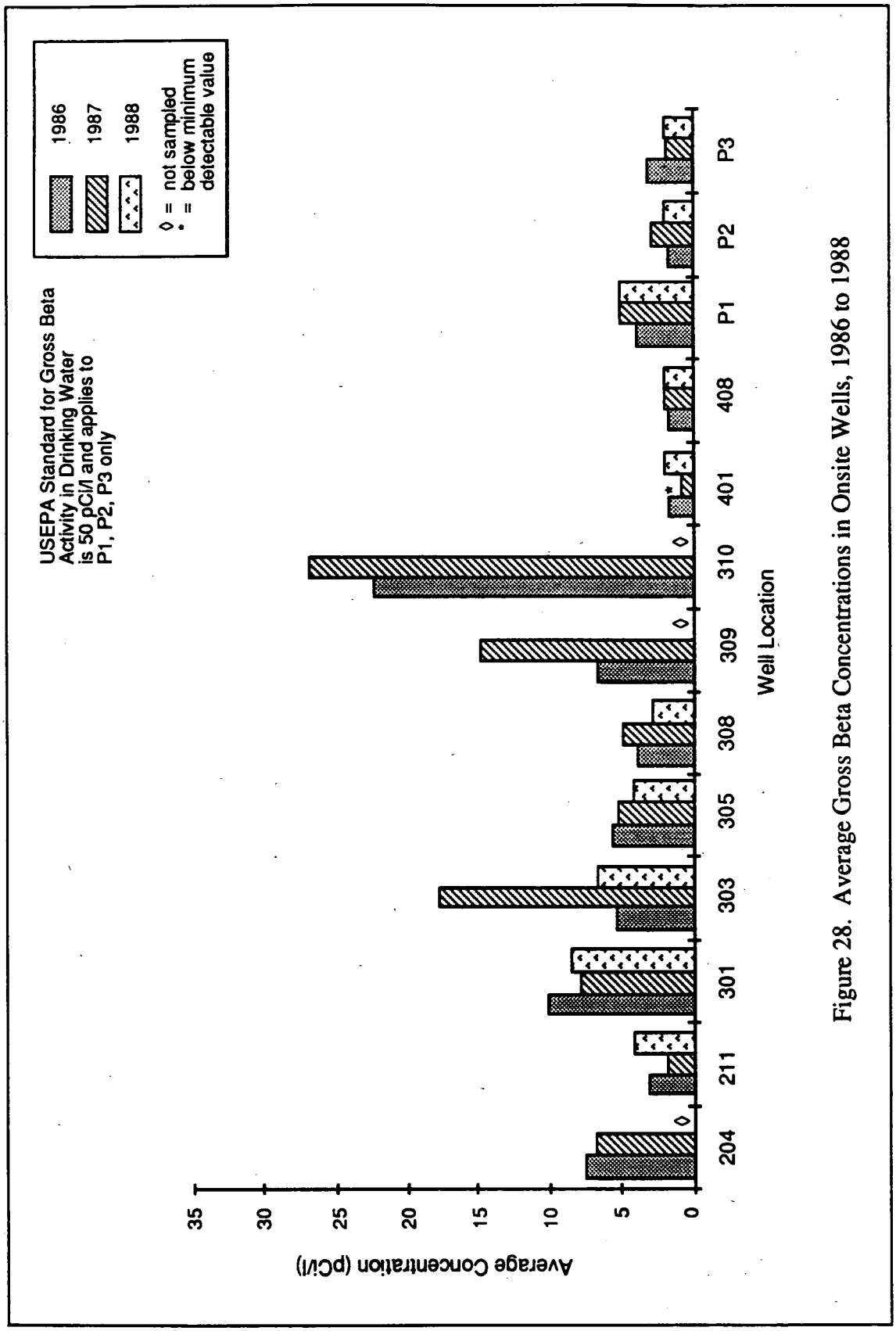

Figure 28. Average Gross Beta Concentrations in Onsite Wells, 1986 to 1988

the standard of 50 pCi/l. Overall, the differences in the two parameters between 1987 and 1988 showed no trends outside of what would be considered due to natural variability, except for well 303, which decreased significantly.

Onsite Monitoring Wells, Nonradiological Parameters. In 1988, wells 204, 309, and 310 were not sampled due to well refurbishing activities. All other onsite wells were sampled once for nitrate concentrations, and the results were less than the USEPA drinking water standard of 10 mg/l (Table 16). However, well 310 had exceeded the standard in 1986 and 1987, but a comparison with 1988 data could not be made because the well was not sampled due to refurbishing (Figure 29).

The onsite samples were also analyzed for sulfate, chloride, and pH (Tables 17, 18, and 19). All onsite wells were within the USEPA standard of 250 mg/l for sulfate and chloride, and the pH values are similar to 1987 values. Sulfate concentrations in the onsite wells ranged from 16 mg/l in well 308 to 159 mg/l in well P-2, and the average sulfate levels in individual wells vary considerably from year to year. Chloride concentrations ranged from 12 mg/l in well 408 to 41 mg/l in well P-1.

Offsite Monitoring Wells, Radiological Parameters. During 1988, twenty-eight offsite wells belonging to individuals and companies in the vicinity of the FMPC were sampled monthly for total uranium (Figure 30). Wells 6 and 20 were sampled as part of the offsite program in prior years; however, in 1988, the owner of well 6 moved and the well is no longer sampled, and well 20 was plugged. Well 31 was added to the monitoring program in 1988, but the owners chose to stop participating in the program after the September sampling.

As in past years, the average uranium concentrations in samples collected in 1988 from the offsite wells, except for wells 12, 15, and 17, were well below the standard of 40 pCi/l (1.5 Bq/l), and were within the natural background range for uranium content in groundwater. The average uranium concentration in well 17 was below the standard, but some monthly samples were higher. All the data from the offsite sampling program are presented in Table 20. Figures 31 and 32 show average uranium concentrations found in offsite wells during 1986-1988. No clear trends were evident in the majority of the offsite wells, and any differences in the data were probably due to natural, sampling, and analytical variability.

Contaminated surface water seeping into the aquifer from the Storm-Sewer Outfall Ditch and Paddy's Run was identified in 1985 as the probable source of above-background concentrations of uranium in offsite wells 12, 15, and 17.[22] The Stormwater Retention Basin, which began operations in late 1986, has greatly reduced discharges of contaminated stormwater to the Storm-Sewer Outfall Ditch and Paddy's Run.

Offsite Monitoring Wells, Nonradiological Parameters. In May 1988, in addition to the monthly sampling for radiological parameters, the FMPC collected samples from the offsite wells and analyzed them for sixteen metals (Table 21). Of these 16 metals, no DOE or USEPA standards have been established for calcium, potassium, magnesium, and nickel. Though concentrations of iron and manganese were generally higher than USEPA drinking water guidelines, their concentrations are typical for groundwater in this area.[23,24,25] Concentrations of the six other metals analyzed for were well within guidelines.

Sampling Surface Water

The FMPC Surface Water Sampling Program was developed to measure the effects of routine discharges of treated effluents into the Great Miami River and of stormwater runoff into Paddy's Run. The Stormwater Retention Basin now collects all surface runoff (except for occasional overflows - there was one overflow in 1988 of 1.6 million gallons) from the production area, administration area, and the parking lot. Surface water in Paddy's Run was monitored to measure the effects of general runoff into the creek from the waste storage area and other areas of the FMPC.

In 1988, surface water was sampled for radiological and nonradiological parameters at four onsite and five offsite locations along

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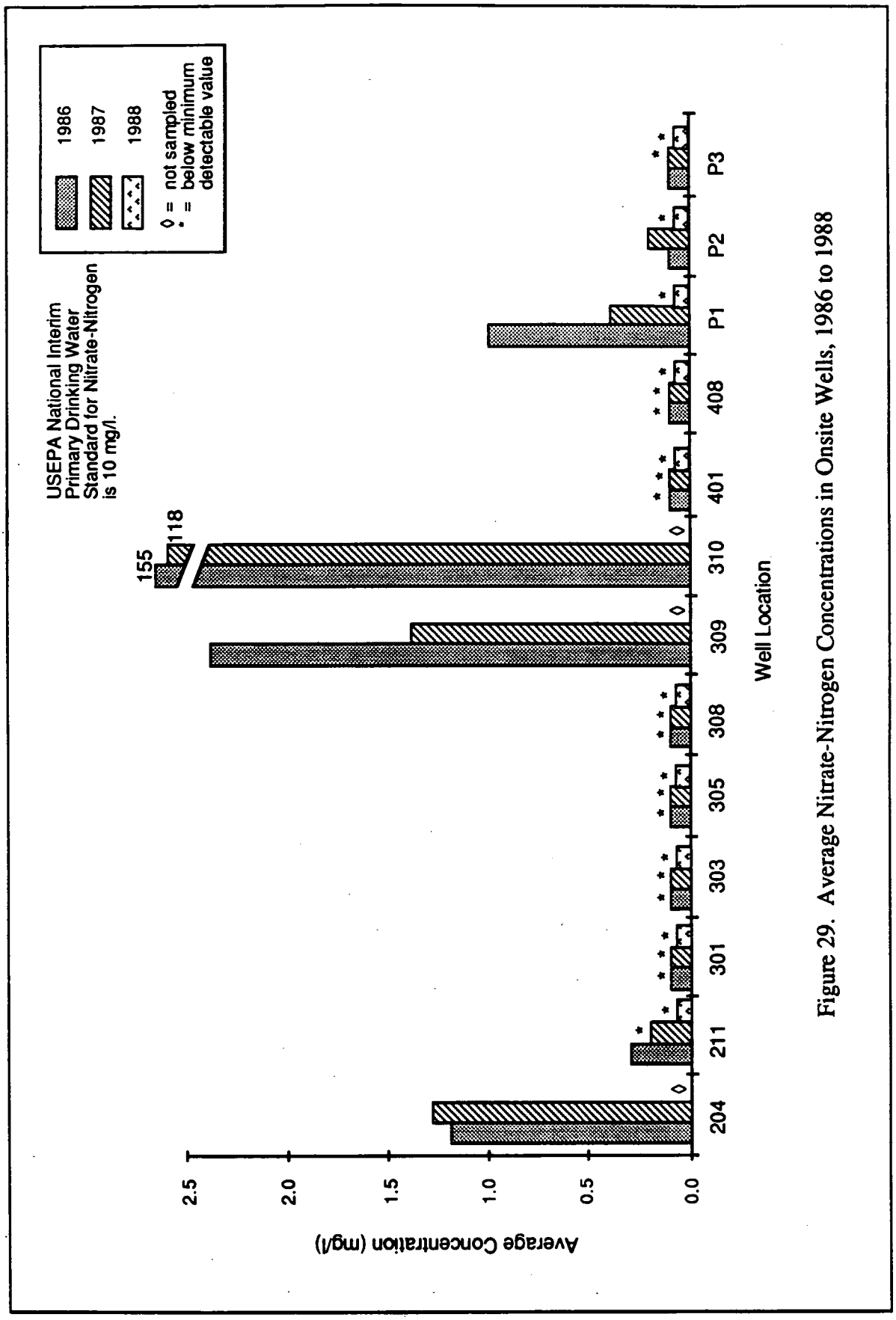

Figure 29. Average Nitrate-Nitrogen Concentrations in Onsite Wells, 1986 to 1988

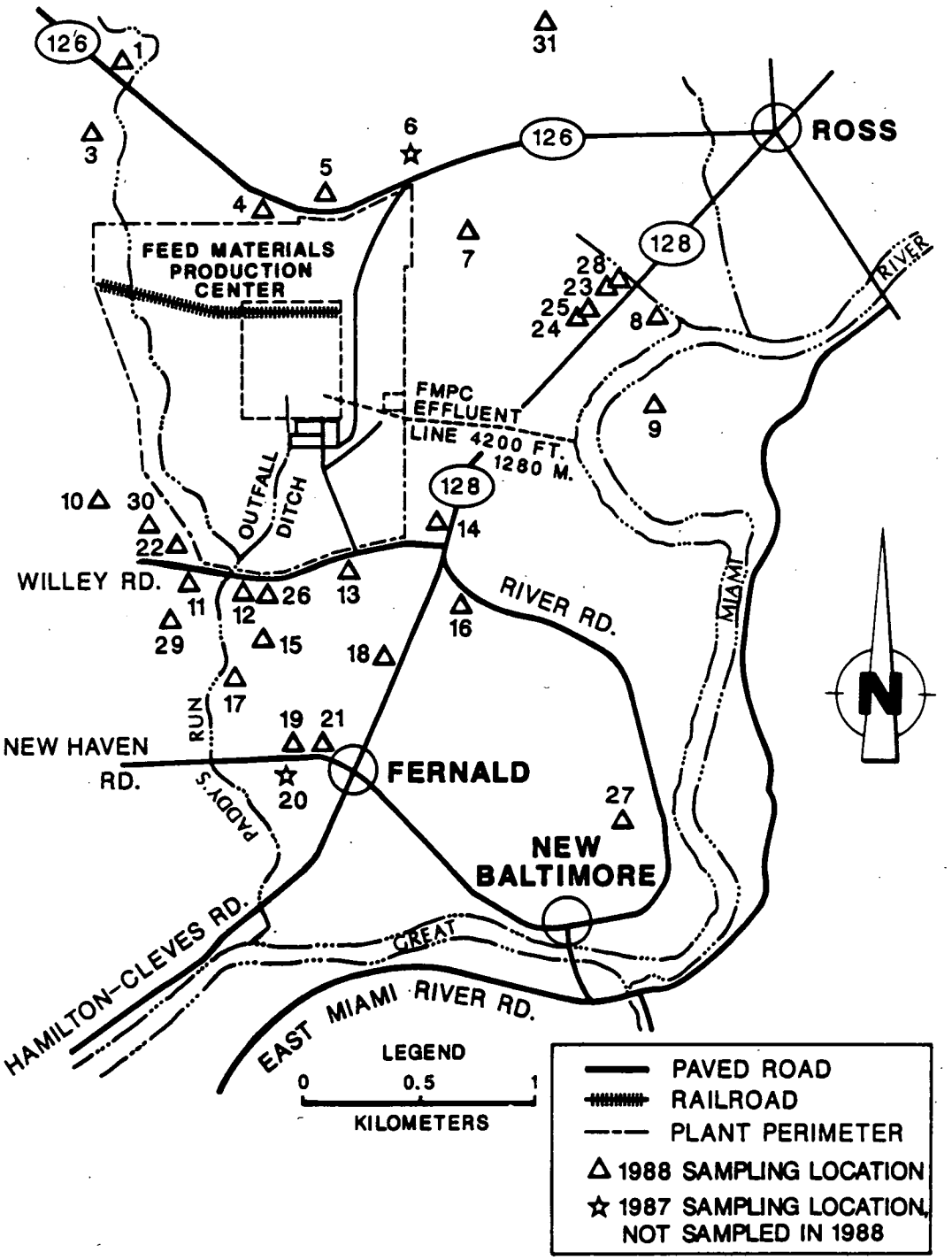

Figure 30. Offsite Groundwater Sampling Locations

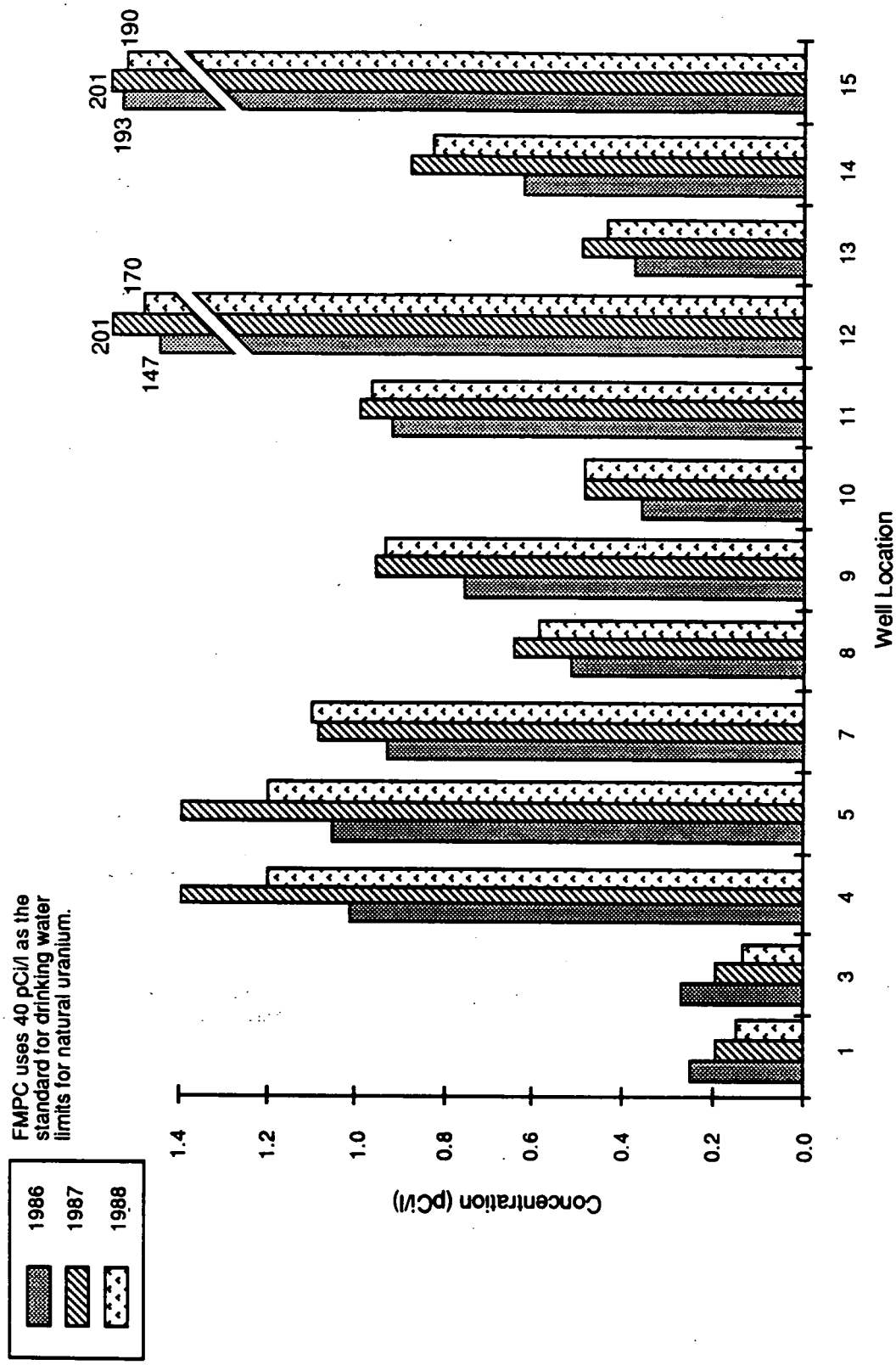

Figure 31. Average Uranium Concentrations in Offsite Wells, 1986 to 1988

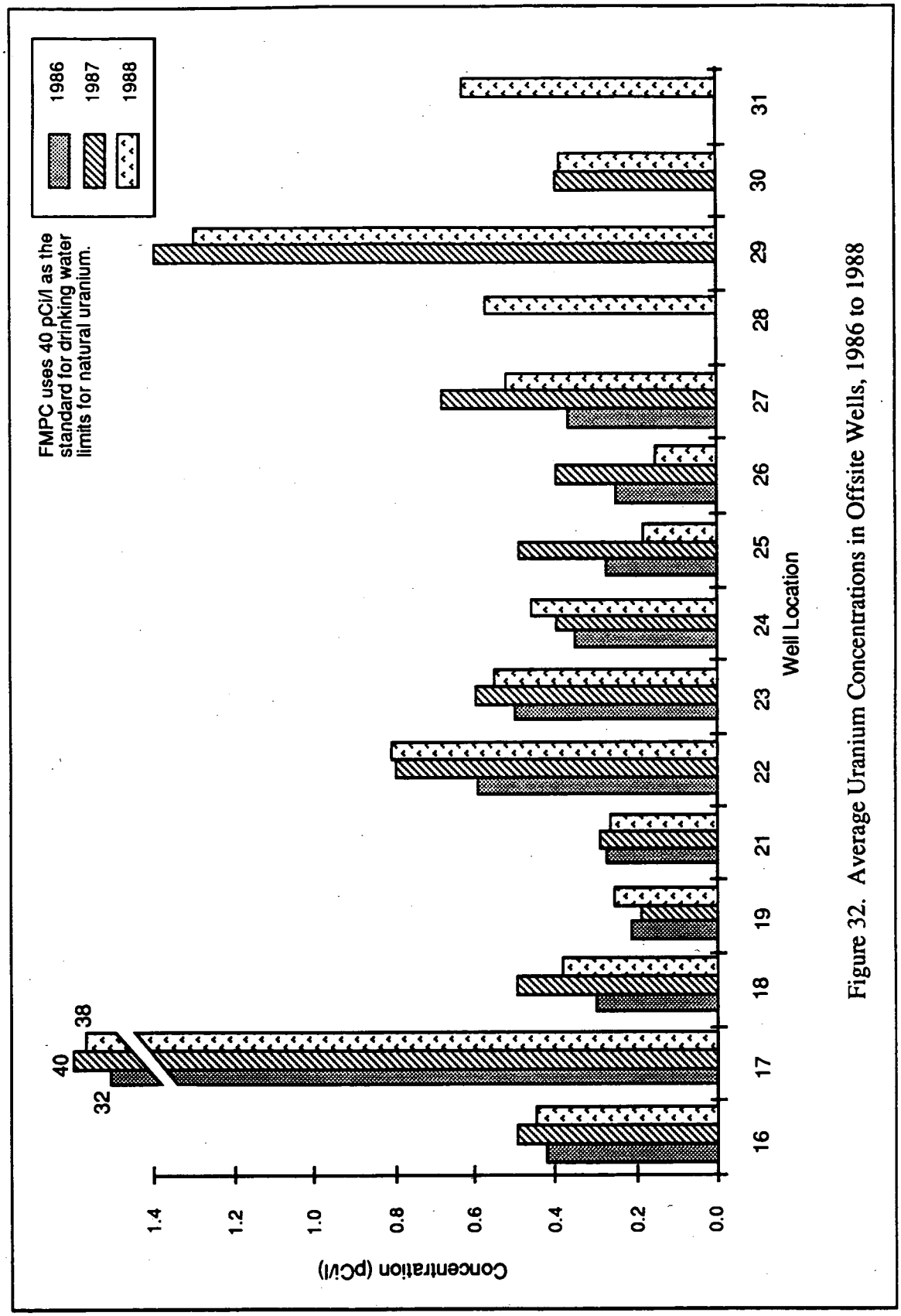

Figure 32. Average Uranium Concentrations in Offsite Wells, 1986 to 1988

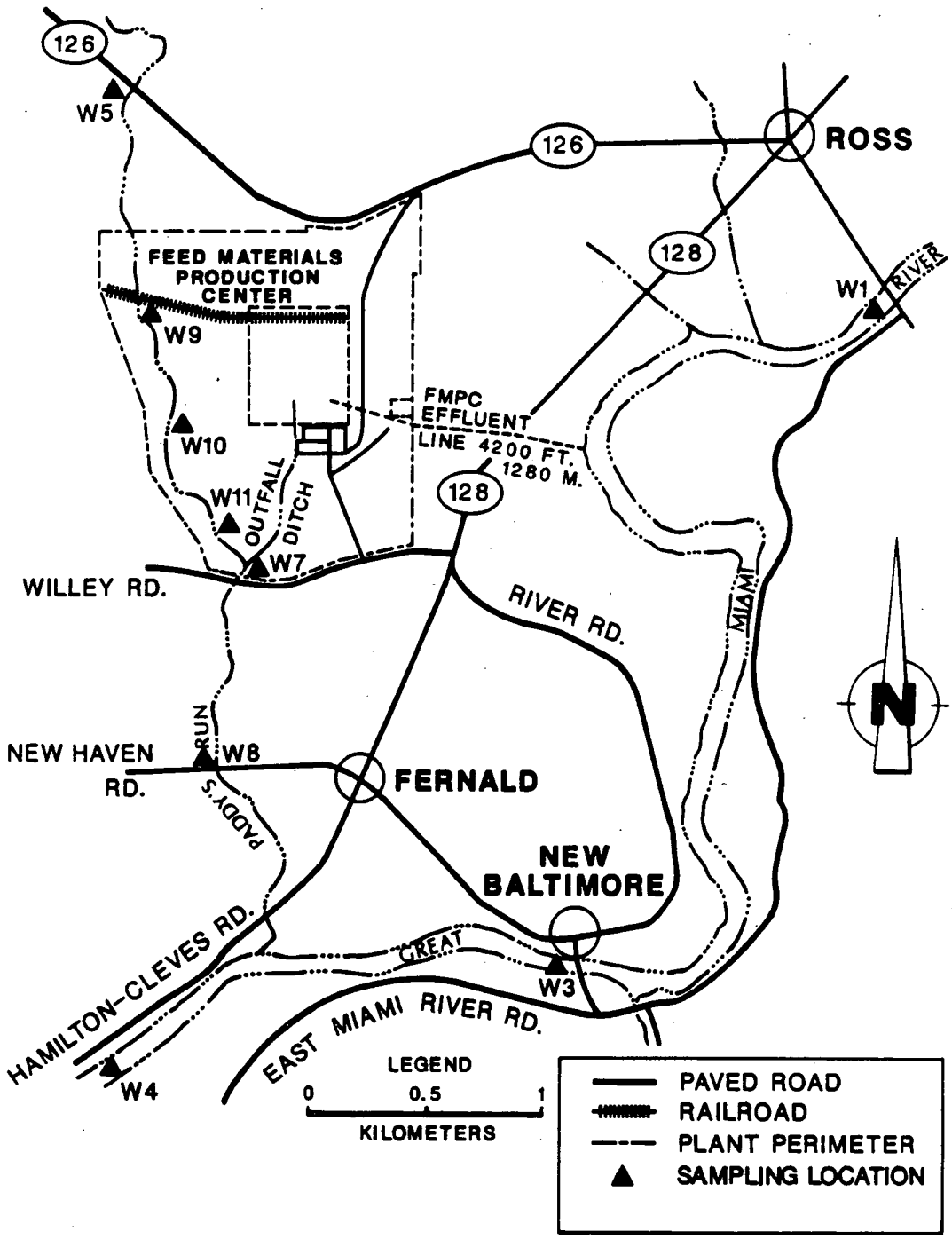

Figure 33. Surface Water Sampling Locations

Paddy's Run and along the Great Miami River (Figure 33). Depending on the sampling location, the frequency of collection of surface water varied along with the parameters that were analyzed.

Surface water grab samples were collected daily at sampling stations W1 and W3, and weekly at W4 on the Great Miami River. These samples were analyzed for isotopic radium. Samples were also taken once each week and analyzed for pH, fluoride, nitrate, chloride, and radiological parameters such as gross alpha, gross beta, and uranium. Semiannual composites for the Great Miami River locations were analyzed for cesium-137, strontium-90, technetium-99, and isotopic uranium.

At the six locations along Paddy's Run, weekly grab samples were collected (when water was flowing) and analyzed for pH, gross alpha, gross beta, and total uranium. Two-month composites of weekly samples at W5 were analyzed for isotopic radium, as were monthly composites at W7 (or W8 if W7 was dry). A summary of the 1988 analytical results follows.

Radiological Parameters. All average total uranium concentrations at surface water sampling locations were well within the standard of 550 pCi/l, which applies to offsite discharges. As shown in Figure 34, differences in average total uranium concentrations between 1987 and 1988 showed no trends except at W10, which increased.

The average background level of uranium in surface water in the vicinity of the FMPC is approximately 1 pCi/l (0.04 Bq/l), which was measured at the sampling location along the Great Miami River upstream of the FMPC. Above-background concentrations were found at the locations along Paddy's Run, except for W5, which is upstream from the site (Table 22). These elevated concentrations were probably due to stormwater runoff flowing from the Waste Storage Area into Paddy's Run above the Storm-Sewer Outfall Ditch. The concentrations are not an immediate concern, but future results will be carefully analyzed to quickly identify long-term trends.

Figure 35 is a plot of the average gross alpha concentrations at surface water sampling locations during 1986 through 1988. Gross alpha concentrations in 1988 were virtually identical to 1987 concentrations for all locations except W10, which also had higher uranium concentrations. No applicable standards exist for gross alpha concentrations in surface water not used as a source of drinking water.

Figure 36 shows a plot of the average gross beta concentrations at surface water sampling locations during 1986 through 1988. Gross beta concentrations for all locations were virtually the same in 1988 when compared to 1987, except for location W4 which decreased, and W10 which increased significantly to 21 pCi/l (0.79 Bq/l). This increase is consistent with uranium and gross alpha measurements at this location.

Table 22 also presents the various radionuclides detected at surface water sampling locations in 1988. Most radioisotope concentrations in the Great Miami River and Paddy's Run did not differ significantly from 1987 concentrations. In 1988, radium-226 and -228, uranium-238, and total uranium concentrations were unchanged or lower in Paddy's Run and the Great Miami River, except for W10. Concentrations of cesium-137, uranium-235/-236 and technetium-99 were not detectable in 1988. Concentrations of uranium-234 were lower in 1988 at all three Great Miami River locations.

The FMPC conducted additional stormwater sampling in drainage ditches as part of the Best Management Practices Plan (BMP) (Figure 37). All 1988 surface water sampling locations displayed uranium concentrations within the DOE standard of 550 pCi/l or 20.4 Bq/l (which is a standard that applies to offsite discharges). However, sampling results indicated the runoff contained above-background concentrations of uranium and may have contributed to higher uranium concentrations in Paddy's Run (Table 23).[22]

Nonradiological Parameters. Table 24 provides the nitrate concentrations detected at sampling locations along Paddy's Run and the Great Miami River in 1988. The data indicated that operations at the FMPC did not affect nitrate levels in Paddy's Run because there were

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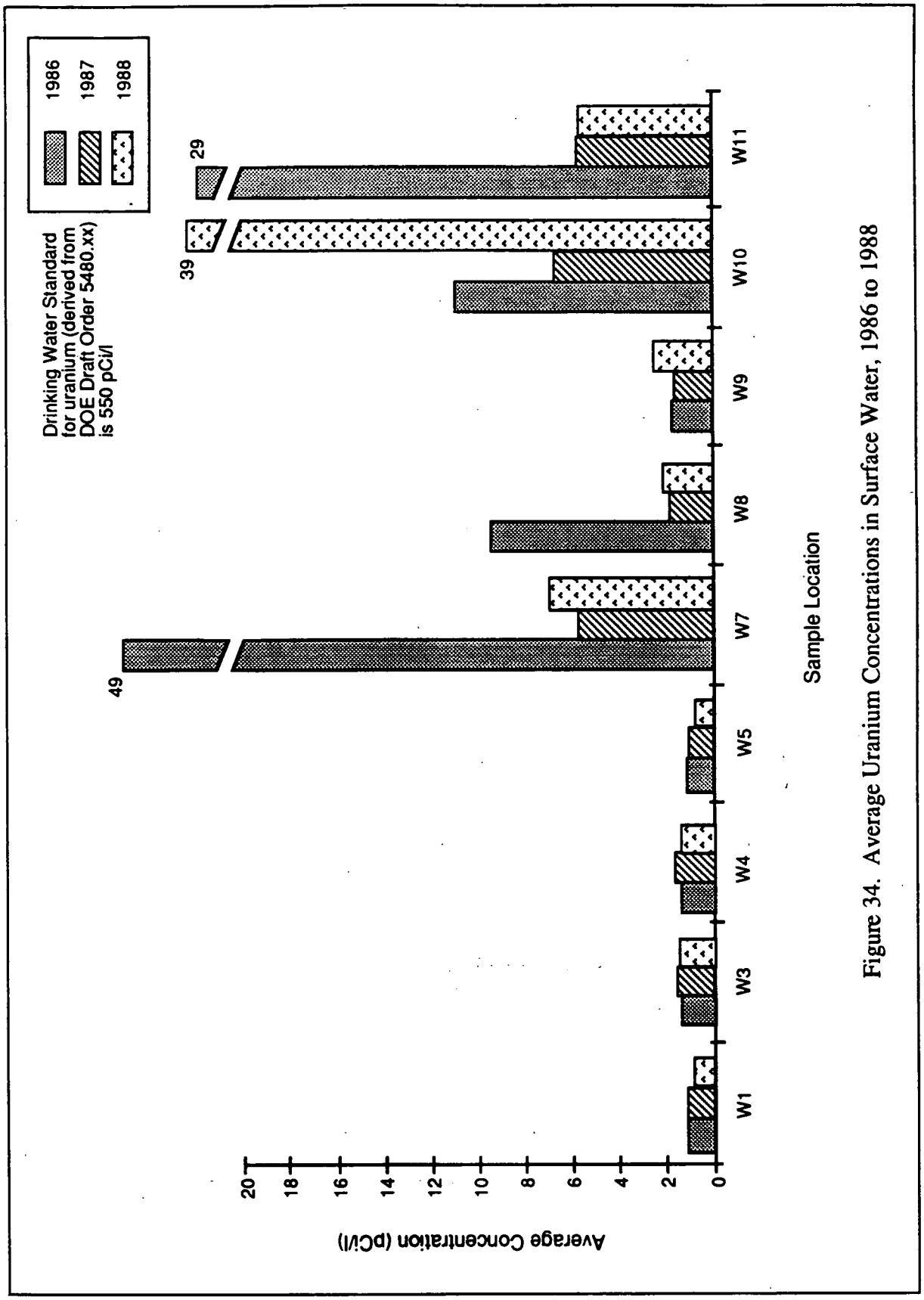

Figure 34. Average Uranium Concentrations in Surface Water, 1986 to 1988

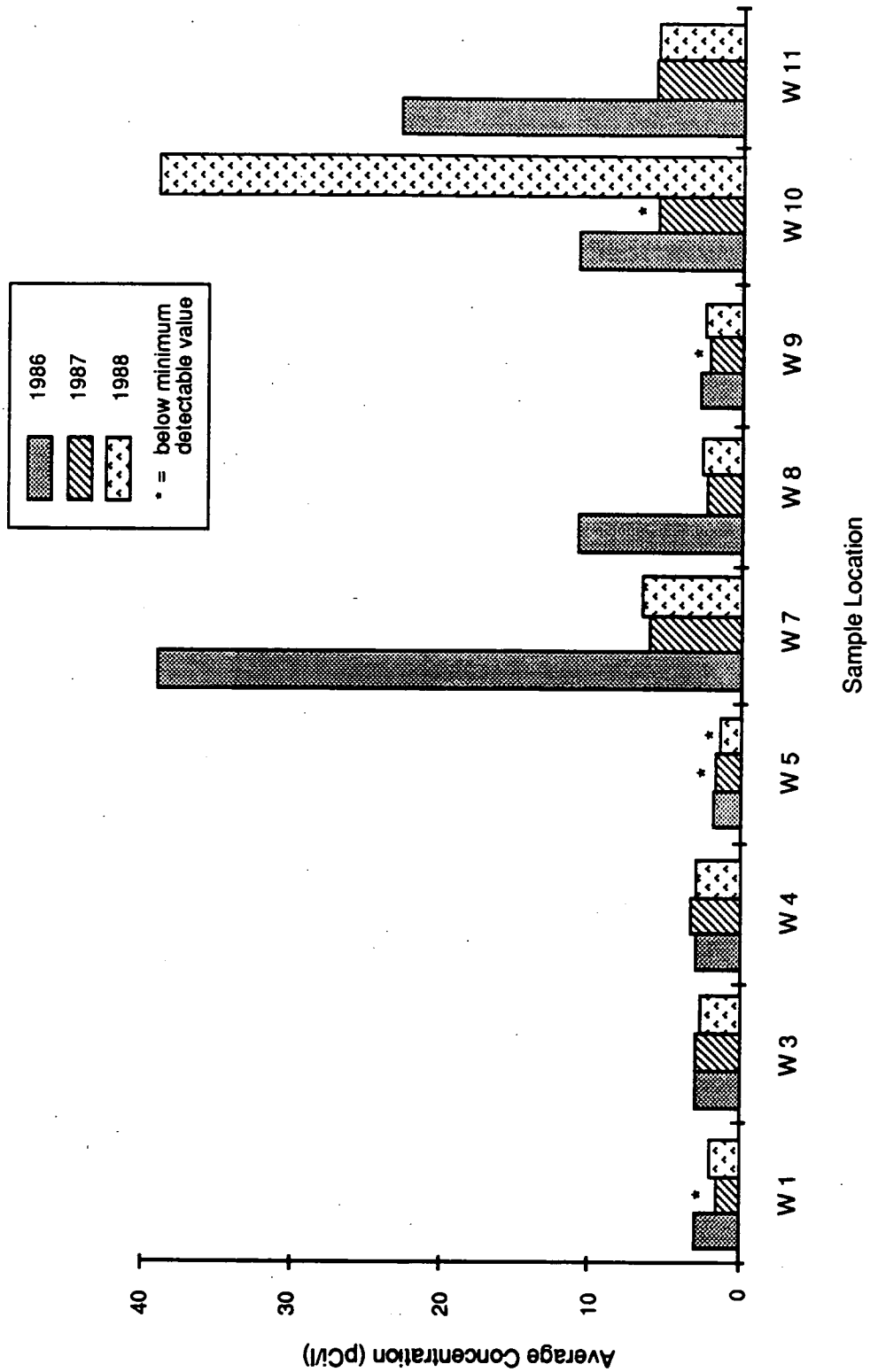

Figure 35. Average Gross Alpha Concentrations in Surface Water, 1986 to 1988

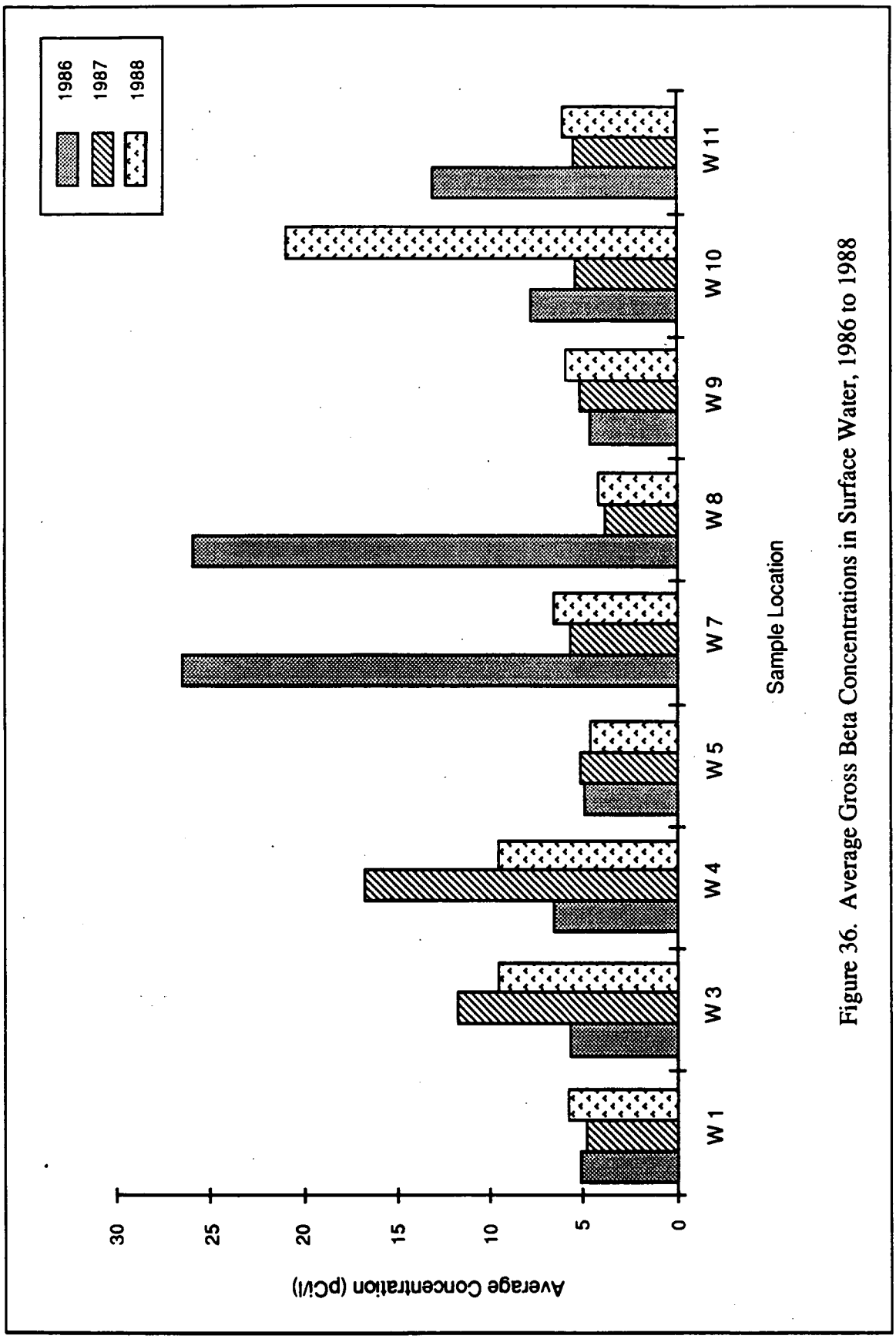

Figure 36. Average Gross Beta Concentrations in Surface Water, 1986 to 1988

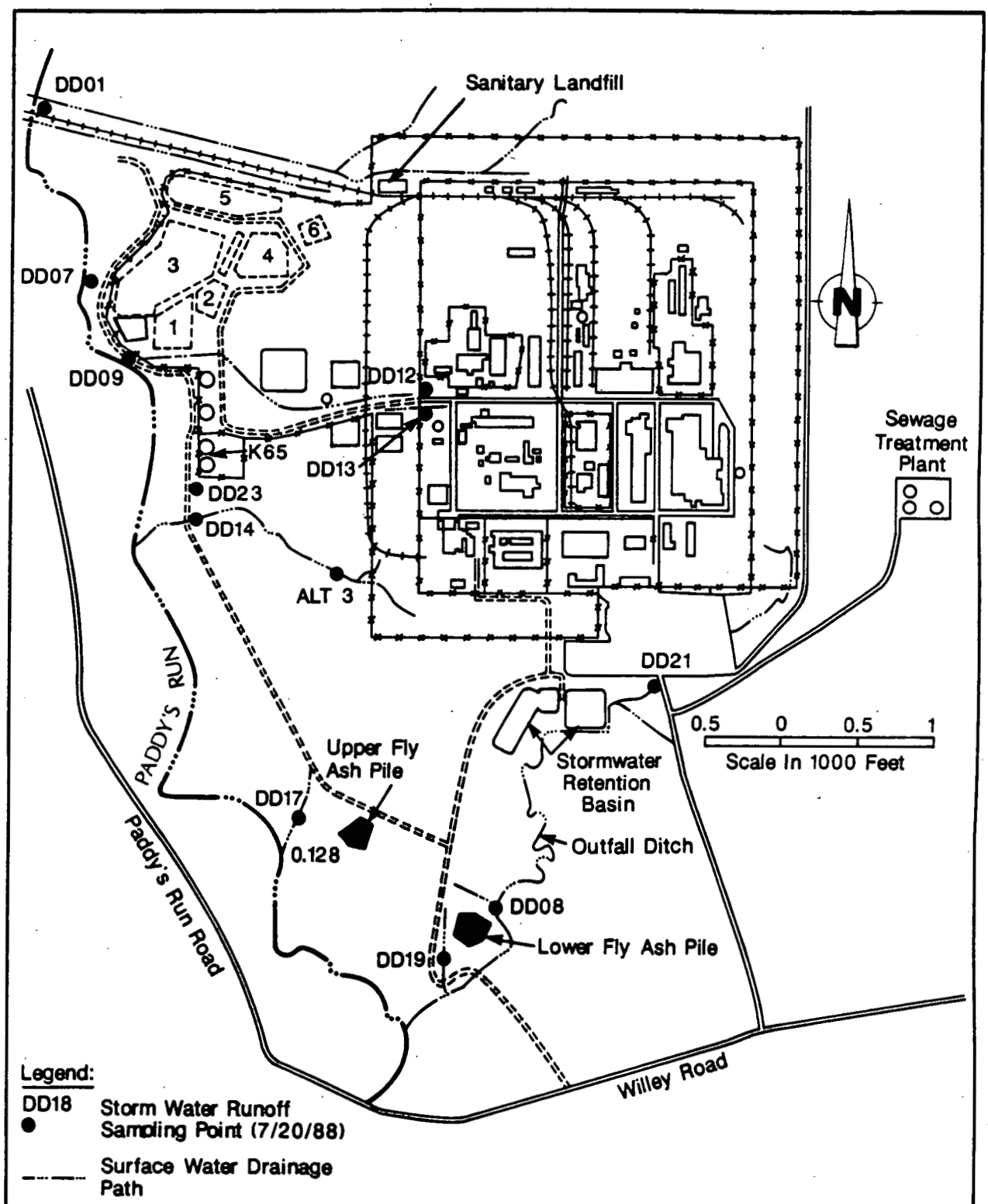

Figure 37. Drainage Ditch Sampling Locations

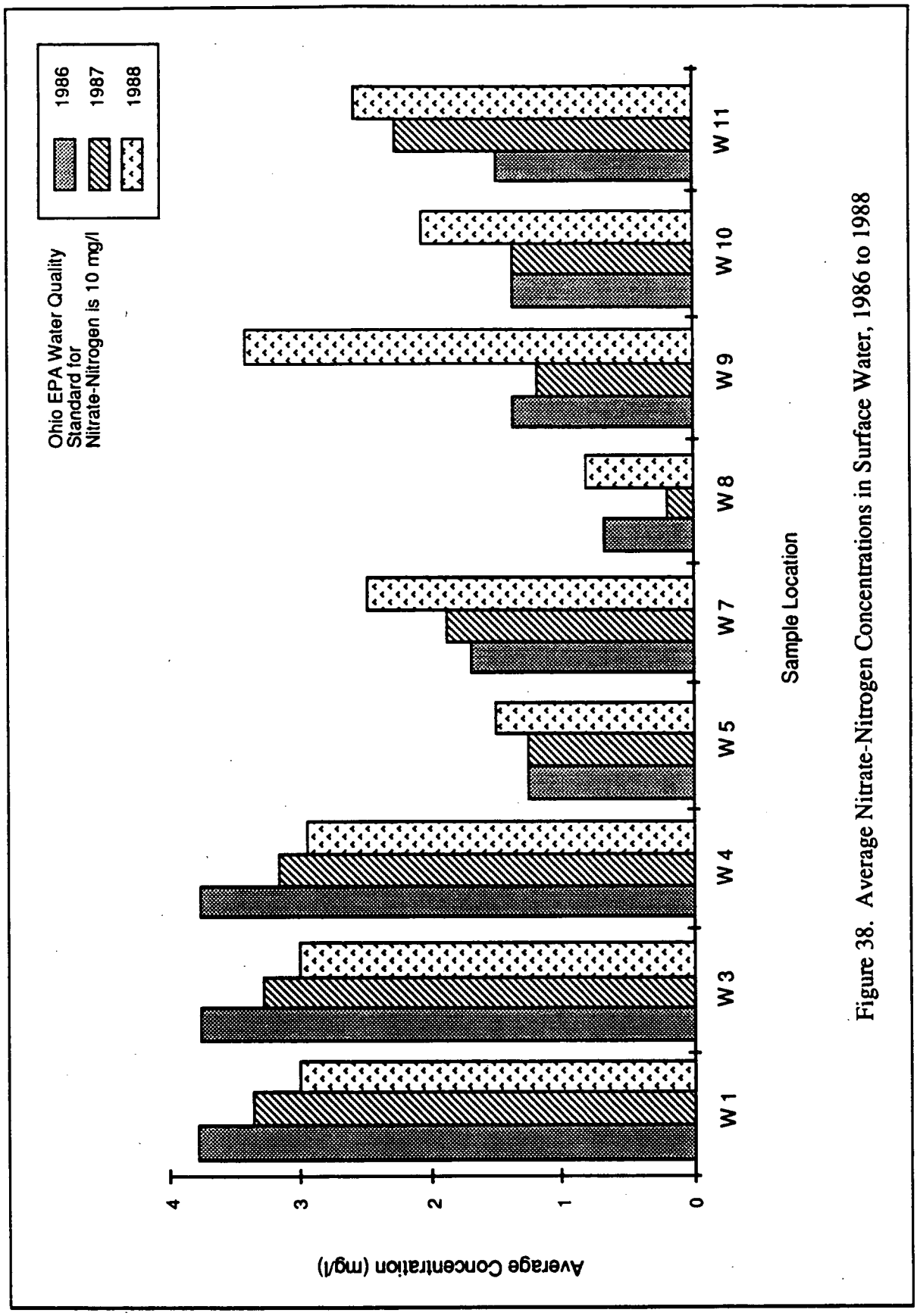

Figure 38. Average Nitrate-Nitrogen Concentrations in Surface Water, 1986 to 1988

no significant differences between upstream and downstream concentrations of nitrates. The nitrate levels in both streams were within the USEPA drinking water standard of 10 mg/l.

Figure 38 shows the nitrate-nitrogen concentrations in surface water during 1986 through 1988. Nitrate concentrations decreased from 1987 levels along the Great Miami River, but have increased along Paddy's Run. These increases more than likely can be attributed to the drought that was experienced in the summer of 1988. With the usual agricultural activity and consequential nitrate releases into water systems and a decrease in water volume, there would be less dilution of nitrates in Paddy's Run, and consequently higher concentrations than in previous years.

Fluoride levels in 1988 were relatively low (0.61 mg/l or less), and these levels were within the USEPA drinking water standards of 4.0 mg/l, as shown in Figure 39 and Table 24.

Sampling FMPC Liquid Effluents

The FMPC uses three systems for treating liquid wastes. These systems are for process wastewater, sanitary wastewater, and stormwater runoff. Figure 40 illustrates the flow paths of the liquid waste streams and the major points of treatment. Figure 41 provides a map of the seven National Pollutant Discharge Elimination System (NPDES) effluent sampling locations. The NPDES is discussed in the section on nonradiological parameters.

Radiological Parameters. Liquid effluent samples were collected continuously by an automatic sampler in proportion to the total flow at Outfall 001 (Manhole-175), which is the final sampling point in the FMPC effluent line into the Great Miami River. Twenty-four hour composite samples at Outfall 001 were collected daily and analyzed for uranium content and alpha and beta activity. One-month composites of the daily samples were analyzed for radium-226 and radium-228, and 24 semimonthly composite samples were analyzed for 18 other radionuclides.

During 1988, the total amount of uranium (858 kg, 1,892 lb) present in the liquid effluent discharged into the Great Miami River at Outfall 001 was 11.4% greater than in 1987. The amount of curies of uranium released increased 4%, from 0.52 Ci or 1.9×10^{10} Bq in 1987, to 0.55 Ci or 2.0×10^{10} Bq in 1988 (Table 25). The increase may be attributed to a greater quantity of stormwater runoff being collected and discharged at Manhole-175 in 1988 versus 1987. Although the area experienced a drought for several weeks during the early summer, the total rainfall for 1988 was average according to Greater Cincinnati International Airport data.

This stormwater runoff, steam condensate, and other uncontrolled runoff in the production area were collected in the storm-sewer system. Uranium may enter the system from settled airborne emissions' fallout flushed into the storm-sewer system by the rains, and through accidental spills and runoff from concrete pads and roads. In prior years, more of the surface water runoff has flowed into Paddy's Run, and any uranium in that runoff would not have been monitored at Manhole-175.

For 1988, the total amount of uranium present in stormwater runoff which flowed into the Storm-Sewer Outfall Ditch during overflow from the Stormwater Retention Basin (Outfall 002) was 5.4 kg (11.9 lb, 0.0036 Ci or 1.3×10^{-8} Bq). This is significantly lower than in years prior to the SWRB's operation. Water from the SWRB is pumped to Manhole-175 where it is monitored before it is discharged into the Great Miami River.

Figure 42 compares curies of uranium isotopes measured at Outfall 001 during 1988 to values from 1986 and 1987 data. Table 25 is a summary of the radionuclides analyzed in 1988, more than half of which were at concentrations less than detectable. For those radionuclides that were present at detectable levels, concentrations of strontium-90 decreased, while concentrations of technetium-99, thorium-232, uranium-236, -238, and total uranium increased in 1988 at Outfall 001 compared to 1987. The 1988 concentrations of uranium-234 and -235 were at the same level as 1987 concentrations.

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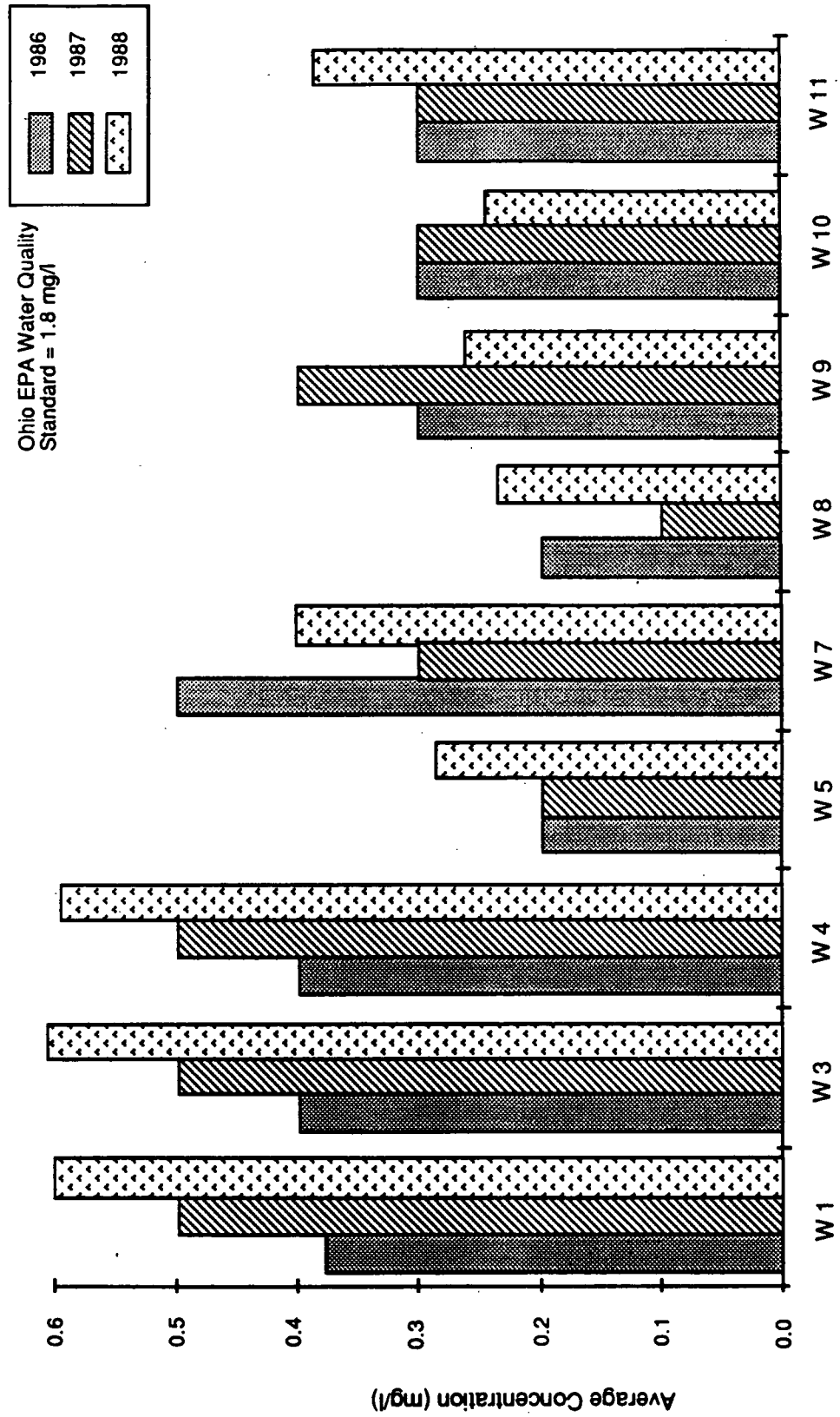

Figure 39. Average Fluoride Concentrations in Surface Water, 1986 to 1988

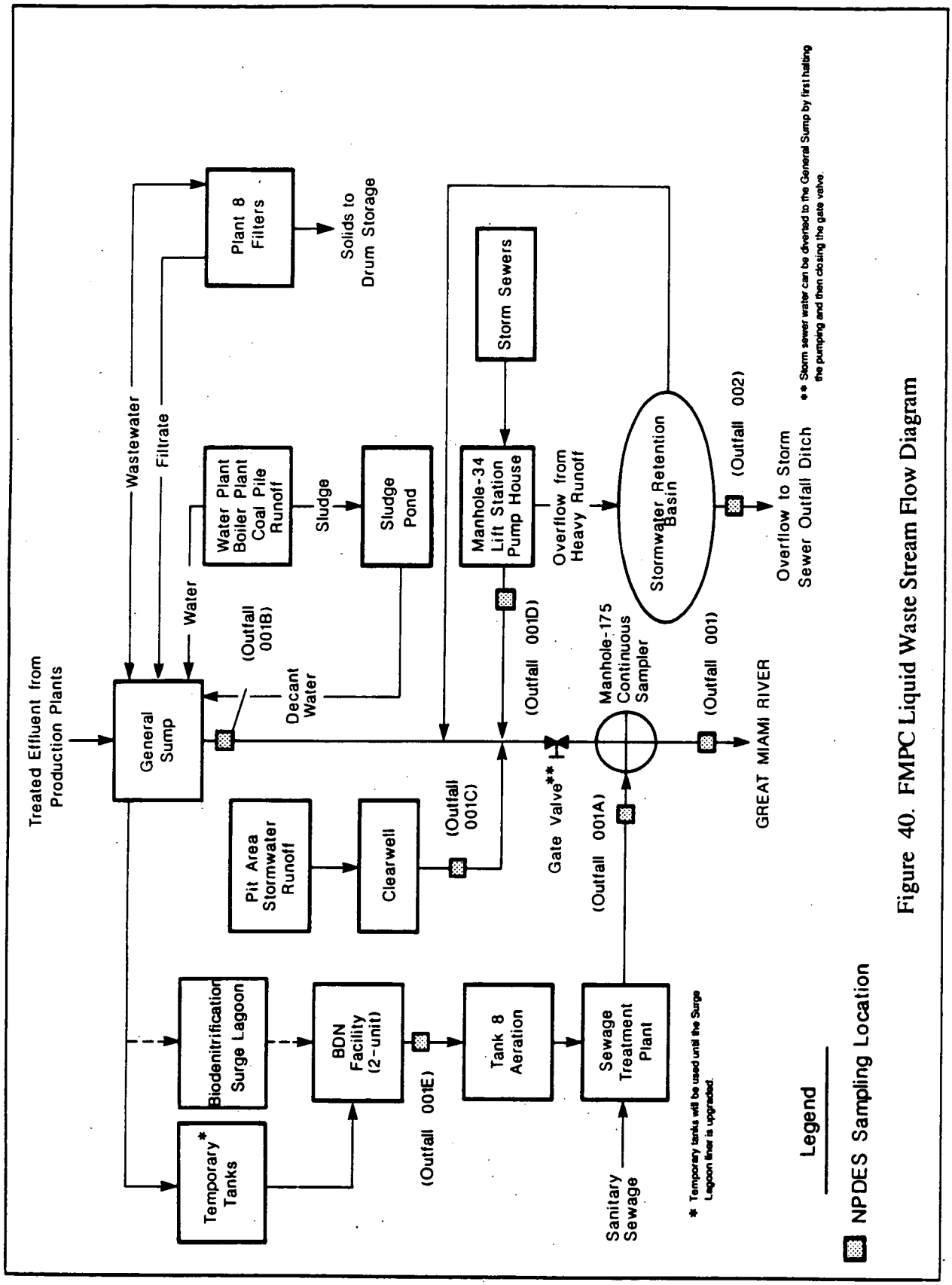

Figure 40. FMPC Liquid Waste Stream Flow Diagram

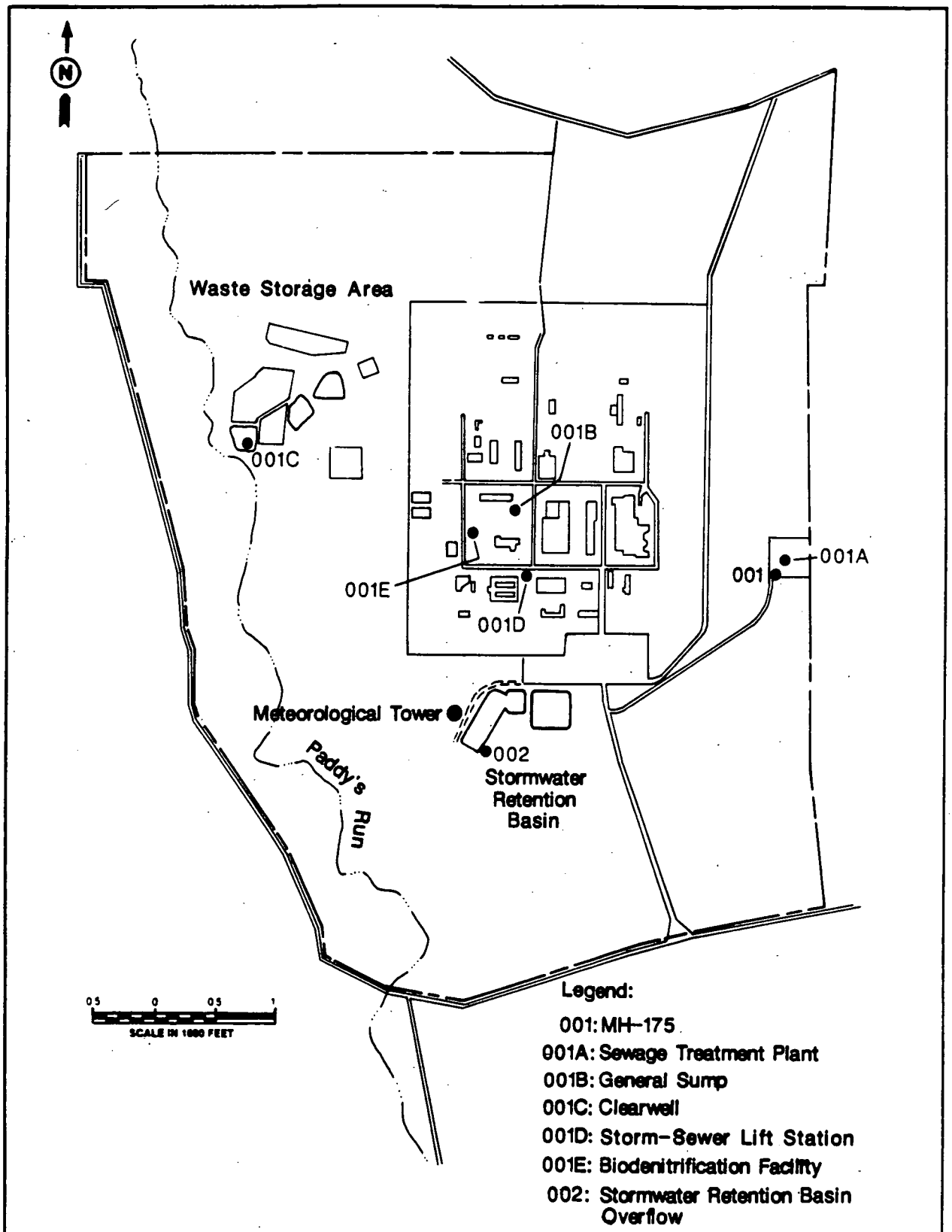

Figure 41. NPDES Effluent Sampling Locations at the FMPC, 1988

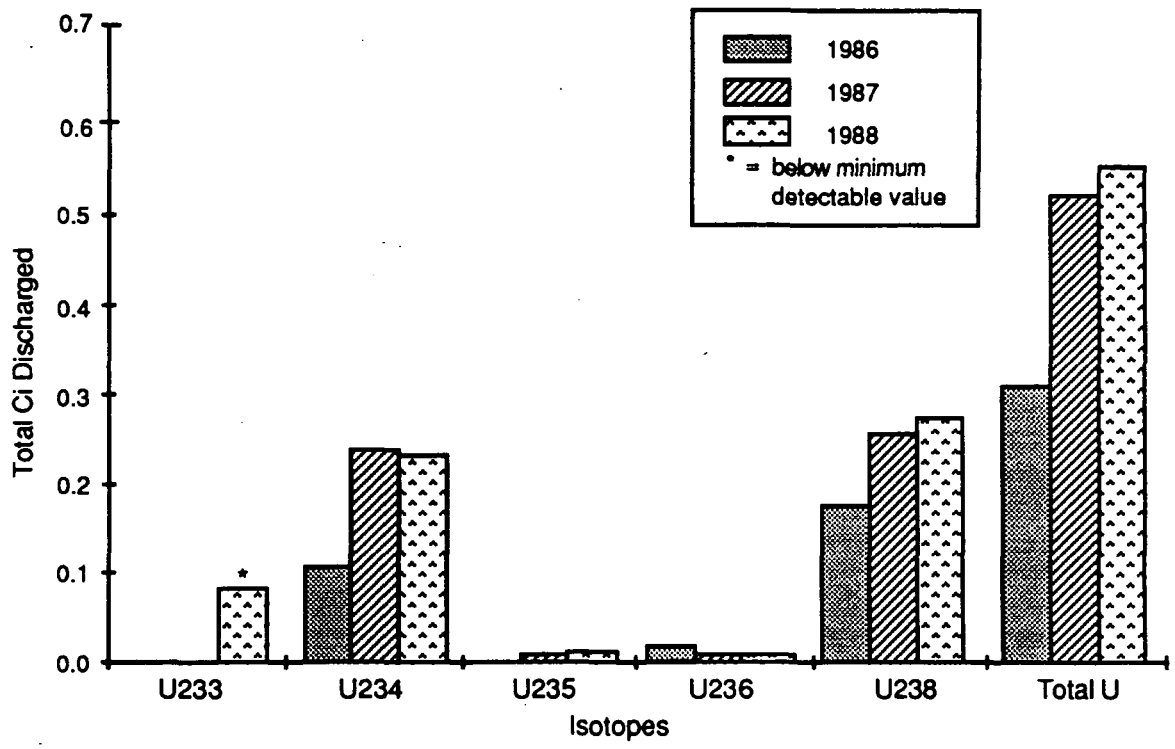

Figure 42. Uranium Discharged at NPDES Sampling Point 001, 1986 to 1988

Reporting Nonradiological Parameters Under the NPDES Permit. The NPDES permit is issued by the State of Ohio to control the discharge of nonradiological pollutants to Ohio waters. It specifies sampling locations, sampling and reporting schedules, discharge limitations, water quality standards, and other restrictions on FMPC discharges to the Great Miami River and Paddy's Run. There are seven regulated discharge locations; two discharges are directly to Ohio waters, and five are internal contributing wastewater streams. These discharges are sampled at varying frequencies, and the analytical results are reported monthly to the OEPA.

Over 950 samples of liquid effluents were collected at the NPDES sampling points during 1988 and were analyzed for nonradiological parameters. The results indicated that the FMPC met the NPDES daily maximum and monthly average permit limits more than 88% of the time (Table 26).

Of the noncompliances, about 76% involved the Sewage Treatment Plant, which exceeded the limit for five-day biochemical oxygen demand (BOD_5) 35 times, the limit for total suspended solids (TSS) 42 times, and the limit for fecal coliform bacteria five times. The FMPC satisfied the NPDES concentration limits for both BOD_5 and TSS at the Sewage Treatment Plant 86% of the time during 1988. Compliance rates for BOD_5 and TSS mass limits were 45% and 31%, respectively. The average nitrate concentrations in the plant effluent at Outfall 001 decreased from an average of 78 mg/l during 1986 to an average of 36 mg/l in 1987, but increased to 47 mg/l in 1988.

The FMPC has taken several measures to improve compliance with the limits established in the NPDES permit. One of the major steps has been to build a demonstration-scale Biodenitrification Facility (Building 18D in Figure 1) to reduce the level of nitrates in process effluents. Although the demonstration-scale Biodenitrification Facility has enabled the FMPC to comply with NPDES nitrate limits, operation of the facility has aggravated NPDES noncompliance problems at the Sewage Treatment Plant as noted in the preceding

paragraphs. The increased flow and additional BOD_5 and TSS loading from the biodenitrification effluent stresses the capabilities of the Sewage Treatment Plant. The NPDES limits (BOD_5 and TSS) for the Sewage Treatment Plant are based on the 1980 FMPC employment level and wastewater flow rates. Both were significantly lower at that time than they were in 1988.

To reduce NPDES violations at the Sewage Treatment Plant, the FMPC installed an aerator to Tank 8 and a portable box clarifier at the General Sump for the biodenitrification effluent. This eliminated TSS and BOD_5 concentration violations and significantly reduced TSS and BOD_5 mass loading violations at the Sewage Treatment Plant. In addition, a new cleaning procedure was instituted for the ultra-violet disinfection system to eliminate fecal coliform NPDES noncompliances. Figure 43 illustrates how these steps have helped reduce NPDES violations during 1988.

Plans have been developed to upgrade the Biodenitrification Facility to production scale by constructing a separate biological treatment system to remove BOD_5 and TSS from the biodenitrification effluent. Biodenitrification effluent will be discharged directly to the Great Miami River after treatment in this system rather than being treated at the Sewage Treatment Plant, thus reducing stress on that facility.

As measured at Outfall 001, the FMPC released an average of 2,100 m^3 (0.556 million gallons) of water per day into the Great Miami River in 1988, a 3.5% decrease over 1987 discharges. This decrease can be attributed in part to the three-month production strike in the autumn. In 1988, a total of 6,000 cubic meters (1.6 million gallons) of runoff water overflowed the SWRB into Paddy's Run via Outfall 002. The overflow occurred February 1-4. This is a significant decrease from the years before the SWRB was in operation. Since the overflow discharge is a function of the amount of rainfall, the discharges at 002 cannot be controlled once the SWRB starts to overflow.

During 1988, the FMPC submitted a NPDES permit renewal application to OEPA. In May

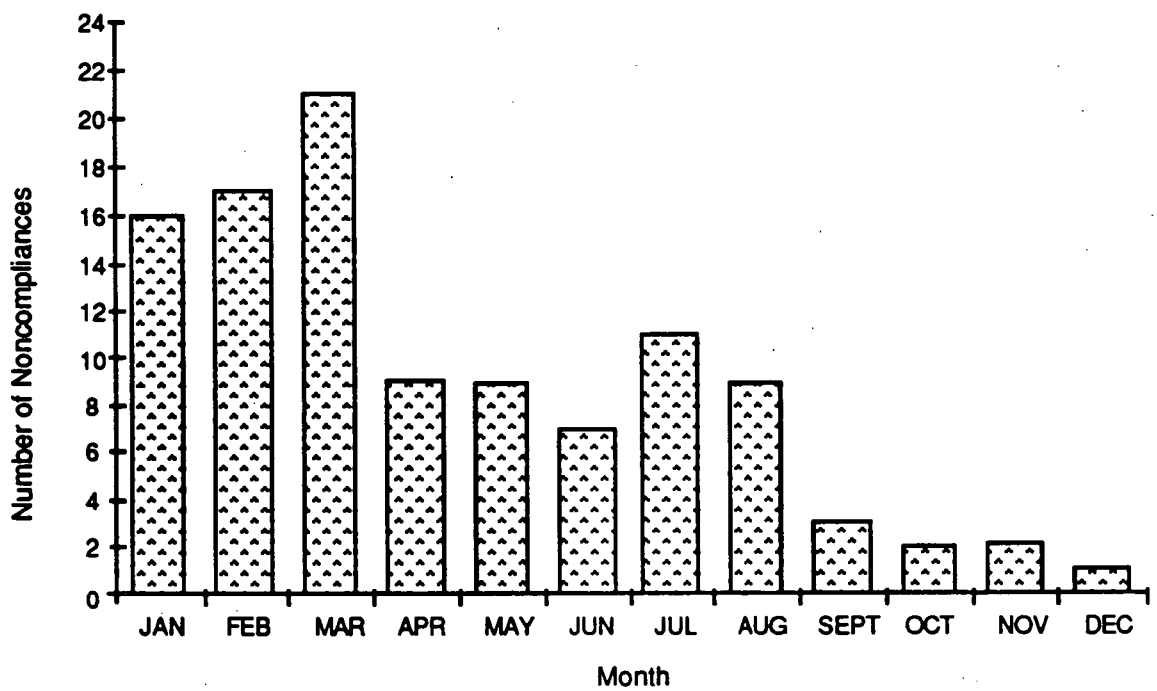

Figure 43. NPDES Noncompliance, 1988

1988 the FMPC collected three rounds of sampling and analyzed for priority pollutants. The analytical results along with a water balance and process descriptions were compiled into the NPDES permit renewal application and sent to the OEPA on August 1, 1988.

A new NPDES permit for the FMPC may cover up to five years of facility operation and can include a variety of control restrictions. It will combine technology- and production-based pollutant discharge limitations. Technology-based limits will apply to conventional pollutants such as BOD_5, TSS, pH, and bacteria. Production-based limits apply to toxic pollutants such as heavy metals like chromium, copper, and nickel, and nonmetallics like fluoride.

Production-based pollutant discharge limitations require the use of the best available technology (BAT). The industrial wastewater treatment facilities at the FMPC are currently being upgraded to meet these requirements. All construction is scheduled to be completed not later than 1991.

Production-based pollutant discharge limitations are preferably based on at least one year of actual production data, but FMPC production has been too erratic over the last several years to do this. Instead, these limits can be based on projected production or production capacities if the applicant can establish a valid reason for the production fluctuations. The FMPC satisfies this requirement because the general change in the operational direction of the site to remediation from production creates an uncertainty in production numbers.

Sampling Sediment

Sediment sampling is conducted to measure the cumulative effects of routine discharges of treated effluents into the Great Miami River and to measure the effects of general runoff from the Waste Storage Area into Paddy's Run.

There are currently no DOE or USEPA standards for uranium or other radionuclides in sediment. However, characterization studies for Paddy's Run and Great Miami River sediments, including sediment sampling and analysis for radiological constituents, are being addressed in the ongoing RI/FS.

For purposes of comparison, naturally-occurring uranium concentrations in Ohio soil range from 1.5 pCi/g (0.04 Bq/g) to 4.4 pCi/g (0.16 Bq/g).[20] As an additional control measurement, the FMPC took sediment samples at four locations along the Great Miami River north of the site. The average uranium concentration was 1.3 pCi/g (0.05 Bq/g), which is in the range for background levels of uranium in soil. All the results from the FMPC sediment sampling program were within the average background level, except for locations along the Storm-Sewer Outfall Ditch.

Sediment samples were collected and analyzed for radiological parameters from nine locations along the Great Miami River. Three separate samples were collected at each location in Paddy's Run and the Storm-Sewer Outfall Ditch - one from each bank and one from the center of the stream bed. Seventy-two samples were taken at 24 locations at 100 meter intervals along Paddy's Run north of the confluence with the Storm-Sewer Outfall Ditch; 54 samples were taken at 18 locations at 200 meter intervals along Paddy's Run south of the confluence; and 27 samples were taken from nine locations at 100 meter intervals along the Storm-Sewer Outfall Ditch. The area sampled is shown in Figure 44. All sediment samples were analyzed for technetium-99 and isotopes of uranium, thorium, radium, and plutonium, and the results are presented in Table 27.

Average radionuclide concentrations in sediment samples collected in 1988 varied slightly at each location. Average concentrations of technetium-99 plutonium-238 and plutonium-239/240 were less than detectable for sediments sampled at the Great Miami River, Paddy's Run, and the Storm-Sewer Outfall Ditch.

Great Miami River Sediment Results. During 1988, there was no significant difference between the average uranium, thorium, and radium concentrations found in the samples from locations upstream or downstream of the FMPC effluent line to the Great Miami River. The data indicated that operations at the FMPC did not affect the levels of these radionuclides in the Great Miami River. Uranium, thorium, and radium concentrations in Great Miami River

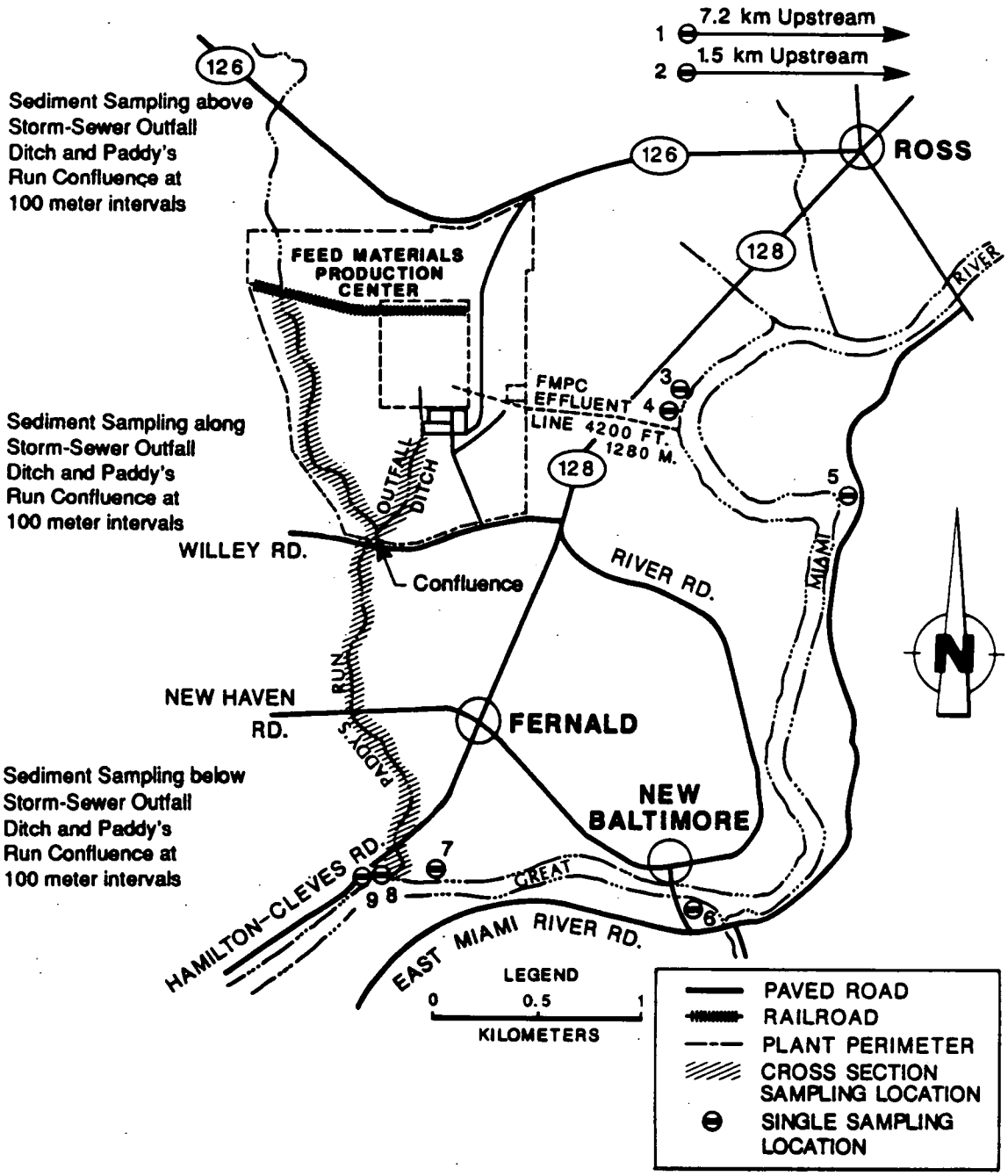

Figure 44. Sediment Sampling Locations

sediments above the FMPC outfall are considered to be at background levels commonly found in the area.

Storm-Sewer Outfall Ditch Sediment Results. During 1988, above-background concentrations of uranium were measured in sediments collected from the Storm-Sewer Outfall Ditch. In general, isotopic uranium, thorium, and radium concentrations increased in sediments near the Stormwater Retention Basin and decreased toward the confluence of the Storm-Sewer Outfall Ditch and Paddy's Run. This trend is expected since contaminated plant runoff seeping into the aquifer from the Storm-Sewer Outfall Ditch and Paddy's Run was identified as the probable source of above-background concentrations of uranium in three offsite wells, which were not used for drinking water.[22]

Paddy's Run Sediment Results. Radionuclide concentrations between locations along Paddy's Run did not follow any cross-sectional or longitudinal trends; slight variations may be due to sediment flushing during heavy storms, differential settling of sediments in bends or pools, or groundwater infiltration. There was no correlation between uranium concentrations in the sediments from Paddy's Run and uranium in surface water from the creek.

Sampling Fish

Fish were collected from three locations on the Great Miami River in September 1988, with the aid of a fisheries research team from the University of Cincinnati (Figure 45). Using electroshock techniques, the team collected 350 fish representing 25 species: 85 from sampling location 1; 111 from location 2; and 154 from location 3. A total of 61 fish samples from all three locations were initially placed in plastic bags and packed in ice, then later scaled and the heads and entrails removed and discarded. A fish was filleted if its total weight was greater than 800-900 g (about 2 lb). The fillets were then frozen, packed in dry ice, and shipped to an independent testing laboratory for uranium analysis.

A University of Cincinnati study determined that the diversity and abundance of fish populations in the Great Miami River have not changed appreciably since 1984.[26] The same types of fish were collected in the same types of habitats in the river. Some river habitats changed from 1985 to 1988 due to gravel quarrying and the removal of part of the dam at sampling location 3. The university scientists report that populations of fish throughout the river have remained healthy between 1985 and 1988.

The average uranium concentration reported in fish from all three sampling locations was markedly higher in 1988 than in previous years, although no significant increases of uranium were noted in FMPC effluent, Great Miami River water, or sediment along the river. The fish data for 1987 and 1988 are presented in Table 28. Some significant laboratory analytical procedure differences from previous years' analyses (by different laboratories) are suspected to be at least partly responsible for the anomalous results. Samples have been reanalyzed to confirm this, but data interpretation and analysis will not be completed in time to include in this report. Other possible effects are the extremely low flow rate and unprecedented high water temperature during the 1988 summer.

Conclusions from the reanalysis of the fish sampling data will be reported in the FMPC Environmental Annual Report for 1989. For this report, however, the data are assumed to be valid, and the dose from eating fish from the location of maximum uranium concentration (location 2, Figure 45) was calculated in Chapter 2. The calculations assumed average U.S. consumption of fish as reported by the U. S. National Marine Fisheries Services.[14]

Summary

During 1988, the FMPC took thousands of samples of environmental media in the various pathways and evaluated the results against federal and state standards. With the exception of anomalous increases in uranium concentrations in fish, which are being re-examined, no unusual trends were noted. Some differences from previous years could be attributed to varying environmental conditions, such as periods of drought during the early summer of 1988.

The data from the environmental monitoring and sampling program are also used in dose calculations. The results are provided in Table 1.

No harmful health effects are expected as the result of operations at the FMPC during 1988.

In addition to sampling and analyzing environmental media to monitor effects of FMPC production on the environment, the FMPC maintains a Quality Assurance Program to guide the collection and analysis of data. This program is described in the next chapter.

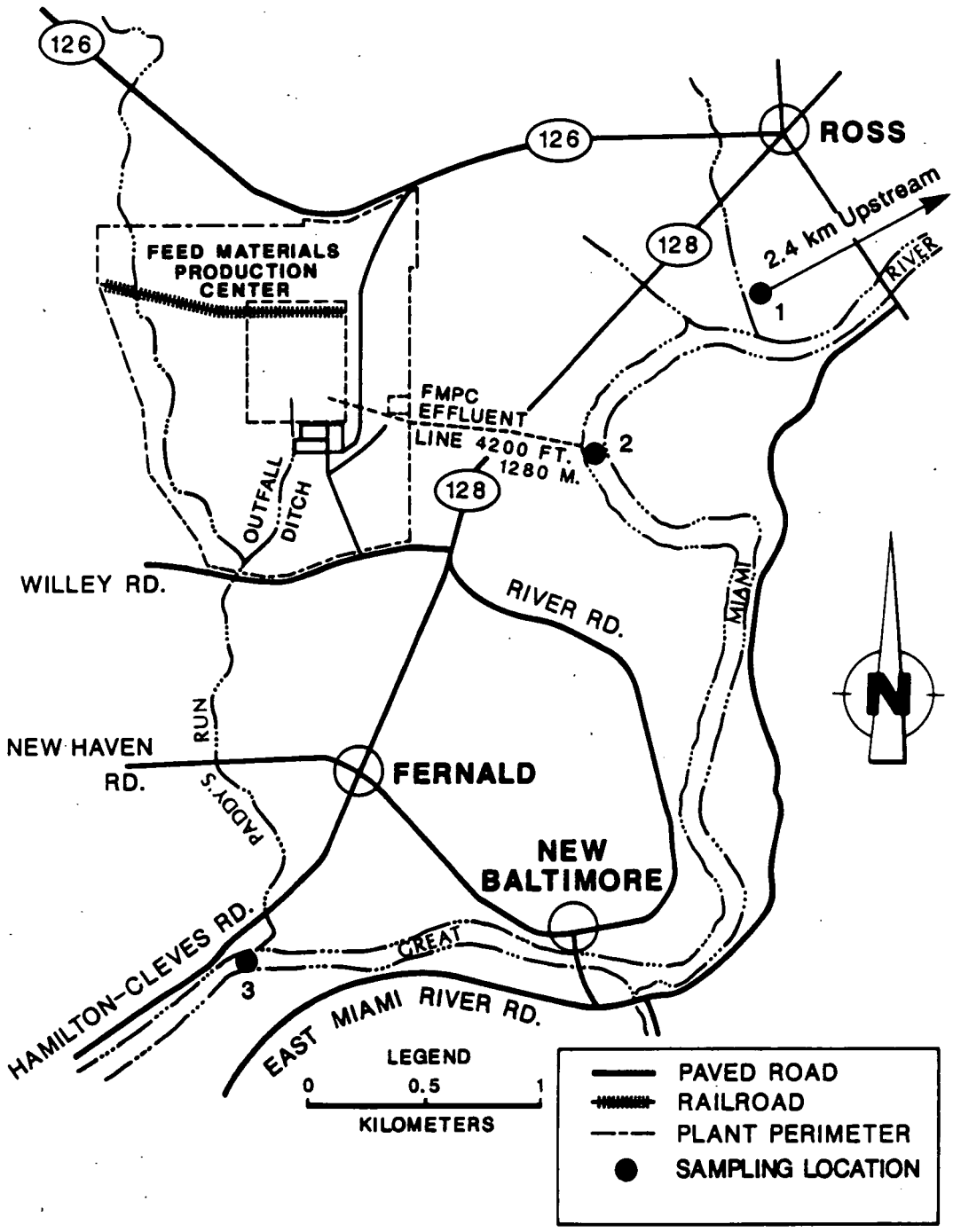

Figure 45. Fish Sampling Locations

Chapter Four
Verifying the Data

The integrity of the Environmental Monitoring Program and this report depends on the quality of the samples collected, the accuracy of the sample analyses, and the validity of data generated from the performed analysis. To ensure the integrity of all operations, the FMPC developed and maintains a comprehensive Quality Assurance Plan which meets the requirements of the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) Nuclear Quality Assurance (NQA-1) standard "Quality Assurance Program Requirements for Nuclear Facilities."[27] This standard, which is universally recognized in the nuclear energy industry, is the means of implementing a Quality Assurance (QA) program that ensures operational excellence at the FMPC. The compliance of the QA program with NQA-1 has been confirmed through a number of external audits conducted by DOE, and are discussed in this chapter.

The FMPC implements its QA plan through detailed work procedures with built-in assurance measures. To ensure that all departments of the FMPC comply with detailed procedures, the QA department continually and independently monitors their performance through a system of planned audits, surveillances, and inspections.

Environmental Sampling Quality Assurance

The FMPC maintains strict quality assurance and quality control measures to ensure that field samples accurately reflect conditions in the environment. This is accomplished through procedures which specify the identification, preservation, holding times, and control of environmental samples collected for laboratory analysis. Moreover, tamperproof tape is placed around the sample-container opening to prohibit "foul play." To ensure that the samples are not left unattended, the FMPC uses chain-of-custody controls.

As QA and QC checks, the FMPC takes duplicate samples at random for all types of environmental samples (except air, which is checked using spiked samples), and includes field and trip blanks during sampling to check sample-bottle quality and sampling and analytical procedures.

For example, the FMPC laboratory fills a sample bottle with distilled water before the sampling team leaves for the field. During sampling, this bottle - known as a field blank - is opened to the air at each sampling location. When sampling is completed, the field blank is capped until it is analyzed in the laboratory.

The laboratory also provides a trip blank, which is a bottle filled with distilled water and sealed with tamperproof tape. Like the field blank, this bottle is taken to each sampling location. However, it remains capped and sealed until all samples are analyzed in the laboratory. All samples collected during one sampling program period are analyzed at the same time.

Analytical Laboratory Quality Assurance

Quality assurance is an integral part of the FMPC analytical laboratories' operations. Laboratory QA consists of a structured program of actions taken to help ensure that reliable results are obtained when analyzing environmental samples. Laboratory QA is designed to:

- Make certain that analytical methodologies comply with USEPA protocol and methods of analysis
- Provide a means to systematically and objectively evaluate analytical performance
- Identify problems so that they can be promptly corrected
- Detect and prevent the use of questionable data.

In addition to the QA departmental overview, day-to-day surveillance of each of the laboratories onsite is conducted by an internal quality control group known as the Site Analytical Quality Assurance (SAQA) section. SAQA prepares control samples which are submitted to the laboratories for analysis along with field samples. Control samples include National Institute of Standards and Technology (formerly the National Bureau of Standards) reference materials, USEPA radionuclide solutions, compounds of precisely known purity, standardized reference solutions, duplicate field samples, and field samples to which known amounts of contaminates have been added. At least 10% of the total number of samples are control samples which are analyzed with the field samples.

SAQA evaluates the control sample results and regularly submits reports to the FMPC analytical laboratories for use in identifying potential areas of concern. If a significant problem is indicated, SAQA notifies the laboratories so that corrective actions can be initiated and suspect results for field samples can be evaluated and rejected. In addition to SAQA control samples, the individual laboratories perform daily instrument calibrations and stability checks and routinely analyze reagent blanks and standards along with the field samples.

Because of the great number of analyses required to support all the various environmental monitoring activities, the FMPC uses commercial laboratories to supplement its own analytical resources. Commercial laboratories must meet stringent requirements before being selected to provide environmental analytical services. To select the best qualified laboratory, a review of various QA specifications is conducted including personnel qualifications, analytical procedures, sample handling and preservation, data evaluation and record keeping, and requirements for precision, accuracy, and minimum detectable levels. Test samples are then sent to the candidate laboratories to evaluate their analytical capabilities. Onsite audits of the laboratories' facilities and operations are conducted by FMPC personnel before final selections are made. Upon selecting the laboratories, control samples are submitted regularly with field samples in order to continue monitoring their performance.

Comparing Results

In addition to the procedures described above, the FMPC regularly takes part in several QA programs with outside organizations. The FMPC participates in DOE's Quality Assurance Program which is conducted by its Environmental Measurements Laboratory (EML). In this program, the FMPC receives and analyzes samples of water and air and submitted results for comparison with the results obtained by EML. In making the inter-laboratory comparison, a ratio was computed by dividing the FMPC result by the EML result for each sample. If the results agreed exactly, the ratio was one. The average value of the ratios for all samples analyzed in 1988 ranged from 0.95 to 1.13 and averaged 1.06, which was less than a 10% average variation and indicated a good agreement with EML.

Laboratories which perform NPDES permit analyses are required to participate in a QA program administered by the USEPA. Since NPDES samples are analyzed in-house, FMPC laboratories are included in this program. As stipulated by the USEPA, a corresponding QA sample must be analyzed for each parameter listed in the NPDES permit. The NPDES permit parameters which are analyzed by FMPC laboratories are discussed in Chapter Three under Sampling FMPC Liquid Effluents. The USEPA evaluates the results for the QA samples only as satisfactory or unsatisfactory. All FMPC results submitted during 1988 were assessed as satisfactory by the USEPA.

Another QA practice at the FMPC is the analysis of Proficiency Environmental Testing (PET) samples. PET samples are solutions which consist of known quantities of standard anions and cations of interest to FMPC. Each month, the SAQA section submits PET samples to the various onsite laboratories which analyze them concurrently with field samples. Results obtained for the QA samples are compiled by the SAQA section and submitted for evaluation. A report is then provided to SAQA comparing the FMPC laboratories' results to the reference values for each sample and to the results obtained by other laboratories participating in the PET program. The use of this commercially-available service provides an additional resource for detecting analytical problems so that corrective actions can be initiated and errors eliminated.

To further enhance the QA Program, the FMPC continued a split sampling program with the Ohio Department of Health that began in 1987. Sampling team members from FMPC and ODH collected monthly surface water and groundwater samples, quarterly milk samples, and semiannual sediment samples. The FMPC has not received any results from ODH for the 1988 program and no comparisons can be made. If the results become available, the FMPC will publish them next year. The comparison of FMPC and ODH results in 1987 showed that the data were very similar with no significant discrepancies. Sample collection continues in 1989.

Throughout 1988, the FMPC submitted QA samples to a commercial laboratory for offsite air filter analysis. The purpose of the QA program was to assess the commercial laboratory's analytical results for air filters containing known amounts of uranium. The amounts of uranium added to the filters were in the range of results routinely reported by the laboratory and varied by a factor of ten.

Twenty-six quality control air filter samples were analyzed in 1988. One sample was excluded from the sample population because of problems encountered by the laboratory in its analysis. Analytical results from the contract laboratory demonstrated an average error of slightly more than 10% for the QA air filters. This performance was considered satisfactory for analyses at environmental levels, although last year's average error was slightly less. Figure 46 shows the ratio of contract laboratory analyses to FMPC spikes for the 25 samples included in the study. The values ranged from 0.40 to 1.60 with an average of 0.89. This QA program for air filter analyses will continue in 1989.

Data Validation, Reduction, and Reporting

Laboratory data are checked to assure that the analyses requested were performed and that the data provided appeared accurate. The data were evaluated for the following:

- Central tendency and dispersion using arithmetic mean, geometric mean, range, and standard deviation
- Precision and accuracy within and between laboratories
- 95% confidence limits for the mean.

The data were reduced to a more meaningful and easy-to-comprehend form which can be tabulated or charted. Tabular data included ranges, averages, 95% confidence limits, and percent of standard. Comparisons between years were often made to indicate long-term trends. This information was evaluated and interpreted where possible. Plant operations, remedial activities, pollution control, analytical techniques, and incidents during the year were considered in the interpretation of the data.

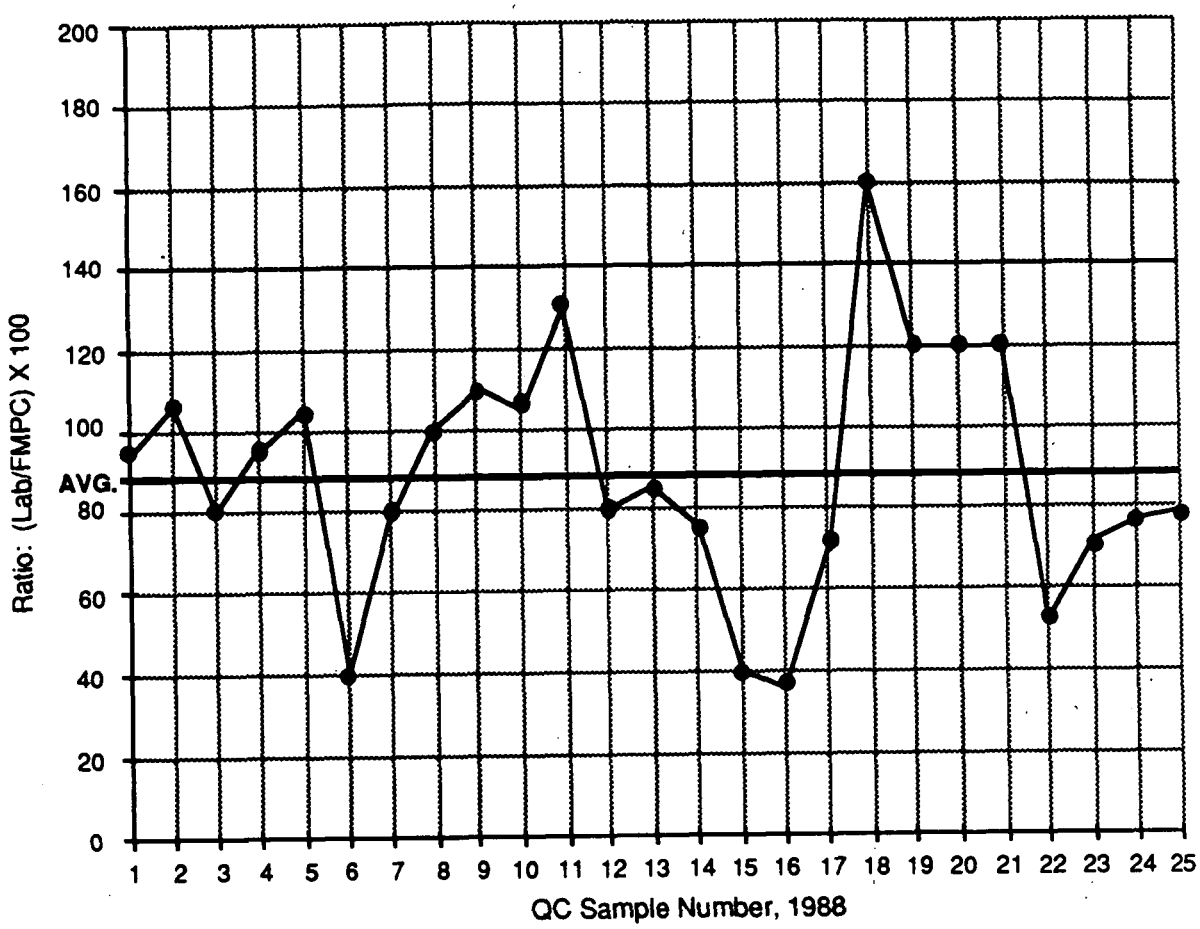

Figure 46. Air Filter Uranium Spiked Samples (QC)

Summary

The verification of data for environmental monitoring is a comprehensive program. Appropriate sampling procedures must be followed and proper analytical procedures practiced, data must be verified, validated, and presented in meaningful form, and results must be properly reported. The overall performance of the FMPC laboratories, as determined by QA audits and inter-laboratory comparisons, was of a level which ensured that reliable environmental data were reported. The next chapter describes the waste management activities at the FMPC.

Chapter Five
Waste Management Activities

As a result of production operations, the FMPC generates materials which contain substances at concentrations not economically feasible to recover. These materials, designated as wastes, are governed by federal, state, and local regulations. In order to determine the proper methods for handling and disposing of these wastes, the FMPC must determine the specific components of the wastes. This is known as characterizing the wastes and is an important and necessary part of waste management. This chapter highlights 1988 waste management activities at the FMPC, including storing, shipping, and disposing of low-level radioactive waste, conventional solid waste, and mixed hazardous waste (radioactive, hazardous waste).[28]

Examples of types of waste are listed below:

Low-level radioactive waste

- Process residues (slags, neutralized raffinates, sump sludges)
- Sediments from the Stormwater Retention Basin and the Biodenitrification Surge Lagoon
- Scrap wood (pallets)
- Construction rubble
- Scrap metal (baled drums)

Conventional industrial wastes

- Nonprocess trash
- Spent lime sludge
- Boiler Plant fly ash and water treatment sludges
- Sewage sludges

Mixed hazardous waste

- Contaminated cutting and cooling oils
- Solvent still bottoms and sludges
- Spent $BaCl_2$ salts
- PCB-containing materials
- Xylene
- Tributyl phosphate/kerosene
- Mercury-contaminated spill absorbent
- Solvents
- Materials used to clean-up spills of RCRA waste (gloves, clothing, absorbent)
- Material containing lead, such as residue from sand blasting operations.

Objective of the Solid Waste Program

The objective of the FMPC's Solid Waste Management Program is to dispose of, treat, or safely store solid wastes in compliance with all applicable regulations. This objective covers both solid waste that is currently generated and that which was generated after the waste pits were closed, but before offsite waste disposal shipments began. This latter waste is called backlog solid waste. The waste storage area is shown in Figure 47.

The FMPC's strategy for meeting this objective is as follows:

- Pursue a waste minimization program
- Dispose of as much solid waste as possible offsite
- Maintain and upgrade storage facilities for solid waste that cannot be disposed of or eliminated

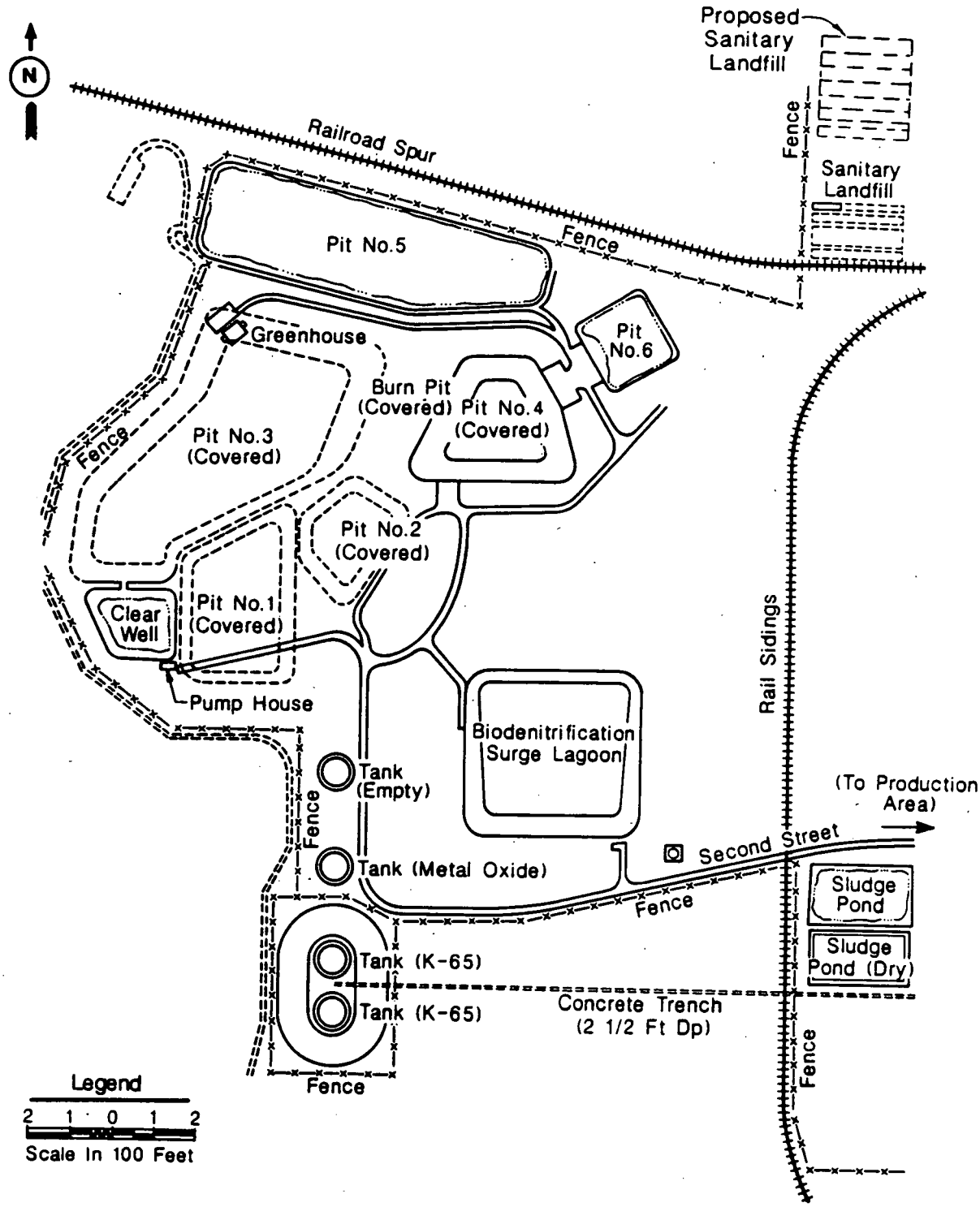

Figure 47. Map of the FMPC Waste Storage Area

- Develop and implement programs to reduce disposal costs.

Low-level Radioactive Waste Management

The FMPC production process generates the majority of the low-level waste onsite, and most of the low-level wastes are packaged and shipped offsite for disposal. The FMPC shipped a total of 9,499 m^3 (335,224 ft^3) of waste offsite in 1988, despite not making any shipments for three months due to a strike by hourly employees (October - December). This volume of waste would cover a football field to a depth of about seven feet. Specific waste shipment data for 1988 can be found in Table 29.

The largest amount of process waste is produced during the reduction of UF_4 with metallic magnesium. Most of this waste is magnesium fluoride (MgF_2). It is contaminated with uranium and uranium oxide and also contains some magnesium and magnesium oxide. The MgF_2 slag from the reduction process in Plant 5 is processed into a powder. Some of this material is reused while the remainder is packaged and prepared for offsite disposal.

The second largest process waste is generated when MgF_2 is processed to recover the uranium. The neutralized, filtered precipitate left after most of the enriched uranium is extracted (leached) from the MgF_2 is called slag leach filter cake. This filter cake, contaminated with trace amounts of uranium, is the largest component of backlog residue waste; it must be dried before it is shipped offsite.

Neutralized, filtered raffinate, the third largest process waste, is generated following extraction of uranium from refinery feed materials. Other process wastes contaminated with uranium include dust collector residues, sump sludges, uranium metal chips, and spilled uranium salts. These process residues are packaged for disposal or further processing.

Once an item used in the production process becomes contaminated with uranium, it is classified as low-level waste if it cannot be used again. These items include metal drums, wooden pallets, and trash such as rags, paper, and wood. A large inventory of crushed, baled drums has accumulated at the FMPC, and packaging and disposing of this backlogged waste is currently in progress. In addition, all of the backlogged contaminated scrap wood was shipped to an offsite contractor for processing and disposal, but FMPC is generating another pile of scrap wood. Replacement materials for wooden pallets are being investigated.

Other wastes, such as scrap metal and construction rubble (soil and building materials) are generated from the large number of ongoing renovation projects at the FMPC. Scrap metal is radiologically surveyed at the point of generation. If it is uncontaminated and potentially usable, it is stockpiled for shipment to local scrap dealers or for use elsewhere at the site. Contaminated scrap metal that cannot be used again at the site is packaged and shipped offsite for disposal.

Contaminated scrap metal that is thick-gauge and potentially usable is transported to the scrap yard on the decontamination pad and will eventually be recycled as part of DOE's scrap reclamation program. In this program, private companies will decontaminate the scrap metal and return it to the private sector.

The FMPC is also storing approximately 1,350 tons of contaminated scrap copper on a controlled pad (a concrete pad with curbs to control stormwater runoff) in the northwest part of the site. The copper scrap, consisting mostly of motor windings, was transferred to the FMPC as a result of an upgrade of other DOE facilities during the 1970's.

As a result of ongoing maintenance, renovation, and restoration activities, the FMPC has accumulated an increasing inventory of construction rubble. This was in addition to the backlog of construction rubble that exists at the FMPC. The FMPC Construction Rubble Program reviewed data to determine whether rubble was radioactively contaminated and/or contained constituents subject to RCRA regulations. Materials that were subject to RCRA regulations were managed under the requirements of that program. Other materials were managed as solid waste by the Waste Operations group.

Some of the contaminated rubble was shipped offsite, whereas construction rubble containing low-level contamination was stored onsite for use as backfill in the process area.

Significant emphasis has been placed on cleanup of sites prior to construction in an effort to reduce the quantity of contaminated construction rubble. Selected construction sites in the production area were moved to a different location if the soil at the original location contained above-background levels of uranium. For example, uranium concentrations in the soil at the original location for the Decommissioning and Decontaminating facility were above this guideline. Consequently, the location was moved to avoid generating contaminated construction rubble. The RI/FS will determine the appropriate actions for removing contaminated soil throughout the site.

Other low-level wastes included contaminated trash from the production area and sludge from the sewage treatment plant. Trash was placed in dumpsters designated for low-level wastes, which were located throughout the production area. This trash was then transported to Plant 2/3, where it was compacted into bales and packaged in nylon-reinforced plastic bags for shipment offsite. Sewage treatment sludge was concentrated in the sewage treatment plant's anaerobic digester. After drying, this material was drummed and shipped to Plant 1 for sampling before being sent to the Plant 8 for heating. Then the ash was drummed as low-level waste and shipped offsite for disposal.

To reduce the amount of material that must be treated as low-level or mixed waste, the FMPC developed a waste minimization program. This program receives priority attention because of increasing burial costs, concern over continued availability of burial space, and decreasing availability of storage space at the FMPC. Also, Westinghouse Corporate policy, the 1984 RCRA amendments, and DOE Order 5820.2A require a waste minimization program.

Wherever applicable, site policies and procedures were written so that consideration was given to the amount of waste that will be created for a particular operation. For example, one procedure implemented segregation and isolation techniques used as the waste was generated to minimize the volume of nonprocess waste that must be handled. By monitoring trash produced in offices and other contamination-free zones within the production area, the FMPC was able to send uncontaminated trash to a sanitary landfill instead of a low-level waste disposal facility, thereby significantly reducing disposal costs.

Although the FMPC minimized waste wherever possible, a revised economic discard limit (EDL) for materials containing uranium was issued in 1988 which increased the amount of material onsite designated as waste. The EDL is the amount of uranium that must be present in material to make it feasible to process the material to recover the uranium. Based upon the revised EDL, over 27,000 drum equivalents of residues once considered to contain recoverable amounts of uranium were categorized as waste.

Since the reclassified residues are chemically similar to those of the original backlog nonrecoverable residues, FMPC plans to process the residues for offsite disposal. The impact of the reclassified nonrecoverable residues on the original backlog waste reduction goal is that it will take an additional 13 months to process and ship the residues. The FMPC plans to process and ship this material by the end of 1992.

Conventional Solid Waste Management

The FMPC also generates nonradioactive wastes normally associated with a large industrial facility: boiler plant waste, nonprocess trash, and potable-water treatment sludge.

The Boiler Plant produces fly ash, sludges from boiler water treatment, and runoff from the coal pile. Fly ash is taken to the fly ash pile in the southwest corner of the site. A cover will eventually be placed over the fly ash pile to prevent water runoff and air dispersal. The boiler water sludges and coal pile runoff are currently drained to a retention pond, and from there the water goes to the General Sump for treatment. The unlined retention pond was studied as part of the plan to upgrade the Coal

Storage Facility, and this is discussed in Chapter 6.

The FMPC drinking water was treated with water softeners. The lime from this process was collected in sludge beds on the western side of the site; these beds were nearly full. Options were being studied to address this problem, as well as the overall problem of how to dispose of all types of conventional solid waste.

Managing Mixed Waste

The third major category of waste at the FMPC is mixed radioactive/hazardous waste, referred to as mixed waste. These wastes are regulated under the Resource Conservation and Recovery Act (RCRA). RCRA was passed in 1976, along with subsequent amendments in the 1980's, to address a problem of enormous magnitude - how to safely dispose of the huge volumes of municipal and hazardous waste generated nationwide. The goals set by RCRA are:

- To protect human health and the environment
- To reduce waste and conserve energy and natural resources
- To reduce or eliminate the generation of hazardous waste as expeditiously as possible.

RCRA contains three distinct, yet interrelated programs. The first program, outlined under Subtitle D of RCRA, encourages states to develop comprehensive plans to manage solid wastes. For the FMPC, solid wastes refer to those wastes disposed of at a local landfill. The second program under RCRA, Subtitle C, establishes a system for controlling hazardous waste from the time it is generated until its ultimate disposal. That is where the phrase "cradle to grave" originates. Hazardous waste may include materials such as degreasers or solvent cleaners that are used in several FMPC plant operations. The last of the three programs is outlined in Subtitle I and regulates underground storage tanks that contain petroleum or hazardous substances. The FMPC checks for leaks and maintains an inventory control system on its three in-service underground storage tanks. RCRA sets performance standards for new tanks and requires leak detection, prevention and correction at underground tank sites.

Identifying and Storing Mixed Wastes at the FMPC

The USEPA maintains lists of wastes that are designated as hazardous or exhibited characteristics of ignitibility, corrosivity, flammability, or reactivity. Of the 67 identified waste streams at the FMPC, 19 were identified as hazardous wastes and are managed according to RCRA regulations.

If new processes or modifications to existing processes generate new waste streams, they are sampled immediately to determine if they are hazardous; the FMPC reports new waste stream characterizations to OEPA and USEPA-Region V. For example, in late 1988, the FMPC sand-blasted and painted the FMPC water towers, and since the paint that was removed contained lead, a new waste stream was generated.

The FMPC stores the majority of mixed wastes in 55-gallon drums at designated locations onsite. Additional wastes are stored in two spent solvent bulk storage tanks at the Pilot Plant. The FMPC also stores mixed wastes generated at the RMI Company in Ashtabula, Ohio.

Developing RCRA Plans

The FMPC has developed two plans to establish guidelines and goals for complying with RCRA: the RCRA Implementation Plan and the Underground Storage Tank Management Plan.

The RCRA Implementation Plan defines a comprehensive program so the site can comply with RCRA and all State of Ohio solid, hazardous waste and underground storage regulations. In addition, the program involves the RCRA requirements as stated in the Federal Facility Compliance Agreement (FFCA) and the Consent Decree with the State of Ohio, and it includes ten separate sets of actions and milestones. To coordinate compliance activities, the FMPC appointed a RCRA Program Manager in January 1989.

Subtitle I of RCRA was created to prevent leaks of petroleum products and regulated substances (defined as hazardous under CERCLA) from underground tanks that could pollute the environment, especially groundwater. There are two fiberglass tanks (Tank #1 & #2) with a total capacity of 3,000 gallons that were installed in 1976 to store gasoline. The remaining eleven tanks are steel, and all but one were installed during plant construction 37 years ago. That tank was installed 26 years ago. The FMPC plans to remove all of these steel tanks from the ground. Such out-of-service tanks will be examined for previous leaks and marked for removal or closure.

RCRA Reporting Requirements

Additional RCRA compliance activities include submitting various reports for mixed wastes at the FMPC. These reports include the State Generator and the Facility Annual Report, and the Federal Generator and Facility Biennial Report. Furthermore, the FMPC is conducting the groundwater assessment for waste pit 4, a RCRA landfill. These reports are covered in the following paragraphs.

The FMPC must submit an annual Generator Hazardous Waste Report because the site generates over 1,000 kg (2,200 lb) per month of mixed waste. This includes wastes from one-time generation such as equipment decommissioning, as well as recurrent generation, such as waste from ongoing production processes.

This report compiles site-specific information concerning the destination, type, and amount of hazardous wastes sent offsite during 1988. Manifests and waste analyses are the major references used to complete this form. The FMPC did not ship any RCRA hazardous waste in 1988.

The FMPC must submit an annual Facility Hazardous Waste Report, which compiles site-specific information concerning the origin, type, amount, and management method of hazardous wastes at the FMPC during 1988. The Facility Annual Report for 1988 presented 19 waste stream designations with corresponding Department of Transportation hazard classes, USEPA identification numbers, and the amount for each waste stream.

The FMPC must prepare and submit a biennial report to the USEPA-Region V Administrator by March 1 of each even numbered year. The Biennial Report must include the following information: (1) the FMPC facility USEPA identification number; (2) the report calendar year; (3) other facilities USEPA identification number that shipped wastes to the FMPC, such as RMI Company; (4) the description and quantity of each waste that the FMPC received; (5) the method of treatment, storage, or disposal of each hazardous waste; (6) monitoring data; and (7) signed certification by the FMPC.

The annual Generator and Facility Hazardous Waste reports were submitted to fulfill the Biennial report requirements for 1987 activities.

Due to the disposal of the hazardous waste barium chloride in waste pit 4 from 1980 to 1983, the FMPC was required, under RCRA, to assess the effect of waste pit 4 on groundwater near the pit. The FMPC had to identify whether hazardous waste or hazardous waste constituents have entered the groundwater, and, if so, the rate, extent of migration and concentration of any hazardous waste or hazardous waste constituents in the groundwater. This was accomplished by conducting two major monitoring programs: first the RCRA Detection program, and, after results were analyzed, the RCRA Groundwater Quality Assessment.

To complete the first action, the FMPC conducted six rounds of groundwater sampling around waste pit 4 from August 1985 to December 1987. The location of the wells is shown in Figure 48. Comparisons of data from designated wells that are both upgradient and downgradient of waste pit 4 indicated that statistically significant changes had occurred downgradient in the indicator parameters pH, specific conductance, and total organic carbon (TOC). Data from Round 6 sampling, conducted in late 1987, are presented in Appendix B.[29]

Once the results were confirmed by additional sampling, the FMPC began the second required action in November 1987 by submitting a groundwater assessment plan to USEPA. This plan called for the assessment program to be included as part of the site-wide RI/FS investigation.

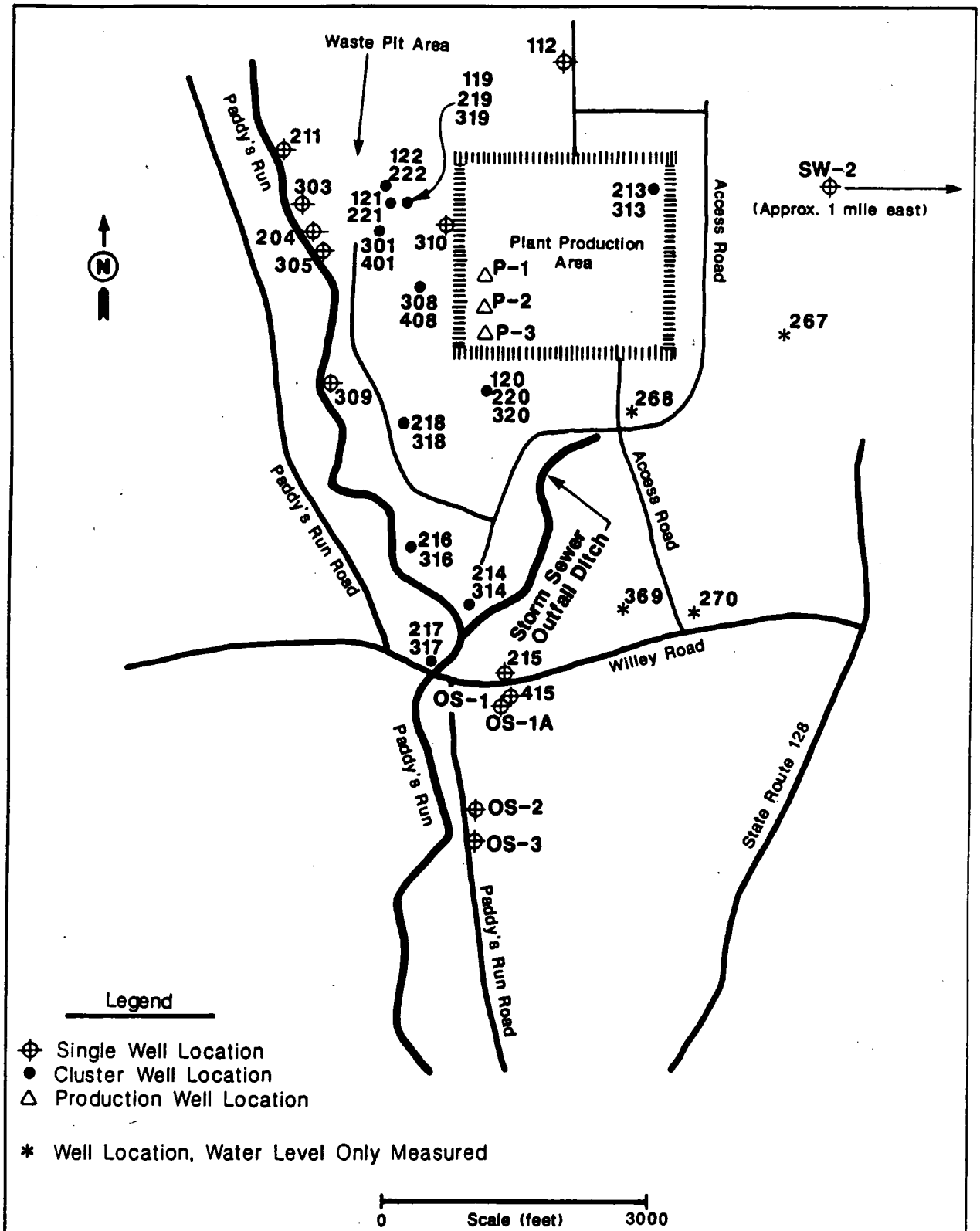

Figure 48. RCRA Well Locations

Four rounds of sampling from more than 200 wells on and offsite were completed during 1988 and the first quarter of 1989, and over 200 parameters were analyzed, including radionuclides, general water quality indicators, metals, volatile and semivolatile organics on the Hazardous Substance List (HSL), inorganics, pesticides and polychlorinated biphenyls (PCB's), primary drinking water organics, organo-phosphorus pesticides, and dioxins. This sampling has shown that the constituents of major concern in the FMPC groundwater are uranium, gross alpha, gross beta, chloride, sulfate, nitrate, dichlorinated ethylene, and total dissolved solids. This confirms results of previous sampling. Barium, the RCRA constituent of waste pit 4, was not found in concentrations above drinking water standards in the groundwater near the waste pits. In general, organic compounds were found at concentrations of less than 30 ppb.[30] These data will be available in the final RI/FS report.

The USEPA commented on the assessment plan in early 1989. As a result, the FMPC plans to narrow the scope of the plan by performing quarterly sampling of 43 wells in and around the waste pits. This will enable the FMPC to continue evaluating the effect of the waste pits on regional groundwater.

Wastes Governed by the Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) requires the FMPC to prepare annual reports concerning the status of articles containing PCB's present at the FMPC. This report addresses the number of PCB articles in service: the number removed from service, the dates of removal, storage, and offsite shipment, and methods of disposal.

At the end of 1987, 112 large, low-voltage capacitors that had been removed from service over the past several years were stored at the FMPC. In January 1988, due to the radioactive surface contamination of these capacitors, which contained PCB's, the FMPC shipped them to the TSCA incinerator at the Oak Ridge Gaseous Diffusion Plant for incineration.

Assuring Compliance with Waste Handling Procedures

All of the activities associated with the waste materials at the FMPC receive the same detailed attention to quality as do production activities. Waste is characterized, handled, packaged, and stored according to very detailed procedures, which incorporate controls to assure that the FMPC meets applicable environmental regulations as well as other requirements. Site Quality Assurance overviews all waste operations to ensure procedural compliance and effectiveness.

An independent organization certifies that waste destined for offsite disposal has been properly prepared for shipment. The certification process involves close review of all characterization data and other paperwork supporting shipment, a visual verification of package and vehicle integrity, and observing the loading of waste packages into the vehicles to assure the containers are not damaged. These activities were placed in the Quality Assurance organization during 1988 to further strengthen the groups overview role.

Summary of Waste Management Activities

The FMPC continues to make significant progress in reducing the amount of waste stored onsite. The amount of backlog waste has been reduced by more than 40% since October 1986, and a waste minimization program is now in place. In addition, the FMPC has renewed its emphasis on complying with RCRA waste regulations. These actions have significantly reduced the potential for environmental problems related to waste management activities.

The FMPC has been making significant improvements in several additional areas, and this progress is described in the following chapter.

Chapter Six
Special Studies and Significant Events

In addition to the ongoing data collection and analysis performed as part of the environmental monitoring program at the FMPC, several additional studies were initiated or completed during 1988. The FMPC responded to spills and releases of radioactive materials, called unusual events. These additional studies and unusual events are discussed in this chapter. They include:

- Remedial Investigation and Feasibility Study and related projects
- Water compliance activities
- Air compliance activities
- Additional studies and improvements
- Unusual events such as spills or releases of radioactive materials.

Remedial Investigation and Feasibility Study and Related Projects

A comprehensive environmental study entitled the Remedial Investigation and Feasibility Study (RI/FS) is underway at the FMPC. The study is being completed for DOE in cooperative agreement with USEPA and OEPA.

The RI/FS, which began in July 1986, is investigating the nature and extent of potential environmental impacts from past and current operations at the FMPC. Based upon the results of this investigation, the RI/FS will then develop and evaluate engineering alternatives to mitigate the identified environmental concerns.

RI/FS: A Brief Definition

A RI/FS is a comprehensive, environmental investigation conducted in a systematic fashion according to strict federal regulations and guidelines. The RI/FS is broken into two distinct, yet inseparable phases: the Remedial Investigation (RI) and the Feasibility Study (FS). During the remedial investigation phase, a broad-based study is completed to evaluate existing environmental and public health risks associated with past or existing facility operations. These risks are then compared against existing regulatory standards and guidelines to identify potential environmental problems and concerns that must be considered for corrective actions.

The Feasibility Study phase of the RI/FS process develops and evaluates corrective action alternatives to mitigate identified environmental concerns. The Feasibility Study recommends one or more final remedial action alternatives for consideration by the USEPA in its final selection process. Following selection of the alternatives, an approved Record of Decision by USEPA will be issued by DOE, formally documenting the decision process.

The RI: Identifying Problems

DOE has contracted with an independent environmental firm to conduct the RI/FS. To accomplish Remedial Investigation objectives, the following programs were developed to systematically investigate broad environmental concerns:

- Groundwater Monitoring
- Radiation Measurements
- Surface Water and Sediment Sampling
- Surface Soil Sampling
- Biological Resources Sampling Program
- Facilities Testing Program (Remedial Investigation Addendum Work Plan).

Groundwater Monitoring. In order to refine the current level of understanding on the geologic conditions present in the vicinity of the FMPC and to investigate potential impacts of the facility on regional groundwater quality, the FMPC has installed more than 110 wells, both onsite and offsite, as part of the RI/FS. As part of the RI/FS groundwater monitoring program, these new wells along with over 90 existing wells are being sampled on a quarterly basis and analyzed for a full series of radiological and general water quality parameters. The FMPC has received the results from two quarterly rounds of groundwater quality samples as of December 31, 1988.

Data to date confirm the presence of two isolated areas of above-background concentrations of uranium in groundwater. One area is located directly beneath the FMPC Waste Storage Area and the second is to the south of the FMPC. One component of groundwater is directed east from the Waste Storage Area toward the production area. No elevated concentrations of uranium have been detected offsite to the east of the FMPC. The above-background concentrations of uranium present in the groundwater beneath the Waste Storage Area present no near term threat to onsite or offsite populations.

The above-background concentrations of uranium in groundwater to the south of the FMPC are confined to an area at the south boundary of the facility extending approximately 2,500 feet offsite. Groundwater flow at this location is directly to the south along an ancient buried stream bed. Sampling results indicate the above-background concentrations are limited to three private offsite wells. These wells are not used for drinking water. Focused groundwater investigations will continue in this area during 1989 to provide needed information to support ongoing groundwater modeling and feasibility study activities.

Radiation Measurements Programs. The RI/FS Radiation Measurements Program focuses on characterizing surface radiation fields within the FMPC. Radiation measurements were collected along one hundred foot rectangular grids across the facility and are used to locate and quantify radioactive materials on the ground. The RI/FS Radiation Measurements Program was completed during 1988 with the survey of over seven hundred grids. This data are currently being compiled for use in the RI risk assessment process.

Surface Water and Sediment Sampling. The purpose of the RI/FS Surface Water and Sediment Sampling Program is to characterize the radiological and hazardous chemical constituents in the water and sediments in areas where water collects on the ground at the FMPC, and within Paddy's Run and the Great Miami River. During 1988, approximately 60 surface water and 100 sediment samples were collected from drainage areas on the FMPC and from the Great Miami River. As a result of drought conditions within Southwestern Ohio during 1988, sediment and surface water samples were not collected from Paddy's Run. These samples will be collected in 1989, weather permitting. Analytical results from Great Miami River samples were consistent with similar samples collected under the FMPC Environmental Monitoring Program, and in general, indicated no significant or prevalent above-background concentrations of radionuclides in either the

surface water or sediments in the Great Miami River.

Surface Soil Sampling Program. The purpose of the RI/FS Surface Soil Sampling Program is to determine the effect that FMPC operations may have had on near surface soils on and adjacent to the FMPC. The RI/FS Surface Soil Sampling Program was completed during 1988 with the collection of over 1,000 samples. The samples are currently undergoing laboratory analysis with results anticipated in the first half of 1989.

Biological Resources Sampling Program. The purpose of the RI/FS Biological Resources Sampling Program is to determine if significant uptake of radiological or hazardous substance has occurred in local plant and animal life. The Biological Sampling Program was completed during 1988 with the collection of over 250 samples of onsite and offsite vegetation, local garden produce and agricultural products, small mammals and fish and benthic (bottom dwelling) microinvertebrates from Paddy's Run and the Great Miami River. These samples were analyzed for radiological and hazardous substances. The FMPC expects analytical results from these samples in the first half of 1989.

Facilities Testing Program (Remedial Investigation Addendum Work Plan). The purpose of the RI/FS Facilities Testing Program is to determine the nature and extent of any hazardous or radiological constituents that exist in an uncontrolled state within the FMPC production area. The Facilities Testing Program will also study facilities or areas suspected of past disposal operations or releases of hazardous or radiological constituents to the environment. A Facilities Testing Plan was submitted to the USEPA for review and concurrence on November 18, 1988. In an attempt to expedite facilities testing activities, limited sampling activities began near Plant 6 in November 1988. Preliminary results of these samples indicate the presence of above-background concentrations of uranium in an isolated perched water zone in the glacial till in the vicinity of Plant 6. This is discussed in detail later in this chapter. Sampling in this area will continue during 1989 to determine the extent of these above-background concentrations and also to examine other areas within the FMPC production area.

These activities are described in detail in the FMPC RI/FS Work Plan, approved by both the USEPA and DOE. The Work Plan is available for public review in reading rooms at the FMPC Administration Building and the Lane Public Library in Hamilton, Ohio.

The FS: Developing Solutions

The FMPC Feasibility Study, which is also underway, will develop, screen, and provide preliminary analyses of available alternatives. These results will support the in-depth evaluation of alternatives and selection of a proposed plan for remediation.

In an attempt to accelerate the RI/FS process and provide focus on high priority FMPC and community concerns, the Feasibility Study has been segmented into six operable units. These operable units, as identified below, comprise all currently identified environmental concerns at the FMPC. The feasibility study process for Operable Unit No. 4 (K-65 Silos and Silo 3) and Operable Unit No. 6 (South Plume) began in 1988.

- Operable Unit No. 1 - Waste Storage Area including the six waste pits.
- Operable Unit No. 2 - Solid Waste Units including the sanitary landfill, lime sludge ponds and fly ash piles.
- Operable Unit No. 3 - Facilities and Suspect Areas including FMPC Production area.
- Operable Unit No. 4 - Special Facilities including K-65 Silos and Silo 3.
- Operable Unit No. 5 - Environmental Media including regional groundwater and soils.
- Operable Unit No. 6 - The South Plume.

The final Feasibility Study reports will evaluate a number of remedial action alternatives and recommend preferred alternatives based on the defined criteria. The USEPA will propose preferred alternatives and invite public comment on the Feasibility Study reports and the recommended alternatives. After state and community comments are received and studied, the USEPA will select the remediation activities for the FMPC and a Record of Decision will be written for each operable unit.

Stabilizing the K-65 Silos

An agreement between DOE and USEPA requires the FMPC to take action to stabilize the two K-65 waste storage silos located in the waste storage area. This work is being performed as Operable Unit No. 4 of the RI/FS.

The K-65 Silos are concrete storage structures containing radioactive radium-bearing residues from past DOE refinery operations. The K-65 Silos contain approximately 8,800 MT (9,700 t) of waste residues from the Manhattan Project, the World War II program that produced the first atomic weapons. For this work, the United States imported a radium-rich uranium ore called pitchblende from the Belgian Congo. Following processing of the ore, the residual waste materials were stored at the FMPC in two silos, known as the K-65 Silos. These residues produce radon, a radioactive gas. The radioactivity levels of the residues are approximately the same as tailings from uranium mining and milling.

The agreement with USEPA requires the FMPC to address four specific items in connection with the K-65 Silos. These are:

- Provide interim control to ensure the structural integrity of the K-65 Silos
- Provide interim control over radioactive emissions
- Implement a radon and radon decay product monitoring program for the fence line and offsite environs
- Maintain an effective emergency response capability in the event of an unplanned release from the silos.

To comply with this agreement, the FMPC completed a number of actions, which are listed below. The completion date or current status for each item is listed parenthetically.

- Installed protective dome caps over the center 9.1 m (30 ft) diameter of the K-65 Silo domes. (January 1986)
- Applied rigid insulating polyurethane foam layer over the exterior surface of the K-65 Silo domes. (December 1987)
- Installed tower-mounted closed circuit TV cameras for continuous remote surveillance of the K-65 Silos. (August 1987)
- Videotaped the interior of the K-65 Silos showing dome underside in better condition than anticipated. (June 1988)
- Monitored the interior pressure of the K-65 Silos. (Four occasions during May and June 1988)
- Established radon monitoring program at the FMPC site boundary, K-65 Silo exclusion fence, and offsite environs. (Ongoing)
- Constructed and operated a radon treatment system to reduce radon levels in the silos using radon/charcoal absorption techniques. (Eleven occasions during November 1987 - six at silo 1, and five at silo 2)
- Issued the FMPC Emergency Plan (FMPC-2046) which provides a detailed emergency response procedure in the event of an unplanned release from the K-65 Silos. (February 1988)
- Conducted an experiment to test the practicality of a particular type of sampling system. (October 1988).

Stabilizing the K-65 Silos includes near-term activities in response to USEPA requirements as well as the final remediation of the concrete silos and adjacent and underlying soils. The final remediation actions for the K-65 Silos are being addressed as part of the sitewide RI/FS. The actions to be taken will be approved by the USEPA in the Record of Decision on Operable Unit #4 following completion of the RI/FS.

Managing Thorium at the FMPC

Since the early 1970's, the FMPC has served as the federal government's storage site for thorium, a naturally occurring, radioactive element. Even prior to its designation as the federal repository, the FMPC studied possible uses for thorium, and had processed the material for use at other government facilities. All thorium processing at the FMPC ceased in 1979. In 1988, there were approximately 1,100 MT (1,200 t) of thorium stored in a silo, bins, and steel drums and other containers on the plant

site. About two-thirds of this material was processed onsite, with the remaining portion delivered from other DOE facilities.

Thorium-232, the predominant isotope of naturally-occurring thorium, initiates a decay chain in which thoron is produced. Thoron decay produces high-energy gamma rays, and this radiation presents a potential hazard.

The FMPC has carefully managed the thorium to reduce the potential radiation hazard to employees, local residents and the environment. For example, everyone entering thorium storage areas must obtain a radiation work permit which lists the specific safety requirements and additional guidelines that must be observed while in the area. Currently, the FMPC is taking steps to improve its thorium storage capabilities until a final decision is made by the government on the final storage location of the thorium materials.

Current Thorium Storage Areas. The thorium stored at the FMPC consists of various materials, principally thorium oxides (generally a fine powder), processing residues in a variety of forms, and a small quantity of thorium metal. The Plant 8 silo and bins had contained about 175 MT (190 t) of bulk thorium oxide materials, plus inert materials like diatomaceous earth. A small quantity of thorium nitrate solution (9 MT [9.9 t]) is stored as thorium in Pilot Plant Tank 2. The majority of the remaining thorium inventory, approximately 13,300 containers (containers vary in size from 55 gallon drums to drums as small as one gallon), has been stored in warehouses (Buildings 64, 65, 67, and 68 in Figure 1), while 241 containers of thorium have been stored outdoors on concrete pads.

Improving Thorium Storage Areas. The FMPC has developed a comprehensive three-project plan for improving the interim storage conditions for the thorium inventory. All of the thorium materials will be identified, inventoried, and repackaged.

The first project addresses the bulk thorium materials in the Plant 8 silo and bins. In September 1987, the FMPC began the design and construction of the handling system necessary to remove and package the bulk thorium materials. Following construction, the removing, handling, and packaging of thorium began in November 1988. As the bulk materials were removed from the silo and bins, they were placed in double-containment drums called overpacks (a 48-gallon drum is packaged inside a 55-gallon drum), inventoried and monitored. The drums were then stored in a new onsite warehouse. This project was completed in March 1989. The silo and bins are to be decontaminated and demolished.

As part of the second project, the design of a remote system for handling, identifying, and overpacking the thorium drums and containers stored in warehouses and outdoors was completed during 1988. Purchase of the overpacking equipment began in early 1989. The FMPC will first overpack the 241 containers of thorium materials currently in outside storage. Each container will be inventoried, weighed, and scanned to determine the percentage of thorium it contains, then placed in interim storage at the FMPC. When this work is completed, the third project, the overpacking of warehoused thorium materials, will begin.

As a result of completing these projects, the FMPC will significantly reduce the potential for any accidental release of thorium through a structural failure or a deteriorating container. The new facilities and overpacked containers will also protect the thorium materials from the weather, and greatly reduce the possibility of any thorium being released to the environment. By removing all thorium material from the production area and storing it in locations further away from daily operations, any possible exposure to employees who work in the production area will be kept to a minimum.

New Decontamination and Decommissioning Facility

The existing Decontamination and Decommissioning (D&D) Facility (Building 69 on site map, Figure 1) does not have the capacity to support current and projected requirements for decontaminating materials at the FMPC. Many pieces of equipment can be decontaminated and reused, thus reducing the amount of low-level waste onsite. These include maintenance items, furnace pots used in the production process,

T-hoppers used to transport production materials, and scrap metal.

To increase decontamination capacity and to improve the FMPC's contamination control program, a new D&D Facility was planned for the northeastern section of the production area, approximately 61 m (200 ft) east of the existing D&D building. The FMPC intended to treat this as a "clean" construction project. As discussed in Chapter 5, this meant that if uranium concentrations in the soil were at or below background levels, the construction workers would not have to wear dosimeter badges, change clothes at the beginning of the day, or shower and change clothes at the end of the day for radiological purposes.

However, when preliminary site construction activities began in February 1988, soil sampling and radiation surveys revealed areas of elevated uranium concentrations in the soil. To make the area a clean construction site, 46 cm (18 in) of soil would need to be removed.

In an attempt to avoid the substantial effort and cost involved in removing the soil, an alternate site 91 m (300 ft) to the south was sampled and analyzed. This location was found to be suitable, and the new D&D facility will proceed as a clean construction project at the alternate site.

The soil at the original location for the D&D Facility will be cleaned according to the Record of Decision for the appropriate Operable Unit.

Perched Water Zone Under Plant 6

As discussed in the RI/FS section earlier in this chapter, the FMPC is trying to determine the extent of what is thought to be a contaminated perched water zone that was discovered in July 1988, during the excavation phase of a construction project inside Plant 6. A perched water zone is an area of water trapped in the upper till layer and is separated from the water table aquifer by a layer of impervious clay. As excavation progressed in Plant 6, water began entering the base of the pit. The water was pumped out and treated in the Plant 6 water treatment system. Analysis of the water indicated elevated levels of uranium and nitrates. The source of this contaminated water is believed to be a uranium-metal pickling process that uses nitric acid. This pickling process is located next to the excavation.

In an effort to eliminate the water and allow construction to proceed, a 30 cm (12 in) diameter hole was cut, about 1.8 m (6 ft) below the depth of the excavation, through the side wall of an adjacent concrete pit. In the concrete pit was a large holding tank that was no longer in use, plus piping and two sump pumps. The hole allowed the water to drain from the excavated pit into the concrete pit. From there, it was again pumped through the Plant 6 water treatment system. Consequently, the excavation pit dried up, and construction proceeded.

The FMPC will continue to investigate this situation as part of Operable Unit 3 of the RI/FS. Plans are being made to drill borings in and around Plant 6 to determine the boundaries of the perched water zone, and to process any contaminated water found through the Plant 6 water treatment system.

Covering Waste Pit 4

In past operations, the FMPC disposed of production-generated waste in waste disposal pits. As a result, the FMPC has six waste disposal pits which contain such wastes as uranium, thorium, construction rubble, fly ash, and various other wastes unique to the FMPC. None of the waste disposal pits is currently operating for the disposal of waste, and all six pits are being investigated as part of Operable Unit No. 1 of the RI/FS.

Waste pit 4 is unique among the six pits in that it contains an amount of material classified as mixed waste under RCRA. Waste pit 4 has therefore been designated as a hazardous waste landfill. For this reason, the USEPA requested that DOE consider an interim closure of pit 4 to prevent infiltration by surface water which could leak hazardous material into groundwater.

In response, the FMPC cleared the pit surface of organic material, placed a subgrade fill on top of the existing pit surface to form a domed cap over the pit, and then covered the cap with two feet

of clay, compacted to 10^{-7} cm/s permeability. During 1989, the FMPC will complete the interim closure by installing a waterproof flexible membrane liner over the clay. The Groundwater Assessment Program to monitor for any contamination resulting from pit 4 was described in Chapter 5.

Water Compliance Activities

Several significant events and special studies were performed in 1988 to support water compliance activities, including:

- Best Management Practices Plan
- A Study of FMPC discharge to the Great Miami River
- Investigation of the Coal Storage Facility
- Status of water permits
- Water improvement projects.

Best Management Practices Plan

The FMPC submitted a Best Management Practices (BMP) Plan to OEPA in February 1988 to protect the surface waters surrounding the FMPC from any significant release of toxic or hazardous substances. Some of the "best management practices" presented in the plan include:

- A hazardous materials inventory
- A spill risk assessment
- Spill reporting and record-keeping procedures
- Material storage and compatibility requirements, good housekeeping practices, spill prevention, preventative maintenance and inspection, and security practices.

By observing these practices, FMPC employees will reduce the likelihood of a spill, and will know how to respond quickly if a spill does occur.

To facilitate the implementation of the BMP plan, an action plan was prepared that includes such items as training for appropriate employees in BMP procedures, developing a site spill procedure, and stormwater runoff control practices. Seven of the 34 items in the plan were completed by the end of December 1988; the remainder will be completed during 1989 and the first half of 1990. The FMPC BMP Plan was approved by OEPA in October 1988.

A Study of FMPC Effluent Discharge to the Great Miami River

The FMPC effluent, which includes all process wastewater, sanitary wastewater, and stormwater (via the SWRB), is discharged from the FMPC at Manhole-175. This effluent flows through a buried pipeline, 1,280 m (4,200 ft) long, to the Great Miami River. Under terms of the agreement with the state, the FMPC examined the environmental impact associated with the FMPC effluent line (Figure 49). In the investigation, the FMPC was to:

- Determine whether the FMPC discharge to the Great Miami River is located within the zone of influence of any major water production well field, and to qualitatively and quantitatively determine any associated environmental impact
- Locate any leaks or holes in the FMPC effluent line, and stop any leaks identified in the line as soon as possible
- Evaluate the gravel fill around the effluent line to determine if the fill is or has served as a conduit for sewage, industrial waste, or other wastes to the Great Miami Buried Valley Aquifer.

As part of the investigation, the FMPC conducted a hydrogeologic study of FMPC discharge to the Great Miami River. The study included such tasks as collecting and analyzing available information on the hydrologic and hydrogeologic environment in the vicinity of the FMPC outfall, river bed sediment and groundwater sampling, and piezometric (aquifer water level elevation) mapping. The final report of this investigation concluded that there was no observable impact of the pipeline effluent on the quality of water drawn from the Great Miami River Buried Valley Aquifer.[31]

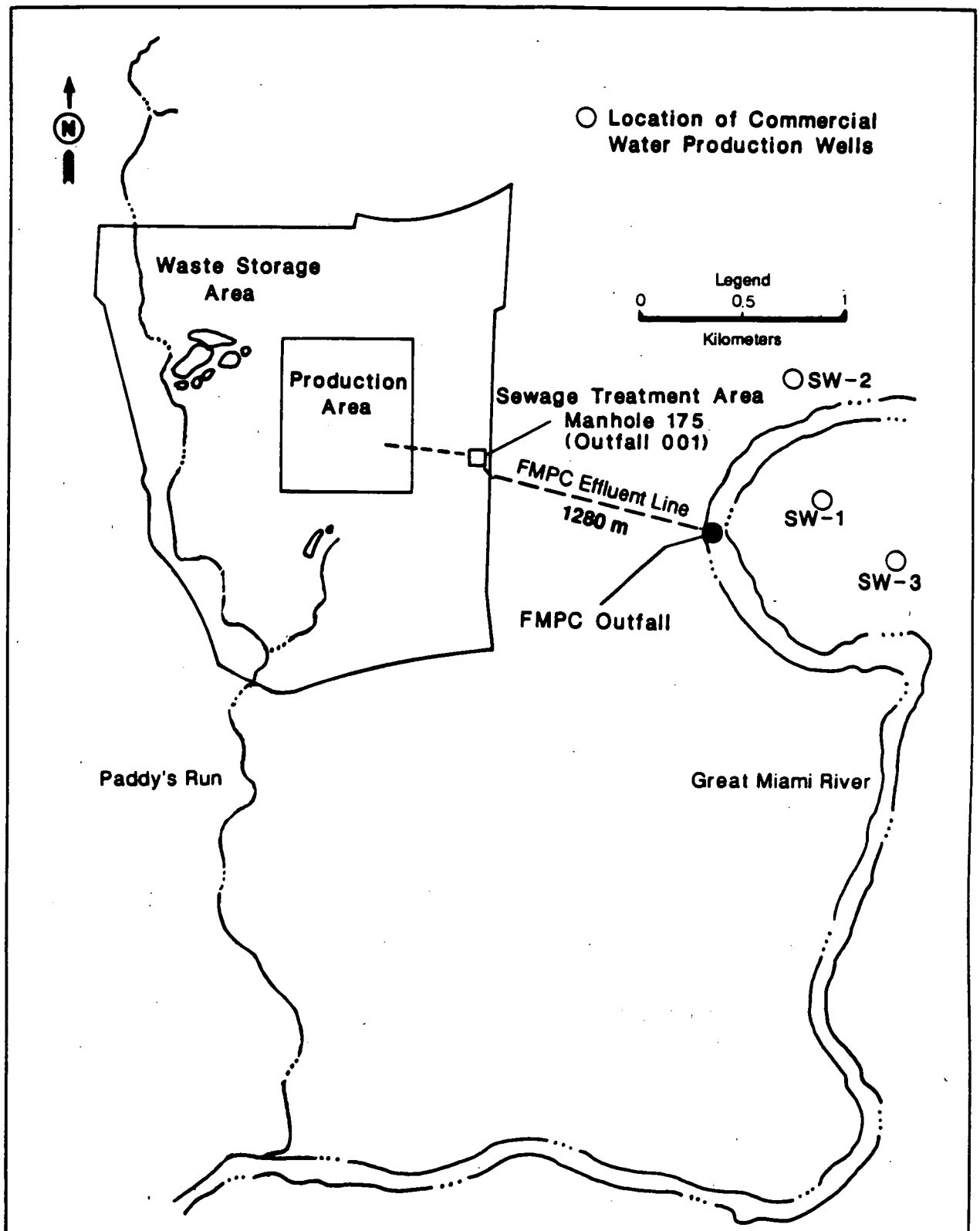

Figure 49. FMPC Discharge to the Great Miami River Study Area

The FMPC completed a video inspection of the interior of nearly the outfall pipeline in 1987. No leaks or cracks were detected during this video inspection. The FMPC will drill 10 borings along the section of pipeline that could not be inspected using the camera. The analysis of the soil borings will enable the FMPC to determine if that section of the pipeline has been leaking. In addition, a flow test also is planned to determine if a change in flow rate can be measured between several points in the pipeline. If there is a measurable drop in flow rate at successive points in the pipeline, then a leak exists. The equipment to measure these flow rates was ordered in December 1988, and the testing should be completed in 1989. The gravel fill around the pipeline will be examined after the flow rate in the pipeline is measured.

The Coal Storage Facility

To comply with the Consent Decree, the FMPC conducted a subsurface investigation of the coal storage facility and its runoff collection basin in July 1988. The purpose of this investigation was to determine the permeability of the soils underlying the area and to determine if any leaching of acidic runoff had occurred. The subsurface investigation included six soil borings, four under the coal storage area and two adjacent to the runoff collection basin. These borings were logged, sampled, classified, and analyzed for soil pH and permeability. Test results showed no evidence of acidic leaching; the existing permeabilities satisfied the requirements set forth in the Consent Decree.

Based on these results, the OEPA has agreed that a liner will not be required beneath the coal storage area, and that a liner will not be required beneath the runoff collection basin provided that the FMPC performs groundwater monitoring close to the basin.

Status of Water Permits

During 1988, the FMPC submitted applications for four wastewater Permits to Install (PTI's) for planned wastewater treatment facilities; OEPA issued three PTI's: the Tank Farm Padwater Collection and Neutralization Sump; the General Sump/Lime Handling System; and the Decontamination & Decommissioning Facility. Actions on the fourth PTI application for pH Control at Manhole-175 were pending at year's end. Actions on the NPDES permit renewal application have been addressed previously in Chapter 3.

Water Improvement Projects

Progress was made on several water improvement projects during 1988. The following principal projects are discussed in the following paragraphs:

- Expanding the Stormwater Retention Basin (SWRB)
- Upgrading the Biodenitrification Surge Lagoon
- Upgrading effluent sampling and monitoring capabilities.

The Stormwater Retention Basin is designed to retain and settle the solids present in stormwater runoff from the site before the stormwater is discharged to the Great Miami River via Manhole-175. By capturing stormwater runoff and controlling its discharge to the river, the SWRB prevents uranium-bearing materials and other solids from entering Paddy's Run.

During 1988 the capacity of the SWRB was expanded to approximately 42,000,000 liters (11 million gallons), which is sufficient to hold the volume of runoff water produced by a 10-year, 24-hour storm event. A 10-year, 24-hour storm event is defined as a 10.4 cm (4.1 in) rainfall at the FMPC in a 24-hour period that has a ten percent chance of occurring in any one year. A rainfall of this magnitude for the FMPC process area, administration area and adjacent parking lots amounts to an estimated 38,600,000 liters (10.2 million gallons) of stormwater. The construction for the expansion began in April 1988 and the expanded SWRB was placed in service on December 28, 1988. This project satisfied a directive established as part of the Consent Decree with the State of Ohio.

The expanded SWRB should significantly reduce the amount of uranium discharged to Paddy's Run compared to years before the SWRB was in

operation. This, in turn, should reduce contamination reaching the aquifer beneath the FMPC.

Biodenitrification Surge Lagoon (BSL) provides for solids settling of production wastewater and stormwater runoff from the waste pit area before processing in the Biodenitrification Facility (BDN). The BSL, which has a capacity of approximately 30,600,000 liters (8.1 million gallons), also facilitates the control of flowrate into the BDN (Facility 18D in Figure 1).

During 1988, the BSL was upgraded by installing a second flexible membrane liner and leak detection and collection system. This provided a three-layer liner system to protect the environment. The installation of the BSL satisfied a directive established as part of the Consent Decree with the State of Ohio.

Upgrading Effluent Monitoring Capabilities. During 1988, the FMPC began an upgrade of the environmental instruments used to provide data for flows and samples of the effluent to the Great Miami River. All of the effluent generated at the FMPC, including stormwater runoff, is monitored for flow at Manhole-175 and sampled prior to release to the river. This monitoring point consisted of an aging building, sampling and analytical instruments.

Discharge flows from various points that feed to Manhole-175 are also measured. These locations include the SWRB, Manhole-34, and the Sewage Treatment Plant. Due to the age and the physical condition of these instruments, their accuracy is limited and it has been difficult to maintain them. By upgrading the monitoring capabilities, the FMPC can obtain a more accurate measurement of flows discharged from the site.

The upgrading project also includes replacing the old samplers with composite flow proportional type samplers. A new building has been constructed at Manhole-175 to house the new analytical and flow instrumentation and sampling equipment. In addition, the new instrumentation installed at the Sewage Treatment Plant, Manhole-34, and the SWRB make it possible to continuously monitor the suspended solids in the FMPC stormwater runoff and to better control the discharge so that the quantity of solids released to the river is reduced.

These improvements in the sampling program enhance the capability of the FMPC to characterize its surface water runoff, and to better protect the groundwater and surface water surrounding the site from pollutants originating there.

Air Compliance Activities

The following is an update on significant events or special studies which were performed or initiated in 1988 as part of the FMPC Air Compliance efforts:

- Stack sampling to support the Federal Facility Compliance Agreement (FFCA)
- Meteorological monitoring system
- National Oceanic and Atmospheric Administration (NOAA) meteorological tests
- Status of air permits.

Stack Sampling and Testing

During 1988, ten stacks at the FMPC were tested to satisfy the Clean Air Act Section of the FFCA. Results of the testing have been incorporated into the source terms listed in Table 2. Particulate emissions from all the stacks tested during 1988 complied with OEPA regulations.

These tests are a way to compare the results of the sampling method commonly used at the FMPC (single point) with the isokinetic Method 5 test specified by USEPA. The Method 5 test consists of sampling effluent air discharged from the stacks for particulate content which, in turn, is analyzed for radionuclide content. The Method 5 test is considered to be a more representative and accurate way of estimating emissions.

In April 1988, the FMPC performed sampling tests on the wet scrubbers in Plant 8, the Scrap Recovery Plant. This testing not only satisfied the FFCA requirements in part, but also provided the basis for updating emission factors that had been calculated and used since the early 1980's

for the Rotary Kiln, oxidation furnace #1, and the box furnace. The primary calciner, for which no emission factor had previously been available, also was tested.

For these tests, the FMPC modified the standard USEPA Method 5 stack sampling equipment to provide long-duration sampling capabilities for wet exhaust streams. These modifications have made it possible to establish significant databases for emissions resulting from several wet exhaust processes. These capabilities have been used to track the emissions of uranium.

Meteorological Monitoring System

The FMPC installed an onsite meteorological monitoring system in August 1986. The system includes a meteorological tower, monitoring instruments, a data logger, and a computer. The tower instruments measure wind speed and direction, ambient air temperature, lapse rate (a measure of atmospheric stability), dewpoint temperature, relative humidity, barometric pressure, sigma theta (the standard deviation of horizontal wind direction over time and also a measure of atmospheric stability), and precipitation.

Before the tower was installed, and at times when the onsite meteorological system was not operating, the FMPC obtained its meteorological data from the Greater Cincinnati International Airport. The onsite system enables the FMPC, and in particular the Emergency Operations Center, to use site-specific meteorological data, thus improving the accuracy of computer models used to estimate the doses from routine releases as well as doses from an accidental release at the FMPC. The data were also used by the AIRDOS computer code in calculating the dose to the population as described in Chapter 2.

The meteorological monitoring system operated satisfactorily for 330 days during 1988. Lightning disrupted operation of the tower on three separate occasions: April 3 to April 21, July 30 to August 8, and October 17 to October 27. The FMPC installed additional surge protection devices in August to help eliminate downtime.

NOAA Meteorological Tests

In October and November 1987, the National Oceanic and Atmospheric Administration conducted a study of meteorological conditions in the vicinity of the FMPC. The purpose of the month-long study was to examine the complexity of the local wind field at the FMPC, and to determine an appropriate level of meteorological monitoring for the region. The study included installing 12 temporary meteorological towers onsite and offsite within a three-mile radius of the site. Temperature, relative humidity, precipitation, solar radiation, and wind speed and direction measurements were taken. Additional measurements were taken onsite to obtain wind profiles to a height of about 1,000 m (3,280 ft).

Based on the data collected during the study, NOAA concluded that the Great Miami River valley and the ridges surrounding the site significantly affect the flow of wind over and near the site. Therefore, under certain meteorological conditions, additional monitoring data should be considered in the atmospheric dispersion model used to simulate the transport and dispersion of pollutants and toxic chemicals in the atmosphere.

To accomplish this, the NOAA report recommended that the FMPC install a six-station network of meteorological stations, with four or five of the stations located offsite, to better reflect the local wind field. However, since the AHF, NH_3, and UF_6 inventories have been removed from the site, the additional towers recommended for the emergency preparedness program would not be warranted under these circumstances. If those chemicals are brought back onsite, the FMPC will again consider installing the additional towers.[32]

Status of Air Permits

Under provisions of the Ohio Administrative Code and to comply with the Clean Air Act, the FMPC must apply for permits to install and to operate equipment that are sources of emissions to the atmosphere. In 1988, the FMPC submitted 32 PTI's and 162 PTO's applications to OEPA for their review and approval. The applications

consist of responses to questions on emissions, process, and control equipment for each source to demonstrate that the FMPC complies with regulations.

Additional Studies and Environmental Improvements at the FMPC

The following section covers a variety of topics, including the status of National Environmental Policy Act (NEPA) documentation at the FMPC, significant improvements and changes in how production chemicals are stored at the site and in what quantities, how the FMPC is prepared to handle emergencies, and the results of independent tests of drinking water in the vicinity of the site.

Complying with the National Environmental Policy Act of 1969

The National Environmental Policy Act of 1969 is the basic national charter for the protection of the environment. NEPA establishes environmental policy, sets goals, and provides means for carrying out a policy. The NEPA environmental review process is intended to help public officials make thoughtful decisions that are based in part on a clear understanding of the environmental consequences of a federal action.

All federal agencies are subject to the mandate of NEPA, and all must abide by the President's Council on Environmental Quality regulations, which provide the direction for incorporating environmental review in the planning and execution of federal actions and set forth procedures for establishing legal documentation of such review. Two of the primary types of NEPA documentation that affect the FMPC, the Environmental Impact Statement (EIS) and the Environmental Assessment (EA), are discussed in the following sections.

Environmental Impact Statement. During 1988, preparations continued on developing a sitewide Environmental Impact Statement to address and evaluate the cumulative environmental impacts of renovation projects that would be conducted at the FMPC over the time period from October 1, 1985 through the mid-1990's. While the DOE has overall responsibility for the EIS, Oak Ridge National Laboratory is responsible for preparing and publishing the EIS.

To better understand the EIS, three key terms must be defined: directed actions, remedial actions, and renovation. **Directed actions** are those actions agreed to or entered into by DOE and various federal and state agencies. These actions include the OEPA Director's Findings and Orders the FFCA with the USEPA, and the Consent Decree with the State of Ohio. These actions are intended to correct potentially serious environmental situations that could exist during the period while the FMPC completes the RI/FS, develops long-term plans to rectify the situations, and completes final remedial activities.. Examples of directed actions are the work on the K-65 silos (sealing the dome exteriors) and the Plant 8 thorium work (removing the thorium from the silo and bins).

Remedial actions address the mitigation or correction of the adverse effects of past operations, such as the waste pit area and the K-65 Silos.

Renovation is defined in the sitewide EIS as "changes to existing facilities and the construction and operation of new and replacement facilities/systems designed to achieve the following: (1) improve environmental safety and health conditions, (2) improve plant reliability, (3) maintain production capacity for future national defense needs, and (4) enhance management of hazardous and radioactive waste materials."

Originally, the scope and Record of Decision for the EIS included assessing the environmental impacts of the projects associated with renovating production operations as well as assessing the impacts of all remedial actions at the FMPC. However, during the development of the EIS, the FFCA was signed. This initiated the sitewide RI/FS of potential areas of the FMPC that may need to be restored. The USEPA became the approving agency for the restoration

activities Record of Decision. This reduced the scope of the EIS to include only an evaluation of cumulative impacts of plant renovation projects. With the enactment of the Director's Findings and Orders and Consent Decree, the EIS was subsequently revised to include these directed actions.

The evolution of the alternatives for the EIS has been very involved. They came about in part from discussions held during the two Public Scoping Meetings in September 1986. In the EIS, the following three alternatives are being evaluated:

- Alternative 1; Full Renovation: This is the proposed action and consists of conducting approximately 300 projects listed in the EIS. This includes projects not completed as of October 1, 1985, projects scheduled through the mid-1990's, and directed actions required by various federal and state orders and agreements.
- Alternative 2; Present Situation - No Further Action: This alternative reflects completing approximately 180 of the 300 projects started before September 30, 1989.
- Alternative 3; Relocating FMPC Production Activities: This alternative would involve relocating all or a portion of FMPC production activities to another part of the FMPC site or to another DOE site. Remedial actions would still be conducted at the FMPC under the RI/FS.

In addition to discussing these alternatives, the EIS assesses the *cumulative* environmental impacts of implementing the alternatives at the FMPC. This means, for example, that the amount of rubble generated by one construction project may not impact environmental conditions, but the rubble generated by several projects, assessed cumulatively, could have a significant impact.

An EIS Task Force was formed in March 1988 with the primary purpose to supply ORNL with current technical data and information for the document. The draft EIS is expected to be released to cooperating agencies, Congress, and the general public during the third quarter (July-Sept) of 1989. After a 60-day public-review period, the EIS will be revised to answer comments made by the public. The final sitewide EIS will then be published, and the DOE will announce a Record of Decision (select an alternative). This should occur two or three months after publication of the final EIS.

Environmental Assessments. Since there are numerous directed actions occurring at the FMPC while the EIS is being prepared, the FMPC must complete Environmental Assessments to document that possible environmental impacts are being addressed for particular projects.

During 1988, the FMPC completed two Environmental Assessments: one for the Thorium Handling project and the second for the Decommissioning and Decontamination Facility. DOE/HQ approved the Thorium Handling project on February 9, 1988, and construction began in April 1988. The D&D facility project was approved by DOE/HQ on August 24, 1988, and construction will begin when all the necessary permits are obtained.

The Bulk Chemical Storage Facility

Since the FMPC began operations in the early 1950's, many of the hazardous chemicals at the site have been stored at the bulk chemical storage facility called the Tank Farm. These chemicals included AHF, dilute hydrogen fluoride (DHF), anhydrous ammonia, kerosene, and nitric acid. The philosophy behind central chemical storage and the original construction techniques conformed with the standards of the day.

Although there had not been any environmental problems with the operation of the Tank Farm, the age of the facility was apparent, and the FMPC wanted to minimize any potential risk to the employees, neighbors of the plant, and the environment associated with the Tank Farm. The FMPC began planning and building decentralized storage vessels, abiding by today's strict codes and incorporating the best available technology. The renovation has been guided by current trends in storage which recognize the benefits of centralized storage, but add emphasis to the specific needs of differing chemicals, including accident scenarios and the

compatibility of chemicals which could come into contact with one another. The following paragraphs describe the actions that have taken place to significantly improve the practice of storing hazardous chemicals at the FMPC.

Testing and Start-Up of the South Ammonia Storage Facility. The first project designed to reduce the potential for spills or releases of hazardous chemicals was the construction of the South Ammonia Storage Facility (SASF). Originally, the ammonia was stored at the Tank Farm (Facility 19B in Figure 1); the new storage facility is located near the Pilot Plant complex where the ammonia was used in production (Facility 13 in Figure 1).

Detailed design checks, Operational Readiness Reviews, Independent Safety Reviews, and independent design reviews were performed on the facility before any anhydrous ammonia was stored in the SASF. Once the design, safety, and construction details were verified, a detailed start-up test was executed. Each piece of equipment was tested against its operating specifications to further verify the process, and deviations were corrected before the facility was approved for general use. In addition, personnel who operate the system have been fully trained in responding to potential hazards and in appropriate safety procedures.

Renovating the Tank Farm. Following completion of the SASF project, the renovation of the south half of the Tank Farm began. The design of the new Tank Farm provides for the safe storage and transfer of hydrofluoric acids (both dilute and anhydrous forms): receiving hydrofluoric acids from onsite transfers, transferring hydrofluoric acids to onsite process areas, and loading hydrofluoric acids onto truck or railcar. Also provided is a specific water treatment facility for acid runoffs.

Removing Anhydrous Hydrogen Fluoride from the Site. While the Tank Farm renovation was proceeding, several policy decisions were made by DOE that had a direct impact on production at the FMPC. The decision to not restart the "N" Reactor at its Hanford, Washington site meant there was no longer a need for the FMPC hydrofluorination operation in Plant 4 and the AHF used as a process feed material.

However, AHF is a by-product of the UF_6 to UF_4 reduction operation in the Pilot Plant, which was still operating. Hence, the FMPC needed a means to dispose of accumulating excess AHF, so the site performed a market analysis to identify a prospective purchaser. Following construction and approval for use of a truck loading facility at the Tank Farm, AHF was sold by the truckload. In this way, all process quantities of AHF and DHF were removed from the FMPC. This action was consistent with FMPC goals to reduce the potential for accidents wherever possible.

Shortly after the "N" Reactor shutdown, the FMPC suspended the UF_6 to UF_4 operations at the Pilot Plant. Since anhydrous ammonia is used as a feed material in the UF_6 to UF_4 operations, this eliminated the need for the FMPC to store large quantities of anhydrous ammonia in the new SASF. The remaining quantities of this chemical have also been removed from site as of the end of April 1989. The removal of these hazardous chemicals eliminates a major safety concern at the FMPC.

Independent Tests Near the FMPC

A three-year testing program conducted by the Ohio Department of Health (ODH) has confirmed that uranium contamination of groundwater wells near the FMPC is confined to three wells located just south of the facility. In addition, the ODH survey found no serious contamination of soil in offsite areas, and found only slightly elevated concentrations of uranium in soil samples collected northeast of the FMPC. ODH collected and analyzed more than 300 water samples during the survey. The three offsite wells at which above-background uranium concentrations were found were originally identified in 1981 when the FMPC began testing nearby offsite wells. The elevated concentrations have been reported in subsequent FMPC Environmental Monitoring Annual Reports.

In addition to the water and soil testing, ODH measured radon levels in 25 homes and 16 other locations near the FMPC. Radon levels above current USEPA guidelines of 4 pCi/l (0.15 Bq/l)

were detected in 40% of the homes tested, but only background or slightly above-background radon levels were detected outdoors at the boundary of the FMPC. The ODH concluded that the source of radon in homes was the geologic condition beneath the homes themselves.[15]

According to the ODH report, radiation measurements taken at 31 locations near the FMPC detected no levels which would represent a threat to the health and safety of nearby residents.

During November 1988, the OEPA sampled drinking water from 17 public water supplies which draw from wells within 16 km (10 mi) of the FMPC. The OEPA tests showed no abnormal amount of radioactivity.

Unusual Events

During 1988, three events that posed potential facility safety problems occurred. These are discussed in the following paragraphs.

Uranyl Nitrate Release

Plant 2/3 is a chemical processing facility which recycles residues containing uranium for eventual reprocessing into uranium metal. On January 18, 1988, an area of the Plant 2/3 roof and nearby ground within the FMPC process area northeast of Plant 2/3 was found contaminated with uranyl nitrate. Officials determined that a series of events had led to the accidental release of about 18 kg (40 lb) of uranium. The incident was reported to county, state, and federal agencies. There were no injuries, and no offsite radioactive or chemical release. Since the release was contained within the production area, it was not included as part of the total uranium emissions from the site during 1988 and, therefore, was not included in the AIRDOS calculations for offsite dose.[33]

In the process of concentrating uranyl nitrate in Plant 2/3, clean water vapor is generated. This vapor has in the past been vented to the atmosphere. The concentrated uranyl nitrate is then transferred to denitration pots for conversion to uranium trioxide, one of the chemical steps in producing uranium metal. FMPC investigators determined that an abnormally low concentration of the solution had been admitted to the concentration tanks causing the solution to boil too vigorously. As a result, some of the solution was carried with escaping water vapor up the vent stack to the atmosphere. Deficiencies in the process control system were identified as having contributed to the release.

Radiation safety activities began immediately. Barricades were defined and setup, and personnel began monitoring for airborne radioactivity. As levels of contamination were determined, work precautions were prescribed for personnel inspecting and decontaminating the area. A total of 135 personnel potentially exposed to the contamination, including decontamination workers, submitted samples for urinalysis. All urine samples for this incident had a uranium content of less than the action limit of 0.015 mgU/l. The median value for all sample groups was no more than would be expected if the same number of employees from the plant were sampled at random.[34]

The FMPC has taken several actions based on the recommendations of the investigating team to prevent a recurrence of the incident, including the rerouting of vapor vent lines through a condenser so that no direct atmospheric venting can take place. Changes in operating procedures and additional training of personnel have been completed, and supplemental monitoring gauges are being installed to further improve the process control.

Uranium-Chip Fire in Plant 6

A uranium chip fire occurred in Plant 6 on October 4, 1988. The fire caused little damage and no injuries, and did not result in any offsite environmental impact.

The fire began when a saw tooth on a milling machine broke off and ignited a drum of depleted uranium-chips. The fire spread to four other drums. The FMPC emergency response team quickly extinguished the fire. The five drums were then placed in special fire containers that were filled with water and placed under a sprinkler outside the building. As a precaution, 19 employees were sent for urinalysis to confirm that they did not have any uranium intake.

Plant 2/3 Gulping Emissions

Approximately 66 kg (145 lb) of uranium were released to the atmosphere from UO_3 and gulping operations at the FMPC's Plant 2/3 Refinery during a four-week period in June 1988.

A DOE investigation concluded that the emissions were caused by an under-sized exhaust scrubber designed to remove traces of uranium trioxide (UO_3) from the exhaust gases from the gulping operations. In the gulping operation, UO_3 produced in denitration pots is transferred to drums or hoppers by a vacuum gulping technique. The investigation report determined that the scrubber used as part of the vacuum system did not operate properly because it was not able to handle the required airflow volume. In addition, the investigators found that a blower and exhaust system continued to operate even when the gulping was not operating. The gulping operation remains out of service pending modifications to prevent this from happening again.

The emissions were identified after filters at air monitoring stations on the FMPC boundaries indicated higher than normal levels of airborne uranium for the week of June 7. After similar readings were recorded for the next two weeks, an investigation was begun to find the source of the elevated uranium readings. By comparing dates and times of the uranium readings at the air monitoring stations with processes known to be operating at those times, the FMPC identified the Plant 2/3 denitration operation as the cause of the emissions on June 30. The process was immediately shut down.

The FMPC investigation team performed stack sampling of a test run for data gathering, consulted with outside experts, and culminated their work with estimates of emissions during 1988 and with recommendations about future operation of the system. The process has not been operated since the test period, but plans have been made to greatly reduce the level of emissions from the system once it returns to operation.

Based upon the data from the air monitoring stations, AIRDOS calculations indicated the maximum effective dose to a resident living near the site during the 25 days of operation was less than 0.08 mrem. This is significantly less than the average 20 mrem that every resident of southwest Ohio received from natural background sources during that same period.

Before the June 1988 incident, the Plant 2/3 gulping operations had not been considered a significant source of uranium emissions from the FMPC, and its emissions were not included in previous reports of historic radionuclide discharges. Estimates of historic emissions from this process have been made by interpreting sampling data collected during the investigation and by incorporating available data about the system and its history of operation. These estimates were included in the most recent FMPC historic radionuclide emissions report.

Site-Wide Review of Air Emissions Sources

Following identification of the Plant 2/3 gulping system as a significant and unquantified source of uranium air emissions, a comprehensive review of all unmonitored process stacks was undertaken to identify and quantify unmonitored emissions. Thirty-five unmonitored operating stacks were found servicing 26 processes. No unmonitored processes were allowed to resume operation following the annual maintenance shutdown in July until the uranium emissions were quantified and shown to satisfy emission criteria. Processes with monitored emissions and nonradioactive processes were permitted to resume operation following the annual maintenance shutdown. Estimates of emissions from unmonitored processes have been included in the most recent FMPC historic radionuclide emissions reports.

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(37) **Feed Materials Production Center,** *Environmental Monitoring Annual Report for 1987,* FMPC-2135, April 30, 1988.

Glossary of Terms

Activity - the rate of disintegration, expressed as disintegrations per second (becquerels) or in units of curies (one curie = 3.7×10^{10} becquerels).

Alpha particle - type of particulate radiation (identical to the nucleus of the helium atom) consisting of two protons and two neutrons.

Aquifer - underground layer of material through which water passes. A saturated permeable geologic unit that can transmit significant quantities of groundwater under ordinary hydraulic gradients.

ALARA - a phrase and acronym (as low as reasonably achievable) used to describe an approach to radiation exposure and emissions control or management whereby the exposures and resulting doses to the public are maintained as far below the specified limits as economic, technical, and practical considerations will permit.

Aliquot - the fraction of a field sample taken for complete processing through an analytical procedure (a "laboratory sample" of a field sample).

Beta particle - type of particulate radiation emitted from the nucleus of an atom that has a mass and charge equal in magnitude to that of the electron.

Blank - a sample of the carrying agent (gas, liquid, or solid) normally used to selectively measure a material of interest that is subjected to the usual analytical procedures process to establish a baseline or background value. This value is then used to adjust or correct the routine analytical results.

Calibration - the adjustment of the system and the determination of system accuracy using known sources and instrument measurements. Adjustment of flow, temperature, humidity, or pressure gauges and the determination of system accuracy should be conducted using standard operating procedures and sources that are traceable to the National Institute of Standards and Technology.

Confidence Coefficient - the chance or probability, usually expressed as a percentage, that a confidence interval includes some defined parameter of a population. The confidence coefficients usually associated with confidence intervals are 90%, 95%, and 99%. For a given sample size, the width of the confidence interval increases as the confidence coefficient increases.

Confidence Interval - a value interval that has a designated probability (the confidence coefficient) of including some defined parameter of the population.

Critical Organ - the human organ or tissue receiving the largest fraction of a specified dose limit.

Critical Pathway - the specific route of transfer of radionuclides from one environmental component to another that results in the greatest fraction of an applicable dose limit to a population group or an individual's whole body, organ, or tissue.

Curie (Ci) and Becquerel (Bq) are units of radioactivity that measure the rate of spontaneous, energy-emitting transformations in the nuclei of atoms. One curie equals 37 billion transformations per second. One becquerel equals one transformation per second. One curie (37 billion Bq) of natural uranium is equivalent to a mass of about 1,500 kilograms (3,300 lb).

Daughter - a nucleus that results from radioactive decay. Also, progeny.

Decay - the disintegration process of an atomic nucleus.

Dose - quantity of radiation absorbed in tissue.

Effluent Monitoring - the collection and analysis of samples or measurements of liquid, gaseous, or airborne effluents for the purpose of characterizing and quantifying contaminants and process stream characteristics, assessing radiation exposures to members of the public, and demonstrating compliance with applicable standards.

Enrichment - a process to increase the percentage of a desired isotope such as uranium-235.

Environmental Detection Limit - the lowest concentration at which a radionuclide in an environmental medium can be unambiguously distinguished for a given confidence level using a particular combination of sampling and measurement procedures, sample volume, analytical detection limit, and processing procedure.

Fugitive Dust - Dust that did not flow through a production stack. This includes materials such as dust from the waste storage areas, administration areas, dust that originated from construction activities.

Gamma ray - type of electromagnetic radiation of discreet energy emitted during radioactive decay of many radioactive elements.

Half life - the length of time for half the atoms of a given radioactive substance to decay.

ICRP - International Commission on Radiological Protection is an organization founded in 1928 and whose function is to recommend international standards for radiation protection.

Ionization - removal of electrons from an atom, such as by means of interaction with radiation.

Isotope - atoms with the same atomic number but different mass number. Isotopes usually have the same chemical properties, but could have very different radiological properties (such as half-life and type of radiation emitted).

Less than Detectable - refers to a measurement or calculated concentration that is not statistically different from the associated background or control value at a selected confidence level.

Lower Limit of Detection - the smallest amount of a contaminant that can be distinguished in a sample by a given measurement procedure at a given confidence level.

Minimum Detection Level - the minimum amount of the constituent or species of interest that can be observed by an analytical instrument and distinguished from background and instrument noise with a specified degree of probability.

Mixed Wastes - hazardous waste that has been contaminated with low-level radioactive materials.

Monitor - 1) to measure certain constituents or parameters in an effluent stream continuously or at a frequency that permits a representative estimate of the amount over a specified interval of time; 2) the instrument or device used in monitoring.

NCRP - National Council on Radiation Protection and Measurements chartered by U.S. Congress in 1914 and charged with developing radiation protection standards.

Nuclide - a general term applicable to all atomic forms of the elements, including isotopes.

Occurrence - any sudden release or sustained deviation from a regulated or planned performance of an operation that has environmental protection and compliance significance.

Onsite - refers to the area within the boundaries of a facility or site that is or can be controlled with respect to access by the general public.

Person-rem - Collective dose to a population group. For example, a dose of one rem to ten people results in a collective dose of ten person-rem.

Plate Out - a thermal, electrical, chemical, or mechanical action that results in a loss of material by deposition on surfaces.

Point Source - the single defined point (origin) of a release such as a stack, vent, or pipe.

Radioactive Material - refers to any material or combination of materials that spontaneously emits ionizing radiation.

Radioisotope - a radioactive isotope.

Radionuclide - refers to a radioactive nuclide. There are several hundred known radionuclides, both artificially produced and naturally occurring; radionuclides are characterized by the number of neutrons and protons in an atom's nucleus and their characteristic decay processes.

Radioactive Emissions - releases of radioactive materials to the environment.

Random Samples - samples that are obtained in such a manner that all items or members of the lot, or population, have an equal chance of being selected in the sample.

Representative Sample - a sample taken to depict the characteristics of a lot or population as accurately and precisely as possible. A representative sample may be a "random sample" or a "stratified sample" depending upon the objective of the sampling and the characteristics of the conceptual population.

Roentgen (R) and coulombs per kilogram (C/kg) - units of exposure to radioactivity. One R equals 2.6×10^{-4} C/kg, and is a measure of the ionization in air due to a source of radioactivity.

Roentgen Equivalent Man (rem) and sievert (Sv) - units of dose which account for the relative biological damage due to the type of radiation involved. One rem equals 0.01 Sv.

Sample - 1) a subset or group of objects selected from a larger set, called the population; 2) an extracted portion of a subset of an effluent stream or environmental medium.

Sampling - the extraction of a prescribed portion of an effluent stream or of an environmental medium for purposes of inspection and/or analysis.

Sensitivity - the minimum amount of a radionuclide or other material of interest that can repeatedly be detected by an instrument, system, or procedure.

Spiked Sample - a normal sample of material (gas, liquid, or solid) to which a known amount of some substance of interest is added. Spiked samples are used to check on the performance of a routine analysis or the recovery efficiency of an analytical method.

Tolerance Limits - a particular type of confidence limit used frequently in quality control work, where the limits apply to a percentage of the individual values of the population.

Appendix A - 1988 Results of FMPC Sampling Program

The FMPC designed and conducted numerous sampling procedures to give accurate indications of the effects of the facility's operation on the environment during 1988. The results of this sampling are provided in the tables on the following pages.

TABLE 1
SUMMARY OF RADIATION DOSE DUE TO 1988 EMISSIONS[1]

Type of Dose	Organ	Dose Equivalent (50-yr Committed) mrem	(mSv)	Standard[2] mrem	% of Standard
I. Individual					
A. Maximum individual dose from all pathways, all nuclides due to air emissions[3,4]	Effective	2.9×10^{0}	(2.9×10^{-2})	1.0×10^{2}	2.9
	Whole Body[5]	8.9×10^{-4}	(8.9×10^{-6})	2.5×10^{1}	0.0036
	Bone Endosteum	1.4×10^{1}	(1.4×10^{-1})	7.5×10^{1}	19.0
	Pulmonary	1.9×10^{1}	(1.9×10^{-1})	7.5×10^{1}	25.0
B. Ingestion[6]					
Vegetables (Potatoes)	Effective	2.5×10^{-2}	(2.5×10^{-4})	1.0×10^{2}	0.025
Great Miami River Water (2 L/day)	Effective	7.2×10^{-2}	(7.2×10^{-4})	1.0×10^{2}	0.072
	Bone Endosteum	1.1×10^{0}	(1.1×10^{-2})	5.0×10^{3}	0.022
Great Miami River Fish (4.4 kg/yr)	Effective	3.1×10^{-1}	(3.1×10^{-3})	1.0×10^{2}	0.31
	Bone Endosteum	4.9×10^{0}	(4.9×10^{-2})	5.0×10^{3}	0.098
Offsite Well Water[7] Well 15 (2 L/day)	Effective	3.2×10^{1}	(3.2×10^{-1})	1.0×10^{2}	32.0
	Bone Endosteum	5.2×10^{2}	(5.2×10^{0})	5.0×10^{3}	10.0
C. Direct External[8]	Whole Body	1.6×10^{1}	(1.6×10^{-1})	1.0×10^{2}	16.0
II. 80 km Population Dose[3]		person-rem	person-Sv		
Committed dose equivalent to 2.5×10^{6} people living within 80 km.	Effective	5.9×10^{1}	(5.9×10^{-1})	...[9]	
	Whole Body	6.6×10^{-2}	(6.6×10^{-4})	...[9]	
	Bone Endosteum	1.8×10^{2}	(1.8×10^{0})	...[9]	
	Pulmonary	4.3×10^{2}	(4.3×10^{0})	...[9]	
III. Other Background Sources of Dose[10]					
A. Natural Radioactivity		mrem/yr	(mSv/yr)		
1. Radon in homes		2.0×10^{2}	(2.0×10^{0})		
2. Other natural background radiation: cosmic radiation plus natural terrestrial isotopes, both external and internal.		1.0×10^{2}	(1.0×10^{0})		
B. Medical diagnosis[11]		5.0×10^{1}	(5.0×10^{-1})		
C. Consumer products		1.0×10^{1}	(1.0×10^{-1})		
D. Atmospheric weapons tests		4.6×10^{0}	(4.6×10^{-2})		

FOOTNOTES FOR TABLE 1

1. Including dose from all radionuclides listed in Table 2.
2. Standards are as included in DOE Draft Order 5400.xx, "Radiation Protection of the Public and the Environment," dated March 18, 1988. Also incorporated are the air emission dose standards of regulation 40 CFR 61, Subpart H (NESHAP).
3. See Table 4 for inhalation dose estimates at all air monitoring stations.
4. Dose estimates provided by ORNL using AIRDOS computer code; 80 km population dose expressed in units of person-rem.
5. Whole body dose equivalent provided by ORNL. It includes external dose from all nuclides listed in Table 2 plus internal exposure from Cs-137, which is deposited uniformly throughout the body.
6. Dose equivalent based on environmental measurements according to ICRP 26/30 methodology. ICRP 26/30 based on 50-year commitment dose conversion factors.
7. Offsite well 15 contained the highest concentration of uranium measured offsite in 1988. Dose calculations based on maximum hypothetical dose from offsite well water ingestion. The DOE Standard was applied because these wells are not a drinking water source.
8. Calculated from measured exposure rate at nearest residence west of the K-65 Silos, using a calibrated Pressurized Ionization Chamber.
9. There are no applicable standards.
10. From NCRP-93, "Ionizing Radiation Exposure of the Population of the United States."
11. Medical dose estimates are population averages and will not necessarily be applicable to each individual.

TABLE 2
1988 FMPC AIRBORNE EMISSIONS[1]

Radionuclide	Curies
U-234	0.0379
U-235	0.00208
U-236	0.00053
U-238	0.0354
Sr-90	0.000159
Tc-99	0.00517
Ru-106	0.00021
Cs-137	0.00121
Ba-137m	0.00121
Ra-226	0.000145
Ra-228	0.000026
Th-228	0.000229
Th-230	0.00291
Th-232	0.000159
Th-234	0.165
Pa-234m	0.0727
Np-237	0.000031
Pu-238	0.00000969
Pu-239	0.0000307
Pu-240	0.0000163
Pu-241	0.0000921

1. Measured and estimated 1988 airborne radionuclide emissions include: monitored stacks, unmonitored stacks, building exhausts, fugitive emissions from the waste pits, Plant 2/3 denitration and gulping emissions, and accidental releases.

TABLE 3
POPULATION DISTRIBUTION WITHIN 80 KM (50 MI) OF THE FMPC

Compass Sector	Estimated Population[1] 0-8 km (0-5 mi)	8-16 km (5-10 mi)	16-32 km (10-20 mi)	32-80 km (20-50 mi)
N	445	3,395	6,743	29,597
NNE	221	18,959	12,805	148,079
NE	489	32,001	36,705	557,783
ENE	2,489	25,760	29,830	55,078
E	512	40,770	70,762	85,240
ESE	713	54,533	150,630	107,365
SE	1,606	36,467	247,846	118,490
SSE	985	28,932	207,202	51,946
S	669	19,214	53,673	39,116
SSW	390	4,217	10,614	21,987
SW	185	2,957	13,066	16,574
WSW	440	4,961	3,930	19,199
W	519	1,765	3,292	31,629
WNW	157	1,361	5,211	21,605
NW	511	1,433	1,802	37,945
NNW	519	1,134	21,042	71,493
Totals	10,850	277,859	875,153	1,413,126

Total in all sectors: 2,576,988

1. Based on "Report of Findings, Population Studies for DOE Feed Materials Production Center, Near Fernald, Ohio, for NLO, Inc.," May 18, 1981.

TABLE 4
ESTIMATED COMMITTED EFFECTIVE DOSE EQUIVALENTS AND PULMONARY DOSE EQUIVALENTS AT AIR MONITORING STATIONS[1]

AMS	Organ	50 Year Dose Commitment,[2] mrem 1987	1988	% of Standard[3]
1	Effective	1.9	2.9 (0.029)	2.9
	Pulmonary	16	23 (0.23)	31
2	Effective	1.9	3.1 (0.031)	3.1
	Pulmonary	16	23 (0.23)	31
3	Effective	4.9	4.0 (0.040)	4.0
	Pulmonary	41	32 (0.32)	43
4	Effective	1.2	1.0 (0.010)	1.0
	Pulmonary	10	7.3 (0.073)	9.7
5	Effective	1.2	1.0 (0.010)	1.0
	Pulmonary	9.8	7.7 (0.077)	10
6	Effective	1.6	1.1 (0.011)	1.1
	Pulmonary	13	8.5 (0.085)	11
7	Effective	0.9	0.7 (0.007)	0.7
	Pulmonary	7.8	4.9 (0.049)	6.5
8	Effective	4.4	5.2 (0.052)	...[4]
	Pulmonary	37	39 (0.39)	...[4]
9	Effective	8.6	7.5 (0.075)	...[4]
	Pulmonary	72	60 (0.60)	...[4]
10	Effective	0.7	0.5 (0.005)	0.5
	Pulmonary	5.9	3.1 (0.031)	4.1
11	Effective	0.6	0.5 (0.005)	0.5
	Pulmonary	5.0	3.4 (0.034)	4.5
12	Effective	0.3	0.4 (0.004)	0.4
	Pulmonary	2.4	2.2 (0.022)	2.9
13	Effective	1.3	1.1 (0.011)	1.1
	Pulmonary	11	7.2 (0.072)	9.6
14[5]	Effective	...[6]	0.6 (0.006)	0.6
	Pulmonary	...[6]	3.6 (0.036)	4.8

1. The effective dose equivalent is the weighted sum of dose equivalents delivered to the individual organs of the body.
2. mSv in parentheses.
3. See footnotes in Table 1 for standards.
4. Onsite AMS; standards for dose to public not applicable.
5. Dose commitment for 1988 for AMS-14 based on measured average radionuclide air concentrations from August to December, 1988.
6. Not sampled in 1987. Sampling begun in August, 1988.

TABLE 5
EXTERNAL RADIATION DOSE, 1988

Sampling Location[1]	Dose Rate (µrem/hr) Annual Average	Maximum	Minimum
AMS 1	9.38	14.38	6.50
AMS 2	10.62	16.34	7.51
AMS 3	10.34	16.85	7.56
AMS 4	9.58	15.52	6.58
AMS 5	9.50	14.97	6.67
AMS 6	15.30	23.53	11.56
AMS 7	9.72	15.80	6.57
AMS 8	9.23	14.79	6.65
AMS 9	12.97	18.56	10.42
AMS 10	8.09	14.15	5.16
AMS 11	10.57	15.93	7.71
AMS 12	9.02	11.44	7.25
AMS 13	8.47	13.97	7.81
BKGD[2]	9.91	15.07	7.62

1. See Figure 11.
2. Background is average of measurements at two locations (BKGD-1 and BKGD-2) between 25 and 40 km from the FMPC.

TABLE 6
RADON IN AMBIENT AIR

Sampling Location[1]	1988 Average pCi/l	(Bq/l)	1987 Average pCi/l	(Bq/l)
• AMS 1	0.7	(0.025)	0.5	(0.020)
• AMS 2	1.0	(0.038)	0.5	(0.017)
AMS 3	. . . [2], see FMPC - E		1.1	(0.041)
• AMS 4	0.7	(0.024)	1.0	(0.038)
AMS 5	. . . [2], see FMPC - I		0.6	(0.022)
• AMS 6	1.0	(0.038)	1.3	(0.047)
• AMS 7	1.5	(0.056)	0.7	(0.024)
AMS 8	0.8	(0.029)	0.5	(0.019)
AMS 9	0.8	(0.028)	0.4	(0.015)
AMS 10	0.8	(0.030)	0.7	(0.027)
AMS 11	0.9	(0.033)	0.7	(0.027)
AMS 12	0.7	(0.024)	0.5	(0.017)
AMS 13	0.5	(0.020)	0.7	(0.024)
AMS BK1	. . . [2]		0.7	(0.024)
AMS BK2	. . . [2]		0.8	(0.030)
• FMPC-A	1.3	(0.047)	1.5	(0.054)
• FMPC-B	1.7	(0.063)	1.3	(0.048)
• FMPC-C	1.4	(0.053)	1.3	(0.048)
• FMPC-D	1.1	(0.041)	1.1	(0.040)
• FMPC-E	1.2	(0.044)	0.9	(0.035)
• FMPC-F	1.1	(0.042)	1.3	(0.046)
• FMPC-G	0.9	(0.034)	0.7	(0.026)
• FMPC-H	1.0	(0.035)	0.9	(0.032)
• FMPC-I	1.7	(0.063)	2.1	(0.078)
• FMPC-J	0.9	(0.034)	1.0	(0.038)
• FMPC-K	2.1	(0.079)	2.9	(0.11)
• FMPC-L	1.3	(0.047)	0.7	(0.026)
• FMPC-M	2.0	(0.074)	1.8	(0.065)
• FMPC-N	0.8	(0.028)	0.9	(0.032)
• FMPC-O	1.3	(0.048)	1.9	(0.069)
• FMPC-P	0.9	(0.035)	0.7	(0.026)
RES 1	1.3	(0.047)	1.2	(0.046)
RES 2	0.9	(0.034)	0.9	(0.034)
RES 3	1.0	(0.036)	1.0	(0.038)
BKGD 1	0.3	(0.011)	0.4	(0.016)
BKGD 2	0.9	(0.034)	0.8	(0.028)
Fenceline				
Average	1.2	(0.045)	1.2	(0.043)
Std.Dev.	± 0.41	(± 0.015)	± 0.57	(± 0.021)
Background				
Average	0.62	(0.023)	0.66	(0.024)
Std. Dev.	± 0.43	(± 0.016)	± 0.14	(± 0.005)
Net				
Fenceline	0.60	(0.022)	0.49	(0.018)
Std. Dev.	± 0.60	(± 0.022)	± 0.59	(0.022)

0305-57

• FMPC Fenceline Location
1. See Figures 12 and 13.
2. Not analyzed - sampling station discontinued.

TABLE 7
PARTICULATES, URANIUM AND GROSS BETA CONCENTRATION IN AIR

Sampling Location[1]	Particulates[2a] µg/m³ Number of Samples	Minimum	Maximum	1988 AVG.	1987 AVG.	Uranium[2b] µCi/ml x 10^{-15} Number of Samples	Minimum	Maximum	1988 AVG.	1987 AVG.	Beta[2c] µCi/ml x 10^{-15} Number of Samples	Minimum	Maximum	1988 AVG.	1987 AVG.
AMS 1	52	15.4	66.7	31.6	29.0	52	0.00	39.1	2.60	1.88	52	9.54	51.4	24.2	23.7
AMS 2	52	16.7	77.2	38.2	31.9	52	0.00	36.6	2.57	1.92	52	11.81	58.9	27.3	24.5
AMS 3	52	10.1	67.3	35.7	31.9	51	0.13	25.2	3.59	4.94	51	13.80	63.1	28.8	28.7
AMS 4	52	20.8	72.1	39.4	34.7	52	0.00	6.5	0.77	1.22	52	10.11	60.2	27.4	24.5
AMS 5	52	17.7	70.9	36.6	30.7	52	0.00	6.0	0.83	1.18	52	12.25	83.6	32.9	26.7
AMS 6	51	17.6	66.5	36.6	33.5	51	0.05	3.6	0.90	1.55	51	12.75	76.8	30.2	27.4
AMS 7	52	16.6	74.3	37.3	34.8	52	0.00	5.4	0.50	0.94	52	10.67	93.6	34.2	29.6
AMS 8	52	19.7	84.5	39.8	34.5	52	0.00	48.2	4.32	4.40	52	11.68	67.4	27.5	28.6
AMS 9	52	15.2	79.1	40.8	37.8	52	0.24	44.1	6.78	8.61	52	11.00	66.0	28.9	30.4
AMS 10	52	22.1	107.1	51.0	47.2	52	0.00	1.7	0.25	0.71	52	7.85	37.5	21.4	11.3
AMS 11	52	20.3	85.5	40.9	42.3	52	0.00	3.2	0.29	0.60	52	10.58	83.9	23.7	14.2
AMS 12	51	18.3	80.2	37.8	35.2	51	0.00	4.0	0.14	0.29	51	10.49	41.6	22.6	9.9
AMS 13	51	26.6	122.4	48.7	44.5	51	0.00	7.4	0.63	1.26	49	7.14	116.4	28.4	12.1
AMS 14	21	17.3	57.7	37.1	...[3]	21	0.00	0.75	0.18	...[3]	21	7.23	32.0	23.3	...[3]

0305-60

1. See Figure 11.
2. The following guidelines were used for comparison:
   a. Particulates = 50 µg/m³ (annual arithmetic mean) as stated in 40 CFR Part 50, National Ambient Air Quality Standards, July 1, 1988.
   b. Uranium = 100 x 10^{-15} µCi/ml as stated in DOE Order.
   c. Gross Beta = 100,000 x 10^{-15} µCi/ml as stated in 10 CFR Part 20, Appendix B.
3. Not Sampled.

TABLE 8
RADIONUCLIDES IN AIR
(page 1 of 2)

Concentration of Radionuclides at Air Monitoring Stations[1,2,3] in $\mu Ci/m^3 \times 10^{-12}$

Radionuclide	Derived Concentration Guides[4] $\mu Ci/m^3 \times 10^{-6}$	AMS 1	AMS 2	AMS 3	AMS 4	AMS 5	AMS 6	AMS 7	AMS 8
Cs-137	400	< 27	< 24	< 27	< 17	< 26	< 23	< 19	< 26
Np-237	0.02	< 1.5	< 1.7	< 1.7	< 1.5	< 1.5	< 1.4	< 1.4	< 1.5
Pu-238	0.03	< 0.53	< 0.50	< 0.65	< 0.40	< 0.37	< 0.35	< 0.54	0.93 ± 0.44
Pu-239/240	0.02	7.7 ± 3.0	11 ± 4.2	5.6 ± 2.5	3.7 ± 1.4	2.6 ± 1.0	2.3 ± 0.88	3.5 ± 1.5	16 ± 4.9
Pu-241	1	23 ± 0.38	34 ± 0.51	23 ± 0.40	9.9 ± 0.20	6.8 ± 0.16	12 ± 0.25	10 ± 0.15	55 ± 0.56
Ra-226	1	54 ± 9.6	50 ± 9.1	48 ± 8.7	56 ± 9.8	38 ± 7.5	56 ± 9.7	24 ± 5.0	46 ± 8.4
Ra-228	3	60 ± 38	80 ± 40	73 ± 41	51 ± 35	< 60	< 59	< 58	68 ± 42
Ru-106[5]	30	< 1100	< 1000	< 1200	< 1100	< 1100	< 880	< 1100	< 1200
Sr-90	9	< 120	26 ± 15	65 ± 15	62 ± 16	110 ± 19	102 ± 33	< 20	< 32
Tc-99	2000	1800 ± 250	1300 ± 190	1600 ± 220	820 ± 360	600 ± 120	610 ± 130	220 ± 90	2600 ± 330
Th-228	0.04	13 ± 3.4	6.9 ± 3.9	9.0 ± 3.7	9.2 ± 2.7	12 ± 3.2	13 ± 3.2	8.7 ± 3.0	12 ± 3.6
Th-230	0.04	120 ± 17	250 ± 38	180 ± 27	71 ± 11	61 ± 10	89 ± 13	63 ± 11	390 ± 50
Th-232	0.007	15 ± 3.7	6.3 ± 3.7	5.5 ± 3.0	6.3 ± 2.2	6.1 ± 2.4	7.4 ± 2.4	3.9 ± 2.1	10 ± 3.3
U-234	0.09	1100 ± 66	1100 ± 64	1400 ± 82	320 ± 15	320 ± 23	340 ± 21	180 ± 36	1800 ± 100
U-235	0.1	55 ± 2.4	55 ± 2.3	69 ± 3.0	16 ± 0.56	16 ± 0.58	18 ± 0.79	10 ± 0.32	89 ± 3.7
U-236	0.1	66 ± 3.1	67 ± 3.1	75 ± 3.5	16 ± 0.70	17 ± 0.73	17 ± 0.84	9.2 ± 0.87	100 ± 5.1
U-238	0.1	1300 ± 53	1300 ± 55	2100 ± 64	420 ± 17	480 ± 19	520 ± 22	300 ± 15	2300 ± 130
U Total	. . . [6]	2600 ± 85	2600 ± 81	3600 ± 104	770 ± 23	830 ± 29	900 ± 30	500 ± 39	4300 ± 160

0305-61

TABLE 8
RADIONUCLIDES IN AIR
(page 2 of 2)

Radionuclide	Derived Concentration Guides[4] $\mu Ci/m^3 \times 10^{-6}$	Concentration of Radionuclides at Air Monitoring Stations[1,2,3] in $\mu Ci/m^3 \times 10^{-12}$					
		AMS 9	AMS 10	AMS 11	AMS 12	AMS 13	AMS 14
Cs-137	400	< 19	< 11	< 17	< 14	< 20	< 33
Np-237	0.02	< 1.5	0.08 ± 0.04	0.18 ± 0.06	0.08 ± 0.05	0.35 ± 0.09	0.18 ± 0.11
Pu-238	0.03	1.3 ± 0.50	< 0.11	< 0.14	0.28 ± 0.16	< 0.18	< 0.32
Pu-239/240	0.02	12 ± 3.4	1.2 ± 0.30	1.1 ± 0.29	< 0.19	3.8 ± 0.88	1.6 ± 0.47
Pu-241	1	55 ± 0.57	< 45	< 61	< 99	< 73	< 130
Ra-226	1	17 ± 5.0	2.6 ± 1.8	4.6 ± 2.5	11.3 ± 3.6	3.7 ± 2.2	8.7 ± 4.1
Ra-228	3	89 ± 44	< 33	< 43	< 49	< 48	< 110
Ru-106[5]	30	< 3200	< 830	< 1100	< 890	< 500	< 3500
Sr-90	9	120 ± 35	15 ± 9.1	< 127	33 ± 12	43 ± 14	< 21
Tc-99	2000	6600 ± 840	160 ± 62	220 ± 82	< 140	370 ± 100	< 260
Th-228	0.04	16 ± 4.4	19 ± 3.6	25 ± 4.6	15 ± 2.4	32 ± 5.3	53 ± 8.0
Th-230	0.04	300 ± 40	76 ± 13	62 ± 12	77 ± 14	180 ± 25	120 ± 19
Th-232	0.007	5.6 ± 2.7	15 ± 3.0	21 ± 4.0	14 ± 3.1	24 ± 4.2	23 ± 4.5
U-234	0.09	3000 ± 190	93 ± 15	100 ± 17	50 ± 9.7	230 ± 36	66 ± 10
U-235	0.1	140 ± 6.7	4.7 ± 0.74	5.2 ± 0.86	2.5 ± 0.49	12 ± 1.8	3.3 ± 0.52
U-236	0.1	160 ± 7.3	5.0 ± 0.79	5.6 ± 0.92	2.7 ± 0.52	12 ± 1.9	3.6 ± 0.56
U-238	0.1	3500 ± 160	130 ± 20	140 ± 23	68 ± 13	310 ± 49	90 ± 14
U Total	. . .[6]	6800 ± 250	230 ± 36	260 ± 42	120 ± 24	560 ± 89	160 ± 26

0305-61

1. See Figure 11.
2. Reported in units of $\mu Ci/m^3 \times 10^{-12}$ of air, uncertainties are counting uncertainties only at the 95% C.L.
3. A composite of 51 weekly samples at AMS 3 and AMS 6; 21 weekly samples at AMS 14; 52 weekly samples at all other air monitoring stations.
4. Derived concentration guides from draft DOE Order 5400.xx, 3-18-88. Continuous inhalation of this concentration will result in an effective dose equivalent of 100 mrem/yr (1 mSv/yr).
5. Composite sample activity adjusted to midpoint of sampling.
6. Not Applicable.

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TABLE 9
SAMPLING LOCATIONS FOR SOIL AND VEGETATION, 1988

1987 Sampling Location		1988 Location[1]
Routine Soil	Parallel Soil/Vegetation	Soil/Vegetation
1		1
2		2
3		3
4		4
5		5
6		6
7		7
	12	15
14		17
	4	19
17		20
15		21
13		22
8		23
	17	24
	5	25

1. See Figure 22.

TABLE 10
URANIUM AND FLUORIDE IN SOIL AND VEGETATION SAMPLES, 1988
(page 1 of 2)

Sample Number	Sampling Location[3]	Distance in km from FMPC[4]	Soil[1]			Vegetation[2]			
			Sample Depth (cm)	Total Uranium pCi/g dry[5]		Total Uranium pCi/g dry[5]		Fluoride (ppm)	% of Fluoride Standard [6]
PS01\PG01	1	0.16	0-5	5.1	(0.19)	5.6	(0.21)	1.9	2.4
			5-10	2.8	(0.10)				
PS02\PG02	2	1.1	0-5	9.4	(0.35)	0.61	(0.02)	2.6	3.3
			5-10	10	(0.38)				
PS03\PG03	3	0.16	0-5	73	(2.7)	0.68	(0.03)	< 1.2	< 1.5
			5-10	47	(1.8)				
PS04\PG04	4	0.49	0-5	5.4	(0.20)	1.5	(0.06)	< 1.0	< 1.3
			5-10	5.7	(0.21)				
PS05\PG05	5	0.64	0-5	5.1	(0.19)	0.28	(0.01)	< 0.96	< 1.2
			5-10	5.8	(0.21)				
PS06\PG06	6	0.63	0-5	6.9	(0.26)	0.24	(0.01)	< 1.1	< 1.4
			5-10	7.3	(0.27)				
PS07\PG07	7	1.3	0-5	5.7	(0.21)	0.14	(0.01)	3.9	4.9
			5-10	3.1	(0.12)				
PS08\PG08	8	0.15	0-5	19	(0.70)	0.54	(0.02)	2.1	2.6
			5-10	23	(0.83)				
PS09\PG09	9	0.10	0-5	26	(0.97)	0.02	(0.001)	2.1	2.6
			5-10	23	(0.83)				
PS10\PG10	10	2.6	0-5	1.4	(0.05)	0.12	(0.004)	2.5	3.1
			5-10	1.8	(0.07)				
PS11\PG11	11	3.7	0-5	2.6	(0.10)	0.08	(0.003)	3.2	4.0
			5-10	2.4	(0.09)				
PS12\PG12	12	2.2	0-5	2.0	(0.08)	5.0	(0.19)	7.1	8.9
			5-10	1.4	(0.05)				
PS13\PG13	13	4.2	0-5	3.4	(0.13)	0.39	(0.01)	7.2	9.0
			5-10	2.7	(0.10)				
PS14\PG14	14	5.4	0-5	2.7	(0.10)	0.04	(0.002)	3.7	4.6
			5-10	2.7	(0.10)				
PS15\PG15	15	1.9	0-5	1.6	(0.06)	0.04	(0.002)	5.8	7.3
			5-10	1.6	(0.06)				
PS16\PG16	16		0-5	...[7]	...[7]	...[7]	...[7]	...[7]	...[8]
			5-10	...[7]	...[7]				

TABLE 10
URANIUM AND FLUORIDE IN SOIL AND VEGETATION SAMPLES, 1988
(page 2 of 2)

Sample Number	Sampling Location[3]	Distance in km from FMPC[4]	Soil[1]		Vegetation[2]		
			Sample Depth (cm)	Total Uranium pCi/g dry[5]	Total Uranium pCi/g dry[5]	Fluoride (ppm)	% of Fluoride Standard [6]
PS17\PG17	17	3.7	0-5	1.4 (0.05)	< 0.03 (< 0.02)	< 0.02	< 0.03
			5-10	1.4 (0.05)			
PS18\PG18	18	5.1	0-5	4.7 (0.18)	< 0.03 (< 0.02)	6.4	8.0
			5-10	3.4 (0.13)			
PS19\PG19	19	8.8	0-5	1.4 (0.05)	< 0.03 (< 0.02)	18	23
			5-10	2.0 (0.08)			
PS20\PG20	20	3.7	0-5	2.7 (0.10)	0.01 (0.001)	12	15
			5-10	2.0 (0.08)			
PS21\PG21	21	3.9	0-5	1.4 (0.05)	0.01 (0.001)	7.6	9.5
			5-10	2.0 (0.08)			
PS22\PG22	22	5.0	0-5	1.4 (0.05)	< 0.03 (< 0.02)	5.3	6.6
			5-10	1.4 (0.05)			
PS23\PG23	23	4.3	0-5	2.0 (0.08)	0.01 (0.001)	4.1	5.1
			5-10	1.4 (0.05)			
PS24\PG24	24	2.4	0-5	5.4 (0.20)	0.74 (0.03)	3.4	4.3
			5-10	4.7 (0.18)			
PS25\PG25	25	2.7	0-5	3.4 (0.13)	0.05 (0.002)	15	19
			5-10	4.7 (0.18)			
PS26\PG26	26	1.8	0-5	4.1 (0.15)	0.09 (0.003)	6.5	8.1
			5-10	3.4 (0.13)			
PS27\PG27	27	1.8	0-5	5.4 (0.20)	0.002 (0.0001)	15	19
			5-10	6.1 (0.23)			
PS28\PG28	28	40	0-5	2.7 (0.10)	0.28 (0.01)	9.1	11
			5-10	2.0 (0.08)			
PS29\PG29	29	24	0-5	2.7 (0.10)	< 0.03 (< 0.02)	13	16
			5-10	2.7 (0.10)			

1. Parallel soil samples taken at depth intervals of 0-5 cm and 5-10 cm.
2. Plant material primarily brome grass (Bromus sp.), but other genera represented: Allium, Daucus, Hordeum, Medicago, Melilotus, Poa, Secale and Triticum.
3. See Figure 22.
4. For the purpose of this table, the center of the production area was used for distance measurements.
5. Bq/g in parentheses.
6. No Ohio standard established; Kentucky standard of 80 ppm used.
7. Not sampled.
8. Not applicable.

TABLE 11
AVERAGE URANIUM CONCENTRATION IN FARM AND GARDEN PRODUCE WITHIN 30 KM (19 MI) OF THE FMPC, 1988

Location[1]										
Garden Number	1	2	3	4	5	6	7	8	9	10
Approx. Dist. (km)	1.3	3.8	0.8	24	1.0	0.8	8.0	3.2	30	24
Leafy Vegetables[2]										
Cabbage	...[3]	...[3]	< 0.014	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	0.029 ± 0.007
Spinach	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	< 0.014
Roots & Stems[2]										
Potatoes	...[3]	...[3]	0.028 ±0.007	...[3]	...[3]	...[3]	< 0.014	< 0.014	...[3]	...[3]
Potatoes, Sweet	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	< 0.014	...[3]	< 0.014
Turnip	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	< 0.014
Fruit[2]										
Beans, Green	< 0.014	< 0.014	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]
Corn	...[3]	...[3]	...[3]	...[3]	< 0.014	< 0.014	...[3]	...[3]	...[3]	...[3]
Peppers, Green	...[3]	0.015 ±0.004	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]
Pumpkin	0.060 ±0.012	...[3]	...[3]	...[3]	< 0.014	...[3]	...[3]	...[3]	...[3]	...[3]
Tomato	0.037 ±0.008	...[3]	...[3]	< 0.014	< 0.014	...[3]	...[3]	...[3]	0.014 ±0.003	...[3]
Apple, Roman	...[3]	...[3]	< 0.014	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]
Apple, Delicious	...[3]	...[3]	< 0.014	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]	...[3]

1. Garden numbers shown correspond to locations shown in Figure 23.
2. pCi/g dry weight. Bq/g = pCi/g x 0.037
3. Not sampled.

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TABLE 12
RADIONUCLIDES IN MILK, 1988

Month	Radionuclide	FMPC Dairy (pCi/l)	Control Dairy (pCi/l)[1]
Jan	U-Total	< 0.7	< 0.7
Feb	U-234	0.45 ± 0.12	0.26 ± 0.09
Feb	U-235, -236	0.10 ± 0.05	0.08 ± 0.05
Feb	U-238	0.41 ± 0.12	0.22 ± 0.08
Feb	Th-228	0.09 ± 0.07	0.10 ± 0.05
Feb	Th-230	0.28 ± 0.11	0.11 ± 0.05
Feb	Th-232	< 0.05	0.07 ± 0.04
Feb	Ra-226	0.30 ± 0.30	< 0.30
Feb	Ra-228	< 1.2	< 1.2
Feb	Sr-90	< 2.0	< 2.0
Feb	Tc-99	< 15.0	< 15.0
Feb	U-Total	1.0 ± 0.14	< 0.7
Mar	U-Total	< 0.7	< 0.7
Apr	U-Total	< 0.7	< 0.7
May	U-Total	< 0.7	< 0.7
Jun	U-Total	< 0.7	< 0.7
Jul	U-Total	< 0.7	< 0.7
Aug	U-Total	< 0.7	< 0.7
Sep	U-Total	< 0.7	< 0.7
Oct	U-Total	< 0.7	< 0.7
Nov	U-Total	< 0.7	< 0.7
Dec	U-Total	< 0.7	< 0.7

1. 25 mi (40.5km) WSW of FMPC

TABLE 13
URANIUM IN ONSITE WELL WATER, 1988

Sampling Point[1]	Number of Samples	Concentration pCi/l					
		Minimum	Maximum	Average[2]		95% C.L.[3]	% of Standard
204	1	...[4]	...[4]	5.1	(0.19)	...[4]	...[4]
211	3	0.07	0.68	0.29	(0.01)	0.68	...[5]
301	3	0.68	13	8.6	(0.32)	14	...[5]
303	2	1.8	10	6.0	(0.22)	37	...[5]
305	3	2.7	3.0	2.9	(0.11)	0.29	...[5]
308	3	0.14	0.34	0.23	(0.01)	0.21	...[5]
309	2	1.2	6.4	3.8	(0.14)	24	...[5]
310	2	2.0	16	8.8	(0.33)	61	...[5]
401	3	0.07	0.14	0.09	(0.003)	0.08	...[5]
408	3	0.20	0.20	0.20	(0.01)	...[4]	...[5]
P1	3	0.07	0.20	0.14	(0.01)	0.14	0.34[6]
P2	3	0.07	0.14	0.11	(0.004)	0.08	0.28[6]
P3	3	0.07	0.14	0.09	(0.003)	0.08	0.23[6]

1. See Figure 24.
2. Bq/l in parentheses.
3. C.L. = confidence level; ± value applicable to the average concentration.
4. Not applicable.
5. Percent of Standard has been calculated for **reference** purposes **only**. The standard (40 pCi/l) only applies to finished water in public water systems. These wells are used for monitoring purposes **only** and are not used for consumption by the public. Percent of Standard relates to the average value.
6. Standard used is 40 pCi/l (1.5 Bq/l). This value is the median value in the range of values (30 to 50 pCi/l) which DOE has directed FMPC to use as interim drinking water limits for natural uranium. (DOE letter 288-88). Percent of Standard relates to the average value.

TABLE 14
GROSS ALPHA CONCENTRATIONS IN ONSITE WELL WATER, 1988

Sampling Point[1]	Number of Samples	Concentration pCi/l					
		Minimum	Maximum	Average[2]		95% C.L.[3]	% of Standard
204	0	...[4]	...[4]	...[4]	...[4]	...[4]	...[4]
211	1	...[5]	...[5]	0.90	(0.03)	...[5]	6.0[6]
301	1	...[5]	...[5]	12	(0.43)	...[5]	78[6]
303	1	...[5]	...[5]	3.6	(0.13)	...[5]	24[6]
305	1	...[5]	...[5]	2.3	(0.08)	...[5]	1.5[6]
308	1	...[5]	...[5]	0.45	(0.02)	...[5]	3.0[6]
309	0	...[4]	...[4]	...[4]	...[4]	...[4]	...[4]
310	0	...[4]	...[4]	...[4]	...[4]	...[4]	...[4]
401	1	...[5]	...[5]	< 0.90	(0.03)	...[5]	6.0[6]
408	1	...[5]	...[5]	< 0.45	(0.02)	...[5]	3.0[6]
P1	2	< 0.45	< 0.45	< 0.45	(0.02)	...[5]	3.0[7]
P2	1	...[5]	...[5]	1.4	(0.05)	...[5]	9.0[7]
P3	1	...[5]	...[5]	0.90	(0.03)	...[5]	6.0[7]

1. See Figure 24.
2. Bq/l in parentheses.
3. C.L. = confidence level; ± value applicable to the average concentration.
4. Not sampled.
5. Not applicable.
6. Percent of Standard has been calculated for **reference** purposes **only**. USEPA drinking water standards do not apply to these wells, since they are used for monitoring purposes **only** and are not used for consumption by the public. Percent of Standard relates to the average value.
7. DOE has directed FMPC to use the USEPA standard for gross alpha activity in drinking water which is 15 pCi/l (0.6 Bq/l). This standard applies only to water sampled from the FMPC production wells. Percent of Standard relates to the average value.

TABLE 15
GROSS BETA CONCENTRATIONS IN ONSITE WELL WATER, 1988

Sampling Point[1]	Number of Samples	Concentration pCi/l				
		Minimum	Maximum	Average[2]	95% C.L.[3]	% of Standard
204	0	...[4]	...[4]	...[4] ...[4]	...[4]	...[4]
211	1	...[5]	...[5]	4.1 (0.15)	...[5]	8.0[6]
301	1	...[5]	...[5]	8.1 (0.30)	...[5]	16[6]
303	1	...[5]	...[5]	6.3 (0.23)	...[5]	13[6]
305	1	...[5]	...[5]	4.1 (0.15)	...[5]	8.0[6]
308	1	...[5]	...[5]	3.2 (0.12)	...[5]	6.0[6]
309	0	...[4]	...[4]	...[4] ...[4]	...[4]	...[4]
310	0	...[4]	...[4]	...[4] ...[4]	...[4]	...[4]
401	1	...[5]	...[5]	1.8 (0.07)	...[5]	4.0[6]
408	1	...[5]	...[5]	1.8 (0.07)	...[5]	4.0[6]
P1	1	...[5]	...[5]	5.0 (0.18)	...[5]	10
P2	1	...[5]	...[5]	1.8 (0.07)	...[5]	3.6
P3	1	...[5]	...[5]	1.8 (0.07)	...[5]	3.6

1. See Figure 24.
2. Bq/l in parentheses.
3. C.L. = confidence level; ± value applicable to the average concentration.
4. Not sampled.
5. Not applicable.
6. Percent of Standard has been calculated for **reference** purposes **only**. USEPA drinking water standards do not apply to these wells, since they are used for monitoring purposes **only** and are not used for consumption by the public. Percent of Standard relates to the average value.
7. DOE has directed FMPC to use the USEPA standard for gross beta activity in drinking water which is 50 pCi/l (1.9 Bq/l). This standard applies only to water sampled from the FMPC production wells. There is currently no gross beta standard which can be applied to surface water or monitoring wells which are not drinking water sources. Percent of Standard relates to the average value.

TABLE 16
NITRATE-NITROGEN IN ONSITE WELL WATER, 1988

Sampling Point[1]	Number of Samples	Concentration mg/l				
		Minimum	Maximum	Average	95% C.L.[2]	% of Standard
204	0	...[3]	...[3]	...[3]	...[3]	...[3]
211	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[5]
301	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[5]
303	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[5]
305	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[5]
308	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[5]
309	0	...[3]	...[3]	...[3]	...[3]	...[3]
310	0	...[3]	...[3]	...[3]	...[3]	...[3]
401	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[5]
408	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[5]
P1	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[6]
P2	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[6]
P3	1	...[4]	...[4]	< 0.10	...[4]	< 1.0[6]

1. See Figure 24.
2. C.L. = confidence level; ± value applicable to the average concentration.
3. Not sampled.
4. Not applicable.
5. Percent of Standard has been calculated for **reference** purposes **only**. USEPA drinking water standards do not apply to these wells since they are used for monitoring purposes **only** and are not used for consumption by the public. Percent of Standard relates to the average value.
6. 10 mg/l per 40 CFR Part 141, National Interim Primary Drinking Water Standard. Percent of Standard relates to the average value.

TABLE 17
SULFATE IN ONSITE WELL WATER, 1988

Sampling Point[1]	Number of Samples	Concentration mg/l				
		Minimum	Maximum	Average	95% C.L.[2]	% of Standard
204	0	...[3]	...[3]	...[3]	...[3]	...[3]
211	1	...[4]	...[4]	112	...[4]	45[5]
301	1	...[4]	...[4]	79	...[4]	32[5]
303	1	...[4]	...[4]	95	...[4]	38[5]
305	1	...[4]	...[4]	86	...[4]	34[5]
308	1	...[4]	...[4]	16	...[4]	6.4[5]
309	0	...[3]	...[3]	...[3]	...[3]	...[3]
310	0	...[3]	...[3]	...[3]	...[3]	...[3]
401	1	...[4]	...[4]	7.0	...[4]	2.8[5]
408	1	...[4]	...[4]	7.0	...[4]	2.8[5]
P1	1	...[4]	...[4]	159	...[4]	64[6]
P2	2	40	47	44	31	17[6]
P3	1	...[4]	...[4]	26	...[4]	10[6]

1. See Figure 24.
2. C.L. = confidence level; ± value applicable to the average concentration.
3. Not sampled.
4. Not applicable.
5. Percent of Standard has been calculated for **reference** purposes **only**. USEPA drinking water standards do not apply to these wells, since they are used for monitoring purposes **only** and are not used for consumption by the public. Percent of Standard relates to the average value.
6. 250 mg/l per 40 CFR Part 143, National Interim Secondary Drinking Water Standard. Percent of Standard relates to the average value.

TABLE 18
CHLORIDE IN ONSITE WELL WATER, 1988

Sampling Point[1]	Number of Samples	Concentration mg/l				
		Minimum	Maximum	Average	95% C.L.[2]	% of Standard
204	0	...[3]	...[3]	...[3]	...[3]	...[3]
211	1	...[4]	...[4]	23	...[4]	9.2[5]
301	1	...[4]	...[4]	21	...[4]	8.4[5]
303	1	...[4]	...[4]	27	...[4]	11[5]
305	1	...[4]	...[4]	21	...[4]	8.4[5]
308	1	...[4]	...[4]	17	...[4]	6.8[5]
309	0	...[3]	...[3]	...[3]	...[3]	...[3]
310	0	...[3]	...[3]	...[3]	...[3]	...[3]
401	1	...[4]	...[4]	23	...[4]	9.2[5]
408	1	...[4]	...[4]	12	...[4]	4.8[5]
P1	1	...[4]	...[4]	41	...[4]	16[6]
P2	2	24	32	28	36	11[6]
P3	1	...[4]	...[4]	13	...[4]	5.2[6]

1. See Figure 24.
2. C.L. = confidence level; ± value applicable to the average concentration.
3. Not sampled.
4. Not applicable.
5. Percent of Standard has been calculated for **reference** purposes **only**. USEPA drinking water standards do not apply to these wells, since they are used for monitoring purposes **only** and are not used for consumption by the public. Percent of Standard relates to the average value.
6. 250 mg/l per 40 CFR Part 143, National Interim Secondary Drinking Water Standard. Percent of Standard relates to the average value.

TABLE 19
pH IN ONSITE
WELL WATER, 1988

Sampling Point[1]	Number of Samples	pH
204	0	...[2]
211	1	7.5
301	1	7.4
303	1	7.5
305	1	7.5
308	1	8.8
309	0	...[2]
310	0	...[2]
401	1	7.4
408	1	7.5
P1	1	7.4
P2	2	7.5[3]
P3	1	7.5

1. See Figure 24.
2. Not sampled.
3. Both sample results were 7.5.

TABLE 20
URANIUM IN OFFSITE WELL WATER, 1988

Sampling Point[1]	Number of Samples	Concentration pCi/l					
		Minimum	Maximum	Average[2]		95% C.L.[3]	% of Standard[4]
1	12	0.07	0.27	0.15	(0.01)	0.04	0.38[4]
3	11	0.07	0.14	0.13	(0.005)	0.01	0.32[4]
4	12	0.81	1.8	1.2	(0.04)	0.01	3.0[4]
5	12	0.95	1.8	1.2	(0.05)	0.004	3.0[4]
7	12	0.95	1.3	1.1	(0.04)	0.06	2.8[4]
8	12	0.47	0.81	0.59	(0.02)	0.004	1.5[4]
9	12	0.61	1.0	0.93	(0.03)	0.005	2.3[4]
10	12	0.34	0.81	0.49	(0.02)	0.002	1.2[4]
11	12	0.74	1.2	0.99	(0.04)	0.003	2.5[4]
12	12	140	200	170	(6.3)	0.003	430[5]
13	12	0.20	1.3	0.42	(0.02)	1.2	1.0[4]
14	12	0.68	0.95	0.82	(0.03)	0.003	2.1[4]
15	12	170	210	190	(7.0)	0.004	480[5]
16	12	0.27	0.61	0.43	(0.02)	0.37	1.1[4]
17	8[6]	32	49	38	(1.4)	5.3	95[5]
18	12	0.27	0.54	0.38	(0.01)	0.05	0.96[4]
19	12	0.07	0.54	0.25	(0.01)	0.09	0.62[4]
21	12	0.20	0.34	0.27	(0.01)	0.002	0.68[4]
22	11	0.68	1.1	0.81	(0.03)	0.07	2.0[4]
23	12	0.41	0.81	0.55	(0.02)	0.002	1.4[4]
24	11	0.34	0.61	0.46	(0.02)	0.05	1.2[4]
25	4[7]	0.14	0.20	0.19	(0.01)	0.05	0.47[4]
26	12	0.14	0.34	0.17	(0.01)	0.04	0.42[4]
27	12	0.41	0.61	0.51	(0.02)	0.04	1.3[4]
28	4[7]	0.47	0.81	0.58	(0.02)	0.22	1.4[4]
29	12	1.2	1.5	1.3	(0.05)	0.07	3.3[4]
30	12	0.27	0.54	0.39	(0.01)	0.04	0.97[4]
31	6[8]	0.47	0.74	0.64	(0.02)	0.10	1.6[4]

1. See Figure 30.
2. Bq/l in parentheses.
3. C.L. = Average concentration; ± value applicable to the average concentration.
4. Percent of Standard relates to the average value reported. Standard used is 40 pCi/l (1.5 Bq/l). This value is the median value in the range of values (30 to 50 pCi/l) which FMPC has been directed to use as an interim drinking water limit for natural uranium in drinking water. See letter DOE-288-88.
5. Percent of Standard has been calculated for **reference** purposes **only**. The standard (40 pCi/l) only applies to finished water in public water systems. These wells are used for monitoring purposes only, the water contained in them is not consumed. Percent of Standard relates to the average value.
6. Not sampled during the latter period of 1988 because the well pump was inoperable.
7. Quarterly sampling as available.
8. Well owner withdrew from sampling program.

TABLE 21
METALS IN OFFSITE WELL WATER, 1988

Sampling Point[1]	Ag[2]	As[2]	Ba[2]	Ca	Cd[2]	Cr[2]	Cu[3]	Fe[3]	K	Mg	Mn[3]	Na	Ni	Pb[2]	Se[2]	Zn[3]
	Concentration mg/l															
1	< 0.001	0.014	0.381	79.0	< 0.001	< 0.001	0.012	3.92	1.30	24.2	0.019	17.4	< 0.001	< 0.001	0.002	0.022
3	< 0.001	0.010	0.462	80.4	< 0.001	< 0.001	0.004	3.995	1.49	24.8	0.017	32.2	< 0.001	< 0.001	0.001	0.008
4	0.001	0.004	0.055	133	< 0.001	0.001	0.026	0.486	3.44	67.0	0.001	49.4	< 0.001	0.002	0.014	0.033
5	< 0.001	0.001	0.050	164	< 0.001	< 0.001	0.041	0.939	3.07	59.6	0.048	40.0	< 0.001	0.001	0.003	0.142
7	< 0.001	0.003	0.073	120	< 0.001	< 0.001	0.011	1.27	2.57	33.5	0.125	9.45	< 0.001	< 0.001	0.004	0.038
8	< 0.001	0.001	0.062	90.3	< 0.001	< 0.001	0.008	0.219	3.46	28.2	0.176	19.2	< 0.001	< 0.001	< 0.001	0.009
9	< 0.001	< 0.001	0.087	78.0	< 0.001	< 0.001	0.006	0.379	3.31	28.5	0.555	36.8	< 0.001	< 0.001	0.005	0.009
10	< 0.001	0.002	0.056	112	< 0.001	< 0.001	0.006	3.845	2.82	30.2	0.255	11.2	0.001	< 0.001	0.001	0.007
11	< 0.001	0.001	0.050	83.1	< 0.001	< 0.001	0.052	0.213	3.15	25.2	0.001	32.8	0.002	< 0.001	0.004	0.106
12	< 0.001	0.002	0.041	82.4	< 0.001	< 0.001	0.016	0.181	3.69	22.6	0.001	11.4	0.002	< 0.001	0.002	0.138
13	< 0.001	0.002	0.040	90.5	< 0.001	< 0.001	0.025	0.212	2.68	27.4	0.029	16.5	0.001	< 0.001	0.009	0.013
14	< 0.001	0.003	0.105	113	< 0.001	< 0.001	0.011	1.08	5.42	33.2	0.278	23.8	0.002	< 0.001	0.008	0.015
15	< 0.001	0.006	0.041	79.2	< 0.001	< 0.001	0.043	0.184	4.99	20.8	0.008	10.7	< 0.001	< 0.001	0.006	0.042
16	< 0.001	< 0.001	0.078	105	< 0.001	< 0.001	0.010	0.228	2.28	30.6	0.001	31.4	< 0.001	< 0.001	0.007	0.008
17	0.001	0.004	0.066	97.0	< 0.001	< 0.001	< 0.001	2.29	2.74	24.6	0.399	13.4	< 0.001	< 0.001	0.005	0.011
18	0.001	0.002	0.070	104	< 0.001	< 0.001	< 0.001	3.31	2.41	28.3	0.234	10.2	< 0.001	< 0.001	0.004	0.005
19	0.001	0.094	0.039	167	< 0.001	< 0.001	0.013	2.94	52.2	58.8	0.320	21.2	0.001	0.002	0.016	0.019
21	< 0.001	0.004	0.074	104	> 0.001	< 0.001	0.009	2.655	2.31	28.1	0.261	10.2	< 0.001	< 0.001	0.007	0.038
22	< 0.001	0.007	0.036	87.2	< 0.001	< 0.001	0.009	0.227	3.58	23.0	0.068	11.2	0.002	< 0.001	0.003	0.042
23	< 0.001	< 0.001	0.043	88.8	< 0.001	< 0.001	0.011	0.342	1.43	27.0	0.070	4.75	< 0.001	< 0.001	0.001	0.008
24	0.001	< 0.001	0.051	118	< 0.001	< 0.001	< 0.001	0.246	2.95	35.5	0.078	7.24	< 0.001	< 0.001	0.009	0.032
26	< 0.001	0.006	0.068	105	< 0.001	< 0.001	0.011	2.91	2.06	28.2	0.313	7.04	0.001	< 0.001	0.006	0.053
27	< 0.001	< 0.001	0.073	120	< 0.001	< 0.001	0.176	0.239	3.81	27.2	0.003	19.8	< 0.001	< 0.001	0.008	0.262
29	< 0.001	0.003	0.078	104	< 0.001	< 0.001	0.007	6.09	4.15	30.0	0.261	11.2	< 0.001	< 0.001	0.009	0.010
30	< 0.001	0.001	0.50	99.8	< 0.001	< 0.001	0.020	0.210	3.82	27.5	< 0.001	22.6	< 0.001	0.001	< 0.001	0.014
31	< 0.001	0.003	0.005	34.8	< 0.001	< 0.001	< 0.001	0.271	1.31	12.8	0.047	8.82	< 0.001	< 0.001	< 0.001	0.011

1. See Figure 30. Samples were not taken at sampling points 2, 6, 20, 25 and 28.
2. USEPA Drinking Water Guidelines: (Taken from 40 CFR Part 141 National Interim Primary Drinking Water Regulations-Subpart B-Maximum Contaminant Levels, July 1, 1984). Ag = 0.05 ppm; As = 0.05 ppm; Ba = 1.0 ppm; Cd = 0.010 ppm; Cr = 0.05 ppm; Pb = 0.05 ppm; Se = 0.01 ppm.
3. USEPA Drinking Water Guidelines: (Taken from 40 CFR Part 143 National Secondary Drinking Water Regulations-Section 143.3-Secondary Maximum Contaminant Level Cu = 1.0 ppm; Fe = 0.3ppm; Mn = 0.05 ppm; Zn = 5.0 ppm.

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TABLE 22
RADIONUCLIDES IN SURFACE WATER, 1988
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Radionuclide	Sampling Point[1]	Number of Samples[2]	Concentration[3] pCi/l Minimum	Maximum	Average		95% C.L.[4]	% of Standard[5]	Standard[6] pCi/l
Gross Alpha[7]	W1	52	0.9	6.8	2.1	(0.08)	0.31	...[8]	...[7]
	W3	52	1.4	8.6	2.9	(0.11)	0.36	...[8]	
	W4	52	1.4	6.3	3.0	(0.11)	0.33	...[8]	
	W5	50	0.45	3.2	< 1.5	(0.06)	0.16	...[8]	
	W7	14	4.1	15	6.8	(0.25)	1.5	...[8]	
	W8	22	1.4	4.1	2.7	(0.10)	0.32	...[8]	
	W9	33	< 0.45	11	2.6	(0.10)	0.73	...[8]	
	W10	24	1.4	824	39	(1.5)	69	...[8]	
	W11	16	3.2	11	5.7	(0.21)	1.1	...[8]	
Gross Beta[7]	W1	52	3.6	11	6.1	(0.23)	0.45	...[8]	...[7]
	W3	52	3.6	36	9.8	(0.36)	1.5	...[8]	
	W4	52	3.6	28	9.8	(0.36)	1.4	...[8]	
	W5	50	2.3	8.6	4.8	(0.18)	0.34	...[8]	
	W7	14	3.6	14	6.8	(0.25)	1.6	...[8]	
	W8	22	1.8	9.9	4.2	(0.15)	0.87	...[8]	
	W9	33	2.7	16	5.9	(0.22)	1.2	...[8]	
	W10	24	3.2	369	21	(0.79)	31	...[8]	
	W11	16	3.6	9.5	6.2	(0.23)	0.88	...[8]	
Cs-137	W1	2	< 4.4	< 6.6	< 5.5	(< 0.20)	< 10	< 0.18	3000
	W3	2	< 4.5	< 7.2	< 5.9	(< 0.22)	< 12	< 0.20	
	W4	2	< 3.9	< 7.5	< 5.7	(< 0.21)	< 16	< 0.19	
Ra-226	W1	12	< 0.45	0.45	< 0.45	(0.02)	...[8]	< 0.45	100
	W3	12	< 0.45	0.45	< 0.45	(< 0.02)	...[8]	< 0.45	
	W4	12	0.45	0.45	0.45	(0.02)	...[8]	0.45	
	W5	6	< 0.45	< 0.45	< 0.45	(< 0.02)	...[8]	< 0.45	
	W7	5	< 0.45	< 0.45	< 0.45	(< 0.02)	...[8]	< 0.45	
	W8	6	< 0.45	0.90	0.53	(0.02)	0.18	0.53	
Ra-228	W1	12	< 0.45	0.90	0.56	(0.02)	0.12	0.56	100
	W3	12	< 0.45	< 0.45	< 0.45	(< 0.02)	...[8]	< 0.45	
	W4	12	< 0.45	< 0.45	< 0.45	(< 0.02)	...[8]	< 0.45	
	W5	6	< 0.45	0.90	0.60	(0.02)	0.22	0.60	
	W7	5	< 0.45	0.90	0.54	(0.02)	0.22	0.54	
	W8	6	< 0.45	< 0.45	< 0.23	(0.01)	< 0.24	< 0.23	
Sr-90	W1	2	0.21	0.33	0.27	(0.01)	0.54	0.27	100
	W3	2	0.14	0.23	0.19	(0.01)	0.40	0.19	
	W4	2	0.08	0.14	0.11	(0.004)	0.26	0.11	

TABLE 22
RADIONUCLIDES IN SURFACE WATER, 1988
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Radionuclide	Sampling Point[1]	Number of Samples[2]	Concentration[3] pCi/l Minimum	Maximum	Average	95% C.L.[4]	% of Standard[5]	Standard[6] pCi/l
Tc-99	W1	2	< 10.4	< 10.6	< 10.5 (< 0.39)	< 0.90	< 0.01	100,000
	W3	2	< 9.2	< 9.6	< 9.4 (< 0.35)	< 1.8	< 0.01	
	W4	2	< 9.1	< 9.5	< 9.3 (< 0.34)	< 1.8	< 0.01	
U-234	W1	2	0.78	0.86	0.82 (0.03)	0.35	0.16	500
	W3	2	0.89	1.2	1.1 (0.04)	1.5	0.21	
	W4	2	0.93	0.94	0.94 (0.03)	0.02	0.19	
U-235/236	W1	2	< 0.02	< 0.02	< 0.02 (< 0.001)	< 0.05	< 0.004	500
	W3	2	< 0.02	< 0.02	< 0.02 (< 0.001)	< 0.02	< 0.004	
	W4	2	< 0.02	< 0.02	< 0.02 (< 0.001)	< 0.02	< 0.004	
U-238	W1	2	0.73	0.78	0.75 (0.03)	0.23	0.13	600
	W3	2	0.86	1.1	0.97 (0.04)	0.98	0.16	
	W4	2	0.86	1.0	0.95 (0.04)	0.80	0.16	
Total Uranium	W1	52	0.61	1.6	0.98 (0.04)	0.06	0.18	550
	W3	52	0.81	2.8	1.5 (0.01)	0.10	0.27	
	W4	52	0.81	2.9	1.4 (0.05)	0.09	0.26	
	W5	50	0.34	1.4	0.78 (0.03)	0.07	0.14	
	W7	50	2.9	16	7.0 (0.26)	2.6	1.3	
	W8	22	1.0	4.8	2.1 (0.08)	0.43	0.38	
	W9	33	0.27	21	2.6 (0.09)	1.4	0.47	
	W10	24	1.4	812	39 (1.4)	68	7.1	
	W11	16	2.7	13	5.7 (0.21)	1.5	1.0	

1. See Figure 33.
2. Samples are composited for radium analyses as follows: one-month composites of daily samples from W1 and W3; one-month composites of weekly samples from W4, two-month composites of weekly samples from W5, and one-month composites of all available weekly samples from W7. Semiannual composites were used for those isotopes where two samples are noted.
3. Bq/l in parentheses.
4. C.L. = confidence level; ± value applicable to the average concentration.
5. Percent of Standard is calculated from average value. Neither the Great Miami River nor Paddy's Run is used as a source of public drinking water downstream from the FMPC, but DOE effluent discharge standards have been used in these calculations.
6. Drinking Water Guidelines from DOE Draft Order 5400.xx, 3-18-88.
7. No applicable DOE Standard.
8. Not applicable.

TABLE 23
URANIUM CONCENTRATIONS IN STORMWATER DRAINAGE DITCH, 1988

Sampling Location[1]	Total Uranium Concentration[2] in pCi/l
DD01	3 (0.11)
DD07	905 (34)
DD08	17 (0.63)
DD09	368 (14)
DD12	389 (14)
DD13	151 (5.6)
DD14	361 (13)
DD17	87 (3.2)
DD19	176 (6.5)
DD21	2 (0.07)
DD23	80 (3)
DDALT/3	592 (22)

1. See Figure 37.
2. Bq/l in parentheses.

TABLE 24
ION AND pH LEVELS IN SURFACE WATER, 1988

Parameter	Sampling Point[1]	Number of Samples	Concentration (mg/l) Minimum	Maximum	Average	95% C.L.[2]	% of Standard	Standard[3]
Fluoride	W1	51	0.30	1.2	0.60	0.06	15	4.0 mg/l
	W3	51	0.30	1.4	0.61	0.06	15	
	W4	51	0.30	1.7	0.59	0.07	15	
	W5	12	0.10	0.60	0.28	0.09	7.0	
	W7	5	0.20	0.80	0.40	0.31	10	
	W8	8	0.10	0.50	0.23	0.12	6.0	
	W9	10	0.10	0.50	0.27	0.07	7.0	
	W10	7	0.10	0.50	0.24	0.11	6.0	
	W11	5	0.20	0.80	0.38	0.30	9.5	
Nitrate (as N)	W1	52	0.50	7.4	3.0	0.43	30	10 mg/l
	W3	52	0.20	7.5	3.0	0.45	30	
	W4	52	0.10	7.5	2.9	0.46	29	
	W5	11	0.10	4.2	1.5	0.87	15	
	W7	5	1.9	3.5	2.5	0.73	25	
	W8	8	< 0.10	5.0	0.76	1.3	7.6	
	W9	10	< 0.10	24	3.4	4.9	34	
	W10	7	0.20	39	2.1	1.1	21	
	W11	5	1.9	3.8	2.6	0.84	26	
Chloride	W1	52	40	159	94	9.1	37	250 mg/l
	W3	52	39	155	92	8.7	37	
	W4	52	38	156	90	8.4	36	
	W5	12	8.0	51	36	8.2	14	
	W7	5	9.0	33	24	11	9.6	
	W8	8	6.0	29	12	6.4	4.8	
	W9	10	8.0	46	28	8.1	11	
	W10	7	9.0	46	29	10	12	
	W11	5	10	34	24	11	9.6	
pH[4]	W1	52	8.0	9.2	8.7	0.56	...[5]	6.5 - 9.0
	W3	52	8.1	9.2	8.2	0.47	...[5]	
	W4	52	8.0	9.6	8.2	0.47	...[5]	
	W5	50	7.6	8.4	7.9	0.06	...[5]	
	W7	14	7.9	8.5	8.3	0.07	...[5]	
	W8	22	7.2	8.2	7.8	0.08	...[5]	
	W9	33	7.7	8.4	8.1	0.06	...[5]	
	W10	24	7.9	8.5	8.2	0.05	...[5]	
	W11	16	7.9	8.4	8.3	0.07	...[5]	

1. See Figure 33.
2. C.L. = confidence level; ± value applicable to the average concentration.
3. Ohio EPA Water Quality Standards, Administrative Code Chapter 3745-1 (Public Water Supply Use Designation).
4. pH is reported in standard units.
5. Average pH value is within the acceptable standard range.

TABLE 25
RADIONUCLIDES RELEASED AT DISCHARGE 001, 1988

Radionuclide[1]	Total Curies 1987	Total Curies 1988[2]	Average Concentration[3] pCi/l	Standard[3,4] pCi/l	% of Standard[5]
Ac-227	. . . [6]	$< 1.6 \times 10^{-2}$ ($< 5.9 \times 10^{8}$)	$< 2.2 \times 10^{1}$ ($< 8.1 \times 10^{-1}$)	10	< 217
Cs-137	$< 7.5 \times 10^{-3}$	$< 4.9 \times 10^{-3}$ ($< 1.8 \times 10^{8}$)	$< 6.5 \times 10^{0}$ ($< 2.4 \times 10^{-1}$)	3000	< 0.2
K-40	. . . [6]	$< 6.8 \times 10^{-2}$ ($< 2.5 \times 10^{9}$)	$< 8.4 \times 10^{1}$ ($< 3.1 \times 10^{0}$)	7000	< 1.2
Np-237	$< 2.4 \times 10^{-4}$	$< 3.3 \times 10^{-5}$ ($< 1.2 \times 10^{6}$)	$< 4.5 \times 10^{-2}$ ($< 1.7 \times 10^{-3}$)	30	< 0.2
Pb-210	. . . [6]	$< 6.6 \times 10^{-3}$ ($< 2.4 \times 10^{8}$)	$< 8.6 \times 10^{0}$ ($< 3.2 \times 10^{-1}$)	30	< 29
Pu-238	$< 5.6 \times 10^{-5}$	$< 1.6 \times 10^{-5}$ ($< 5.9 \times 10^{5}$)	$< 2.2 \times 10^{-2}$ (8.0×10^{-4})	40	< 0.1
Pu-239/240	$< 5.6 \times 10^{-5}$	$< 2.3 \times 10^{-5}$ ($< 8.5 \times 10^{5}$)	$< 2.8 \times 10^{-2}$ ($< 1.0 \times 10^{-3}$)	30	< 0.1
Ra-226	$< 4.0 \times 10^{-3}$	$< 2.4 \times 10^{-3}$ ($< 8.9 \times 10^{7}$)	$< 6.7 \times 10^{0}$ ($< 2.5 \times 10^{-1}$)	100	< 6.7
Ra-228	$< 3.9 \times 10^{-3}$	$< 2.1 \times 10^{-3}$ (7.9×10^{7})	$< 5.6 \times 10^{0}$ ($< 2.1 \times 10^{-1}$)	100	< 5.6
Ru-106	$< 3.3 \times 10^{-2}$	$< 3.2 \times 10^{-2}$ ($< 1.2 \times 10^{9}$)	$< 4.2 \times 10^{1}$ ($< 1.6 \times 10^{0}$)	6000	< 0.7
Sr-90	2.2×10^{-3}	1.2×10^{-3} (4.4×10^{7})	1.6×10^{0} (5.7×10^{-2})	1000	0.2
Tc-99	2.7×10^{0}	5.9×10^{0} (2.2×10^{11})	7.2×10^{3} (2.7×10^{2})	100000	7.2
Th-228	$< 4.0 \times 10^{-4}$	3.2×10^{-4} (1.2×10^{7})	4.1×10^{-1} (1.5×10^{-2})	400	0.1
Th-230	$< 4.8 \times 10^{-4}$	7.4×10^{-4} (2.7×10^{7})	9.2×10^{-1} (3.4×10^{-2})	300	0.3
Th-232	$< 3.6 \times 10^{-4}$	8.7×10^{-5} (3.2×10^{6})	1.1×10^{-1} (4.2×10^{-3})	50	0.2
Th-234	. . . [6]	$< 7.9 \times 10^{-2}$ (2.9×10^{9})	7.9×10^{1} (2.9×10^{0})	10000	0.8
U-233	. . . [6]	$< 8.3 \times 10^{-2}$ ($< 3.1 \times 10^{9}$)	$< 9.8 \times 10^{1}$ ($< 3.6 \times 10^{0}$)	500	< 20
U-234	2.4×10^{-1}	2.4×10^{-1} (8.9×10^{9})	3.1×10^{2} (1.2×10^{1})	500	63
U-235	1.2×10^{-2}	1.2×10^{-2} (4.4×10^{8})	1.5×10^{1} (5.6×10^{-1})	600	2.5
U-236	1.0×10^{-2}	1.1×10^{-2} (4.2×10^{8})	1.5×10^{1} (5.5×10^{-1})	500	3.0
U-238	2.6×10^{-1}	2.8×10^{-1} (1.0×10^{10})	3.4×10^{2} (1.3×10^{1})	600	57
U-total[9]	5.2×10^{-1}	5.5×10^{-1} (2.0×10^{10})	6.9×10^{2} (2.5×10^{1})	550	125

1. Radionuclide concentrations in the plant effluent discharged to the Great Miami River through the effluent pipeline (with the exception of the two radium isotopes) are determined from two 6-month composites.
2. Bq in parentheses.
3. Bq/l in parentheses.
4. As stated in DOE Draft Order 5400.xx, March 18, 1988.
5. Percent of standard relates to the average value reported.
6. Not analyzed in 1987.
7. Not analyzed in 1988.
8. Not applicable.
9. Total uranium does not include U-233, which was not detected in any samples in 1988.

TABLE 26
NPDES DATA, 1988

Sampling Location[1]/ Parameter	Units	Number of Samples	Daily Minimum	Daily Maximum	Annual Average	NPDES Permit Limits: Daily Maximum	NPDES Permit Limits: Monthly Average	Percent Compliance
Discharge 001 (MH175)								
Flow Rate	MGD	Continuous	0.115	1.330	0.556	...[4]	...[4]	...[4]
pH	pH Units	Daily Grab	7.2	9.1	...[4]	Range = 6.5 to 9.0		99
Suspended Solids[2]	mg/l	51	2.0	72	14	40	20	86
Ammonia (as N)	mg/l	51	< 0.1	5.9	< 0.5	...[4]	...[4]	...[4]
Oil & Grease	mg/l	51	<5	8	<5	15	...[4]	100
Residual Chlorine	mg/l	47	< 0.02	0.1	< 0.04	0.1	...[4]	100
Nitrate (as N)	mg/l	51	1.3	246	47	...[4]	...[4]	...[4]
Discharge 002[3] (Storm-Sewer Outfall)								
Flow Rate	MG/Event	Continuous	...[4]	...[4]	0.4	...[4]	...[4]	...[4]
pH	pH Units	Grab/Event	...[4]	...[4]	...[4]	Range = 6.5 to 9		100
Suspended Solids[2]	mg/l	25	...[4]	...[4]	76	100	30	75
Oil & Grease	mg/l	25	...[4]	...[4]	<5	15	...[4]	100
Sampling Location 001A (Sewage Treatment Plant)								
Flow Rate	MGD	Continuous	0.09	0.4	0.26	...[4]	...[4]	...[4]
pH	pH Units	Daily Grab	7.5	8.9	...[4]	Range = 6.5 to 9.0		100
BOD_5	mg/l	51	2	91	15	40	20	86
Suspended Solids	mg/l	51	1	62	15	40	20	88
Fecal Coliform[2]	MPN/100ml	47	1	6000	2600	2000	1000	89
BOD_5	kg/day	51	0.4	120	17	10	5	45
Suspended Solids	kg/day	51	0.3	93	17	10	5	33
Sampling Locations 001B & C (Combined General Sump & Clearwell)								
Flow Rate	MGD	Continuous	0.000	0.50	0.05	...[4]	...[4]	...[4]
Suspended Solids	kg/day	51	< 0.0001	19	1.4	13	< 6.2	98
Chromium (+6)	kg/day	51	< 0.0001	0.002	0.0003	0.008	< 0.004	100
Chromium (total)	kg/day	51	< 0.0001	0.004	0.0006	0.1	< 0.05	100
Iron	kg/day	51	0.0003	0.51	0.04	0.85	0.41	100
Nickel	kg/day	51	< 0.0001	0.01	0.0009	0.26	< 0.12	100
Copper	kg/day	51	0.0001	0.01	0.0009	0.05	0.03	100
Sampling Location 001D (Storm-Sewer Lift Station)								
Flow Rate	MGD	Continuous	0.008	0.72	0.17	...[4]	...[4]	...[4]
Suspended Solids	mg/l	51	<2	370	< 19	100	30	90
Oil & Grease	mg/l	51	<5	<5	<5	15	...[4]	100
Sampling Location 001E (Bioreactor)								
Flow Rate	MGD	Continuous	0.025	0.219	0.13	...[4]	...[4]	...[4]
Nitrate-Nitrogen	kg/day	52	0.03	300	57	124	62	77
Ammonia-Nitrogen	kg/day	52	0.03	5.8	0.61	18	12	100

TABLE 27
RADIOISOTOPES IN GREAT MIAMI RIVER, PADDY'S RUN, AND STORM-SEWER OUTFALL DITCH SEDIMENTS, 1988 (page 1 of 2)

		Isotope Concentration[2] pCi/g (dry weight)											
Location[1]	Statistics	PU-238	Pu-239/ 240	Ra-224	Ra-226	Ra-228	Tc-99	Th-228	Th-230	Th-232	U-234	U-235/ 236	U-238
Paddy's Run Above Storm-Sewer Outfall	minimum	< 0.002	< 0.002	0.26	0.14	0.19	< 1.0	0.17	0.32	0.17	0.04	< 0.01	0.24
	maximum	< 0.003	< 0.003	0.80	1.4	1.1	< 1.0	0.66	2.5	0.87	1.3	0.10	1.5
	average	< 0.003	< 0.003	0.45	0.65	0.41	< 1.0	0.36	0.63	0.35	0.53	< 0.05	0.62
	95% CL[3]	...[4]	...[4]	0.30	0.05	0.03	...[4]	0.03	0.07	0.03	0.05	...[4]	0.06
Storm-Sewer Outfall	minimum	< 0.001	< 0.001	0.32	0.21	0.35	< 1.0	0.29	0.49	0.30	0.81	< 0.05	0.92
	maximum	0.02	0.05	1.7	0.98	1.8	< 1.0	1.7	1.8	1.7	25	2.6	38
	average	< 0.004	< 0.005	0.77	0.72	0.74	< 1.0	0.64	0.91	0.64	4.5	0.38	5.6
	95% CL[3]	...[4]	...[4]	0.12	0.07	0.13	...[4]	0.12	0.14	0.12	1.8	0.20	2.8
Paddy's Run Below Storm-Sewer Outfall	minimum	< 0.01	< 0.01	0.19	0.42	0.23	< 0.90	0.10	0.21	0.07	0.06	< 0.05	0.32
	maximum	< 0.05	< 0.05	0.90	2.1	0.85	< 0.90	0.74	4.8	1.0	2.8	0.23	3.1
	average	< 0.01	< 0.01	0.44	0.69	0.41	< 0.90	0.34	0.67	0.32	0.68	0.06	0.77
	95% CL[3]	...[4]	...[4]	0.04	0.09	0.04	...[4]	0.04	0.09	0.04	0.12	0.01	0.15
Great Miami River Above FMPC Effluent Line	minimum	< 0.01	< 0.01	0.37	0.52	0.39	< 0.90	0.14	0.36	0.13	0.40	< 0.01	0.52
	maximum	< 0.01	< 0.01	0.81	0.80	0.73	< 0.90	0.62	0.87	0.44	0.60	< 0.05	0.95
	average	< 0.01	< 0.01	0.62	0.71	0.60	< 0.90	0.38	0.66	0.32	0.53	< 0.04	0.69
	95% CL[3]	...[4]	...[4]	0.46	0.34	0.38	...[4]	0.49	0.54	0.34	0.23	...[4]	0.46

1. See Figure 44.
2. Multiply pCi/l by 0.037 to obtain Bq/l.
3. C.L.= confidence level; ± value applicable to the average concentration.
4. Not applicable.

TABLE 27
RADIOISOTOPES IN GREAT MIAMI RIVER, PADDY'S RUN, AND STORM-SEWER OUTFALL DITCH SEDIMENTS, 1988 (page 2 of 2)

		Isotope Concentration[2] pCi/g (dry weight)											
Location[1]	Statistics	PU-238	Pu-239/240	Ra-224	Ra-226	Ra-228	Tc-99	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Great Miami River Below FMPC Effluent Line, Above Paddy's Run	minimum	< 0.01	< 0.01	0.36	0.50	0.36	< 0.90	0.12	0.32	0.10	0.60	< 0.05	0.63
	maximum	< 0.01	< 0.01	1.1	1.0	0.82	< 0.90	0.46	0.59	0.47	0.91	< 0.05	0.85
	average	< 0.01	< 0.01	0.69	0.76	0.54	< 0.90	0.28	0.44	0.25	0.69	< 0.05	0.71
	95% CL[3]	...[4]	...[4]	0.49	0.32	0.31	...[4]	0.25	0.17	0.23	0.21	...[4]	0.14
Great Miami River Below Paddy's Run	minimum	< 0.01	< 0.01	0.24	0.42	0.21	< 0.90	0.12	0.33	0.11	0.38	< 0.05	0.37
	maximum	< 0.01	< 0.01	0.75	0.77	0.77	< 0.90	0.34	0.54	0.32	0.63	< 0.05	0.58
	average	< 0.01	< 0.01	0.49	0.59	0.49	< 0.90	0.23	0.44	0.22	0.51	< 0.05	0.48
	95% CL[3]	...[4]	...[4]	2.3	1.6	2.5	...[4]	0.99	0.94	0.94	1.1	...[4]	0.94

1. See Figure 44.
2. Multiply pCi/l by 0.037 to obtain Bq/l.
3. C.L.= confidence level; ± value applicable to the average concentration.
4. Not applicable.

TABLE 28
URANIUM CONCENTRATION IN FISH, 1987/88

Sampling Location[1]	Family[2]	Number of Samples 1987	Number of Samples 1988	Concentration[3] pCi/g Minimum 1987	Minimum 1988	Maximum 1987	Maximum 1988	Average[4] 1987	Average[4] 1988	95% C.L.[5] 1987	95% C.L.[5] 1988
1 (Upstream)	1	5	6	0.0021	0.0042	0.0494	0.32	0.0120	0.14	0.0232	0.10
	2	1	2	0.0025	< 0.0005	0.0025	< 0.0007	0.0025	< 0.0006	...[6]	...[6]
	3	3	6	0.0004	< 0.0006	0.0019	0.059	0.0011	0.014	0.0011	0.022
	4	8	8	0.0006	0.0068	0.0041	0.30	0.0024	0.088	0.0009	0.075
	5	0	2	...[6]	0.011	...[6]	0.92	...[6]	0.46	...[6]	4.1
	Total	17	24	0.0004	< 0.0005	0.0494	0.92	0.0050	0.11	0.0057	0.081
2 (Outfall)	1	3	6	0.0027	< 0.0005	0.0106	0.069	0.0056	0.039	0.0089	0.025
	2	6	4	0.0009	0.0042	0.0047	0.62	0.0029	0.22	0.0013	0.39
	3	6	4	0.0034	< 0.0005	0.0053	0.66	0.0041	0.19	0.0007	0.44
	4	4	9	0.0044	0.0025	0.0181	0.73	0.0087	0.10	0.0077	0.17
	5	2	3	0.0044	0.0025	0.0042	0.34	0.0030	0.22	0.0108	0.39
	Total	21	26	0.0009	< 0.0005	0.0181	0.73	0.0047	0.13	0.0016	0.088
3 (Down-stream)	1	0	2	...[6]	0.0022	...[6]	2.1	...[6]	1.1	...[6]	9.5
	2	1	0	0.0021	...[6]	0.0021	...[6]	0.0021	...[6]	...[6]	...[6]
	3	2	12	0.0007	0.0032	0.0040	1.2	0.0023	0.21	0.0146	0.23
	4	19	2	0.0020	0.052	0.0214	0.11	0.0067	0.082	0.0019	0.27
	5	1	0	0.0016	...[6]	0.0016	...[6]	0.0016	...[6]	...[6]	...[6]
	Total	23	16	0.0007	0.0022	0.0214	2.1	0.0059	0.30	0.0018	0.30

1. See Figure 45.
2. Family: 1 = Cyprinidae (carp)
   2 = Catastomidae (carpsucker, redhorse, hogsucker)
   3 = Centrarchidae, Sciaenidae (bass, sunfish, drum, sauger, crappie)
   4 = Clupeidae (gizzard shad)
   5 = Ictaluridae (catfish)
3. All concentrations in dry weight.
4. Multiply by 0.037 to obtain Bq/g (dry wt.).
5. C.L. = confidence level; ± value applies to the average concentration.
6. Not Applicable.

TABLE 29
WASTE SHIPMENT DATA, 1988

Material Description	Cubic Feet
Scrap Wood	55,500
Magnesium Fluoride	27,371
Baled Trash	33,618
Filter and Sump Cake	67,092
Refuse Metal	109,931
Furnace Salt	4,528
Dust Collector Residues	1,302
Incinerator Ash	3,034
Construction Rubble	8,874
Asbestos	15,349
Graphite	7,212
Unrecoverable Residues	1,235
PCB Capacitors	178
TOTAL	335,224

Appendix B - Results for Round 6 RCRA Sampling

The FMPC relies on the data from several programs to monitor the effects of its operation on the environment. The FMPC/RCRA Monitoring Program is one example of a groundwater monitoring program. All onsite wells and offsite wells 8, 12, 15, 17, and 26 were sampled quarterly in 1986 and semiannually in 1987. In many instances, cross comparisons among three laboratories were used to verify data. Identification letters and numbers of offsite wells sampled and reported for the RCRA program are not the same as the identification letters and numbers used in this report. Well 8 in the EMR is identified as SW-2 in the RCRA sampling data, well 12 is OS-1, well 15 is OS-2, well 17 is OS-3, and well 26 is 15d.

This appendix lists the parameters analyzed for the RCRA groundwater sampling program, and includes the results of sampling round six conducted in late 1987. However, the data for round six were not available until 1988; consequently, they are presented in this report. Sampling round one was reported in the 1985 Environmental Monitoring Report, rounds two and three were reported in the 1986 FMPC Environmental Monitoring Report, and results of rounds four and five were reported in the 1987 EMR.[35,36,37]

Parameters Analyzed for RCRA Groundwater Sampling

A. For General Water Quality

1. Chloride
2. Iron
3. Manganese
4. Phenols (total)
5. Sodium
6. Sulfate

B. For Indicators of Contamination (Quadruplicate Analysis)

1. pH
2. Specific Conductance
3. Total Organic Carbon (TOC)
4. Total Organic Halogen (TOX)

C. For Drinking Water Suitability

1. Arsenic
2. Barium
3. Cadmium
4. Chromium
   - Hexavalent
   - Total.
5. Fluoride
6. Lead
7. Mercury
8. Nitrate (as N)
9. Selenium
10. Silver
11. Gross alpha
12. Gross beta
13. Radium
14. Endrin
15. Lindane
16. Methoxychlor
17. Toxaphene
18. 2,4-D
19. 2,4,5-TP Silvex
20. Coliform Bacteria

D. Other Metals, Organics, and Site Specific Parameters

1. Nickel
2. Cyanide
3. Copper
4. Zinc
5. Magnesium
6. Calcium
7. Phosphorus
8. Chlorobenzene
9. Chlorodibromomethane
10. Chloroethane
11. 2-chloroethylvinyl Ether
12. Chloroform
13. Dichlorobromomethane
14. Dichlorodifluoromethane
15. Total Dissolved Solids (TDS)
16. Total Potassium
17. Chemical Oxygen Demand (COD)
18. perChloroethylene
19. cis-1,2-Dichloroethylene
20. Tributylphosphate
21. Acrolein
22. Acrylonitrile
23. Benzene
24. bis (chloromethyl) Ether
25. Bromoform
26. Bromodichloromethane
27. Bromomethane
28. Carbontetrachloride
29. Chloromethane
30. 1,2-Dichlorobenzene
31. 1,3-Dichlorobenzene
32. 1,4-Dichlorobenzene
33. 1,1-Dichloroethane
34. 1,2-Dichloroethane
35. 1,1-Dichloroethylene
36. 1,2-Dichloropropane
37. 1,2-Dichloropropylene
38. Ethylbenzene
39. Methylbromide
40. Methylchloride
41. trans-1,2-Dichloroethylene
42. 1,3-Dichloropropene
43. 1,1,2,2-Tetrachloroethane
44. Tetrachloroethylene
45. Toluene
46. 1,1,1-Trichloroethane
47. 1,1,2-Trichloroethane
48. Trichloroethylene
49. Trichlorofluoromethane
50. Vinyl Chloride

E. Radionuclides

1. Potassium 40
2. Total Uranium
3. Radium 226
4. Radium 228
5. Technetium 99
6. Thorium 228
7. Thorium 230
8. Thorium 232
9. Cesium 137
10. Strontium 90
11. Ruthenium 106
12. Neptunium 237
13. Plutonium 238
14. Plutonium 239
15. Plutonium 240

TABLE 30
SIXTH ROUND WATER LEVEL ELEVATION, 1987

Well location	Depth to Water(ft)	Casing Elevation(MSL)	Grade(MSL)	Water Table Elevation(MSL)
P-1	NA	578.66	576.66	NA
P-2	NA	579.16	577.16	NA
P-3	NA	579.36	577.36	NA
301	NA	585.55	583.47	NA
401	65.92	585.31	583.81	519.39
303	NA	560.86	559.30	NA
204	35.75	556.85	556.15	521.10
305	NA	557.09	555.53	NA
308	57.00	576.60	574.90	519.60
408	57.00	576.62	574.82	519.62
309	36.51	557.23	555.31	520.72
310	69.51	588.39	586.56	518.88
211	65.23	585.78	583.64	520.55
112	35.85	639.67	637.48	603.82
213	72.93	590.37	588.71	517.44
313	72.75	590.36	588.72	517.61
214	16.80	535.79	533.76	518.99
314	16.80	535.81	533.71	519.01
215	61.51	579.65	577.80	518.14
415	63.90	579.41	577.80	515.51
216	23.00	542.28	540.47	519.28
316	22.81	542.13	540.50	519.32
217	17.10	536.19	534.43	519.09
317	17.33	536.35	534.28	519.02
218	53.43	573.36	571.31	519.93
318	41.75	573.88	571.56	532.13
219	65.23	585.38	583.26	520.15
319	65.00	585.25	583.20	520.25
119	7.62	584.96	582.98	577.34
220	56.72	574.44	573.42	517.72
320	57.90	574.71	573.31	516.81
120	6.15	574.73	573.21	568.58
221	65.62	586.02	594.42	520.40
121	4.50	585.61	584.06	581.11
222	67.25	587.95	587.93	520.70
122	8.45	588.91	587.93	580.46
SW-2	NA	NA	NA	NA
OS-1	63.90	581.83	581.35	517.93
OS-2	NA	NA	NA	NA
OS-3	NA	NA	NA	NA
OS-1A	14.48	581.83	581.83	567.35
*268	61.90	579.93	577.93	518.03
*267	78.00	595.58	593.22	517.58
*270	76.82	594.22	592.17	517.40
*369	57.81	576.02	574.07	518.21

MSL = Mean Sea Level.
NA = Not Available.
*= Not Sampled.

TABLE 31
SHALLOW (TILL) FMPC GROUNDWATER SAMPLING RESULTS, SIXTH ROUND, 1987
(All results in ppm except as noted)

Well location	112	119	120	121	122	OS-1A
Chloride	110.0	420.0	4.0	14.0	90.0	20.0
Iron	0.064	1.270	0.098	0.450	0.130	< 0.050
Manganese	< 0.015	1.500	0.390	0.980	2.130	< 0.015
Phenols	< 0.005	< 0.005	0.005	< 0.005	0.005	0.010
Sodium	226.000	418.000	2.670	10.000	22.900	20.900
Sulfate	4.0	280.0	40.0	220.0	410.0	84.0
Silver	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Arsenic	< 0.0025	< 0.0025	< 0.0025	< 0.0025	0.003	< 0.0025
Barium	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200
Calcium	17.600	456.000	77.300	119.000	323.000	99.200
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cyanide	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.005
Chromium						
-Total	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
- Hexavalent	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Copper	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
Fluoride	0.76	0.30	1.13	0.94	0.61	0.61
Mercury	< 0.0002	< 0.0002	< 0.0003	< 0.0002	0.0003	< 0.0002
Potassium	12.200	1.950	0.970	1.300	4.220	18.200
Magnesium	43.000	165.000	19.700	55.000	135.000	30.200
Nickel	< 0.005	0.010	< 0.005	< 0.005	< 0.005	< 0.005
Nitrate	< 0.02	0.06	0.56	0.42	0.35	1.14
Lead	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus	< 0.02	0.11	0.13	0.28	0.13	0.09
Selenium	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Zinc	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020
T.D.S.	642	2480	344	780	1840	484
C.O.D.	< 10	25	14	17	85	< 10
pH[1,2]	7.76	6.65	7.26	7.23	6.92	7.66
Conductivity[1,3]	1120	5310	510	857	2240	837
T.O.C.[1]	< 1	5.00	4.75	5.75	7.00	3.25
T.O.X.[1,4]	< 10	210	28	10	32	< 10
Coliform[7]	< 2	350	250	1000	< 2	325
Alachlor[4]	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Lindane[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Endrin[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Methoxychlor[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Toxaphene[4]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
2,4-D[4]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2,4,5-TP,Silvex	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
VOC's						
1,1,2,2-Tetrachloroethane[4]		1.54	...	...	...	...
Cloroethene[4]	...	0.87	...	...	...	...
Bromoform[4]	...	0.91	...	...	...	...
cis-1,2-Dichloroethene[4]	...	29.50	...	...	...	...
1,1 Dichlorethane[4]	...	15.00	...	...	...	...
1,2-Dichlorobenzene[4]	...	0.83	...	...	...	...
Gross Alpha[5]	< 1	7	5	964	149	< 1
Gross Beta[5]	7	77	12	3310	988	24
Radium 228[5]	< 1	< 1	< 1	23	4	< 1
Uranium[11]	1.0	40	< 1.0	6440	4200	< 1.0

TABLE 32
SAND AND GRAVEL AQUIFER
FMPC GROUNDWATER SAMPLING RESULTS INSIDE PRODUCTION AREA, SIXTH ROUND, 1987

(All results in ppm except as noted) page 1 of 2

Well location	301	401	303	204	204 (DUP)	305	308	408	310	213	213 (DUP)	313	219	319	221	222
Chloride	18.0	20.0	21.0	25.0	24.0	18.0	18.0	12.0	85.0	26.0	27.0	64.0	46.0	52.0	43.0	89.0
Iron	2.010	4.790	0.952	0.183	0.179	2.060	6.110	2.540	< 0.050	2.530	2.510	6.770	< 0.050	< 0.050	< 0.050	< 0.050
Manganese	0.596	0.361	0.385	< 0.015	< 0.015	0.502	0.438	0.387	4.620	0.176	0.186	0.341	< 0.015	2.370	< 0.015	< 0.015
Phenols	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Sodium	12.200	15.300	12.400	14.000	14.400	9.000	11.700	13.300	132.000	12.900	13.800	46.100	26.600	45.100	57.600	32.200
Sulfate	68.0	13.0	92.0	44.0	52.0	72.0	44.0	9.0	780.0	116.0	112.0	300.0	92.0	400.0	88.0	108.0
Silver	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Arsenic	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.005	< 0.0025	0.003	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Barium	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	<0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200
Calcium	95.500	82.200	84.100	81.600	83.000	94.900	50.000	8.000	359.000	8.000	109.000	182.000	131.000	201.000	167.000	144.000
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cyanide	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	0.006	< 0.005	< 0.005
Chromium																
-Total	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.007	< 0.005	< 0.005
-Hexavalent	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.007	< 0.005	< 0.005
Copper	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
Fluoride	0.11	0.11	1.64	0.39	0.32	0.09	0.16	0.16	0.10	0.11	0.13	0.20	0.17	0.16	0.16	0.46
Mercury	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Potassium	2.040	0.888	2.700	2.810	2.830	2.080	2.760	1.220	14.300	2.590	2.630	4.220	3.420	6.160	7.280	4.840
Magnesium	26.600	23.500	23.400	21.000	21.200	26.400	24.800	21.900	58.400	27.800	27.600	20.400	30.500	25.100	28.400	46.800
Nickel	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.009	< 0.005	< 0.005	< 0.005	< 0.005	0.008	< 0.005	< 0.005
Nitrate	< 0.02	< 0.02	< 0.02	0.63	0.63	< 0.02	< 0.02	< 0.02	71.00	< 0.02	< 0.02	< 0.02	34.20	0.13	76.70	52.00
Lead	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus	< 0.02	0.08	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.07	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

TABLE 32
SAND AND GRAVEL AQUIFER
FMPC GROUNDWATER SAMPLING RESULTS INSIDE PRODUCTION AREA, SIXTH ROUND, 1987

(All results in ppm except as noted) page 2 of 2

Well location	301	401	303	204	204 (DUP)	305	308	408	310	213	213 (DUP)	313	219	319	221	222
Selenium	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Zinc	< 0.020	0.402	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	0.226	< 0.020	0.028	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	0.028
T.D.S.	416	352	404	380	336	464	292	344	2000	448	608	860	712	908	988	864
C.O.D.	< 10	< 10	17	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
pH[1,2]	7.43	7.39	7.36	7.39	7.38	7.30	7.46	7.45	6.86	7.17	7.16	7.00	7.32	6.98	7.26	7.27
Conductivity[1,3]	630	590	575	558	558	633	437	528	2350	775	765	1310	960	1180	1280	1220
T.O.C.[1]	< 1	< 1	1	1	< 1	< 1	< 1	< 1	< 1	1.75	1.78	3.25	1.00	1.00	1.00	1.00
T.O.X.[1,4]	39	< 10	51	54	< 10	29	< 10	< 10	< 10	< 10	64	38	143	< 10	< 10	88
Coliform[7]	< 2	< 2	180	9	23	< 2	< 2	< 2	< 2	< 2	< 2	22	< 2	< 2	< 2	< 2
Alachlor[4]	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Lindane[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Endrin[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Methoxychlor[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Toxaphene[4]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
2,4-D[4]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2,4,5-TP,Silvex[4]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Gross Alpha[5]	4	< 1	2980	2	3	2	< 1	< 1	< 1	< 1	< 1	< 1	9	2	31	3
Gross Beta[5]	15	< 3	14,100	17	19	9	16	7	62	5	6	10	1290	12	2770	1220
Radium 226[5]	< 1	< 1	16	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228[5]	< 1	< 1	294	< 1	< 1	< 1	...	...	...	...	...	...	< 1.0	< 1.0	12.0	< 1.0
Strontium 90[5]	...	...	...	...	...	...	...	...	...	...	...	...	< 1.0	< 1.0	22.0	< 1.0
Uranium[11]	< 1	< 1	11,700	< 1	< 1	< 1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	7.0	< 1.0	9.0	< 1.0

TABLE 33
GROUNDWATER SAMPLING RESULTS
FMPC PLANT PRODUCTION WELLS,
SIXTH ROUND, 1987

(All results in ppm except as noted)

Well Location	P-1	P-2	P-3	P-3(DUP)
Chloride	40.0	32.0	13.0	13.0
Iron	5.700	3.600	2.630	2.650
Manganese	0.423	0.400	0.389	0.385
Phenols	< 0.005	< 0.005	< 0.005	< 0.005
Sodium	37.200	20.000	11.900	11.700
Sulfate	140.0	36.0	32.0	40.0
Silver	< 0.030	< 0.030	< 0.030	< 0.030
Arsenic	< 0.0025	< 0.0025	0.003	0.003
Barium	< 0.200	< 0.200	< 0.200	< 0.200
Calcium	126.000	103.000	84.600	85.500
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001
Cyanide	< 0.005	< 0.005	< 0.005	0.006
Chromium				
-Total	< 0.005	< 0.005	< 0.005	< 0.005
-Hexavalent	< 0.005	< 0.005	< 0.005	< 0.005
Copper	< 0.025	< 0.025	< 0.025	< 0.025
Fluoride	0.15	0.12	0.18	0.20
Mercury	< 0.002	< 0.002	< 0.002	< 0.002
Potassium	4.690	1.800	1.370	1.790
Magnesium	34.900	29.300	20.300	20.800
Nickel	< 0.005	< 0.005	< 0.005	< 0.005
Nitrate	< 0.02	< 0.02	< 0.02	< 0.02
Lead	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus	0.12	0.11	0.07	< 0.02
Selenium	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Zinc	< 0.020	< 0.020	< 0.020	< 0.020
T.D.S.	604	436	352	360
C.O.D.	< 10	< 10	< 10	< 10
pH[1,2]	7.26	7.37	7.35	7.38
Conductivity[1,3]	1020	773	566	571
T.O.C.[1]	1	1	2.25	2.25
T.O.X.[1,4]	16	19	< 10	< 10
Coliform[7]	< 2	< 2	< 2	< 2
Alachlor[4]	< 2.0	< 2.0	< 2.0	< 2.0
Lindane[4]	< 0.2	< 0.2	< 0.2	< 0.2
Endrin[4]	< 0.2	< 0.2	< 0.2	< 0.2
Methoxychlor[4]	< 0.2	< 0.2	< 0.2	< 0.2
Toxaphene[4]	< 0.5	< 0.5	< 0.5	< 0.5
2,4-D[4]	< 1.0	< 1.0	< 1.0	< 1.0
2,4,5-TP-Silvex	< 0.5	< 0.5	< 0.5	< 0.5
Gross Alpha[5]	< 1	< 1	< 1	< 1
Gross Beta[5]	6	4	< 3	< 3
Radium[5]	< 1	< 1	< 1	< 1
Uranium[11]	< 1.0	< 1.0	< 1.0	< 1.0

TABLE 34
SAND AND GRAVEL AQUIFER
FMPC GROUNDWATER SAMPLING RESULTS
OUTSIDE PRODUCTION AREA,
SIXTH ROUND, 1987

(All results in ppm except as noted) page 1 of 4

Well location	309	211	314	215	415	216	316	217	317
Chloride	23.0	20.0	21.0	19.0	27.0	24.0	23.0	33.0	21.0
Iron	0.142	2.360	0.907	< 0.050	2.730	0.200	< 0.050	< 0.050	1.640
Manganese	0.067	0.154	0.093	< 0.015	0.343	0.025	< 0.015	0.122	0.267
Phenols	0.006	< 0.005	< 0.005	< 0.005	0.005	< 0.005	0.008	< 0.005	< 0.005
Sodium	12.700	10.500	13.000	11.000	7.190	15.000	12.900	10.600	8.900
Sulfate	64.0	76.0	60.0	60.0	88.0	64.0	68.0	100.0	76.0
Silver	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Arsenic	< 0.0025	< 0.0025	< 0.0025	< 0.0025	0.003	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Barium	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200
Calcium	84.700	99.300	105.000	77.800	113.000	89.900	79.400	124.000	95.100
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cyanide	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005	< 0.005
Chromium									
-Total	< 0.005	< 0.005	0.018	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
-Hexavalent	< 0.005	< 0.005	< 0.010	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Copper	0.050	< 0.025	0.025	< 0.025	< 0.025	0.026	< 0.025	< 0.025	< 0.025
Fluoride	0.20	0.26	0.13	0.18	0.18	0.16	0.18	0.13	0.16
Mercury	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0003	< 0.0003	< 0.0002	< 0.0002
Potassium	2.060	0.910	2.220	2.440	1.640	2.750	1.990	2.000	1.980
Magnesium	24.100	25.700	29.500	20.400	25.100	23.700	22.500	26.600	20.200
Nickel	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Nitrate	1.54	< 0.02	1.46	1.98	< 0.02	0.98	1.30	< 0.02	< 0.02
Lead	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus	0.08	< 0.02	< 0.02	< 0.02	< 0.02	0.39	0.04	< 0.02	< 0.02

TABLE 34
SAND AND GRAVEL AQUIFER
FMPC GROUNDWATER SAMPLING RESULTS
OUTSIDE PRODUCTION AREA,
SIXTH ROUND, 1987

(All results in ppm except as noted) page 2 of 4

Well location	218	318	318 (DUP)	220	320	SW-2	OS-1	OS-2	OS-3
Chloride	8.0	12.0	12.0	22.0	23.0	44.0	22.0	19.0	24.0
Iron	< 0.050	0.799	0.187	< 0.050	1.110	< 0.050	< 0.050	< 0.050	1.540
Manganese	< 0.015	0.056	0.030	0.027	0.185	0.151	< 0.015	< 0.015	0.389
Phenols	< 0.005	0.015	0.019	< 0.005	< 0.005	< 0.005	< 0.005	0.016	< 0.005
Sodium	5.500	7.100	6.600	15.300	12.300	19.200	14.300	10.100	10.600
Sulfate	44.0	68.0	64.0	64.0	88.0	76.0	60.0	52.0	68.0
Silver	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Arsenic	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Barium	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200	< 0.200
Calcium	105.000	83.500	90.000	83.500	97.100	109.000	93.300	89.200	109.000
Cadmium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cyanide	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Chromium									
-Total	< 0.005	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
-Hexavalent	< 0.005	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Copper	< 0.025	0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
Fluoride	0.21	0.21	0.23	0.22	0.13	0.17	0.22	0.17	0.16
Mercury	< 0.0002	< 0.0002	0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Potassium	1.430	0.632	0.711	2.520	2.130	3.100	3.190	3.160	2.810
Magnesium	25.700	32.000	32.900	19.400	23.800	28.500	21.700	20.900	23.100
Nickel	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005
Nitrate	1.24	< 0.02	< 0.02	2.84	< 0.02	1.93	2.04	2.21	< 0.02
Lead	< 0.005	0.007	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

TABLE 34
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(All results in ppm except as noted) page 3 of 4

Well location	309	211	314	215	415	216	316	217	317
Selenium	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Zinc	< 0.020	< 0.020	< 0.020	< 0.020	0.092	< 0.020	< 0.020	< 0.020	< 0.020
T.D.S.	364	444	346	335	490	336	332	527	420
C.O.D.	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
pH[1,2]	7.57	7.38	7.67	7.45	7.44	7.49	7.53	7.13	7.26
Conductivity[1,3]	540	709	530	561	620	560	540	775	633
T.O.C.[1]	< 1.00	2.25	1.75	2.25	< 1.00	1.00	1.00	3.25	1.25
T.O.X.[1,4]	16	10	98	68	< 10	< 10	< 10	47	21
Coliform[7]	31	< 2	9900	< 2	< 1	< 1	4	< 2	< 2
Alachlor[4]	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Lindane[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Endrin[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Methoxychlor[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Toxaphene[4]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
2,4-D[4]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2,4,5-TP, Silvex[4]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
VOC's									
1,1,1 Trichloro-ethane[4]	...	...	...	5.13	...	...	...	...	...
Gross Alpha[5]	< 1	< 1	7	35	< 1	5	3	< 1	< 1
Gross Beta[5]	18	< 3	17	95	4	12	17	< 3	< 3
Radium-226[5]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Uranium[11]	< 1.0	< 1.0	13.0	269.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

TABLE 34
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FMPC GROUNDWATER SAMPLING RESULTS
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(All results in ppm except as noted) page 4 of 4

Well location	218	318	318 (DUP)	220	320	SW-2	OS-1	OS-2	OS-3
Selenium	< 0.0025	< 0.0025	< 0.0025	< 0.005	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Zinc	< 0.020	< 0.020	< 0.020	< 0.020	0.020	0.066	0.359	0.095	0.022
T.D.S.	383	368	408	376	400	531	444	384	444
C.O.D.	< 10	< 10	< 10	< 10	< 10	< 10	20	< 10	15
pH[1,2]	7.37	7.36	7.36	7.45	7.36	7.38	7.49	7.56	7.44
Conductivity[1,3]	560	570	590	551	561	690	580	530	600
T.O.C.[1]	2.00	< 1.00	< 1.00	< 1.00	2.25	< 1.00	< 1.00	< 1.00	< 1.00
T.O.X.[1,4]	24	18	25	22	< 10	< 10	< 10	< 10	39
Coliform[7]	< 2	26	14	3	< 2	< 2	1	29	< 2
Alachlor[4]	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Lindane[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Endrin[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Methoxychlor[4]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Toxaphene[4]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
2,4-D[4]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2,4,5-TP, Silvex[4]	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Gross Alpha[5]	< 1	< 1	< 1	< 1	< 1	1	59	59	10
Gross Beta[5]	7	12	14	21	4	17	104	99	23
Radium-226[5]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1	< 1	1	< 1
Uranium[11]	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	0.0	396.0	319.0	204.0

Footnotes for 31-34

NA = Not Analyzed
ND = Not Detected
(DUP) = Results from replicate sample

1. Average of four tests.
2. pH results in standard units
3. Conductivity results in µmhos/cm.
4. Concentrations reported in ppb.
5. Results in pCi/l
6. Standard is for Radium-226 plus Radium-228.
7. Reported in per 100 ml.
8. Maximum Permissible Activity taken from World Health Organization, 1970 European Standards. National Primary Drinking Water Regulation for gross beta is 4 mrem/year.
9. Taken from 40 CFR Part 141 National Interim Primary Drinking Water Regulations - Subpart B - Maximum Contaminant Levels, July 1, 1984.
10. Taken from 40 CFR Part 143 National Interim Secondary Drinking Water Regulations - Section 143.3 - Secondary Maximum Contaminant Levels.
11. Uranium values measured by FMPC in mg/l.

Appendix C
1988 Environmental Monitoring Annual Report Distribution Lists

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