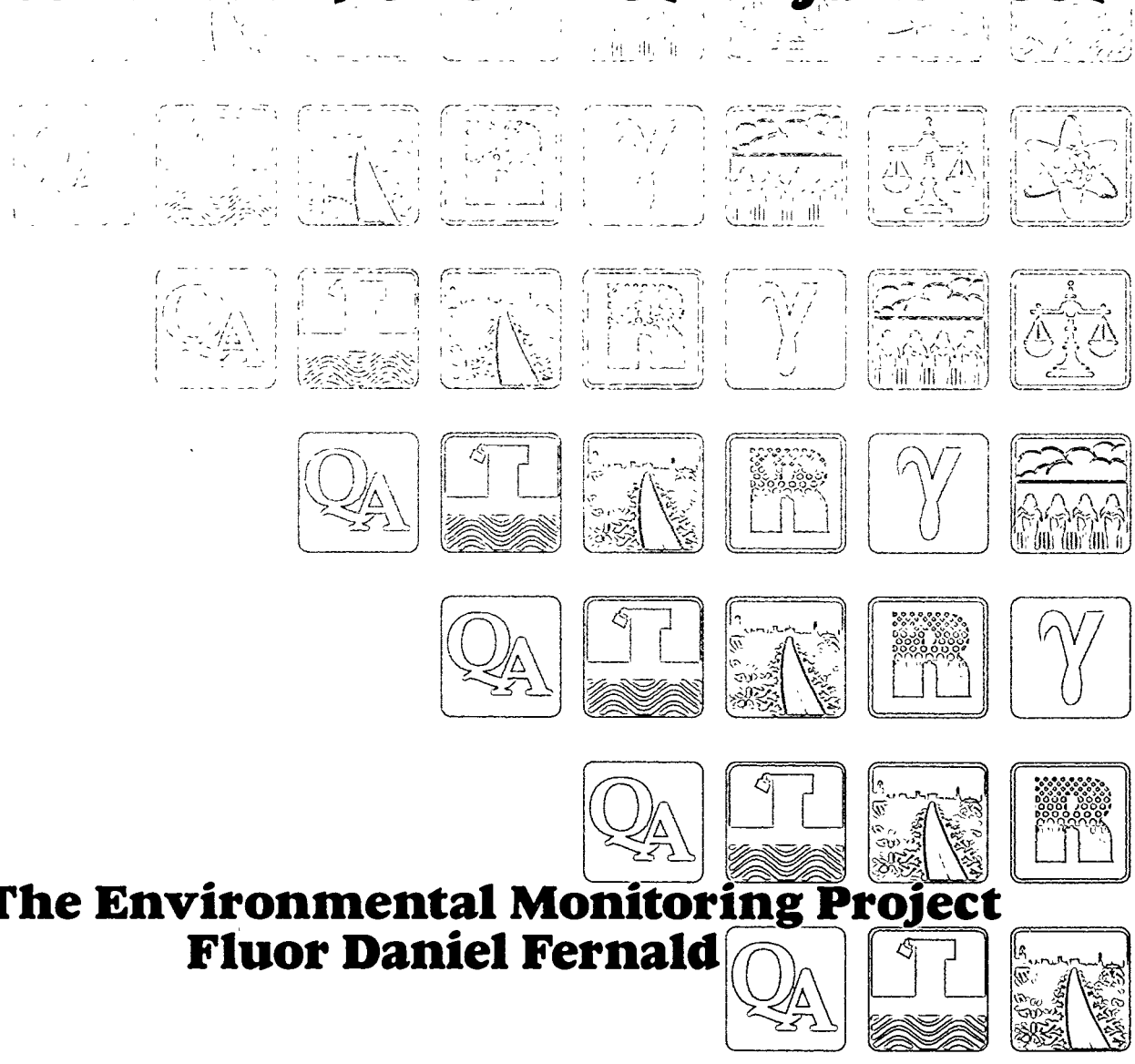
FEMP–2538
SPECIAL
UC–707

FERNALD
Environmental Management Project

1996
Site Environmental Report

U.S. Department of Energy Fernald Field Office
Contract DE-A24-92OR21972 June 1997



By The Environmental Monitoring Project
Fluor Daniel Fernald

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Prepared for

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Prepared by

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Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

ACA	Amended Consent Agreement
AEC	Atomic Energy Commission
AHF	Anhydrous Hydrogen Fluoride
AIRDOS	EPA Dose Model: AIRDOS-EPA (MO-79)
ALARA	As Low As Reasonably Achievable
AMS	Air Monitoring Station
ANSI	American National Standards Institute
ARAR	Applicable or Relevant and Appropriate Requirement
ASER	Annual Site Environmental Report
AWWT	Advanced Wastewater Treatment
BAT	Best Available Technology
BDN	Biodenitrification Facility
BMP	Best Management Practices
BRA	Baseline Risk Assessment
BSL	Biodenitrification Surge Lagoon
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
CO	Carbon Monoxide
CPID	Closure Plan Information and Data
CSOU	Comprehensive Sitewide Operable Unit
CWA	Clean Water Act
CX	Categorical Exclusion
D&D	Decontamination and Dismantling
DCG	Derived Concentration Guideline
DE	Drum Equivalent
DFO	Director's Final Findings and Orders
DOE	Department of Energy
DQO	Data Quality Objective
EA	Environmental Assessment
EDE	Effective Dose Equivalent
EIS	Environmental Impact Statement
EM	Environmental Monitoring
EML	Environmental Measurements Laboratory
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ES&H	Environment, Safety, and Health
ETS	Effluent Treatment System
FACA	Federal Advisory Committee Act
FDF	Fluor Daniel Fernald
FEMP	Fernald Environmental Management Project
FFCA	Federal Facility Compliance Agreement
FFCAct	Federal Facility Compliance Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FMPC	Feed Materials Production Center
FONSI	Finding of No Significant Impact
FRL	Final Remediation Level
FS	Feasibility Study
FS/PP	Feasibility Study/Proposed Plan
GQAPP	Groundwater Quality Assessment Program Plan
HSL	Hazardous Substances List
HWMU	Hazardous Waste Management Unit
IAWWT	Interim Advanced Wastewater Treatment
ICRP	International Commission on Radiological Protection
IROD	Record of Decision for Interim Remedial Action
LDR	Land Disposal Restriction
MCL	Maximum Contaminant Level
μCi	microcurie
mrem	millirem
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOD	Notice of Deficiency
NON	Notice of Noncompliance
NOV	Notice of Violation
NO_x	Nitrogen Oxide
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Response Center
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
OAC	Ohio Administrative Code
ODH	Ohio Department of Health
OEPA	Ohio Environmental Protection Agency
OHPO	Ohio Historic Preservation Office
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PCB	Polychlorinated Biphenyls

pCi	picocurie
PEIC	Public Environmental Information Center
PET	Proficiency Environmental Testing
PTI	Permit to Install
PTO	Permit to Operate
QA	Quality Assurance
QF	Quality Factor
RA	Remedial Action
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RDWP	Remedial Design Work Plan
rem	Roentgen Equivalent Man
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
RM	River Mile
RQ	Reportable Quantity
RvA	Removal Action
RvAWP	Removal Action Work Plan
SACD	Stipulated Amendment to Consent Decree
SARA	Superfund Amendments and Reauthorization Act
SCQ	Sitewide CERCLA Quality Assurance Project Plan
SDWA	Safe Drinking Water Act
SER	Site Environmental Report
SERC	State Emergency Response Commission
SHPO	State Historic Preservation Officer
SO_2	Sulfur Dioxide
SPCC	Spill Prevention Control and Countermeasure
SSOD	Storm Sewer Outfall Ditch
SU	Standard Units
SWMU	Solid Waste Management Unit
SWRB	Stormwater Retention Basin
TLD	Thermoluminescent Dosimeter
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facility
UNH	Uranyl Nitrate Hexahydrate
VOC	Volatile Organic Compounds
WEMCO	Westinghouse Environmental Management Company of Ohio
WM/PP	Waste Minimization/Pollution Prevention

Conversion Table

Multiply	By	To Obtain	Multiply	By	To Obtain
inches (in)	2.54	centimeters (cm)	cm	0.394	in
feet (ft)	0.3048	meters (m)	m	3.281	ft
miles (mi)	1.609	kilometers (km)	km	0.622	(mi
pounds (lb)	0.454	kilograms (kg)	kg	2.203	lb
tons	0.9078	metric tons	metric tons	1.102	tons
gallons	3.79	liters (L)	L	0.264	gallons
square feet (ft^2)	0.0929	square meters (m^2)	m^2	10.76	ft^2
acres	0.405	hectares (ha)	ha	2.469	acre
cubic yards (yd^3)	0.7646	cubic meters (m^3)	m^3	1.308	yd^3
cubic feet (ft^3)	0.0283	cubic meters (m^3)	m^3	35.31	ft^3
picocuries (pCi)	10^{-12}	Curies (Ci)	Ci	10^{12}	pCi
pCi/L	10^{-6}	microcuries per liter (µCi/L)	µCi/L	10^{6}	pCi/L
Ci	3.7×10^{10}	Becquerels (Bq)	Bq	2.7×10^{-11}	Ci
pCi	0.037	Bq	Bq	27.03	pCi
millirem (mrem)	0.001	rem	rem	1000	mrem
rem	0.01	Sievert	Sv	100	rem
parts per million (ppm)	1000	parts per billion (ppb)	ppb	0.001	ppm
Fahrenheit (°F)	(°F - 32) x 5/9	Celsius (°C)	°C	(°C x 9/5) + 32	°F
For Natural Uranium in Water					
pCi/L	0.0015	mg/L	mg/L	675.7	pCi/L
pCi/L	1.48	µg/L	µg/L	0.6757	pCi/L
ppb	0.6757	pCi/L	pCi/L	1.48	ppb
ppm	1	mg/L	mg/L	1	ppm
For Natural Uranium in Soil					
pCi/g	1.48	µg/g	µg/g	0.6757	pCi/g
ppm	1	µg/g	µg/g	1	ppm

Multiple	Decimal Equivalent	Prefix	Symbol
10^{6}	1,000,000	mega-	M
10^{3}	1,000	kilo-	k
10^{2}	100	hecto-	h
10	10	deka-	da
10^{-1}	0.1	deci-	d
10^{-2}	0.01	centi-	c
10^{-3}	0.001	milli-	m
10^{-6}	0.000001	micro-	µ
10^{-9}	0.000000001	nano-	n
10^{-12}	0.000000000001	pico-	p
10^{-15}	0.000000000000001	femto-	f
10^{-18}	0.000000000000000001	atto-	a

Executive Summary

Radon Monitoring

Radon is transported through the air pathway and is, therefore, discussed here. However, radon monitoring results are reported separately in this Site Environmental Report from the air pathway in order to improve the presentation of information and regulations that are unique to radon.

In 1996, the average fence line radon concentration was 0.7 ± 0.7 pCi/L. The 1995 average concentration was approximately 0.7 ± 0.4 and below the guideline of 3.0 pCi/L. For comparison, the average background concentration measured in 1996 was 0.6 ± 0.5 pCi/L.

Liquid Pathway: Effluent and Surface Water

The effluent and surface water component of the liquid pathway is monitored to determine any impacts from the FEMP on the Great Miami River and Paddys Run. The Environmental Monitoring Program examines the effluent and surface water results, along with sediment and fish results because they are also part of the liquid pathway.

In 1996, approximately 125 kg (275 lbs.) of uranium were discharged to the Great Miami River. Approximately 166 kg (366 lbs.) of uranium reached Paddys Run through uncontrolled stormwater runoff. Another 6 kg (13 lbs.) of uranium were released due to overflow of the Stormwater Retention Basin. The total effluent release of 298 kg (656 lbs.) represents a decrease of approximately 4% from 1995.

The liquid effluent discharged to the Great Miami River did not result in a statistically significant difference between upstream concentrations and downstream concentrations. Paddys Run continued to show effects of stormwater runoff from the site. The nearest offsite sampling location had a concnetration of 2.0 ± 1.4 pCi/L as compared to 0.7 ± 0.2 pCi/L at the background upstream location.

Radionuclide concentrations in the Great Miami River and Paddys Run sediments for 1996 were consistent with previous years' data and did not indicate a build-up of radioactive pollutants in the sediment.

In 1996, fish from three locations along the Great Miami River were sampled for uranium. Results indicated that uranium concentrations were no greater in fish caught downstream of the site effluent line than in those caught upstream.

The National Pollutant Discharge Elimination System (NPDES) permit specifies sampling locations, sampling and reporting schedules, discharge limits, water quality standards, and other restrictions on the Fernald site effluents discharged to the Great Miami River and Paddys Run. Out of the 2,355 NPDES samples taken at internal and external monitoring locations in 1996, there were 8 violations of NPDES limits at the final monitoring point before effluents are discharged to the river. The violations concerned the oxygen concentrations, BOD-5 maximum

daily allowance concentrations, and one exceedence of the maximum concentration for fecal coliform bacteria in the effluent released to the Great Miami River.

Liquid Pathway: Groundwater

The FEMP carefully monitors the groundwater beneath and in the vicinity of the site to identify and track the movement of pollutants which may be present in the Great Miami Aquifer. In 1996 the FEMP routinely sampled 32 private wells for total uranium. Three of these wells, each of which is in an area of known groundwater contamination, had an average uranium concentration above the proposed EPA standard of 13.5 pCi/L (20 ppb).

Aside from the private well sampling program, the FEMP conducts comprehensive groundwater sampling of several site-owned wells. In 1996, 33 monitoring wells were sampled quarterly for RCRA constiuents. Ten constituents from this program had concentrations above the corresponding final remediation levels (FRLs). Additionally, 58 monitoring wells were sampled quarterly in the South Plume during 1996. Sixteen monitoring wells exhibited concentrations of total uranium above 20 ug/L (13.5 pCi/L). One monitoring well indicated a maximum arsenic concentration of 0.10 mg/L which is above the Primary Drinking Water Standard of 0.05 mg/L.

Estimated Radiation Dose for 1996

Scientists calculate potential radiation *doses* to nearby residents by utilizing mathematical models which include offsite radionuclide concentrations determined through environmental monitoring and sampling.

In 1996, the hypothetical maximally-exposed individual living nearest the FEMP, exclusively consuming local foodstuffs and fish, along with drinking water from a well in the Fernald area, could have received a maximum committed effective dose of approximately 1.0 *mrem*. (This dose is exclusive of the dose received from radon.) This dose can be compared to the limit of 100 mrem for all pathways (also exclusive of radon) that was established by the International Commission on Radiological Protection and adopted by DOE.

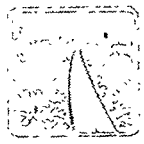
Dose Attributable to Radon

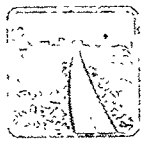
Just as radon monitoring results are discussed separately from the air pathway monitoring results, the dose attributable to radon is discussed separately from the rest of the estimated radiation dose for 1996.

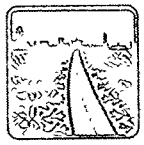
As discussed above, the radon concentration measured at the site fence line in 1996 was 0.7 ± 0.7 pCi/L. The effective dose calculated from this concentration was estimated to be 504 mrem, and it includes the annual dose received from average background levels of radon (approximately 200 mrem per year).

1

The Fernald Environmental Management Project







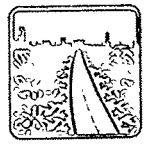
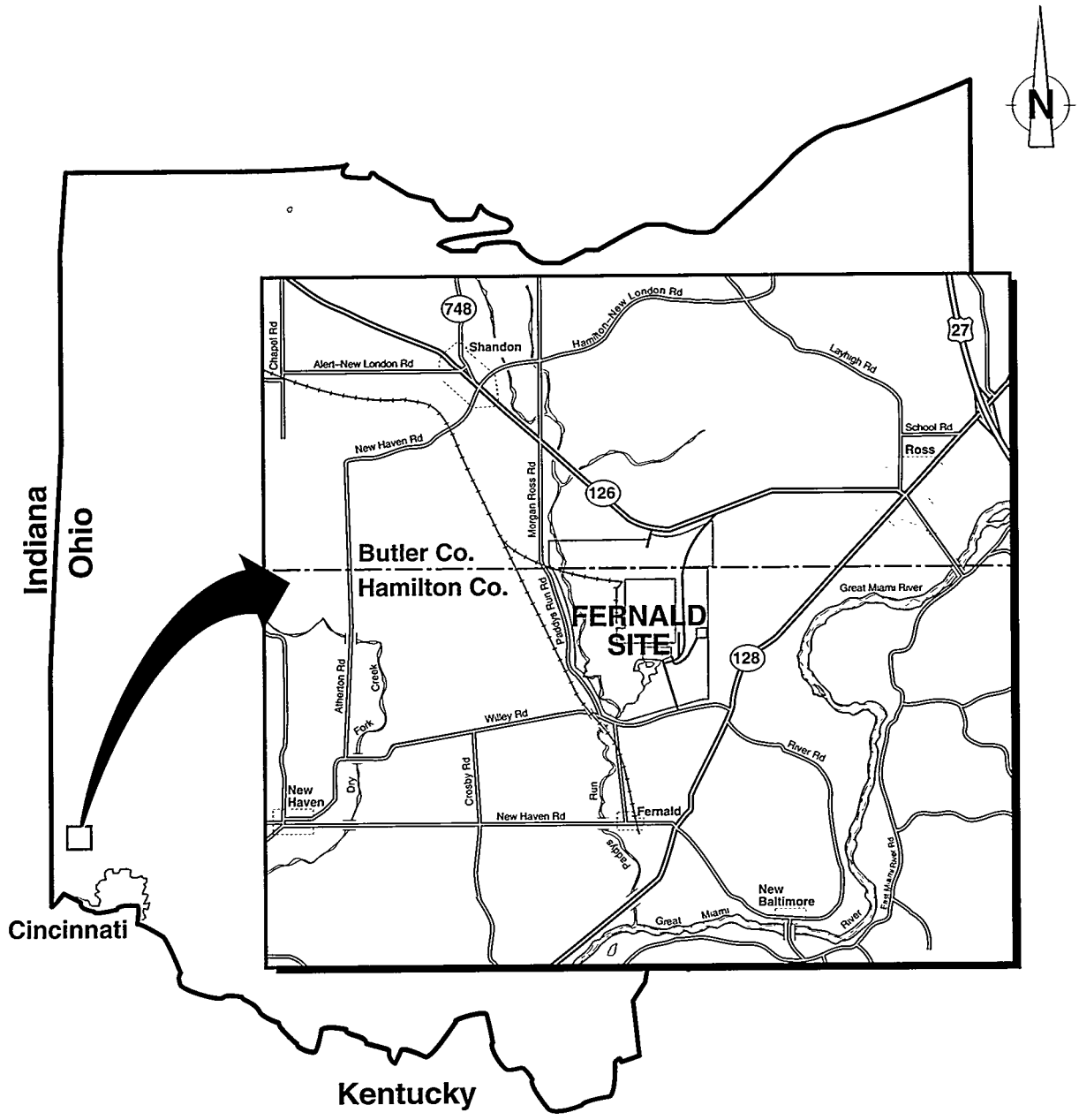


Figure 1: FEMP and Vicinity



The Fernald Site covers about 425 hectares (1,050 acres).

Figure 2: Former Site Production Process

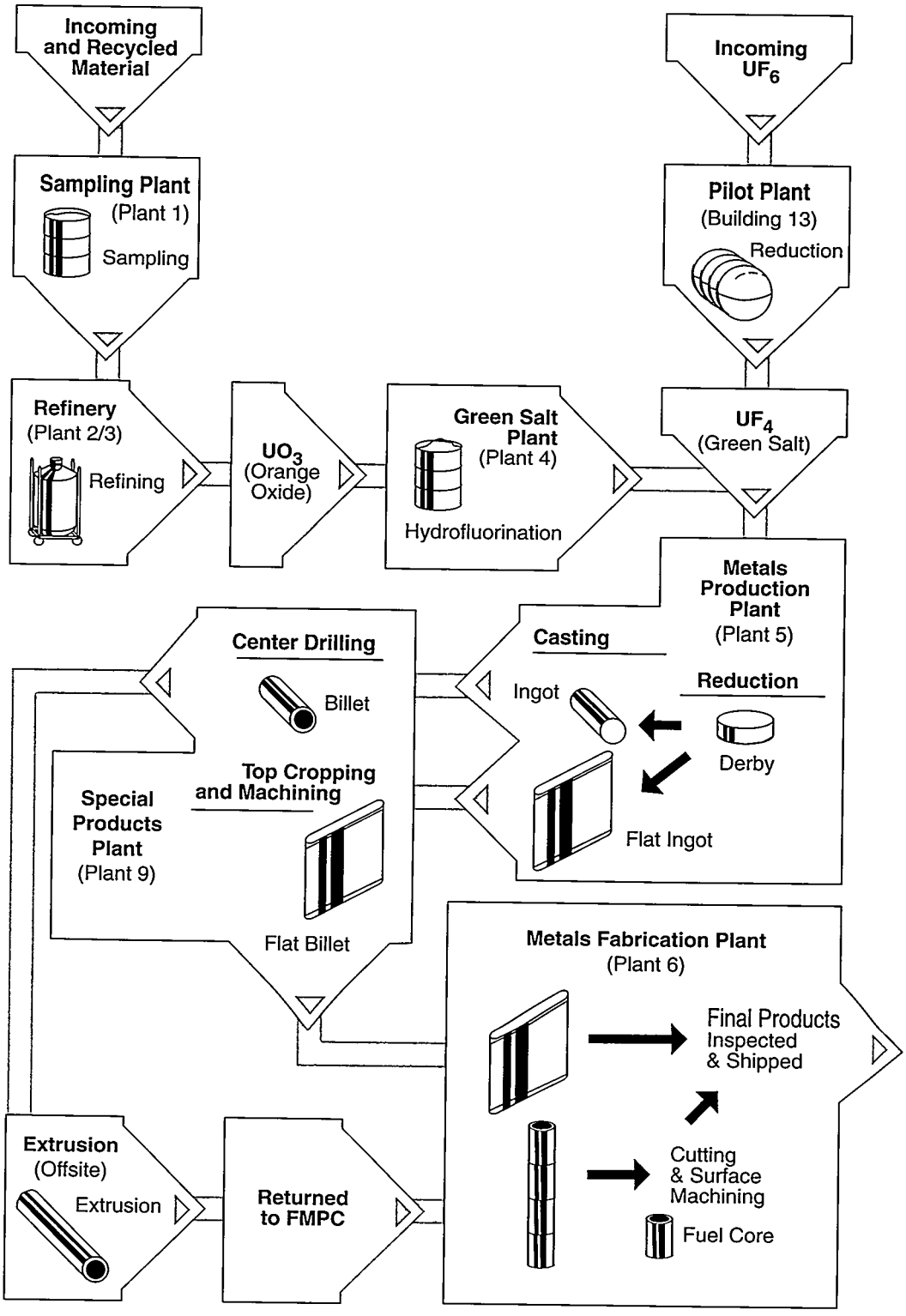
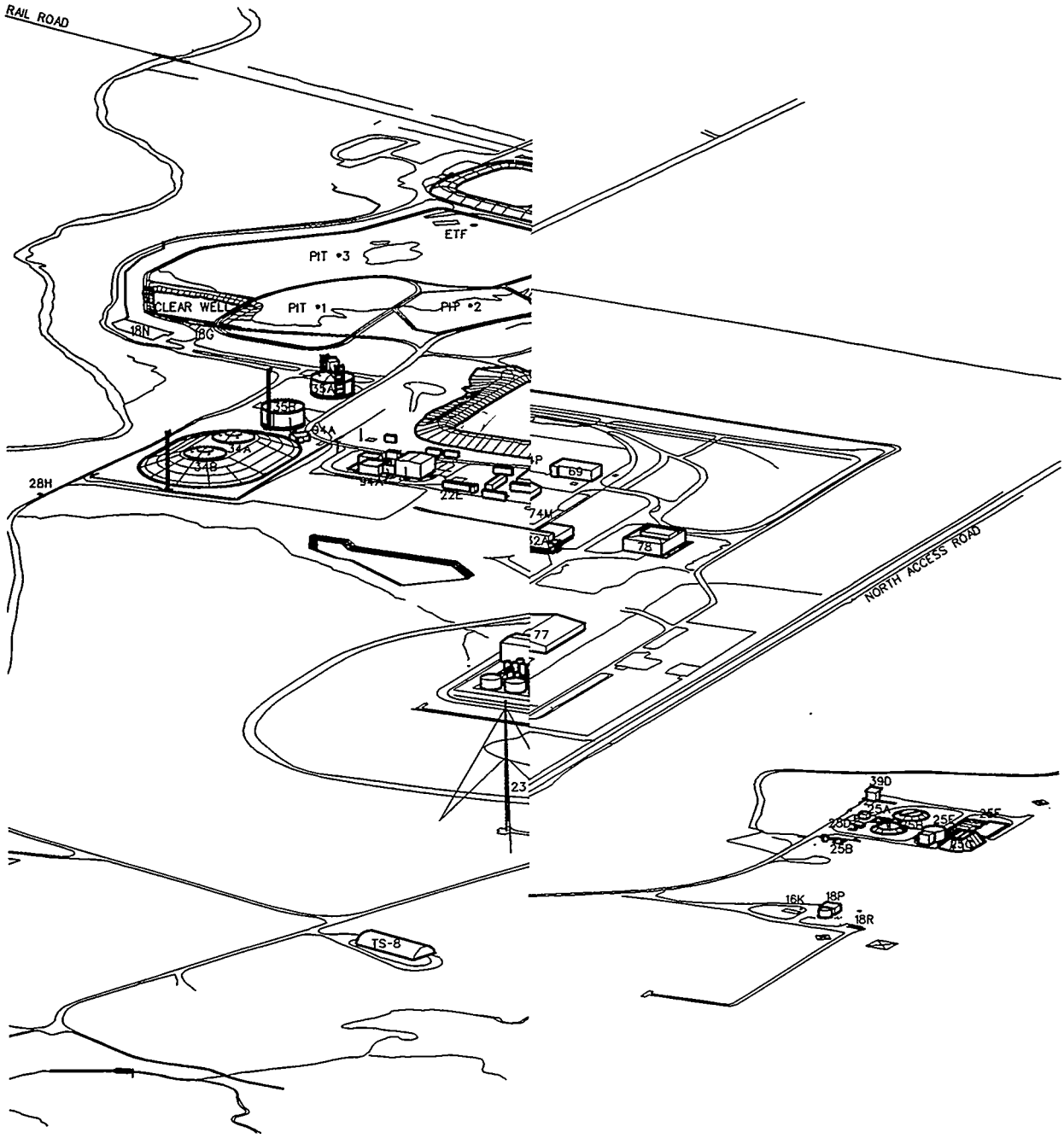


Figure 3: Fernald Site Perspective



Building ID No.	Title
23	Meteorological Tower
24A	Railroad Scale House
24B	Railroad Engine House
25A	Chlorination Building
25B	M.H. #175/Eff. Line/Sampling Building
25C	Sewage Lift Station Building
25D	UV Disinfection Building
25E	Digester & Control Building
25F	Sludge Drying Beds
25G	Primary Settling Basins
25H	Trickling Filters
25J	10 Plexs Sewage Lift Station
26A	Pump House-HP Fire Protection
26B	Elevated Water Storage Tank
26C	Main Electrical Substation Riser House
28A	Security Building
28B	Industrial Relations Building
28D	Guard Post On West End Of "2nd" Street
28E	Guard Post at T81
28F	Skeet Range Building
28G	Guard Post Northwest of Building 45
28H	Guard Post South of K-65 Area
28J	Security Checkpoint (South Access Road)
28K	Security Checkpoint (East Parking Lot)
28L	Guard Post (North Access Road) (Removed)
28M	Guard Post on "F" Street (Proposed)
30A	Chemical Warehouse
30B	Drum Storage Warehouse
30C	Old Ten-Ton Scale (Removed)
31A	Vehicle Repair Garage
31B	Old Truck Scale
32A	Magnesium Storage Building
32B	Building 32 Covered Loading Dock
34A	K-65 Storage Tank (North)
34B	K-65 Storage Tank (South)
34C	RTS Building
35A	Metal Oxide Storage Tank (North)
35B	Metal Oxide Storage Tank (South)
37	Pilot Plant Annex
38A	Propane Storage
38B	Cylinder Filling Station
39A	Incinerator Building
39B	Waste Oil Decant Shelter
39C	Incinerator Sprinkler Riser House
39D	Sewage Treatment Plant Incinerator
44A	Trailer Complex (6-Plex)
44C	Trailer Complex (7-Plex South)
44D	Trailer Complex (7-Plex North)
44E	Trailer Complex (10-Plex)
45A	Construction Division Building
45B	Utility Shed East Of Rust Trailers
46	Vehicle Repair Garage Annex
51A	Advanced Wastewater Treatment Facility (AWWTF)
51B	Slurry Dewatering Facility
52	RTRAK Building
53A	Health & Safety Building
53B	In-Vivo Building
54A	Six To Four Reduction Facility #1
54B	Pilot Plant Warehouse
54C	Pilot Plant Dissociator Shelter
55A	Slag Recycling Building
55B	Slag Recycling Pit/Elevator
56A	Cp Storage Warehouse
56B	Storage Shed (West) (Removed)
56C	Storage Shed (East) (Removed)
60	Quonset Hut #1
61	Quonset Hut #2
62	Quonset Hut #3
63	KC-2 Warehouse
64	Thorium Warehouse
65	(Old) Plant 5 Warehouse
66	Drum Reconditioning Building
67	Plant 1 Thorium Warehouse
68	Pilot Plant Warehouse
69	Decontamination Building
71	General In-Process Warehouse
72	Drum Storage Building
73A	Fire Brigade Training Center Bldg. (Removed 9/6/95)
73B	Fire Training Pond (Removed)
73C	Fire Training Tank (Removed)
73D	Fire Training Burn Trough (Removed)
73E	Confined Space Burn Tank (Removed)
74A	Plant 2 East Pad
74B	Plant 2 West Pad
74C	Plant 8 East Pad
74D	Plant 8 West Pad
74E	Plant 4 Pad
74F	Plant 7 Pad
74G	Plant 5 East Pad
74H	Plant 5 South Pad
74J	Plant 6 Pads
75K	Plant 9 Pad
74L	Building 65 West Pad
74M	Building 64 East Pad & R.R. Dock
74N	Building 12 North Pad
74P	Decontamination Pad
74Q	Plant 8 Old Metal Dissolver Pad
74R	Plant 8 North Pad
74S	Building 63 West Pad
74T	Plant 1 Storage Pad
74U	Pilot Plant Pad
74V	Laboratory Pad
74W	Incinerator Building Pad
77	Finished Products Warehouse (4A)
78	D & D Building
79	Plant 6 Warehouse
80	Plant 8 Warehouse
81	Plant 9 Warehouse
82A	Receiving/Incoming Materials Insp.
82B	Fuel Loading/Unloading Facility
88	Clearwell Line
89A	Southeast Parking Lot
89B	Main Parking Lot (South)
89C	Taco Parking Lot (South)
89D	Contractor Parking Lot (Southwest)
89E	Construction Parking Lost (West)
89F	Rimia Parking Lot (East)
90A	On-Site Disposal Facility (Proposed)
90B	South Field Borrow Area (Proposed)
90C	Southeast Field Borrow Area (Proposed)
93A	Southwest Boiler House
94A	CRU 4 Vitrification Pilot Plant
94B	CRU 4 Fernald Residues Vitrification Plant (FRVP) (Prop.)
T76	CRU 1 & Safe Shutdown Offices
T77	CRU 4 Offices
T80	CRU 5 Offices
T81	CRU 3 Offices

The first production steps involved chemical processing that ended with an intermediate product commonly called green salt (uranium tetrafluoride, UF_4). The green salt was then blended with magnesium-metal granules, placed in a closed reduction pot, and heated in furnaces in Plant 5 (see Figure 3, building ID No. 65). The product of this operation was a mass of uranium metal called a *derby*.

Some derbies were sent directly to other DOE sites, while the FEMP remelted the remainder, along with uranium scrap-metal recovered from earlier production, and poured them into graphite molds to form *ingots*. Ingots varied in weight, size, and shape according to how they were to be used at other DOE sites. Machining of these ingots occurred in Plants 6 and 9, after which the *billets* (machined ingots) were shipped to other DOE sites, principally the Savannah River Site in Aiken, South Carolina, and the Hanford Site in Richland, Washington.

Handling and Storing Radioactive and Hazardous Materials

Although the FEMP no longer produces uranium metals, it continues to store materials once used here and at other DOE sites. Some of the radioactive and hazardous materials that were handled or stored onsite during 1996 include:

Radioactive

- Dilute hydrogen fluoride,
- Magnesium fluoride (MgF_2) contaminated with uranium,
- Pitchblende ore residues containing radium stored in the K-65 silos,
- *Radioactive materials* in the waste pits,
- Scrap metal contaminated with uranium compounds,
- Thorium and thorium compounds stored within the production area,
- Uranium compounds, and
- Uranium metal.

Hazardous

- Heavy metals,
- Hydrochloric acid,
- Laboratory chemicals,
- Methanol,
- Nitric acid,
- Process waste,
- Sodium hydroxide, and
- Sulfuric acid.

The FEMP continues to reduce its inventory of radioactive and hazardous materials by recycling, transferring materials for beneficial use by other parties, or treating and disposing of them at designated waste disposal facilities.

Environmental Restoration Activities

In fulfillment of its current mission, the FEMP continues to strive for compliance with all environmental regulations while working toward site restoration. During 1996, this was evident as many activities took place that will contribute to the final remediation of the FEMP. Some of the more prominent activities during 1996 are described next.

Thorium Overpacking Project

The FEMP serves as the DOE repository for thorium—a radioactive material that was used in nuclear research and development programs as a potential reactor fuel. Fluor Daniel Fernald workers began packaging thorium drums on May 6, 1996. The project has established multiple safety guidelines and compliance requirements to ensure safe operations and the safety of the workers. The project is more than halfway to the target to overpack 5,600 deteriorated drums of thorium for safe transportation and permanent, off-site disposal. As of April 1, 1997, an estimated 4,489 drums have been safely overpacked. The two-year operation, targeted for completion in September 1997, is ahead of schedule. DOE and Fluor Daniel Fernald anticipate the project will be completed safely in the summer of 1997. The disposition of thorium has been an ongoing effort since June 1992.

Early completion of the thorium overpacking project will free up two large buildings for other FEMP waste stabilization projects, or for early dismantling as part of the overall effort to take down more than 125 buildings in the former production area.

DOE and Fluor Daniel Fernald have achieved a 75 percent dose reduction by implementing numerous productivity improvements suggested by project workers. A significant cost savings is anticipated as a result of completing the project ahead of schedule.

Vitrification Pilot Plant

In 1996, construction was completed on the Vitrification Pilot Plant (VitPP). The VitPP is a pilot-scale treatability study facility designed to vitrify both surrogate (Phase I) and actual radioactive K-65 materials (Phase II). Full-scale remediation will use vitrification to convert residues from silos 1 and 2 into a glass form that is stable, durable, and safe for permanent disposal. Radon gas, a principal product of radium radioactive decay, will be trapped in the vitrified material to eliminate further emissions of radon to the environment. The vitrified residues will be containerized, transported, and disposed at the Nevada Test Site (NTS).

The VitPP was energized on May 18, 1996, initiating bakeout of the melter. During the bakeout, the melter reached 1,100 degrees Celsius. The bakeout was followed by Phase I operations utilizing nonradioactive surrogate material. Phase I activities were completed during three campaigns prior to melter draining on December 26, 1996.

Approximately 36 tons of glass were produced during Phase I vitrification.

Plant 4 Decontamination & Decommissioning (D&D)

In support of the FEMP's accelerated remediation plan, Plant 4 D&D activities began in March 1995. Plant 4, a four-story structure, was built in 1953 to house the chemical processes (hydrofluorination) that produced green salt (described on page 4). The building was emptied, cleaned, and stripped down to its structural-steel framework.

Plant 4 was demolished on August 24, 1996, when explosive charges attached to key structural supporting members were detonated to drop the steel superstructure to the ground. The implosion was successful, and all activities were completed as planned.

Plant 1 Decontamination & Decommissioning (D&D)

Fluor Daniel Fernald subcontractor Babcock and Wilcox continued decontamination and dismantling activities in 1996 in Plant 1 and in two small buildings adjacent to the plant. During the former production years, ore concentrates and recycled materials were weighed, sampled, and milled in Plant 1 for distribution to other on-site processes.

Plant 1 is the third major production plant to be dismantled as part of the FEMP's cleanup mission. Controlled Demolition Incorporated (CDI), a specialty demolition contractor, employed the same dismantling technique used to fell Plant 4 and Plant 7, which weakened the steel members and caused the structure to collapse. Some of the benefits of imploding the structure, compared with other demolition approaches, include:

- reduced radiological contamination exposures to the workers,
- minimized environmental and personal exposure to lead-based paint,
- reduced worker exposure to high elevations, and
- shortened the overall schedule, which reduces the cost of the project.

Plant 1 was successfully imploded as scheduled on February 22, 1997. With the implosion complete, steel concrete and other materials will be size-reduced, stacked and placed back on the Plant 1 foundation. Final disposition of approximately 400 tons of Plant 1 structural steel and other materials will be consistent with the Operable Unit 3 Record of Decision (ROD) for Final Remedial Action.

Above-Grade Dismantlement of (Temporary) High and Low Nitrate Tanks

Two, 1 million-gallon each, temporary wastewater holding tanks were dismantled five years earlier than originally scheduled. The tanks consisted of braced sheet metal walls with two bottom layers of geomembrane liner and single layer floating membrane cover. The tanks had been used to store FEMP wastewaters for biodenitrification treatment temporarily while modifications to the existing

Biodenitrification Surge Lagoon were made in 1987. Following the lagoon modications, the tanks remained in service to supplement pre-treatment storage capacity; the high nitrate tank, for example, was used recently to store high-nitrate wastewaters generated from the uranyl nitrate (UNH) Removal Action #20 Project.

The tanks were initially scheduled for dismantlement in 2001 as part of the Operable Unit 3 Remedial Action. However, Operable Units 1 and 2 plans identified the need to construct in the area of these tanks in 1996 and 1997, respectively. Therefore, the planning and implementation of the dismantlement of the tanks were accelerated to 1996.

The dismantlement of the tanks included the following activities:

- Characterization and monitoring of the tank contents;
- Removal of tank contents (waste sludge and water);
- Waste sludge dewatering, packaging, and storage for future disposal;
- Dismantlement of the tanks; and
- Tank components packaging and storage for future disposal or reuse.

The walls and braces are potentially reusable.

The Low Nitrate Tank was dismantled in July, enabling the Operable Unit 1 activity to begin on schedule. The High Nitrate Tank was dismantled in December, enabling the Operable Unit 2 activity to begin on schedule. The project completion report was transmitted to the EPA in January, 1997.

Advanced Wastewater Treatment (AWWT) Slurry Dewatering Facility Online

The AWWT Slurry Dewatering Facility, located next to the AWWT facility, became operational in 1996. The primary purpose is the processing (dewatering) of waste slurries and sludges from the AWWT facilities and those generated from future groundwater treatment. The dewatering of miscellaneous FEMP waste sludges (i.e., those from the Sewage Treatment plant and other FEMP facilities) may also be performed at this new facility.

The AWWT Slurry Dewatering Facility process consists of slurry conditioning (ph adjustment, coagulation/flocculation, filter aid addition), slurry thickening, and dewatering by pressure filtration. The dewatered filter cake is containerized in boxes or drums for storage and transport to waste management facilities.

Legacy Mixed Waste Shipped Off Site

On September 20, 1996, Mixed Waste Projects personnel successfully completed shipment of 28,000 lbs of legacy mixed waste to Envirocare of Utah, Inc., for treatment and disposal. The project included contaminated lead solids that did not meet unrestricted free-release limits. Lead solids were decontaminated, and those

meeting the limits were placed into a recycle program and will be shipped to a vendor for recycling. Those that did not meet those limits were shipped to Envirocare for macroencapsulation to meet hazardous waste land disposal restrictions.

The project processed approximately 65,000 lbs of lead; 28,000 lbs of lead were free-released for recycle; 28,000 lbs of lead were shipped to Envirocare for treatment and disposal; and 9,000 lbs of oversized lead required size reduction to meet Envirocare's waste acceptance criteria. In addition to the decontamination efforts, Mixed Waste Projects released approximately 30,000 lbs of lead acid batteries for recycle and received over $1,000 in return. The money will be used to support future recycling efforts.

FEMP Continues Shipments of Uranium Metal Inventory

Approximately half of the FEMP's 32 million net pound inventory of uranium metal products have been removed from the FEMP — either transferred to other DOE sites or sold to commercial vendors for non-military use.

Fluor Daniel Fernald has completed shipments of 969,310 lbs (440 metric tons) of depleted uranium metal derbies to Manufacturing Sciences Corporation. The final shipment of normal uranium oxides to Allied Signal was made on June 24, 1996, completing the contract to ship 708,658 net lbs of the material. Fluor Daniel Fernald is now preparing to ship approximately 470,000 lbs of normal uranium metal to Allied Signal (the remaining inventory of normal uranium metal at the FEMP). DOE and the United States Enrichment Corporation (USEC) signed an agreement on February 6, 1996, for USEC to serve as DOE's broker for the marketing and sale of the FEMP's remaining enriched uranium product inventory for commercial use in the private sector. The FEMP currently warehouses approximately 6.7 million lbs of enriched material.

Contracts are being negotiated for the commercial sale of the bulk of the remaining inventory that needs to be removed from the FEMP by April 1999 to support planned decontamination and decommissioning projects. The DOE-FEMP and Fluor Daniel Fernald continue to look for alternative off-site storage facilities as a contingency for any unsold product materials, since the buildings currently housing these uranium metal products are targeted for dismantling.

Liquid Waste Project Completed Ahead of Schedule

Fluor Daniel Fernald completed a project to ship legacy liquid mixed waste to the Toxic Sub-

Future Land Use at the FEMP

The Fernald Citizens Task Force (CTF) focused its future use recommendations on creating a broad understanding of how the FEMP could best be utilized following remediation, rather than identifying specific land use plans for the property. The CTF believes specific uses of the property should be determined (within the general guidelines established by the CTF) closer to the time of reuse by the people most impacted by that use. Following those guidelines, it was recommended that residential and agricultural uses be avoided on the property. However, productive use of the land was considered important as well. Accordingly, remediation levels recommended by the CTF allow for all other uses, including the potential for recreation and industry. The CTF also recommended that a substantial buffer area separate the planned on-site disposal cell and any other uses of the property.[1]

stance Control Act (TSCA) incinerator, located in Oak Ridge, Tennessee, 40 days ahead of schedule. The final liquid mixed waste shipment from this project to the TSCA incinerator was completed August 21, 1996. The regulatory milestone for completion of this project was September 30, 1996.

The legacy waste shipped to the TSCA incinerator was identified in the *Site Treatment Plan.* The project included bulking drummed waste into 21,000 gallon tanks for sampling and analysis as required to meet the TSCA Incinerator Waste Acceptance Criteria. Upon acceptance by TSCA Operations, the waste was loaded into tankers for shipment to the incinerator.

As a result of the shipments to the TSCA incinerator, the FEMP's waste inventory has been reduced by approximately 100,500 gallons, which includes the 51,500 gallons shipped during fiscal year 1995 and the 49,000 gallons shipped during fiscal year 1996.

Environmental Program Information

The FEMP conducts environmental program activities to *monitor* environmental quality in the area surrounding the FEMP. Some of these activities include the Environmental Monitoring Program, the Meteorology Program, the Waste Minimization Program, and Natural Resource Management, which are described below.

Environmental Monitoring Program

Federal and state waste management requirements applied during the FEMP operation period are still in effect because of the onsite waste storage. Earlier regulations were often less stringent, and the consequences of past operations are still evident. Today, FEMP personnel continue to investigate these effects on the environment. The Environmental Monitoring Program plays a key role in this effort. Like any complex program or investigation, the Environmental Monitoring Program was developed after careful consideration of many components. For example, former FEMP production processes which involved both radioactive and nonradioactive materials resulted in air and liquid releases to the environment. The monitoring program is largely based upon the flow of these materials through the air and liquid pathways. Additional program components address contamination risks associated with cleanup procedures.

Environmental monitoring activities seek to determine the amount of radioactive and nonradioactive materials that leave the FEMP and enter the surrounding environment.

In short, this year-round program has several responsibilities:

- Ensure the FEMP has procedures in place to detect any unexpected release of materials so that corrective actions can be taken;
- Measure progress in correcting problems from past operations and in

implementing improved environmental management practices;

- Closely monitor releases to ensure air emission and liquid effluent standards and guidelines are not exceeded;
- Evaluate the impact of FEMP activities (past and present) on the environment;
- Estimate the radiation dose that area residents may be exposed to as a result of former production operations and current cleanup activities at the FEMP; and
- Measure progress in correcting problems from past operations and in implementing improved environmental management practices.

Meteorology Program

The FEMP's meteorological monitoring system was installed in August 1986. The meteorological tower is 60 meters (197 feet) tall, with monitoring equipment at both the 10-meter (33-foot) and 60-meter (197-foot) heights. The tower instruments measure wind speed and direction, ambient air temperature, relative humidity, barometric pressure, solar radiation, and precipitation (see Table 1 on page A-2 for a partial summary).

The meteorological instruments are inspected and calibrated regularly to ensure they are functioning properly. The system is down during routine maintenance periods but not for a length of time that significantly affects the database. While the system is down, it is possible to obtain a limited amount of meteorological data from the Greater Cincinnati–Northern Kentucky International Airport, located about 27 km (18 miles) south of the FEMP.

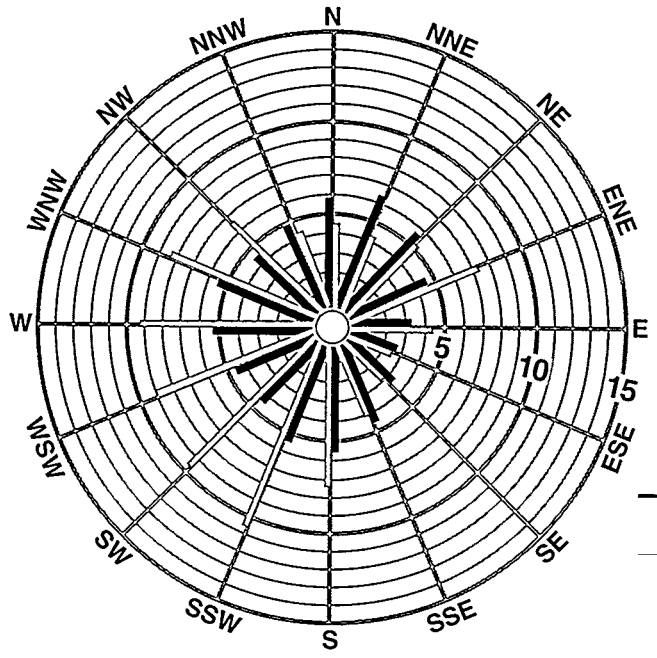
Meteorological data gathered at the FEMP are primarily used to evaluate climatic conditions at the FEMP. The Environmental Monitoring Program uses atmospheric models to determine how airborne effluents are mixed and dispersed. These models are then used to assess the impact of operations on the surrounding environment, in accordance with DOE requirements.

Airborne pollutants are subject to existing weather conditions. Wind speed and direction, rainfall, and atmospheric stability play a role in predicting how pollutants are distributed in the environment. Weather data, particularly wind speed and direction, provide guidance in collecting environmental samples and determining sites for monitoring stations.

Figures 4 and 5 (on the next page) are annual wind roses, which illustrate the average wind speed and general direction measured at the 10-meter (33-foot) and 60-meter (197-foot) levels in 1996. The prevailing winds were from the south-southwest at both the 10- and 60-meter level, 11% and 12% respectively.

The prevailing winds occur as the result of the general west-to-east flow of air at the mid-latitudes of the earth. The winds blowing from the northeast were usually

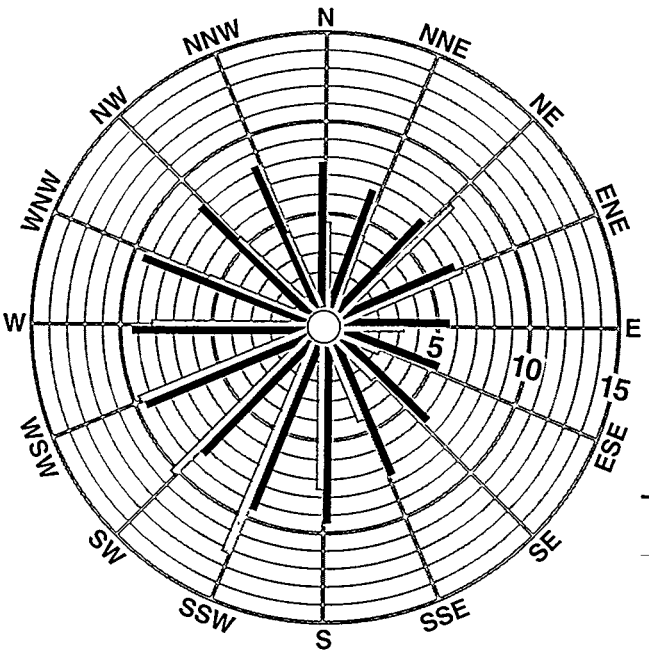
Figure 4: 1996 Wind Rose Data, 10-Meter Height



LEGEND

- Average wind speed from this direction.
- Percentage of time that the wind blew from this direction.

Figure 5: 1996 Wind Rose Data, 60-Meter Height



LEGEND

- Average wind speed from this direction.
- Percentage of time that the wind blew from this direction.

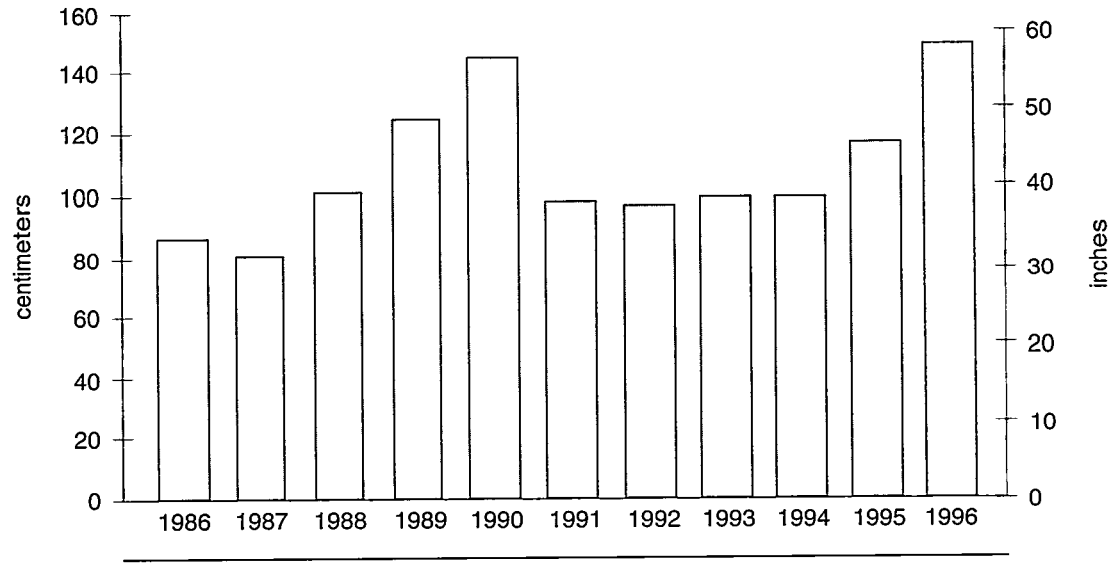
a result of drainage winds which frequently occur overnight along the Great Miami River basin. Overnight, during periods of cooling, the earth cools more rapidly at higher elevations. The cooler, more dense air will then flow down to areas of lower elevation. Hence, air can drain down a valley creating a light downhill breeze. Consequently, as the proper conditions occur, cooler, more dense air flows from higher elevations farther up the Great Miami River basin toward the lower elevations to the south-southwest.

In 1996, the precipitation measured at the FEMP was 148.96 cm (58.6 inches), which is higher than the average annual precipitation of 104 cm (41 inches) for 1985 through 1995. Figure 6 shows 1996 total precipitation for the area in relation to the annual precipitation amounts recorded since 1986. (Precipitation totals through 1992 were taken from the measurements made at the Greater Cincinnati/ Northern Kentucky International Airport because of a computer software problem at the FEMP meteorological tower. This problem was corrected, and the 1993 through 1996 totals were obtained from measurements made at the FEMP.)

Waste Minimization Program

Environmental remediation activities generate significant amounts of waste requiring management. At first glance, waste minimization does not seem to apply to remediation work because the goal of waste minimization is to reduce the total amount of waste generated. However, the real challenge of the Waste Minimiza-

Figure 6: Annual Precipitation Data, 1986 – 1996



Precipitation totals prior to 1993 are from the Greater Cincinnati – Northern Kentucky International Airport. Totals from 1993 through 1996 are from the FEMP.

tion Program is to reduce the amount of secondary waste generated during remediation and to recycle or reuse primary waste, as appropriate.

The Waste Minimization Program at the FEMP has been recognized by DOE as a benchmark program for applying waste minimization and pollution prevention principles at a remediation site. The FEMP has developed an exceptional model for project planning and project integration to ensure that the most cost-effective decisions are made and that communications between all organizations are ongoing and effective.

The Waste Minimization Program created waste disposition options for project activities. When evaluating waste dispositions, dependency on disposal is reduced when alternatives exist. The idea is to drive waste toward more cost-effective options, such as sanitary waste or reuse.

Waste minimization accomplishments in 1996 are listed below:

- 155 tons of scrap metal were decontaminated and released for resale or recycle through the Material Release Facility;
- The FEMP Reuse Waste Minimization Board realized a cost savings of over $200,000;
- 9,000 lbs of aluminum cans were donated to local schools, and over 1,200 laserjet cartridges were sent to a local vendor for refurbishment;
- 240,212 lbs of office paper and cardboard were recycled;
- Controlled area trash segregation program realized a cost savings of $131,675.00.

Natural Resource Management

The management of natural resources will be an ongoing process throughout federal ownership of the FEMP. Natural resources have aesthetic, ecological, educational, historical, recreational, and scientific value to the United States. Discussions on the following topics provide information on the natural resources found on FEMP property:

- ecology;
- threatened and endangered species;
- wetlands; and
- cultural resources.

Ecology

Representative of the regional ecology, the area's natural vegetation is comprised of a broad-leafed deciduous forest, dominated by maple hardwoods. Some of these naturally wooded areas still exist north of the FEMP and in the Paddys Run (a small creek beginning north of the FEMP and flowing southward along the FEMP's western boundary) watershed to the west. Sixty-two acres immediately north of the production area were planted with white and Austrian pines as part of

a 1973 environmental improvement project. Non-native grasslands cover most of the remainder of the FEMP, and local dairy farmers leased FEMP pastures for their herds to graze, consistent with the property's former agricultural uses. The plant diversity provides abundant cover for deer, eastern cottontails, woodchucks, and bobwhite quail; predatory birds, such as red-tailed hawks, have also been observed on FEMP property. Song sparrows, blue jays, cardinals, and robins nest in the pine plantations, while Paddys Run is home to numerous species of small fish, including minnows, darters, and shiners.

Between 1986 and 1991, biologists from Miami University in Oxford, Ohio, conducted a comprehensive ecological study of the FEMP. In addition to collecting extensive ecological baseline data, they also studied plants and animals to determine if any species were being stressed by former FEMP operations. Based on statistical analyses, the study concluded that the FEMP's impact on the natural habitat did not appear to be different from the ecological impact of any other local industrial site.[2]

Threatened and Endangered Species

The Endangered Species Act states that all federal agencies must seek to conserve federally-listed, threatened, and endangered species. The FEMP conducted surveys in 1994 and 1995 to establish baseline information on any threatened or endangered species that may be found onsite. The results of the surveys showed that good-to-excellent habitat exists along Paddys Run and the Storm Sewer Outfall Ditch for the federally-listed endangered Indiana bat (*Myotis sodalis*). The surveys also found habitat for the state-listed, endangered cave salamander (*Eurycea lucifuga*) in one onsite well, an offsite well, and a ravine in the northern section of the FEMP. A population of state-listed, threatened Sloan's crayfish (*Orconectes sloanii*) was found in the northern sections of Paddys Run. A follow up survey for the Sloan's crayfish was conducted in 1996 in Paddys Run. The survey found a large, healthy population still residing in the stream. Additional follow up surveys for the above-listed species will be conducted as needed.

Wetlands

Wetlands are defined as areas covered or saturated with water for enough time to support growth of hydrophyte vegetation and the formation of hydric soil. A wetland delineation was conducted onsite in December 1992 and January 1993. A total of 15 hectares (36 acres) of freshwater wetlands were delineated. Delineated wetlands included 11 hectares (27 acres) of palustrine forested wetlands, 3 hectares (7 acres) of drainage ditches/swales, and 1 hectare (2 acres) of isolated persistent emergent and scrub/shrub wetlands.

Floodplains

Floodplains within the FEMP property are confined to the north-south corridor containing Paddys Run. Outside of the FEMP boundaries, the 100- and 500-year floodplains of the Great Miami River extend west of the Big Bend region, which is

east of the FEMP. It also extends northward along Paddys Run from the confluence of the two waterways past the southern boundary of the FEMP.

Cultural Resources

Factors such as geologic setting, surface waters, soils, vegetation, and climate determine the population and cultural growth of an area. The FEMP and surrounding area are located in a region of rich soil and many sources of water, such as the Great Miami River. As a result, the area has a rich cultural resource diversity. This diversity is evident by the number of historical periods represented in the area's history. These periods include the Paleo-Indian Occupation (12000 BC – 8000 BC), Archaic Occupation (8000 BC – 1000 BC), Woodland Tradition (1000 BC – 1000 AD), Mississippian Tradition (1000 AD – 1660 AD), and Historic Times (1660 AD – present).

Local Geography

A variety of regional physical, ecological, and human characteristics form the context in which environmental monitoring results must be analyzed. By studying various elements of the local geography, scientists and engineers are better able to identify the impact of former production activities. Remedial techniques are then designed to restore the physical environment to its original state or to an established cleanup standard. The following sections describe several of the characteristics of these elements, beginning with the geologic origins of the area.

Geologic History

About 450 million years ago, in the Late Ordovician period, sediments were deposited in a shallow sea. These sediments solidified over time to become predominantly shale with alternating thin layers of limestone. These strata are known universally as the Cincinnatian Series. The shale is the relatively impermeable bedrock underlying the FEMP.

An ancient river cut into the shale bedrock to about 60 meters (200 feet) below the present-day Great Miami River, forming a channel named the New Haven Trough. Later, the Illinoisan and Wisconsin glaciers (about 40,000 years ago and 10,000 years ago, respectively) advanced into the area during the Pleistocene epoch. These glaciers crushed rocks as the ice moved southward from the arctic region. As the glaciers receded, they filled the trough with sand and gravel sediments.[3]

The last of the glaciers in the Fernald area deposited a relatively impermeable *glacial till* over the sands and gravel. A mix of clay, silt, sand, gravel, and cobbles, this glacial till is unevenly deposited throughout the area and makes up the local *overburden.*

The Great Miami River and its tributaries have eroded significant portions of the overburden and left *terrace remnants,* which stand higher than surrounding bottom lands of the river valley. The FEMP lies on top of one of these terrace remnants, about 177 meters (580 feet) above sea level. The property rises to 213 meters (700 feet) at the northern boundary of the FEMP and slopes downward to 168 meters (550 feet) at Paddys Run. North and south-southwest of the FEMP, the hills peak at about 260 meters (850 feet) and 235 meters (770 feet), respectively. The elevation of the Great Miami River, east of the FEMP, is about 165 meters (540 feet), while the land rises gently to about 183 meters (600 feet) west of the FEMP. Figure 7 (on page 20) presents a cross-section of the area.

Lithology

Lithology is the study, classification, and mapping of rocks and rock formations. This science is vital in determining the location, flow, and direction of groundwater. The shale underlying the FEMP forms the floor and valley walls of the New Haven Trough and is generally between 18 and 60 meters (60 and 200 feet) below the ground surface. The elevation of the bedrock surface varies from 100 meters (330 feet) above sea level south of the production area to 122 meters (400 feet) just north of the FEMP.[4]

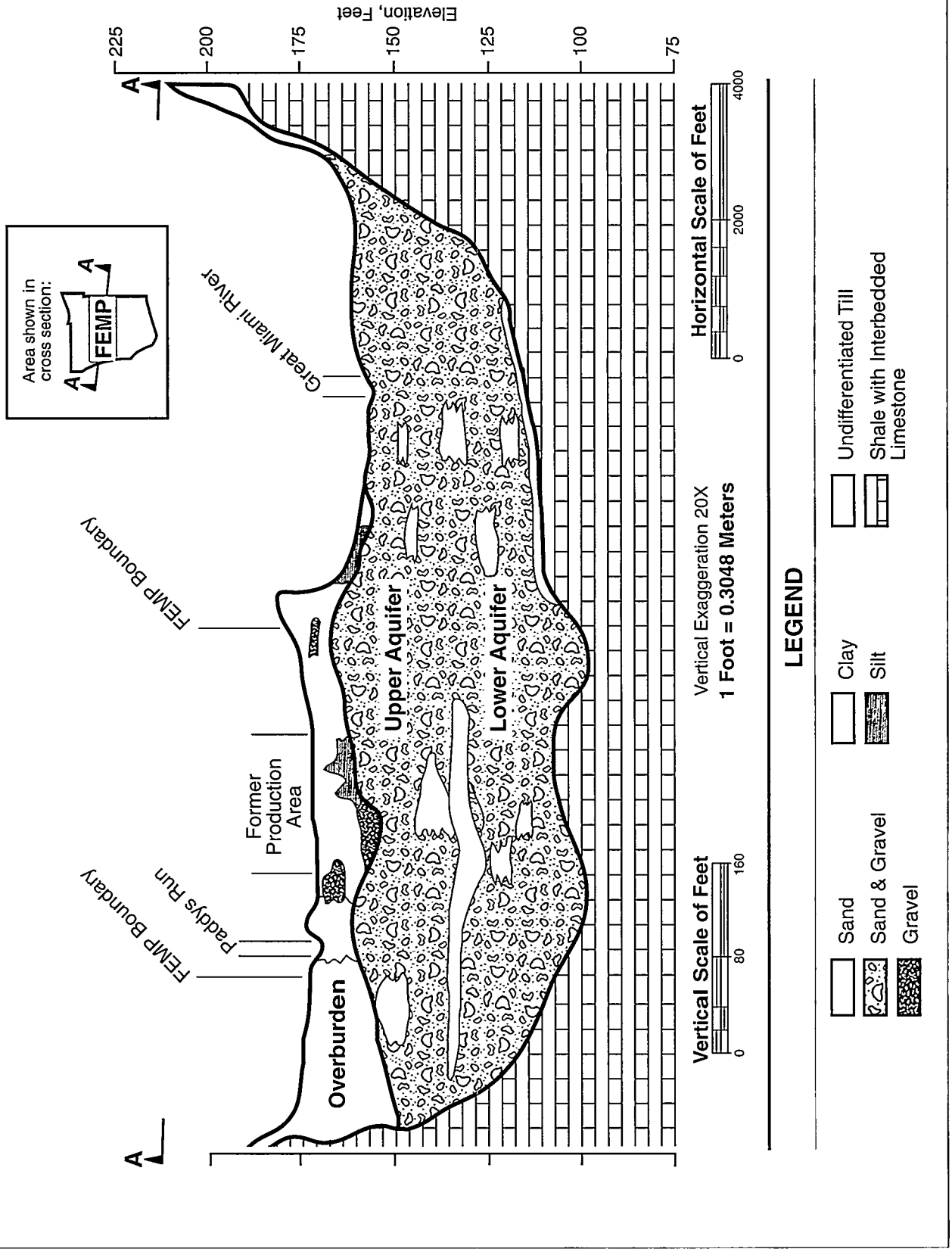
The layer of sand and gravel filling the New Haven Trough is up to 60 meters (200 feet) thick. This relatively porous material makes up the Great Miami Aquifer. About 30 to 38 meters (100 to 125 feet) below the surface of the FEMP, the sand and gravel are divided by a greenish-black silty clay layer, about 3 to 6 meters (10 to 20 feet) thick.[4,5] Data collected as part of the Remedial Investigation and Feasibility Study (RI/FS) suggest that the clay layer extends from west of Paddys Run to the center of the former production area and is present beneath the waste pits area. The clay layer does not extend east or south of the former production area.

A silty clay glacial till overlies the sand and gravel aquifer. This dense overburden, ranging in thickness between 6 and 15 meters (20 and 50 feet), varies in composition both vertically and horizontally. The elevation of the base of the overburden is 165 meters (540 feet) above sea level.[4,5,6] The silty clay overburden continues north and east of the site, where it rests upon the shale bedrock. However, in the lower reaches of Paddys Run and the Storm Sewer Outfall Ditch, the clay has eroded, exposing the underlying sand and gravel and giving the aquifer direct contact with surface runoff.

Groundwater Hydrology

Hydrology is the study of the properties, distribution, and circulation of water through the local environment. While surface hydrology, discussed in the next section, is the study of drainage systems like rivers, streams, and rainwater runoff, groundwater hydrology focuses on the movement of water below the earth's surface.

Figure 7: Cross-Section of the New Haven Trough, Looking North



Groundwater beneath the FEMP exists in the glacial overburden as perched water in a sand and gravel aquifer and, to a much lesser extent, in the underlying bedrock. Perched water occurs when water sinking through the earth from the surface is trapped above very dense clay. Some of this perched water may slowly seep through the clay, but most remains trapped. At the FEMP, perched water is generally found between 0.3 and 3 meters (1 to 10 feet) below the surface. Perched water in the glacial overburden occurs sporadically and is not a sufficient source of drinking water. In the overburden, water does not move as easily as water in the sand and gravel aquifer below because most perched water occurs in isolated pockets.[7]

Water sinking through the glacial overburden quickly collects in the sand and gravel aquifer, saturating it. Most water is prevented from sinking further by the nearly impermeable rock floor. The top of the aquifer is about 25 meters (82 feet) beneath the FEMP, and the aquifer is between 38 and 53 meters (125 and 175 feet) thick. As shown in Figure 8 (page 22), the groundwater in the sand and gravel aquifer is moving east under the waste pits and production areas, while on the southern edge of the FEMP, groundwater moves generally to the south. These groundwater flow data are used to track and forecast the movement of contaminants that may be found in the aquifer.

There may be groundwater even deeper in the slightly permeable rock layers below the sand and gravel aquifer; however, this water is essentially trapped in cracks and fissures and does not contribute any significant amount to the entire flow system.

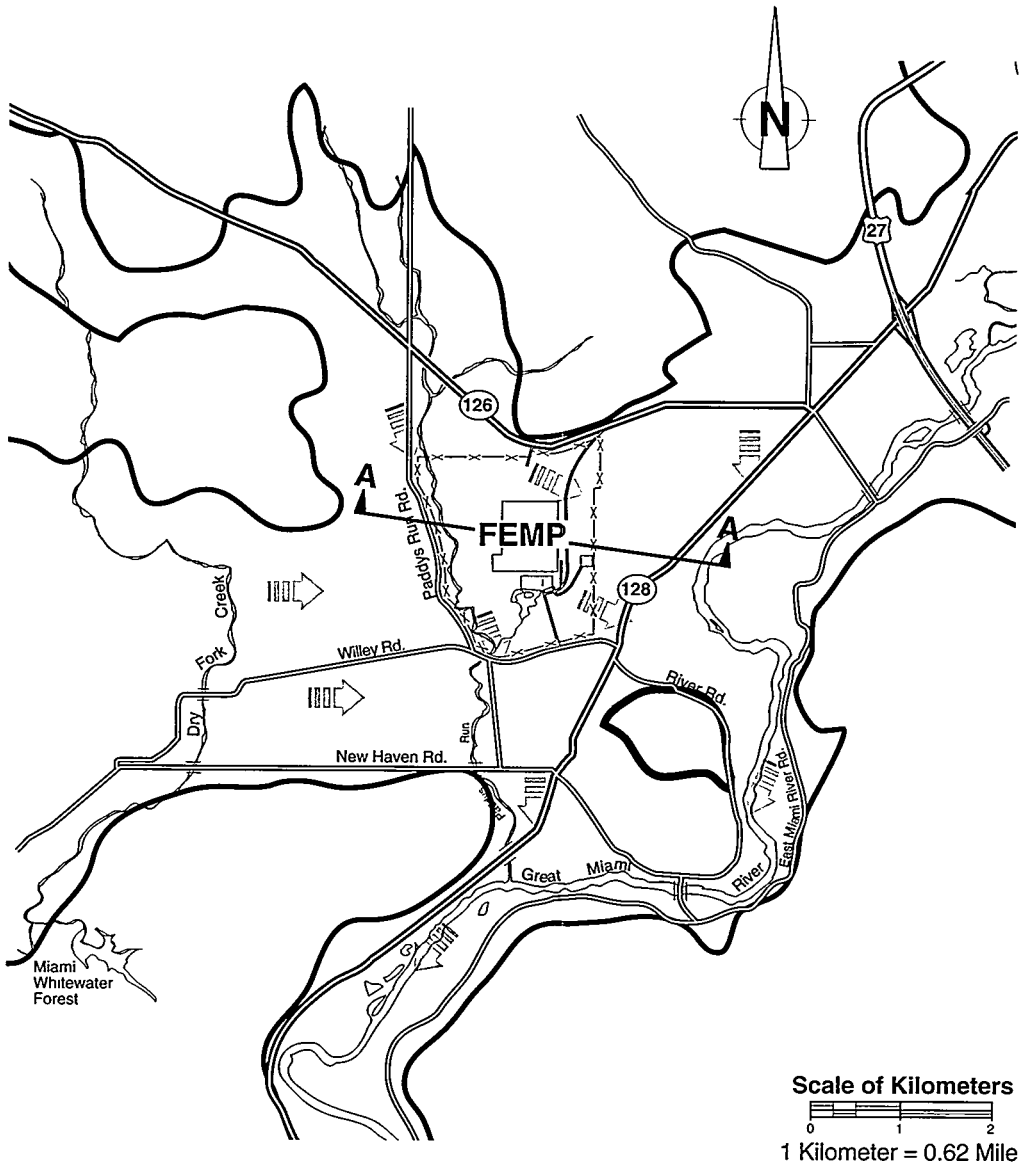
Surface Hydrology

The FEMP is part of the Great Miami River drainage basin, although it is above the floodplain (see Figure 9 on page 23). Natural drainage from the FEMP to the Great Miami River is primarily via Paddys Run, a small creek beginning north of the FEMP and flowing southward along the FEMP's western boundary.

This intermittent stream begins losing flow to the underlying sand and gravel aquifer south of the Waste Pits Area. Finally, about 2.4 km (1.5 miles) south of the FEMP, Paddys Run empties into the Great Miami River.

In addition to natural drainage through Paddys Run, FEMP runoff from the former production area and Waste Pits Area is collected, treated, and discharged to the Great Miami River. Since January 17, 1995, the majority of this runoff has been treated for uranium removal in the Advanced Wastewater Treatment Facility before being discharged. The river, about 1 km (0.6 mile) east and south of the FEMP, runs in a southerly direction and flows into the Ohio River about 39 km (24 miles) downstream of the FEMP. Although turbulence makes the Great Miami River unsafe for swimming, some people do fish there. The segment of the river between Fernald and the Ohio River is not designated as a source of public drinking water.

Figure 8: Buried Valley Aquifer Underlying the Fernald Site and Vicinity



LEGEND

- Buried Valley Aquifer
- General Direction of Groundwater Flow
- Plant Perimeter
- A A Location of Cross-Section Shown in Figure 7

Figure 9: Great Miami River Drainage Basin

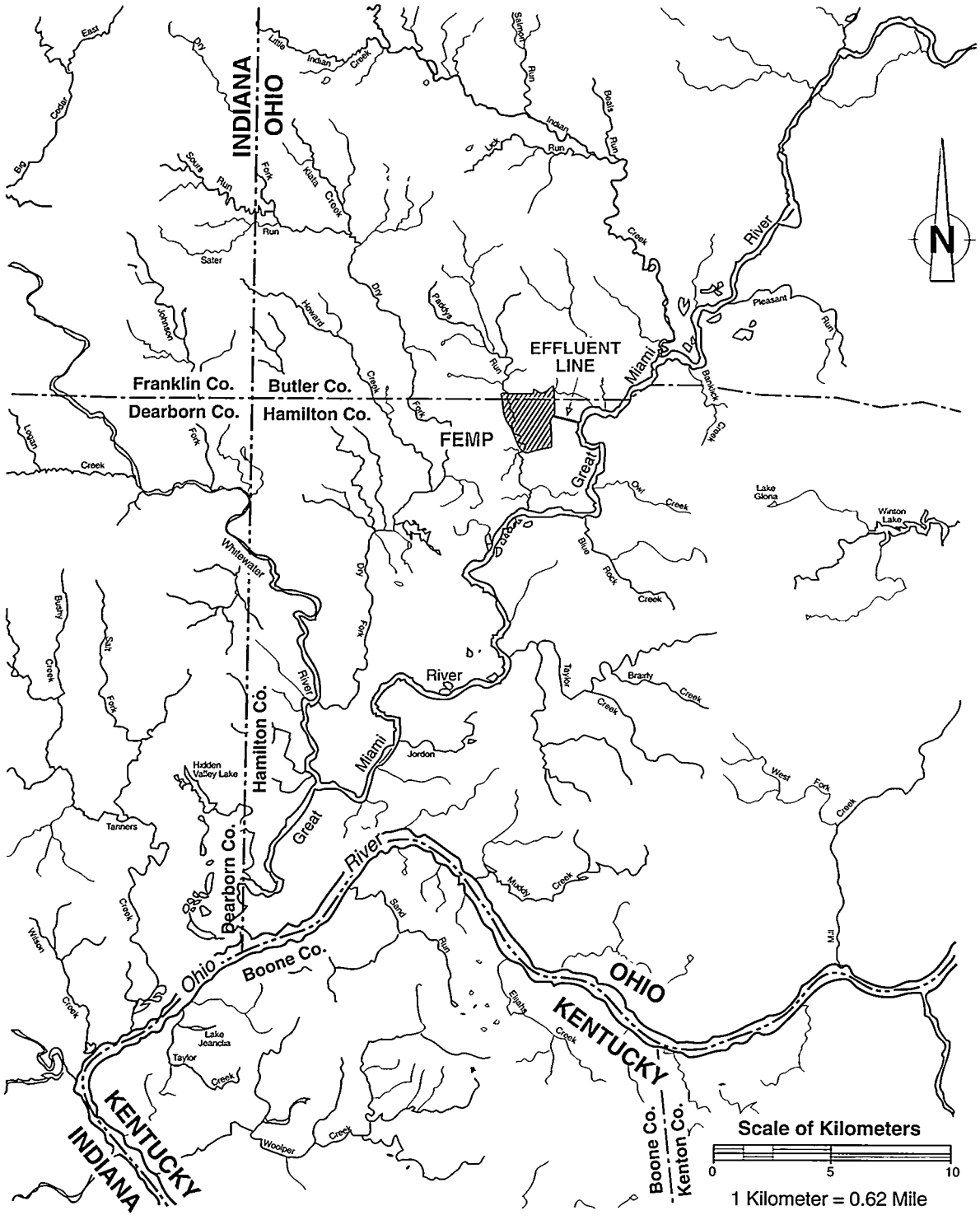
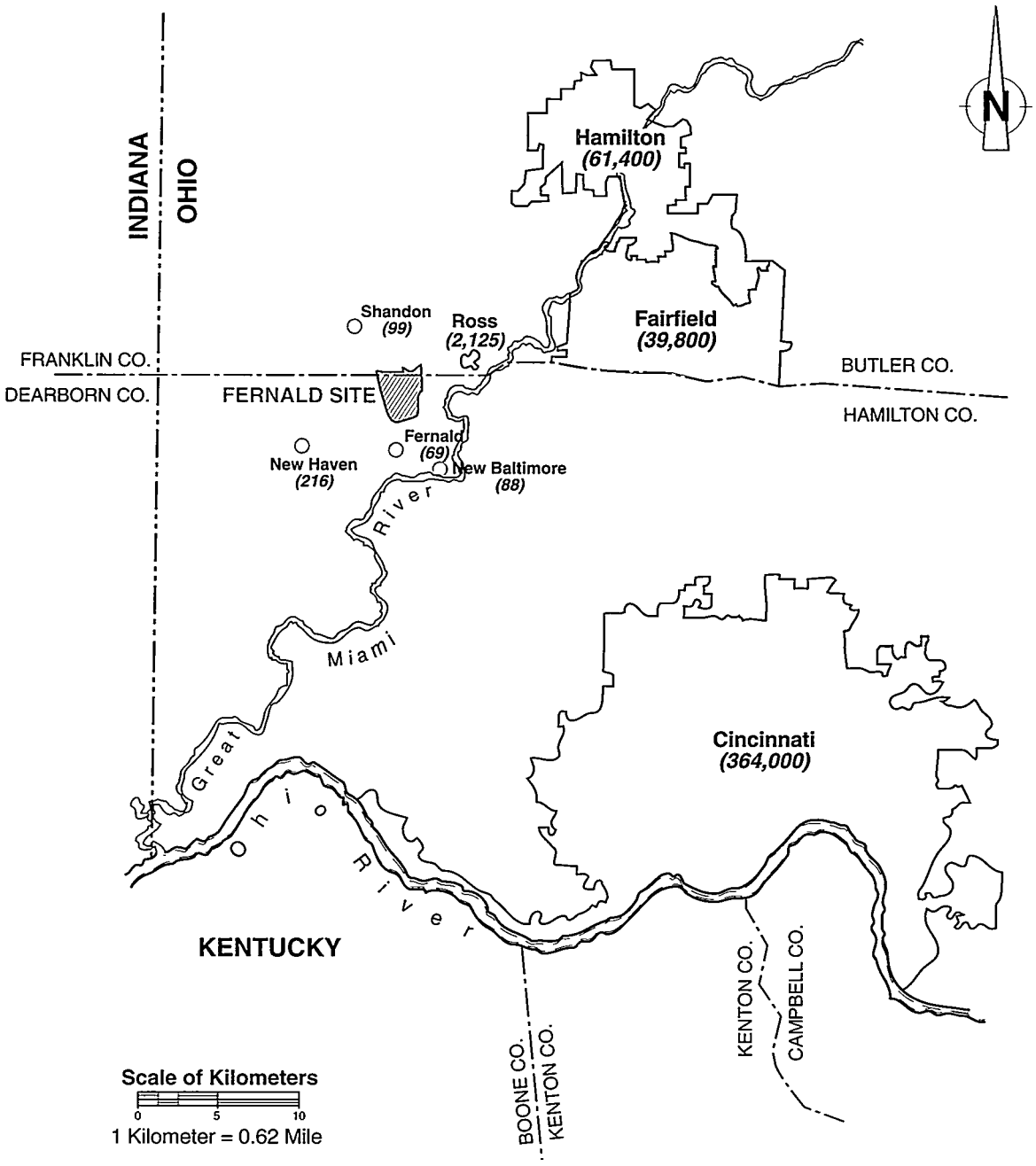


Figure 10: Major Communities in Southwestern Ohio



LEGEND

○ Population in parenthesis estimated in 1989

▭ Population in parenthesis from 1990 U.S. Census Figures

The average flow rate for the Great Miami River in 1996 was 190 cubic meters per second (6,600 cubic feet per second), measured daily approximately 16 km (10 river miles) upstream of the effluent discharge.[8]

Demography and Land Use

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the FEMP (see Figure 10). Downtown Cincinnati is approximately 27 km (18 miles) southeast of the FEMP, and the cities of Hamilton and Fairfield are 10 to 13 km (6 to 8 miles) to the northeast. There is an estimated population of 14,600 within 8 km (5 miles) of the FEMP, and an estimated 2.74 million within 80 km (50 miles). Table 2 on page A-3 shows an estimate of population distribution in the surrounding areas.

The area's major economic activities rely heavily on the physical environment. Farming and raising beef cattle account for the majority of the land use in the area. Major crops include field corn, sweet corn, soybeans, and winter wheat. Several nearby farms also sell produce locally or in nearby urban markets.

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 valley. A Cincinnati Water Works station is located 2 km (1.25 miles) upstream of the FEMP's effluent discharge to the river; presently, this company pumps about 76,000 m^3 (20 million gallons) of groundwater per day, for sale primarily to Greater Cincinnati industries.

Exposure Pathways to Humans

To protect the local environment, the Environmental Monitoring Program focuses on *exposure pathways*. A pathway is a route by which materials could travel between the point of release and the point of delivering a radiation or chemical dose to a person. These pollutants may reach people directly via a primary pathway, through contaminated air or water, or through a secondary pathway, such as the food chain. One example of a secondary pathway is the air-to-soil-to-roots-to-produce-to-human pathway. In this scenario, a gas or dust particle released from a stack settles on a field or a plant and is absorbed into the soil. A plant may then absorb the pollutant through its roots; the chemical would then pass into the rest of the plant, including the edible portions.

This scenario presents a simplified pathway materials may take. The actual route can be very complex, and the quantity of material that could eventually reach people would be very small. To develop an understanding of the complexity, take another look at the pathway and consider that not all materials released settle out of the air; some fraction may be washed out by rain and enter surface water or groundwater. Of the fraction that does settle, not all falls onto fields, and not all of

that fraction on fields is absorbed by the roots of plants. This process of dilution and separation continues until some small fraction of what is released in the air may reach the leaves or fruit of the plant. Although certain plants, animals, and soils may concentrate specific materials and are, therefore, important points in pathways that should be sampled, pathways frequently overlap, and it is difficult to trace them precisely. Environmental sampling and analysis are performed to detect the presence and concentration of pollutants throughout the air and liquid pathways.

Although both radioactive and nonradioactive materials can reach people through the same pathways, the pathway scenarios presented here and throughout the report will focus on radioactive contamination because this is of significant concern at the FEMP. Much of this report, as well as the Environmental Monitoring Program itself, focuses on radioactive contamination. Uranium is the major radioactive pollutant at the FEMP; however, some of the uranium processed was recycled from nuclear reactors and contains trace concentrations of *fission* products (such as strontium-90 and cesium-137) and *transuranic*s (such as neptunium-237, plutonium-239, and plutonium-240). These trace *nuclide*s are radioactive and also exist in the environment as a result of fallout from weapons testing and emissions from other nuclear facilities.

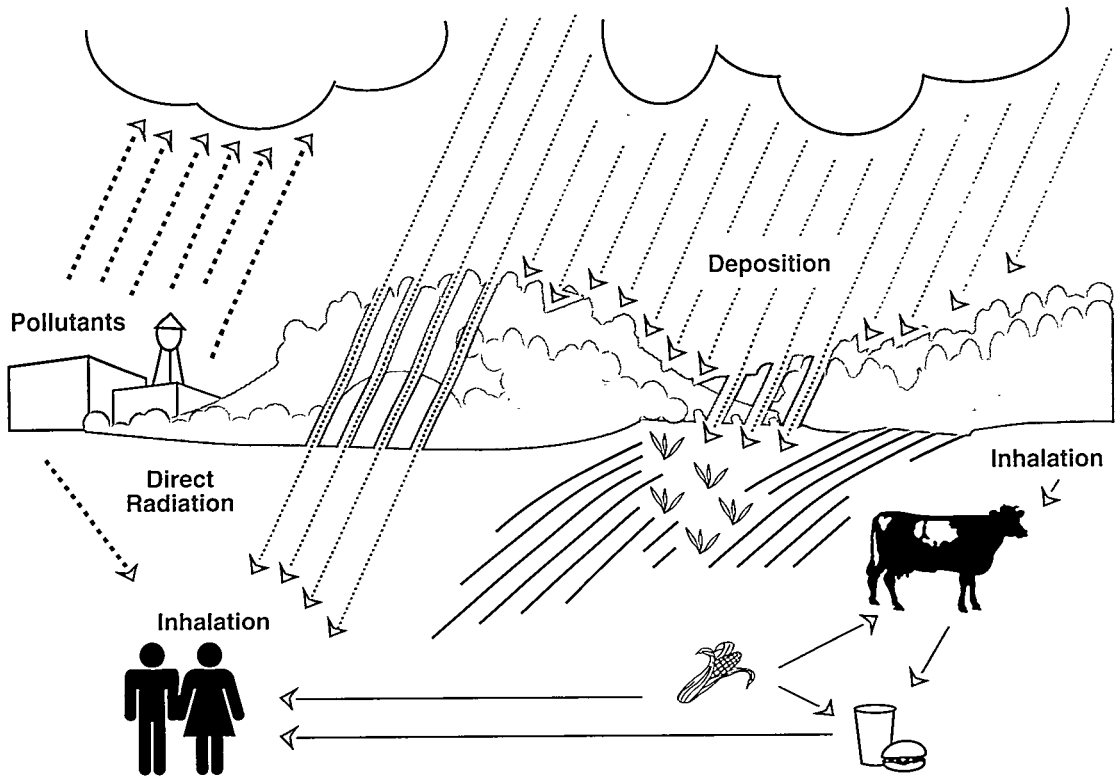
To organize the many existing pathways, the Environmental Monitoring Program centers on two major pathways: air and liquid. These pathways provide a basis for the environmental sampling program and direct which environmental samples and models will be used in estimating dose. (Direct radiation, a third pathway, is monitored with radiation detection instruments that measure radiation emitted directly from the FEMP, particularly from the K-65 silos. Direct radiation is discussed further in Chapter Four.) The following sections describe how materials may follow the air and liquid pathways and briefly describe environmental monitoring procedures.

Air Pathway

The air pathway includes the airborne pollutants that may be carried from the FEMP through emissions and direct radiation (see Figure 11). Stack and building vent emissions are obvious sources of pollutants, but dust from construction and remediation activities, waste handling, and wind erosion are also potential sources. The form and chemical makeup of pollutants influence how they are dispersed in the environment as well as how they may deliver radiation doses. For example, fine particles and gases may be inhaled, while larger, heavier particles tend to settle and deposit on grass or soil. Chemical properties determine whether the pollutant will dissolve in water, be absorbed by plants and animals, or settle in sediments and soils.

For the environmental scientist, the first step in monitoring the air pathway is to measure the pollutants at the point of release. Measurements may include particle

Figure 11: General Air Pathways to Humans

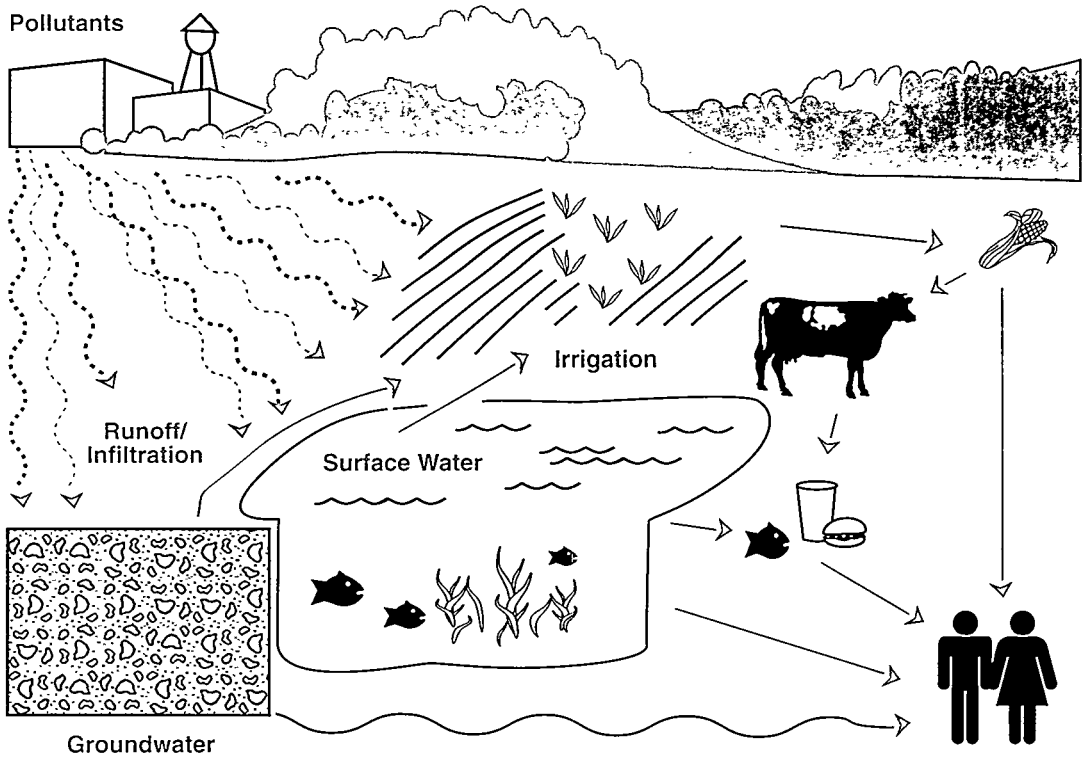


size distributions, chemical form of pollutant, temperature, and velocity of the pollutant as it leaves the stack. All of these factors and others can influence dispersion and behavior of pollutants. It is also possible to estimate the concentration of contaminants in the air once the emissions pass through the stack. The FEMP operated 20 air monitoring stations 24 hours a day, seven days a week, during 1996 to monitor these air emissions. Radon is also monitored as part of the air pathway and is discussed in Chapter 8.

Liquid Pathway

The liquid pathway includes all releases that could carry waterborne pollutants (see Figure 12 on the next page). The principal liquid pathways include the effluent discharge line to the Great Miami River, the overflow spillway from the Stormwater Retention Basin, which discharges to Paddys Run, uncontrolled stormwater runoff (much of which also flows to Paddys Run), and groundwater. The first step in monitoring the liquid pathway is to sample the effluent streams as they leave the FEMP. The potential dose that could be delivered via the liquid pathway can be estimated by the type and concentration of each pollutant. Some pollutants in the liquid effluent may be carried along as suspended solids, which eventually settle out as sediment in the stream bed; other pollutants are dissolved in the water and could be absorbed by plants and animals.

Figure 12: General Liquid Pathways to Humans



Sediment sampling in Paddys Run and the Great Miami River provides information on whether pollutants are accumulating in the stream beds. Fish sampling can show whether pollutants are being absorbed by aquatic animals and how much radioactive material could reach people if they eat fish from the Great Miami River. Fish are known as *biological indicators* because they can concentrate certain pollutants as they come into contact with them. Therefore, the longer-term influence of the FEMP can be measured through fish sampling.

Groundwater is an important component of the liquid pathway because it is the source of water for homes and farms in the area. Extensive sampling of the wells onsite and in the surrounding area provides information about the aquifer. By sampling the aquifer in many locations and at varying depths, scientists can determine the extent of any contamination.

Each pathway has specific standards and guidelines which define the allowable dose limits for the pathway, and these are discussed in the next section.

Environmental Standards and Guidelines

As part of data analysis, scientists compare the data to established standards and guidelines whenever possible. These standards and guidelines have been established by many national and international scientific and government groups, including the National Council on Radiation Protection and Measurements (*NCRP*), the International Commission on Radiological Protection (*ICRP*), United States Environmental Protection Agency (EPA), Ohio EPA (OEPA), and DOE. These groups have studied the effects of radioactive and nonradioactive materials moving through the many environmental pathways to people. From this information, standards and guidelines have been established to ensure protection of employees, people in the surrounding communities, and the environment.

DOE adopts standards recommended by various groups of experts and publishes them in DOE orders, thereby establishing the recommendations as limits to be met by DOE facilities. For example, DOE Order 5400.5, Radiation Protection of the Public and the Environment, defines the guidelines for radiation exposure to the public based upon recommendations of the ICRP.[9,10] Through reports and other guidance, the ICRP recommended a system of dose limits. Almost all countries with nuclear programs have adopted these recommendations, which provide a scientific basis for radiological protection and the selection of dose limits.

Once DOE publishes a standard in a DOE Order, such as 5400.5, each DOE site must meet the limits of radiation exposure established in that order. These limits refer to the amount of exposure that a person beyond a facility's boundary could receive from breathing the air or drinking the water. The standards in DOE Order 5400.5 require that routine activities not cause a member of the public to receive an annual effective dose from all radioactive sources (except radon and its decay products) greater than 100 mrem. This dose, known as the primary dose limit, is in addition to natural *background radiation.* (Chapter Two, Fundamentals of Radiation and Health Hazards, gives basic information about radiation and its measurement). Underlying all rules and requirements is the philosophy of keeping exposures As Low As Reasonably Achievable (*ALARA*). Therefore, DOE expects doses from its operations to be just a small fraction of the 100 mrem per year limit.

In addition to the requirements of the primary dose limit and the ALARA process, DOE is subject to several pathway and source-specific limits defined in other federal regulations. These imposed dose limits include, but are not restricted to, doses from the air pathway and from the liquid pathway. For example, the Code of Federal Regulations (CFR) states that the air pathway (air emissions and fugitive emissions from a facility) cannot contribute more than a 10 mrem effective dose equivalent in one year to a member of the public. Again, doses from radon and its decay products are covered separately.[11] Although the FEMP is connected to the public water supply and is no longer subject to the Safe Drinking Water Act (SDWA), dose limits for operators of public water systems, the 4 mrem/year dose

limit of the SWDA is used for comparison in evaluating the calculated dose from well water.[12] DOE Order 5400.5 also establishes guidelines for concentrations of radionuclides in air emissions and in liquid effluent. These concentrations, referred to as *Derived Concentration Guidelines* (DCGs), are initial screening levels that enable FEMP personnel to review emissions and effluent data and determine if there is a need for further investigation.

The FEMP follows these standards and guidelines in its daily operations and must provide monitoring results on a regular basis to DOE, EPA, and OEPA in reports that include the following:

- Annual NESHAP Subpart H Report to EPA;
- Monthly NPDES Discharge Monitoring Report to OEPA;
- Effluent Information System/Onsite Discharge Information System to DOE; and
- Quarterly Consent Agreement Report to EPA.

The FEMP has completed its sitewide Remedial Investigation/Feasibility Study (RI/FS) obligations, and final Records of Decision for all five of the FEMP's Operable Units are now in place. With the conclusion of the FEMP's RI/FS and remedy selection process, focus is now being directed to the safe and efficient implementation of FEMP remediation activities and facility decontamination and dismantlement (D&D) operations. In recognition of this shift in emphasis toward remedy implementation, the FEMP's Environmental Monitoring Plan (EMP) is being revised and tailored to accommodate the sitewide remediation monitoring needs brought into play by the FEMP's final remedy decision documents. The revised plan has been designated as the Integrated Environmental Monitoring Plan (IEMP) and is the successor to the FEMP EMP. The EMP historically has provided comprehensive on- and off-property environmental surveillance capabilities that specifically addressed the monitoring and reporting needs associated with active uranium production at the FEMP. The IEMP will provide a remediation-specifc focus by redirecting existing environmental monitoring program elements toward sitewide remediation activities and by incorporating any new regulatory requirements for sitewide monitoring, reporting, and remedy performance tracking that have been activated by the formal Applicable or Relevant and Appropriate Requirements (ARARs) that are part of the FEMP's remedy selection documents. Ultimately, the IEMP also will serve as the reporting link for the project-specific emission control monitoring activities that will accompany the individual remediation and D&D projects as needed over the life of the FEMP remediation program.

This SER compares the results of the FEMP's monitoring program to specific standards for various pollutants. Some pollutants do not yet have standards and DCGs established. Furthermore, there are instances where standards do not exist for specific media, such as uranium in soil, grass, produce, or fish. Where no standards or guidelines are available, other points of reference are presented in order

to help the reader assess the impact of FEMP operations. For example, results are compared with background data from areas unaffected by the FEMP activities. FEMP scientists look for trends by comparing results from 1996 with results from previous years.

The remainder of this report discusses some basic facts about radiation and other health hazards, compliance activities, and the Environmental Monitoring Program for 1996.

Fundamentals of Radiation and Health Hazards

Due to former operations, radioactive materials and hazardous chemicals are stored at the FEMP. These materials have hazards associated with them of which the reader should be aware. Some of the information may be difficult for the non-scientist to interpret, since terms unique to radiation and its potential health effects are used extensively throughout this report.

This chapter provides a way to put that information into perspective by introducing the following topics:

- The atom,
- Radioactivity and radiation,
- The units used to measure radiation,
- Background radiation,
- The effects of radiation,
- Definitions of terms,
- Laws regulating health hazards, and
- Types of health threats.

Readers already familiar with the concepts and terms used in the study of radiation and its health hazards may wish to proceed directly to Chapter Three.

The Atom

The world contains many different elements in liquid, solid, or gaseous form. All have one thing in common: they are made up of atoms. Atoms can be thought of as an extremely small sphere (a hydrogen atom's radius is approximately 10^{-8} cm). They contain three types of particles: the proton, the neutron, and the electron (see Figure 13).

The proton is positively charged and has a mass of only 1.7×10^{-27} kg. The neutron has no charge and has a mass slightly greater than the proton. These particles are found at the center of the atom, a dense region known as the nucleus. (Think of it as a planet.) The electron is negatively charged and has a mass of 9×10^{-31} kg (around 2000 times smaller than the proton and neutron). Therefore, the mass of the atom is principally associated with the nucleus. The electrons travel around the nucleus in what is known as the "electron cloud." (Think of it as the planet's atmosphere.)

Protons and electrons behave like magnets. Just as opposite magnetic poles are drawn toward each other, protons and electrons are attracted toward each other. This energy of attraction would make the electrons fall into the nucleus if it were not for the electrons energy of motion, which keeps them constantly moving and away from the protons. The balance between the electrons energy of motion and the energy of attraction keeps them in orbit.

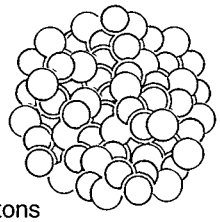
Atoms are found in an electrically neutral state in which the total negative charge balances the total positive charge. In other words, the number of electrons must equal the number of protons. The number of electrons and their distance relative to the nucleus determines the chemical reactivity of the atom. The number of protons in the nucleus differentiates the atom from atoms of other elements and is referred to as the atomic number. For example, a hydrogen atom has one proton. If a hydrogen atom were to gain a proton, it would no longer be hydrogen; it would be helium, having two protons. The constituent element of greatest concern at the FEMP is uranium, having 92 protons and 92 electrons.

The sum of the protons and neutrons in the nucleus is called the mass number. Unlike protons, the number of neutrons contained in an atom of an element can vary because neutrons have no charge that

Figure 13: Structure of the Atom

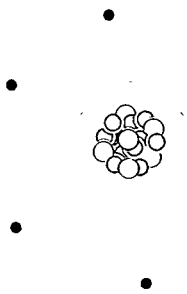
The Nucleus of an Atom

The nucleus has many protons (white) and neutrons (orange). Notice that there are never two protons touching each other. Similar to a magnet, the positively charged protons repel each other. There must be neutrons separating the protons.



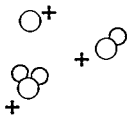
Electrons Orbiting the Nucleus

The electrons, like the protons, repel each other. Only two electrons can be on a path around the nucleus, and the two are always at opposite ends of the path. There will be as many paths as needed to hold all of the electrons.



The Hydrogen Nucleus

The hydrogen nucleus always has one proton and can have zero, one or two neutrons. The protons are positive and the neutrons are neutral.



The Hydrogen Atom

The hydrogen atom consists of the nucleus and the electron orbiting the nucleus. Since the hydrogen atom has one proton, it must have one electron to be electrically neutral.

needs to be balanced by electrons. For example, a hydrogen atom always has one proton, but it can have either zero, one, or two neutrons. The different hydrogen atoms are called isotopes of hydrogen. Isotopes are identified by their mass number. A hydrogen atom without a neutron is referred to as hydrogen, where 1 is the mass number. The hydrogen isotope with one neutron is referred to as deuterium, and the isotope with two neutrons is referred to as tritium.

Most of the uranium at the FEMP contains 146 neutrons to go with the 92 protons present in every uranium nucleus; therefore, the mass number is 238 (146 neutrons + 92 protons = 238). Uranium-234 has 142 neutrons + 92 protons; uranium-235 has 143 neutrons + 92 protons; and uranium-236 has 144 neutrons + 92 protons. All isotopes of uranium are radioactive. The ratio of the number of neutrons to the number of protons in the nucleus determines the stability of the atom. An unstable atom is radioactive.

Radioactivity and Radiation

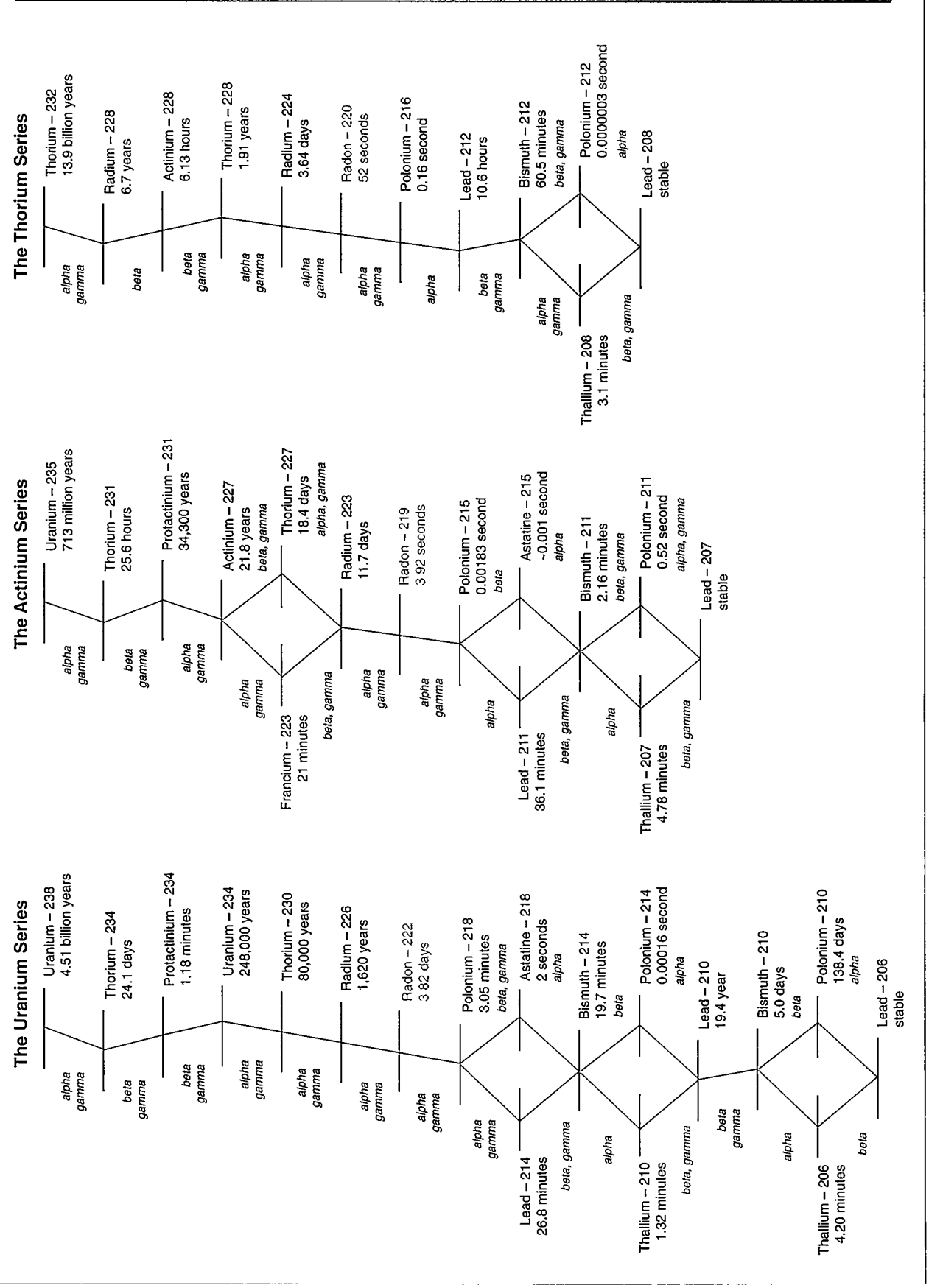
Radioactivity is the process in which an unstable atom spontaneously decays or disintegrates, releasing radiation. Radiation is the energy released as particles or waves when the disintegration or decay of the nucleus occurs. Three main forms of radiation are encountered at the FEMP. They are alpha particles, beta particles, and gamma rays. The differences between alpha particles, beta particles, and gamma rays will be clarified in the discussions that follow. It should be noted, however, that not all radioactive substances emit all three types of radiation.

Radioactive Decay

Atoms are radioactive because their nucleus is too large (because of the number of protons and neutrons), or because they have too much energy to remain stable. By emitting radiation, the nucleus releases energy and moves toward a more stable, less energetic state. Radioactive decay occurs everywhere on earth because of naturally occurring radioactive elements. When most radioactive atoms decay, the resulting atom is also radioactive. A long series of radioactive atoms is known as a radioactive decay chain. Each of the various radioactive atoms (radionuclides) created during the decay sequence has its own rate of decay, known as a half-life. The half-life of a radioactive substance is the amount of time it takes to lose half of its radioactivity, or for half to become the next element in the chain. There are three natural radioactive decay chains remaining today (see Figure 14). All decay chains found in nature begin with an isotope with an extremely long half-life. They are still present because their half-lives are comparable to the age of the earth.

One chain begins with uranium-238 and ends with non-radioactive lead-206 (this isotope of lead is stable and does not decay). The uranium decay sequence is common in nature and at the FEMP. Uranium-238 emits an alpha particle (two protons

Figure 14: Decay Chains



and two neutrons) and becomes thorium-234. Then a neutron in thorium-234 breaks up, producing a proton and an electron. The electron is expelled from the nuclues as a beta particle; the new nucleus usually has too much energy, which is released as gamma rays. The decay process continues in this manner until the element becomes stable as lead-206. Much of the uranium and thorium at the FEMP was chemically purified, with the other elements shown in the decay series being separated. These separated elements are found in certain wastes stored onsite. For example, the waste material stored in the K-65 Silos contains radium-226, separated from its parents in the uranium chain by chemical processing of uranium ore.

To better illustrate the idea of half-life; look at the short-lived isotope thorium-234. Its half-life is 24 days. If you started with 1,000 atoms of thorium-234, after 24 days you would have 500. The other 500 atoms would have decayed into protactinium-234^{m}. After another 24 days you would have 250, and so on. In contrast, the half-life of some isotopes are very long, such as uranium-238 ($t = 4.5 \times 10^{9}$ years). All the radionuclides in the uranium chain should be thought of as "eventual" lead-206 atoms. This will be the case many billions of years into the future when all uranium-238 and its radioactive daughters have decayed.

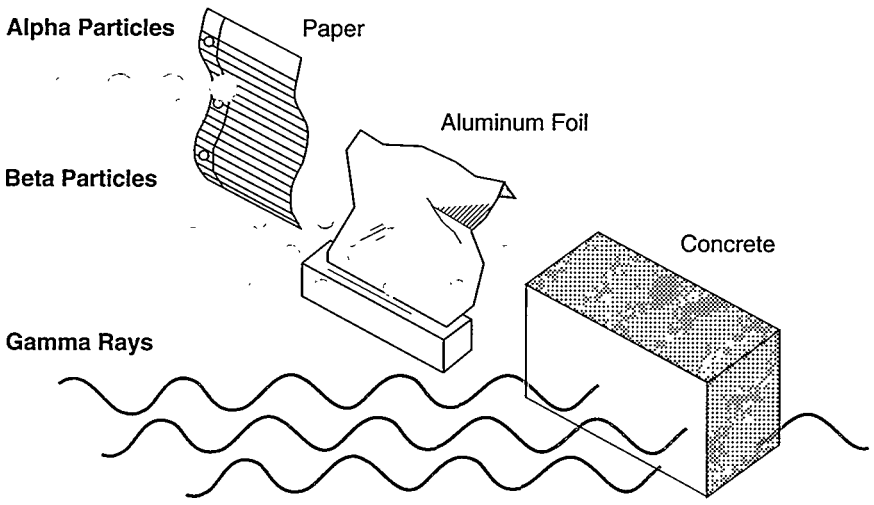
Alpha Particles

Alpha particles consist of two protons and two neutrons and are released from radioactive atoms with a large neutron-to-proton ratio. Because they are heavy charged particles, they quickly lose their energy of motion by interacting with the electrons of surrounding atoms. Alpha particles do not travel very far when emitted – 1 to 8 centimeters (0.4–3 inches) in air. They are unable to penetrate any solid material, such as paper or skin, to any significant depth (see Figure 15). However, if alpha particles are released inside the body, they can damage the soft internal tissues by depositing their energy in a very small volume. Uranium isotopes decay by emitting alpha particles; if uranium particles are inhaled or swallowed, the alpha particles may damage internal tissue. Some other radionuclides present at the FEMP that decay by emitting alpha particles include isotopes of thorium (228, 230, and 232).

Beta Particles

Beta particles are best thought of as electrons emitted by the break-up of a neutron. They are much smaller than the alpha particle and travel at nearly the speed of light. Thus, they can travel approximately 2–4 meters (6–12 feet) in air. As shown in Figure 15, they can penetrate solid materials to a depth of 1 cm (0.4 inch). Beta particles interact with other atoms in ways similar to alpha particles, but because they are smaller, faster, and have less charge, they cause less concentrated damage when interacting with tissue. Thorium-234, a decay product of uranium-238, emits beta particles.

Figure 15: Types of Ionizing Radiation



Gamma Rays

Gamma rays are bundles of electromagnetic energy, which behave as though they were particles. These pseudo-particles are called photons. They are similar to visible light but of a much higher energy. For example, X-rays are a type of high-energy electromagnetic radiation; excessive exposure to X-rays can damage the body. Gamma rays are generally more energetic than X-rays. They can travel long distances and can penetrate skin, and, depending on their energy, can penetrate substantial distances into solid materials such as concrete or steel (see Figure 15). Gamma rays are often released during radioactive decay along with alpha and beta particles. Some material stored in the K-65 Silos decay by emitting gamma rays. Potassium-40 is an example of a naturally occurring radionuclide that decays by emitting a relatively high-energy gamma ray. The typical human body contains about 110,000 picocuries of potassium-40 (units of radiation are discussed below).

Interaction with Matter

When radiation interacts with other materials, it affects the atoms of those materials by knocking the electrons out of orbit. This causes the atom to lose its electrical neutrality, becoming 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 ionization of body tissue can result in cell damage.

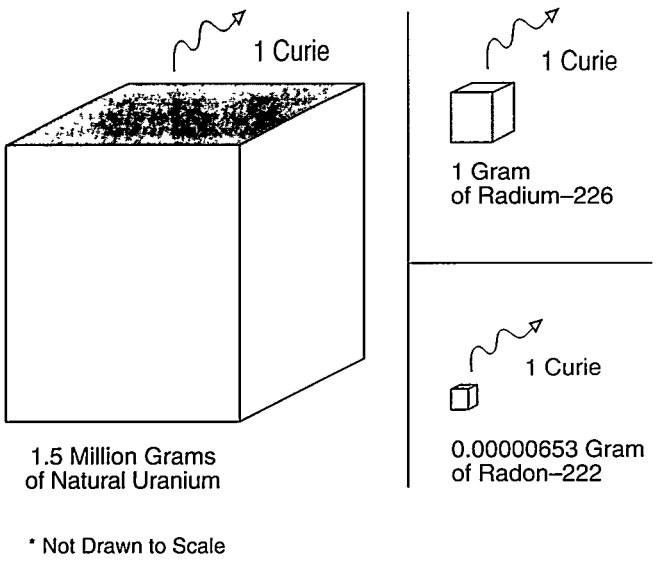
Units of Measurement

To measure the effect of radiation, scientists have developed ways to measure levels and intensity of radiation. Some of these measurement units are technical and may require some explanation. Additional terms are included in the glossary of this report (see Appendix E).

Activity

Activity is the number of nuclei in a material that decays per unit of time. An amount of radioactive material that decays at a rate of 37 billion atoms per second

Figure 16: Comparison of Disintegration Rate*



* Not Drawn to Scale

has an activity of one Curie (Ci). Smaller sub-units of the Curie are often used in this report. Two common units are the microcurie (mCi), one millionth of a Curie, and the picocurie (pCi), one trillionth of a Curie. The amount of radioactive material required to emit one Curie depends on the disintegration rate. For example, about one gram of radium-226, with a half-life of 1,622 years, emits one Curie of activity. On the other hand, it would require about 1.5 million grams of uranium-238, which has a half-life of 4.5 billion years, to equal one Curie because uranium-238 is less radioactive than radium-226. Radon-222, with a half-life of only 3.8 days, is even more radioactive than radium-226, and only 0.0000065 grams of radon-222 is needed to equal one Curie (see Figure 16).

Dose Equivalent

Dose equivalent is used when comparing the effects of different types of radiation. Alpha, beta, and gamma radiation affect the body to different degrees. To take these different effects into account, each type of radiation is assigned a quality factor (QF). The more damaging the type of radiation, the higher the QF. For beta and gamma radiation, the QF is one. For alpha radiation, the QF is 20. The QF number is multiplied by an absorbed dose to calculate the exposed person's dose equivalent. Dose equivalent is a measure of the amount of radiation that is delivered to a region of the body. The Roentgen equivalent man (rem) unit is used to express dose equivalent. The more rem, the higher the potential damage. Because the amount of radiation we receive from background and the FEMP is so small, millirem (mrem) is often used instead of rem. One mrem is equal to 1/1000 of a rem.

The term "dose" is used in four different ways in this report: organ dose, effective dose, committed effective dose, and whole body dose.

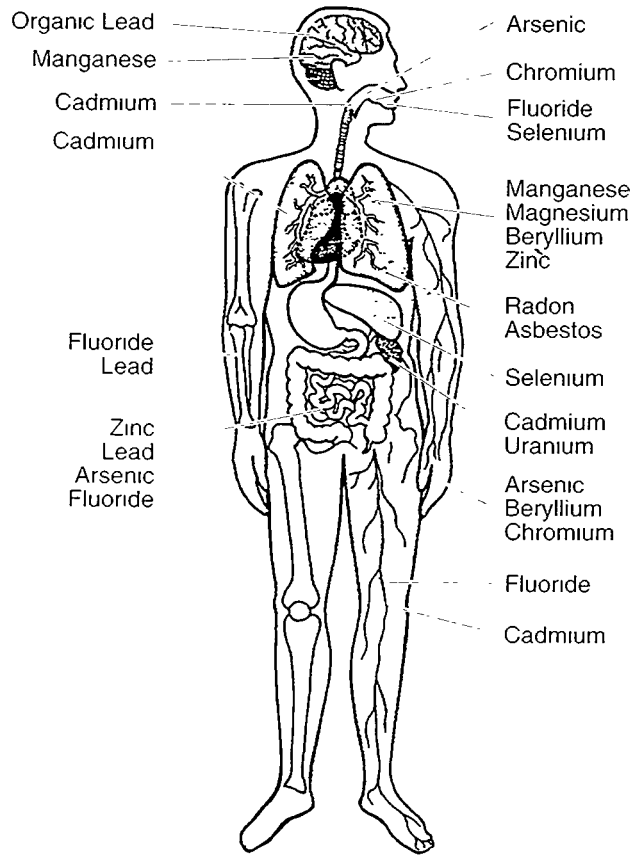
The organ dose is the amount of radiation received by an individual organ in the body. The amount of radiation any organ will absorb depends upon a variety of factors (for example, the way the radiation entered the body and the type of radiation). Therefore, when discussing the organ dose, scientists often refer only to the organ of greatest importance called the critical organ. The critical organ varies from situation to situation. It is determined based on things such as the amount of radiation received, the chemistry of the radionuclide, the sensitivity of that organ to the particular form of radiation, and the importance of that organ to the body.

Based on the radionuclides found onsite, scientists have identified the critical organs as the lung, kidney, and bone surface (endosteum). Figure 17 shows which organs are most affected by various substances found at the FEMP.

The effective dose expresses how much of a health risk radiation doses pose to individuals. To determine the effective dose, scientists first estimate each organ dose. Then, because some organs are more sensitive to radiation than others, the organs are given different weighting factors (see the shaded box on the next page), similar to quality factors. The greater the risk an organ has of developing cancer and the more important that organ is to human health, the higher the weighting factor. The weighting factor is multiplied by the organ dose for each organ. These numbers are then added together to give the effective dose.

The National Council on Radiation Protection and Measurements (NCRP) and International Commission on Radiological Protection (ICRP) recommend that an individual not be exposed to more than 100 mrem effective dose per year for all pathways (in addition to the amount a person receives from background and medical radiation). This recommendation applies to the general public for long-term, continuous exposures.[13] The DOE guideline for dose to members of the public is 100 mrem per year from all pathways (excluding dose from radon and its daughters). The National Emission Standards for Hazardous Air Pollutants (NESHAP) limit for effective dose is 10 mrem per year from radionuclides (excluding dose from radon and its daughters) released via the air pathway.[11]

Figure 17: Organs Affected by Substances Found at the FEMP



The committed effective dose is the total amount of radiation an individual receives over a specified period of time from radioactive materials inside the body. When a person breathes or eats something that contains radioactive materials, the radiation within those materials is not all released at once. Half of the radiation is released over a period of time equal to the half-life of the radioactive material. Meanwhile, the body excretes radioactive materials at various rates determined by the individual's metabolism and the biochemistry of the radioactive material. Scientists have developed the concept of the committed effective dose to estimate the total amount of radiation one will receive over time (generally a 50-year period) from the radioactive materials taken into the body in a given time period.

Organ or Tissue	Weighting Factor
Gonads	0.25
Breasts	0.15
Red Bone Marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone Surfaces	0.03
Remainder	0.30

In the chart at left, "Remainder" means the five other organs with the highest dose (e.g., liver, kidney, spleen, thymus, adrenal, pancreas, stomach, small intestine, or upper and lower large intestine, but excluding skin, lens of the eye, and extremities). The weighting factor for each of these organs is 0.06. Thus, the collective weighing factor of these five organs making up "Remainder" is 0.30.

The whole body dose is the amount of radiation an individual receives when the entire body is irradiated evenly by direct (gamma) radiation. For example, cosmic and terrestrial radiation (see Figure 18) deliver a whole body dose.

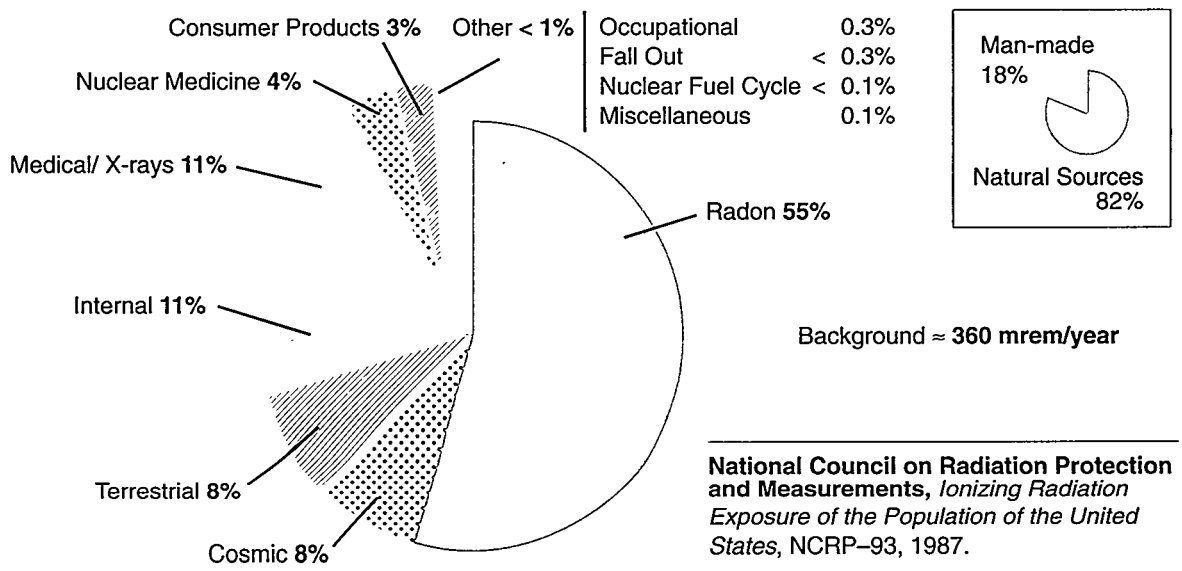
Exposure to Background Radiation

The dose terms defined in the preceding paragraphs apply to more than just the radiation we may be exposed to from facilities like the FEMP. All people are constantly exposed to other background and man-made sources of radiation. Such radiation includes the decay of radioactive elements in the earth's crust, a steady stream of high-energy particles from space called cosmic radiation, naturally occurring radioactive isotopes in the human body (like potassium-40), medical procedures, man-made phosphate fertilizers (phosphates and uranium are often found together in nature), and even household items like televisions. In the United States, a person's average annual exposure to background radiation is 360 mrem.[13] The DOE guidelines (as well as other radiological guidelines) apply to exposure individuals receive in addition to background radiation and medical procedures.

As shown in Figure 18, radon is the largest contributor to background radiation. At an average of 200 mrem per year, naturally occurring radon accounts for more than half of the background dose in the United States.[10] Radon is discussed further in Chapter Eight.

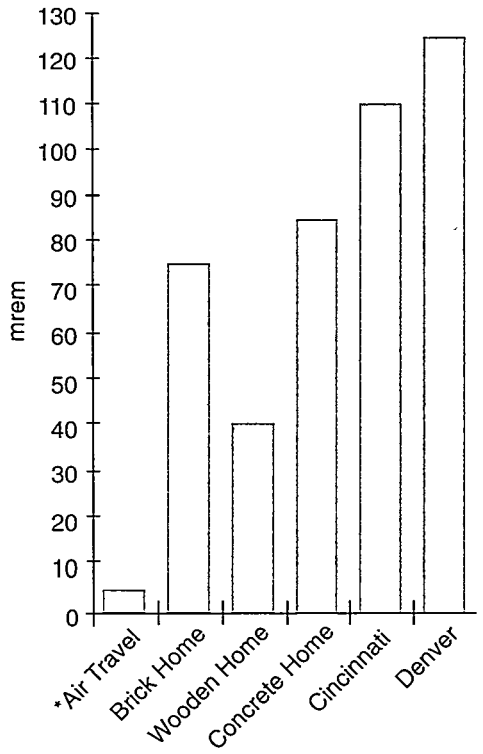
Background radiation dose will vary in different parts of the country. For example, living in the Cincinnati area will produce an annual exposure level of approximately 110 mrem, while living in Denver will produce an annual exposure level of approximately 125 mrem. This difference is attributed to soil composition and distance above sea level. Another factor that affects annual radiation dose is the type of building material used in homes. Figure 19 shows that the annual dose received from living in a brick or concrete house is about two times greater than that from living in a wood frame house. Also shown is a single round-trip flight

Figure 18: Exposure to Background Radiation



National Council on Radiation Protection and Measurements, *Ionizing Radiation Exposure of the Population of the United States*, NCRP–93, 1987.

Figure 19: Breakdown of Average U.S. Radiation Exposures



* 1 mrem for each 4,030 km (2,500 miles)

from Cincinnati to London (or the equivalent) produces an exposure of approximately 4 mrem.[14] In comparison, the dose received at the FEMP fenceline from an entire year is estimated to be about 1.1 mrem, excluding dose from radon and its daughters.

One way to measure how much radiation we are exposed to is to complete a personal radiation dose worksheet, like the one on the next page.

Effects of Radiation

The observed effects of radiation on humans have been divided into two categories, somatic and genetic. Somatic effects develop in the directly exposed individual, including a developing fetus. Genetic effects are those that are observed in the offspring of the exposed person. This section explains why this is true and how somatic and genetic effects may occur.

Personal Background Radiation Dose Worksheet*

Source of Radiation		Annual Dose (mrem)
Earth and Sky		
	Cosmic radiation at sea level	26
	Cosmic radiation above sea level Add 1 mrem for every 100 feet above sea level (Cincinnati is approximately 600 feet above sea level.)	
	Jet plane travel/high altitude exposure to cosmic radiation Add 1 mrem for every 2,500 miles flown	
	Terrestrial radiation	28
	Radon (background)	200
	Nuclear testing fallout	5
Your Body		40
Television Viewing	Add 0.15 mrem for every hour of viewing per day (For example, if you watched an average of 4 hours of TV a day in 1996, add 0.6 mrem.)	
Medical X-ray and Radiopharmaceutical Diagnosis		
	Add 10 mrem for each chest X-ray	
	Add 500 mrem for lower gastrointestinal-tract X-ray procedure	
	Add 300 mrem for each radiopharmaceutical examination	
Total		

* The information is drawn from two major sources:

- BEIR Report–III–National Academy of Sciences, Committee on Biological Effects of Ionizing Radiations, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences, Washington, DC, 1980, and
- National Council on Radiation Protection and Measurements Report No. 93, 1987.

Somatic Effects

Continuous exposure to low levels of radiation can produce gradual somatic changes over extended time. For example, someone may develop cancer 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. Therefore, the most likely somatic effect of low-level radiation is believed to be a small increased risk of cancer.[15]

There are groups of people under medical observation that have been exposed to high levels of radiation. The groups include the atomic bomb survivors of Hiroshima and Nagasaki, uranium miners in the United States and eastern Europe, a group of workers who used paint containing radium, early users of X-ray machines, some DOE employees working in the defense facilities, and people

suffering from illnesses where radioactive material was used for treatment. Those individuals were exposed to high levels of radiation and were at greater risk for somatic effects. We know this because, at these higher radiation doses, the number of radiation effects increases as the level of radiation dose increases. After studying the health effects of radiation on these groups of people, scientists still cannot extrapolate with certainty how much cancer, if any, may have been caused by low-level radiation.

A whole-body dose of 1,000 rem of radiation delivered instantaneously would probably kill a person. A dose of 600 to 1,000 rem causes severe sickness, but there is some chance for recovery. A dose of 200 to 600 rem causes some sickness with a very good chance for recovery. A dose of 100 to 200 rem could possibly cause some vomiting, but probably no demonstrable long-lasting effects.[16]

Significant clinical symptoms of radiation probably would not be seen in individuals who have been exposed to less than 100 rem.[17] Most scientists believe that there are no directly observable short-term radiation effects on human beings exposed to less than 10 rem because the biological damage created by this level of radiation is too small to result in near-term clinical symptoms.

Estimates on the value of the threshold level for radiation effects, if such a level exists, vary significantly. As mentioned above, some scientists believe it could be as high as 10 rem.[16] Others insist there is no threshold level below which radiation exposure is safe.[18] 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.

Genetic Effects

A single ionizing event has the potential to cause a genetic effect. To understand this, it is helpful to look at the structure of a human cell. Human cells normally contain 46 chromosomes, 23 from the mother and 23 from the father. These 46 chromosomes contain about 10,000 genes, which are passed to the offspring and 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 by affecting their 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.[15] Radiation is not the only cause of such changes. Spontaneous mutations and chemically induced mutations have been observed.

The mutated genes from one parent can be passed to offspring. They typically have no effect on the offspring as long as the genes from the other parent are not mu-

tated in the same way. However, the genes stay in the chromosomes of the offspring and are passed on to following generations. In reproducing, if both parents pass similar mutated genes to the offspring, the mutation would become present in the characteristics of the offspring.[16]

There is no evidence that there are radiation levels below which chromosomes are not affected; however, genetic effects of radiation have never been clearly demonstrated to occur in people.[19,20]

Health Hazards at the FEMP

Aside from radiation and its effects, there are other health hazards associated with the FEMP. In order to understand these other health hazards, it is helpful to be familiar with the terminology and laws that define and regulate these hazards.

Definitions of Terms

Many terms refer to substances that are subject to regulation under one or more federal environmental laws. State laws and regulations also provide similar terminology that may be confused with the federally defined terms. Many of these terms appear to be synonymous and are easily confused.

A ***hazardous chemical***, as defined by the Occupational Safety and Health Administration (OSHA), is any chemical that is a physical hazard or a health hazard. Physical hazards include combustible liquids, compressed gases, explosives, flammables, organic peroxides, oxidizers, pyrophorics, and reactives. A health hazard, on the other hand, is any chemical for which there is good evidence that acute or chronic health effects occur in exposed people. Among the list of hazardous chemicals are carcinogens, irritants, corrosives, neurotoxins, and agents that damage the lungs, skin, eyes, or mucous membranes.

A ***hazardous material***, as defined by the Department of Transportation, is a substance or material in a quantity and form that may pose an unreasonable risk to health and safety or property when transported in commerce. With more than 16,000 entries, the Hazardous Materials Table includes explosives, oxidizing materials, corrosives, flammables, gases, poisons, radioactive substances, and agents capable of causing disease.

A ***hazardous substance*** as defined by CERCLA is any substance designated under Section 311 of the Clean Water Act; any element, compound, mixture, solution, or substance designated as hazardous under Section 102 of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); any listed or characteristic Resource Conservation and Recovery Act (RCRA) hazardous waste; any toxic or pollutant listed under Section 307 of the Clean Water Act; any hazardous air pollutant listed under Section 112 of the Clean Air Act; and any

imminently hazardous chemical substance or mixture subject to Section 7 of the Toxic Substances Control Act (TSCA).

A ***hazardous waste*** is a solid waste that also meets one of the criteria for designation as a hazardous waste in accordance with Subtitle C of RCRA. RCRA regulations impose requirements for treatment, storage, and disposal of such wastes. Hazardous wastes may cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness. These kinds of wastes may also pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. Hazardous wastes are either listed in the regulations promulgating RCRA or are "characteristic" wastes. "Characteristic" hazardous wastes include those that are ignitable, corrosive, reactive, or toxic. All RCRA Subtitle C listed or characteristic hazardous wastes are also CERCLA hazardous substances.[21]

Laws Regulating Health Hazards

Some of the federal laws that regulate health hazards are discussed below. The first, ***CERCLA***, provides for the remediation of hazardous substances at National Priority List (Superfund) sites. CERCLA has its own reporting and response requirements when a hazardous substance released to the environment exceeds a reportable quantity.

As previously discussed, ***RCRA Subtitle C*** provides for the safe treatment and disposal of hazardous waste and regulates hazardous waste management practices for generators, transporters, and owners and operators of treatment, storage, and disposal facilities.

Section 6 of ***TSCA*** authorizes EPA to initiate civil actions regarding hazardous chemical substances or mixtures that present an imminent and unreasonable risk of serious or widespread injury to health or the environment. There is no "list" of imminently hazardous chemical substances or mixtures, but EPA currently regulates under Section 6 of TSCA Polychlorinated Biphenyls (PCB), asbestos, and hexavalent chromium.

The ***Clean Air Act*** established the National Emission Standards for Hazardous Air Pollutants (NESHAP). There are many hazardous air pollutants, including asbestos, benzene, beryllium, coke oven emissions, inorganic arsenic, mercury, radionuclides, and vinyl chloride.

Types of Health Threats

There are many types of potential health threats (aside from the radioactive risks already discussed) related to the hazardous substances at the site. They should all be addressed and understood by both area residents and onsite workers so the substances will be handled properly and safely or avoided whenever possible. Carcino-

gens, corrosives, explosives, flammables, irritants, and poisons/toxins are all potentially harmful.

Carcinogens are substances that have the potential to cause cancer. A common carcinogen at the FEMP is asbestos. When asbestos particles are inhaled into the lungs, they may damage the alveoli (the air sacs lining the lungs). This damage makes the lungs more susceptible to cancer, especially in smokers.

Corrosives are chemicals that cause a substance to wear away or deteriorate. Many common chemicals are potentially corrosive. For example, vapors from ammonia may be corrosive to the eyes, respiratory system, and other moist tissues. Blindness may result from a large exposure to these vapors.

Explosions can occur in many situations. If an unstable solid or liquid changes suddenly into a quickly expanding gas, especially in a tightly closed container, an explosion can occur. Rapid nuclear fission may also cause a substance to explode. During these explosions, energy is released, often in the form of heat and sometimes radiation. This energy release may cause injury resulting from the impact of debris or burns to exposed skin.

Flammable materials are any materials that can be easily set on fire and burn readily. Paints, gases, and fuels are common flammable materials at the FEMP. Hydrogen, for example, is a very flammable gas. An obvious health hazard associated with flammable material is the potential for burns.

An ***irritant*** is a substance that causes an organ or any part of the body to become inflamed or sore. A common solvent used at the FEMP, 1,1,1-trichloroethane, can be an irritant to the skin and the eyes upon contact.

Poisons and toxins are substances that may cause illness or death when ingested or absorbed into the body. Nearly all chemicals have the potential to become poisonous or toxic when used improperly or in excessive amounts. A toxin that destroys nerves or nervous tissue is called a neurotoxin.

The next chapter, "Environmental Compliance Summary," presents the FEMP's status with several environmental regulations. The environmental monitoring data are presented in Chapters Four, Five, and Six. Chapter Seven presents a discussion of the estimated radiation doses to which the people near the site might be exposed and how these results were calculated. Chapter Eight discusses the Radon Monitoring Program and presents the 1996 radon monitoring and dose results.

3

Environmental Compliance Summary

Environmental Compliance Summary

The FEMP must comply with environmental requirements established by a number of agencies governing daily operations at the FEMP. These requirements fall into four general categories:

- Requirements imposed by federal statutes and regulations,
- Requirements imposed by state and local statutes and regulations,
- Requirements imposed by DOE Orders and directives, and
- Site-specific requirements imposed through agreements with regulatory agencies.

Because these requirements are initiated by several different sources, enforcement likewise falls under several federal, state, and local agencies. The EPA develops, promulgates, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by Congress. EPA Region 5 implements the Comprehensive Environmental Response, CERCLA process, with the active participation of the OEPA. For some programs, EPA has authorized the State of Ohio to allow Ohio to have primary enforcement authority. For these programs, Ohio promulgates state regulations which must be at least as stringent as the federal requirements and may be more stringent than the federal requirements. OEPA has authorized programs that issue permits, review compliance reports, inspect facilities and operations, and oversee compliance with the Resource Conservation and Recovery Act, the Clean Air Act, the Clean Water Act (RCRA), and the Safe Drinking Water Act. The site is also subject to several legal agreements with EPA Region 5 and/or OEPA. DOE Headquarters issues directives to its field offices and conducts compliance audits. In addition, the FEMP conducts internal audits.

The FEMP's progress in maintaining compliance with all environmental regulations is summarized in this chapter. It is divided into two main sections — "Compliance Status" and "Major Accomplishments and Issues." Additionally, the status of several environmental permits is discussed within the appropriate regulatory categories. This summary covers calendar year 1996 as required by DOE reporting requirements.

Compliance Status

This section presents a summary of the FEMP's compliance status with respect to federal and state environmental regulations.

Comprehensive Environmental Response, Compensation and Liability Act

The FEMP is on the National Priorities List (NPL), a list of sites requiring environmental cleanup under CERCLA, as amended. Consistent with the requirements of CERCLA Section 120, a Consent Agreement was signed by DOE and EPA in April 1990 which outlined activities and schedules to be performed in order to remedy FEMP conditions. This agreement was amended in September 1991. Collectively, the Consent Agreement and the Amended Consent Agreement (ACA), jointly referred to as the ACA, divided the FEMP into operable units (OUs) to more effectively manage the study portions (defined on page 51 of this chapter) of the CERCLA remedial response process. The OUs were defined as presented in the table on the next page, based on their location or the potential for similar technologies to be used in FEMP remediation.

The ACA provided schedules for the completion of the remedial investigation (RI) and feasibility study (FS) activities for each operable unit; initiated removal actions, which are tasks undertaken to abate immediate threats to the environment and public health; and provided a mechanism for the FEMP to add additional removal actions on a yearly basis.

In broad terms, the remedial response process for remediating sites under CERCLA consists of three general phases. The first phase is site characterization. This phase determines what contaminants are present and at what levels, and also evaluates the potential impacts of those contaminants on human health and the environment. Activities associated with this phase are the RI and the Baseline Risk Assessment (BRA).

The second phase is remedy selection. This phase develops and evaluates different cleanup alternatives and, with appropriate public involvement, selects a remedy. Activities associated with this phase are the FS, Proposal Plan (PP), and public comment period, which culminate in the selection of CERCLA remedial action in the ROD and its attached responsiveness summary (RS).

The first and second phases discussed above are commonly referred to as the "study" portions of the process. The final phase is actual FEMP cleanup.

The study phases of the process at Fernald are essentially complete and actual cleanup has started. Initial characterization of the FEMP began in 1986. In 1991, a segmented RI and FS began to complete characterization and supports remedy selection for all five study areas (operable units) targeted for remediation; this

OU	Descriptive Title	Description
OU1	Waste Pits Area	• Waste Pits 1 – 6 • Clearwell • Burn Pit • Berms, liners, and soil within the OU boundary
OU2	Other Waste Units	• Solid Waste Landfill • Inactive Flyash Pile • Active Flyash Pile (now inactive) • North and South Lime Sludge Ponds • Other south field disposal areas • Berms, liners and soil within the OU boundary
OU3	Former Production Area	Production area and production-associated facilities and equipment (includes all above- and below-grade improvements) including, but not limited to: • all structures, equipment, utilities, effluent lines, K-65 transfer line • wastewater treatment facilities • fire training facilities • coal pile • scrap metals piles • drums, tanks, solid waste, waste, product, feedstocks, thorium
OU4	Silos 1 – 4	• Silos 1 and 2 (containing K-65 residues) • Silo 3 (containing cold metal oxides) • Silo 4 (empty and never used) • Decant tank system • Berms and soil within the OU boundary
OU5	Environmental Media	• Groundwater • Surface water and sediments • Soil not included in the definitions of OUs 1 – 4 • Flora and fauna
CSOU	Comprehensive Sitewide Operable Unit	A comprehensive unit encompassing OUs 1 – 5 to ensure that actions taken under the individual OUs are protective of human health and the environment on a site-wide basis. This is not a specific FEMP area.

process is substantially complete. The Final Design of the On-Site Disposal Facility, the OSDF Remedial Action Work Plan, and the Final Design of the OSDF Leachate Conveyance System were approved by EPA on November 25, 1996. The OU3 ROD for Final Remedial Action was signed on September 24, 1996. The ROD for OU5 was signed on January 31, 1996 by the EPA and OEPA. By the end of 1996, there were signed Records of Decision, which document remedy selection, for all of the five operable units. All selected remedies have been approved by EPA with the concurrence of OEPA. It should be noted that a Record of Decision for Interim Remedial Action (IROD) for OU3 was signed by DOE and EPA in July 1994 in order to provide for quicker progress in the decontamination and dismantlement of buildings and support structures, thereby lessening their potential immediate threat to the environment. The IROD was followed by a Final OU3 ROD, which was signed September 24, 1996.

The selected cleanup options primarily use technologies and process options that have been successfully implemented at CERCLA sites throughout the country. For the one innovative technology selected (which is vitrification, the OU4 se -

lected remedy), operational and technical issues associated with the Vitrification Pilot Plant have led to schedule delays resulting in submittal of the following milestones being missed: 1) New Radon Treatment System, Title I Design (September 30, 1996); 2) Phase II Remedial Action Work Plan (October 7, 1996); 3) Silo Superstructure Award/Construction (November 13, 1996); 4) Vitrification Plant Title I Design (December 4, 1996); 5) Design Criteria Package, Pre-Final (December 4, 1996); and 6) New Radon Treatment System, Title I/II Design, Pre-Final (January 2, 1997).

A request for extension under Section XVIII of the 1991 Amended Consent Agreement, as amended under CERCLA Sections 120 and 126(a) was submitted to the EPA for these milestones on September 26, 1996. The EPA denied the request for extension on October 2, 1996. An agreement with the EPA, dated October 9, 1996, suspends dispute resolution until May 1997, by which time DOE expects to obtain the information necessary to make the decision to proceed with vitrification or to pursue an alternative form of stabilization for Silos 1 and 2.

CERCLA requires that remedial action for a particular OU begin within 15 months of the date that its ROD is signed, so actual cleanup activities will be underway for the FEMP in a matter of months. In addition, over 30 short-term removal actions, designed to eliminate or control contamination sources prior to final cleanup, have been completed or are now in progress at the FEMP.

Superfund Amendments and Reauthorization Act

The Superfund Amendments and Reauthorization Act of 1986 (SARA) amended CERCLA and was enacted, in part, to clarify and expand CERCLA ("Superfund") requirements. The SARA Title III, Section 312 Emergency and Hazardous Chemical Inventory Report for 1996 was completed and submitted to OEPA and other local emergency planning/response organizations in February 1997. The report (Extremely Hazardous Substances and Hazardous Chemicals) lists the amount and location of hazardous chemicals/substances stored or used in amounts greater than the minimum reporting threshold during any one given 24-hour period.

The SARA Title III, Section 313 Toxic Chemical Release Inventory Report was submitted to OEPA and EPA by July 1, 1996. The report is required for any toxic chemical or chemical category (as listed in the appropriate Federal Regulation), that is manufactured, processed, or otherwise used at a facility in quantities greater than the respective reporting threshold during a period of one calendar year. The Toxic Chemical Release Inventory Report lists routine and accidental releases, as well as information about the activities, uses, and waste for each reported toxic chemical. The report also includes source reduction and recycling information as required by the Pollution Prevention Act of 1990.

For any offsite release meeting or exceeding the reportable quantity (RQ), SARA Title III, Section 304 requires immediate notifications to local emergency plan-

ning committees (LEPC) and the state emergency response commission (SERC). All releases occurring at the FEMP are evaluated to ensure that proper notifications are made in accordance with SARA Section 304. In addition to SARA, releases are also evaluated for notification under CERCLA Section 103, RCRA, the Toxic Substances Control Act (TSCA), the Clean Air Act (CAA), the Clean Water Act (CWA), Ohio environmental laws and regulations, and the Ohio Fire Code. Department of Transportation regulations are also followed. Depending on the respective requirements, notifications may also be made to the National Response Center (NRC), and to the appropriate federal, state, and local regulatory entities.

In 1996, one FEMP release was reported to offsite agencies. On February 20, 1996, pipe insulation, suspected to contain asbestos, fell from the overhead piping onto the gravel near Plant 2/3. Broken pipe insulation, containing asbestos, must be considered "friable." Currently, the policy at the FEMP is to assume a 70% content of asbestos, if unknown. Using this basis, the amount of asbestos that was released to the environment exceeded the RQ by 1 pound. Therefore, the release was reported to the National Response Center. No report was made to state or local authorities as the release did not reach offsite. Later, analysis indicated no asbestos, but the initial report was made on information known at the time.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) as amended regulates treatment, storage, and disposal of hazardous waste. OEPA has been authorized to enforce its hazardous waste regulations in lieu of the federal RCRA program.

Past operations and ongoing cleanup activities generate both hazardous wastes and mixed wastes (containing hazardous and radioactive components). Since there are a limited number of facilities in the United States that can treat or dispose of mixed waste, most of the mixed waste has been stored onsite. Plans for treatment of mixed wastes are developed and implemented under the FFCA.

In addition to being subject to state and federal regulation, hazardous waste management is subject to the 1988 Consent Decree and its Stipulated Amendment (SACD) entered into between the State of Ohio and DOE. A Director's Findings and Orders (DF&O) was also issued by Ohio Environmental Protection Agency (OEPA) on June 6, 1996. The DF&O contained provisions which exempted the FEMP from obtaining a hazardous waste facility installation and operation permit for hazardous waste storage activities identified in the current RCRA Part A/B Permit Application provided that the FEMP complies with the terms of the permit application and other applicable OEPA hazardous waste laws and regulations.

The FEMP completed or initiated several activities relating to mixed waste storage and treatment during 1996. These included submittal of the RCRA Annual Report and submittal of the Annual Update to the FFCAct Site Treatment Plan (STP). Upgrades to the Plant 8 Warehouse (Building 80) were initiated in 1996 to

accommodate the storage of containers of hazardous wastes with free liquids. Secondary containment is being constructed and the floor will be recoated with a chemically resistant sealant.

Federal Facility Compliance Act

The FEMP stores mixed wastes that are subject to the RCRA Land Disposal Restrictions (LDR). These restrictions currently prohibit the storage of certain hazardous waste streams for longer than one year unless an extension is approved by EPA or the appropriate state regulatory agency (i.e., OEPA).

The FFCAct of October 1992, an amendment to RCRA, provided DOE with an exemption from enforcement under the LDR storage prohibition provided that the FEMP complies with the plans and schedules for mixed waste treatment provided in the FFCAct STP and the implementing Director's Findings and Orders (DF&O) issued by OEPA on October 4, 1995. An amendment to the STP to ship specific wastestreams off-site for treatment by macroencapsulation was submitted to OEPA in June 1996. In December 1996, the FEMP submitted the STP Annual Update to OEPA. The update described the status of mixed waste treatment projects developed under the STP, added newly generated/newly identified wastestreams to the STP and certified that the FEMP met all regulatory milestone dates for the treatment of mixed wastes established in the STP and implementing DF&O through September 30, 1996.

The plans developed to implement the DF&O on the STP are incorporated in Removal Action No. 9, Removal of Waste Inventories. Detailed information on FEMP activities which treated or shipped waste under RA No. 9 are provided in the tables on pages 71 and 72. The OU3 ROD signed by EPA on September 24, 1996 adopts the procedures and disposition decisions of RA No. 9 to continue the disposition of the products, residues, and nuclear materials generated during site operations.

In 1996, the FEMP initiated and completed a number of projects to treat mixed waste. These projects reduced the total quantity of stored mixed waste by 54% as compared to 1995 and included the following activities:

- Completed treatment by chemical precipitation and cement stabilization of 39,272 pounds of barium chloride residues;
- Neutralized 36,801 lbs. of corrosive wastes;
- Stabilized 5,660 lbs. of reactive wastes;
- Treated 18,507 lbs. of oxidizers, uranyl and thorium nitrate solids and liquids and other thorium-contaminated wastes by chemical precipitation, chemical reduction and cement stabilization;
- Treated 899,311 lbs. of inorganic mixed waste using a cement-based stabilization process as part of the Mixed Waste Stabilization Project;
- Shipped 385,887 lbs. of liquid mixed waste to the K-25 Toxic Substances Control Act (TSCA) Incinerator in Oak Ridge, Tennessee for treatment;

- Shipped 3,209 lbs. of mercury wastes to Nuclear Fuel Services, Inc. in Erwin, Tennessee for treatment by amalgamation; and
- Shipped 27,708 lbs. of lead waste to Envirocare of Utah in Clive, Utah for treatment by macroencapsulation prior to disposal.

The plans developed to implement the DF&O on the STP are incorporated in RA No. 9, Removal of Waste Inventories. Detailed information on FEMP activities which treated or shipped waste under RA No. 9 are provided in the tables on pages 71 and 72. The OU3 ROD signed by EPA on September 24, 1996 adopts the procedures and disposition decisions of RA No. 9 to continue the disposition of the products, residues, and nuclear materials generated during FEMP operations.

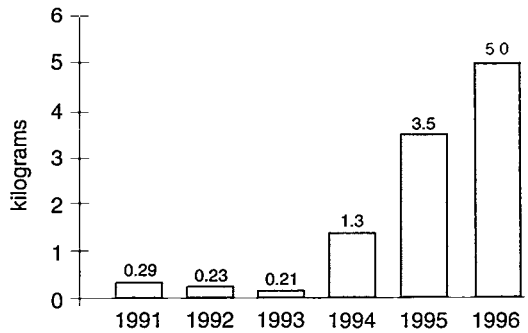
Clean Air Act

OEPA has authority to enforce its requirements in lieu of the federal Clean Air Act (CAA), except for the enforcement of the National Emission Standards for Hazardous Air Pollutants (NESHAP) for radionuclides and radon. Most FEMP air emission sources are regulated by OEPA as particulate, chemical, or toxic emission sources, and by EPA as radionuclide sources.

The NESHAP standard for radionuclide air emissions from DOE facilities imposes a limit of 10 mrem per year on the effective dose equivalent (EDE) to the maximally-exposed individual as a result of all emissions (with the exception of radon) from the facility in a single year. This standard also imposes requirements for continuous monitoring of certain emission sources and periodic confirmatory measurements of smaller sources. All NESHAP monitoring points at the FEMP are in compliance with the requirements.

Because the FEMP is a former uranium processing plant, uranium is the radioactive particulate of most concern in monitoring airborne emissions. The site estimated that airborne uranium emissions totaled 5.0 kg (11.1 lbs) for 1996 (Figure 20). This increase from 3.5 kg in 1995 is attributed primarily to increased excavation of the soils in the north area of the site in support of preparation for the Onsite Disposal Facility and upgrades to the railyard. The resultant 1996 dose to the maximally exposed offsite resident is 0.66 mrem and represents 6.6% of the NESHAP Subpart H limit of 10 mrem.

Figure 20: Total Kilograms of Uranium to Air, 1991 – 1996



In 1993, the State of Ohio regulation limiting sulfur dioxide (SO_2) emissions became effective, which reduced the allowable SO_2 emission level from the FEMP's coal-fired burners (the only Clean Air Act-defined major source at the FEMP) from 2.0 lbs (0.91 kg) $SO_2/10^6$ BTU heat input to 1.3

pounds (0.60 kg) $SO_2/10^6$ BTU heat input. The FEMP began purchasing a low-sulfur coal in 1991 when the regulation was revised, and has been in compliance with the reduced limit since that time. However, the coal-fired boilers were taken out of service in 1996 in preparation for D&D, and have been replaced by smaller gas-fired units.

Clean Water Act

Under the Clean Water Act (CWA), the FEMP is governed by NPDES regulations which require the control of discharges of nonradioactive pollutants to Ohio waters.

National Pollutant Discharge Elimination System Effluent Regulation

The NPDES permit issued by the State of Ohio specifies discharge and sampling locations, sampling and reporting schedules, and discharge limitations. Current monitoring locations are referenced in Figure 21. The current permit 1IO00004*ED became effective November 1, 1995, and expires March 31, 1998.

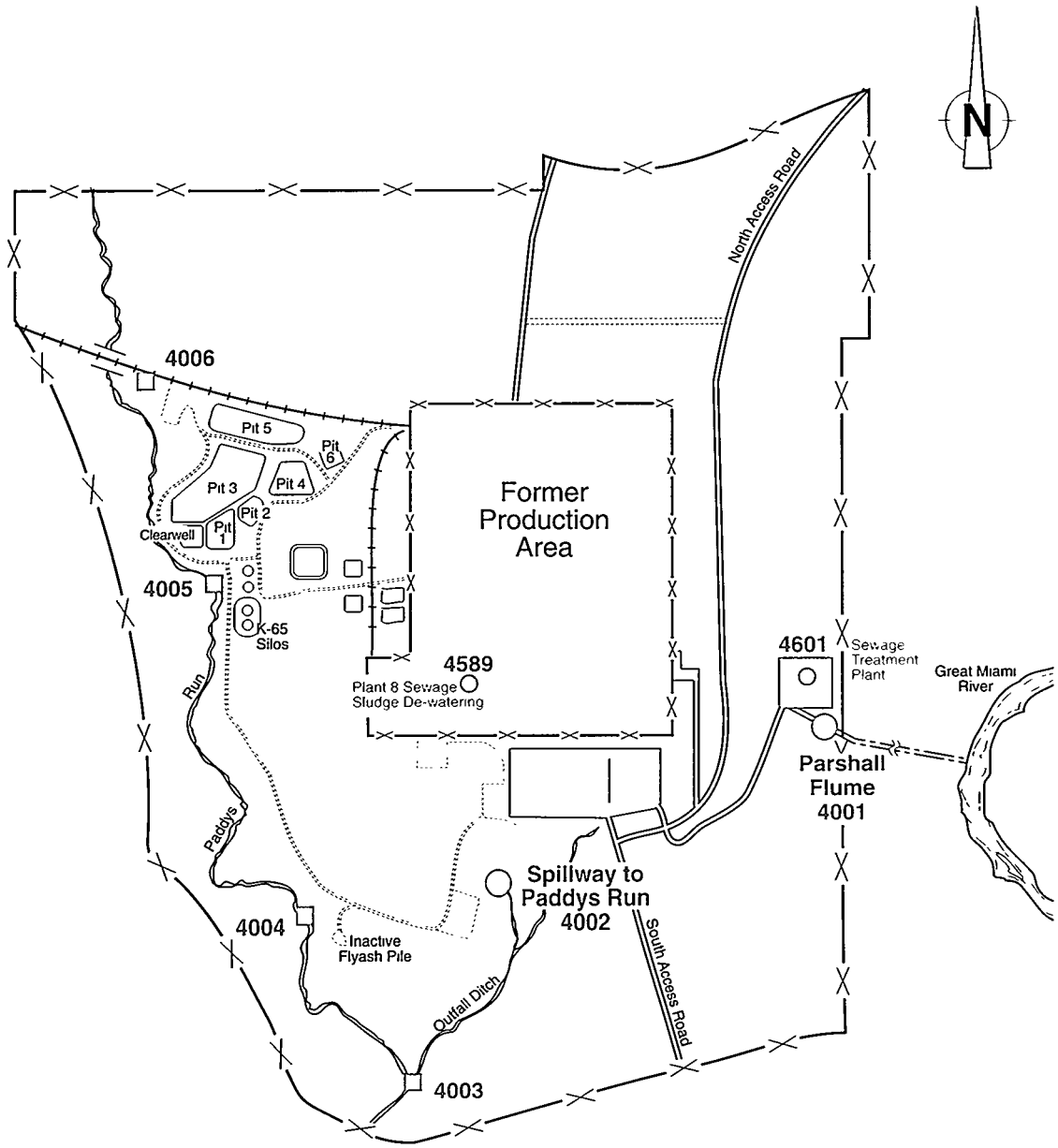
In 1996, the FEMP complied with the discharge limits specified by the NPDES permit 99.7% of the time. Of the 2,355 monitoring results reported to OEPA during the year, only 8 were not within the discharge limits specified by the permit. Only one violation occurred (a low dissolved oxygen reading in June 1996) at the final outfall (Outfall 4001) to the Great Miami River. The remaining violations occurred at an internal location measuring Sewage Treatment Plant effluent (Outfall 4601). Greater detail concerning all these non-compliances can be found in Table 10 on Page A-15 of this report. All non-compliant conditions were reported to OEPA, as required by the NPDES permit.

During 1996, the FEMP implemented the NPDES required acute toxicity screen used for measuring the toxic effect of the FEMP effluent on certain test species. Additionally, the FEMP was required to collect samples from the Great Miami River (GMR) downstream from the FEMP discharge and measure the toxic effect on the same test species. The FEMP contracted with a private laboratory to collect all the necessary samples and perform the necessary acute biassays. All assays were well within specified limitations. The six bioassays completed for the FEMP effluent and the GMR showed no appreciable lethal effect or adverse effect on the test organisms. With the successful completion of the six required bioassays, the FEMP met the OEPA condition for ceasing further toxicity studies.

National Pollutant Discharge Elimination System Stormwater Regulation

Issuance of the November 1, 1995, NPDES permit included four stormwater monitoring locations. These four monitoring locations are shown in Figure 21 as follows:

Figure 21: NPDES Effluent and Stormwater Monitoring Locations



LEGEND

- ○ NPDES Internal Monitoring Location
- ◯ NPDES External Discharge to Ohio Waters
- □ NPDES Stormwater Monitoring Location
- ×—× Plant Perimeter
- ×—×—× Former Production Area Perimeter
- Effluent Line to Great Miami River

- 4003 Collecting runoff from the east and south;
- 4004 Collecting runoff from the Inactive Flyash pile;
- 4005 Collecting runoff from the western property perimeter, excluding the waste management facilities; and
- 4006 Collecting runoff from the northern property perimeter.

All required data was successfully obtained. The only effluent limitation stipulated at these four stormwater monitoring locations is for pH for which the FEMP demonstrated compliance 100% of the time.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) regulates generation and treatment of drinking water supplied to the public. The FEMP drinking water system was regulated by OEPA as a non-transient, non-community public drinking water system. However, on February 17, 1996 the FEMP made final connection to Cincinnati Water Works (CWW) for supply of all the FEMP potable water needs. As such, the FEMP is now a service connection of CWW and no longer regulated as a public drinking water system.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) regulates the manufacturing, use, storage, and disposal of toxic materials. Under TSCA, EPA regulates polychlorinated biphenyls (PCBs) and PCB items from past operations, maintenance activities, and remediation activities at the FEMP. Non-radiologically contaminated PCBs and PCB items are shipped to TSCA-approved commercial disposal facilities for incineration on an "as-needed basis." Radiologically contaminated PCB liquids are shipped to a TSCA permitted DOE incinerator in Oak Ridge, TN.

Radiologically contaminated PCB solids have no current treatment or disposal options and will remain in storage onsite until treatment or disposal capacity is available. Options for their disposal are scheduled to be pursued in conjunction with Removal Action No. 9, Removal of Waste Inventories. Mixed waste treatment technology developed as part of the STP pursuant to the FF CA is being considered for treatment of radiologically contaminated PCB solids.

During September 1996, the inventory of drummed radioactively contaminated PCB solids was relocated from Building 63 (KC-2 Warehouse) to Building 79. Utilities are being permanently shut off at KC-2, which is connected to a feeder line that runs through the Boiler Plant Complex. The Boiler Plant is scheduled for D&D in late 1997.

EPA conducted a routine TSCA compliance inspection of the FEMP on September 21, 1994. No violations of PCB regulations were identified during the inspection. EPA did not conduct an inspection of the FEMP's TSCA program in 1996.

In August 1996 the EPA and DOE signed the FFCA on the storage of PCBs. Within six months of the signed agreement with EPA, the DOE must submit an Annual Report required under the PCB FFCA. The FEMP has provided the necessary information to support the development of the PCB annual report.

Ohio Solid Waste Act

The Ohio Solid Waste Act of 1988 act and its subsequent revisions regulate infectious waste. The FEMP is registered with OEPA as a large generator of infectious waste, generating more than the 23 kg (50 lbs) per month limit. All infectious wastes generated in the medical department are transported to a licensed treatment facility for incineration. FEMP personnel conduct annual surveillances of the onsite medical department, the transporter, and the treatment facility to ensure that the waste is properly managed.

Federal Insecticide, Fungicide, and Rodenticide Act

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), EPA and OEPA regulate the registration, storage, labeling, and use of pesticides (such as insecticides, herbicides, and rodenticides). Personnel perform all insecticide and rodenticide applications onsite. Personnel also perform herbicide applications for weed control as needed in the Administrative Support area. A subcontractor performs an annual herbicide application in various locations within the Controlled area.

All pesticide applications at the FEMP are conducted according to Federal and State regulatory requirements. As a result of the annual FIFRA program inspection conducted on September 21, 1994, EPA Region 5 found the FEMP to be in full compliance with the requirements mandated by FIFRA. There were no EPA inspections of the FEMP's FIFRA program in 1996.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires the evaluation of environmental, socioeconomic, and cultural impacts before any action, such as a construction or cleanup project, is initiated by a Federal agency. DOE has published implementing regulations at 10 CFR 1021 specifically addressing the compliance requirements of NEPA and the integration of NEPA with other regulatory requirements (e.g., CERCLA).

Compliance with NEPA continued in 1996. However, due to the initiation of remedial design and remedial actions, required NEPA evaluations were relatively limited. A second Supplemental Analysis was completed for Operable Unit 4 that addressed the proposed change in the treatment of Silo 3 waste (i.e., vitrification to

stabilization) from what was originally selected in the integrated Operable Unit 4 Feasibility Study-Environmental Impact Statement and Record of Decision. The Supplemental Analysis was integrated with the Evaluation of Silo 3 Alternatives Evaluation which was approved by the NEPA Compliance Officer at the DOE-Ohio Field Office in September of 1996.

An Environmental Assessment was completed in 1995 for the disposition of the Native American Remains uncovered as part of the Public Water Supply Project. A Finding of No Significant Impact (FONSI), to close out the NEPA Environmental Assessment process, was placed on hold by DOE-FEMP until final disposition of the remains could be negotiated with the participating Native American Tribes and Groups. The FONSI is anticipated in early 1997 and will be made available to stakeholders prior to final disposition of the remains.

Endangered Species Act

The Endangered Species Act (ESA) requires the protection of any federal-listed threatened or endangered species found at the site as well as any critical habitat that is essential for the species' existence. In addition, EPA ecological guidelines direct CERCLA sites to identify any threatened species present on the property or in off-property areas affected by FEMP activities.

The baseline ecological survey conducted by Miami University (Oxford, Ohio) in 1986-87, as well as RI/FS surveys in 1988 and consultation with the Ohio Department of Natural Resources and U.S. Fish and Wildlife Service, have established a list of federal- and state-listed threatened and endangered species that potentially or actually occur onsite or have habitat onsite. Surveys to update the information on federal- and state-listed threatened and endangered species were initiated in 1993. Marginal habitat for the cave salamander (*Eurycea lucifuga* — state-listed endangered), was determined to be present on the FEMP; however, no salamanders were found on the FEMP. Two surveys for the Sloan's crayfish (*Orconectes sloanii* — state-listed threatened) were completed and showed populations of this species on the FEMP in the northern sections of Paddys Run. Also, surveys for the Indiana bat (*Myotis sodalis* — federally-listed endangered) revealed suitable habitat within the riparian areas along Paddys Run, especially in the northern section of the FEMP where the trees are older, the canopy is more complete, and water remains in the creek throughout the year.

In 1996, a survey was conducted to update the status of the Sloan's crayfish in the northern reaches of Paddys Run. The results revealed a healthy population of crayfish, with Sloan's crayfish found in every location sampled. In all, over 200 Sloan's crayfish were found in the northern reaches of Paddys Run, where suitable habitat exists.

10 CFR 1022 - Compliance with Floodplain/Wetlands Review Requirements

DOE regulation 10 CFR 1022 specifies the requirements for a floodplain/wetland assessment where DOE is responsible for providing federally undertaken, financed, or assisted construction and improvements. It provides for compliance with Executive Orders 11988 and 11990. No floodplain/wetland assessments were conducted in support of FEMP activities in 1996.

National Historic Preservation Act

The FEMP site is found within an area rich in historic and prehistoric cultural resources. Protection of these resources is mandated through several laws and regulations, including the National Historic Preservation Act. In 1995, several activities were conducted to avoid and address impacts to cultural resources.

On March 24, 1994, the Ohio Historic Preservation Office commented that the FEMP was eligible for listing on the National Register of Historic Places as a result of the role the FEMP played in the Cold War. DOE concurred and entered into negotiations with the Ohio Historic Preservation Office and the U.S. Advisory Council on Historic Preservation. These parties worked to develop an approach to document the buildings that will be demolished as part of remedial activities. A draft Programmatic Agreement was written that outlines the mitigation requirements agreed upon by the Ohio Historic Preservation Office and the U.S. Advisory Council on Historic Preservation. The final draft was approved by DOE-FEMP and the Ohio Historic Preservation Office on November 16, 1995 and was forwarded to the Advisory Council on Historic Preservation for final approval.

An archeological survey for the Public Water Supply Project — the installation of water pipelines along approximately 14 miles (23 km) of state and county roadways in Hamilton and Butler counties — was conducted and revealed a number of significant prehistoric archaeological sites, including one that contained Native American human remains. Since impacts to the human remains could not be avoided, the removal of the burials was agreed to by the Ohio Historic Preservation Office and participating Native American Tribes and Groups. These agreements were recorded in a Memorandum of Agreement between DOE and the Ohio Historic Preservation Office. Other interested parties, such as the Cincinnati Museum of Natural History, were consulted as well. In accordance with the Native American Graves Protection and Repatriation Act, federally-recognized Native American tribes were contacted and asked to provide input regarding excavation, research, and reburial procedures. As discussed in the NEPA compliance section, an Environmental Assessment was prepared to provide an opportunity for all stakeholders to comment regarding disposition of the remains. The Miami Tribe of Oklahoma has filed a claim for possession of the remains under the Native

American Graves Protection and Repatriation Act. Negotiations continue with the Miami Tribe, other Native American tribes, and the Ohio Historic Preservation Office regarding disposition of the remains.

Additional archeological surveys were conducted in several locations on the FEMP for various projects, including the South Field Nine Well Extraction System and the Operable Unit 2 Alternate Borrow Area. Several prehistoric and historic sites were discovered as a result of these surveys. Any potential for impacts to these sites will be addressed through consultation with the Ohio Historic Preservation Office.

Natural Resource Trusteeship

CERCLA, Executive Order 12580, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR Part 300), require that DOE act as a Trustee for natural resources at its federal facilities. These same documents also appoint other federal departments, such as the Department of the Interior (DOI), as well as representatives of state government and Native American tribes, as Trustees for natural resources. The Trustee's role is to act as guardian for natural resources at the FEMP (that is, on or off the FEMP property).

DOE initiated contact with the Fernald Natural Resource Trustees in 1993. The Trustees — who include DOE, DOI and OEPA — are currently meeting monthly to discuss potential impacts to natural resources and coordinate Trustee activities. The Trustees tentatively agreed to focus on a streamlined method for assessing natural resource impacts and restoration at the site, as an alternative to conducting a formal Natural Resource Damage Assessment. Participants in the Trustee discussions include: DOI, U.S. Fish & Wildlife Service, OEPA, Ohio Attorney General's Office, DOE and its contractor, and EPA.

Trustees agreed in 1996 to pursue integrating on-property natural resource restoration activities with remedial activities at the FEMP in an effort to resolve DOE's liability for injuries to natural resources. The Trustees jointly issued a letter to the EPA in September of 1996, which was made available to Stakeholders, stating their approach for resolving the Trusteeship process at the FEMP. The Trustees have developed conceptual natural resource restoration plans and shared those plans with the Fernald Citizens Task Force and Community Reuse Organization in 1996. Development of a Natural Resource Impact Assessment and Natural Resource Restoration Plans were initiated in 1996 and it is anticipated that these plans will be available for stakeholder review in 1997. Public Involvement in the Natural Resource Trusteeship process is essential and any questions or input into this process is always invited by contacting DOE-FEMP or the other Trustees directly.

Major Accomplishments and Issues

This section presents significant compliance-related accomplishments and issues for 1996.

Comprehensive Environmental Response, Compensation and Liability Act

This section presents significant CERCLA response action accomplishments and issues for 1996. The reader is encouraged to access the numerous documents described below, the administrative record for the FEMP, the periodically issued OU-specific Fernald Progress Reports, and the Fernald Project Cleanup Report, all of which are available at the Fernald Public Environmental Information Center (PEIC).

As discussed previously, all FEMP cleanup is mandated by the ACA, which specifies the schedule of activities the DOE must perform, and the dates by which they must be performed. The EPA has approved all documentation and decisions to date. OEPA, which has been actively participating, also has concurred with the documentation and decisions produced to date. The length of time for remediation is specified in the Records of Decision; deliverable dates for design submittals appear in the Remedial Design Work Plans for the individual OUs.

OU1 Record of Decision Signed in March 1995

Operable Unit 1 field work during 1996 consisted mainly of the railway upgrade and construction of an access road and stormwater retention basin(s).

Field work for OU1 during CY 1996 included the following:

1. Site Preparation (Initiation of 15 Month Criteria) – construction of waste processing facility, construction of waste loadout facility including upgrades to current rail system, installation of erosion controls, and construction of the stormwater management system for the operation facility (OU1 Pre-final Design Package, Site Improvement Plan)
2. North Railyard Preparation – cleared, graded, and constructed stormwater controls and sedimentation basin for the north railyard that will be constructed in CY 97. (OU1 Pre-final Design Package, Site Improvement Plan).

OU1 also constructed the West Impacted Stockpile and sedimentation basin for the Soil Project. This activity should fall under OU2. (OU1 Pre-final Design Package, Amendment of the Site Improvement Plan)

OU2 Record of Decision Signed in June 1995

The Final Design of the On-Site Disposal Facility (OSDF), the OSDF Remedial Action Work Plan, and the Final Design of the OSDF Leachate Conveyance System were approved by EPA on November 25, 1996. The OSDF will be located on

CERCLA Remedial Response Actions

OU	Summary of Fernald's CERCLA Remedial Response Activities for 1996
OU1	• Initiation of Substantive On-Site Remediation per the OU1 ROD began April 1. • The OU1 Remedial Action Work Plan was submitted October 17, EPA approved December 10 and OEPA conditionally approved December 23. • The Decision Document for an Alternative Remedial Action Subcontracting Approach (ARASA) was approved March 6. • The ARASA Scope of Work was submitted for-information and comment-only June 28. • The OU1 Remedial Design Pre-Final Design Packages I & II, Response to Comments, were submitted June 13, EPA approved June 28 and OEPA conditionally approved July 18. • An Addendum to the Final Operable Unit 1 Remedial Design Work Plan was submitted March 19, EPA approved June 28 and OEPA conditionally approved July 18. • The OU1 Remedial Pre-Final Design Packages I & II were submitted March 19, EPA approved June 28 and OEPA approved July 18.
OU2	• The Preliminary Design Package for Waste Unit Remediation was submitted to EPA/OEPA on May 28. • The Haul Road Pre-Design Package was submitted to EPA/OEPA on May 29. • The Draft Remediation Action Work Plan (RAWP) for Haul Road was submitted to EPA/OEPA on May 29. • The Draft Final OSDF RAWP was submitted to EPA/OEPA on June 28. • The Draft OSDF RAWP was submitted to EPA/OEPA on April 11. • The Draft Final RAWP for Haul Road was submitted to EPA/OEPA on August 8. • The Haul Road Preliminary Design Package was submitted to EPA/OEPA on January 29. • The OSDF Pre-Final Design Package was submitted to EPA/OEPA on June 28. • The OSDF Final Design Package was submitted to EPA/OEPA on October 14. • The OSDF Test Pad Work Plan was approved by EPA on May 20. • The OSDF Soil-Geosynthetic Interface Direct shear Testing Work Plan was approved by EPA on July 18. • The OSDF Design Package, OSDF RAWP and Leachate Conveyance System Design were approved by EPA on November 25. • Design and RAWP for Haul Road and Rerouted North Entrance Road were approved by EPA on September 27.
OU3	• Building 4A was successfully demolished on August 24. • The OU3 RI/FS/PP was approved March 22. • The Final OU3 ROD was signed September 24. • Plant 1 D&D is ongoing. • The High and Low Nitrate Tanks were successfully removed in December. • The Boiler Plant/Water Plant Complex Implementation Plan was approved by OEPA December 30, and conditionally approved by EPA on January 16, 1997. • The Draft Thorium/Plant 9 Complex Implementation Plan was submitted to EPA/OEPA on January 2, 1997.

CERCLA Remedial Response Actions (continued)

OU	Summary of Fernald's CERCLA Remedial Response Activities for 1996
OU4	• The 90% Pre-Final Silo Superstructure Title I/II Design Package was submitted to EPA on May 2. • EPA and DOE agreed to enter informal dispute resolution on October 9 regarding the following missed milestones: 1) New Radon Treatment System, Title I Design (September 30, 1996); 2) Phase II Remedial Action Work Plan (October 7, 1996); 3) Silo Superstructure Award/ Contstruction (November 13, 1996); 4) Vitrification Plant Title I Design (December 4, 1996); 5) Design Criteria Package, Pre-Final (December 4, 1996); and 6) New Radon Treatment System, Title I/II Design, Pre-Final (January 2, 1997).
OU5	• The Final OU5 ROD was signed by EPA on January 31. • The Draft RDWP for Remedial Actions at OU5 was submitted to EPA on April 1. • The Draft Final RDWP for Remedial Actions at OU5 was submitted to EPA on June 27. • The Final RDWP for Remedial Actions at OU5 was submitted to EPA on August 23. • The Draft Integrated Environmental Monitoring Plan was submitted to EPA on August 1. • The Draft Baseline Remedial Strategy Report was submitted to EPA on October 1. • The Preliminary Injection Demonstration & South Plume Optimization Module Design Packages were submitted to EPA on October 1. • The Draft Phase II South Field Injection Test Report was submitted to EPA on October 1. • The Draft Restoration Area Verification Sampling Program Project Specific Plan was submitted to EPA on October 1.

the east side of the FEMP and will be approximately 3,700 feet by 800 feet with a maximum height of 64 feet. The cap and liner that will enclose the waste material will be a multi-layer system that includes both natural (e.g., clay) and man-made (e.g., high-density polyethylene liners) materials.

OSDF Test Pads were constructed from April 22, 1996 to July 3, 1996 in accordance with OEPA requirements. Monitoring of the test pads continued until September 1996. Results demonstrated that the construction materials and methods planned for the clay layer of the OSDF cap and liner will meet the OEPA permeability requirements.

Subcontractor proposals for construction of Phase I of the OSDF were received on December 12, 1996.

The Final Design of the Haul Road and Rerouted North Entrance Road and the Roads Remedial Action Work Plan were approved by EPA on September 27, 1996.

A contract was awarded on October 7, 1996 for construction of the Haul Road and Rerouted North Entrance Road.

OU3 Record of Decision for Interim Remedial Action Signed in July 1994

Design plans and specifications for performing the interim remedial action are in progress. EPA approved the OU3 RD/RA Work Plan for Interim Remedial Action, and the Building 4A Implementation Plan for the dismantling of Plant 4, on February 17, 1995. Building 4A was successfully imploded on August 24, 1996, and the Project Completion Report was submitted to the EPA and OEPA on January 16, 1997.

The draft Plant 1 Complex - Phase I Implementation Plan for the dismantling of eight components of Plant 1 was submitted to the regulatory agencies on February 26, 1996. D&D of the Plant 1 Complex is well underway, with implosion of Building 1A completed on February 22, 1997.

D&D of the High and Low Nitrate Tanks has been completed. The Implementation Plan for this project was approved on June 28, 1996. Dismantlement of the two tanks was completed on December 24, 1996, with Certification of Construction Completion on January 7, 1997; the Project Completion Report was submitted to the Agencies on January 30, 1997.

Two other projects have begun design for final dismantlement. The Draft Final Boiler Plant/Water Plant Implementation Plan was submitted to the Agencies on December 4, 1996; it was approved by OEPA on December 30, 1996, and conditionally approved by EPA on January 15, 1997. Award of the subcontract is expected by February 28, 1997, with project start in March 1997. The draft Thorium/Plant 9 Complex Implementation Plan was submitted to the Agencies on January 2, 1997.

OU3 Record of Decision for Final Remedial Action approved September 1996

As agreed to by both EPA and signed September 1996, a streamlined RI/FS Report was prepared to support the decision on final disposition of materials removed during the decontamination and dismantling of the former production buildings, structures, and equipment. The final combined OU3 RI/FS with the Proposed Plan was submitted to EPA and OEPA on February 22, 1996, and was approved on March 22, 1996. The OU3 ROD for Final Remedial Action was signed on September 24, 1996; the selected remedy is selected material treatment, on-property disposal, and off-site disposition of material generated by the OU3 interim remedial action and OU3 removal actions. Subsequent to the signing of the ROD, a public workshop was conducted to help develop a decision methodology for determining the viability of recycling of OU3 debris.

The Integrated Remedial Design and Remedial Action Work Plan has been developed to allow for streamlined OU3 remedial action with the OU3 ROD. The Integrated RD/RA Work Plan was submitted to the Agencies on November 20, 1996.

Consistent with the Integrated RD/RA Work Plan, the Thorium/Plant 9 Complex Implementation Plan for Above-Grade Decontamination and Dismantlement was submitted to the Agencies on January 2, 1997.

OU4 Remedial Design Work Plan Approved in June 1995

The selected OU4 remedial action, as presented in the OU4 ROD (signed by EPA on December 7, 1994), is to remove and vitrify the contents of Silos 1-3 and the decant sump tank, then ship the vitrified waste for disposal at the Nevada Test Site (NTS).

The OU4 Remedial Design Work Plan was approved by the EPA on June 15, 1995. The RDWP established a milestone schedule for documents prepared in support of remediation activities. The 90% Pre-Final Silo Superstructure Title I/II Design package was submitted to EPA on May 2, 1996.

Per the RDWP, a phased approach will be utilized for accomplishing the Remedial Action Work Plan. Phase I of the RAWP includes activities that support construction of the Fernald Residues Vitrification Plant (FRVP). These activities include underground utilities and site preparation, silo superstructure construction, and construction of the new radon treatment system. Phase I of the RAWP was approved by EPA on November 20, 1995. The 90% Pre-Final package for the Underground Utilities and Site Preparation was approved by EPA on October 23, 1995. Two other documents were approved by EPA in support of OU4 activities in 1995; both the 30% Design Criteria Package and the 90% Functional Requirements Document were approved September 21, 1995.

Operational and technical issues associated with the Vitrification Pilot Plant (VITPP) have led to schedule delays resulting in submittal of the following milestones being missed: 1) New Radon Treatment System, Title I Design (September 30, 1996); 2) Phase II Remedial Action Work Plan (October 7, 1996); 3) Silo Superstructure Award/Construction (November 13, 1996); 4) Vitrification Plant Title I Design (December 4, 1996); 5) Design Criteria Package, Pre-Final (December 4, 1996); and 6) New Radon Treatment System, Title I/II Design, Pre-Final (January 2, 1997).

A request for extension under Section XVIII of the 1991 Amended Consent Agreement, as amended under CERCLA Sections 120 and 106(a) was submitted to the EPA for these milestones on September 26, 1996. The EPA denied the request for extension on October 2, 1996. An agreement with the EPA, dated October 9, 1996, suspends dispute resolution until May 1997, by which time DOE expects to obtain the information necessary to make the decision to proceed with vitrification or to pursue an alternative form of stabilization for Silos 1 and 2.

On December 13, 1996 FDF issued the "Draft Final Evaluation of Silo 3 Residues Alternatives" to the EPA and OEPA for review. The report evaluates the ability of

an alternative stabilization/solidification technology to remediate Silo 3 residues in a manner as safe and cost-effective as vitrification.

Vitrification Pilot Plant

Construction of the OU4 VITPP was completed with melter bakeout starting May 18, 1996. Phase I operations began with initiation of Campaign 1 on June 19, 1996. Campaign 1 was completed on July 31, 1996 and Campaign 2 was completed on September 25, 1996.

Phase I Campaign 4 activities were initiated on November 29, 1996. VITPP operations were suspended during Campaign 4 as a result of an incident that occurred on December 26, 1996. A small stream of non-radioactive molten glass leaking from the bottom of the melter unit resulted in the contents of the melter unit being emptied into a secondary containment designed to capture it. The molten glass was mostly contained but a small amount that leaked onto the floor, igniting the epoxy floor paint, was quickly extinguished and resulted in no additional damage. Non-radioactive surrogate material, simulating the silo waste, was being vitrified at the time of the incident. The DOE and FDF have initiated an evaluation to determine why it happened and what impact it may have on the project's path forward.

OU5 Record of Decision Signed January 31, 1996

The proposed Final OU5 ROD was signed by DOE and submitted to EPA and OEPA on December 21, 1995. The OU5 ROD was then signed by EPA on January 31, 1996. The selected remedial action for OU5 consists of excavation of contaminated soil, placement of the soil in an on-property disposal facility, and the restoration of the Great Miami Aquifer to its full beneficial use by pumping and treating contaminated groundwater.

The Draft RDWP for Remedial actions at OU5 was submitted to EPA and OEPA on April 1, 1996. After addressing comments from EPA and OEPA, the Draft Final RDWP was submitted on June 27, 1996. The Draft Final RDWP describes and defines the activities and establishes the schedule for developing and submitting the plans and final construction drawings, specifications, and procurement documents necessary for the implementation of the OU5 selected remedy. The RDWP describes the remedial design strategies separately for aquifer restoration and soil remediation.

The Draft RAWP for Aquifer Restoration at OU5 was submitted to EPA and OEPA on October 30, 1996. The RAWP describes the remedial activities and defines enforceable construction schedules for the Draft Integrated Environmental Monitoring Plan (IEMP) was submitted to EPA and OEPA on August 1, 1996. The EPA and OEPA sent comments on the Draft IEMP on September 26 and 16 respectively. The IEMP, which is a deliverable under the RDWP, describes a site-wide monitoring program for all media, including groundwater, surface water, sediment, air, and produce.

Several other RDWP deliverables were submitted on October 1, 1996. These are the Draft Baseline Remedial Strategy Report, the Preliminary Injection Demonstration and South Plume Optimization Module Design Packages, the Draft Phase II South Field Injection Test Report, and the Draft Restoration Area Verification Sampling Program Project Specific Plan.

Advanced Wastewater Treatment System

The AWWT Facility is located at Building 51 in the southwest corner of the former production area. Operation of the AWWT Facility began in 1995. The facility provides final treatment of FEMP contaminated stormwater and wastewater. The facility has a design treatment capacity of 1,100 gpm-700 gpm for stormwater (Phase I) and 400 gpm for wastewater (Phase II). It also provides treatment for contaminated groundwater associated with FEMP groundwater remediation; Phase I and/or Phase II can receive groundwater influent when the supply of stormwater and/or wastewater is low. An expansion of the AWWT has been designed for dedicated treatment of contaminated groundwater and is scheduled to begin operation in 1998.

The AWWT Facility consists of two parallel treatment systems, Phase I and Phase II, each of which have the following process operations:

1. Flow equalization and pH adjustment in preparation for the downstream coagulation process. Sulfuric acid and caustic are used for pH adjustment.
2. Coagulation/flocculation with alum and polymer, followed by clarification for reduction of suspended solids.
3. Filtration to remove residual suspended solids from the clarifier overflow.
4. Adsorption with activated carbon for organic contaminant removal. This process step has been removed from the Phase I system.
5. pH adjustment prior to downstream ion exchange process.
6. Six ion exchange resin vessels in the Phase I system. Three ion exchange resin vessels in the Phase II system. The ion exchange process is the final uranium removal step that provides the necessary low uranium discharge concentration (<20 ppb) to meet the FEMP discharge requirements.
7. Final pH adjustment, filtration, and discharge: The Phase I and II treated streams are combined in a pH mixing/recycle tank, filtered using tubular filters, and discharged to the SWRB Valve House for subsequent discharge to the GMR.

Based on the operating experience gained in the initial year of operation, several process enhancements were implemented or initiated in 1996. These included:

a. Modification of ion exchanger internal devices to improve flow distribution and backwashing capability, and to alleviate resin leakage from the vessels.
b. The addition of a polymer feed system, based on laboratory testing, has resulted in improvement of the clarification process.
c. Installation of new multimedia filters was initiated to provide improved

post-clarification filtration. The new filters were placed into operation in 1997.

d. Modification of the existing ion exchange resin regeneration system was designed and will be implemented in 1997. This will provide a much simpler, safer, and more cost effective process than the existing system.

CERCLA Removal Response Actions

In the course of RI or FS efforts, certain conditions are occasionally identified which call for more immediate action to abate an imminent threat to health and the environment, including actions necessary to monitor, assess, or evaluate the threat. These actions are called "removal actions" and are initiated when there is a need to accelerate cleanup activities to address releases or potential releases of hazardous substances. Removal actions are coordinated with EPA and OEPA.

An overall completion status summary of FEMP removal response actions is presented below. Brief descriptions of those actions are then presented, organized first by completion status and then by removal action number. An overall summary of the scope and status of all CERCLA removal response actions at the FEMP is then presented. Removal actions that were conducted as combined RCRA Closures/CERCLA Removal Actions in 1996 are addressed later in this chapter under RCRA Closures.

Completed in 1996

Conducted as a combined RCRA Closure/CERCLA Removal Action (Removal Action No. 20). RA 20 was the Uranyl Nitrate Hexahydrate (UNH) Stabilization of HWMU Nos. 46-50 which included HWMU No. 13, Nitric Acid Recovery (NAR) System and Removal Action No. 9, Thorium Nitrate Solidification HWMU No. 54. EPA approved RAWP August 9, 1994. Field work on all tanks

Fernald Removal Actions Completion Summary

Status	Count	#	Title
Previously completed	24		
Completed in 1996	3	20	Stabilization of UNH Inventories (HWMU Nos. 46–50)[1]
		28	Contamination at the Fire Training Facility (HWMU No. 1)[1]
		15	Scrap Metal Piles
Ongoing	5	3	South Groundwater Contamination Plume
		9	Removal of Waste Inventories
		12	Safe Shutdown
		17	Improved Storage of Soil and Debris
		26	Asbestos Removals
Total	32		

Key

[1]*Done as combined RCRA Closure/CERCLA Removal Action*

completed in 1995 with the exception of Tanks F1-25 and F1-26. Decontamination of F1-25 and F1-26 completed in 1996.

Removal Action 28 was conducted as a combined RCRA Closure/CERCLA Removal Action. Field work began in July 1994 and continued in 1995. The RA was completed in 1996, addressing soil cleanup and will be managed as an integrated closure under the June 1996 DF&O.

Removal Actions Ongoing (Excluding Combined RCRA/CERCLA Activities)

Removal Action No. 3 – South Groundwater Contamination Plume

Past operations at the site have resulted in a uranium contamination plume (the South Plume) in the Great Miami aquifer at a location south of the site property. Removal Action No. 3 was initiated to prevent or minimize the further migration of the South Plume and to mitigate the effects of the contamination on local groundwater users. To date, the main body of the South Plume continues to be captured by a recovery well system. Further optimization of the recovery well system will occur as part of the South Plume Optimization Module described in the Remedial Design and Remedial Action Work Plans for aquifer restoration.

Removal Action No. 9 – Removal of Waste Inventories

This removal action involves the characterization, overpacking, and disposition of low-level radioactive waste materials. Fernald continues to operate an aggressive waste shipping program which began in 1985; 1996 waste shipping activities are listed in the table below.

Fernald's 1996 Removal of Waste Inventories Under Removal Action No. 9

Category	Destination	Drum Equivalents
Uranium production residues	DOE Nevada Test Site, NV	8,228
Process area scrap	DOE Nevada Test Site, NV	11,609
Contaminated trash	DOE Nevada Test Site, NV	1,728
Thorium	DOE Nevada Test Site, NV	6,008
UNH residue	DOE Nevada Test Site, NV	3,144
Stabilized mixed waste	DOE Nevada Test Site, NV	2,445
Stabilized thorium nitrate	DOE Nevada Test Site, NV	537
Legacy Construction waste	DOE Nevada Test Site, NV	4,467
Newly generated construction waste	DOE Nevada Test Site, NV	9,311
Destination subtotal, Calendar Year 1996		47,477
Scrap copper motor windings	Manufacturing Sciences Corporation	346
Liquid Mixed Waste Project	TSCA Incinerator	1,509
Non-LDR Project	Envirocare	48
Total to Offsite, Calendar Year 1996		49,380

Several mixed waste treatment projects are being conducted under Removal Action No. 9 and in accordance with Director's Findings and Orders issued by OEPA on October 4, 1995. These waste streams are being treated to meet RCRA land disposal restrictions (LDR) and will be shipped offsite for final disposition after treatment is complete.

Fernald's 1996 Waste Treatment Activities Under Removal Action No. 9

Mixed Waste Treatment Project	Quantity of Waste Treated in m^3
Fernald Mixed Waste Stabilization Project	372
Liquid Mixed Waste Project	29.4
Chemical Treatment	
Neutralization, precipitation, deactivation, stabilization (NPDS)	85*
Decontamination	7.4
Solvent extraction	0
Mercury amalgamation	4.4
Total Treated, 1995	498.2

* *This figure includes 25 drums (5 m^3) of pyrophoric material that were characterized as non-RCRA low level waste. The total* ***mixed*** *waste treated in this project is 80 drums.*

Removal Action No. 12 – Safe Shutdown

This removal action was initiated to ensure the safe and permanent shutdown of production facilities in the former production area. This includes the removal of uranium and other process/raw materials and waste materials from equipment, lines and ductwork. Materials removed are packaged for disposition.

Safe shutdown activities in the Plant 9/Thorium Complex have been completed. Plant 5 safe shutdown activities began January 1996 and are underway in Plant 2/3. Safe shutdown activities in the Pilot Plant have been completed.

Removal Action No. 15 – Scrap Metal Piles

Plans are being finalized for the removal and offsite processing of the containerized scrap copper pile. This portion of the project is currently on hold until a treatability/engineering study is completed. A contract for conducting this engineering study on 30 tons of scrap copper wire containing asbestos insulation was awarded to Manufacturing Sciences Corp. of Oak Ridge, TN, and is expected to be completed in April 1997. The results of the study are being evaluated; a final decision on disposition of the remaining copper will be made in accordance with the OU3 ROD for final Remedial Action. The FEMP has submitted a closeout report for this Removal Action to the agencies.

Removal Action No. 17 – Improved Storage of Soil and Debris

This removal action was initiated to address contaminated soil and debris generated as a result of continued construction and maintenance projects, removal actions, and remedial actions at the FEMP.

The FEMP requested and received EPA approval to cancel the planned construction of the three planned temporary covered storage structures and pursue more viable alternatives. These changes are the result of a re-evaluation of evolving waste and debris management methodologies and public concerns regarding the construction of additional storage structures at FEMP.

The removal action work plan was revised to develop an interim site-wide soil and debris management program, in order to facilitate integrated implementation of the FEMP's RODs, as well as individual remedial action plans, prior to disposition of the remedial-action- or removal-action-generated waste at the OSDF or at an approved offsite treatment/disposal facility. The revised removal action work plan will be effective until the OSDF is operational and the appropriate remedial action plans are implemented. The Revision 3 of the RA No. 17 Work Plan was approved by the agencies October 18, 1996. Bulk storage of certain categories of debris from Plant 7, Plant 4, and Plant 1 D&D activities has begun on the Plant 1 Pad and the Plant 4 Slab. Air monitoring around the Plant 1 Pad confirmed that there were minimal releases of contaminants to the atmosphere from this activity.

Removal Action No. 26 – Asbestos Removals

This removal action documents the ongoing asbestos abatement activities at the FEMP to manage asbestos in-place and mitigate the potential for asbestos fiber release and migration. Abatement activities within the ongoing Asbestos Program include repairs, encasement, encapsulation or removal of asbestos containing materials which exist in many buildings on the FEMP. Abatements to date include small-scale in-situ repairs, encasement, encapsulation, removals, and the completion of the large-scale asbestos abatement. Field activities in support of asbestos abatement are continuing, including the removal of asbestos-bearing thermal insulation in pipes, tanks, and valves throughout the FEMP. The scope of this removal action will be integrated into the OU3 final remedial action in accordance with the OU3 ROD signed September 24, 1996.

Resource Conservation and Recovery Act

Stipulated Amendment to Consent Decree (SACD)

The Stipulated Amendment to Consent Decree (SACD) requires that the FEMP identify all Hazardous Waste Management Units (HWMUs) at the facility. As a result, burners, incinerators, furnaces, stills, process equipment, tank units, dust collectors, and other potential waste containment units were evaluated to determine if these units were HWMUs or Solid Waste Management Units (SWMUs). In 1996, the FEMP completed a review of the evaluation process, regulatory basis, and technical assumptions used to determine whether the designation of these units as HWMUs was justified. OEPA approval was sought to change the designation for several HWMUs to SWMUs. In 1996, the FEMP received approval from OEPA to reclassify one HWMU to a SWMU (see page 74 for list). Closure activities continued for other HWMUs. OEPA determined that six HWMUs were closed in accordance with OEPA regulations. Refer to the table of HWMU Closure Activities on the next page for further information.

1996 Fernald RCRA HWMU Closure Activities

HWMU	Unit Name & Status
3	Waste Oil Storage in Garage: Closure certification acceptance received from OEPA on June 6, 1996.
7/8	Drummed HF Residue Storage NW of Plant 4: Closure certification acceptance received from OEPA on July 2, 1996.
13	Wheelabrator Dust Collector: Closure certification acceptance received from OEPA on April 5, 1996.
31/32	Bulk Storage Tanks T-5 and T-6: Closure certification acceptance received from OEPA on November 29, 1996.
46-50	Uranyl Nitrate Hexahydrate (UNH) Tanks: Conducted as a combined RCRA Closure/CERCLA Removal Action (Removal Action No. 20). EPA approved RAWP August 9, 1994. Field work on all tanks completed in 1995 with the exception of Tanks F1-25 and F1-26. Decontamination of F1-25 and F1-26 completed in 1996.
52	North and South Spent Solvent Tanks: Closure certification acceptance received from OEPA on June 24, 1996.
54	Thorium Nitrate Tank T-2: Declared a HWMU June 1994, as a result of exceeding the 90-day storage of a hazardous waste, based on corrosivity (D002), cadmium (D006), and chromium (D007). Completed processing of tank's contents in 1995 as part of CERCLA Removal Action No. 9. Final report submitted in 1996.

Changes/Additions to Wastestreams in 1996 Facility RCRA Annual Report

The 1995 RCRA Annual Report reported 358 hazardous/mixed wastestreams in storage. The 1996 RCRA Annual Report identified 209 hazardous/mixed wastestreams in storage. Their total included 64 new hazardous/mixed wastestreams which were added to the 1996 RCRA Annual Report. The 213 remaining wastestreams from the 1995 RCRA Annual Report which were not reported in storage in 1996 were dispositioned as follows:

- 125 wastestreams were treated on-site through the Mixed Waste Stabilization Project, the Wastewater Treatment Project and the Neutralization/Precipitation/Deactivation/Stabilization Project and are no longer in inventory;
- 30 wastestreams were bulked and shipped to the TSCA Incinerator. The solids portion was assigned to another Material Evaluation Form (MEF);
- 24 wastestreams were repackaged/consolidated under the Mixed Waste Segregation Project and assigned to another MEF;
- 14 wastestreams were recharacterized as non-hazardous;
- 11 wastestreams were shipped off-site for treatment at a commercial facility and are no longer in inventory;
- 4 wastestreams were recharacterized and added to another RCRA MEF;

- 3 wastestreams were recharacterized as pending;
- 1 wastestream was archived into a pending MEF; and
- 1 wastestream was contained in a drum which was found to be empty.

The total amount of waste stored onsite has decreased by 54%. Total quantities of hazardous waste are presented below for calendar years 1995 and 1996.

Category	1995	1996	Decrease	Decrease, %
Hazardous waste	2,914,759 lbs.	1,335,622 lbs.	1,579,137	54

Thorium Management

A Thorium Management Strategy and schedule of accomplishments were developed as part of the SACD to provide a plan to complete RCRA determinations of thorium materials and to improve the storage of thorium materials at the FEMP. The Thorium Management Strategy was initiated as part of the SACD and is based on three primary objectives:

- To maintain environmentally stable interim storage of the thorium inventory while minimizing personnel radiation exposure;
- To implement required further actions to complete RCRA evaluations of the thorium materials; and
- To implement long-term storage and disposal alternatives.

In 1996, the FEMP shipped 2,172 drum equivalents or 46,707 cubic feet of thorium material to the DOE (NTS) for disposal. Additional shipments are planned for 1997.

RCRA Closures

During 1996, the FEMP continued to work on integrating RCRA closure activities with CERCLA response actions. The integration effort was formally recognized by the signing of an OEPA DF&0 in June 1996. The DF&0 between OEPA and U.S. DOE-FEMP, and FDF integrated RCRA closure activities of HWMUs with CERCLA cleanup activities.

During 1996, the OEPA gave concurrence to reclassify the Hilco Oil Recovery Unit from a HWMU to a Solid Waste Management Unit (SWMU).

RCRA Routine Groundwater Monitoring Program – Director's Final Findings and Orders

This DF&O, signed September 10, 1993, describes an alternate groundwater monitoring system with a routine monitoring program that allows hazardous waste monitoring requirements to be fulfilled by the CERCLA process already in progress. This resolves the integration difficulties involving the state hazardous waste facility groundwater monitoring regulations and the CERCLA require -

ments at the FEMP. Findings of the 1996 sampling and analyses from this routine groundwater monitoring program, as presented in the 1996 RCRA Annual Report, indicate that other than the contamination comprising the South Plume, there are no concentrations of contaminants detected at the routine monitoring program well locations that trigger the need for action ahead of the final OU5 groundwater remedy. The contamination comprising the South Plume is observed in two routine monitoring program wells and is presently being addressed by Removal Action No. 3 — South Groundwater Contamination Plume. These findings are consistent with those indicated in the OU5 Remedial Investigation Report.

Removal of Site Product Inventories

In June 1995 a contract was signed with AlliedSignal, Morristown, New Jersey, for all remaining normal uranium tetrafluoride (UF4), uranium trioxide (UO3), and uranium octoxide (U308) that met their specifications. Normal uranium contains 0.711 percent of naturally-occurring uranium-235. The material will be used to produce uranium hexafluoride (UF6) for commercial customers. A total of 708,658 net lbs were shipped against this contract, mostly in 1995.

In November 19, 1993, a contract was signed with Manufacturing Sciences Corporation, Oak Ridge, Tennessee, for all depleted uranium derby metal. A total of 969,310 net lbs. were shipped against this contract; the 1996 portion is shown below.

The table below shows a breakdown of these product inventories as they were shipped in 1996.

Fernald's 1996 Removal of Site Product Inventories

Category	Destination	Quantity Shipped in Lbs.
Normal compounds	AlliedSignal	31,426
Depleted uranium derbies	Manufacturing Sciences Corp.	285,186
Total to Offsite, Calendar Year 1996		316,612

Safety & Health Self-Assessment Program

Self-assessment is a quality assurance and continuous process improvement function that identifies strengths and weaknesses of programs, policies, and procedures in order to provide opportunities for improvement. The Safety & Health (S&H) Self-Assessment Program has been established to encompass all programs, departments, and sections within the S&H Division. The FEMP's comprehensive assessment program includes assessment of safety and health, and encompasses all FEMP activities. Assessment activities consist of performance- and compliance-based assessments conducted against applicable DOE Orders, regulations, and procedures pertaining to the functional area programs being assessed. Assessments are performed in order to determine the reliability, adequacy, and compli-

ance of S&H programs with identified requirements. The program includes all appraisals, surveillances, audits, and walkthroughs that evaluate S&H aspects of activities by both internal personnel and external agencies.

In 1996, 50 assessments were performed in such varied areas as Emergency Preparedness, Industrial Hygiene, Fire Protection, Document Control, and Safety Analysis.

Stakeholder Involvement

The historical chronology of how stakeholders became involved in FEMP-related decisions and activities is detailed in the Fernald Environmental Management Project (FEMP) *Community Relations Plan,* January 1995. The chronology demonstrates how increased stakeholder awareness of site operations prompted DOE to move from the non-participatory "decide, announce, defend" strategy to the two-way approach of shared decision-making. Through ongoing, two-way communications, DOE, Fluor Daniel Fernald and stakeholders work together to accomplish the safe and timely cleanup of the FEMP.

During 1996 and the first quarter of 1997, DOE and Fluor Daniel Fernald held over 20 public workshops, roundtables and meetings, including one public hearing to solicit stakeholders' formal comments on the *Proposed Plan for Operable Unit 3 Final Remedial Action.* During each meeting, stakeholders had an opportunity to meet directly with site decision makers and technical personnel and provide input into cleanup decisions. Some of the meeting topics included:

- design of the on-site disposal facility;
- plans for innovative technology demonstrations;
- final cleanup decisions for disposition of Operable Unit 3 materials;
- formation and organization of the Fernald Community Reuse Organization (CRO);
- material recycling decisions;
- remediation of the Silos project, including Silo 3 and the Vitrification Pilot Plant;
- remediation of the Waste Pit Remedial Action Project and discussion of the Alternative Remedial Action Subcontracting Approach.

Through the Fernald Envoy Program, FEMP personnel continued person-to-person exchanges with community leaders on cleanup progress. To reinforce the FEMP's commitment to shared decision making, envoys communicated stakeholders' ideas and input back to site management.

In addition to these FEMP-sponsored public meetings, stakeholders also had numerous opportunities to participate in and learn about Fernald-related activities and issues through other organizations, including the Ohio EPA; the Fernald Citizens Task Force; FRESH; local township trustees; the Fernald Health Affects Subcommittee; the Centers for Disease Control; NIOSH; and the Fernald CRO.

DOE established the Fernald CRO in August 1996 to address social and economic issues impacting the workforce and surrounding communities as a result of downsizing and eventual closure of the FEMP.

To inform stakeholders of cleanup progress and opportunities for participation throughout the year, DOE and Fluor Daniel Fernald conducted 110 site tours (in 1996); participated in speaking engagements; developed topical fact sheets, the *Fernald Report* – a monthly stakeholder publication – and videotapes of cleanup progress; and sent post card notices of public meetings and the availability of cleanup documents for review. Copies of these materials were available to the public in the Public Environmental Information Center.

DOE Complex-Wide Performance Indicator Status

In July 1994, DOE and the prime contractor, FDF, signed a major modification to FDF's contract, representing the first significant action under DOE's contract reform initiatives nationwide. Performance based contracting, as outlined in this modification, is a significant departure from the management and operating (M&O) type contract that DOE has traditionally awarded at other sites. The modified contract provides FDF a financial incentive for managing the environmental remediation process as efficiently as possible. Unlike M&O type contracts, this contract requires FDF to accept financial responsibility for its actions at Fernald, including any fines or civil penalties that might arise from FDF's own negligence. In return, FDF is granted more authority to make aggressive decisions about remediation methods.

Under the new performance-based fee system, FDF and DOE agree upon a set of specific, measurable goals to be reached during a given six-month period. FDF earns bonus fee only when it exceeds those goals; satisfactory achievement of Perfomance Objectives and Criteria (POC) by itself is simply expected and no longer earns any fee. The system also can result in forfeiture of base fee if FDF fails to meet minimum performance requirements.

In addition to the Contract Reform recommendations, the Performance Based Fee Determination Plan also serves to align the Fernald site criteria with DOE's Environmental Management Vision. This Vision establishes goals to:

- Manage/eliminate urgent risks and inherent threats;
- Provide a safe workplace i.e., one that is free from accidents, injuries and adverse health effects;
- Improve the system through managerial and financial internal controls;
- Be more outcome oriented (as opposed to process oriented);
- Focus the Technology Development Program on major obstacles to progress and involve the best talent in the DOE and national science and engineering communities; and
- Develop a stronger partnership between the Department and its stakeholders.

The Performance Based Fee Determination Plan details two areas against which the Contractor is evaluated: (1) General Contract Performance, and (2) Milestone Completion. It provides the standardization necessary to ensure effective development, administration and coordination of all phases of the Performance Based Fee evaluation process which is divided into two fiscal year periods (October through March and April through September annually). DOE uses this Plan as one of several tools to evaluate the Contractor's success in meeting requirements of the performance based environmental management contract. The contract stresses achieving programmatic goals safely, quickly, and at a reasonable cost through the use of innovative approaches. The objective of the previously mentioned Contract provisions is to afford the Contractor an opportunity to earn increased fee commensureate with the achievement of performance levels beyond those considered "satisfactory."

The Contractor's input is integral to the process of developing POCs and Milestones. The Contractor's input is particularly important since the performance goals established by DOE in the plan are aggressive. The goals are worded so that the standard for excellence is attainable, while requiring a well-managed and concerted effort on the part of the Contractor.

In addition to the special management emphasis in the General Contract Performance POCs and Milestones identified for each six-month plan, the Contractor receives incentives for attaining high standards of excellence as measured against performance standards consistent with best available practices. The plan is designed to motivate the Contractor to identify new problems to DOE, and to develop and implement effective and economical corrective actions.

The Performance Based Fee Plan consists of the POCs listed below. Contractor performance is evaluated using objective, measurable and verifiable performance criteria tied to the Fernald Mission Statement.

This approach prevents "dilution" of the focus of the Plan and defines DOE's primary needs and expectations for *Excellent* performance, including goals of DOE Headquarters' Office of Environmental Management, as well as Fernald-specific goals. In addition to a number of established milestones, the contractor's performance was measured against the following POCs in 1996:

1. Safe Clean-up (Environment, Public and Worker):
   - 1.a. Timely Identification, Categorization and Control of Safety and Health Deficiencies,
   - 1.b. Reduction of Radiation Dose,
   - 1.c. Continue Safety First/Employee Involvement/Voluntary Protection Program Activities,
   - 1.d. Subjective Evaluation of all FDF Safety and Health Programs (FY96-1)
   - 1.d. Conduct of Operations (FY96-2),
   - 1.e. Conduct of Operations (FY96-1),
   - 1.e. Reducing Radiological Occurrences (FY96-2),

1.f. Conduct of Operations (FY96-1),

1.f. As Low As Reasonably Achievable (ALARA) (FY96-2),

1.g. Reducing Radiological Occurrences (FY96-1),

1.g. Enhanced Work Planning (FY96-2),

1.h. Timely Completion of Functional Area Audits (FY96-2),

1.i. Subjective Evaluation of All FDF Safety and Health Programs (FY96-2),

2. Least-Cost, Earliest and Final Clean-up:

2.a. Small and Minority Business Participation (FY96-1),

2.a. Waste Management/CRU 3 (Waste Minimization/ Recycle) (FY96-2),

2.b. Property Management (FY96-1),

2.b. Proportion of Support Costs to Remediation Costs (FY96-2),

2.c. Cost Savings/Additional Work (FY96-1),

2.c. Compliance with FY-96 Baseline (FY96-2),

2.d. Compliance with FY-96 Work Plan (FY96-1),

2.d. Mixed Waste Treatment Projects (FY96-2),

2.e. Project Tracking System (PTS) (FY96-1),

2.e. Waste Shipment (FY96-2),

2.g. Mixed Waste Treatment Projects (FY96-1),

2.g. Nuclear Material Disposition Project (FY96-2),

2.h. Low Level Waste Disposition (FY96-1),

2.h. Technology Development Program (FY96-2),

2.i. Waste Characterization (FY96-1),

2.i. 10-Year Plan Implementation/ Performance Measures (FY96-2),

2.j. Waste Minimization Recycling (FY96-1),

2.j. Thorium Overpacking Project (FY96-2),

2.k. Nuclear Material Disposition Project (FY96-1),

2.k. Funds Utilization (FY96-2),

2.l. Evaluation of Waste Management, Safe-Shutdown and Landlord Activities (FY96-1),

2.l. Subjective Evaluation of FDF's Performance In Critical Areas Within the Least-Cost, Earliest and Final Clean-Up Program (FY96-2),

2.m. Subjective Evaluation of Technology Development Program (FY96-1),

2.n. Boilerhouse Replacement Project (FY96-1),

2.o. Performance Measures (FY96-1),

2.p. Integration of Work Activities and Processes (FY96-1),

2.q. Annual Maintenance Work Plan (FY96-1),

3. Addressing Stakeholder Concerns

3.a. Subjective Evaluation of FDF's Internal and External Stakeholder Program.

Summary of Permits

The FEMP was required to have five different types of Environmental Permits during calendar year 1996. These involved wastewater treatment, storage of RCRA waste, air emission sources, and wetland disturbances. One additional type of permit common to the FEMP that was not needed in 1996 is a Water Permit to Install which is required for any new or substantial changes in the wastewater system.

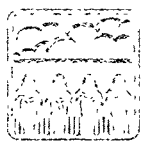
Those permits required for 1996 are identified in the following table.

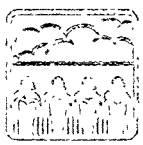
Summary of Permits

Type of Permit		Issuing Agency	Permit Number	Comments
NPDES	1	EPA	OH1IO00004*ED	Permit includes stormwater.
RCRA TSD	1	EPA	OH6890008976	Part A & B permit applications are on file.
Air Permit to Operate (PTO)	28	OEPA	Premise No. 1431110128	
Air Permit to Install (PTI)	1	OEPA	14-4253	Draft permit for the modification of the 100 MMBTU/HR gas/-2 oil fired boiler.
Wetland 404/401	2	Corps of Engineers OEPA	N/A No. 26	Issued under National Permit.

4

Air Pathway Monitoring





Air Pathway Monitoring

This chapter describes the air pathway components which may become contaminated as a result of airborne emissions from the FEMP. Although the direct radiation monitoring program is not a true component of the air pathway, a discussion of the program and results are included here for convenience.

As discussed in Chapter One, the public may be exposed to radiation from the FEMP through the air pathway. This includes emissions from specific point sources, such as plant stacks, as well as dust from large, open areas, such as the waste pit area. When production operations were suspended in July, 1989, the major point source emissions from the FEMP were eliminated. Since then, the principal sources of airborne uranium emissions have been the cooling tower mists, which have low levels of uranium contamination, and fugitive dust from locations where environmental remediation activities are underway.

FUGITIVE DUST

The term fugitive dust is used to describe the small amounts of contaminated soil, waste materials, and construction dusts released from the FEMP as a result of ongoing remediation work. Sources of fugitive dust at the FEMP include: dust generated as contaminated material is moved or repackaged; small amounts of soil carried away by the wind during soil excavation; wind erosion of waste pit materials which are not covered by water; and soil erosion during dry, windy weather. Dust from construction and remediation activities, waste handling, and wind erosion are potential sources of airborne emissions from the FEMP.

Air pathway monitoring focuses on airborne pollutants that may be carried from the FEMP as a particulate or gas and how these pollutants are distributed in the environment. The form and chemical makeup of pollutants influence how they are dispersed in the environment and how they may deliver radiation doses. For example, fine particles and gases remain suspended, while larger, heavier particles tend to settle and deposit on grass or soil. Chemical properties determine whether the pollutant will dissolve in water, be absorbed by plants and animals, or settle in sediments and soils.

Results in Brief: 1996 Air Pathway

Air – Data collected from fenceline air monitoring stations show that average concentrations of uranium were all less than 1% of the DOE standard. Airborne uranium emissions for 1996 were estimated to be 5 kg.

Soil – The 1996 results indicate uranium concentrations from ten samples onsite and six samples offsite are within historical ranges. The offsite samples were 19% lower than in 1995, while the onsite samples indicated a 37% reduction over last year's averages.

Grass – The 1996 results indicate uranium concentrations in the ten samples onsite and the six samples offsite are within the range of historical concentrations and suggest 1996 emissions have not significantly affected uranium concentrations in the environment.

Produce – Uranium concentrations in produce were consistent with previous years' data. Laboratory analyses did not detect any significant differences in uranium concentrations between produce grown near the FEMP and produce grown at outlying locations.

Direct Radiation – Measurements of direct radiation indicate levels increase with proximity to the K-65 silos. However, these levels are 72% lower than radiation levels measured in 1991 prior to the addition of the bentonite layer within the K-65 silos. These measurements are consistent with the fact that the silos contain radium and its decay products, which contribute to the direct radiation in the vicinity.

Boiler Plant – During June of 1996, three gas-/oil-fired boilers were put into service, and the two coal-fired boilers were permanently taken out of service. With the exception of 14 short-term opacity excursions (typically less than 18 minutes in length, and associated with boiler start-up or load change), all emissions were well below permit limits.

Monitoring for Radioactive Pollutants

During 1996, FEMP personnel continued to monitor radioactive materials in the air pathway by sampling air, soil, grass, and produce. This monitoring enables scientists to evaluate the effects of the remediation efforts at the FEMP and fulfill the site's obligations toward ongoing environmental surveillance and dose estimating.

Air Sampling for Radioactive Particulates

The first step in monitoring the air pathway is measuring the emission rate of the pollutants at the point of release after they have gone through treatments and filtering. This is done by means of stack sampling, and it provides preliminary information on how much pollutant is released and how it will behave in the environment. The second step in air pathway monitoring involves measuring the pollutant concentration in ambient air onsite and at the FEMP boundary. Because only a few stacks and vents continue to emit pollutants at the FEMP, airborne emissions from monitored stacks are substantially lower than those during the years of production. However, monitoring of overall FEMP emissions (stack and fugitive emissions) continues through the use of air monitoring stations (AMSs) located onsite, near the fenceline, and at several locations in nearby communities.

Airborne pollutants are subject to existing weather conditions. Thus, wind speed and direction, rainfall, and temperature play a role in predicting how pollutants are distributed in the environment. Weather data, particularly wind speed and direction, provide input for selecting locations to collect environmental samples and locating monitoring stations.

During 1996, the FEMP operated 20 air monitoring stations 24 hours a day, seven days a week, as part of the Air Monitoring Program. Scientists selected the locations for the AMSs, as shown in Figure 22, for several reasons:

- AMS 1A was moved to the former production area fenceline on July 31, 1996. This relocation was necessary for two reasons: to provide data at the former production area fenceline and to ensure a stable electrical supply as decontamination and decommissioning remediation activities at the FEMP (decommissioning of utility services) increase. The new location was designated AMS 1B.
- AMS 2 through AMS 7 provide data at the fenceline to ensure guidelines for offsite exposure are not exceeded.
- AMS 8 and AMS 9 are in the prevailing wind direction at the FEMP. They were added in 1986 to the northeast sector of the FEMP based on a computer model that predicted where the highest ground-level concentrations of airborne uranium from plant operations would be found. In mid-1994, AMS 9 was moved to a location just outside of the former production area. The new location was designated AMS 9A. On August 13, 1996, AMS 8 and 9A were relocated to the FEMP fenceline due to

increased construction activities (On-site disposal facility test pad) and stable utility services. The new locations were designated as AMS 8A and 9B respectively.

- AMS 10 through AMS 14 are located at schools and industries near the FEMP and provide additional monitoring of emissions at these points.
- AMS 15 and AMS 16 were installed in 1989 to obtain additional background data. AMS 15 was located near the University of Cincinnati in Cincinnati, Ohio. In late 1994, road construction near AMS 15 required the monitor to be taken out of service. A replacement station (AMS 21) was installed on the Cincinnati State Technical and Community College campus in May 1995. AMS 16 is located in Miamitown, Ohio.
- AMS 17 through AMS 20 were installed in 1992 to provide increased monitoring of the waste pit emissions.

At each AMS, air is drawn through a 20-cm-by-25-cm (8-inch-by-10 inch) filter at a rate of about 1.3 m^3 per minute (about 45 ft^3 per minute). Changes in flow rate over the sampling period are monitored and accounted for by inspecting charts that continuously record flow data.

Air monitoring personnel collect the filters from the AMSs for analysis at two-week intervals. Two-week composite samples are more cost-effective than weekly analysis and free laboratory resources needed to support other monitoring efforts.

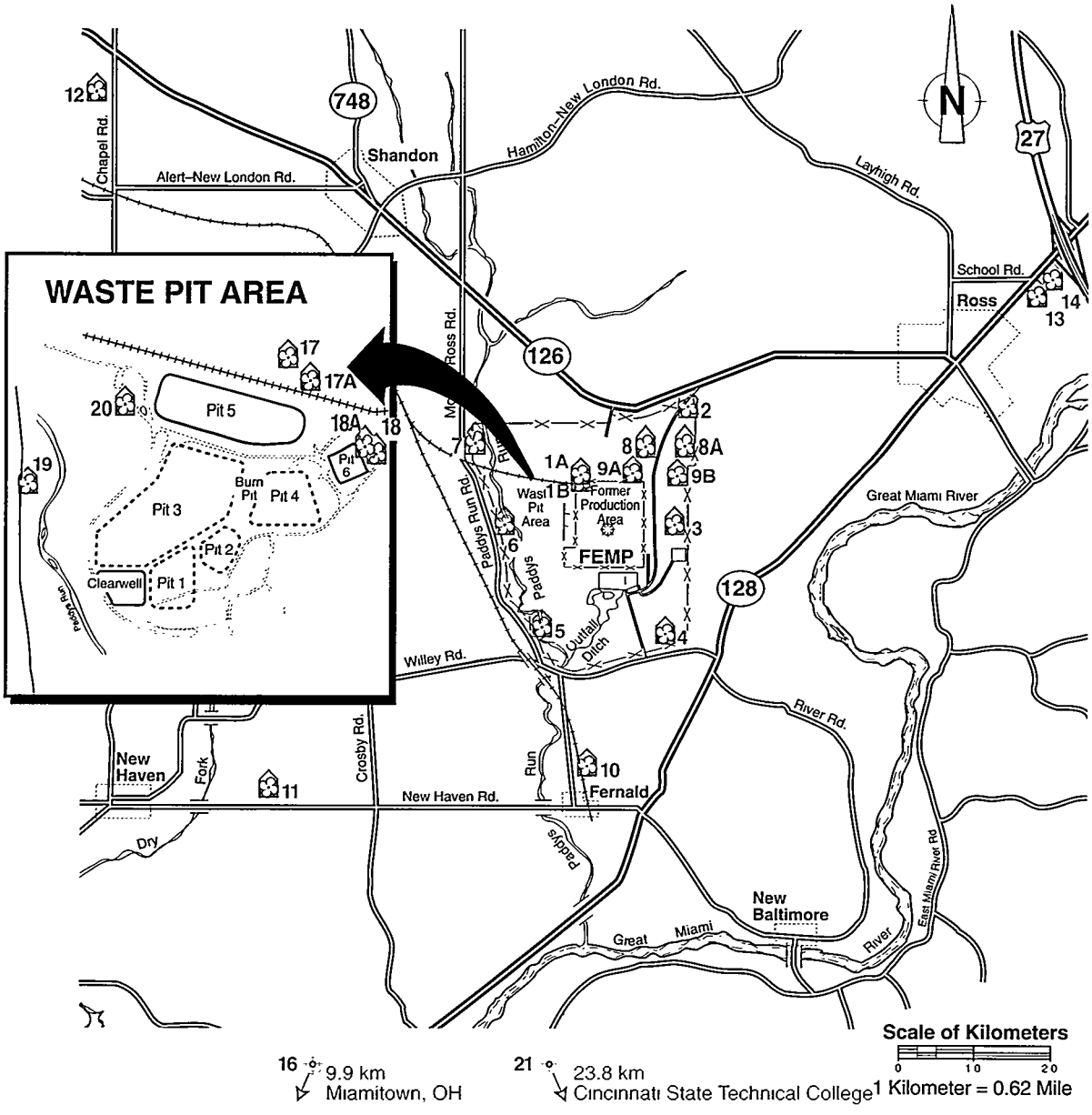
At the laboratory, technicians store the filters for at least three days following collection to allow naturally occurring, short-lived radionuclides (such as radon

Method Used to Determine Airborne Emissions

The total airborne uranium emissions are determined by summing the estimated and measured emissions from a number of stacks, vents, and processes onsite. Measured and estimated uranium emissions for 1996 totaled 5.0 kg (11.1 lbs). Uranium discharges from monitored stacks were the only measured emissions. Emissions from all other sources listed here are estimated. Airborne emissions are expected to remain at low levels for several years. However, a future increase in emissions is possible as contaminated buildings and equipment are dismantled during remediation activities.

Emission Category	Amount of Uranium Emission	Sources	Comments
Monitored Stacks	0.018 kg	Three stacks	High efficiency filters used to control emissions
Unmonitored Stacks Vents	0.87 kg	Plants 6 & 8, Buildings 11, 15, 20, 53, and 71	Estimated based on processes and amount of material handled in each facility
Fugitive/diffuse Sources	4.2 kg	Plants 1, 4, 5, 6, & 8 Buildings 20, 65, 71, 78, Waste Pits, & SCEP	Estimate based on ambient air monitoring data and meteorological conditions

Figure 22: Air Monitoring Locations



LEGEND

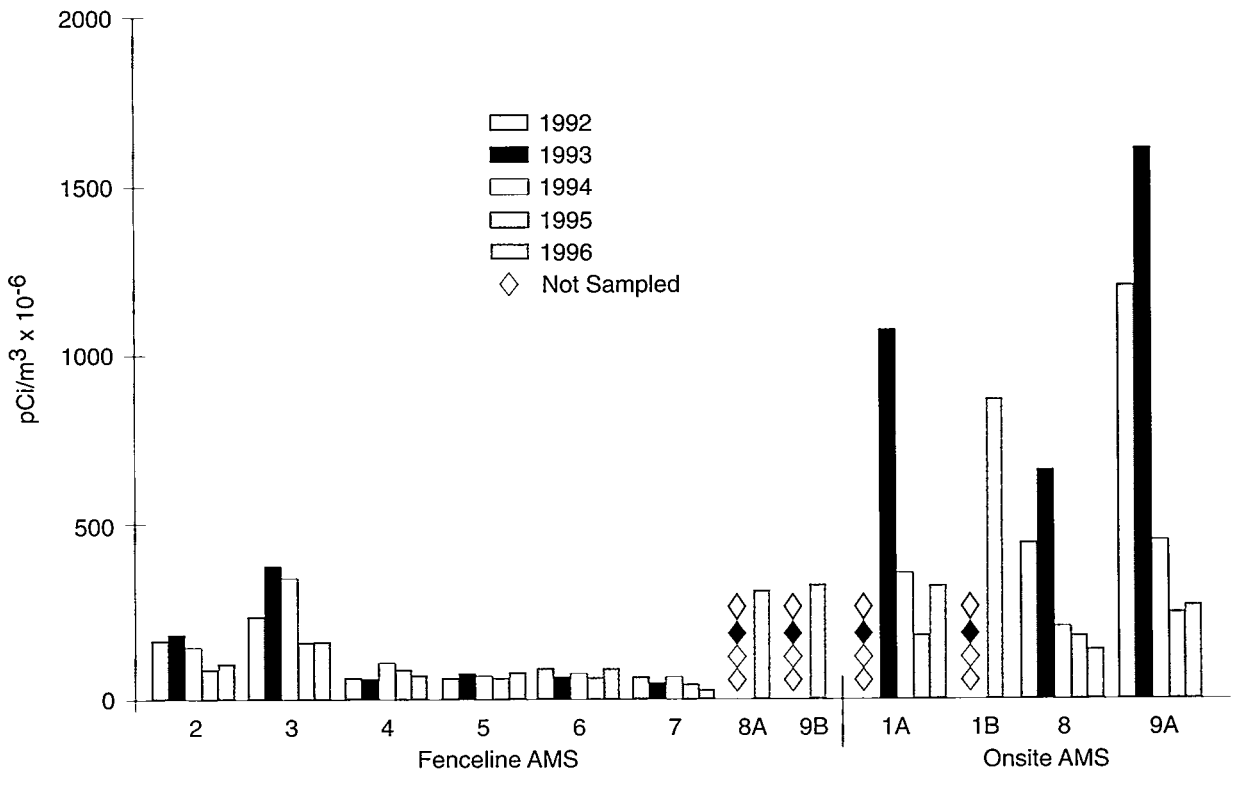
- Air Monitoring Station (AMS)
- Distance from Center of Former Production Area to Sampling Locations off Map
- Plant Perimeter
- Former Production Area Perimeter

daughters) to decay. It is important to note that this holding period does not affect the amount of uranium on the filters. After the holding period, analysts heat the filters to 500°C (932°F) to remove organic matter. Finally, they dissolve these filters in acid and analyze the resulting solutions for uranium. A portion of each of these solutions is retained to prepare an annual composite, which is then analyzed for trace concentrations of radionuclides such as isotopes of radium, plutonium, and thorium.

DOE Order 5400.5, "Radiation Protection of the Public and the Environment," establishes guidelines for concentrations of radionuclides in air emissions. These guidelines, referred to as Derived Concentration Guidelines (DCGs), are concentrations of radionuclides that, under conditions of continuous exposure for one year by one exposure mode, would result in a dose of 100 mrem to members of the public. Current EPA regulations, however, limit dose to 10 mrem per year. Thus, the DCGs are not concentration limits, but reference values that enable FEMP personnel to review effluent data and determine if there is a potential to exceed the limits on dose to members of the public.

The average concentrations of uranium at the eight fenceline AMSs (AMS 2 through AMS 9B) were all less than 1% of the DOE guideline. Table 3 on page

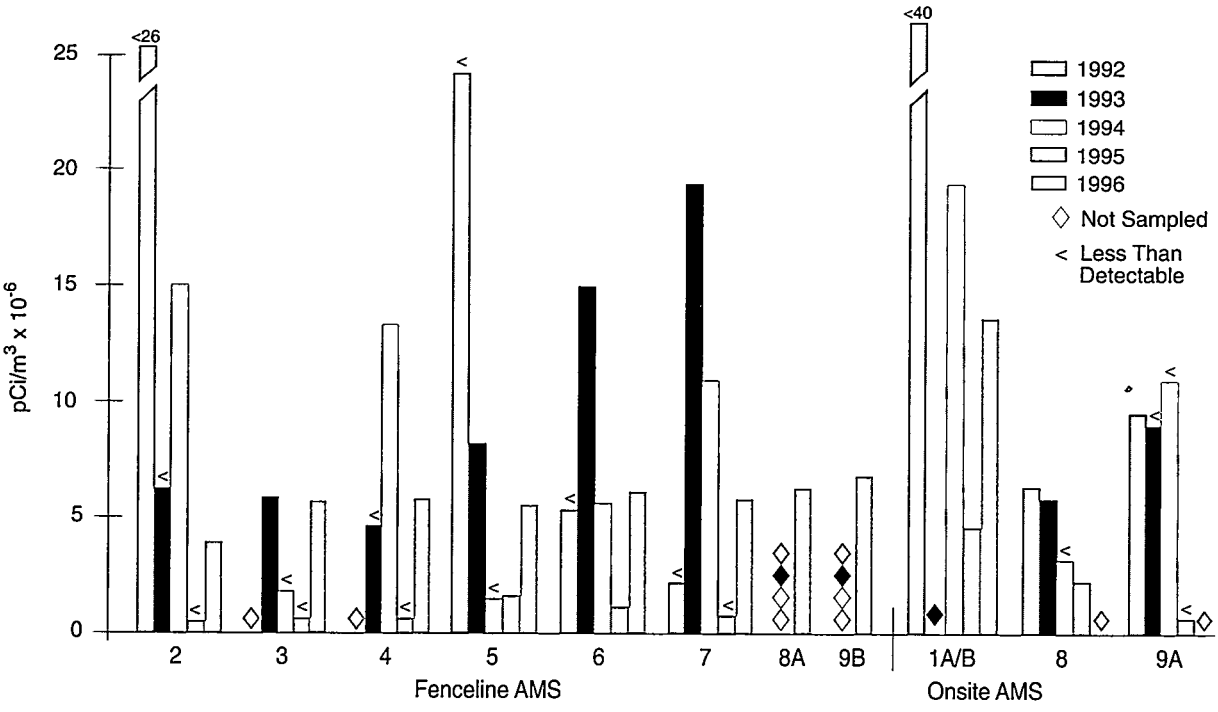
Figure 23: Average Uranium Concentrations in Air, 1992 – 1996



A-4 lists 1996 data for uranium concentrations. Figure 23 compares uranium concentrations at the air monitoring stations for 1992 through 1996.

The data for concentrations of trace radionuclides in 1996 are presented in Table 4 on pages A-5 through A-7. The results indicate that concentrations of trace radionuclides at the onsite and fenceline locations are well below DOE guidelines. Concentrations of thorium-232 measured at the AMSs for 1992 through 1996 are presented in Figure 24. Thorium-232 and its decay products are stored in quantity at selected locations onsite and are considered potential environmental contaminants.

Figure 24: Average Thorium–232 Concentrations in Air, 1992 – 1996



Less-than-detectable Concentrations

The less than symbol (<) is used here when the concentration of thorium-232 in air could not be reliably measured in the sample which was analyzed. That is, the amount of thorium-232, if present at all in the sample, was below the minimum measurable concentration. Thus, a concentration of <40 pCi/m^3 x 10^{-6} means the thorium concentration was less than 40 pCi/m^3 x 10^{-6} but actually could have been anywhere from 0.00 to 39.9 pCi/m^3 x 10^{-6}. While it is difficult to accurately compare these data that do not have reliable measurements from year to year, it is important to keep in mind that even the highest concentrations shown here are well below the DOE limit. The DCG for thorium-232 in air is 7,000 pCi/m^3 x 10^{-6}.

Monitoring Plant 1 & Plant 4 Decontamination & Decommissioning (D&D)

Prior to dismantling operations, four ambient air monitors were placed around Plant 1 and seven around Plant 4. The monitoring effort was designed to verify that negligible amounts of airborne radionuclide contaminants were released to the environment while dismantling the buildings. The monitors also provided data for evaluating the effectiveness of contamination control techniques. The Plant 4 monitors began operating in March 1995, and operated continuously through November 1996, while the Plant 1 monitors went into operation in December 1995. The monitors were similar to boundary air monitors in that air was drawn through a 20-cm-by-25-cm (8-inch-by-10 inch) filter at a rate of about 1.3 m^3 per minute (about 45 ft^3 per minute). Filters were changed weekly and analyzed for total uranium. The locations of the Plant 1 and Plant 4 monitors are shown in Figures 25 and 26, on pages 91 and 92.

Through 1996, Plant 1 monitoring results indicated that airborne uranium levels were relatively constant during the removal of equipment and duct work from the plant interior. Airborne uranium levels remained below the DOE derived concentration guidelines (DCGs) for uranium in the air in the vicinity of Plant 1. As previously described, the DCGs are used for comparative purposes and are not strict limits on the airborne uranium concentration. Table 5 on page A-8 is a summary of the weekly airborne uranium concentrations measured during the dismantling project. Plant 1 was imploded on February 22, 1997. The air monitors will continue to be in place until the rubble removal phase is complete.

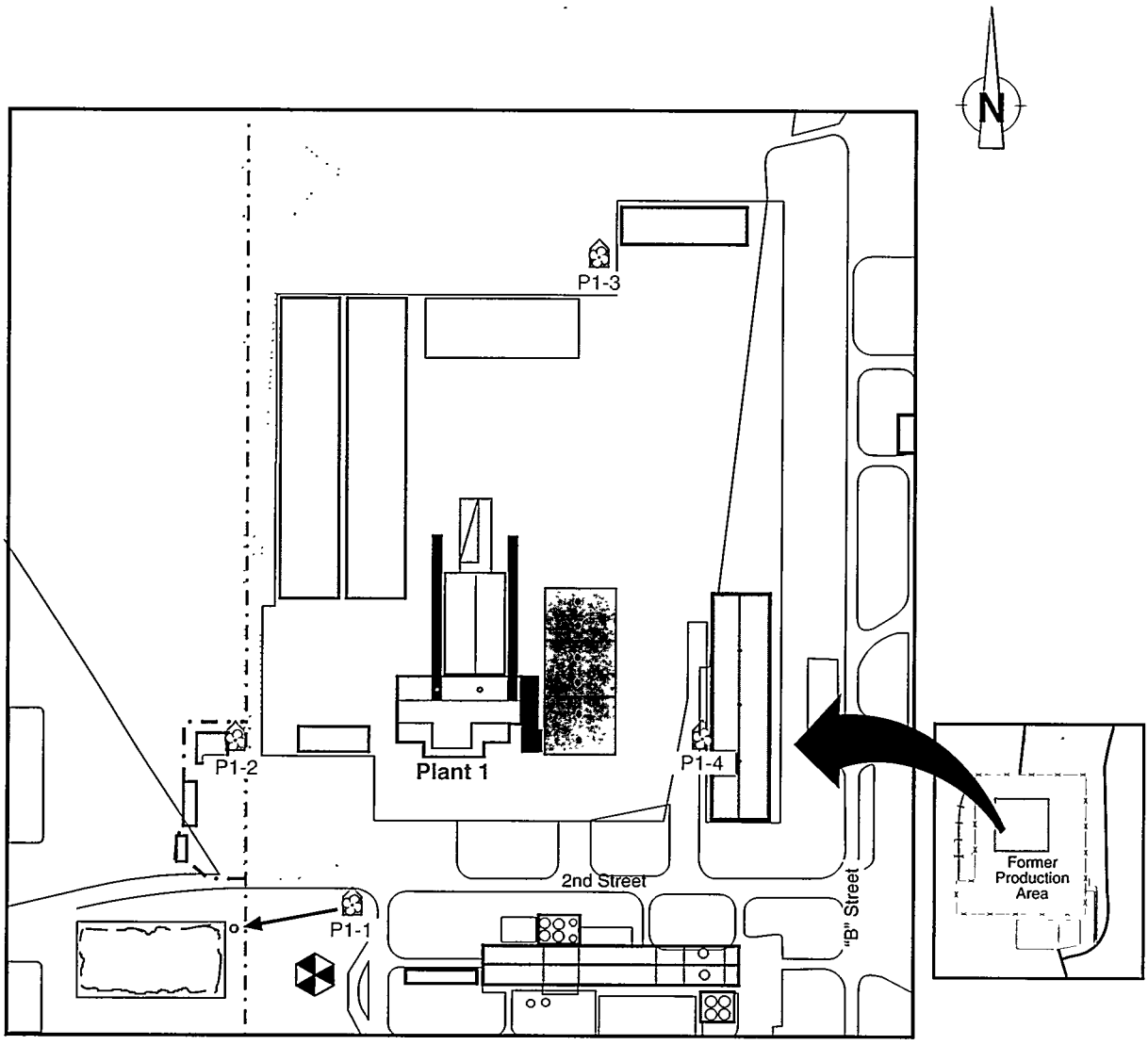
Through November 1996, Plant 4 monitoring results indicated that airborne uranium levels were relatively constant during D&D. Airborne uranium levels remained below the DOE guideline for uranium in air in the vicinity of Plant 4. Table 6 on page A-9 is a summary of the weekly airborne uranium concentrations measured during the dismantling project. Plant 4 was imploded on August 24, 1996 and post implosion airborne monitoring continued through the rubble removal phase. This monitoring indicated that airborne uranium levels were well below the DOE guideline.

Air monitoring in the vicinity of Plants 1 and 4 verified that negligible amounts of radionuclide contaminants were released while dismantling the buildings. Air monitors will continue to be used to verify adequate control over airborne releases for dismantling projects that differ in nature from the Plant 1 and 4 projects.

Soil Sampling for Uranium

FEMP technicians collect annual soil samples at air monitoring stations onsite and at offsite locations to evaluate changes in uranium concentrations that may occur through deposition and soil resuspension. In 1996, a new location was added to fully encircle the FEMP (See Figure 27 on page 93 for sampling locations). Uranium found in the soil may be naturally occurring, added by fertilizers, or a result

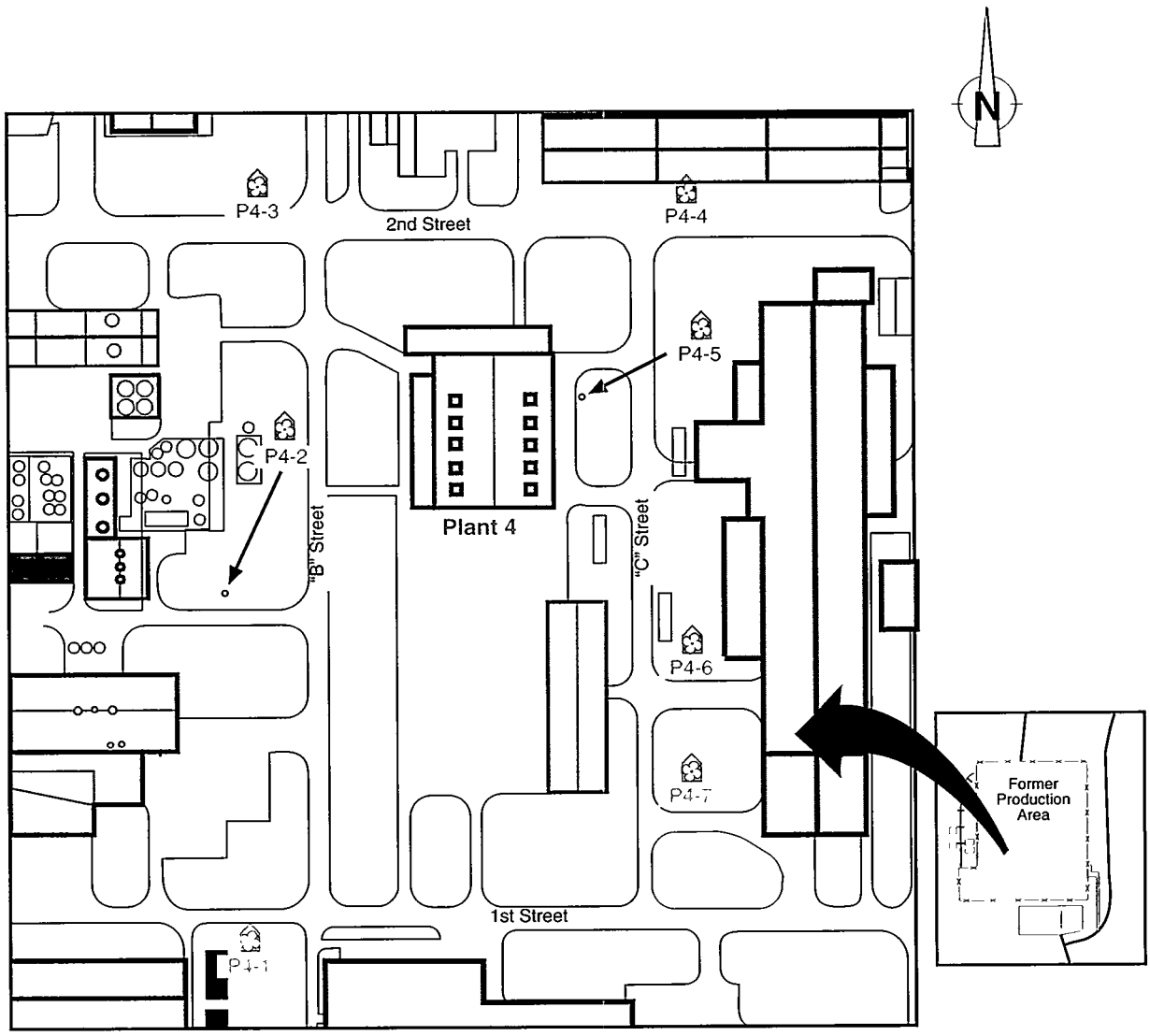
Figure 25: Plant 1 Monitoring Locations



LEGEND

Plant 1 (P1) Air Monitoring Location

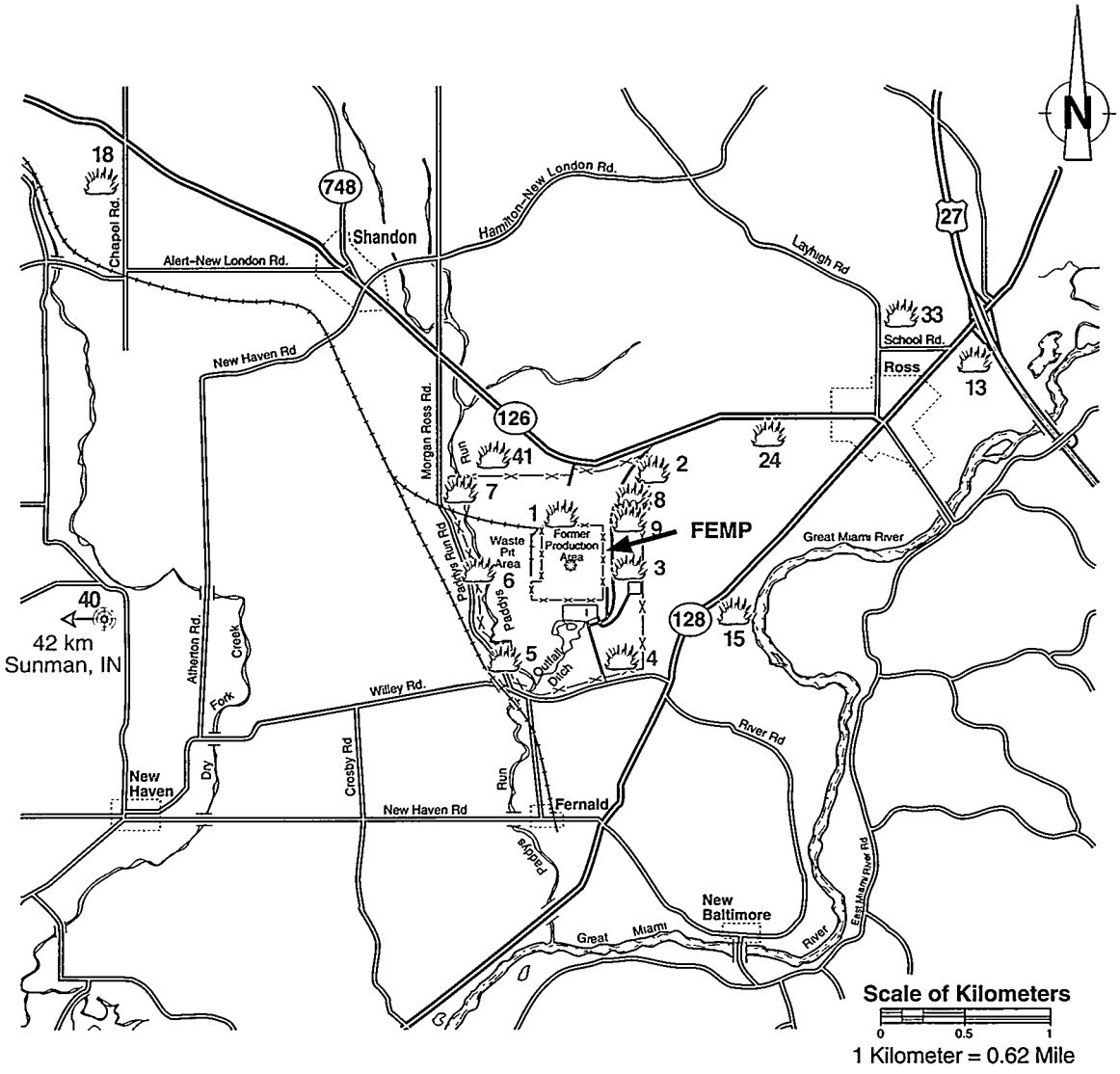
Figure 26: Plant 4 Monitoring Locations



LEGEND

Plant 4 (P4) Air Monitoring Location

Figure 27: Soil and Grass Sampling Locations



LEGEND

- Sampling Locations
- Distance from Center of Former Production Area to Sampling Locations off Map
- Plant Perimeter
- Former Production Area Perimeter

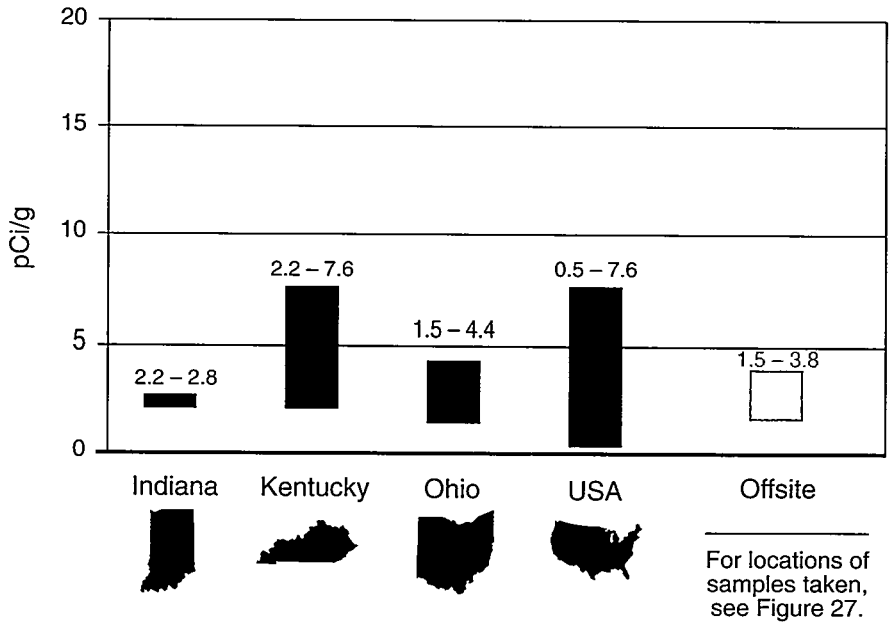
of FEMP operations. The amounts of uranium naturally present in rocks and soil vary greatly (See Figure 28).

Uranium occurs naturally in many materials. The earth's crust, for example, contains about 2.7 pCi/g (4 ppm) of uranium. These ores are mostly uranium-238, but do contain about seven-tenths of one percent (0.711%) of uranium-235. Due to the natural abundance of the uranium-235 isotope, and contribution from uranium-234, the total radioactivity due to uranium is approximately double the uranium-238 value (See Figure 28).

As part of this program, technicians collect 5-cm (2-inch) deep core of soil from undisturbed plots, excluding grass, which is evaluated separately. Results show that uranium concentrations in soil samples onsite and at the fenceline ranged from 2.9 pCi/g at location four to 27 pCi/g at location three (see Table 7 on page A-10). The higher concentrations in onsite soil are indicative of the soil contamination known to exist at the FEMP, particularly in the northeast quadrant of the FEMP. For comparison, the OU5 ROD clean-up values for soil re-mediation are 33.8 pCi/g (50 ppm). Please refer to Table 28 on page A-47 for a listing of all FRL values for comparison.

The uranium concentrations in the offsite samples ranged from 1.5 pCi/g at sample location 18 to 3.8 pCi/g at sample location 24. For comparison purposes, the range of uranium concentrations in offsite samples can be evaluated against values from different reference sources. The FEMP conducted a study to determine the range of concentrations present in soil near the FEMP. Soil samples were analyzed for a number of radionuclides; however, only uranium results are reported here. Results from this study show the mean uranium concentration is

Figure 28: Range of Total Uranium Occurring in Surface Soils



2.1 pCi/g with an upper limit (95% tolerance limits) of 2.8 pCi/g.[22] Additionally, in the FEMP OU5 RI/FS, offsite soil uranium concentrations ranged from 1.7 pCi/g to 2.7 pCi/g. The comparison to offsite uranium concentrations suggest that FEMP emission have not significantly affected the average uranium concentrations in the local environment.

Based on soil sampling which has shown no impact from air emissions since the cessation of production, the sampling of soils adjacent to air monitors will not continue. However, an extensive soil sampling effort will commence to ensure that soils are cleaned up to levels below the final remediation levels.

Grass Sampling for Uranium

FEMP personnel analyze grass for uranium to determine if airborne emissions are affecting the uranium concentration in grass. One new grass sample location was added in 1996 in order to fully encircle the FEMP with monitoring locations. Uranium contamination in vegetation may result from transfer of uranium from the soil through absorption by the plant, deposition of eroded soil, or from uranium deposited on the surface of the plant from the air. As a general rule, uranium is not selectively absorbed by plants because it serves no useful purpose in the plant's metabolic processes. However, small amounts of uranium may be absorbed through a plant's normal growth processes.

Samples of grass were collected at the same locations as soil. Subsamples of grass were collected from the area around the soil sample location and then combined to form a composite sample. Each grass sample was a composite of at least three subsamples clipped near ground level. The composite samples weighed about 500 grams (1 lb). An offsite laboratory air-dried and then analyzed the samples for uranium.

Standards have not been established for uranium in grass; however, comparing results of samples collected at the FEMP, and with the results of samples collected at offsite and outlying locations provides a means to evaluate the impact of FEMP emissions on uranium concentration in grass.

In addition to soil sample results, Table 7 on page A-10 reports the following uranium concentrations in fenceline and offsite grass samples:

- Fenceline results for 1996 ranged from 0.01 to 0.34 pCi/g (dry weight), and
- Offsite results from 1996 ranged from 0.0065 to 0.14 pCi/g (dry weight).

The results indicate the 1996 uranium concentrations are within the range of historical concentrations.

Future sampling efforts at the FEMP will focus on primary pathways such as the air pathway and less on secondary pathways such as grass. Since negligible impacts to grass have been observed routine grass sampling will be discontinued.

Produce Sampling for Uranium

As mentioned in Chapter One, the FEMP is surrounded by farmland. Locally grown sweet corn and tomatoes are two of the major crops sold from roadside stands within three miles of the FEMP. Local residents also grow and sell beets, potatoes, apples, lettuce, pumpkins, cucumbers, and peppers.

With air emissions reduced to very low levels, the possibility of uranium contamination in produce from air deposition is also very low. While washing the produce before eating removes any surface contamination which may be present, some uranium may be taken up by plants through their root systems and incorporated into their edible portions. Soil samples are also collected in conjunction with the produce in order to verify negligible amounts of uranium have been deposited through the air pathway. Uranium detected in produce may be uranium that is deposited from the air pathway, naturally occurring in the soil, or added by fertilizers.

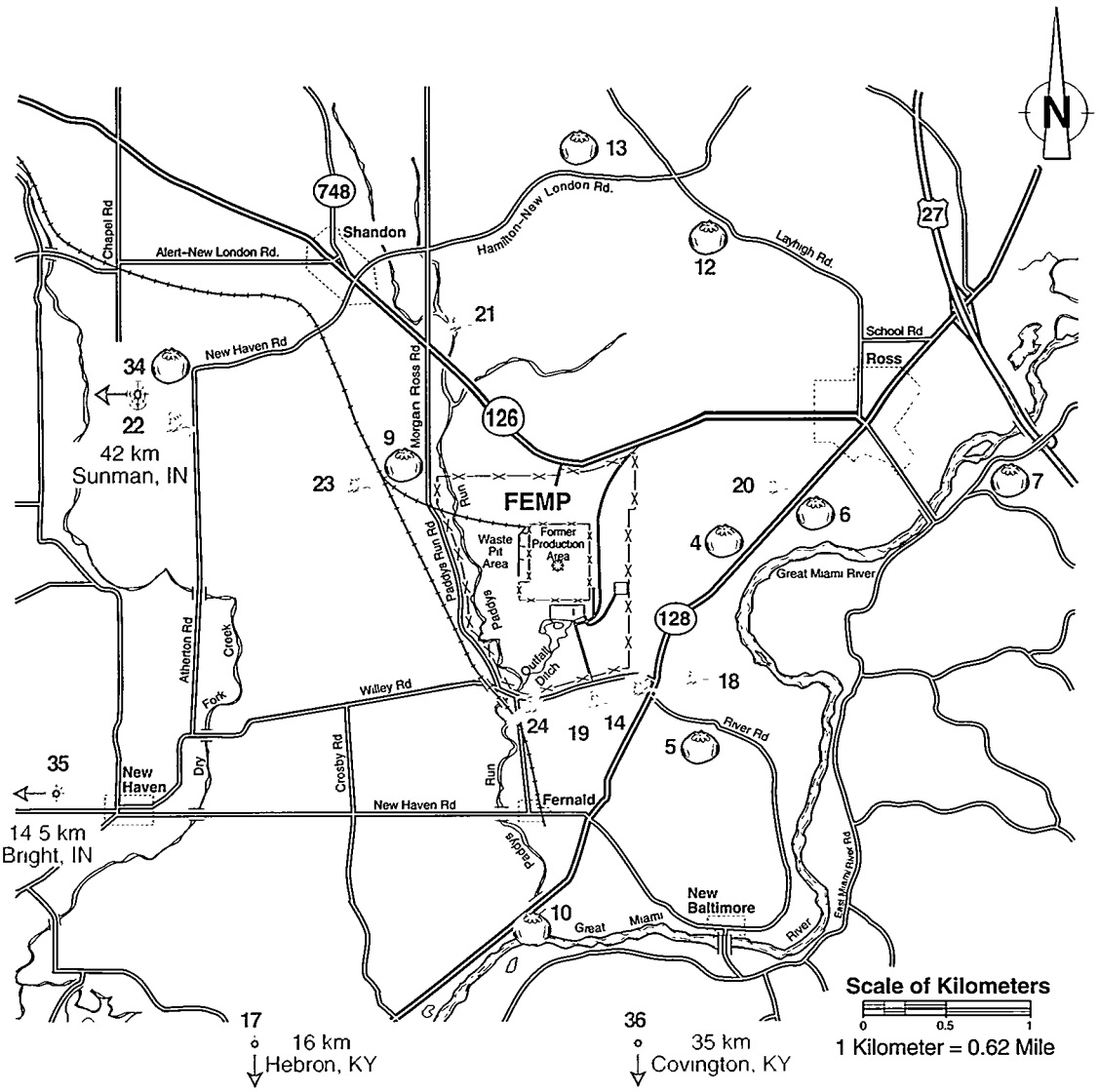
Technicians sample produce each year to determine if uranium concentrations in produce grown near the FEMP (0-5 km or 0-3 miles) are higher than concentrations in produce grown at distant locations (11-42 km or 7-26 miles) and are, therefore, a pathway of exposure from FEMP emissions. (See Figure 29 for sampling locations). The sample results are then used to estimate the potential dose to people from this component of the air pathway (see Chapter Seven).

The results of the produce and soil sampling program are reported in Table 8 on page A-11. In general, uranium concentrations varied greatly for each type of produce. Comparisons between the average uranium concentrations in tomatoes grown near the FEMP with concentrations grown distant from the FEMP indicate the average concentrations were higher at the outlying locations. These comparisons suggest that there is no substantial impact today from past or current FEMP emissions on produce grown in the area.

Monitoring for Direct Radiation

Direct radiation (X-rays, gamma rays, energetic beta particles, and neutrons) originates from sources such as cosmic radiation, naturally occurring radionuclides in soil, worldwide fallout from nuclear weapons testing, and radioactive materials at the FEMP. The largest source of direct radiation at the FEMP is the material stored in the K-65 silos. Gamma rays and X-rays are the dominant types of radiation emitted from the silos. Energetic beta particles and neutrons are not a significant component of direct radiation at the FEMP because uranium, thorium, and their decay products do not emit this radiation at levels that create a public exposure concern.

Figure 29: Produce Sampling Locations



LEGEND

Sampling Locations:
- Cash Crop
- Garden Produce

- Plant Perimeter
- Former Production Area Perimeter
- Distance from Center of Former Production Area to Sampling Locations off Map
- Center of FEMP at Plant 4

Direct radiation levels at and around the FEMP are continuously measured at 30 locations with *thermoluminescent dosimeters (TLDs)*. TLDs absorb and store the energy of direct radiation within the thermoluminescent material. By heating the thermoluminescent material under controlled conditions, the stored energy is released as light, measured, and correlated to the amount of direct radiation. Figure 30, located on page 99, shows the location of the TLD monitoring points.

These monitoring points were selected based on the need to monitor the K-65 silos, the FEMP boundary, and several offsite locations, including background locations. Three TLDs are placed at each monitoring location for a three-month period, yielding accurate and consistent quarterly measurements.

Results of direct radiation measurements for 1996 are provided in Table 9 on page A-13. Direct radiation fields vary from one location to another because of the differences in the terrestrial and cosmic components of natural background radiation. For example, varying concentrations of naturally occurring radium, thorium, and their decay products in soil result in different measured radiation levels. As expected, measurements of direct radiation indicate levels are higher in the area near the K-65 silos. However, these levels are 72% lower than radiation levels measured in 1991 prior to the addition of the bentonite layer within the K-65 silos. An estimated dose from direct radiation is provided in Chapter Seven.

TLD results from fenceline locations do not show any increasing or decreasing trends over the past five years. The 1996 results were similar to the 1995 results. In 1996, the procedure for analyzing the TLD's was revised to incorporate new algorithms which enhanced the lower limit of detection. This increased the level of detection with a corresponding increase in uncertainty.

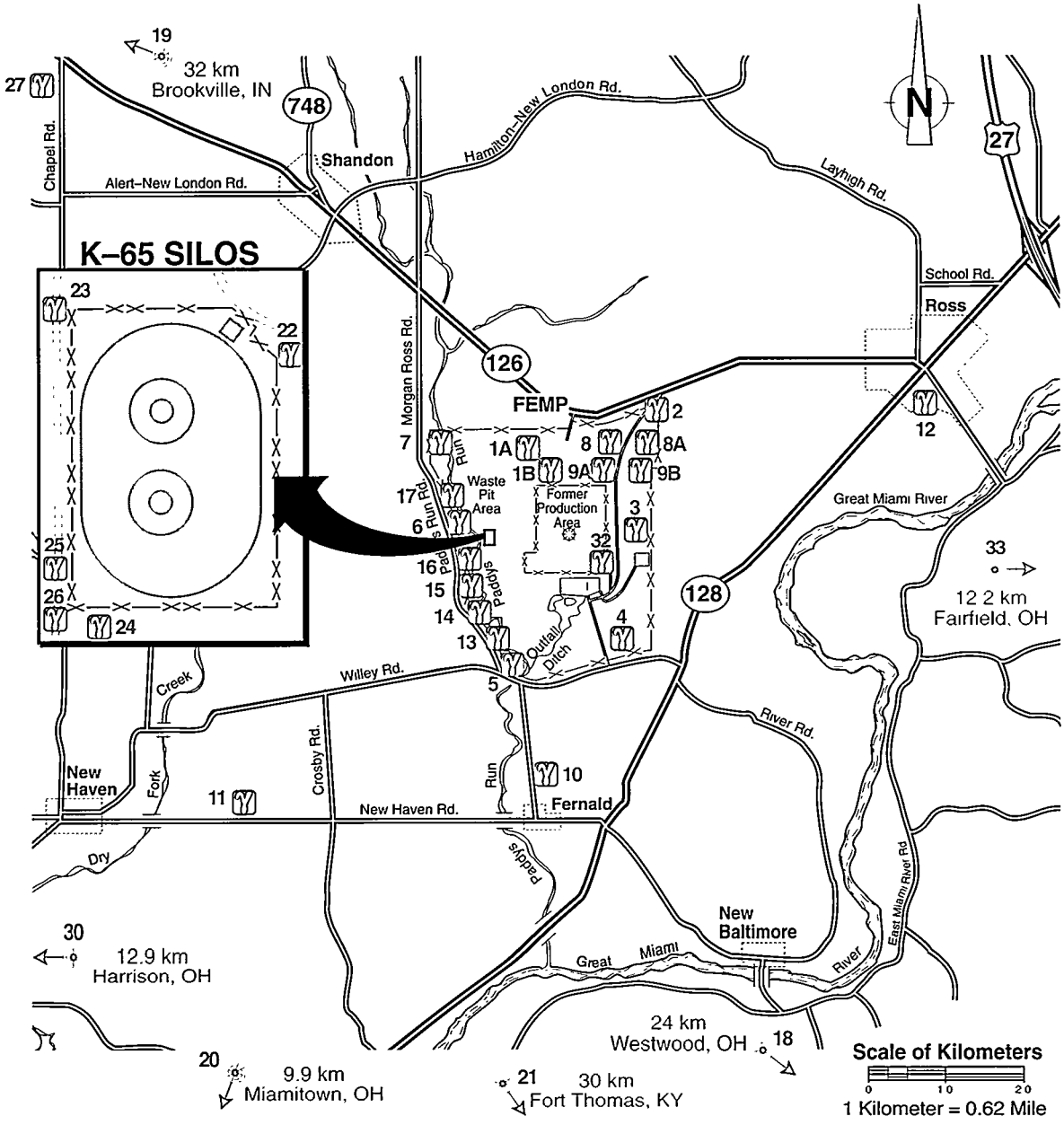
Monitoring for Nonradioactive Pollutants

OEPA requires an estimate of emissions from the Boiler Plant as part of the FEMP's effort to demonstrate compliance with the Clean Air Act. The FEMP estimated the amount of nonradioactive pollutants including particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and carbon monoxide (CO) and measured the shade, or density, of particulate emissions from the coal-fired boilers. Shade, or density, also called *opacity,* is a measure of how much light is blocked by particulate matter present in stack emissions.

On June 1, 1996, three gas-/oil-fired boilers were put into service and the coal-fired boilers were taken out of service. On June 21, 1996, the two coal-fired boilers were permanently taken out of service. This action caused a change in fuel supply for the boilers to natural gas with diesel fuel as a back-up source for the three smaller boilers. This change will affect future air emissions, in that emissions from natural gas and fuel oil-fired boilers are significantly lower than coal-fired boilers.

In order to estimate SO_2 emissions, scientists regularly determine the sulfur content and heat content of the fuel. Using this information and the total amount of fuel burned, the amount of SO_2 emissions can be calculated. For 1996, SO_2 emissions from all boilers were calculated to be 154,000 kg (340,000 lbs). This was well below the allowable limit calculated from information in the permit issued by OEPA.

Figure 30: Direct Monitoring Locations



LEGEND

- Dosimeter Location
- Distance from Center of Former Production Area to Dosimeter Locations off Map
- Plant Perimeter
- Former Production Area Perimeter
- Center of FEMP at Plant 4

Air Emissions

OEPA maintains an inventory system for actual air emissions from major point sources; the inventory is reported by the Department of Environmental Services – Air Quality Management (formerly the Southwestern Ohio Air Pollution Control Agency). The totals presented here are in kilograms.

	Hamilton County 1995	Butler County 1995	Combined Counties 1995	FEMP Boiler Plant 1995	FEMP Boiler Plant 1996
Particulates	3.5 million	5 million	8.5 million	14,000	7,700
SO_2	81 million	8.6 million	89.6 million	298,000	154,000
NO_x	29 million	7 million	36 million	131,000	68,000
CO	1.5 million	21 million	22.5 million	48,000	26,000

Note: Current air emissions reported by the Department of Environmental Services – Air Quality Management (1995).

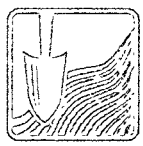
The NO_x and CO emissions are estimated using EPA-developed emission factors. NO_x emissions for all boilers for 1996 were estimated to be 68,000 kg (150,000 lbs). Carbon monoxide emissions for all boilers in 1996 were estimated to be 26,000 kg (57,000 lbs). To date, the OEPA has not set NO_x or CO limits for FEMP industrial processes.

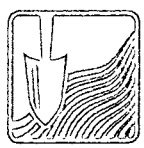
Electrostatic precipitators reduce particulate emissions from the coal-fired boilers. Particulate emissions from the gas and diesel-fired boilers are minimal. The particulate emissions from all boilers were estimated to be 7,700 kg (17,000 lbs) for 1996. The opacity of the emissions from the two FEMP coal-fired boilers were continuously monitored by instruments until their closure. During 1996, the coal-fired boilers operated 5,114 hours, and 30,684 opacity measurements were made and recorded at six-minute intervals. There were a total of 14 excursions of the opacity standard. These excursions were brief, typically less than 18 minutes in length, and associated with boiler start-up or load changes.

In addition to directly affecting concentrations of contaminants in soil, grass, and other media discussed in this chapter, the air pathway can indirectly influence contaminant concentrations in the liquid pathway. Stormwater runoff is one way materials released in the air can be transported into surface water such as Paddys Run. Eventually, these contaminants may affect groundwater quality as well. The next two chapters describe the monitoring program for the liquid pathways at the FEMP, beginning with effluent and surface water monitoring in Chapter Five.

5

Liquid Pathway: Effluent and Surface Water Monitoring





Liquid Pathway: Effluent and Surface Water Monitoring

The second pathway that the FEMP monitors is the liquid pathway. Contaminants leave the FEMP by two primary mechanisms: (1) monitored liquid effluents released to the Great Miami River, and (2) uncontrolled stormwater runoff from areas drained by tributaries of Paddys Run. The FEMP continues to monitor this pathway due to contamination from past operations. Monitoring will continue in the future in order to gauge releases associated with cleanup activities. By limiting the concentration of radionuclides in the effluent and reducing the amount of stormwater runoff to Paddys Run, the FEMP can lessen its impact on the various components of the liquid pathway.

Results in Brief: 1996 Liquid Pathway: Effluent and Surface Water

Effluent – In 1996, approximately 125 kg (275 lbs) of uranium were discharged in effluent released to the Great Miami River. Approximately 166 kg (366 lbs) of uranium reached Paddys Run through uncontrolled stormwater runoff. Another 6 kg (13 lbs) of uranium were released due to Paddys Run overflows of the Stormwater Retention Basin. The total effluent release of 298 kg (656 lbs) decreased 4% from 1995.

Surface Water – In 1996, downstream Great Miami River total uranium concentrations were not statistically different from upstream concentrations. Downstream Paddys Run total uranium concentrations were elevated above background upstream concentrations due to uncontrolled stormwater runoff. The nearest offsite sampling location (W7) had a concentration of 2.0 ± 1.4 pCi/L as opposed to 0.7 ± 0.2 pCi/L at the background upstream location (W5). For reference, the Final Remediation Level for uranium in surface water is 318 pCi/L (530 ppb).

Sediment – In 1996, there was no significant build-up of radionuclides in local waterway sediments. Total uranium concentrations in Great Miami River sediments south of the FEMP effluent line were not statistically different than at the background location. Total uranium concentrations in onsite Paddys Run sediments were greater (~28%) than at background locations.

Fish – In 1996, total uranium concentrations in Great Miami River fish caught downstream of the FEMP effluent line were not statistically different than those found in upstream fish.

NPDES – In 1996, out of 2,355 NPDES compliance opportunities there were 8 violations. This represents an in-compliance factor of 99.66%.

Liquid pathway monitoring is divided into five components: (1) liquid effluent monitoring, (2) surface water sampling, (3) sediment sampling, (4) fish sampling, and (5) groundwater monitoring. This chapter discusses the sampling methodologies and results obtained from the first four components listed above. These data are used to evaluate impacts on the Great Miami River and Paddys Run due to FEMP liquid effluents.

Monitoring for Radioactive Pollutants

This section of this chapter centers on radioactive pollutants. The discussion begins with a description of effluent flow, followed by examination of the sampling and analysis program for the liquid effluent. The discussion continues with the surface water and sediment sampling programs, and ends with the fish sampling program.

Effluent Sampling for Radionuclides

In 1996, approximately 17 billion liters (4.5 billion gallons) of Great Miami River water flowed past the FEMP effluent line per day.[8] The FEMP is required to monitor and treat liquid effluents as necessary before discharge by way of the Parshall Flume. A daily average of 9.1 million liters (2.4 million gallons) of effluent was discharged to the river. Therefore, each unit of discharged effluent was combined with about 1,870 units of river water.

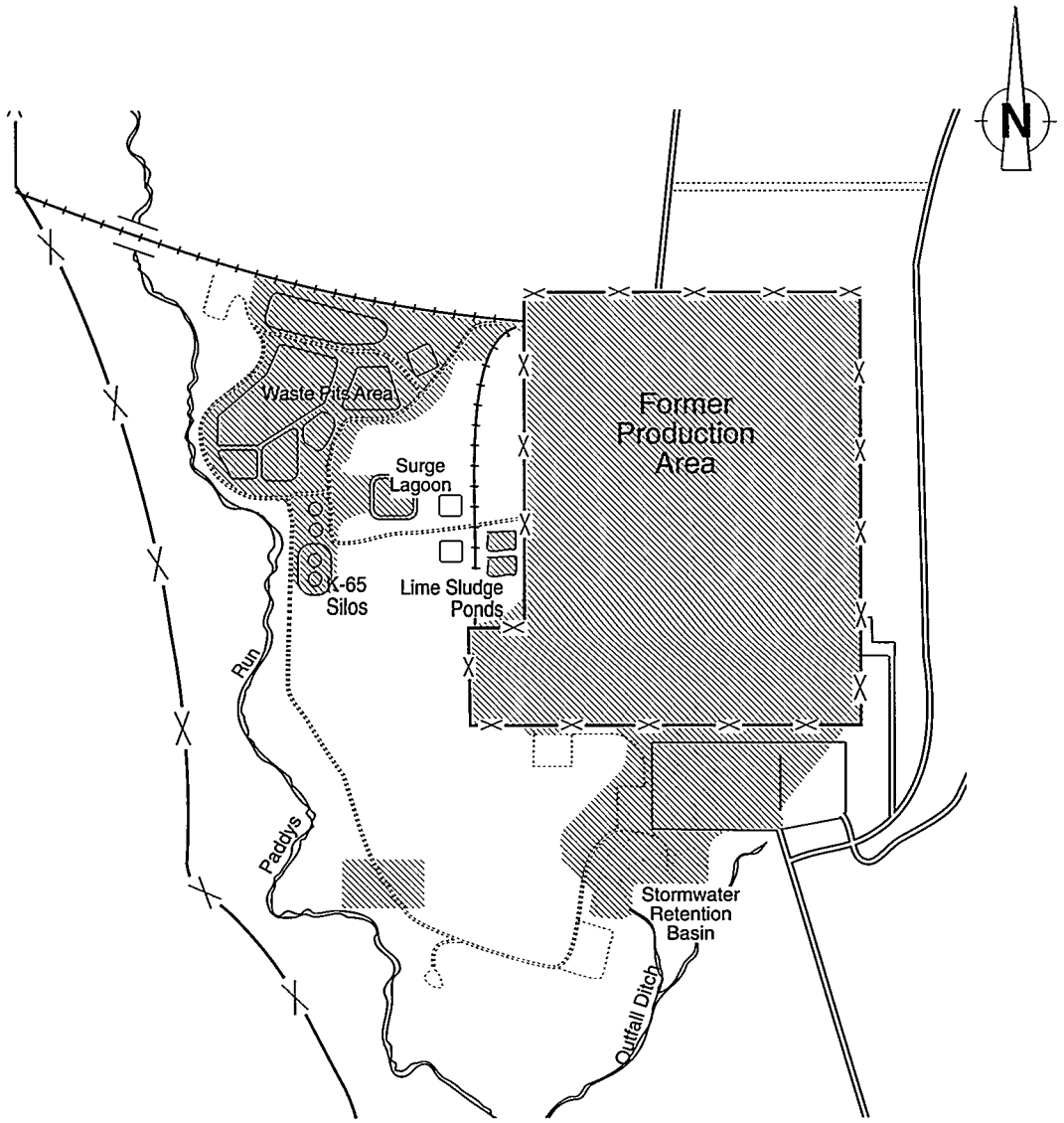
The FEMP also monitors stormwater runoff to Paddys Run in areas of uncontrolled runoff and at the Storm Sewer Outfall Ditch (SSOD) due to overflow or bypass of the Stormwater Retention Basin (SWRB). Since the SWRB began operations in 1986, the amount of uranium reaching Paddys Run by way of the SSOD has been reduced. Figure 31 shows areas of controlled stormwater runoff.

Sources of Effluent

Liquid effluent has been categorized into twelve "streams." Figure 32 on page 104 illustrates effluent flow and treatment points.

- Streams one and two consist of contaminated stormwater runoff that is collected from the waste pit and waste pit perimeter area. Effluent from these streams is pumped to the Biodenitrification Surge Lagoon (BSL). Up until 1996, this water was treated in the Biodenitrification Facility (BDN) towers to reduce nitrates. This liquid is treated in Phase II of the Advanced Wastewater Treatment Facility (AWWT) for uranium removal prior to discharge through Parshall Flume. At that time, all existing sources of nitrates inventory were deemed processed and the BDN towers were permanently removed from service and prepared for future D&D.
- The third stream results from perched groundwater. If necessary, this effluent is treated for volatile organic compounds (VOCs) by the Plant 8 Granular Activated Carbon System before entering the contaminated side of the General Sump.

Figure 31: Area of Controlled Stormwater Runoff



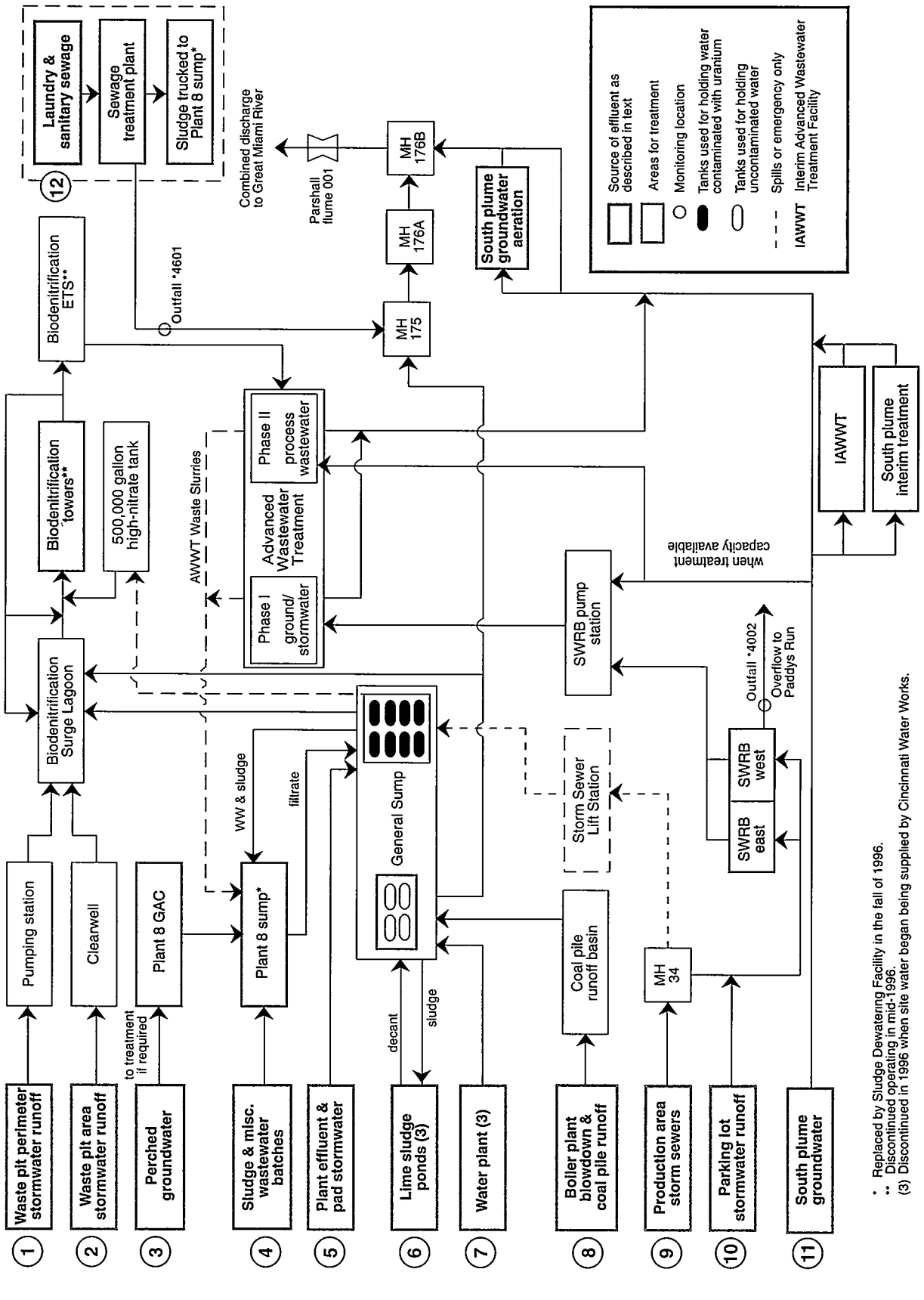
LEGEND

Shaded Areas are Collected and Eventually Discharged to the Great Miami River

Plant Perimeter

Former Production Area Perimeter

Figure 32: FEMP Effluent Flow Diagram



* Replaced by Sludge Dewatering Facility in the fall of 1996.
** Discontinued operating in mid-1996.
(3) Discontinued in 1996 when site water began being supplied by Cincinnati Water Works.

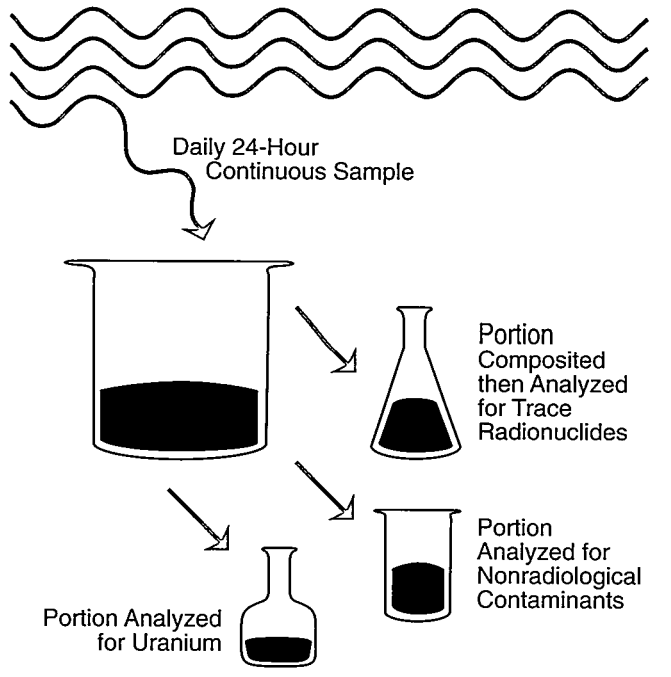
- The fourth stream, which existed during most of 1996, was the dewatering and packaging of sludge in Plant 8 which was removed from the temporary nitrate tanks as part of that remediation activity (see Chapter 1). Also included were the treatment of other miscellaneous batches of wastewater which required removal of heavy metals. In Plant 8, this material is filtered. the liquid filtrate is sent to the contaminated side of the General Sump, while the decanted sludge is drummed and stored as low-level radioactive waste. All liquids send directly to the contaminated side of the General Sump are combined. If treatment is not required, the combined liquid is sent to the BSL. If treatment for uranium and heavy metals is necessary, the combined liquied is sent to the Plant 8 treatment system. At the end of 1996, after the sludge from the temporary nitrate tanks was completely processed, Plant 8 was removed from service. In the future, miscellaneous batches of wastewater which will require heavy metal removal will be sent to the Sludge Dewatering Facility (SDF). The SDF, an auxiliary facility located adjacent to the AWWT, was placed into operation in September 1996.
- The fifth stream is the combination of plant effluent and pad stormwater. This combined effluent is pumped directly to the contaminated side of the General Sump.
- The sixth, seventh, and eighth streams are the decant from the Lime Sludge Pond, Water Plant effluent, and the combination of Boiler Plant blowdown and Coal Pile runoff. Each of these streams is pumped to the noncontaminated side of the General Sump. The sixth and seventh streams are sent there directly, while the eighth enters after collection in the Coal Pile Runoff Basin. Streams six and seven were discontinued after February 1996 due to the connection of the FEMP to Cincinnati Water Works. After settling, liquid in the noncontaminated side of the General Sump is sent to either the BSL or Manhole-175, and the sludge is sent to the North Lime Sludge Pond.
- The ninth stream results from parking lot runoff. The tenth stream consists of effluent collected by a network of production area storm sewers. During normal operating conditions, this effluent is directed to the SWRB; however, potential spills can be intercepted and pumped to the contaminated side of the General Sump.
- Stream eleven results from the pumping of the South Plume of the Great Miami Aquifer. Groundwater from the South Plume is pumped onsite where a portion is treated to remove uranium, while the remainder is discharged directly to the Great Miami River. The Aeration Facility ensures that effluents leaving the FEMP contain adequate oxygen levels to comply with the NPDES limit.
- Stream twelve is a combination of sanitary sewage and wastewater from the laundry facility. This effluent is processed at the Sewage Treatment Plant for biological contaminant removal. Afterward, the effluent is sent to Manhole-175. The sludge was trucked to the Plant 8 treatment system for dewatering until September 1996. Sewage sludge generated after September 1996 will be trucked to the Slurry Dewatering Facility (SDF) for dewatering.

Sampling Methodologies

Mixed effluent sampling at the Parshall Flume is performed by continuous operating devices that collect a sample proportional to the volume of effluent flow (flow-proportional samplers). After a period of 24 hours, the accumulated sample is removed for analysis, providing a daily flow-weighted sample of the effluent (see Figure 33).

Scientists analyze the daily flow-weighted sample as a verification of process control and to estimate the quantity of total uranium discharged to the Great Miami River. Additionally, monthly composites are formed from the daily samples and are analyzed for isotopic uranium and 7 other radionuclides. Composites, rather than daily samples, are analyzed because many radionuclides are typically present in only trace amounts. It is neither practical nor cost-effective to perform more frequent analyses.

Figure 33: Continuous Sampling



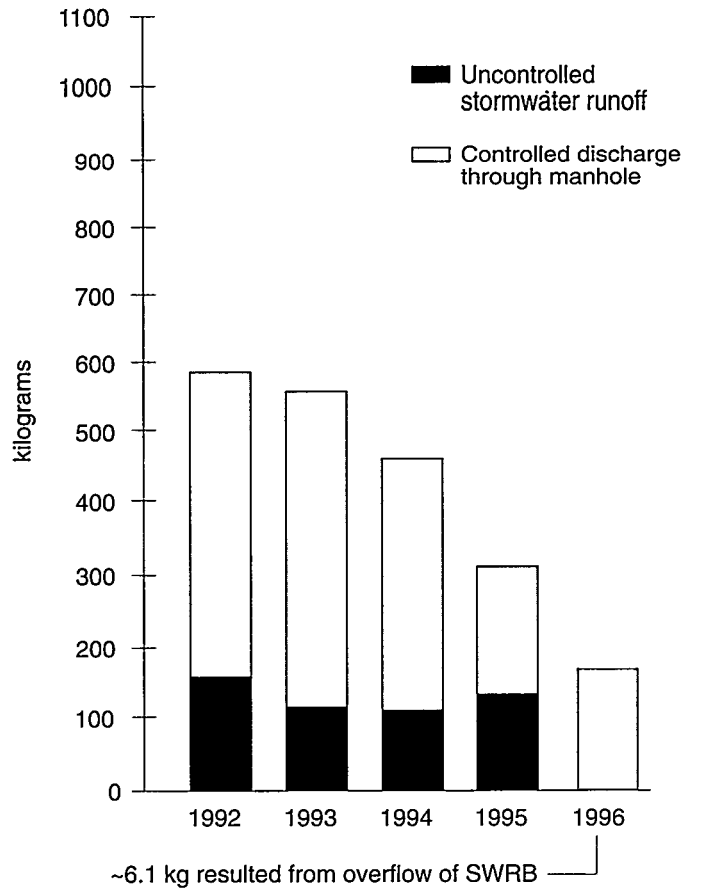
Ingestion of water with a radionuclide concentration at the Derived Concentration Guideline (DCG) would give a dose to members of the public of 100 mrem (assuming the suggested 730 liters ingested per year as listed in guidance documents). For compliance purposes, the average concentration for each radionuclide is compared to the DCG, and a percentage DCG value is reported. These percentages are summed and if the total is above 100%, the FEMP is required to use Best Available Technology (BAT) to reduce radionuclide concentrations in its effluent. The percentage DCG limit was not exceeded in 1996 (see Table 11 on page A-20). In addition to using a comparison of concentrations to the DCG, the site will also comply with the uranium effluent limitation of 20 ppb at the Parshall Flume, beginning January 1998.

Results of Laboratory Analyses

Table 11 on page A-20 summarizes the radionuclide analyses of the liquid effluent discharged to the Great Miami River.

In 1996, 125 kg (275 lbs) of uranium were discharged to the Great Miami River. This was a decrease of 30% in comparison to the 179 kg (393 lbs) of uranium discharged during 1995.

Figure 34: Total Uranium Discharged from the FEMP, 1992 – 1996



Scientists use a general estimate for uranium leaving the FEMP due to uncontrolled stormwater runoff. Approximately, 2.8 kg (6.3 lbs) of uranium leaves the FEMP for every inch of rain. For 1996, the amount of precipitation recorded by the FEMP meteorological system was 146.96 cm (58.6 inches). Therefore, approximately 166 kg (366 lbs) was the estimate for uranium in uncontrolled runoff.

In 1996, the SWRB overflowed because of heavy precipitation recorded in the months of April and May. The quantity of uranium released to the SSOD from these events was estimated to be 6 kg (13 lbs).

Comparisons of total uranium discharges between 1992 and 1996 are shown in Figure 34. The uranium contained in all effluents from the FEMP decreased from an estimated 310 kg (682 lbs) in 1995 to an estimated 298 kg (656 lbs) in 1996. This decrease is similar to the decrease observed over the past several years.

Surface Water Sampling for Radionuclides

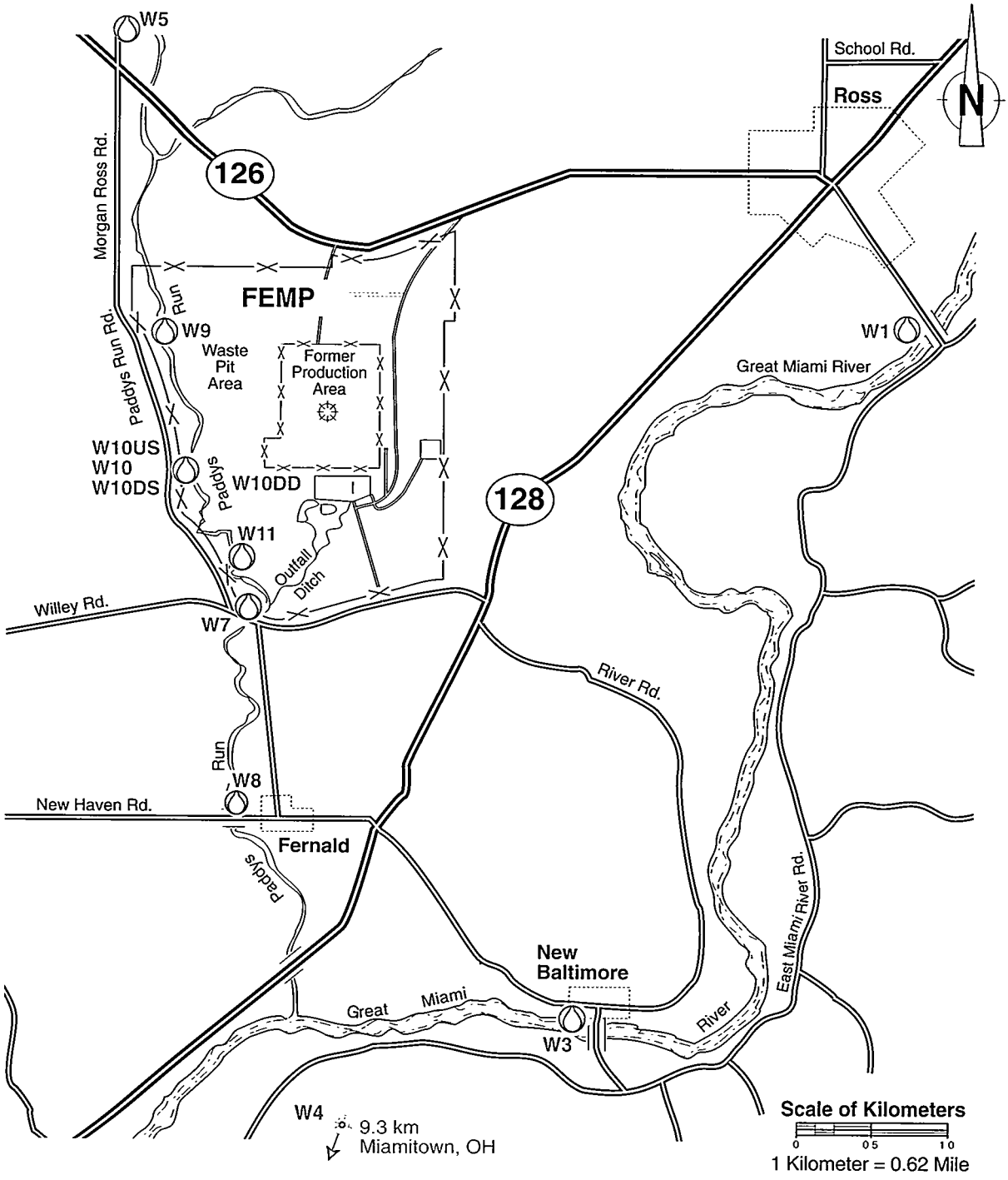
The FEMP's surface water sampling program measures the effects of two sources of contamination on local waterways: (1) discharge of liquid effluents into the Great Miami River, and (2) uncontrolled stormwater runoff into Paddys Run.

Sampling Methodologies

During 1996, surface water was sampled at the following locations (see Figure 35):

- Three locations along the Great Miami River (W1, upstream from the effluent discharge; and W3 and W4, downstream of the effluent line). Weekly grab samples were collected at these locations and analyzed for total uranium. For each location, weekly samples were combined to form monthly composites, which were then analyzed for radium-226 and radium-228. Six-month composites, taken from the individual monthly composites, were analyzed for cesium-137, strontium-90, and technetium-99.

Figure 35: Surface Water Sampling Locations



LEGEND

- Sampling Location
- Distance from Center of Former Production Area to Sampling Locations off Map
- Plant Perimeter
- Former Production Area Perimeter
- Center of FEMP at Plant 4

- Five onsite locations along Paddys Run (W9, W10-US, W10, W10-DS, and W11). Weekly grab samples were collected at these locations and analyzed for total uranium.
- One location along the drainage ditch originating near the Pilot Plant (W10-DD). Weekly grab samples were collected at this location and analyzed for total uranium.
- Three offsite locations along Paddys Run (W5, upstream from the FEMP; and W7 [or W8 if there was not enough water at W7]). Weekly grab samples were collected at these locations and analyzed for total uranium. Bi-monthly composites of the weekly samples from W5 were analyzed for isotopic radium, as were monthly composites at W7 (or W8).

Results of Laboratory Analyses

The radionuclide concentrations found in surface water samples collected during 1996 are summarized in Table 12 on page A-21.

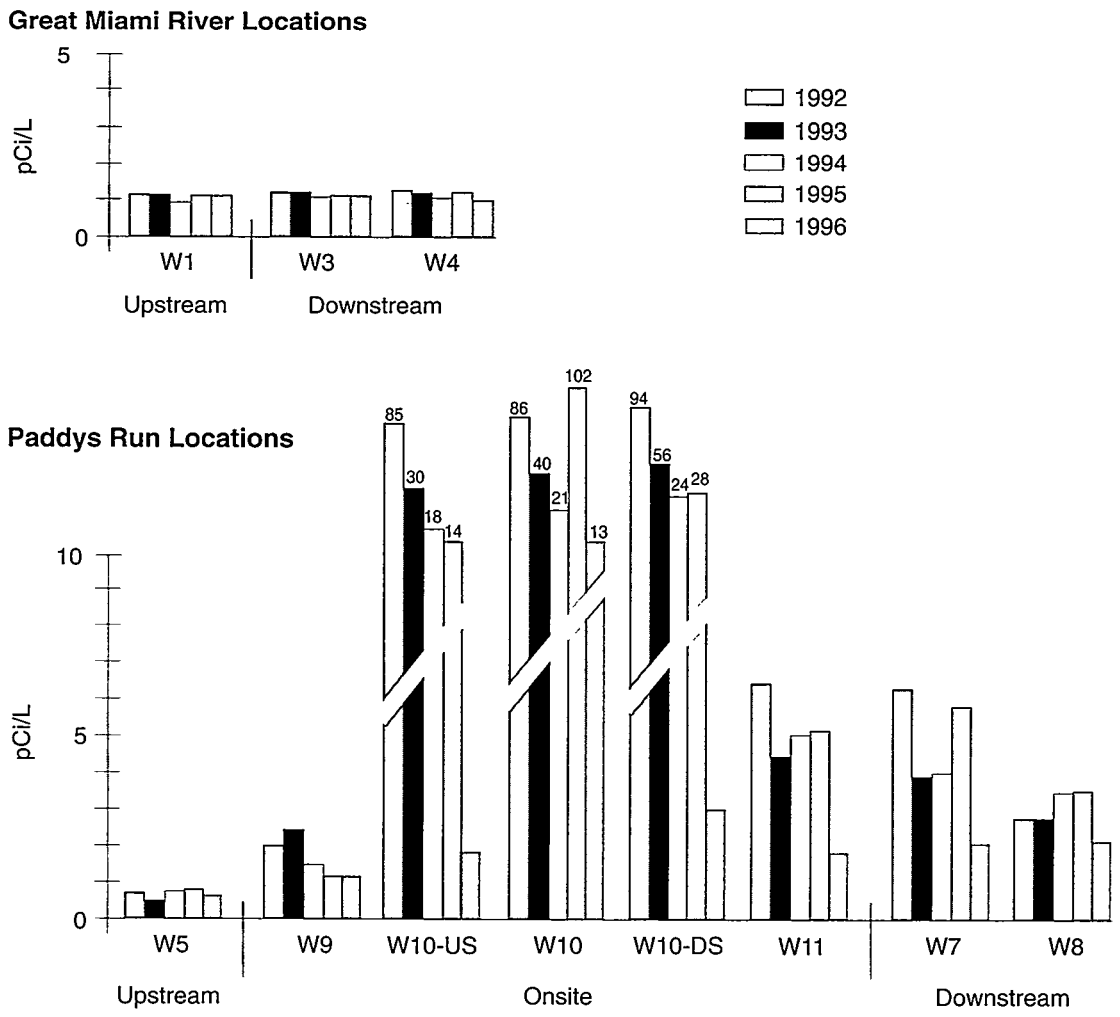
Upstream sampling point W1 is utilized to determine concentrations of uranium and radium naturally present in the Great Miami River. The data indicate that there was no statistical difference in total uranium concentrations at the three sampling locations. Average uranium concentrations were 1.1 ± 0.2 pCi/L at W1; 1.1 ± 0.3 pCi/L at W3; and 1.0 ± 0.3 pCi/L at W4 (all uncertainties are reported at the 95% confidence level). For information purposes, the concentrations are compared to the DCG for water (550 pCi/L). All three average concentrations were at 0.20% of the DCG. Figure 36 shows five-year trends of uranium concentrations in surface water from the Great Miami River and Paddys Run.

Radium-226, radium-228, strontium-90, cesium-137, and technetium-99 results from Great Miami River samples were consistent with previous years.

Monitoring personnel utilized upstream sampling point W5 to determine concentrations naturally present in Paddys Run. The total uranium concentrations downstream of the FEMP were 2.0 ± 1.4 pCi/L at W7 and 2.2 ± 1.4 pCi/L at W8. These concentrations were higher than at the background location W5 (0.7 ± 0.2 pCi/L). However, concentrations at all Paddys Run monitoring locations were well below the suggested DOE guidelines for drinking water, and were less than the proposed EPA standard of 13.5 pCi/L for drinking water (used only for comparison purposes). Additionally, radium-226 concentrations were slightly higher downstream when compared to upstream concentrations. Radium-228 concentrations were less than the minimum detectable concentration (MDC) both upstream and downstream.

Uranium concentrations at W9 and W11 were higher than background at 1.1 ± 1.5 and 1.8 ± 1.4 pCi/L, respectively. Uranium concentrations at W10 varied greatly. This is partly because uranium concentrations in surface water are not directly comparable over short periods of time (week-to-week) due to differing states of dilution, depending on precipitation and flow rates. Often, water from the Pilot

Figure 36: Average Uranium Concentrations in Surface Water, 1992 – 1996



Plant Drainage Ditch (PPDD) does not have sufficient time to completely mix with the water in Paddys Run to provide a homogeneous liquid for sampling. Three additional sampling locations (W10-US, upstream of W10 and near the K-65 silos; W10-DD, in the PPDD; and W10-DS, just downstream of W10) were also monitored for comparison purposes. Uranium concentrations at W10, W10-US, W10-DS, and W10-DD were consistent with previous years in that they were elevated above background. An evaluation of the data from W10-US, W10, and W10-DS support a lognormal distribution, and the quoted statistics are a geometric mean and geometric standard deviation. The elevated values at W10-DD, when compared to both W10 and W10-DS, showed that water from the PPDD, contributes most to the overall uranium concentrations in Paddys Run. A pump was installed in 1996 in order to reduce the amount of uranium reaching Paddys Run from the PPDD.

Sediment Sampling for Radionuclides

Contaminants present in surface water can dissociate and concentrate in the sediments of local waterways. Analysis of sediment samples provides a trending mechanism for evaluating potential cumulative effects of routine effluent discharges and stormwater runoff. Presently, no DOE guidelines or EPA standards have been mandated for radionuclides in sediment. However, the FRL for uranium in sediment has been established at 210 mg/kg (see Table 28 on page A-47).

Sampling Methodologies

During the second and third weeks of June, technicians collected sediment samples at representative locations with the most recent and greatest amount of uranium deposited. Additionally, all samples taken from the SSOD, Paddys Run above the SSOD, and Paddys Run background were analyzed for radium-226 and isotopic thorium. The following locations were sampled in 1996 (see Figure 37):

- Four locations along the SSOD (a quality assurance (QA) sample was also analyzed for this group for a total of five results at this location);
- Four locations along the Great Miami River (OEPA split sample location);
- Eight locations along Paddys Run, north of the SSOD;
- Six locations along Paddys Run, south of the SSOD (a QA sample was also analyzed for this group along with an OEPA split sample). A total of seven results were gathered from this location; and
- Two background locations along Paddys Run, north of the site (a QA sample was also analyzed for this group resulting in three results).

Results of Laboratory Analyses

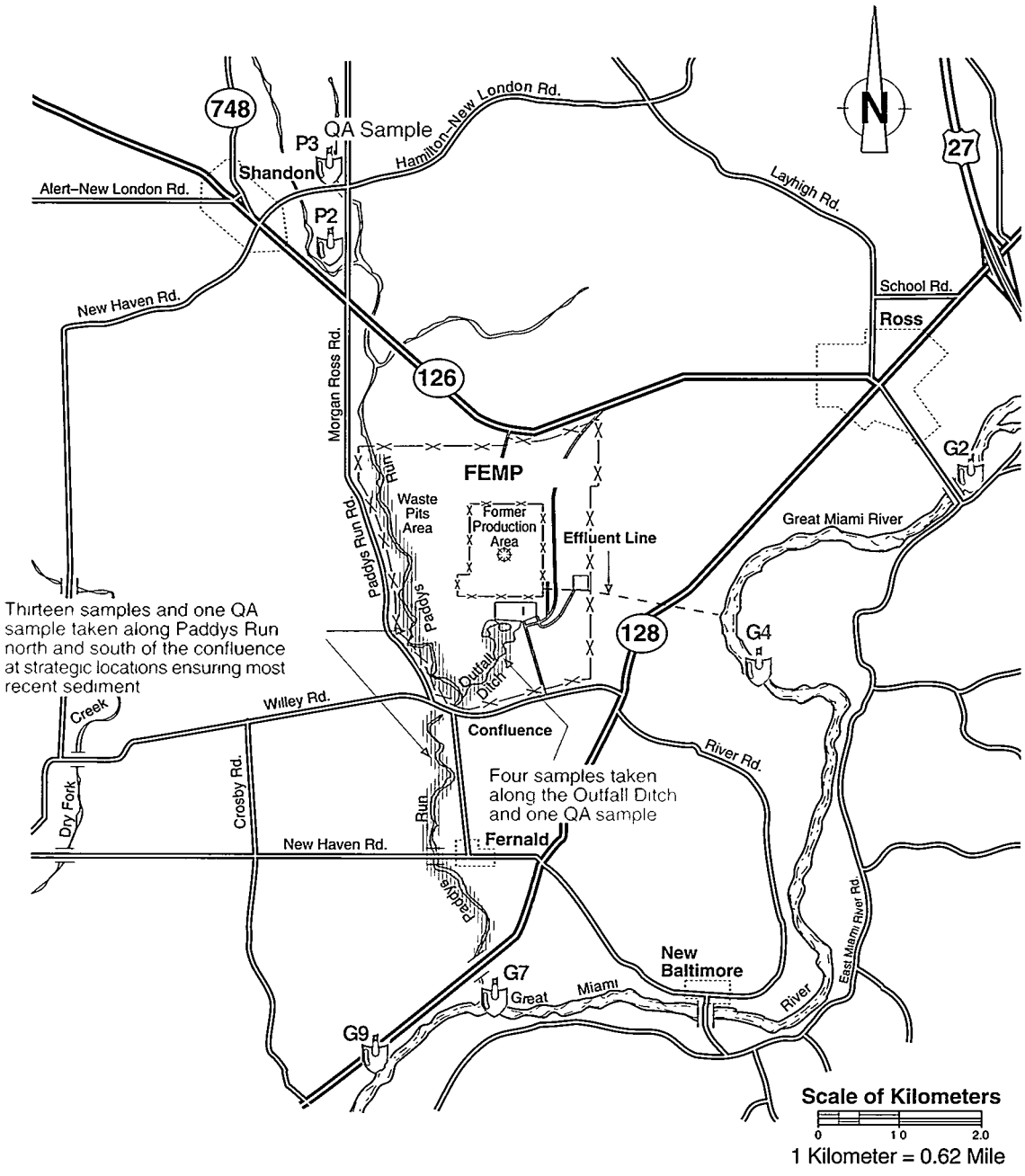
Data in Table 13 on page A-23 suggest that there were no differences in the concentration of uranium found in sediment samples collected from the Great Miami River upstream and downstream of the FEMP's effluent discharge line. FEMP liquid effluent discharges did not cause any discernible increase in uranium levels in the Great Miami River sediment.

Total uranium results for 1996 from Paddys Run locations north and south of the SSOD were above background levels (1.82 ± 0.08 pCi/g) and were 2.30 ± 0.22 and 2.30 ± 0.19 pCi/g, respectively. These levels were slightly higher than those in 1995. The average uranium concentration in the SSOD (6.89 ± 0.46 pCi/g) remains well above background levels. Uranium concentrations at individual locations along this ditch have been elevated in previous years, due to runoff from onsite stormwater flowing into the SSOD over the years. The FRL for uranium in sediment is 210 mg/kg.

Fish Sampling for Uranium

In the areas surrounding the FEMP, fish caught in the Great Miami River are the primary aquatic organisms from which the public could receive radiation exposure. Considering that fish can concentrate radionuclides in their edible tissues,

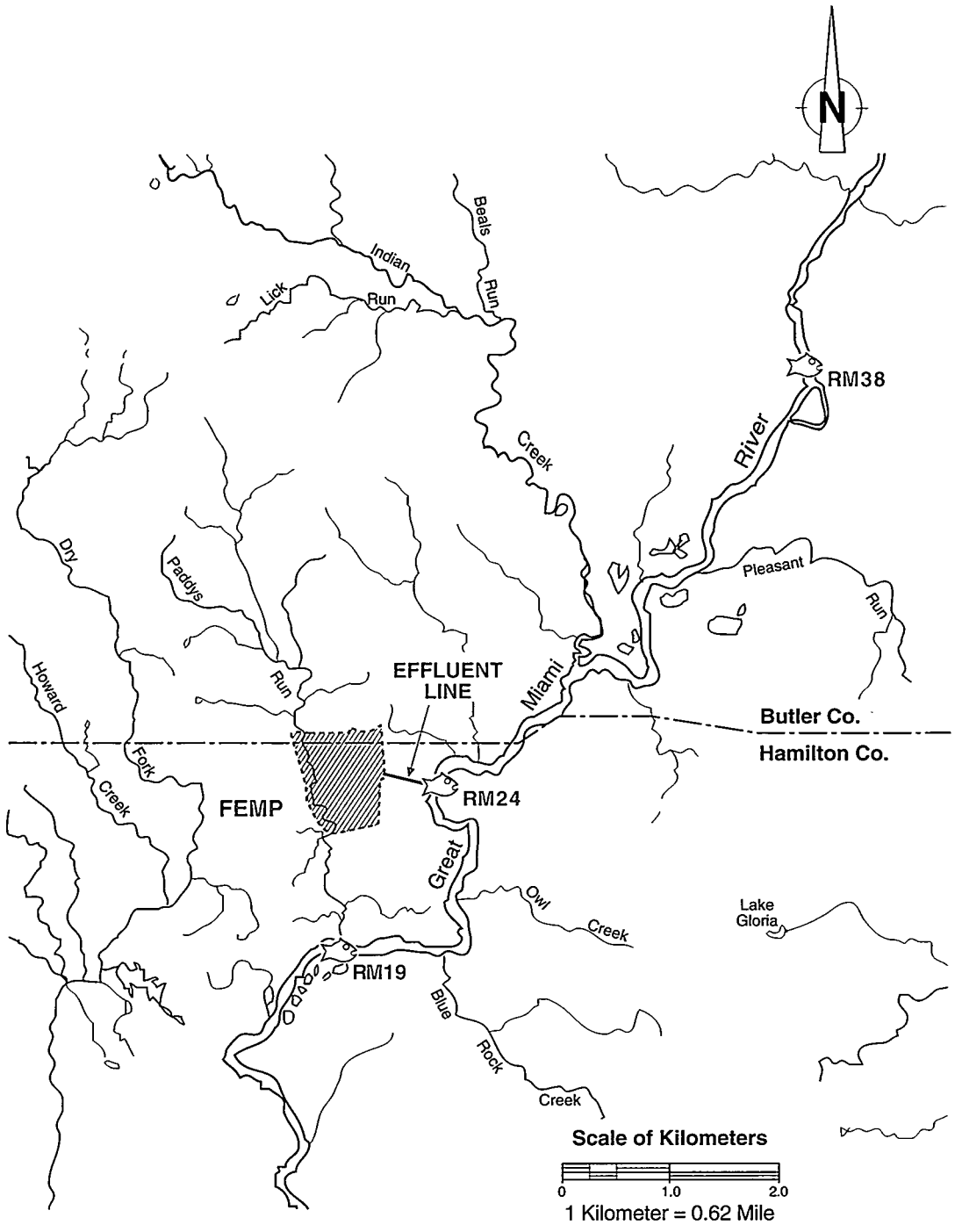
Figure 37: Sediment Sampling Locations



LEGEND

- Single Sampling Location
- Distance from Center of Former Production Area to Sampling Locations off Map
- Plant Perimeter
- Former Production Area Perimeter
- Center of FEMP at Plant 4

Figure 38: Fish Sampling Locations



LEGEND

Fernald Site

Sampling Location

FEMP personnel have been sampling the fish population of this river for over ten years. With the aid of research personnel from the University of Cincinnati, the sampling team utilizes electrofishing, an efficient method for collecting fish that is unbiased with respect to both size and species collected.

Sampling Methodologies

In 1996, a total of 310 fish were collected. A variety of eight families of fish were represented, including Clupeidae (gizzard shad), Cyprinidae (carp, bluntnose minnows, blacktail shiner, creek chub, spotail shiners, suckermouth minnow, and a carp/goldfish hybrid), Lepisosteidae (longnose gar), Catastomidae (smallmouth buffalo, white sucker, highfin carpsucker, golden redhorse, black buffalo, northern hogsucker, river redhorse, river carpsucker, and quillback carpsucker), Centrarchidae (spotted bass, white crappie, bluegill, largemouth bass, black crappie, smallmouth bass, longear sunfish, and green sunfish), Ictaluridae (channel catfish and flathead catfish), and Scianidae (freshwater drum).

The samples were collected at three River Mile (RM) sites along the Great Miami River (see Figure 38 on page 113):

- RM 38, below the Route 127 bridge, north of Hamilton,
- RM 24, at the FEMP effluent discharge line, and
- RM 19, at the outfall point of Paddys Run.

RM 38 is used as a background location due to physical separation of the fish population. Two dams in Hamilton prevent downstream activities from effecting the population, while also preventing upstream migration of fish. However, locations RM 24 and RM 19 have the potential to be influenced by plant effluents as well as backwater species that migrate up from the Ohio River.

Results of Laboratory Analyses

Total uranium analysis on 75 fish samples was performed. Table 14 on page A-25 contains the average uranium concentrations reported in fish from all three sampling locations. Overall, uranium results are consistent with or lower than results from recent years. In 1996, uranium concentrations from FEMP effluents was determined to have no effects on the distribution of fish.

The estimated dose from eating fish caught in the Great Miami River near the FEMP outfall is discussed in Chapter Seven.

Monitoring for Non-radioactive Pollutants

The FEMP monitors the discharge of non-radioactive pollutants in liquid effluent to meet the requirements of the FEMP's National Pollutant Discharge Elimination System (NPDES) permit. The NPDES permitting process for the FEMP is under the jurisdiction of the State of Ohio to control the discharge of nonradioactive

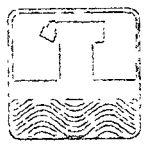
pollutants. The permit specifies sampling and monitoring locations for storm-water reaching Paddys Run, effluent sampling locations for the Great Miami River, sampling and reporting schedules, biomonitoring of combined effluent and the river downstream of our discharge point, discharge limits, and other restrictions on effluents. This permit expires March 31, 1998. A diagram of all monitoring locations is shown in Figure 35 on page 108.

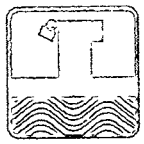
Table 10 on page A-15 contains the NPDES monitoring data for 1996. Out of 2,355 NPDES compliance opportunities for 1996, eight were judged out of compliance with the limits. Three of these non-compliances were due to the minimum daily allowed oxygen level being violated on June 23, 24, and 25 at the Parshall Flume. The remaining events occurred at the sewage treatment plant. Three were due to the maximum daily allowed concentration of BOD-5 being exceeded on June 5, 17, and 19. The maximum daily discharge of BOD-5 was also exceeded on June 24. The other event was an exceedence of the maximum concentration of fecal coliform bacteria on June 19. This represents an in compliance factor of 99.66%.

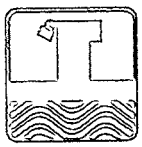
The next chapter discusses the groundwater monitoring program and potential impacts on groundwater quality due to contaminated water migration into the Great Miami Aquifer.

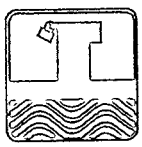
6

Liquid Pathway: Groundwater Monitoring









Liquid Pathway: Groundwater Monitoring

This chapter continues the discussion of the liquid pathway. Groundwater contamination was determined to have resulted from infiltration through the bed of Paddys Run where the glacial overburden had been eroded and the sand and gravel that comprise the aquifer were in direct contact with contaminated surface water. To a lesser degree, groundwater contamination resulted where man-made excavations, such as the waste pits, removed the glacial overburden, exposing the aquifer to contamination. The groundwater beneath and in the vicinity of the FEMP is carefully monitored to identify and track the movement of pollutants that may be present in the Great Miami Aquifer. Scientists can analyze the groundwater and soils sampled during drilling operations to learn much about the soil and its ability to restrict the movement of contaminants into the groundwater. This enables the FEMP to better define the steps it should take to control present contamination and to prevent additional contamination from occurring.

Results in Brief: 1996 Liquid Pathway: Groundwater

Private Well Sampling for Uranium – Thirty-two (32) private wells were sampled for uranium in 1996. Laboratory analyses of the samples indicated three private wells had average uranium concentrations above the proposed Primary Drinking Water (Maximum Contaminant Level [MCL]) Standard of 13.5 pCi/L (20 ppb). (See Figure 43 on Page 128). Each of these private wells is located in an area of known uranium contamination called the South Groundwater Contamination Plume (South Plume).

RCRA Groundwater Monitoring Program – Thirty-three (33) monitoring wells were sampled quarterly for RCRA constituents in 1996. Ten (10) constituents from this program had concentrations above the corresponding Final Remediation Levels (FRLs) (See Table 16 on Page A-27). Please see page 120 for a discussion on FRLs.

South Plume Removal Action Monitoring Program – Fifty-eight (58) monitoring wells in the South Plume were sampled quarterly in 1996. Sixteen (16) monitoring wells exhibited concentrations of total uranium above 20 ug/L (20 ppb) (See Table 17 on Page A-32).

One Monitoring Well, 2636, indicated a maximum arsenic concentration of 0.08 mg/L which is above the Primary Drinking Water Standard of 0.05 mg/L (See Table 18 on Page A-34). This monitoring well is south of the recovery system and outside the induced capture zone. The arsenic in this well, however, is believed to be from other industrial activities in the area and not the FEMP.

KC-2 Warehouse Well Monitoring Program – Monitoring was performed semi-annually at this monitoring well during 1996. None of the two sample rounds indicated concentrations of uranium at or above its proposed Primary Drinking Water Standard or total metals at or above the Primary Drinking Water Standard for each metal.

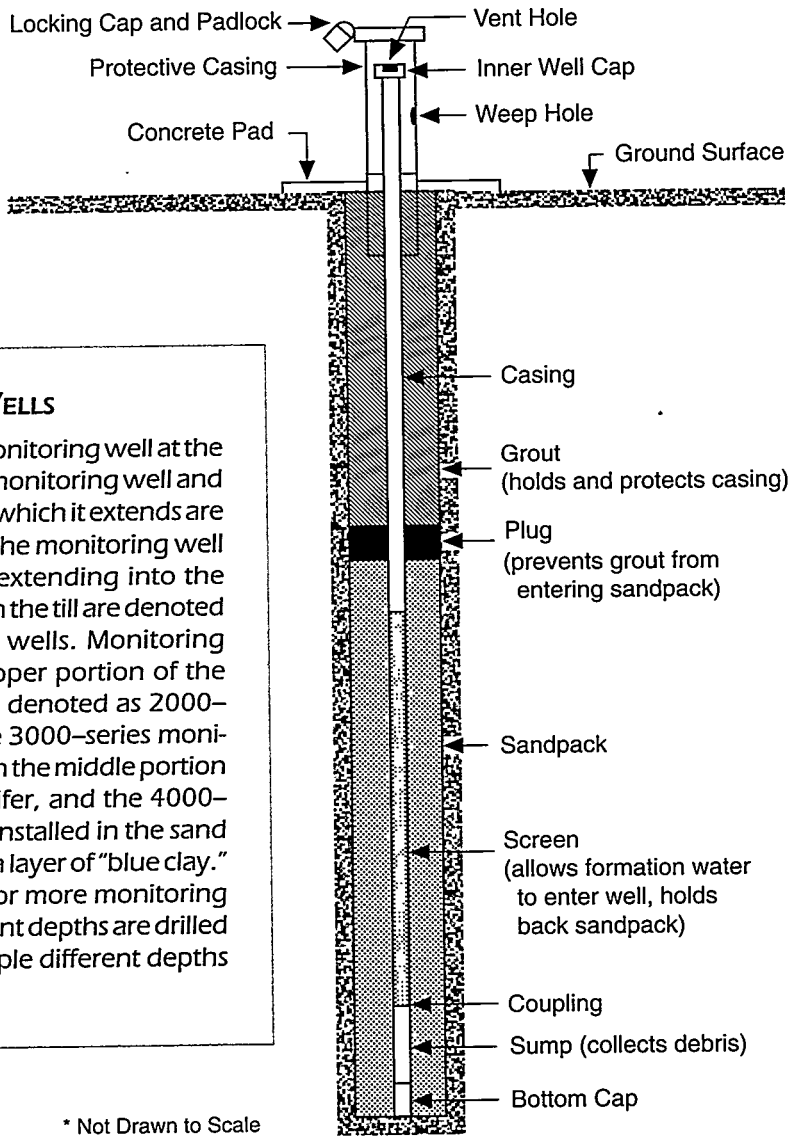
Coal Pile Runoff Basin Monitoring Program – Two monitoring wells were monitored on a quarterly basis for total uranium and non-radioactive parameters in 1996. Sulfate and total dissolved solids were detected above the Secondary Drinking Water Standard (Secondary Maximum Contaminant Level [SMCL]) for both wells.

History of Groundwater Monitoring at the FEMP

Several groundwater monitoring programs have evolved throughout the history of the FEMP. The original three production wells drilled during the construction of the FMPC in 1951 were the first to be monitored. From 1959 to 1965, the FMPC installed 11 monitoring wells in the waste pits area to see if pit operations were affecting the groundwater. These waste pits and production area wells constituted the original ***Environmental Monitoring Groundwater Program.***

Figure 39: Well Diagram*

This diagram depicts the construction of a typical well used for sampling groundwater. These wells are located both on and off the FEMP. They range from 11 – 76 meters (35 – 250 feet) deep.



FEMP Groundwater Wells

Figure 39 depicts a typical monitoring well at the FEMP. The depth of a FEMP monitoring well and the water-bearing zone into which it extends are denoted by the first digit of the monitoring well number. Monitoring wells extending into the perched groundwater within the till are denoted as 1000–series monitoring wells. Monitoring wells extending into the upper portion of the sand and gravel aquifer are denoted as 2000–series monitoring wells. The 3000–series monitoring wells are placed within the middle portion of the sand and gravel aquifer, and the 4000–series monitoring wells are installed in the sand and gravel aquifer beneath a layer of "blue clay." Sometimes a group of two or more monitoring wells (cluster wells) of different depths are drilled at the same location to sample different depths within the aquifer.

* Not Drawn to Scale

In late 1981, the State of Ohio sampled three wells south of the FEMP and found elevated levels of beta activity. This activity was due to potassium-40, a naturally occurring radionuclide which was not present in site production materials. However, sampling also detected above-background concentrations of uranium in other wells near the FEMP. This information was reported to the State in November, 1981.

These findings prompted an expansion of groundwater monitoring in the area. Environmental Monitoring began sampling existing area wells in February 1982, and by 1984, the FEMP officially established the ***Radiological Environmental Monitoring (Private Well) Program*** with the monthly sampling of 32 privately-owned wells.

In August 1985, the FEMP initiated a Resource Conservation and Recovery Act (RCRA) detection groundwater monitoring program around Waste Pit 4 in response to requirements of federal and state hazardous waste regulations. From 1980 to 1983, hazardous waste, as defined under RCRA regulations, had been placed in Waste Pit 4. The detection monitoring program was initiated to determine if hazardous waste was escaping from Waste Pit 4 and entering the groundwater. The program confirmed that the groundwater had been impacted and, as a result, the program was shifted to a RCRA Assessment Monitoring Program in May, 1988. The objective of the RCRA Assessment Monitoring Program is to determine the rate of migration and extent of any hazardous waste contamination in the groundwater.

Final Remediation Levels (FRLs)

The Operable Unit 5 Record of Decision (ROD), signed by EPA in January 1996, established FRLs for FEMP-related contaminants in environmental media (i.e., soil, surface water, sediment, and groundwater). These FRLs are legally binding cleanup levels that will be used to track and certify the completion of the FEMP's remediation process. FRLs were specifically developed for the Great Miami Aquifer for those constituents that are presently in the Great Miami Aquifer and those that have the potential to reach the aquifer within 1,000 years at levels that pose an unacceptable risk to human health and/or the environment.

FRLs were generally developed by the following process. First, a risk assessment was performed to determine constituent-specific concentrations of FEMP-related contamination that may pose an unacceptable risk to human health or the environment (risk-based concentrations). This assessment was completed using Remedial Investigation findings on FEMP- related contamination and conservative, EPA-approved methods.

After risk-based concentrations were determined for each constituent, they were compared to:

- regulatory-based standards (e.g., primary drinking water standards);
- the lowest reasonable and achievable laboratory detection level; and
- background concentrations.

From this comparison, the highest concentration of a particular constituent that complies with regulatory-based standards was selected as the FRL.

The above description of the cleanup level determination process for environmental media at the FEMP is a generalization. Detailed discussion of this process is provided in Section 2 of the Operable Unit 5 Feasibility Study Report (DOE, 1995). Please refer to Table 28 on page A-47 for a listing of all FRLs.

The RCRA Groundwater Program at the FEMP was modified in 1991 when the RCRA Part A Permit Application identified 51 Hazardous Waste Management Units (HWMUs), including nine land-based HWMUs requiring groundwater monitoring. Before June 1991, Waste Pit 4 was the only identified regulated unit requiring groundwater monitoring. The RCRA Groundwater Monitoring Plan was submitted to the EPA in December 1991, replacing the RCRA Assessment Monitoring Program. The Groundwater Monitoring Plan was designed to monitor groundwater downgradient of the nine land-based units. The FEMP defined three monitoring well networks to provide adequate monitoring of the waste pits area, the former production area, and the FEMP property boundary.

By mid-1993, the property boundary network was near completion and well installation on the Production Area network was proceeding. At that time, it was determined that it would be impractical to meet RCRA requirements under the current monitoring program. Specifically, difficulties were encountered while trying to comply with RCRA requirements, causing a duplication of efforts in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and RCRA activities at the FEMP.

In an effort to integrate CERCLA and RCRA monitoring activities under a single program, FEMP personnel proposed an alternate monitoring program. This program is comprised of two components:

1. Groundwater characterization activities under CERCLA (results are provided in Operable Unit 5 RI/FS documents); and
2. Quarterly groundwater monitoring downgradient of the property boundary (RCRA Groundwater Monitoring Program).

In September 1993, this program was accepted by the State of Ohio. The current RCRA Groundwater Program monitors wells located along the downgradient boundary of the FEMP for a select list of contaminants to document the quality of groundwater potentially leaving the property boundaries of the FEMP. These monitoring wells are shown in Figure 45 on page 132.

In May 1988, additional groundwater sampling was initiated as part of the Remedial Investigation and Feasibility (RI/FS). This CERCLA-driven study investigated the nature and extent of potential environmental impacts from past and current operations at the FEMP, with particular regard to the Great Miami Aquifer. By late 1989, more than 200 wells were being sampled under the various programs. Through this effort, an extensive number of wells were sampled to characterize the groundwater.

As a result of evaluating the data collected for the RI/FS process, the nature and extent of groundwater contamination was determined. The following discussion provides information pertaining to the remedy for the cleanup strategy of the Great Miami Aquifer.

FEMP Groundwater Remedy

The areas of the Great Miami Aquifer requiring remediation are shown in Figure 40. These areas were identified in the Operable Unit 5 Feasibility Study and Record of Decision. The groundwater in these areas will be remediated by pumping and treatment.

After the areas requiring remediation were identified, groundwater modeling was used to determine the best locations for pumping wells. This effort identified 28 extraction well locations within the contaminated areas of the aquifer. These 28 extraction well locations, shown in Figure 41 (on page 124), are divided into four pumping systems located both onsite and in the South Plume area. The modeling suggests that a combined maximum pumping rate of 4,000 gallons per minute from the four pumping systems will be required for up to 27 years to remediate the aquifer. Further efforts are being made to reduce the number of years to remediate the aquifer by considering enhancement technologies such as groundwater reinjection and by adding additional pumping locations.

The selected remedy consists of the following key components for regional groundwater:

- Extraction of contaminated groundwater until such time as FRLs are attained at all points in the impacted areas of the Great Miami Aquifer;
- Performance of an engineering study designed to examine the viability of applying reinjection techniques to enhance contaminant recovery from the aquifer system; application of reinjection to groundwater restoration activities where established to be economically and technically viable; and
- Collection of recovered groundwater for treatment and/or discharge to the Great Miami River or reinjection (if deemed appropriate).

Routine Groundwater Monitoring Activities for 1996

As part of the total liquid pathway, the movement of radioactive pollutants into and through the groundwater is of significant concern. This section discusses the results of five programs designed to monitor and assess the groundwater within the vicinity of the FEMP. Each of these five programs conducts sampling activities on a routine basis:

- Radiological Environmental Monitoring (Private Well) Program;
- RCRA Groundwater Monitoring Program;
- South Plume Removal Action Monitoring Program;
- KC-2 Warehouse Well Monitoring Program; and
- Coal Pile Runoff Basin Monitoring Program.

The following sections provide a summary of each program including a brief history and a summary of monitoring activities and results for both radiological and non-radiological sampling efforts.

Figure 40: Areas of the Great Miami Aquifer Requiring Remediation

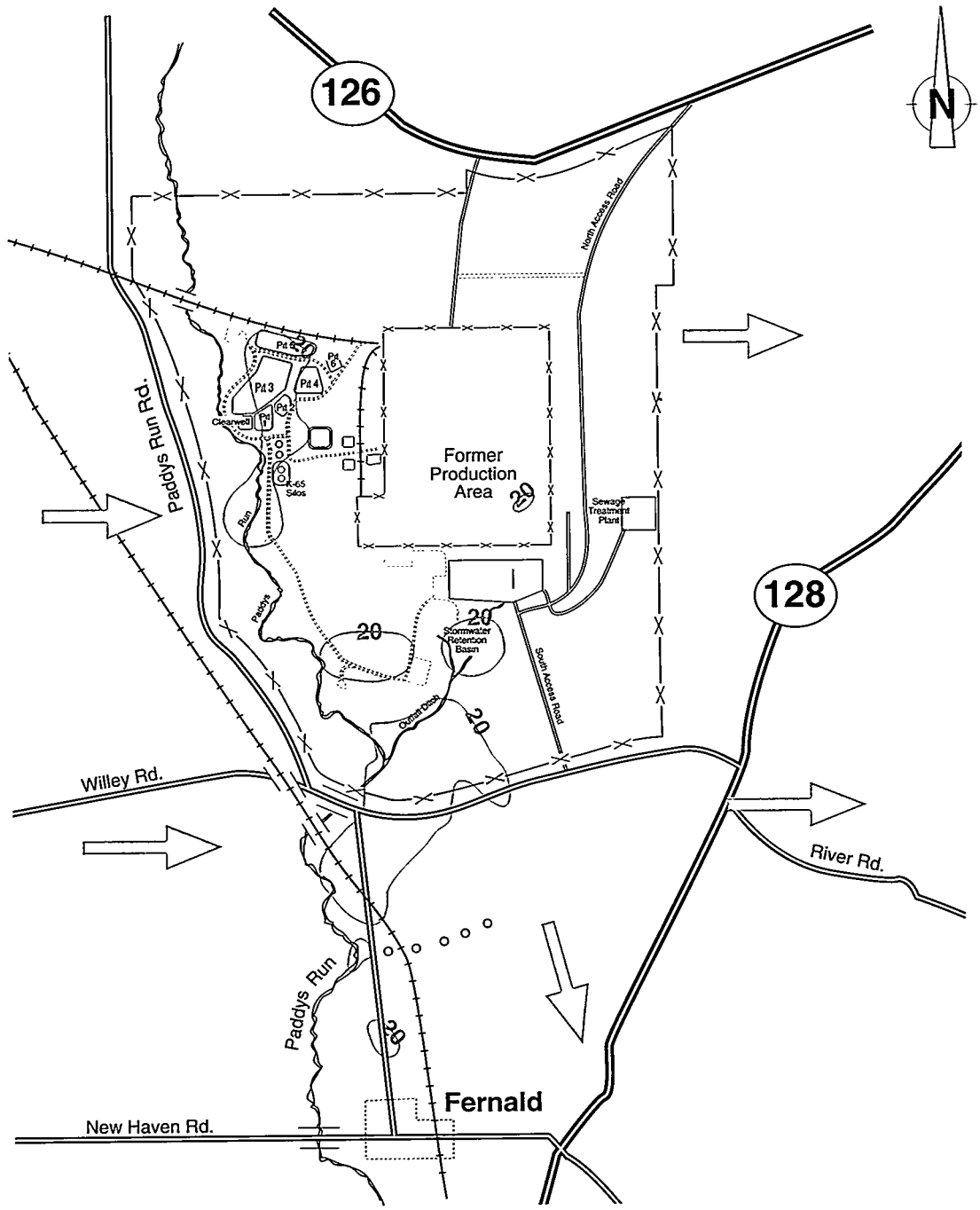
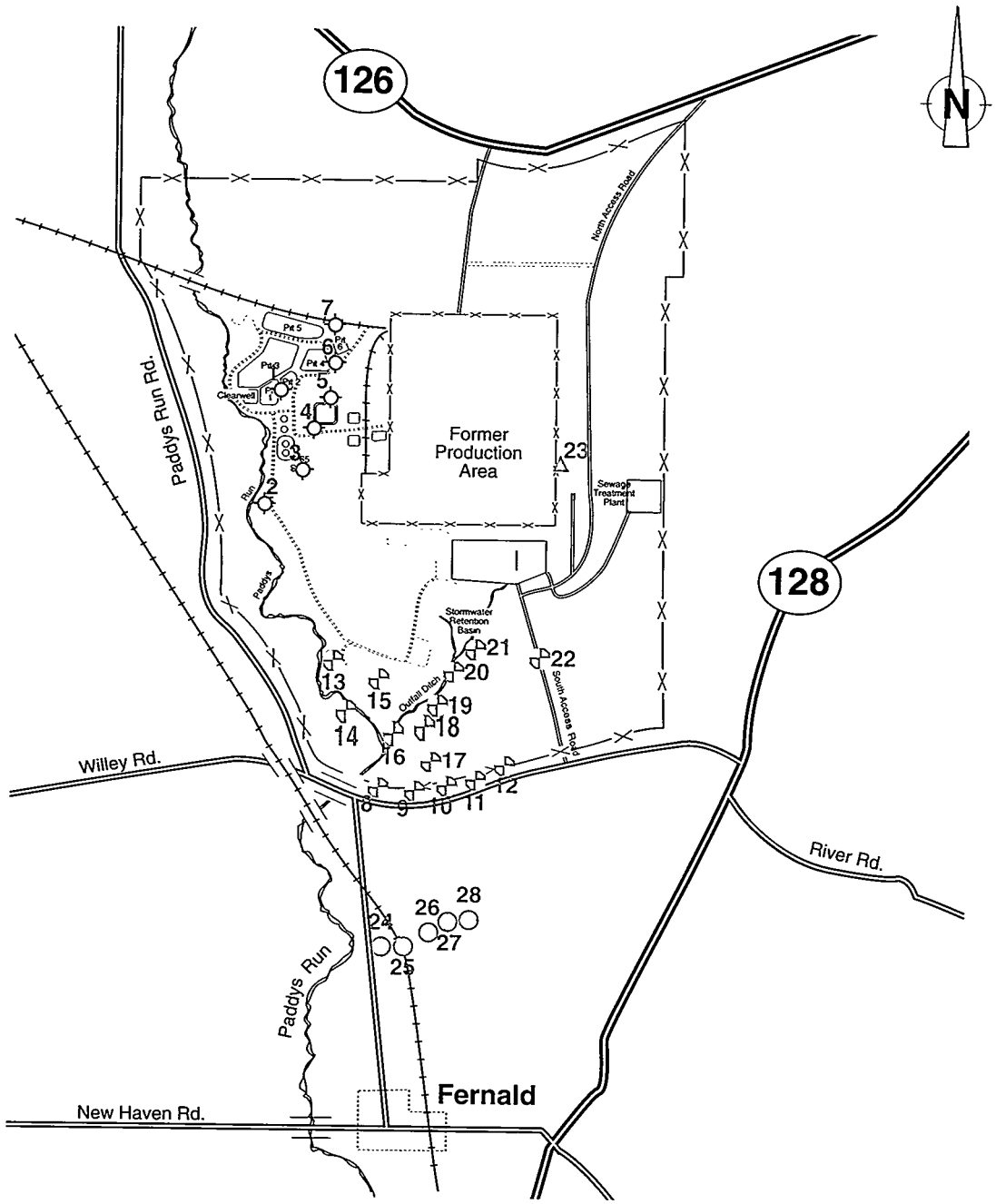


Figure 41: Remediation Well Locations



LEGEND

- System 1 Pumping Well
- System 2 Pumping Well
- System 3 Pumping well
- System 4 Existing Pumping Well
- Plant Perimeter
- Former Production Area Perimeter

Radiological Environmental Monitoring (Private Well) Program

The longest running groundwater monitoring effort (which is ongoing) is the ***Radiological Environmental Monitoring (Private Well) Program***. The program was initiated in 1982 in response to monitoring results indicating above background concentrations of uranium in private wells near the FEMP. By 1984, the FEMP had officially established the program with the monthly sampling of 19 privately-owned wells.

Under the current program, 32 private wells are routinely sampled. At a property owner's request, any drinking water well near the FEMP is sampled for uranium, and the one-time results are reported to the well owner. If any "special request" sample shows a questionable or significant total uranium concentration, or if the private well is determined to provide critical groundwater information in an area, the property owner has the option to participate in the routine sampling program. Private wells are sampled monthly or quarterly depending upon the location, and sampling results are reported annually in the Site Environmental Report.

During 1996, three private wells exceeded the proposed Primary Drinking Water Standard of 20 ug/L (13.5 pCi/L) for uranium with average concentrations of 70.1 ug/L (47.4 pCi/L), 90.2 ug/L (60.9 pCi/L), and 153.2 ug/L (103.5 pCi/L) as referenced in Table 15 on Page A-26. These three private wells are located south of the facility in an area of uranium contaminated groundwater referred to as the South Plume (See Figure 42 on page 127). The groundwater in this area is being remediated as part of the South Groundwater Contamination Plume Removal Action.

Proposed EPA Primary Standard for Uranium in Drinking Water

In addition to comparing results against background levels for substances in the environment, environmental monitoring results are often compared to standards or guidelines. These standards set concentration limits for specific substances in a medium. Standards and guidelines are always set lower than the lowest concentration known to cause illness or injury to humans or the environment.

EPA is responsible for setting standards for substances in drinking water throughout the United States; National Primary Drinking Water Standards are enforceable by federal law. However, in the absence of a EPA standard for a particular substance, guidelines are set by other agencies such as DOE and the Nuclear Regulatory Commission (NRC); these guidelines, however, are only applicable to DOE- or NRC-governed sites.

Through 1990, the only reference for uranium in drinking water was a DOE guideline of 20 pCi/L (30 ppb). Past FEMP reports have used this reference for comparison. However, in 1991, EPA proposed a standard for uranium in drinking water of 13.5 pCi/L or 20 ppb. As of April 1997, this standard had not yet been approved. This 1996 report will continue to use this proposed EPA standard for comparison with well monitoring results, as it is the more stringent of the two. It is important to note that the FRL for uranium is the same as the proposed Drinking Water Standard.

While no measurable increase in health effects can be expected by drinking water with slightly higher than typical background concentrations of uranium, decreasing the amount of uranium ingested may provide valuable peace of mind to concerned homeowners. These concerns are decreasing with the implementation of the public water supply in June 1996. Approximately 140 properties have been connected to the system through contracts administered by the Hamilton County Department of Public Works. All connections meet requirements of OEPA, Hamilton County General Health District and the Cincinnati Water Works.

As a result of the availability of the public water supply, the use of well water in the Fernald area has diminished, thereby limiting the potential for uranium exposure. Of the 33 private wells sampled as part of the private well program, only six are not currently serviced by the public water supply. These six remaining wells are located upgradient of the FEMP and therefore are not impacted by FEMP contamination. Most of the residences that are serviced by the public water supply were required to have their wells properly plugged and abandoned so the wells are no longer available for sampling. As a result of these changes, the private well sampling program for 1997 will include three wells which will be monitored along with numerous FEMP wells to continually assess the performance of the groundwater restoration.

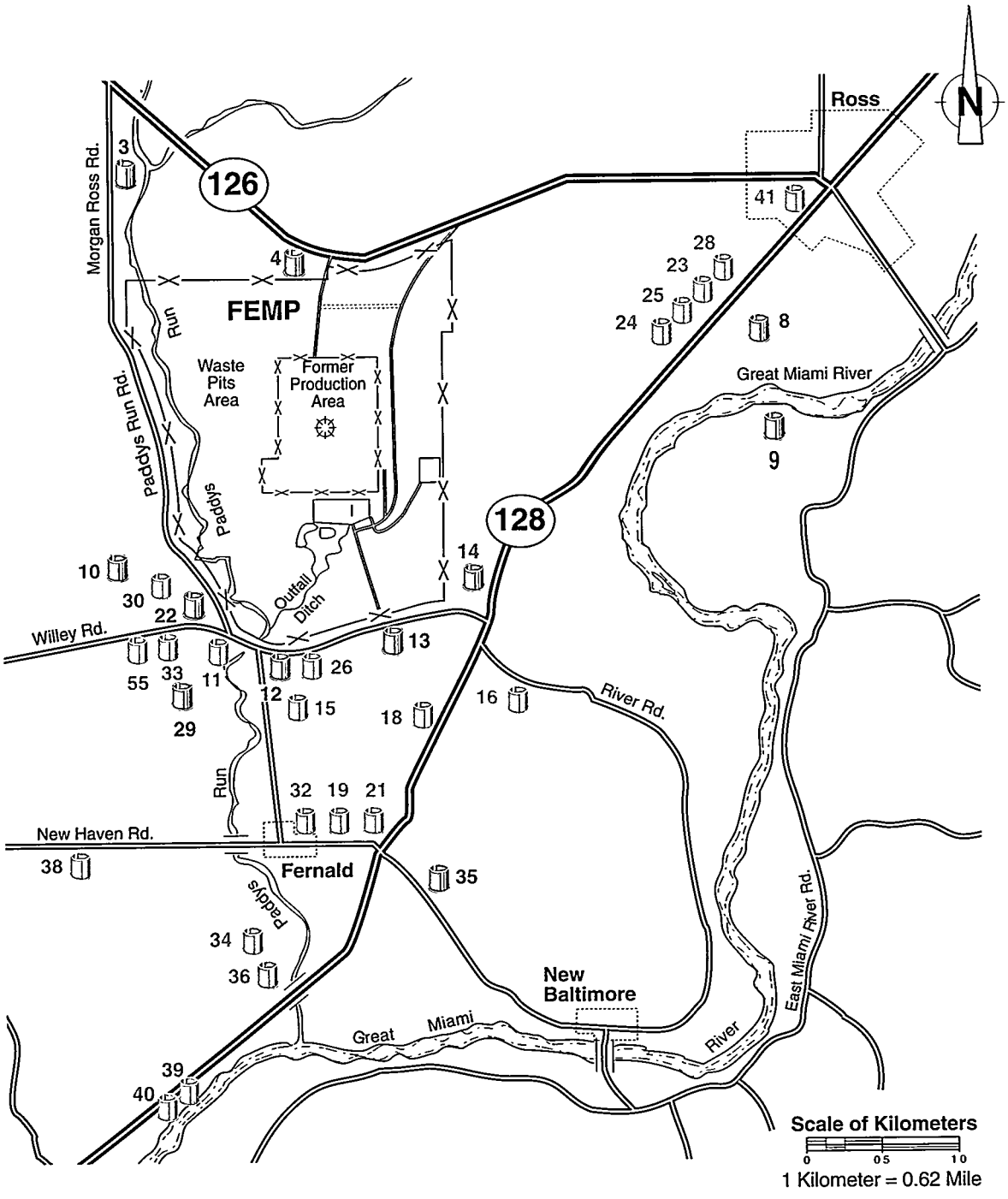
RCRA Groundwater Monitoring Program

The focus of the current RCRA Groundwater Monitoring program is to detect and assess potential changes in groundwater conditions at the FEMP property boundary before they impact offsite locations. This is accomplished through quarterly sampling of 33 monitoring wells (see Figure 45 on page 132) located along the downgradient property boundary for approximately 90 site-specific radiological and nonradiological constituents.

As identified in the discussion of the history of this program, the RCRA Groundwater Monitoring Program was initiated around Waste Pit 4 in 1985 in compliance with federal and state hazardous waste regulations to determine if the hazardous waste unit was impacting groundwater. By 1988, monitoring results from the program indicated that Waste Pit 4 was impacting the groundwater.

In 1991, additional units at the FEMP were identified as requiring groundwater monitoring under RCRA regulations. It was necessary to develop a monitoring strategy to integrate CERCLA and RCRA monitoring activities in order to eliminate redundancies. For this reason, the FEMP proposed an alternate monitoring approach which was accepted by the OEPA in September, 1993. The alternate monitoring approach consists of groundwater contaminant characterization under CERCLA and groundwater monitoring at the downgradient facility boundary under RCRA to detect and assess potential changes in groundwater conditions at the FEMP property boundary.

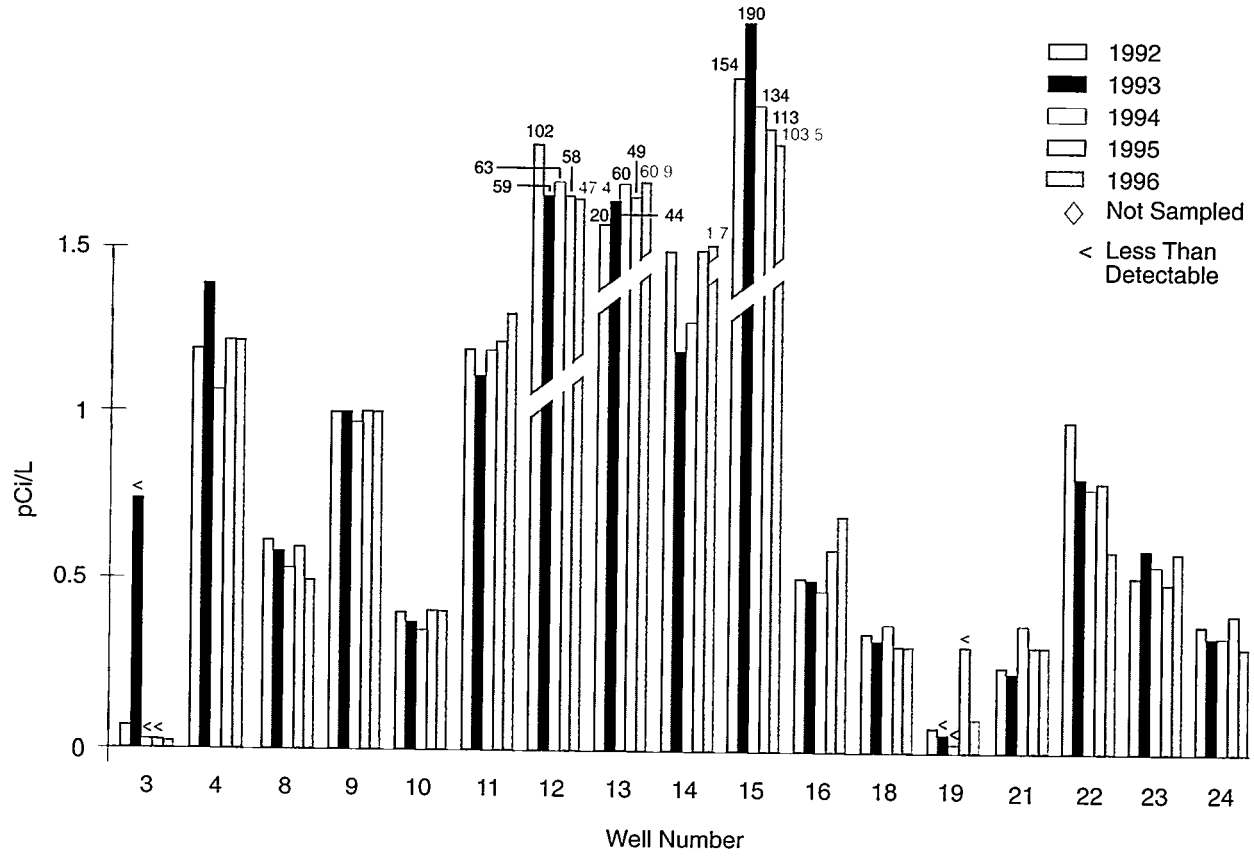
Figure 42: Private Well Monitoring Locations

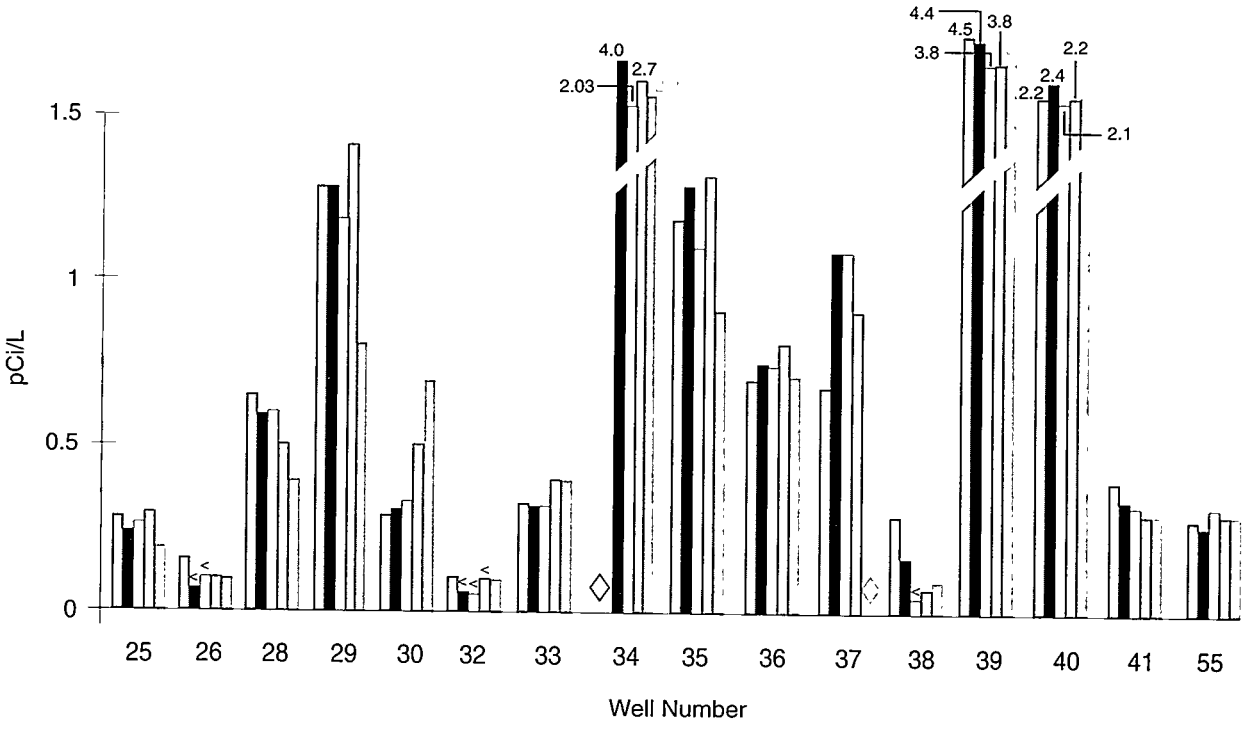


LEGEND

- Current Sampling Locations
- Locations sampled in 1996 - phased out due to public water supply
- Plant Perimeter
- Former Production Area Perimeter

Figure 43: Average Uranium Concentrations in Private Wells, 1992 – 1996





In the past, the data from the RCRA program were compared against Primary and Secondary Drinking Water Standards, to assess potential impacts. However, beginning in 1995, data were compared against proposed FRLs to reflect the transition from characterization to remediation.

The 1996 results from the RCRA monitoring program confirm that other than the contamination comprising the South Plume (currently addressed under Removal Action 3), there are no concentrations of contaminants that trigger the need for action ahead of the final groundwater remedy. This is consistent with the results for the previous program years (1994 and 1995).

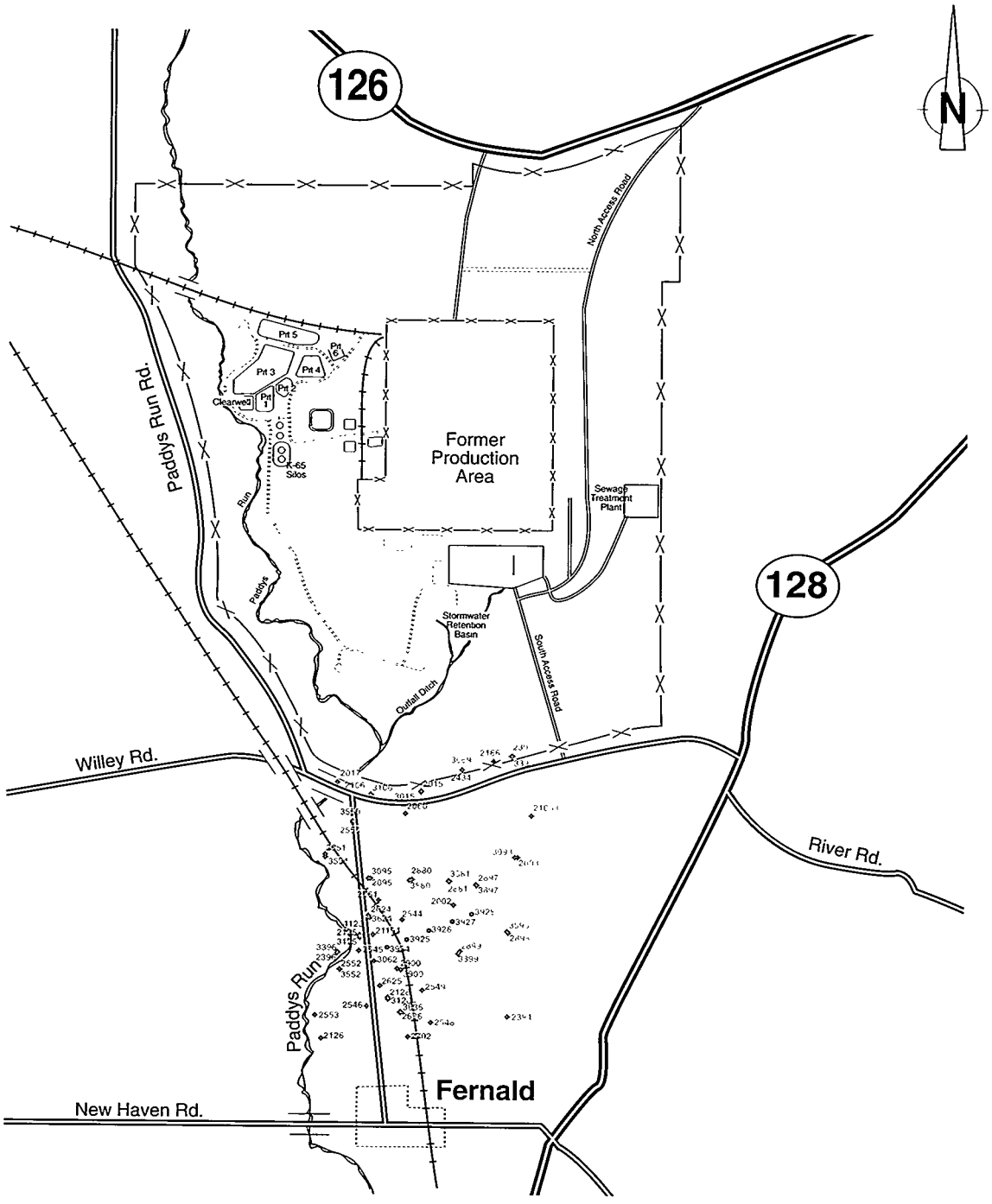
Although no new interim actions are warranted, the 1996 routine monitoring program results showed that ten constituents have concentrations that occasionally exceed their corresponding FRL (See Table 16 on page A-27). Five constituents indicate potential upward trends in concentration data, based upon trend analysis. These are: arsenic in Monitoring Well 2426; chromium at Monitoring Well 2398; manganese in Monitoring Wells 2424, 2426, 2430, and 3431; nickel in Monitoring Well 2398; and total uranium in Monitoring Well 3069. The uranium concentration in Monitoring Well 3069 (located within the current capture zone of the South Plume recovery wells) is being evaluated as part of the South Plume Removal Action Monitoring Program. Arsenic, chromium, manganese, nickel, and total uranium data from the routine monitoring program sampling events will be considered in the remedial design of the groundwater remedy, as necessary. All five of these constituents will be monitored as recommended in the Integrated Environmental Monitoring Plan (IEMP). The IEMP is discussed later in this section.

South Plume Removal Action Monitoring Program

In order to prevent the further migration of contamination to the south with regional groundwater flow, Removal Action 3 was initiated in August 1993, by installing five extraction wells in the South Plume area. These extraction wells pump contaminated groundwater from the South Plume area back to the FEMP where it is monitored, discharged, or treated and then discharged to the Great Miami River through the FEMP outfall discharge line. Figure 40 on page 123 shows the extent of the uranium contamination within the groundwater in the vicinity of the FEMP. The shaded areas in the figure represent those areas where the uranium contamination in the groundwater exceeds the proposed Primary Drinking Water Standard of 20 ug/L (20 ppb). The FRL for uranium in groundwater is also set at 20 ug/L.

In order to monitor the performance of the extraction wells, 58 monitoring wells in the South Plume area are sampled quarterly to determine the effectiveness of the removal action (See Figure 44 on the next page). The monitoring results are reported semi-annually in the South Plume Removal Action Design Monitoring Evaluation Program Plan (DMEPP) Report. This report is submitted to EPA.

Figure 44: South Plume Removal Action Monitoring and Pumping Wells



LEGEND

- South Plume Removal Action Monitoring Well
- South Plume Removal Action Pumping well
- Plant Perimeter
- Former Production Area Perimeter

In January 1995, Extraction Well 5 on the east end of the pumping system was permanently shut down because monitoring data and groundwater modeling showed that this extraction well is no longer needed to remove contaminants from the aquifer. Since this time, the extraction system has operated with four extraction wells pumping at a combined rate of 1,400 gallons per minute (gpm). As of December 31, 1996, the extraction system has pumped over 2.1 billion gallons of uranium contaminated groundwater resulting in the removal of over 136 kg (300 lbs) of uranium from the aquifer in the South Plume area. Monitoring results show that by the second half of 1996, the maximum uranium concentrations in the South Plume area has decreased from a high of 380 ug/L (380 ppb, 257 pCi/L) before pumping began to 158 ug/L (158 ppb, 107 pCi/L).

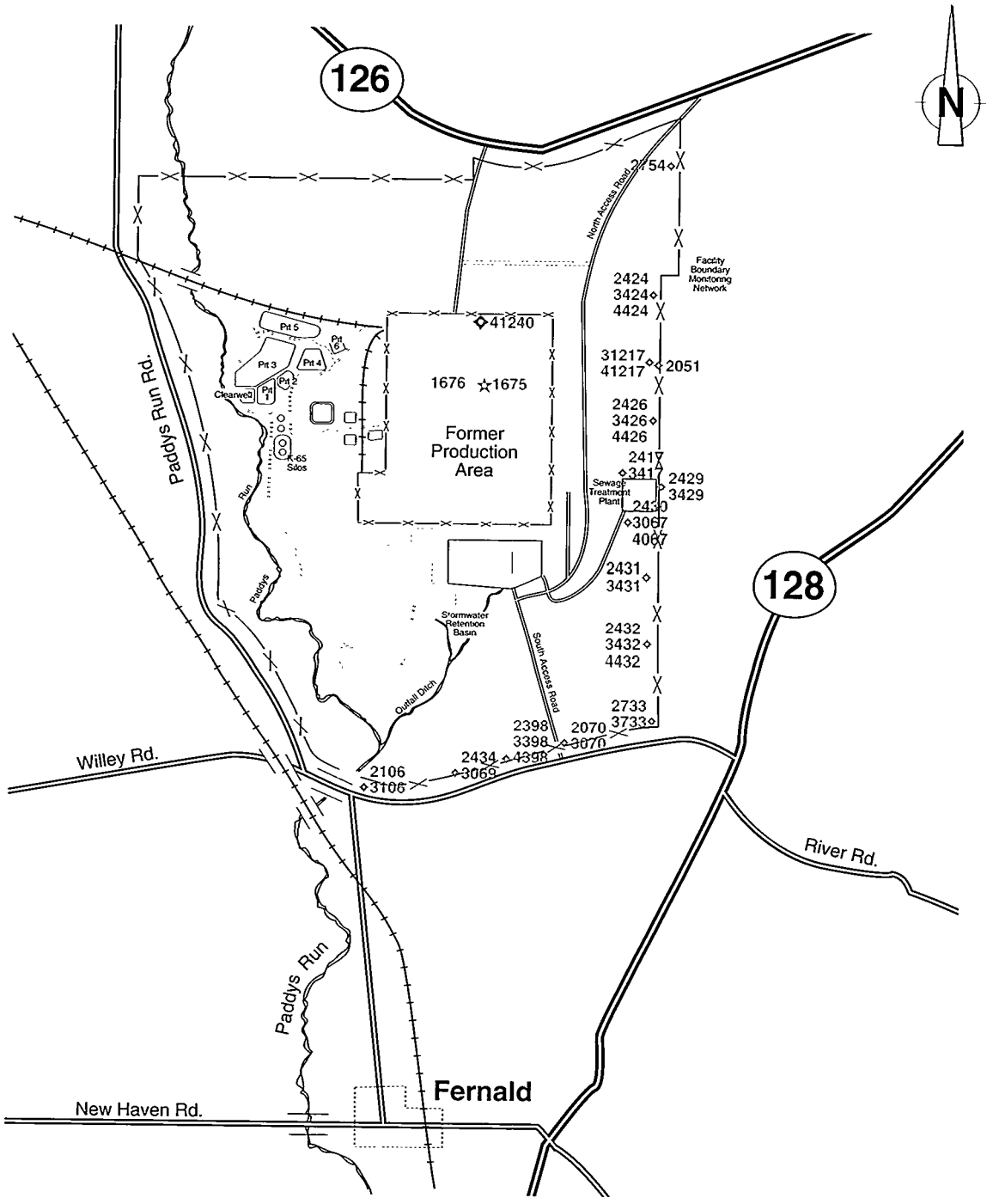
Monitoring from 1996 showed that 16 monitoring wells exhibited uranium concentrations above the 20 ug/L (20 ppb, 13.5 pCi/L) proposed Primary Drinking Water Standard for uranium. The highest concentration was 158 ug/L (158 ppb, 107 pCi/L) (see Table 17 on Page A-32) which occurred at Monitoring Well 2095. This well is within the South Plume area where contamination is being removed by the pumping system. Of the remaining 15 monitoring wells with uranium concentrations above 20 ug/L (20 ppb), 13 are within the area where contamination is being removed by the pumping system. Of these 16 monitoring wells, all but two are within the capture zone of the recovery system. One of these two wells, Monitoring Well 2552, exhibited a maximum total uranium concentration of 24.5 ug/L during 1996. The second monitoring well outside the capture zone, Monitoring Well 2546, exhibited a total uranium concentration of 0.8 ug/L during the third quarter of 1996 and 35 ug/L during the fourth quarter of 1996. The second sample with a concentration of 35 ug/L is not considered to be representative due to excess turbidity in the sample collected.

Monitoring for non-radioactive constituents showed elevated levels of arsenic above the Primary Drinking Water Standard of 0.05 mg/L (50 ppb) in one South Plume monitoring well. The highest concentration, 0.08 mg/L (100 ppb) (see Table 18 on Page A-34), occurred in Monitoring Well 2636, which is south of the South Plume recovery system. This contamination is believed to be from other industrial activities in the area and not the FEMP.

KC-2 Warehouse Well Monitoring Program

The KC-2 Warehouse Monitoring Program was initiated in July 1993. This program consists of monitoring one well, 41240, located in the warehouse (Figure 45). This monitoring was initiated in order to determine the impacts that contaminated sediment in the well was having on the groundwater. Based on the observed consistency in contaminant concentrations in Monitoring Well 41240, DOE has received permission from EPA and OEPA to reduce the sampling frequency from semi-annual sampling to an annual sample which will be collected in August of each year until the well is decommissioned.

Figure 45: RCRA, KC-2 Warehouse and Coal Pile Runoff Monitoring Locations



LEGEND

- ◇ RCRA Monitoring Well
- ◈ KC-2 Warehouse Well
- ☆ Coal Pile Runoff Basin Well
- Plant Perimeter
- Former Production Area Perimeter

The results from both sampling rounds (January 31 and August 15, 1996) are consistent with previously collected samples. It should be noted however, that the samples collected on January 31 were validated as ASL B rather than the customary ASL C due to the fact that no laboratory QC sample was collected. There were no confirmed exceedances of any Primary Drinking Water Standard. The analytical results were also compared to the FRL for applicable analytes as established by the OU5 ROD. All analytes, with the exception of lead were observed at levels below the corresponding FRL in the filtered samples. The filtered lead result of 3.3 ug/L from the August sampling event exceeded the FRL for lead which is 2 ug/L. However, the FEMP Project Specific Plan (PSP) for the Restoration Area Verification Sampling program recommends that the FRL for lead be modified to coincide with the 15 ug/L action level established by the EPA National Primary Drinking Water Regulations. EPA and OEPA have agreed to the lead FRL change. A factsheet discussing this change will be available to stakeholders in 1997.

Coal Pile Runoff Basin Monitoring Program

Two wells, 1675 and 1676, installed in the perched groundwater zone within the glacial overburden are used to monitor the Coal Pile Runoff Basin on a routine basis (See Figure 45). Monitoring is conducted in accordance with Ohio Permit to Install (PTI) No. 05-4172, issued and effective on September 13, 1990. The objective of the monitoring program is to detect any leaching that might occur from the Coal Pile Runoff Basin. These wells are sampled on a quarterly basis for total uranium and non-radioactive parameters.

In 1996, Monitoring Well 1675 had a maximum sulfate concentration of 391 mg/L and Monitoring Well 1676 had a maximum sulfate concentration of 308 mg/L, both of which are below the Primary Drinking Water Standard of 500 mg/L but above the Secondary Drinking Water Standard of 250 mg/L for sulfate. Both of these wells also showed total dissolved solids above the Secondary Drinking Water Standard of 500 mg/L with Monitoring Well 1675 having a maximum value of 1264 mg/L and Monitoring Well 1676 having a value of 1220 mg/L. Although these constituents were detected above their secondary standards in 1996, it should be noted that the presence of the constituents does not pose a threat to human health or to the environment except at considerably higher concentrations.

Fate and transport modeling performed for the OU5 Feasibility Study (FS) showed that the glacial overburden material above the aquifer is protective of the groundwater in the aquifer due to the limited vertical groundwater flow. Because of this, recommendations will be made to the EPA and OEPA to terminate this monitoring program. Pending approval of this recommendation, Monitoring Wells 1675 and 1676 will be plugged and abandoned during remediation of the basin and demolition of the boiler plant complex.

Additional Groundwater Activities for 1996

Significant progress was made in 1996 to integrate all of the groundwater monitoring activities in an effort to streamline the process of meeting the final remediation strategy. This included the development of the IEMP (described later in this section).

Additionally, the draft Restoration Area Verification Sampling Program PSP (DOE 1996) was submitted to the EPA on October 1, 1996. The purpose of the program is to identify the nature of FRL exceedances outside of the aquifer restoration footprint (area affected by the actual pumping of the aquifer). Groundwater recovery systems were designed based on capture of the uranium plume. Therefore, non-uranium FRL exceedances outside the restoration footprint may escape capture by the planned recovery system. Continued monitoring of persistent exceedances with data trend analysis was recommended, as a result of this program, to determine the need for additional action, and will be conducted as part of the IEMP.

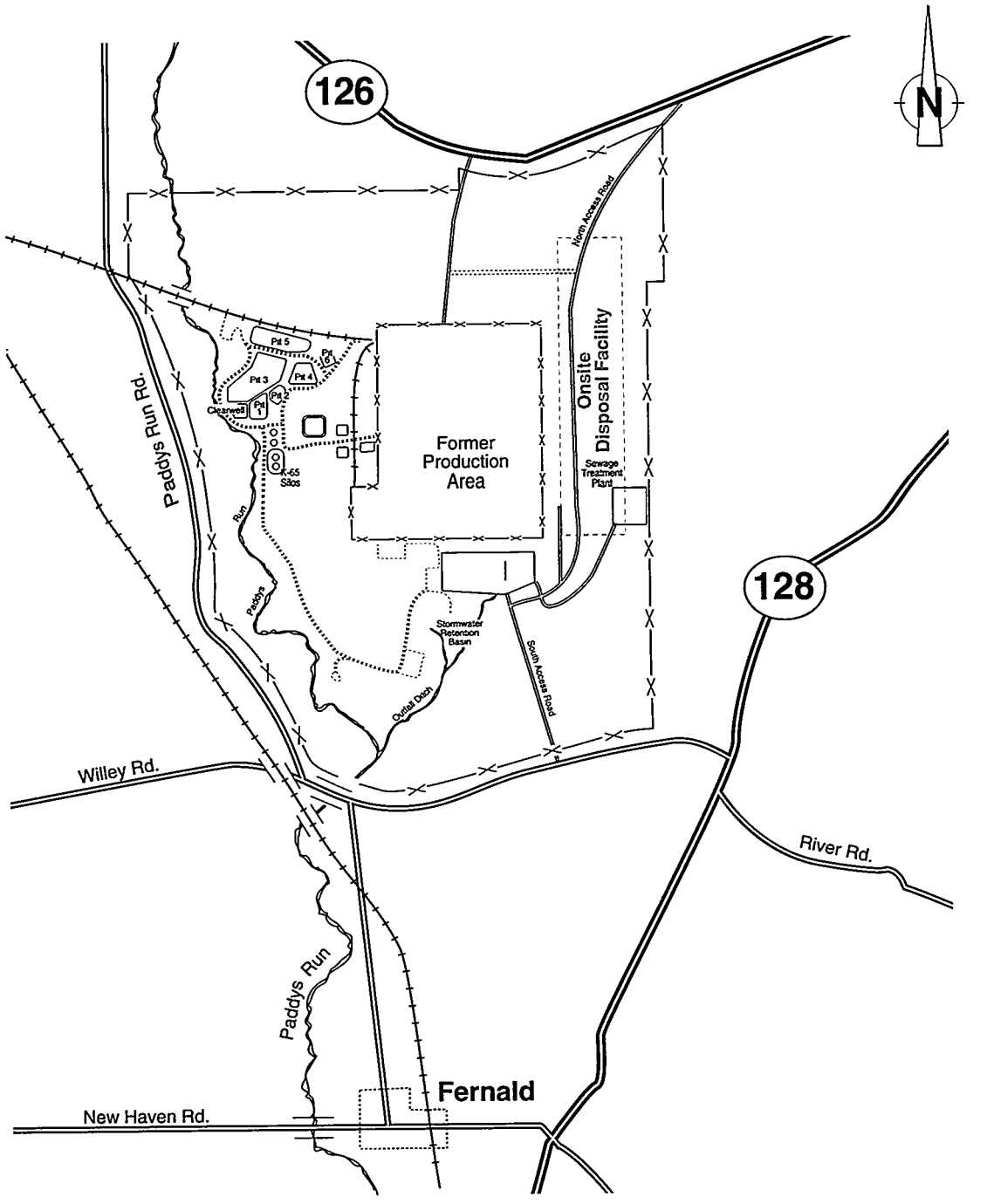
On-Site Disposal Facility (OSDF) Predesign Monitoring Program

Groundwater activities were conducted in the glacial overburden as per the Addendum to the PSP for Phases I and II of the OU2 Predesign Field Investigation submitted to the EPA and OEPA in December 1995. The activities performed under the addendum included slug tests, flow meter readings, tile probes, groundwater and soil sampling, and lysimeter sampling. The results of these activities were presented in the Addendum to the Predesign Investigation and Site Selection Report for the OSDF, which was submitted to the EPA and OEPA on November 7, 1996. The conclusions were as follows:[23]

- Groundwater flow in the glacial overburden is localized and discontinuous;
- The results of the predesign investigation and the addendum study support the OU5 RI conclusions that the vertical groundwater flow pathway in the glacial overburden is more significant than the horizontal flow pathway, with respect to contaminant transport to the Great Miami Aquifer, in that the travel time to the aquifer is shorter in the vertical direction than in the horizontal direction;
- Constituents of Concern (COC) concentrations in the perched groundwater in the area of the OSDF do not pose a threat to human health or the environment;
- Lysimeters installed at the FEMP for the OSDF study required at least 12 months to equilibrate; and
- The drain tile network is adequately identified for removal during OSDF construction.

The OSDF Groundwater Monitoring Plan, as part of the Intermediate and Pre-Final OSDF Design, was submitted in April 1996, and June 1996, respectively.

Figure 46: Location for the On-Site Disposal Facility



This plan outlines the locations of groundwater wells and the plan for collecting and analyzing groundwater and leachate samples for the OSDF. (For the location of the OSDF, see Figure 46.) This plan was revised and submitted to the EPA and OEPA in March 1997. The FEMP received approval in April 1997.

Public Water Supply Program

DOE has supplied bottled water to homeowners whose private wells have been impacted by the South Plume. This action was, however, considered only a temporary solution. The preferred alternative is to eliminate individual homeowner wells that withdraw water from the aquifer and to provide these residents with water from a public water supply.

The primary objective of this program is to protect public health by providing this permanent, reliable, and safe water supply to local residents. DOE committed to providing its fair share of the cost for installation of the water mains in the South Plume area in the form of a grant to the Hamilton County Department of Public Works, the agency responsible for coordinating all water supply within Hamilton County.

The portion of installation that is of particular interest to DOE involves approximately 23 km (14 miles) of water mains within Hamilton and Butler counties. This installation occurred along East Miami River Road from Bolton Water Works to the intersection of State Routes 126 and 128, then south along State Route 128 to approximately 2.7 km (1.7 miles) south of the New Haven Road intersection to Crosby Road. Installation has also occurred along Willey, New Haven, Crosby Road, and Paddys Run roads.

Construction of the main transmission and distribution lines mentioned above was completed in December, 1995. Construction of a 500,000 gallon reservoir located on Crosby Road was started in the fall of 1995. Construction activities resumed in early 1996, and was completed in June, 1996. The FEMP is the largest initial user of water.

Establishing a FEMP Comprehensive Environmental Monitoring Program

The Draft Integrated Environmental Monitoring Plan (IEMP) was submitted to the EPA, OEPA and the Citizen's Task Force Subcommittee on Monitoring for review in August, 1996. The objective of the IEMP was to combine all FEMP monitoring programs into a single program, and to ensure that environmental monitoring efficiently supported remediation activities. The IEMP lists all FEMP regulatory requirements for monitoring and clearly delineates requirements that pertain to site-wide environmental monitoring, which are contained within the scope of the IEMP, from process control monitoring activities which are individual project responsibilities. Beginning in 1998, all environmental monitoring

data will be reported through the IEMP comprehensive annual report and quarterly status summaries.

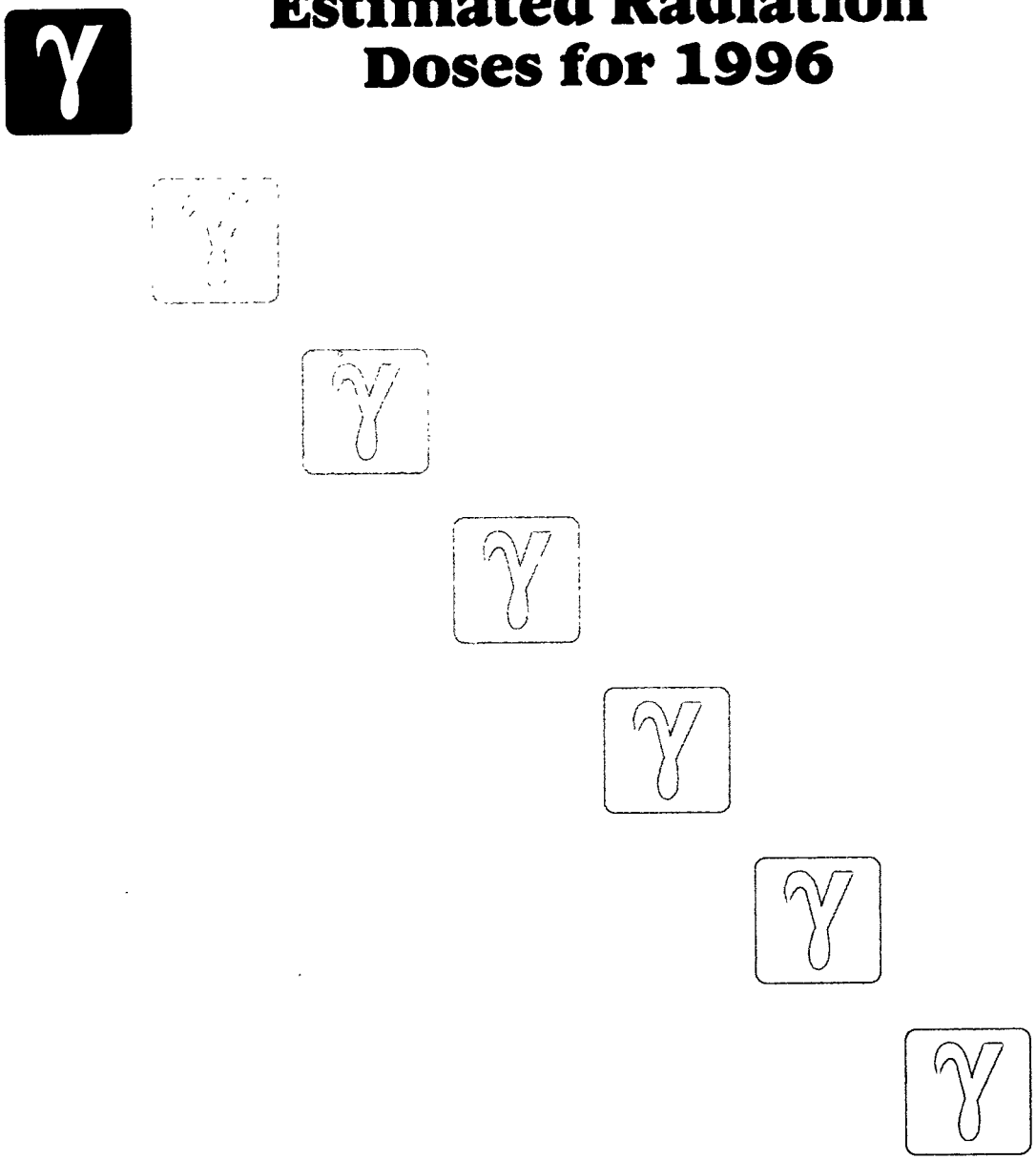
The IEMP reporting schedule will replace the numerous smaller scope environmental data reports that are currently submitted to EPA and OEPA. The Site Environmental Report will also be replaced by the IEMP annual report. The IEMP report will contain an executive summary intended for all readers of all experience and interest level followed by the main body of the document and Appendices that will contain detailed technical information.

The IEMP contains the sampling stategies for groundwater, surface water, sediments, air and produce, as well as sample locations, parameter lists and information on data useage. Comments on the draft IEMP were received from OEPA and EPA and incorporated in a draft final version of the IEMP. The draft final version of the IEMP was transmitted to EPA and OEPA on March 7, 1997. The IEMP is expected to be approved early summer 1997.

Both the air and the liquid pathway allow radioactive and non-radioactive materials to leave the FEMP and are, therefore, monitored. The results from these monitoring activities are used to estimate potential radiation dose, which is discussed next in Chapter 7.

7

Estimated Radiation Doses for 1996



Estimated Radiation Doses for 1996

One of the primary public concerns about any facility that handles radioactive materials is that people working and living in the area may be exposed to harmful amounts of radiation. In response to this concern and to environmental regulations, FEMP personnel are monitoring the ways in which radioactive material could move through the environment and affect people. Background radiation levels and naturally occurring radioactive materials present technical as well as practical problems in trying to directly measure the dose people may actually receive from the FEMP; therefore, scientists estimate dose using models and the results of environmental samples. This chapter provides the following information:

- An explanation of how dose estimates are calculated,
- Dose estimates from several different pathways for 1996, and
- An interpretation of the significance of these estimated doses.

Results in Brief: 1996 Estimated Doses*

Air Pathway

Airborne Emissions – The estimated maximum committed effective dose to a member of the public from 1996 airborne emissions was calculated as 0.66 mrem.

Foodstuffs – The committed effective dose from eating foodstuffs produced within three miles of the FEMP was estimated to be 0.04 mrem.

Direct Radiation – There was no statistical difference between direct radiation measurements at the site fenceline and measurements at background locations. Therefore, no dose was attributed to direct radiation for 1996.

Liquid Pathway

Well Water – The estimated committed effective dose from drinking well water from the area around the FEMP was 0.25 mrem.

Fish – The estimated committed effective dose from eating fish from the river near the FEMP effluent line was 0.006 mrem.

* These doses for 1996 are also presented in Table 19 on page A-35. Information on doses received from other sources is also provided in that table.

Methodology for Calculating Total Radiation Dose

DOE Orders and USEPA regulations require the FEMP to demonstrate that its radionuclide airborne emissions are low enough to ensure that no one in the public receives an effective dose of 10 mrem or more in any one year. (This excludes radon–222 emissions, which are covered under different regulations. Radon regulations, emissions, and estimated dose from radon are presented in Chapter Eight of this report.) Moreover, to determine whether the FEMP is well within the DOE dose limit of 100 mrem per year to members of the public from all exposure pathways, FEMP personnel estimate doses from other components of the air and liquid pathways, as well as direct radiation dose from materials stored onsite. The DOE limit of 100 mrem per year from all pathways is the sum of the doses from radiation external to the body during the year plus the dose from radionuclides taken into the body during the year. This latter dose is called the committed effective dose and is received over a 50-year period.

As described in Chapter One, pathways are the routes along which radioactive material moves and may deliver a dose to the public. Total dose estimates incorporate dose from the air and liquid pathways. Direct radiation is included as a component of the air pathway dose. Monitoring of the air and liquid pathways provides the basis for the extensive environmental sampling described in Chapters Four, Five, and Six. Using these measurements, a dose from each pathway can be estimated using models.

Environmental and Dose Modeling

The FEMP, like many other nuclear facilities, uses models to estimate doses to the public. Models play an important role in environmental monitoring because current technology and the low concentrations of radioactive pollutants in the environment make it impractical to measure environmental doses with standard instruments. The nature of radioactivity and the presence of naturally occurring radioactive materials create difficulties in detecting low levels of radioactivity and distinguishing between natural radioactivity and radioactivity from the FEMP. Models also estimate pollutant concentrations and doses that are below the detection capabilities of instruments and laboratory measurements. These concentrations and doses would be left out in assessing the environmental impacts of the FEMP if models were not used. Environmental and dose models are briefly explained below.

Environmental modeling is a way to represent a complex environmental process, such as atmospheric dispersion of emissions or the air-to-soil-to-produce process, as a set of mathematical formulas. By studying an environmental process, such as dispersion of a pollutant from a stack as it is carried by the wind, scientists can develop a mathematical formula that models the process. They can then use this

model to predict the concentration of the pollutant at a specific location. As additional processes are modeled, it is possible to interconnect them so that the movement of pollutants is predicted by a larger environmental model.

Dose models are developed similarly. By modeling radioactive decay, absorption and removal of radioactive materials in the body, and other physical and biological processes, scientists can develop a dose model to evaluate how radioactive materials deliver a dose. Connecting the dose model to the environmental model provides a means of estimating dose using information gathered through environmental sampling. Models are usually translated into computer programs to conveniently handle the data and calculations.

Although models may be the only comparative way for scientists to estimate dose, they do not necessarily predict all environmental processes. Because the mathematical formulas that represent the environmental and biological processes are simplifications and generalizations, applying them to the specific conditions at the FEMP may lead to differences between predicted and actual concentrations or doses. The results or outputs of models always involve some uncertainty in the accuracy of the estimated dose, and many have built-in assumptions which strongly influence the results. Models may be most beneficial because of their ability to estimate the upper limit of the dose and identify the most influential pollutant or pathway of exposure.

Although the uncertainty associated with the radiation dose calculations has not been quantified, whenever FEMP-specific data were not available for parameter values (for example, food consumption values), conservative values were selected from research literature for use in the dose calculations. Thus, the estimated doses should be viewed as maximum estimates of potential doses resulting from FEMP releases.

Air Pathway Dose Calculations

The air pathway is a route for contaminants to reach people directly as emissions and indirectly through foods contaminated by airborne emissions. This section uses data from air and produce sampling as well as estimates of airborne releases (refer to Chapter Four) to calculate doses. Dose from radon is presented in the next chapter of this report.

Estimated Doses from Airborne Emissions

At the FEMP, scientists obtain dose estimates from onsite airborne emissions measurements using a set of computer programs called CAP88-PC. The FEMP uses CAP88-PC to determine compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) requirements of the Clean Air Act. Within the programs, the AIRDOS (i.e., EPA dose model; MO79) program calcu-

lates concentrations of radionuclides in the air, on the ground, and in food based on estimates of the amount of airborne radioactive material released. The concentrations are then used to calculate the intakes and subsequent doses to people.

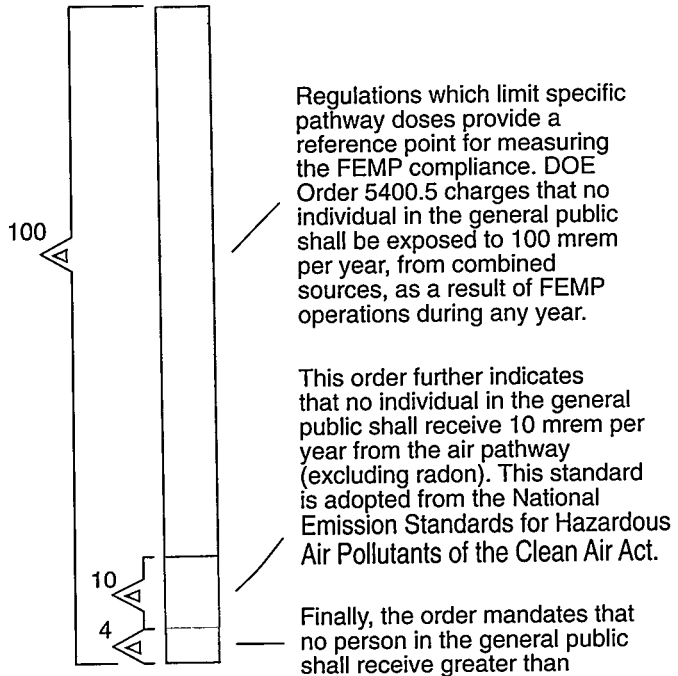
The CAP88-PC program calculates airborne radionuclide concentrations based on estimated, calculated, or measured emission rates. The results from the fenceline ambient air monitoring stations are compared to the CAP88-PC concentrations but are not used in inhalation dose calculations.

The CAP88-PC computer programs calculate both individual and collective doses. Collective dose is the sum of individual doses to people in the FEMP area and is reported in the units of *person-rem*. (For example, if 10 people each receive 1 rem, the collective dose is "10 person-rem;" if 20 people each receive 0.5 rem, that collective dose also is "10 person-rem.") The person-rem unit is used as a broad measure of the radiological impacts of the FEMP and is useful in comparing the risks from site operations with other facilities and industries.

The CAP88-PC programs require a large amount of data to estimate dose, which includes the number, height, and location of release points; wind speed and direction; the amount of radioactive material released; and population distribution in the FEMP area. (Wind rose data summarizing wind speed and direction are shown in Figures 4 and 5 in Chapter One, and estimated airborne radionuclide emissions and population distribution are presented in Tables 20 and 2, in Appendix A.) Although some of the data were obtained through measurements and sampling, many were not readily available and were estimated. Examples of estimated data are the amounts of airborne radioactive material released from the Laboratory Building and the Cooling Tower. The FEMP made very *conservative estimates* for these and all other emission sources that were not measured directly. Conservative estimates, used frequently in environmental monitoring and dose calculations, are based on assumptions about an exposure situation that should result in the highest estimate of a dose. For example, an assumption about estimated doses at the air monitoring stations is that a person is outdoors at one location for 100% of the time during the year. The assumptions are conservative in the sense that they provide a margin of error for underestimating emissions and doses. Conservative estimates of emissions are used to ensure that dose estimates are not underestimated but are the maximum doses that could have resulted from FEMP operations during 1996.

Results of the CAP88-PC programs estimated the maximum effective dose from 1996 airborne emissions to be 0.66 mrem to a person located north, northeast of the former production area. This dose estimate assumed that the person remained outside his or her home 100% of the time in 1996. The dose was well below the NESHAP standard of 10 mrem from the air pathway and was only 0.66% of the DOE guideline of 100 mrem per year from all pathways (see Figure 47).

Figure 47: Department of Energy Dose Limits



The collective effective dose from 1996 airborne emissions (not including radon) to the population within 80 km (50 miles) of the FEMP was also calculated by CAP88-PC. This dose was estimated to be 5.7 person-rem for a population of 2.7 million. For comparison, the same group of people received an estimated collective effective dose of 300,000 person-rem from background radiation, excluding radon.

Estimated Dose from Eating Foodstuffs Produced near the FEMP

Because the CAP88-PC program only calculated doses from 1996 airborne emissions, scientists made additional dose calculations to estimate doses from past emissions that may have accumulated through the food chain. These additional calculations estimate potential dose from consuming locally grown fruits and vegetables.

Uranium deposited in soil during the years the FEMP was in production may be absorbed by produce and farm animals and, therefore, deliver a secondary pathway dose. This estimated dose is based on the conservative assumption that 100% of a person's diet of fruit and vegetables comes from gardens and farms in the FEMP area (see Table 8 on page A-11). This modeled diet assumes an annual consumption of 18 kg (40 lbs) of leafy vegetables (cabbage, lettuce, etc.); 45 kg (100 lbs) of grains (corn, soy beans, wheat, etc.); 68 kg (150 lbs) of fruit; 28 kg (62 lbs) of below-ground vegetables (potatoes, carrots, etc.); and 45 kg (100 lbs) of other vegetables.[24] To represent the foods in the diet, scientists analyzed cabbage, corn, soybeans, apples, potatoes, tomatoes, and green beans from local gardens and farms for uranium. The maximum uranium concentration found in locally produced foods was used to estimate dose. The average background uranium concentration in foods was subtracted from the maximum concentration to account for the natural occurrence of uranium in foods.

The laboratory analysis of foodstuffs determines the total amount of uranium (all uranium isotopes) in the sample. Because any dose from uranium is based on the isotopic composition of uranium, an assumption about the isotopic composition of uranium in foodstuffs must be made to calculate the dose. Scientists assume any uranium detected in the foodstuffs has the isotopic composition of natural ura -

nium. This assumption is reasonable because a large amount of uranium produced at the FEMP had an isotopic composition similar to naturally occurring uranium. Scientists used dose conversion factors to convert the intake of uranium to dose. The conversion factors themselves are the result of modeling the radioactive decay and metabolism of radionuclides in the body.[25]

The committed effective dose to be received over the course of 50 years (to be conservative) will be accounted for in the first year. The committed effective dose from eating foodstuffs was calculated to be 0.04 mrem, less than 0.1% of the DOE dose limit of 100 mrem per year for all pathways. This dose is comparable to the estimated doses from foodstuffs in past years.

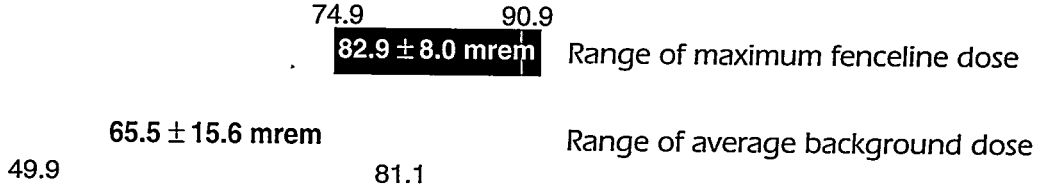
Direct Radiation Dose

Unlike the air and liquid pathways, where a radionuclide in the form of a particulate or gas delivers its dose after inhalation or ingestion, direct radiation dose is the result of radiation (gamma and X-rays) emitted from radionuclides stored onsite. The largest sources of direct radiation are the wastes stored in the K-65 silos and thorium compounds stored at selected locations onsite. Direct radiation dose is estimated using environmental thermoluminescent dosimeter (TLD) measurements (see Chapter Four), rather than through the use of models.

The direct radiation dose was estimated using the highest dose from the thirteen fenceline monitoring locations (see Table 9 on page A-13) and subtracting the average dose measured at six background TLD locations (locations 18, 19, 20, 21, 30, and 33 as shown in Figure 30 on page 99). Limits in the precision on TLD data and variations in natural background radiation require consideration of the uncertainty (the plus/minus [±] values) associated with each measurement in calculating dose. The uncertainty is calculated for a 95% confidence interval (2 sigma) around the average.

Comparison of Fenceline and Background Doses

A comparison of the highest fenceline dose to the average background dose is shown below. From the figure, it is clear that the highest fenceline dose is within the range of the average background dose. This overlap of the doses means that, at the 95% confidence level, the doses are not statistically different from one another.



From the data in Table 9, the highest 1996 fenceline dose occurred at location 9B and is 82.9 ± 8.0 mrem per year (2 sigma). The average background dose from locations 18, 19, 20, 21, 30 and 33 is 65.5 ± 15.6 mrem per year. At first glance, it appears that the direct radiation dose would be 17.4 mrem per year above background at the FEMP fenceline. However, when the range of the background dose measurements is taken into account, there is no statistical difference between the fenceline dose and the average background dose. The data indicate that the highest fenceline dose is between 74.9 mrem (82.9-8.0) and 90.9 mrem (82.9+8.0) per year, while the average background dose is between 49.9 mrem (65.5-15.6) and 81.1 mrem (65.5+15.6) per year. Because the range of background and the range of fenceline doses overlap by 6.2 mrem, there is no firm basis for stating that there is a difference between the fenceline and average background doses. Given this lack of statistical difference between the doses, no dose was attributed to direct radiation for 1996.

TLD results from fenceline locations do not show any increasing or decreasing trends over the past five years. The 1996 TLD results were similar to the 1995 results, but Table 9 indicates some obvious differences between the two. During 1996, the procedure for analyzing the TLDs was revised to incorporate new algorithms, which enhanced the lower limit of detection. This increased the level of detection with a corresponding increase in uncertainty.

Liquid Pathway Dose Calculations

Dose estimates from the liquid pathway are calculated using environmental sample results and dose conversion factors. Measurements of radionuclide concentrations in groundwater, the Great Miami River, and fish from the river are used to estimate dose from the liquid pathway. Descriptions of the monitoring programs for these environmental samples are given in Chapters Five and Six.

Estimated Dose from Drinking Well Water in the Area around the FEMP

As discussed in Chapter Six, the FEMP monitors a number of private drinking water wells for uranium contamination. While most wells have uranium concentrations which are within the 0.07 to 2 pCi/L (0.1 to 3.0 ppb) range of background concentrations, several wells have higher concentrations and are considered to be a source of dose from the FEMP.[26,27]

In order to estimate dose from drinking well water in the area around the FEMP, the average uranium concentration in wells located north and west was subtracted from the maximum concentration found in wells located south and east of the FEMP. Data from wells 3, 4, 10, 22, and 30 were used to provide the average background concentration. The maximum concentration in a drinking water well south and east of the FEMP was found in Well 14 (see Table 15 on page A-26).

For the purpose of dose calculation, the uranium in Well 14 is assumed to have the isotopic composition of natural uranium. Using a consumption rate of 2 liters (0.5 gallon) of water per day, the committed effective dose received from drinking water from Well 14 would be 0.25 mrem per year.

Estimated Dose from Drinking Great Miami River Water

Although the Great Miami River downstream of the FEMP is not designated as a public water supply by OEPA, the FEMP estimated the radiation dose to an individual if that person drank only the water from the river downstream of the discharge point after mixing had occurred.

Scientists used data on the amounts of radionuclides discharged to the Great Miami River (see Table 11 on page A-20) and the average river flow to calculate concentrations in river water. Dose conversion factors were used to convert the intake of radionuclides to dose. Assuming a daily consumption of 2 liters (0.5 gallon) of water, the committed effective dose from FEMP releases received over the course of 50 years would be 0.01 mrem.[36]

Estimated Dose from Eating Fish from the Great Miami River

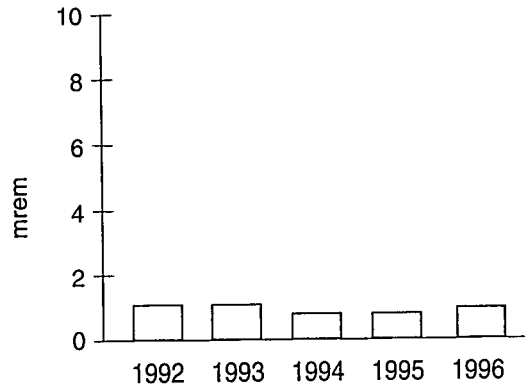
The estimated dose from eating fish from the river was calculated using the maximum uranium concentration in edible fish collected at River Mile (RM) 19 and RM 24 (see Figure 38 on page 113 and Table 14 on page A-25). The average background uranium concentration in edible fish collected at RM 38 was subtracted from the maximum concentration to account for natural occurrence of uranium in the fish. As with other dose calculations, any uranium detected in the fish was assumed to have the isotopic composition of natural uranium.

Assuming an annual consumption of 4.5 kg (10 lbs) of fish from the Great Miami River, the committed effective dose would be 0.006 mrem.[36] This dose is well below the DOE guideline of 100 mrem effective dose per year from all pathways.

Total of Doses to a Maximally-Exposed Individual

The maximally-exposed individual is a hypothetical member of the public who receives the highest calculated effective dose based on the location of his or her home, weather conditions, and the individual pathway doses. Because it is not possible to single out a specific individual in the FEMP area who receives the most dose, the results of the individual pathways and the CAP88-PC evaluation are added to predict the maximum dose that a person could receive. The dose to the maximally-exposed individual is a total of estimated doses from breathing 1996 airborne emissions (excluding radon), consuming foodstuffs produced in the

Figure 48: Dose to Maximally-Exposed Individual, 1992 – 1996



FEMP area, drinking water from a well in the FEMP area, eating fish from the Great Miami River, and receiving the direct radiation dose above background at the FEMP fenceline. The conservative assumptions used throughout the dose calculation process ensure that the dose to the maximally-exposed individual is the upper limit of the actual dose any member of the public receives.

The 1996 dose to the maximally-exposed individual is estimated to be 1.1 mrem, well below the guideline of 100 mrem per year for all pathways. Figure 48 shows the doses to the maximally-exposed individual from 1992 through 1996.

Significance of Estimated Radiation Doses for 1996

One method of evaluating the significance of the estimated doses is to compare them with doses received from background radiation (see Chapter Two). Background radiation yields approximately 100 mrem per year from natural sources, excluding radon. Comparing the maximally-exposed individual dose to the background dose demonstrates that, even with the conservative estimates, the dose from the FEMP is much less than background. Although the estimated dose will be received in addition to the background dose, this comparison provides a basis for evaluating the significance of the estimated doses. A dose that is small in comparison to that of background radiation will produce no measurable health effects.

Another method of determining the significance of the estimated doses is to compare them with dose limits developed to protect the public. The International Commission on Radiological Protection (ICRP) has recommended that members

Dose to Maximally-Exposed Individual

Pathway	Dose Attributable to the Site	Applicable Guideline
Air		
Estimated 1996 emissions	0.66 mrem	10 mrem/air
Foodstuffs grown in Fernald area	0.04 mrem	100 mrem/all pathways
Direct radiation	0.00 mrem	100 mrem/all pathways
Liquid		
Well water in the Fernald area	0.250 mrem	4 mrem/drinking water
Fish from Great Miami River	0.006 mrem	100 mrem/all pathways
Maximally-exposed individual	**~1.0 mrem**	**100 mrem/all pathways**

of the public receive no more than 100 mrem per year as a result of FEMP operations, and DOE has incorporated this limit into Order 5400.5 as well. The sum of all estimated doses from FEMP operations for 1996 was well within this limit.

Radon is subject to different regulations than other components of the air pathway. Likewise, the dose received from radon is regulated separately. Therefore, the Radon Monitoring Program is discussed separately in the next chapter, as well as the dose received from radon at the FEMP.

8

An Introduction to Radon

An Introduction to Radon

The chemical element with atomic number 86 is known as radon (chemical symbol "Rn"). Like all elements of Group VIII on the Periodic Table, it has a very stable electronic structure, and is, therefore, chemically unreactive. Unlike other noble gas elements, radon isotopes are radioactive. As discussed in Chapter 2, three of the isotopes are naturally occurring, each being a member of the natural decay chains shown in Figure 14. Rn-222, (referred to in this section as radon) is one of these isotopes. In fact, it is the only significant contributor (of the three isotopes) to radiation dose (see Chapter 2). It is located in the earth's crust, will concentrate in air, and can be transported considerable distances.

Ironically, radon itself accounts for very little of the radiation exposure individuals receive. Because it does not react chemically, what is inhaled is most likely exhaled. The dose is due for the most part to the residual radioactive material from the decay of radon. This material is known collectively as radon daughter products (polonium-218, lead-214, bismuth-214, and polonium-214).

Results in Brief: 1996 Radon Monitoring

Radon monitoring results and dose estimates are reported separately from the air pathway in order to clarify information and regulations that are unique to radon. The following results are based on data obtained from alpha track-etch detectors:

Fenceline Concentrations–The average fenceline concentration measured in 1996 was approximately 0.7 ± 0.7 pCi/L, well below the DOE limit of 3.0 pCi/L. The 1995 average concentration was approximately 0.7 ± 0.4 pCi/L.

Background Concentrations–The average background concentration measured in 1996 was approximately 0.6 ± 0.5 pCi/L. The 1995 average background concentration was approximately 0.7 ± 0.1 pCi/L.

Environmental Radon

The concentration of radon in the atmosphere shows daily, seasonal, and annual variability. Many factors affect environmental radon concentrations, including the distribution of uranium in the earth's crust, porosity of the soil, local weather conditions, etc. These factors are not constant; for instance, rainfall or snowcover limits radon's ability to escape from the ground. Additionally, extreme temperatures cause cracks and porosity changes in the ground, influencing the rate at which radon escapes.

Fluctuations are also caused by atmospheric conditions. During periods of calm winds and temperature inversions, air is held near the earth's surface, minimizing the mixing of air. Consequently, when these inversions occur, radon's movement is limited vertically, and concentrations tend to increase nearer to the ground. Also, radon is relatively soluble in water. Water transport is a significant mechanism for migration of radon into some homes where groundwater (well water) is used.

Site Specific Considerations

The FEMP stores residual radioactive materials that generate radon. The principal source of radon is radium-bearing waste generated during the extraction of uranium from pitchblende ore. This material is stored in the K-65 Silos (part of the OU4 remediation). Other relatively small radon sources are six Waste Pits (part of the OU1 remediation) and Building 65 Thorium Warehouse (part of the OU3 remediation).

The Radon Monitoring Program has gathered data concerning concentrations at various onsite and offsite locations since the early 1980s. The program assesses potential impacts on the public and the environment and operates within the requirements of DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. This order defines radiological protection requirements, guidelines for cleanup of residual radioactive material, management of resulting wastes and residues, and the release of radiological property. These requirements and guidelines are applicable at the time the property is released.

Radon levels *above interim storage facilities* are regulated and must not exceed the following limits (in addition to background levels):

- 100 pCi/L at any given point;
- Annual average concentration of 30 pCi/L over any facility site;
- Annual average concentration of 3 pCi/L at or above any location outside the facility site; or
- *Flux* rates greater than 20 pCi/m^2 per second from the storage of radon-producing wastes.

The Radon Monitoring Program at the FEMP

Two monitoring schemes ensure compliance with these limits: (1) long-term, time integrating monitoring; and (2) continuous monitoring. Long-term monitoring produces data used for assessing compliance with the annual limits. Long-term monitoring devices used at the FEMP have no electrical requirements and can be placed virtually at any location. In contrast, continuous monitoring assesses compliance with the instantaneous ambient radon concentration limit (100 pCi/L). Continuous monitoring devices used at the FEMP require electricity and are restricted in their placement.

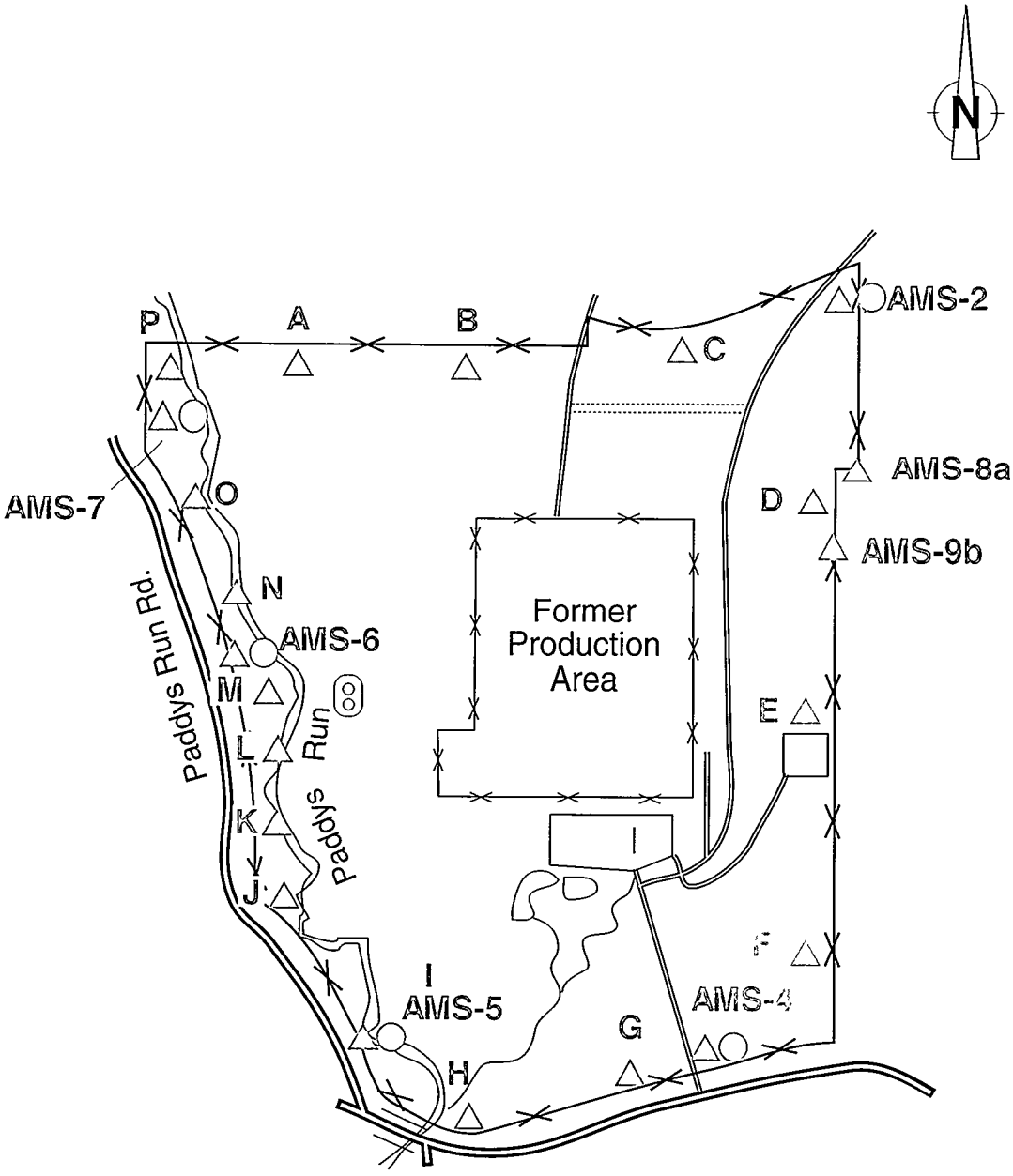
In general, monitoring locations reflect DOE guidance (DOE 1991) and are consistent with siting criteria associated with air particulate monitoring (see Figures 49, 50, and 51). Both indicator and background locations have been selected for comparison purposes. In response to public concerns, several monitors are placed at nearby residences and schools. Additional radon monitoring locations near specific sources ensure regulatory compliance or are used during site-specific project activities that could produce radon. Also, the Federal Facilities Agreement (FFA) requires routine reporting of data from nine continuous radon monitors (collected in hourly intervals and summarized as daily averages). The FFA also requires the continuous measurement (collected in five-minute intervals) of radon concentrations in the headspace of the K-65 Silos. As various remedial activities are initiated at the FEMP, the Radon Monitoring Program may change to ensure effective monitoring resulting from changing work activities.

Long-term, Time-integrating Radon Monitoring Methodology

An *alpha track-etch detector* consists of a plastic cup containing a special plastic chip with a filter over the top of the canister. Radon passes through this filter, and if the radon decays near the plastic chip, its alpha particles can penetrate the chip's surface. This penetration causes microscopic damage tracks in the plastic, which can be visualized by chemical processing (etching). The number of visible tracks is proportional to the number of alpha particles that have penetrated the plastic. This number is related to the average concentration of radon in the cup.

Alpha track-etch detectors are used when monitoring requirements pertain to annual limits because they consider data over long periods of time and provide an overall average concentration. The detectors are placed at many locations and gather both site-specific and background information regarding the dispersion of radon. Currently, there are approximately 62 locations, with two to three detectors placed at each location. Most of the detectors are placed within the immediate vicinity of the K-65 Silos (24 locations) and at the FEMP property fenceline (22 locations). Additionally, data are collected at other onsite locations, three local residences, and nine background locations.

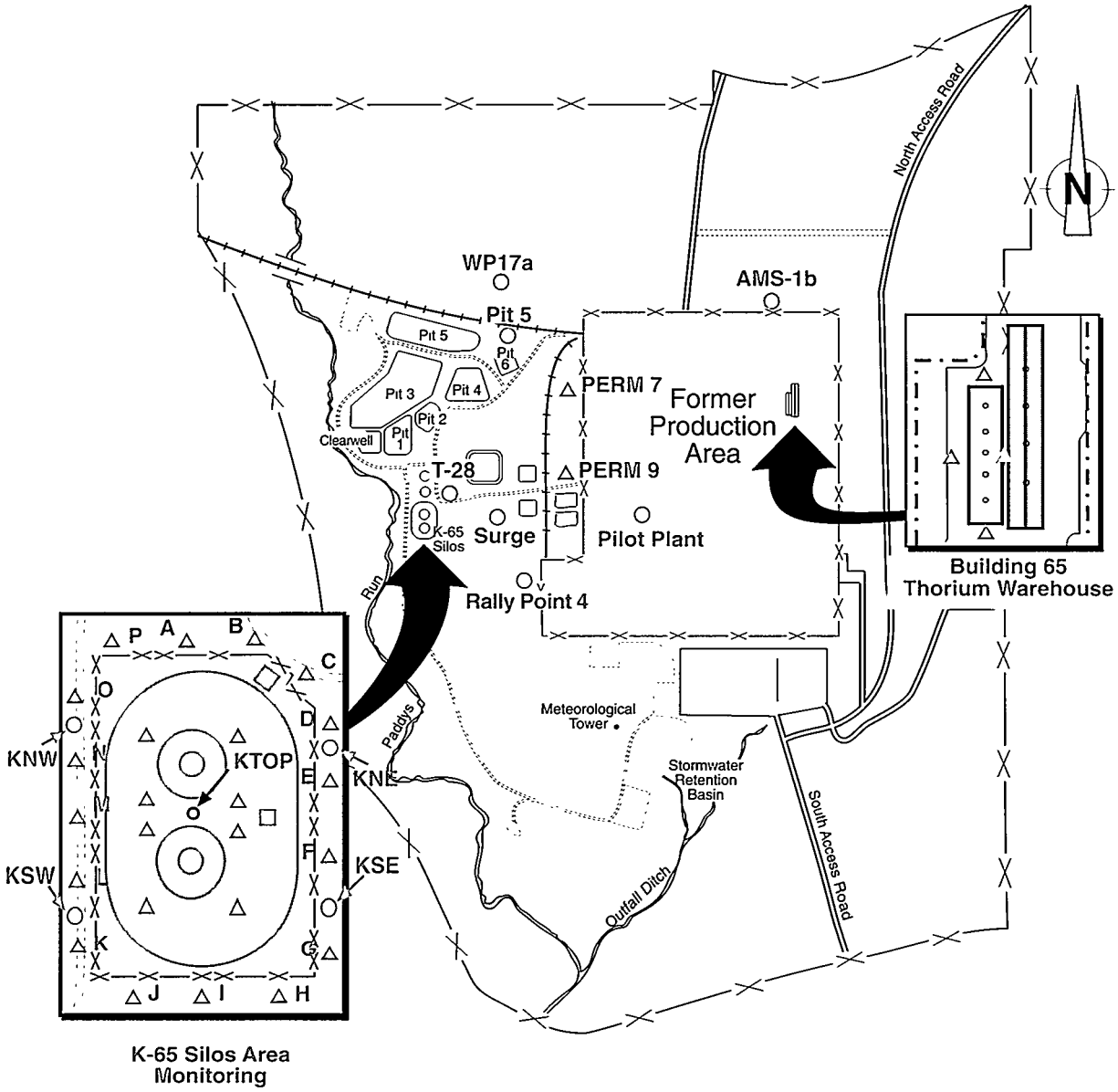
Figure 49: Fenceline Radon Monitoring Locations



LEGEND

- △ Alpha Track-etch Radon Detector
- ○ Continuous Environmental Radon Monitor
- ><—>< Plant Perimeter
- ><–><–>< Production Area Perimeter

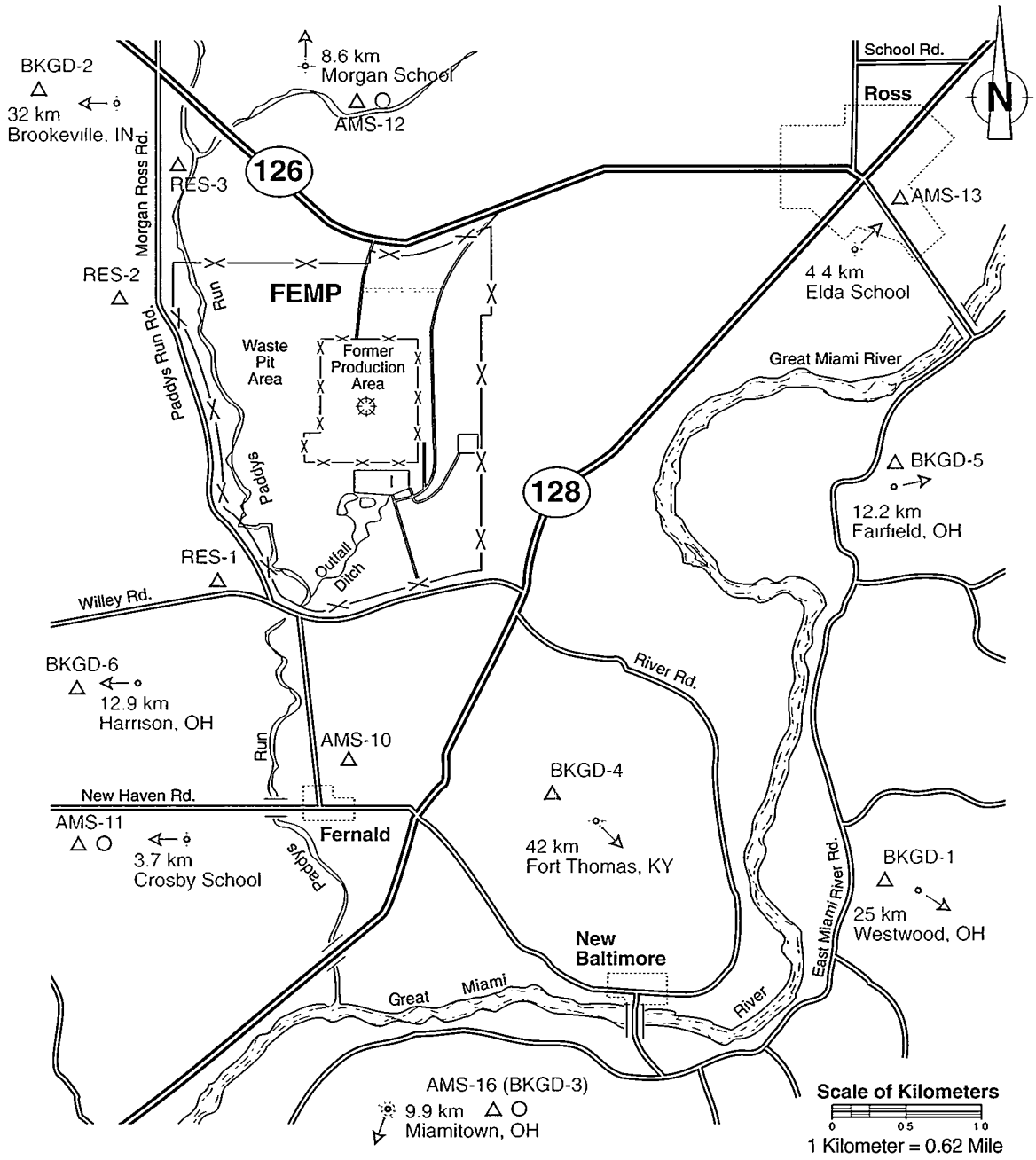
Figure 50: On-Site Radon Monitoring Locations



LEGEND

- □ Continuous K-65 Silo Headspace Radon Monitors
- ○ Continuous Environmental Radon Monitors
- △ Alpha Track-etch Radon Detector
- ×—× Plant Perimeter
- ×—×—× Former Production Area Perimeter

Figure 51: Off-site Radon Monitoring Locations



LEGEND

- Distance from Center of Former Production Area to Sampling Locations off Map
- O Continuous Environmental Radon Monitors
- △ Alpha Track-etch Radon Detector
- Plant Perimeter
- Former Production Area Perimeter

Each long-term radon measurement contains three components: (1) the local natural background radon contribution; (2) the etches present in the plastic before field placement (known as detector background); and (3) the potential FEMP radon contribution. The second component is accounted for by the vendor. Unfortunately, at a specific location, it is impossible to distinguish between the first and third components. Therefore, to determine the radon contribution from FEMP sources, the average background value for all offsite background locations is compared to fenceline radon measurements.

Continuous Radon Monitoring Methodology

Alpha-scintillation detectors utilize special cylindrical containers known as Lucas cells to continuously monitor radon concentrations. This technique can be either active (collected by a pump) or passive (natural airflow) sampling. Environmental data are collected using the passive method. During the passive measurement, radon passes through a layer of foam into the Lucas cell. The foam acts as a diffusion barrier, similar to the filter placed on the alpha track-etch detectors mentioned previously. The inside surface of the detector cell is coated with a crystalline material known as zinc sulfide (ZnS). Alpha particles generated from radon and its daughters produced within the cell react with the ZnS crystals, producing light pulses. The light pulses pass from the cell to a photomultiplier tube, an instrument that generates an electronic signal proportional to the number of light pulses. The strength of the electronic signal corresponds to the radioactivity concentration of radon within the cell.

Continuous monitors reveal important information regarding the dynamics of radon concentrations onsite and offsite. These monitors allow for timely review of radon concentrations, which may indicate concentrations are changing significantly from day-to-day and week-to-week. However, there are certain restrictions to using these monitors. Electrical power is available from a limited number of locations. Additionally, extreme cold weather affects the reliability of the instruments and some of the data are rendered unusable due to instrument malfunction under these severe conditions.

Determining a net radon concentration involves evaluating the three components of the measurement recorded by the continuous radon monitor: (1) natural background radon concentration from the area; (2) potential contributions from radon produced at the FEMP; and (3) the electronic signal and cell background contribution to the reading (electronic noise). This *electronic noise* is a phenomenon common to all types of electronic instrumentation. In a radon-free environment, the continuous monitor will still record a signal, falsely indicating a radon concentration. Studies are ongoing to determine the variability in the electronic noise portion of recorded data and its stability over time. Once studies are complete, an electronic noise background value can be used for each instrument. Therefore, current radon data collected at the FEMP are not corrected for electronic noise. The data are conservative in that the true value is less than the recorded value.

1996 Environmental Radon Monitoring Results

Alpha track-etch results for 1996 are provided in Table 21 on page A-37. Comparison of annual average radon concentrations at the nine background locations to the 22 fenceline locations indicates no measurable contribution at the fenceline from all FEMP sources. The average fenceline radon concentration was 0.7 ± 0.7 pCi/L, considerably less than the DOE limit of 3.0 pCi/L. The range of average values for any location on the fenceline varied from 0.6 ± 0.2 pCi/L to a maximum of 1.0 ± 0.2 pCi/L. The maximum measurement was still considerably less than the DOE limit.

The average background radon concentration as measured by the alpha track-etch monitors was 0.6 ± 0.5 pCi/L. The average concentration for any of the background locations varied from less than 0.5 ± 0.1 pCi/L to a maximum of 1.0 ± 0.4 pCi/L.

Estimated Fenceline Radiation Dose due to Radon

Radon decays producing radioactive daughters that can attach to airborne dust particles. This contaminated dust may be inhaled and deposited within the lungs. As the daughters decay, they emit electrostatically-charged particles that may damage the bronchial epithelium cell layers lining the air passages of the lungs. Most damage is due to the high energy alpha particles emitted upon the decay of polonium-218 and polonium-214. For exposures to radon daughters, the target organ for the radiation dose is the lungs.

Radiation absorbed dose (organ dose) to the bronchial epithelium is computed from the average radon concentration utilizing methods and parameters suggested by the National Council on Radiation Protection (NCRP).[28] This dose is multiplied by the radiation quality factor to give an equivalent dose in millirem. This equivalent organ dose is not comparable to other types of dose presented in this report. To allow for comparison to the other types of dose, another conversion factor is utilized. This tissue weighting factor takes into account the susceptibitlity of the organ to radiation induced cancer. The resulting dose is known as the effective dose equivalent and is comparable to other radiation doses mentioned in this report.

The following table presents the 1996 dose estimates. The table includes both fenceline and background data and information concerning absorbed dose, equivalent dose, and effective dose equivalent. Doses were calculated utilizing the annual average radon concentrations recorded using the alpha track-etch cups and assumed the suggested environmental radon daughter concentration ratio of 70%. All estimates were calculated for a hypothetically maximally-exposed reference man (average body size and breathing rate) who continuously breathed air at the fenceline while engaged in light physical activity 24 hours a day for an entire year.

1996 RADON DOSE ESTIMATES

	Radon Concentration (pCi/L)	Lung Dose (mrad)	Equivalent Lung Dose (mrem)	Effective Dose Equivalent (mrem)
Average Background	0.6	180	3600	430
Average Fenceline	0.7	210	4200	504
Maximum Fenceline	1.0	300	6000	720
DOE Limit	3.0	900	18000	2160

Since there are no limits for effective dose equivalent from radon and its daughters, it is important to refer to the concentration limits imposed by DOE Order 5400.5. As previously stated in this chapter, the annual average limit for radon concentration at the facility fenceline is 3.0 pCi/L. Measured concentrations for both background and fenceline locations are well below this limit. There is no statistically significant difference between average fenceline and background data, and therefore, there is no measurable radon dose from FEMP sources.

Quality Assurance of the Radon Monitoring Program

Radon monitoring at environmental concentrations has many challenges associated with it. For instance, instrumentation used in the surveillance should be rugged, weather-resistant, portable, reliable, and sensitive to low concentrations of radon. Each of the methods utilized at the FEMP includes some, but not all, of the criteria listed. Each year the monitoring program is evaluated, and areas of potential improvement are identified to enhance or upgrade the program.

The analytical vendor for the alpha track-etch detectors participates in the Environmental Protection Agency's Radon Monitoring Program testing and meets its quality assurance requirements. Exposure ranges for testing have been between 180 pCi/L-days to 2,000 pCi/L-days. In addition, the vendor has conducted quality assurance tests at exposures less than 100 pCi/L-days and noticed some variability of data similar to what is observed by the FEMP. Data at higher exposures are much more precise. The annual DOE limit for property fenceline exposures would be approximately 1,100 pCi/L-days (365 days x an average daily concentration of 3.0 pCi/L).

The foremost problem associated with alpha track-etch detectors is the uncertainty of results at low exposures (e.g., 100 pCi/L-days). Conditions that may cause this variability in the results are: (1) using detectors from more than one production lot; and (2) storage of unexposed detectors in an offsite building. Apparently, the sensitivity of detector material varies due to thickness and tempera-

ture fluctuations during material production. Storage and procurement practices have been improved to assure timely delivery of highest quality of fresh detectors for field use from one production lot.

The vendor receives the detectors that are assigned a random number, so they have no idea whether the detectors were placed in the field, or whether the detectors were spikes. When the data are grouped together and analyzed later, the replicate detectors at each location measure nearly the same radon concentrations. This is represented by the low ± values associated with the average concentration at each location. A review for representation and validity is conducted to ensure quality data are presented in this report.

Quality assurance practices include vendor analysis of multiple radon detectors subjected to a low, known radon exposure, commonly referred to as spiking. This practice is used to determine quantitatively the laboratory's ability to measure at environmental levels accurately.

During 1996, spiked radon cups at known total exposures (indicative of expected background exposures) showed an unexplained higher recorded exposure. This suggests that at low total exposures, the processing of the detectors overestimates the actual exposure and ultimately the recorded concentration. Based on this information, all recorded data was corrected for this overestimation. Although much variability is observed at the FEMP's low semi-annual exposures, the data are clearly below the annual concentration limits.

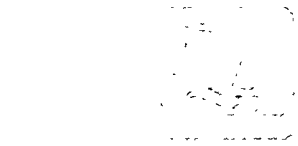
In regard to *continuous monitoring*, one ongoing enhancement is the confirmation that the instrument background of the monitor does not vary throughout the year. When a monitor is calibrated, the vendor typically provides information regarding the instrument and detector background (the "electronic noise") when operating in a radon-free environment.

It has been noted over time that the data recorded by the monitors are affected by extreme environmental conditions throughout the year-long calibration period. Currently, testing is ongoing to ensure the background reading of the instrument is stable. If the instrument background varies, and the initial background reading is programmed, lower radon concentration data might be reported. If it is confirmed that instrument background is not adversely affected by environmental conditions, this data will be appropriately subtracted from each instrument, and a representative lower net radon concentration will be produced in future results.

Program improvement is a continuous process. The next chapter discusses the procedures and practices used at the FEMP to ensure that environmental monitoring data are accurate representations of the conditions at the FEMP.

9

Quality Assurance for the Environmental Monitoring Program



Quality Assurance for the Environmental Monitoring Program

Acquiring data of known quality is essential to environmental sampling and analysis. Because decisions are made and regulatory compliance is derived from environmental data, the FEMP has developed comprehensive procedures that define how environmental sampling and analysis are to be conducted. These procedures generate consistency between programs and ensure environmental sampling and analysis using EPA, DOE, or industry-accepted practices and standards. Quality Assurance (QA) provides the guidelines necessary to monitor the performance of these procedures in a controlled and consistent manner. Adherence to QA requirements generates confidence that environmental data are reliable. The QA process identifies the variability in data, establishes the QA objectives, and defines the level of confidence needed to meet the objectives. The accuracy and precision of sampling and field analysis are measured using traceable standard control samples.

Results in Brief: 1996 Quality Assurance

DOE's Environmental Measurements Laboratory (EML) Evaluation – Soil and air analyses of the DOE EML samples were shown to be within acceptable limits.

EPA's Discharge Monitoring Report – All but two of the FEMP analyses of EPA wastewater samples were within acceptable limits.

Proficiency Environmental Testing (PET) – Of the 1,060 PET samples analyzed, 96% were within acceptable limits.

Sitewide CERCLA Quality Assurance Project Plan

Environmental sampling and analysis activities mandated or supported by EPA must contain a centrally managed QA program. Because the FEMP generates data under CERCLA, it is required to implement procedures that ensure precision, accuracy, completeness, and representativeness of the entire program.

Collection and analysis of environmental samples are integral parts of fulfilling the site's mission and complying with environmental regulations. A single sample of a specific item from a specific location may provide information for a number of remedial activities, restoration, waste management, and regulatory uses. Therefore, it is necessary that all environmental sampling and analysis be conducted in a consistent manner. This will result in usable, valid data of known quality so that use across programs is possible and the level of uncertainty associated with such data is known.

The Sitewide CERCLA Quality Assurance Project Plan (SCQ) was developed and implemented in 1994 for environmental sampling and analysis activities. It establishes minimum standards of performance for operational and analytical activities, while ensuring that these standards are followed by all programs.

Data Quality Objectives

Prior to sample collection, the Data Quality Objective (DQO) process begins. The DQO process provides a means for the decision maker and the technical team to define the level of quality needed in the data to support a decision. The regulatory requirements are identified and the sampling and analysis plans are designed before the samples are generated. When the sampling and analysis plans are designed, the variables established through the DQO process are used to determine the number of samples needed, including QA samples, and to ensure the total level of uncertainty from sampling and analysis is acceptable.

Quality Assurance: Field Activities

Quality assurance on field activities is an important part of the environmental monitoring process. The FEMP's environmental monitoring procedures contain detailed QA measures for meeting the criteria established in the DQOs. Only trained personnel who have demonstrated proficiency in making field measurements and collecting representative samples are permitted to perform these functions. Examples of field activities follow.

Field Analysis

Field measurements offer benefits in time and cost because they provide immediate results on environmental conditions, ensuring that the site maintains compli -

ance with certain parameters. Measurements are made with instruments calibrated against known standards and accepted methods. Instrument QA includes routine performance checks, maintenance, and calibration to help ensure proper operation and accurate field measurements.

Field Documentation

Technicians must accurately and systematically record results of field measurements and information pertinent to sample collection for subsequent evaluation and reference. Procedures direct the environmental sampling process from before sample collection begins to sample delivery to the laboratory. Technicians record events and observations such as weather, location, time of sampling, and any unusual events that may influence the sample in field logbooks. Signing and dating all documents help ensure the traceability and accountability of field activities.

Field QA/Representative Sampling

Environmental samples that field technicians collect must be representative of actual conditions in the environment. As such, the site designs sampling programs to reduce sample degradation, sampling variability, and cross-contamination.

FEMP personnel take precautions to prevent changing of sample constituents by purchasing certified clean sample containers and using sample preservatives when needed. Such precautions are necessary to prevent changes that can occur in some samples due to biodegradation from microorganisms, the loss of volatile compounds with increasing temperature, or the loss of trace metals from solution by adsorption onto sample container walls. Refrigeration, or icing, and the addition of chemical preservatives (such as nitric or sulfuric acid) are used to decrease volatility of organic compounds, control biological and chemical changes, and maintain trace metals in solution.

The use of standardized procedures reduces sampling variability. These procedures ensure consistency from one collection to another. Sampling variability is measured by taking duplicate samples of the same type. The precision of the site's sample collection and laboratory reproducibility is demonstrated when the analytical results for the duplicate samples are within acceptable limits.

When conducting duplicate sampling, a technician collects two samples from the same location. The samples are then submitted to the same laboratory or submitted to separate laboratories as a means of assessing the precision of the analysis. If the results from both analyses are similar, then the precision is verified.

The quality of the sample collection process is also evaluated by means of field and equipment blanks. These sample blanks provide valuable data and provide a means of monitoring the sampling process for cross-contamination. The blanks are transported along with the sample containers being taken by the sampling team

into the field. When sampling is complete, the blanks are submitted along with the field samples for laboratory analyses. A brief description of different types of blanks follows.

Trip blanks are prepared by filling sample containers with de-ionized water. Anything that will be added to the samples to preserve them after collection is also added to the blanks. The containers are then sealed with tamper-proof tape and transported to the sampling location along with the empty sample containers. Trip blank analyses are used to determine whether conditions encountered during sample container shipment and handling have affected sample quality.

Field blanks are prepared in the laboratory or in the field by filling sample containers with de-ionized water. Unlike trip blanks, field blanks are not sealed until after all samples have been collected. The container is opened and exposed to the air while other samples are being collected. Results from the field blanks determine if airborne contamination may have entered the field samples during the collection process.

Equipment rinsate blanks consist of a composite of de-ionized water that has been used for a final rinse in cleaning sampling equipment. Results of equipment rinsate blanks are used to evaluate whether or not sampling equipment was free of contamination before being used to collect additional samples.

Sample Custody

Most environmental samples must be managed according to EPA protocols. One such protocol is referred to as *chain-of-custody*. The custody procedure provides requirements for maintaining sample custody by approved personnel. A sample container and sample must be under custody at all times through final disposition.

All samples are obtained and documented according to the chain-of-custody procedure. This procedure requires personnel relinquishing and receiving custody of samples to sign, date, and note the time on a chain-of-custody record. This practice is done so that the sample integrity is maintained and all data are legally defensible.

Analytical Laboratory Quality Assurance

The FEMP uses a variety of procedures to ensure the laboratories analyzing its samples obtain reliable results. These procedures typically begin with the receipt of samples from the field technicians. Laboratory QA is designed to:

- Ensure use of appropriate measuring equipment;
- Ensure use of approved analytical methods;
- Evaluate analytical performance systematically and objectively;

- Detect and prevent the use of questionable data; and
- Identify appropriate corrective actions.

Analytical Methods

Many of the analytical methods used at the FEMP are stipulated by federal laws and regulations. Additional QA requirements for analytical methods are established in the SCQ. As part of QA, periodic review of the procedures verifies that the appropriate procedures are being used and procedure changes have been approved.

Analytical Performance

QA sample analyses provide day-to-day evaluation of the performance of the site laboratory as well as the contract laboratories. This evaluation is conducted by laboratories analyzing National Institute of Standards and Technology reference materials, EPA radionuclide solutions, standardized reference solutions, spiked samples (samples to which known amounts of contaminants have been added), blank samples, and external proficiency samples. In addition, the site prepares duplicate samples and submits them to the laboratories conducting the analyses. At least 10% of the total number of samples analyzed are QA samples that are analyzed along with the field samples.

FEMP personnel evaluate the QA sample results and regularly submit reports to the laboratories to identify potential areas of concern. In addition to analyzing QA samples, all laboratories perform daily instrument calibrations, stability checks, and reagent checks to monitor for laboratory interference.

Analytical performance is also monitored through sample and matrix spikes. Using these spikes, laboratories determine the percent recoveries of known amounts of analytes that were added to the samples. In addition, matrix interferences can be identified, and the accuracy of the analytical procedures can be established.

Detection of Data Problems and Corrective Action

As part of the QA program, internal and external groups perform surveillances on laboratory operations. Successful completion of on-the-job training and test sample performances are required for all new analysts, and routine performance checks assess their ability to correctly perform the analytical procedures. The accuracy of the analytical method is measured by the results of QA samples. If a problem is indicated, the laboratory is notified so that corrective actions can be taken and suspect results can be evaluated and qualified. Deviations are documented as a means of managing variations that occur in the analytical and data generation process. These reports are issued to the responsible manager and can be used as a means to track improvements in the quality system.

Independent Evaluations of the FEMP Laboratories

In addition to the comprehensive internal QA program, onsite laboratories regularly take part in several QA programs conducted by independent organizations. Participation in these external QA programs provides unbiased evaluations of the onsite laboratory performance and generates added confidence that results obtained for environmental samples are reliable.

External QA evaluations are conducted in the following manner. The organization conducting the evaluation prepares QA samples to which known amounts of a chemical or radioactive component are added. The samples, but not the known values of the test components, are distributed to the participating laboratories that analyze the samples and return the results. The organization administering the program then provides a performance evaluation report comparing the laboratories' results to the true values of the test components. In most cases, the report compares the results obtained by the other participating laboratories. These comparisons show whether the laboratories' analyses are within acceptable limits of accuracy or if improvements are required. Three of these programs are described below.

DOE's Environmental Measurements Laboratory

The Environmental Measurements Laboratory (EML) Program evaluates the performance of laboratories carrying out radionuclide analyses on environmental samples. Routinely, the FEMP receives and analyzes air filters, soil, and water samples for uranium and submits the results for comparison with other laboratories in the program. In making the comparison, DOE computes a ratio by dividing the site's result by the EML result for each analyte. The ratio equals 1.00 when the results agree exactly. Results within 50% (ratios greater than 0.50 and less than 1.5) are considered acceptable.

The ratios for samples analyzed for uranium during 1996 are listed in Table 22 on page A-39. The 1996 air filter sample ratios ranged from 1.00 to 1.1, which is acceptable. The water sample ratios were within acceptable limits since the ratio of results was 1.05 for both water samples. The FEMP has established requirements for all of its contract laboratories to participate in the EML program and their results must be within 50% of the EML results.

EPA's Discharge Monitoring Report

EPA requires all laboratories that perform NPDES permit wastewater analyses to participate in the Discharge Monitoring Report (DMR) QA program. The DMR QA evaluations of the FEMP laboratories' performance began in 1985. This program evaluates the ability of laboratories to measure nonradioactive contaminants in wastewater. As directed by EPA, a corresponding QA sample must be analyzed for each parameter listed in the NPDES permit. The NPDES permit parameters

measured by the FEMP laboratories are discussed in Chapter Five under "Monitoring for Nonradioactive Pollutants." EPA evaluates the results for the QA samples as acceptable or unacceptable.

Results obtained by FEMP laboratories for the 1996 DMR QA samples are summarized in Table 23 on page A-40. Twelve (12) of fourteen (14) results submitted during 1996 for DMR QA were determined to be acceptable by EPA.

Two analytical results, for copper and total suspended solids, fell outside the EPA acceptance limits. An investigation into the cause of the unacceptable results revealed a calculational error in the TSS results. In the case of the copper result, there was no definitive cause for the unacceptable result.

Commercial Proficiency Environmental Testing

The FEMP laboratories also participate in the Proficiency Environmental Testing (PET) QA program. This is a voluntary program administered by a commercial vendor of analytical laboratory QA services. Each laboratory pays a fee to participate. Periodically, the FEMP submits PET samples to the various onsite laboratories concurrently with field samples. Results obtained from these QA samples are compiled and submitted for evaluation by the commercial vendor. A monthly evaluation report is then provided by the vendor comparing the results of the FEMP to the reference values for each sample and to the results obtained by other laboratories participating in the PET program. By using this commercial service, the site has an additional resource for evaluating its laboratory performance.

A summary of the performance of the FEMP laboratories in the PET QA program during 1996 is provided in Table 24 on pages A-41 through A-43. For the parameters reported, 96% of the results met acceptable criteria.

Split Sampling Program

Another enhancement to the FEMP QA program is the split water, sediment, and produce program. The site has participated in this program with the state since 1987. In the split sample program, the true variability in analysis between laboratories is measured with the comparison of sample results that were collected directly from the environment.

This program is very similar to the duplicate sample program described above. Although the sampling is similar, the duplicate samples may measure a single laboratory's precision, whereas the split program measures comparability between two laboratories.

To obtain split samples, technicians alternately add a portion of the sample being collected to two individual sample containers. This collection method helps ensure that both samples are as identical as possible. Split samples are then submit-

ted to two independent laboratories for analysis. The results for the 1996 OEPA split samples are presented in Tables 25, 26 and 27 (pages A-44 through A-46).

These tables show mixed agreement between FEMP and OEPA samples. The surface water and groundwater split sample total uranium results are in good agreement. However, some soil, sediment and grass sample results differ by more than 50%. The reasons for the poor agreement in these sample results are not fully understood. The differences in sample handling and analysis procedures and variations in the sample themselves (despite efforts to homogenize the sample prior to splitting) may contribute to the larger-than-expected differences in the sample results. Although the split sampling program is an important part of the QA program, differences in the sample results do not impact the FEMP's compliance with federal or state regulations.

Contract Laboratory Quality Assurance

Because of the great number of analyses required to support all its various environmental sampling and analyses programs, the FEMP uses commercial laboratories to supplement its onsite analytical laboratories. Commercial laboratories must meet stringent requirements before being selected to provide environmental analytical services. Commercial laboratories, in many cases, must also be certified and have licenses from the state. To select the best qualified laboratory, experienced auditors conduct comprehensive reviews of the laboratory's management, operations, and performance. These reviews are conducted before and during the service life of the contract. Topics typically reviewed during the audits are:

- Analytical equipment;
- Analytical procedures;
- Personnel qualifications;
- Sample handling and preservation;
- Data evaluation and record keeping; and
- Requirements for precision, accuracy, and detection levels.

Auditors also review results obtained in independent QA programs as part of the evaluation of each candidate laboratory's analytical capabilities. Onsite audits of the laboratories' facilities and operations are then conducted by Sampling and Analysis Management, Procurement, and QA personnel before final selections are made. After selecting the laboratories, QA samples are submitted regularly with field samples in order to evaluate the contract laboratories performance on a continuing basis.

Appendices

FEMP Environmental Monitoring Data for 1996

Numerous sampling and analysis data are required to evaluate compliance with environmental regulations and to obtain accurate indications of the FEMP's operations during 1996. The sampling and analysis results are provided in summary tables.

Many of the numerical values listed in the following data tables are preceded by the "less than" symbol (<). The less than symbol is used when the concentration of a chemical species (ion, molecule, compound, or radionuclide) in an environmental media (air, water, or sediment) could not be reliably measured in the sample that was analyzed. That is, the amount of the species, if present at all in the sample, was below the minimum measurable concentration. Thus, a value of <0.68 pCi/L listed as the concentration of uranium in milk means that the uranium concentration was less than 0.68 pCi/L but actually could have been anywhere from 0.00 to 0.67 pCi/L.

The minimum measurable concentration is not the same for all chemical species. For example, 0.25 pCi/g of radium–226 and 0.21 pCi/g of plutonium–238 are the approximate minimum measurable concentrations for sediment samples. In addition to differences in the capabilities of instruments available to measure these properties, these variations exist because of differences in chemical and physical properties of species.

Also, the minimum measurable concentration is not always the same for a specific species in all samples of the same environmental media. That is, the minimum measurable concentration for uranium in groundwater samples may vary for water samples from two different locations. This is so because variations in the kinds or amounts of other substances in the two samples can influence how well a substance can be measured.

In addition, the minimum measurable concentration of a species will not always be the same for identical samples from the same location that are analyzed at different times. This variance occurs because of unavoidable minor fluctuations in the performance of analytical instrumentation used to perform sample measurements.

TABLE 1: Meteorological Data, 1996

	Unit	January	February	March	April	May	June	July	August	September	October	November	December
10-Meter Wind Speed[a]													
Maximum hourly average	kph	31.7	27	28.6	28.6	24.1	19.6	19.6	23.2	21.4	28.8	27.5	27.4
Minimum hourly average	kph	1	1	0.6	0.6	0.3	0.3	0.5	0.5	0.6	0.3	0.6	0.6
60-Meter Wind Speed[a]													
Maximum hourly average	kph	53.9	45.1	53.9	45.5	38.1	37.3	35.2	33.8	32.2	54.7	44.4	52.5
Minimum hourly average	kph	0.8	2.4	1.4	1.3	1.1	0.3	0.3	0.5	0.5	0.3	0.3	0.3
Ambient Air Temperature[b]													
Average	°C	- 2.6	- 0.4	2.1	9.4	n/a	n/a	n/a	23.3	17.6	12.5	3.4	3.1
Maximum	°C	19.7	22.1	21.1	27.2	31.4	33.1	31.2	32.2	28.9	25.4	23.4	18.5
Minimum	°C	- 14.7	- 23.7	-14.3	- 8	n/a	n/a	n/a	12.2	4.1	- 0.4	- 8	- 12.2
Precipitation[c]													
Monthly Total	cm	10.52	3.61	10.64	22.73	27.76	10.49	12.34	6.32	16.59	5.61	10.36	11.99
Daily Maximum	cm	4.55	0.91	4.6	5.36	8.18	1.96	3.1	4.04	5.49	2.77	4.52	2.97

(a) To obtain wind speeds in miles per hour, divide each value by 1.6093.

(b) Ambient air temperature is measured at the 10-meter (33-foot) level. To obtain °F, multiply °C by 9, divide by 5, and add 32.

(c) To obtain precipitation amounts in inches, divide by 2.54.

TABLE 2: Estimated Population Distribution within 80 km (50 miles) of the FEMP, 1996[a]

Compass Sector	0 – 1.6 km (0 – 1 mile)	1.6 – 3.2 km (1 – 2 miles)	3.2 – 4.8 km (2 – 3 miles)	4.8 – 6.4 km (3 – 4 miles)	6.4 – 8 km (4 – 5 miles)	8 – 16 km (5 – 10 miles)	16 – 32 km (10 – 20 miles)	32 – 48 km (20 – 30 miles)	48 – 64 km (30 – 40 miles)	64 – 80 km (40 – 50 miles)
N	2	54	193	20	140	2,157	15,117	7,201	16,590	13,291
NNE	0	71	51	113	147	12,263	8,174	9,742	30,568	86,398
NE	2	202	827	97	90	34,292	38,797	88,477	214,495	331,340
ENE	5	87	1,766	219	13	31,999	32,998	32,039	14,739	29,771
E	3	3	179	301	248	38,285	75,213	50,799	17,863	10,218
ESE	8	54	78	558	739	42,893	160,628	68,672	22,433	13,541
SE	10	200	52	394	680	53,789	271,217	96,398	28,351	11,194
SSE	6	349	165	217	492	21,506	226,652	58,844	12,567	8,122
S	3	7	17	253	538	9,177	32,980	38,030	8,392	9,825
SSW	3	27	205	40	188	5,638	8,999	7,630	5,390	10,277
SW	2	37	26	355	60	4,486	14,209	9,197	3,523	4,341
WSW	0	15	40	511	313	8,540	5,255	7,725	7,556	4,681
W	6	13	37	286	596	1,664	3,547	10,295	5,357	15,708
WNW	5	20	60	123	121	1,093	4,675	4,205	5,714	11,295
NW	1	18	261	269	254	1,196	1,423	3,757	22,376	8,795
NNW	2	7	97	312	722	1,239	12,713	5,128	48,409	15,256
Total	58	1,164	4,054	4,068	5,341	270,217	912,597	498,139	464,323	584,053
Total for all sectors: 2,744,014										

(a) Based on an extrapolation from 1990 census data by Geographic Data Systems Section, Computing and Telecommunications Division at Oak Ridge National Laboratory, April 1992.

TABLE 3: Uranium in Air, 1996

Sampling Location[a]	Number of Samples	Concentration ($pCi/m^3 \times 10^{-6}$) [b] Maximum	Concentration ($pCi/m^3 \times 10^{-6}$) [b] Average	Percent of Standard[c] Maximum	Percent of Standard[c] Average
Fenceline					
AMS 2	27	940	100	0.94	0.10
AMS 3	27	715	170	0.72	0.17
AMS 4	27	420	63	0.42	0.06
AMS 5	27	370	73	0.37	0.07
AMS 6	27	510	91	0.51	0.09
AMS 7	27	200	23	0.20	0.02
AMS8A	11	900	310	0.90	0.31
AMS 9B	11	780	310	0.78	0.31
Onsite					
AMS 1A	16	710	310	0.71	0.31
AMS 1B	12	2900	870	2.9	0.87
AMS 8	7	450	150	0.45	0.15
AMS 9A	7	530	260	0.53	0.26
Waste Pits					
AMS 17	9	120	42	0.12	0.04
AMS17A	19	490	120	0.49	0.12
AMS 18	14	2200	650	2.2	0.65
AMS18A	13	710	350	0.71	0.35
AMS 19	27	210	44	0.21	0.04
AMS 20	27	190	57	0.19	0.06
Offsite					
AMS 10	27	72	21	0.07	0.02
AMS 11	27	220	21	0.22	0.02
AMS 12	27	37	6.9	0.04	<0.01
AMS 13	27	200	27	0.20	0.03
AMS 14	27	75	21	0.08	0.02
AMS 16	27	62	11	0.06	0.01
AMS 21	27	62	18	0.06	0.02

(a) See Figure 22 on page 87 for locations.

(b) The amount of uranium in each sample is chemically determined and converted to units of activity using the conversion constant of 0.68 pCi/μg (natural uranium).

(c) Standard is 100,000 x 10^{-6} pCi/m^3, as listed in DOE Order 5400.5, "Radiation Protection of the Public and Environment."

(d) AMS 1A, 8, 9A, 17, and 18 were relocated during the year to AMS 1B, 8A, 9B, 17A, and 18A, respectively.

TABLE 4: Radionuclides in Air, 1996

Concentration ($pCi/m^3 \times 10^{-6}$) (a)					
Sampling Location(b)	Strontium–90	Technetium–99	Cesium–137	Radium–226	Radium–228
AMS 1/1A	< 2.5	1085 ± 327	< 5.5	17 ± 8.8	14 ± 7.7
AMS 2	< 2.3	998 ± 326	< 5.2	4.5 ± 3.4	< 9.2
AMS 3	< 2.8	1993 ± 598	< 6.8	9.3 ± 5.6	14 ± 8.8
AMS 4	< 2.7	1427 ± 482	5.6 ± 7.7	4.9 ± 3.3	< 12
AMS 5	< 2.3	1453 ± 457	< 5.1	20 ± 15	54 ± 21
AMS 6	2.7± 2.2	922 ± 288	158 ± 23	6.3 ± 3.9	< 7.5
AMS 7	< 3.1	119 ± 75	< 6.7	2.3 ± 2.6	12 ± 8.5
AMS 8A	< 7.0	< 277	< 16	13 ± 7.4	< 25
AMS 9B	< 6.7	363 ± 188	< 17	9.4 ± 5.3	< 20
AMS 10	< 2.6	143 ± 74	15 ± 7.9	< 1.1	< 8.3
AMS 11	< 2.3	< 111	6.7 ± 6.5	7.9 ± 5.2	< 8.1
AMS 12	< 2.4	< 114	< 6.0	9.8 ± 7.7	< 7.4
AMS 13	< 2.4	125 ± 81	6.7 ± 7.2	8.9 ± 5.3	< 8.3
AMS 14	< 2.4	451 ± 151	< 6.6	13 ± 7.2	< 9.0
AMS 16	< 2.4	< 159	< 7.3	12 ± 8.1	< 11
AMS17/17A	< 2.4	310 ± 118	< 6.4	7.4 ± 4.5	< 8.9
AMS18/18A	< 2.8	358 ± 130	6.9 ± 7.3	17 ± 9.3	< 9.0
AMS 19	< 2.4	237 ± 102	< 6.9	11 ± 7.0	< 7.9
AMS 20	< 2.3	217 ± 106	< 6.4	4.1 ± 3.0	< 7.2
AMS 21	< 2.6	< 122	< 7.1	10 ± 6.0	< 9.9
DCG(c)	9,000,000	2,000,000,000	400,000,000	1,000,000	3,000,000

TABLE 4: Radionuclides in Air, 1996

Concentration ($pCi/m^3 \times 10^{-6}$) (a)					
Sampling Location(b)	Thorium–228	Thorium–230	Thorium–232	Uranium-234	Uranium-235/236
AMS 1/1A	16 ± 6.0	50 ± 19	13 ± 4.8	298 ± 117	32 ± 13
AMS 2	5.7 ± 2.2	10 ± 3.8	4.0 ± 1.5	48 ± 20	10 ± 4.0
AMS 3	7.3 ± 2.8	14 ± 5.1	5.8 ± 2.2	73 ± 30	15 ± 6.0
AMS 4	6.6 ± 2.5	11 ± 4.0	5.9 ± 2.2	28 ± 12	4.6 ± 2.0
AMS 5	7.0 ± 2.3	8.6 ± 3.3	5.6 ± 2.1	26 ± 11	3.4 ± 1.4
AMS 6	6.8 ± 2.6	11 ± 4.1	6.1 ± 2.3	29 ± 12	13 ± 5.4
AMS 7	5.9 ± 2.0	9.2 ± 3.2	5.9 ± 1.9	22 ± 8.7	2.9 ± 1.4
AMS 8A	7.0 ± 2.6	21 ± 7.6	6.3 ± 2.4	154 ± 57	26 ± 10
AMS 9B	7.2 ± 3.0	18 ± 7.0	6.9 ± 2.7	161 ± 59	18 ± 7.2
AMS 10	9.0 ± 3.3	13 ± 4.8	8.3 ± 3.1	21 ± 8.6	2.2 ± 1.1
AMS 11	6.8 ± 3.0	8.6 ± 4.0	6.1 ± 2.6	13 ± 5.4	1.5 ± 0.8
AMS 12	5.5 ± 2.3	7.9 ± 3.4	5.0 ± 2.1	10 ± 4.6	1.1 ± 0.7
AMS 13	8.3 ± 3.1	11 ± 4.3	6.3 ± 2.4	24 ± 9.7	4.0 ± 1.8
AMS 14	6.9 ± 2.4	9.0 ± 32	5.4 ± 1.9	16 ± 6.7	1.6 ± 0.9
AMS 16	9.3 ± 3.4	9.5 ± 3.7	7.8 ± 2.9	11 ± 5.2	2.0 ± 1.0
AMS17/17A	6.9 ± 2.7	13 ± 4.9	6.1 ± 2.3	39 ± 16	4.5 ± 2.0
AMS18/18A	14 ± 5.3	28 ± 9.5	12 ± 4.3	88 ± 33	25 ± 9.5
AMS 19	6.2 ± 2.4	8.3 ± 3.4	5.0 ± 1.9	36 ± 14	5.8 ± 2.4
AMS 20	5.0 ± 2.1	9.1 ± 3.7	5.0 ± 1.9	25 ± 9.3	8.0 ± 3.1
AMS 21	11 ± 4.0	11 ± 4.5	8.7 ± 3.3	14 ± 6.2	1.2 ± 0.8
DCG(c)	40,000	40,000	7,000	90,000	100,000

TABLE 4: Radionuclides in Air, 1996

Concentration ($pCi/m^3 \times 10^{-6}$) (a)			
Sampling Location (b)	**Uranium-238**	**Plutonium-238**	**Plutonium-239/240**
AMS 1/1A	423 ± 167	< 0.2	0.4 ± 0.3
AMS 2	50 ± 20	< 0.2	< 0.2
AMS 3	78 ± 33	< 0.4	0.4 ± 0.3
AMS 4	25 ± 11	< 0.2	< 0.2
AMS 5	29 ± 11	< 0.3	< 0.2
AMS 6	34 ± 14	< 0.3	< 0.2
AMS 7	21 ± 8.2	< 0.3	< 0.3
AMS 8A	152 ± 57	< 0.6	< 0.6
AMS 9B	154 ± 57	< 0.8	< 0.6
AMS 10	25 ± 10	< 0.3	< 0.2
AMS 11	12 ± 4.9	< 0.4	< 0.4
AMS 12	11 ± 4.6	< 0.4	0.9 ± 0.6
AMS 13	24 ± 9.4	< 0.4	< 0.4
AMS 14	18 ± 7.1	< 0.3	< 0.4
AMS 16	10 ± 4.5	< 0.4	< 0.4
AMS17/17A	60 ± 23	< 0.4	< 0.4
AMS18/18A	233 ± 85	< 0.4	< 0.4
AMS 19	34 ± 13	< 0.3	< 0.3
AMS 20	27 ± 11	< 0.3	< 0.4
AMS 21	15 ± 6.4	< 0.3	< 0.4
DCG(c)	100,000	30,000	20,000

(a) Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(b) See Figure 22 on page 87 for sampling locations.

(c) Derived concentration guides from DOE Order 5400.5, "Radiation Protection of the Public Environment," February 1990. Continuous inhalation of this concentration will result in a committed effective dose equivalent of 100 mrem (1 mSv).

Table 5: Plant 1 Monitoring Results, 1996

Uranium in Air

Sampling Location[a]	Number of Samples	Concentration ($pCi/m^3 \times 10^{-6}$)[b]		Percent of Standard[c]	
		Maximum	Average	Maximum	Average
P1-1	51	6,100	1,000	6	1
P1-2	52	4,100	860	4	1
P1-3	52	7,300	740	7	1
P1-4	52	17,000	2,800	17	3

(a) See Figure 25 on page 91 for sampling locations.

(b) The amount of uranium in each sample is chemically determined and converted to units of activity using the conversion constant of 0.68 pCi/ug (natural uranium).

(c) Standard is based on 100,000 x 10-6 pCi/m^3 per year at the FEMP boundary, as listed in DOE Order 5400.5, "Radiation Protection of the Public and Environment."

Table 6: Plant 4 Monitoring Results, 1996

Uranium in Air

Sampling Location[a]	Number of Samples[b]	Concentration ($pCi/m^3 \times 10^{-6}$)[c]		Percent of Standard[d]	
		Maximum	Average	Maximum	Average
P4-1	44	15,000	2,800	15	3
P4-2	45	83,000	6,500	83	7
P4-3	44	19,000	3,000	19	3
P4-4	45	40,000	6,300	40	6
P4-5	45	151,000	19,000	151	19
P4-6	45	33,000	4,000	33	4
P4-7	45	31,000	5,000	31	5

(a) See Figure 26 on page 92 for sampling locations.

(b) Partial year results, 1/05/96 through 11/08/96.

(c) The amount of uranium in each sample is chemically determined and converted to units of acitivity using the conversion constant of 0.68 pCi/ug (natural uranium).

(d) Standard is based on 100,000 x 10-6 pCi/m^3 per year at the FEMP boundary, as listed in DOE Order 5400.5, "Radiation Protection of the Public and Environment."

TABLE 7: Total Uranium in Grass and Soil, 1996

Sampling Location[a]	Distance from Center of the FEMP (km)	Grass Uranium Concentration (pCi/g dry)[b]	Soil Uranium Concentration (pCi/g dry)[b]
Fenceline			
3	0.4	0.068 ± 0.0021	27.0 ± 1.7
1C	0.5	0.039 ± 0.0011	14.9 ± 1.0
9B	0.5	0.066 ± 0.002	21.0 ± 1.3
41	0.6	0.13 ± 0.0039	23.0 ± 1.5
6	0.6	0.081 ± 0.0024	7.4 ± 0.2
8A	0.6	0.34 ± 0.01	18.3 ± 1.2
4	0.7	0.016 ± 0.00088	2.9 ± 0.07
2	0.8	0.047 ± 0.0014	8.1 ± 0.22
5	0.8	0.017 ± 0.00055	5.8 ± 0.15
7	0.8	0.011 ± 0.00041	3.5 ± 0.09
Offsite			
15	1.0	0.0074 ± 0.0003	1.8 ± 0.05
24	1.4	0.022 ± 0.00068	3.8 ± 0.09
33	2.3	0.0065 ± 0.00026	2.2 ± 0.06
13	2.6	0.025 ± 0.00081	3.5 ± 0.1
18	3.4	0.061 ± 0.002	1.5 ± 0.05
40	42	0.14 ± 0.0045	1.6 ± 0.04

(a) Locations (see Figure 27 on page 93) are listed in order of increasing distance from the center of the FEMP former production area.

(b) To obtain Bq/g, multiply pCi/g by 0.037. The plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

TABLE 8: Total Uranium in Produce and Soil, 1996

Sampling Location[a]	Distance from Center of the FEMP (km)	Concentration (pCi/g dry) [b]
Soil		
19 K2	1.4	3.58 ± 0.12
9	1.6	1.62 ± 0.1
14 K1	1.6	3.31 ± 0.11
23	1.6	1.89 ± 0.07
24 K3	1.6	3.24 ± 0.11
4	1.9	2.09 ± 0.06
18 K4	1.9	3.45 ± 0.12
18 K5	1.9	2.70 ± 0.09
18 K6	1.9	3.24 ± 0.11
18 K7	1.9	1.69 ± 0.06
6	2.0	6.01 ± 0.18
20	2.1	3.31 ± 0.11
20	2.1	3.31 ± 0.11
21	2.4	2.64 ± 0.1
21	2.4	1.96 ± 0.07
5	2.9	1.08 ± 0.07
12	3.6	2.16 ± 0.06
13	3.8	2.09 ± 0.06
10	4.0	1.49 ± 0.05
7	4.9	1.82 ± 0.06
35	14.5	2.09 ± 0.06
17	16.0	1.49 ± 0.04
17	16.0	0.68 ± 0.04
36	35.0	1.96 ± 0.06
22	42.0	3.31 ± 0.11
34	42.0	1.76 ± 0.05

Sampling Location[a]	Concentration (pCi/g[c]
Tomatoes	
9	0.0057 ± 0.00023
4	0.0015 ± 0.000049
5	0.0014 ± 0.000071
12	0.00028 ± 0.000016
13	0.00069 ± 0.000034
10	0.00069 ± 0.000034
7	0.0002 ± 0.00002
35	0.0022 ± 0.000095
17	0.047 ± 0.0037
34	0.0012 ± 0.000046
Green Peppers	
4	0.00021 ± 0.000021
6	0.00038 ± 0.000019
5	0.0016 ± 0.00008
12	0.0044 ± 0.00019
36	0.00041 ± 0.000021
Potatoes	
6	0.0011 ± 0.00011
17	0.0011 ± 0.00011
Apples	
9	0.0023 ± 0.00011
13	0.0012 ± 0.000046
10	0.00014 ± 0.000014
7	0.00016 ± 0.000016
17	0.0055 ± 0.00028

Sampling Location[a]	Concentration (pCi/g)[c]
Corn	
14	0.0015 ± 0.000092
24	0.0011 ± 0.000075
4	0.0011 ± 0.00011
18	0.0018 ± 0.00013
18	0.0015 ± 0.000098
6	0.00075 ± 0.000045
20	0.0015 ± 0.0001
21	0.00086 ± 0.000086
12	0.002 ± 0.00009
13	0.0013 ± 0.000038
10	0.00091 ± 0.000037
35	0.00075 ± 0.00003
17	0.00088 ± 0.000044
22	0.0014 ± 0.000055
34	0.00023 ± 0.000023
Green Beans	
4	0.00056 ± 0.000056
6	0.002 ± 0.0001
5	0.0018 ± 0.00006
17	0.0021 ± 0.00011
34	0.0017 ± 0.000069
Cabbage	
12	0.0031 ± 0.00013
35	0.0015 ± 0.000075
17	0.001 ± 0.000051

TABLE 8: Total Uranium in Produce and Soil, 1996

Sampling Location[a]	Concentration (pCi/g)[c]
Soybeans	
19	0.005 ± 0.0002
23	0.0042 ± 0.00042
18	0.005 ± 0.00025
18	0.011 ± 0.00056
20	0.0057 ± 0.00028
21	0.0049 ± 0.00015

Sampling Location[a]	Concentration (pCi/g)[c]
Squash/Zucchini	
9	0.00082 ± 0.000041
6	0.00036 ± 0.000036
5	0.00067 ± 0.000033
10	0.00088 ± 0.00003
35	0.00066 ± 0.000022
17	0.00052 ± 0.000026

Sampling Location	Concentration (pCi/g)[c]
Cucumber	
9	0.0012 ± 0.00005
4	0.00049 ± 0.000024
6	0.00026 ± 0.00001
5	0.00023 ± 0.000011
13	0.00058 ± 0.000029
36	0.00052 ± 0.000026

(a) Locations (see Figure 29 on page 97) are listed in order of increasing distance from the center of the FEMP former production area.

(b) Soil concentrations are in dehydrated form.

(c) To obtain Bq/g, multiply pCi/g by 0.037. The plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

TABLE 9: Environmental TLD Direct Radiation Measurements, 1996

Location Description[a]	Location Number	1996 Dose Rate (mrem/yr)[b,c]	1995 Dose Rate (mrem/yr)[b,c]
Fenceline			
AMS 2	2	73 ± 7.0	70 ± 4.1
AMS 3	3	67 ± 6.4	62 ± 3.6
AMS 4	4	64 ± 6.1	61 ± 3.6
AMS 5	5	67 ± 6.5	65 ± 3.8
AMS 6	6	75 ± 7.2	70 ± 4.1
AMS 7	7	67 ± 6.5	64 ± 3.7
AMS 8A (d)	8A	77 ± 7.5	N/A
AMS 9B (d)	9B	83 ± 8.0	N/A
FEMP fenceline near K-65 silos	13	71 ± 6.9	68 ± 4.0
FEMP fenceline near K-65 silos	14	71 ± 6.9	66 ± 3.9
FEMP fenceline near K-65 silos	15	73 ± 7.0	68 ± 4.0
FEMP fenceline near K-65 silos	16	78 ± 7.5	70 ± 4.1
FEMP fenceline near K-65 silos	17	70 ± 6.8	67 ± 3.9
Onsite			
AMS 1A (d)	1A	140 ± 14	130 ± 7.8
AMS 1B (d)	1B	82 ± 7.9	N/A
AMS 8 (d)	8	66 ± 6.4	64 ± 3.8
AMS 9A (d)	9A	88 ± 8.5	89 ± 5.2
K-65 perimeter fence	22	630 ± 60	450 ± 26
K-65 perimeter fence	23	630 ± 61	430 ± 25
K-65 perimeter fence	24	460 ± 44	280 ± 16
K-65 perimeter fence	25	560 ± 54	330 ± 19
K-65 perimeter fence	26	330 ± 32	250 ± 14
OSH Building, Room 218[d]	32	55 ± 5.4	51 ± 3.0

TABLE 9: Environmental TLD Direct Radiation Measurements, 1996

Location Description[a]	Location Number	1996 Dose Rate (mrem/yr)[b,c]	1995 Dose Rate (mrem/yr)[b,c]
Offsite			
AMS 10	10	55 ± 5.3	52 ± 3.0
AMS 11	11	67 ± 6.5	64 ± 3.7
AMS 13	12	60 ± 5.8	56 ± 3.3
Westwood, OH	18	74 ± 7.2	71 ± 4.2
Brookville, IN	19	63 ± 6.0	59 ± 3.5
Miamitown, OH	20	59 ± 5.7	56 ± 3.3
Ft. Thomas, KY	21	68 ± 6.6	66 ± 3.9
AMS 12	27	62 ± 5.9	59 ± 3.4
AM Field Office, Harrison, OH	30	60 ± 5.8	58 ± 3.4
Fairfield, OH	33	69 ± 6.7	68 ± 4.0

(a) See Figure 30 on page 99 for locations.

(b) Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(c) Dose is calculated from the sum of quarterly measurements at each location.

(d) Relocated TLDs with dose rates extrapolated for the year.

TABLE 10: NPDES Summary Data, 1996

Sampling Location and Parameter	Units[a]	Monitoring Frequency	Daily Monitoring Results			Permit Limits[c]		Percent Compliance[d]
			Minimum	Maximum	Average[b]	Daily Maximum	Monthly Average	
Discharge 4001 (Parshall Flume to Great Miami River)								
Flow Rate	MGD	Continuous	0.122	4.757	2.388	N/A	N/A	N/A
pH	S.U.	Continuous	6.6	9.9	N/A	Range = 6.5 to 9.0		100.00
Temperature	C	Daily Grab	5	26	15	N/A	N/A	N/A
Oil & Grease	mg/l	Weekly Grab	< 5	< 5.0	< 5	10	10	100.00
Dissolved Oxygen	mg/l	Weekly Grab	< 5	12.4	9.6	Minimum = 5.0		97.96 (f)
Suspended Solids	mg/l	Weekly Comp	< 2	37.8	< 3.7	45	30	100.00
BOD-C	mg/l	Weekly Comp	< 2	8.6	< 2.1	30	20	100.00
BOD-C	kg/d	Weekly Comp	< 1.21	42.62	< 18.43	315	210	100.00
Oil & Grease	kg/d	Weekly Grab	< 2.56	< 79.22	< 44.09	105	105	100.00
Suspended Solids	kg/d	Weekly Comp	< 1.02	283.19	< 33.7	473	315	100.00
Copper	µg/l	Weekly Comp	< 14	15.7	< 14	N/A	N/A	N/A
Ammonia	mg/l	Weekly Comp	< 0.1	2.65	< 0.26	N/A	N/A	N/A
Fluoride	mg/l	Weekly Comp	0.25	2.32	0.91	N/A	N/A	N/A
Chromium (+6)	µg/l	Weekly Grab	< 6	< 6.0	< 6	N/A	N/A	N/A
Nitrite + Nitrate	mg/l	Weekly Comp	1.3	18.5	7.2	N/A	N/A	N/A
CER	TUa	Bimonthly Comp	10 %	20 %	< 12 %	Less than 50% mortality		100.00
PI	TUa	Bimonthly Comp	10 %	< 10%	< 10 %	Less than 50% mortality		100.00
							Percent Compliance	**99.94**
Discharge 4002 (Spillway to Paddys Run)								
Flow Rate	MGD	Estimate	1.462	3.168	2.254	N/A	N/A	N/A
pH	S.U.	Event/Grab	7.8	8.2	N/A	Range = 6.5 to 9.0		100.00
Oil & Grease	mg/l	Event/Grab	< 5.0	< 5.0	< 5.0	10	N/A	100.00
Chromium (+6)	µg/l	Event/Grab	< 6.0	< 6.0	< 6.0	19	N/A	100.00
Copper	µg/l	Event/Comp	< 14.0	18.9	< 15.3	45	N/A	100.00
Nickel	µg/l	Event/Comp	< 17.0	< 17.0	< 17.0	3137	N/A	100.00
Silver	µg/l	Event/Comp	< 10.0	< 10.0	< 10.0	11.6	N/A	100.00
Chromium (T Rec)	µg/l	Event/Comp	< 6.0	< 6.0	< 6.0	3986	N/A	100.00
Suspended Solids	mg/l	Event/Comp	24.0	37.0	27.0	50	N/A	100.00
Phosphorus	mg/l	Event/Comp	0.14	0.19	0.17	N/A	N/A	N/A
Ammonia	mg/l	Event/Comp	< 0.10	0.27	0.15	N/A	N/A	N/A
Fluoride	mg/l	Event/Comp	0.40	0.52	0.44	N/A	N/A	N/A
Nitrite & Nitrate	mg/l	Event/Comp	0.9	1.7	1.2	N/A	N/A	N/A
Chlorine - Residual	mg/l	Event/Grab	0.01	0.01	0.01	N/A	N/A	N/A
							Percent Compliance	**100.00**

TABLE 10: NPDES Summary Data, 1996

Sampling Location and Parameter	Units[a]	Monitoring Frequency	Daily Monitoring Results			Permit Limits[c]		Percent Compliance[d]
			Minimum	Maximum	Average[b]	Daily Maximum	Monthly Average	
Discharge 4003 (Stormwater Runoff to Paddys Run)								
Flow Rate	MGD	Estimate	3.277	5.183	4.230	N/A	N/A	N/A
pH	S.U.	2/Year Grab	7.7	8.4	N/A	Range = 6.5 to 9.0		100.00
Oil & Grease	mg/l	2/Year Grab	< 5.0	< 5.0	< 5.0	N/A	N/A	N/A
Chromium (+6)	µg/l	2/Year Grab	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Lead	µg/l	2/Year Comp	< 30.5	< 35.6	< 32.5	N/A	N/A	N/A
Copper	µg/l	2/Year Comp	< 14.0	15.8	< 14.7	N/A	N/A	N/A
Nickel	µg/l	2/Year Comp	< 17.0	< 17.0	< 17.0	N/A	N/A	N/A
Silver	µg/l	2/Year Comp	< 10.0	< 10.0	< 10.0	N/A	N/A	N/A
Ammonia	mg/l	2/Year Comp	< 0.10	0.12	< 0.11	N/A	N/A	N/A
Fluoride	mg/l	2/Year Comp	0.21	0.22	0.21	N/A	N/A	N/A
Phosphorus	mg/l	2/Year Comp	0.52	0.90	0.67	N/A	N/A	N/A
Chromium (T Rec)	µg/l	2/Year Comp	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Suspended Solids	mg/l	2/Year Comp	252.0	304.0	272.0	N/A	N/A	N/A
Nitrite + Nitrate	mg/l	2/Year Comp	2.0	3.6	2.6	N/A	N/A	N/A
Discharge 4004 (Stormwater Runoff from Inactive Flyash Pile)								
Flow Rate	MGD	Estimate	0.081	0.128	0.105	N/A	N/A	N/A
pH	S.U.	2/Year Grab	7.6	8.2	N/A	Range = 6.5 to 9.0		100.00
Oil & Grease	mg/l	2/Year Grab	< 5.0	< 5.0	< 5.0	N/A	N/A	N/A
Chromium (+6)	µg/l	2/Year Grab	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Lead	µg/l	2/Year Comp	< 35.6	38.4	< 37.3	N/A	N/A	N/A
Copper	µg/l	2/Year Comp	< 14.0	< 14.0	< 14.0	N/A	N/A	N/A
Nickel	µg/l	2/Year Comp	< 17.0	< 17.0	< 17.0	N/A	N/A	N/A
Silver	µg/l	2/Year Comp	< 10.0	< 10.0	< 10.0	N/A	N/A	N/A
Ammonia	mg/l	2/Year Comp	< 0.10	< 0.10	< 0.10	N/A	N/A	N/A
Fluoride	mg/l	2/Year Comp	0.20	0.28	0.23	N/A	N/A	N/A
Phosphorus	mg/l	2/Year Comp	0.5	1.1	0.7	N/A	N/A	N/A
Chromium (T Rec)	µg/l	2/Year Comp	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Suspended Solids	mg/l	2/Year Comp	132.0	200.0	174.0	N/A	N/A	N/A
Nitrite + Nitrate	mg/l	2/Year Comp	1.5	2.7	2.0	N/A	N/A	N/A

TABLE 10: NPDES Summary Data, 1996

Sampling Location and Parameter	Units[a]	Monitoring Frequency	Daily Monitoring Results Minimum	Maximum	Average[b]	Permit Limits[c] Daily Maximum	Monthly Average	Percent Compliance[d]
Discharge 4005 (Stormwater Runoff from Area West of Former Production Area)								
Flow Rate	MGD	Estimate	0.490	0.773	0.632	N/A	N/A	N/A
pH	S.U.	2/Year Grab	7.5	8.0	N/A	Range = 6.5 to 9.0		100.00
Oil & Grease	mg/l	2/Year Grab	< 5.0	< 5.0	< 5.0	N/A	N/A	N/A
Chromium (+6)	µg/l	2/Year Grab	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Lead	µg/l	2/Year Comp	34.0	< 35.6	< 34.6	N/A	N/A	N/A
Copper	µg/l	2/Year Comp	< 14.0	< 14.0	< 14.0	N/A	N/A	N/A
Nickel	µg/l	2/Year Comp	< 17.0	< 17.0	< 17.0	N/A	N/A	N/A
Silver	µg/l	2/Year Comp	< 10.0	< 10.0	< 10.0	N/A	N/A	N/A
Ammonia	mg/l	2/Year Comp	0.11	0.29	0.22	N/A	N/A	N/A
Fluoride	mg/l	2/Year Comp	0.42	0.49	0.46	N/A	N/A	N/A
Phosphorus	mg/l	2/Year Comp	0.36	0.56	0.44	N/A	N/A	N/A
Chromium (T Rec)	µg/l	2/Year Comp	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Suspended Solids	mg/l	2/Year Comp	54.0	132.0	84.0	N/A	N/A	N/A
Nitrite + Nitrate	mg/l	2/Year Comp	1.1	1.6	1.4	N/A	N/A	N/A
Discharge 4006 (Stormwater Runoff from North End of Property)								
Flow Rate	MGD	Estimate	1.162	1.838	1.500	N/A	N/A	N/A
pH	S.U.	2/Year Grab	7.4	8.1	N/A	Range = 6.5 to 9.0		100.00
Oil & Grease	mg/l	2/Year Grab	< 5.0	< 5.0	< 5.0	N/A	N/A	N/A
Chromium (+6)	µg/l	2/Year Grab	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Lead	µg/l	2/Year Comp	< 35.6	68.1	< 55.5	N/A	N/A	N/A
Copper	µg/l	2/Year Comp	< 14.0	< 14.0	< 14.0	N/A	N/A	N/A
Nickel	µg/l	2/Year Comp	< 17.0	< 17.0	< 17.0	N/A	N/A	N/A
Silver	µg/l	2/Year Comp	< 10.0	< 10.0	< 10.0	N/A	N/A	N/A
Ammonia	mg/l	2/Year Comp	< 0.10	0.27	< 0.20	N/A	N/A	N/A
Fluoride	mg/l	2/Year Comp	0.21	0.29	0.24	N/A	N/A	N/A
Phosphorus	mg/l	2/Year Comp	0.36	0.66	0.54	N/A	N/A	N/A
Chromium (T Rec)	µg/l	2/Year Comp	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Suspended Solids	mg/l	2/Year Comp	33.0	134.0	95.0	N/A	N/A	N/A
Nitrite + Nitrate	mg/l	2/Year Comp	0.6	2.1	1.5	N/A	N/A	N/A

TABLE 10: NPDES Summary Data, 1996

Sampling Location and Parameter	Units[a]	Monitoring Frequency	Daily Monitoring Results Minimum	Maximum	Average[b]	Permit Limits[c] Daily Maximum	Monthly Average	Percent Compliance[d]
Discharge 4589 (Sewage Treatment Plant Sludge after Dewatering)								
Lead	mg/kg	1/Year	No Sludge Removed During 1996			N/A	N/A	N/A
Zinc	mg/kg	1/Year				N/A	N/A	N/A
Copper	mg/kg	1/Year				N/A	N/A	N/A
Nickel	mg/kg	1/Year				N/A	N/A	N/A
Mercury	mg/kg	1/Year				N/A	N/A	N/A
Cadmium	mg/kg	1/Year				N/A	N/A	N/A
Chromium	mg/kg	1/Year				N/A	N/A	N/A
Sludge Weight	Tons	1/Month				N/A	N/A	N/A
Discharge 4601 (Sewage Treatment Plant)								
Flow Rate	MGD	Continuous	0.020	0.232	0.088	N/A	N/A	N/A
pH	S.U.	Daily Grab	6.5	8.2	N/A	N/A	N/A	N/A
BOD-5	mg/l	2/Week Comp	< 2.0	239.4	< 5.8	40	20	96.58 (g)
Ammonia	mg/l	2/Month Comp	< 0.10	6.48	1.4	N/A	N/A	N/A
Fecal Coliform (e)	#Col/100 ml	Weekly Grab	< 20	> 9000	< 391	2000	1000	96.88 (h)
Suspended Solids	mg/l	2/Week Comp	< 2.0	28.4	4.3	40	20	100.00
BOD-5	kg/d	2/Week Comp	< 0.18	92.43	< 2.12	24.2	12.1	98.29 (i)
Suspended Solids	kg/d	2/Week Comp	< 0.33	13.33	1.60	24.2	12.1	100.00
Zinc	µg/l	2/Year Comp	27.8	35.5	31.8	N/A	N/A	N/A
Lead	µg/l	2/Year Comp	< 30.5	< 35.6	< 33.1	N/A	N/A	N/A
Copper	µg/l	2/Year Comp	< 14.0	16.3	< 15.2	N/A	N/A	N/A
Nickel	µg/l	2/Year Comp	< 17.0	< 17.0	< 17.0	N/A	N/A	N/A
Cadmium	µg/l	2/Year Comp	< 5.0	< 5.0	< 5.0	N/A	N/A	N/A
Mercury	µg/l	2/Year Comp	< 0.2	< 0.2	< 0.2	N/A	N/A	N/A
Chromium (T Rec)	µg/l	2/Year Comp	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
Chromium (+6)	µg/l	2/Year Grab	< 6.0	< 6.0	< 6.0	N/A	N/A	N/A
							Average Percent Compliance	**98.60**
Discharge 4901 (Downstream Monitoring for Acute Toxicity)								
CER	% aff	Bimonthly Comp	0 %	0 %	0 %	Less than 50% mortality		100.00
PI	% aff	Bimonthly Comp	0 %	0 %	0 %	Less than 50% mortality		100.00
							Average Percent Compliance	**100.00**

TABLE 10: NPDES Summary Data, 1996

(a) MGD stands for million gallons per day, and S.U. stands for standard units.

(b) Flow-weighted daily averages are shown as less than (<) if more than one quarter of the values were less than the detection limit.

(c) Values have been rounded for consistency of data presentation.

(d) Percent compliance is determined by comparing the noncompliance with the compliance opportunities.

(e) Geometric mean due to Lognormal Distribution.

(f) 3 daily minimum noncompliance events (06/23/96, 06/24/96, and 06/25/96).

(g) 3 daily maximum noncompliance events (06/05/96, 06/17/96, and 06/19/96) and 1 monthly average noncompliance event (June 1996).

(h) 1 daily maximum noncompliance event (06/24/96).

(i) 1 daily maximum noncompliance event (06/19/96) and 1 monthly average noncompliance event (June 1996).

N/A Not applicable.

TABLE 11: Radionuclides Discharged to the Great Miami River, 1996

Parshall Flume, Outfall 4001[a]

Radionuclide[b]	Total Curies 1996	1996 Average Concentration (pCi/L)[c]	DCG[d] (pCi/L)	Percent of DCG[e]
Strontium-90	0.00054	0.45	1000	0.05
Technetium-99	< 0.37	< 112	100000	< 0.11
Actinium-228[f]	0.0097	2.94	60000	0.01
Radium–224[g]	0.00017	0.05	400	0.02
Radium–226	0.00065	0.2	100	0.20
Radium–228	< 0.0097	< 2.94	100	< 2.94
Thorium–228	< 0.00017	< 0.05	400	< 0.01
Thorium–230	< 0.0001	< 0.03	300	< 0.01
Thorium–231[h]	0.0018	0.55	100000	0.01
Thorium–232	< 0.000057	< 0.02	50	< 0.04
Thorium–234[i]	0.042	12.57	10000	0.13
Uranium–234	< 0.041	< 12.31	500	< 2.46
Uranium–235	0.0018	0.55	600	0.09
Uranium–236	0.0009	0.29	500	0.06
Uranium–238	0.042	12.57	600	2.10

a) Effective November 1, 1995, Parshall Flume replaced Manhole-175 as monitoring location for discharges to the Great Miami River.

(b) Radionuclide concentrations in plant effluent discharged to the Great Miami River are determined from analysis of monthly or quarterly composites of 24-hour continuous sampling devices.

(c) Averages are flow-weighted. To obtain Bq/L, multiply by 0.037.

(d) As stated in DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

(e) Percent of standard relates to the average concentration. Where less than (<) is reported, the maximum possible value is assumed.

(f) Considered in radioactive decay equilibrium with radium-228.

(g) Considered in radioactive decay equilibrium with thorium-228.

(h) Considered in radioactive decay equilibrium with uranium-235.

(i) Considered in radioactive decay equilibrium with uranium-238.

TABLE 12: Radionuclides in Surface Water, 1996

Parameter	Sampling Location[a]	Number of Results	Concentration (pCi/L)[b]			Percent of DCG			
			Minimum	Maximum	Average	Minimum	Maximum	Average	DCG[c]
Great Miami River									
Total Uranium									
Upstream of Effluent Line	W1	49	0.6 ± 0.1	1.5 ± 0.2	1.1 ± 0.2	0.11	0.27	0.20	550
Downstream of Effluent Line	W3	49	0.6 ± 0.1	1.4 ± 0.2	1.1 ± 0.3	0.11	0.26	0.20	550
Downstream of Effluent Line	W4	48	0.6 ± 0.1	6.8 ± 1.4	1.0 ± 0.3	0.11	1.23	0.18	550
Radium–226[d]									
Upstream of Effluent Line	W1	12	0.120 ± 0.042	0.350 ± 0.100	0.210 ± 0.018	0.12	0.35	0.21	100
Downstream of Effluent Line	W3	12	0.140 ± 0.049	0.340 ± 0.089	0.220 ± 0.016	0.14	0.34	0.22	100
Downstream of Effluent Line	W4	12	0.170 ± 0.050	0.480 ± 0.120	0.240 ± 0.018	0.17	0.48	0.24	100
Radium–228[d]									
Upstream of Effluent Line	W1	12	< 0.230	4.000 ± 1.500	< 1.730	< 0.23	4.00	< 1.73	100
Downstream of Effluent Line	W3	12	< 0.270	7.200 ± 2.200	< 1.710	< 0.27	7.20	< 1.71	100
Downstream of Effluent Line	W4	12	< 0.250	4.600 ± 1.700	< 1.620	< 0.25	4.60	< 1.62	100
Strontium–90[d]									
Upstream of Effluent Line	W1	2	0.15 ± 0.050	0.54 ± 0.34	0.35 ± 0.34	0.015	0.054	0.035	1,000
Downstream of Effluent Line	W3	2	0.12 ± 0.047	0.43 ± 0.36	0.28 ± 0.36	0.01	0.04	0.03	1,000
Downstream of Effluent Line	W4	2	0.16 ± 0.007	0.45 ± 0.32	0.31 ± 0.32	0.02	0.05	0.03	1,000
Cesium–137[d]									
Upstream of Effluent Line	W1	2	< 3.2	< 4.0	< 3.6	< 0.107	< 0.133	< 0.120	3,000
Downstream of Effluent Line	W3	2	< 4.0	4.2 ± 4.2	< 4.1	< 0.133	< 0.140	< 0.137	3,000
Downstream of Effluent Line	W4	2	< 2.9	< 4.0	3.5	< 0.097	< 0.133	< 0.115	3,000
Technetium–99[d]									
Upstream of Effluent Line	W1	2	< 8.3	< 14.0	< 11.2	< 0.008	< 0.014	< 0.011	100,000
Downstream of Effluent Line	W3	2	< 8.2	< 10.0	< 9.1	< 0.008	< 0.010	< 0.009	100,000
Downstream of Effluent Line	W4	2	< 8.0	< 11.0	< 9.5	< 0.008	< 0.011	< 0.010	100,000

TABLE 12: Radionuclides in Surface Water, 1996

Parameter	Sampling Location[a]	Number of Results	Concentration (pCi/L)[b]			Percent of DCG			
			Minimum	Maximum	Average	Minimum	Maximum	Average	DCG[c]
Paddys Run									
Total Uranium									
Upstream of the FEMP	W5	45	0.3 ± 0.1	0.9 ± 0.1	0.7 ± 0.2	0.05	0.16	0.12	550
Onsite	W9	46	0.3 ± 0.1	3.6 ± 0.5	1.1 ± 1.5	0.05	0.65	0.21	550
Onsite	W10-US	26	0.7 ± 0.1	12.2 ± 1.4	1.8 ± 3.0	0.12	2.21	0.32	550
Onsite	W10	29	0.5 ± 0.1	328.4 ± 16.2	12.8 ± 18.9	0.10	59.71	2.33	550
Onsite	W10-DD	45	31.1 ± 4.1	530.4 ± 26.4	56.8 ± 2.0	5.65	96.44	10.32	550
Onsite	W10-DS	26	0.7 ± 0.1	17.6 ± 2.0	2.7 ± 4.3	0.12	3.19	0.49	550
Onsite	W11	25	1.0 ± 0.2	4.0 ± 0.6	1.8 ± 1.4	0.18	0.72	0.33	550
Downstream of the FEMP	W7	23	0.9 ± 0.2	4.0 ± 0.6	2.0 ± 1.4	0.17	0.72	0.37	550
Downstream of the FEMP	W8	36	1.1 ± 0.2	5.5 ± 0.8	2.2 ± 1.4	0.20	1.00	0.39	550
Radium–226[d]									
Upstream of the FEMP	W5	6	0.026 ± 0.018	0.110 ± 0.048	0.060 ± 0.009	0.03	0.11	0.06	100
Downstream of the FEMP	W7	7	0.022 ± 0.027	0.170 ± 0.054	0.070 ± 0.008	0.02	0.17	0.07	100
Downstream of the FEMP	W8	5	0.041 ± 0.020	0.170 ± 0.054	0.110 ± 0.012	0.04	0.17	0.11	100
Radium–228[d]									
Upstream of the FEMP	W5	6	< 0.320	3.300 ± 2.300	< 1.970	< 0.32	3.30	< 1.97	100
Downstream of the FEMP	W7	7	< 0.240	8.000 ± 2.800	< 2.350	< 0.24	8.00	< 2.35	100
Downstream of the FEMP	W8	5	< 0.240	8.000 ± 2.800	< 1.340	< 0.24	8.00	< 1.34	100

(a) See Figure 35 on page 108 for sampling locations.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) Standards as listed in DOE Order 5400.5, "Radiation Protection of the Public and Environment." The standards are based on drinking 730 liters (about 200 gallons) of water per year. The FEMP compares data from the Great Miami River and Paddys Run to these standards even though neither is designated as a public water supply by OEPA (OEPA Regulations, Vol. 1, 3475–1–21).

(d) Samples are composited as follows:
- One-month composites of weekly samples from W1 and W3, W4 and either W7 or W8.
- Two-month composites of weekly samples from W5.
- Semi-annual composites were used for those isotopes where two samples are recorded.

TABLE 13: Radionuclides in Great Miami River, Paddys Run, and Storm Sewer Outfall Ditch Sediments, 1996

Radionuclide	Number of Samples	Concentration (pCi/g dry)[b,c] Minimum	Maximum	Average for All Samples
Great Miami River North of the Effluent Line [a]				
Total Uranium	1	N/A	N/A	0.88 ± 0.03
Great Miami River South of the Effluent Line [d]				
Radium-226	1	N/A	N/A	0.55 ± 0.06
Thorium-228	1	N/A	N/A	0.45 ± 0.06
Thorium-230	1	N/A	N/A	0.58 ± 0.06
Thorium-232	1	N/A	N/A	0.41 ± 0.04
Total Uranium	3	0.68 ± 0.02	2.38 ± 0.04	0.88 ± 0.05
Paddys Run Background (North of S.R. 126 [e]				
Radium–226	3	0.90 ± 0.13	1.10 ± 0.09	0.98 ± 0.18
Thorium–228	3	0.91 ± 0.10	1.10 ± 0.10	1.00 ± 0.17
Thorium–230	3	0.87 ± 0.08	1.90 ± 0.14	1.32 ± 0.20
Thorium–232	3	0.77 ± 0.08	0.86 ± 0.08	0.81 ± 0.13
Total Uranium	3	1.35 ± 0.04	2.77 ± 0.07	1.82 ± 0.08
Paddys Run North of the Storm Sewer Outfall Ditch				
Radium–226	8	0.72 ± 0.11	1.60 ± 0.20	0.93 ± 0.29
Thorium–228	8	0.58 ± 0.06	1.40 ± 0.13	0.82 ± 0.22
Thorium–230	8	0.60 ± 0..05	3.40 ± 0.23	1.13 ± 0.30
Thorium–232	8	0.52 ± 0.05	1.10 ± 0.10	0.70 ± 0.18
Total Uranium	8	0.95 ± 0.02	7.43 ± 0.18	2.30 ± 0.22
Storm Sewer Outfall Ditch[e]				
Radium–226	5	0.68 ± 0.12	1.40 ± 0.18	0.97 ± 0.25
Thorium–228	5	0.85 ± 0.07	1.90 ± 0.28	1.26 ± 0.36
Thorium–230	5	1.20 ± 0.10	4.00 ± 0.45	2.44 ± 0.55
Thorium–232	5	0.66 ± 0.07	1.80 ± 0.25	1.13 ± 0.31
Total Uranium	5	2.50 ± 0.06	14.19 ± 0.35	6.89 ± 0.46

TABLE 13: Radionuclides in Great Miami River, Paddys Run, and Storm Sewer Outfall Ditch Sediments, 1996

Radionuclide	Number of Samples	Concentration (pCi/g dry)[b,c] Minimum	Maximum	Average for All Samples
Paddys Run South of Storm Sewer Outfall Ditch[d],[e]				
Radium-226	1	N/A	N/A	0.68 ± 0.11
Thorium-228	1	N/A	N/A	0.65 ± 0.07
Thorium-230	1	N/A	N/A	0.88 ± 0.08
Thorium-232	1	N/A	N/A	0.63 ± 0.06
Total Uranium	7	1.50 ± 0.04	4.50 ± 0.13	2.30 ± 0.19

(a) See Figure 37 on page 112 for sampling locations.

(b) Multiply pCi/g by 0.037 to obtain Bq/g.

(c) The plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(d) Includes OEPA split samples.

(e) Includes QA samples.

TABLE 14: Total Uranium Concentrations in Fish from the Great Miami River, 1996

Sampling Location(a)	Family(b)	Number of Samples	Concentration pCi/g (c)		
			Minimum	Maximum	Geometric Mean
RM 38 Upstream of the Hamilton Dam	1	6	0.0016	0.0042	0.0029
	2	5	0.0015	0.0036	0.0023
	3	4	0.0017	0.0049	0.0029
	4	3	0.0016	0.003	0.002
	5	7	0.00076	0.0033	0.0016
	Location Summary	**25**	**0.00076**	**0.0049**	**0.0022**
RM 24 At the Effluent Line	1	4	0.0016	0.0037	0.0025
	2	11	0.00032	0.003	0.0015
	3	1	0.0047	0.0047	0.0047
	5	4	0.00031	0.0024	0.00089
	6	1	0.002	0.002	0.002
	9	4	0.0012	0.0018	0.0015
	Location Summary	**25**	**0.00031**	**0.0047**	**0.0016**
RM 19 At confluence of Paddys Run and the Great Miami River	1	2	0.0018	0.0038	0.0028
	2	8	0.0014	0.0055	0.0021
	3	7	0.0017	0.012	0.0058
	4	2	0.0007	0.0078	0.0043
	5	4	0.0005	0.003	0.0017
	9	2	0.0015	0.0016	0.0016
	Location Summary	**25**	**0.0005**	**0.012**	**0.0024**

(a) See Figure 38 on page 113 for sampling locations.

(b) Family:

1 = Cyprinidae (carp and shiner)

2 = Catostomidae (carpsucker, redhorse, quillback, and buffalo)

3 = Clupeidae (gizzard shad)

4 = Centrarchidae (bludgill, sunfish, smallmouth and largemouth bass)

5 = Ictaluridae (yellow bullhead and catfish)

6 = Lepisosteidae (longnose gar)

7 = Percicthyidae (white bass). No samples collected from this family.

8 = Percidae (logperch and sauger). No samples collected from this family.

9 = Scianidae (fresh water drum)

(c) Multiply by 0.037 to obtain Bq/g (dry weight).

TABLE 15: Total Uranium in Private Wells, 1996

Well Number[a]	Number of Samples	Concentration (pCi/L)[b] Minimum	Maximum	Average	Percent of Standard[c] Minimum	Maximum	Average
3	11	< 0.1 ± 0.1	0.3 ± 0.1	< 0.1 ± 0.1	< 0.5	2.5	< 0.7
4	11	0.9 ± 0.1	1.4 ± 0.2	1.2 ± 0.2	6.5	10.0	8.7
8	11	0.5 ± 0.1	0.6 ± 0.1	0.5 ± 0.1	3.5	4.5	4.0
9	11	0.9 ± 0.1	1.1 ± 0.2	1.0 ± 0.2	6.5	8.0	7.1
10	10	0.3 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	2.5	3.0	2.9
11	5	1.0 ± 0.1	1.7 ± 0.3	1.3 ± 0.4	7.5	12.5	9.4
12[d]	10	0.9 ± 0.1	87.8 ± 6.8	47.4 ± 8.8	6.5	650.7	351.0
13[d]	12	23.6 ± 2.0	83.1 ± 6.8	60.9 ± 4.5	175.2	615.6	451.3
14	12	1.4 ± 0.2	2.0 ± 0.3	1.7 ± 0.1	10.0	15.0	12.8
15[e]	5	99.3 ± 8.1	108.1 ± 8.8	103.5 ± 14.3	735.8	800.8	766.8
16[e]	4	0.5 ± 0.1	0.9 ± 0.2	0.7 ± 0.3	4.0	7.0	4.9
18[e]	5	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	2.0	2.5	2.4
19[e]	4	< 0.1 ± 0.1	< 0.1 ± 0.1	< 0.1 ± 0.1	< 0.5	< 0.5	< 0.5
21[e]	5	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	1.5	2.5	2.0
22	11	0.5 ± 0.1	0.7 ± 0.1	0.6 ± 0.1	4.0	5.5	4.8
23[e]	5	0.2 ± 0.1	0.9 ± 0.1	0.6 ± 0.2	1.5	6.5	4.2
24[e]	5	0.2 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	1.5	3.0	2.1
25[e]	2	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	1.5	1.5	1.5
26[e]	4	< 0.1 ± 0.1	0.1 ± 0.1	< 0.1 ± 0.1	< 0.5	0.5	< 0.5
28[e]	2	0.3 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	2.0	4.0	3.0
29	11	0.3 ± 0.1	1.3 ± 0.2	0.8 ± 0.2	2.0	9.5	5.9
30[e]	4	0.6 ± 0.1	0.7 ± 0.1	0.7 ± 0.2	4.5	5.5	4.8
32[e]	5	< 0.1 ± 0.1	0.1 ± 0.1	< 0.1 ± 0.1	< 0.5	0.5	< 0.5
33[e]	5	0.3 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	2.5	3.0	2.6
34[e]	6	1.3 ± 0.4	3.0 ± 0.4	2.2 ± 0.4	9.5	22.5	15.9
35[e]	7	0.3 ± 0.1	1.3 ± 0.2	0.9 ± 0.3	2.0	9.5	6.7
36[e]	5	0.6 ± 0.1	0.9 ± 0.1	0.7 ± 0.2	4.5	6.5	5.4
38[e]	2	< 0.1 ± 0.1	< 0.1 ± 0.1	< 0.1 ± 0.1	< 0.5	< 0.5	< 0.5
39[d]	4	3.9 ± 0.6	4.8 ± 0.7	4.3 ± 1.1	28.5	35.5	32.0
40[d]	5	2.0 ± 0.3	3.0 ± 0.5	2.5 ± 0.6	14.5	22.0	18.5
41[e]	5	0.2 ± 0.1	0.5 ± 0.1	0.3 ± 0.2	1.5	3.5	2.5
55[e]	2	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	2.0	2.0	2.0

(a) See Figure 42 on page 127 for well locations. Wells are numbered in order of first time sampled.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) Proposed EPA standard of 13.5 pCi/L (20 ppb).

(d) These wells are used for monitoring purposes only.

(e) No longer sampled due to Public Water Supply Hookup.

TABLE 16: Summary Statistics and Trend Analysis for Routine Monitoring Program Wells Constituent Concentrations Above Final Remediation Levels, 1988–1996 Data

Constituent (FRL)	Well	Location	Number of Samples[a]	Number of Samples Above FRL	Minimum (mg/L)[b,c]	Maximum (mg/L)[d]	Mean (mg/L)	Standard Deviation (mg/L)	Trend
Fluoride (0.89 mg/L)	2754(e)	1							
	2424	2	14	4	0.22	1.6	0.65	0.55	Not significant
	3424	2	13	4	0.37	1.8	0.81	0.56	Not significant
	4424	2	13	4	0.08	1.9	0.72	0.64	Not significant
	2051	3	29	4	0.14	1.2	0.40	0.32	Not significant
	31217	3	13	4	0.16	1.7	0.61	0.62	Not significant
	41217	3	13	4	0.33	2	0.93	0.73	Not significant
	2426	4	14	4	0.045	1.5	0.51	0.57	Not significant
	3426	4	13	4	0.19	1.1	0.49	0.37	Not significant
	4426	4	14	4	0.26	1.9	0.76	0.68	Not significant
	2417	5	17	3	0.055	1.3	0.38	0.43	Not significant
	3417	5	13	1	0.065	0.9	0.37	0.32	Not significant
	2429	6	14	3	0.13	1.2	0.41	0.42	Not significant
	3429	6	13	1	0.09	0.9	0.3	0.2	Not significant
	2430	7	15	4	0.11	1.6	0.50	0.57	Not significant
	4067	7	17	2	0.18	1	0.39	0.28	Not significant
	2431	8	13	3	0.11	1	0.37	0.37	Not significant
	2432	9	14	4	0.12	1.2	0.40	0.40	Not significant
	3432	9	13	2	0.1	1	0.4	0.3	Not significant
	2733	10	14	3	0.055	1.2	0.38	0.37	Not significant
	2398	12	21	2	0.05	0.9	0.3	0.3	Not significant
	3398	12	16	1	0.09	0.9	0.3	0.3	Not significant
	4398	12	14	1	0.1	0.9	0.3	0.3	Not significant
	2434	13	16	2	0.065	1	0.34	0.32	Down, Marginal
	3106	14	24	1	0.075	0.9	0.24	0.24	Not significant

TABLE 16: Summary Statistics and Trend Analysis for Routine Monitoring Program Wells Constituent Concentrations Above Final Remediation Levels, 1988–1996 Data

Constituent (FRL)	Well	Location	Number of Samples[a]	Number of Samples Above FRL	Minimum (mg/L)[b,c]	Maximum (mg/L)[d]	Mean (mg/L)	Standard Deviation (mg/L)	Trend
Antimony (0.006 mg/L)	2754(e)	1							
	2424	2	15	1	0.001	0.0305	0.0120	0.00998	Down, Marginal
	41217	3	13	1	0.001	0.0357	0.0126	0.0120	Down, Significant
	4426	4	16	1	0.001	0.0318	0.0117	0.0107	Down, Significant.
	3417	5	13	1	0.001	0.0392	0.0130	0.0125	Down, Significant
	2432	9	14	1	0.001	0.0305	0.0124	0.0105	Down, Significant
	3070	11	16	2	0.001	0.0305	0.0131	0.00905	Down, Marginal
Arsenic (0.05 mg/L)	2426	4	14	1	0.0008	0.146	0.0108	0.0245	Up, Significant
Beryllium (0.004 mg/L	2754(e)	1							
Cadmium (0.014 mg/L)	2754(e)	1							
	2424	2	15	1	0.0005	0.155	0.00282	0.00393	Down, Significant
	2417	5	15	1	0.0005	0.0163	0.00260	0.00393	Down, Significant
	2733	10	14	1	0.0005	0.0191	0.00305	0.00489	Down, Significant
Chromium (0.022 mg/L)	2754(e)	1							
	41217	3	13	1	0.0014	0.0962	0.00981	0.0260	Not Significant
	2733	10	14	1	0.0014	0.0533	0.00771	0.0135	Not Significant
	2398	12	15	3	0.00145	0.0571	0.0138	0.0197	Up, Marginal
	3398	12	15	1	0.0014	0.0306	0.00427	0.00733	Not Significant
	2106	14	17	1	0.0010	0.0256	0.00474	0.00720	Not Significant
Cobalt (0.17 mg/L)	2754(e)	1							

TABLE 16: Summary Statistics and Trend Analysis for Routine Monitoring Program Wells Constituent Concentrations Above Final Remediation Levels, 1988–1996 Data

Constituent (FRL)	Well	Location	Number of Samples[a]	Number of Samples Above FRL	Minimum (mg/L)[b,c]	Maximum (mg/L)[d]	Mean (mg/L)	Standard Deviation (mg/L)	Trend
Lead (0.002 mg/L)	2754(e)	1							
	2424	2	15	1	0.0003	0.0027	0.00093	0.00062	Down, Marginal
	4424	2	13	1	0.0003	0.013	0.0017	0.0034	Down, Marginal
	31217	3	13	1	0.0003	0.02	0.002	0.005	Not Significant
	41217	3	13	2	0.0003	0.0043	0.0015	0.0013	Not Significant
	2426	4	14	4	0.0003	0.0061	0.0018	0.0016	Not Significant
	3426	4	13	2	0.0003	0.0032	0.0012	0.00079	Not Significant
	4426	4	16	1	0.0003	0.0031	0.0011	0.00069	Not Significant
	2417	5	15	2	0.0003	0.0037	0.0011	0.0010	Not Significant
	3429	6	13	2	0.0003	0.0038	0.0012	0.0010	Not Significant
	2430	7	16	2	0.0003	0.0146	0.00168	0.00220	Not Significant
	3067	7	16	1	0.0003	0.0029	0.00093	0.00066	Not Significant
	2431	8	13	2	0.0003	0.0025	0.00095	0.00071	Not Significant
	3431	8	15	3	0.0004	0.0112	0.00246	0.00347	Not Significant
	2432	9	14	1	0.0003	0.0049	0.0012	0.0012	Not Significant
	3432	9	13	1	0.0003	0.0003	0.00095	0.00056	Not Significant
	2733	10	14	2	0.0003	0.0243	0.00271	0.00626	Not Significant
	3733	10	14	2	0.0003	0.0155	0.00147	0.00214	Not Significant
	2070	11	16	4	0.0003	0.0085	0.0014	0.0013	Down, Significant
	3070	11	16	2	0.0003	0.0047	0.0011	0.0011	Down, Significant
	2398	12	14	2	0.0003	0.0026	0.0010	0.00071	Not Significant
	2434	13	15	1	0.0003	0.0062	0.0018	0.0019	Not Significant
	3069	13	16	2	0.0003	0.0111	0.00119	0.00131	Not Significant
	3106	14	16	1	0.0003	0.0088	0.0018	0.0027	Not Significant

TABLE 16: Summary Statistics and Trend Analysis for Routine Monitoring Program Wells Constituent Concentrations Above Final Remediation Levels, 1988–1996 Data

Constituent (FRL)	Well	Location	Number of Samples[a]	Number of Samples Above FRL	Minimum (mg/L)[b,c]	Maximum (mg/L)[d]	Mean (mg/L)	Standard Deviation (mg/L)	Trend
Manganese (0.90 mg/L)	2754(e)	1							
	2424	2	15	3	0.0137	2.83	0.687	0.735	Up, Significant
	2426	4	14	1	0.326	1.87	0.625	0.271	Up, Significant
	2430	7	16	1	0.005	1.25	0.524	0.270	Up, Significant
	3431	8	15	1	0.0629	0.982	0.412	0.215	Up, Significant
	2733	10	14	2	0.0063	1.27	0.347	0.412	Not Significant
Nickel (0.10 mg/L)	2754(e)	1							
	41217	3	13	1	0.003	0.117	0.0154	0.0307	Not Significant
	2398	12	15	1	0.003	0.791	0.0668	0.201	Up, Marginal
Selenium (0.05 mg/L)	2754(e)	1							
Vanadium (0.038 mg/L)	2754(e)	1							
	3424	2	13	1	0.001	0.0399	0.00630	0.0111	Not Significant
Zinc (0.021 mg/L)	2754 (e)	1							
	2424	2	15	4	0.0008	0.0914	0.0161	0.0238	Not Significant
	3424	2	13	1	0.0009	0.0247	0.00515	0.00612	Down, Marginal
	41217	3	13	1	0.0032	0.0221	0.00962	0.00532	Not Significant
	2426	4	14	2	0.0008	0.047	0.0088	0.012	Not Significant
	3426	4	13	1	0.0015	0.0699	0.0115	0.0182	Not Significant
	4426	4	16	1	0.0008	0.026	0.0074	0.0068	Not Significant
	2417	5	15	1	0.0012	0.0296	0.00798	0.00762	Not Significant
	2430	7	16	1	0.0017	0.0314	0.00761	0.00696	Not Significant
	2431	8	13	1	0.001	0.0534	0.00841	0.0137	Not Significant
	3431	8	14	1	0.0015	0.124	0.0148	0.0318	Not Significant
	2432	9	14	1	0.0015	0.0271	0.00720	0.00650	Not Significant
	4432	9	12	1	0.0015	0.216	0.0237	0.0607	Not Signifiicant
	2733	10	13	2	0.0015	0.152	0.0208	0.0403	Down, Significant
	3070	11	16	1	0.0009	0.0894	0.0120	0.0220	Not Significant
	3398	12	14	1	0.0015	0.0568	0.00858	0.0141	Not Significant
	2434	13	15	1	0.0015	0.0235	0.00682	0.00604	Not Significant
	2106	14	16	2	0.0009	0.0242	0.00712	0.00762	Not Signfiicant
	3106	14	16	1	0.0015	0.0789	0.00936	0.0910	Down, Marginal

TABLE 16: Summary Statistics and Trend Analysis for Routine Monitoring Program Wells Constituent Concentrations Above Final Remediation Levels, 1988–1996 Data

Constituent (FRL)	Well	Location	Number of Samples[a]	Number of Samples Above FRL	Minimum (pci/L)[b,c]	Maximum (pci/L)[d]	Mean (pci/L)	Standard Deviation (pci/L)	Trend
Radium-228 (20 pCi/L)	4424	2	12	1	0	23.262	2.3988	6.5814	Not Significant
Thorium-228 (4 pCi/L)	2754 (e)	1							
Thorium-232 (1.2 pCi/L)	2754 (e)	1							

Constituent (FRL)	Well	Location	Number of Samples[a]	Number of Samples Above FRL	Minimum (µg/L)[b,c]	Maximum (µg/L)[d]	Mean (µg/L)	Standard Deviation (µgL)	Trend
Total Uranium (20 µg/L)	2754 (e)	1							
	2424	2	15	1	0.006	23.521	2.9424	5.8067	Not Significant
	2430	7	16	1(f)					
	3070	11	20	1(g)					
	2398	12	20	1(f)					
	3398	12	12	1(g)					
	3069	13	27	12	0.335	223.58	55.070	61.320	Up, Significant
	2106	14	25	15	1.0885	88.6	51.103	17.617	Not Significant
bis(2-Ethylhexyl) phthalate (6.0 µg/L)	3106	14	4	1(h)					
Methylene Chloride (5 µg/L)	2432	9	14	1	0.5	110	5.8	14	Not Significant

NOTE: Highlighting indicates a 1996 FRL exceedance. Arsenic and methylene chloride had a FRL exceedance for the first time in 1996.

(a) Number of samples used to perform Mann-Kendall test for trend and to assess against FRLs; data qualified with Z or R not used in analysis.

(b) For values where the lowest concentration is below the detection limit, the minimum value is set at half the detection limit for trend analysis.

(c) For values where the lowest concentration is below zero, the minimum value is set at zero for trend analysis.

(d) For values where the highest concentration is below the detection limit, the maximum value is set at half the detection limit for trend analysis.

(e) Not representative of aquifer conditions; therefore, trend analysis not performed.

(f) Erroneous result in 1996 as documented in the 1996 RCRA Annual Report; therefore, trend analysis not performed.

(g) Erroneous result in 1994 (concentration of approximately 1 ug/L for total uranium) documented in the 1994 RCRA Annual Report; therefore trend analysis not performed.

(h) Isolated elevated concentration; therefore, trend analysis not performed.

TABLE 17: Comprehensive Groundwater Samples Concentrations Above EPA Proposed Standard, 1996 (a)

Well	Location	Sample Date	Concentration (pCi/L)	Concentration (ppb)
11547	East Field, Onsite	1-25-96	36	54
11547	East Field, Onsite	1-25-96	32	48
11547	East Field, Onsite	3-06-96	15	21
11547	East Field, Onsite	3-06-96	14	21
2015	West Field, Onsite	2-15-96	89	132
2015	West Field, Onsite	5-02-96	90	134
2015	West Field, Onsite	6-17-96	95	140
2015	West Field, Onsite	8-12-96	99	146
2015	West Field, Onsite	10-17-96	105	156
2046	South Field, Onsite	11-15-96	262	388
2060	South Plume, Willey Rd.	2-07-96	34	50
2060	South Plume, Willey Rd.	5-03-96	30	45
2060	South Plume, Willey Rd.	8-08-96	28	41
2060	South Plume, Willey Rd.	10-08-96	19	28
2061	South Paddys Run Rd.	2-07-96	100	148
2061	South Paddys Run Rd.	4-30-96	103	152
2095	South Paddys Run Rd.	2-14-96	98	145
2095	South Paddys Run Rd.	4-18-96	99	147
2095	South Paddys Run Rd.	10-17-96	107	158
2106	South Plume, Onsite	1-16-96	40	60
2106	South Plume, Onsite	4-08-96	22	33
2106	South Plume, Onsite	6-12-96	28	42
2106	South Plume, Onsite	7-09-96	29	43
2106	South Plume, Onsite	9-09-96	36	53
2166	South Plume, Onsite	2-13-96	45	66
2166	South Plume, Onsite	5-01-96	47	69
2166	South Plume, Onsite	8-07-96	32	48
2166	South Plume, Onsite	10-08-96	36	54
2398	South Plume, Onsite	1-15-96	19	28
2424	East Field, Onsite	7-09-96	16	24
2430	East Field, Onsite	7-16-96	50	75
2545	South Paddys Run Rd.	2-12-96	22	32
2545	South Paddys Run Rd.	5-09-96	14	21
2545	South Paddys Run Rd.	8-12-96	16	24
2545	South Paddys Run Rd.	10-11-96	20	30
2546	South Paddys Run Rd.	10-21-96	24	35
2550	South Paddys Run Rd.	2-09-96	57	84
2550	South Paddys Run Rd.	5-02-96	53	78
2550	South Paddys Run Rd.	8-08-96	58	86
2550	South Paddys Run Rd.	10-21-96	53	79
2551	South Paddys Run Rd.	2-09-96	19	28
2551	South Paddys Run Rd.	5-01-96	16	24
2551	South Paddys Run Rd.	8-08-96	15	22
2551	South Paddys Run Rd.	10-11-96	18	26
3924	South Plume, Offsite	11-27-96	30	44
3924	South Plume, Offsite	12-30-96	28	42
3925	South Plume, Offsite	1-30-96	21	31
3924	South Plume, Offsite	8-28-96	30	44
3924	South Plume, Offsite	9-25-96	31	46
3924	South Plume, Offsite	10-31-96	29	43
2552	South Paddys Run Rd.	2-07-96	14	21
2552	South Paddys Run Rd.	8-07-96	17	25
2552	South Paddys Run Rd.	10-11-96	16	23
2624	South Paddys Run Rd.	2-12-96	43	63
2754	East Field, Onsite	1-10-96	18	27
2754	East Field, Onsite	7-09-96	17	26
2945	South Field, Onsite	11-18-96	1208	1790
2954	South Field, Onsite	11-18-96	1127	1670
3062	South Paddys Run Rd.	5-09-96	37	55
3069	South Plume, Onsite	1-15-96	151	224
3069	South Plume, Onsite	4-09-96	86	128
3069	South Plume, Onsite	6-19-96	74	110
3069	South Plume, Onsite	7-09-96	77	113
3069	South Plume, Onsite	9-09-96	111	164

TABLE 17: Comprehensive Groundwater Samples with Uranium Concentrations Above EPA Proposed Standard, 1996

Well	Location	Sample Date	Concentration (pCi/L)	Concentration (ppb)
3125	South Paddys Run Rd.	2-14-96	30	44
3125	South Paddys Run Rd.	5-09-96	45	66
3125	South Paddys Run Rd.	8-08-96	43	63
3125	South Paddys Run Rd.	10-09-96	39	58
31560	South Plume, Onsite	2-07-96	193	286
31560	South Plume, Onsite	2-07-96	142	211
31560	South Plume, Onsite	2-07-96	129	191
31560	South Plume, Onsite	2-07-96	119	177
31561	South Plume, Onsite	2-22-96	28	42
31561	South Plume, Onsite	2-22-96	30	45
31561	South Plume, Onsite	2-22-96	33	49
31561	South Plume, Onsite	2-22-96	39	58
31562	South Plume, Onsite	4-02-96	111	165
31562	South Plume, Onsite	4-02-96	115	170
31562	South Plume, Onsite	4-02-96	119	177
31562	South Plume, Onsite	4-02-96	115	170
31567	South Plume, Onsite	3-14-96	28	41
3924	South Plume, Offsite	1-30-96	34	50
3924	South Plume, Offsite	2-26-96	31	46
3924	South Plume, Offsite	3-25-96	30	45
3924	South Plume, Offsite	4-30-96	28	41
3924	South Plume, Offsite	5-28-96	28	42
3924	South Plume, Offsite	6-21-96	29	43
3924	South Plume, Offsite	7-31-96	29	43
3925	South Plume, Offsite	2-26-96	19	28
3925	South Plume, Offsite	3-25-96	19	28
3925	South Plume, Offsite	4-30-96	19	28
3925	South Plume, Offsite	5-28-96	16	24
3925	South Plume, Offsite	6-21-96	16	23
3925	South Plume, Offsite	7-31-96	16	23
3925	South Plume, Offsite	8-28-96	19	28
3925	South Plume, Offsite	9-25-96	17	25
3925	South Plume, Offsite	10-31-96	17	25
3925	South Plume, Offsite	11-27-96	18	26
3925	South Plume, Offsite	12-30-96	17	25

(a) EPA Proposed Standard for Uranium = 20 ppb (13.5 pCi/L).

TABLE 18: Nonradioactive Substances above Primary Drinking Water Standards, 1996

Substance	Well Location	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)(a)
Antimony	2754 East Field	9-10-96	0.0067	0.006
Antimony	3070 East Field	7-10-96	0.0127	0.006
Arsenic	2426 East Field	9-11-96	0.146	0.05
Arsenic	2636 South Paddys Run Road	1-4-96	0.0834	0.05
Arsenic	2636 South Paddys Run Road	1-22-96	0.0816	0.05
Arsenic	2636 South Paddys Run Road	2-5-96	0.0754	0.05
Arsenic	2636 South Paddys Run Road	2-12-96	0.082	0.05
Arsenic	2636 South Paddys Run Road	3-1-96	0.0695	0.05
Arsenic	2636 South Paddys Run Road	3-4-96	0.0723	0.05
Arsenic	2636 South Paddys Run Road	3-11-96	0.0786	0.05
Arsenic	2636 South Paddys Run Road	3-18-96	0.0724	0.05
Arsenic	2636 South Paddys Run Road	4-22-96	0.0649	0.05
Arsenic	2636 South Paddys Run Road	8-5-96	0.0674	0.05
Arsenic	2636 South Paddys Run Road	9-12-96	0.0526	0.05
Arsenic	2636 South Paddys Run Road	9-19-96	0.0582	0.05
Arsenic	2636 South Paddys Run Road	9-25-96	0.0539	0.05
Arsenic	2636 South Paddys Run Road	10-16-96	0.074	0.05
Arsenic	2636 South Paddys Run Road	10-30-96	0.056	0.05
Arsenic	2636 South Paddys Run Road	11-8-96	0.061	0.05
Arsenic	2636 South Paddys Run Road	11-13-96	0.0663	0.05
Arsenic	2636 South Paddys Run Road	11-27-96	0.0573	0.05
Cadmium	2434 South Plume, Onsite	1-15-96	0.0093	0.005
Cadmium	2754 East Field	9-10-96	0.0064	0.005
Chromium	2754 East Field	1-10-96	0.259	0.1
Chromium	2754 East Field	7-9-96	0.902	0.1
Chromium	2754 East Field	9-10-96	1.55	0.1
Lead	3733 East Field	7-10-96	0.0155	0.015
Nickel	2398 South Plume, Onsite	4-9-96	0.791	0.1
Nickel	2754 East Field	4-9-96	0.297	0.1
Nickel	2754 East Field	7-9-96	4.77	0.1
Nickel	2754 East Field	9-10-96	0.807	0.1
Sulfate	2424 East Field	4-8-96	635	500
Sulfate	2424 East Field	4-8-96	622	500
Sulfate	2424 East Field	7-9-96	1430	500
Thallium	2424 East Field	1-15-96	0.0065	0.002
Thallium	2434 South Field, Onsite	1-15-96	0.0053	0.002
Thallium	3429 East Field	1-15-96	0.0057	0.002

(a) EPA drinking water regulations taken from 40 CFR Part 141, National InterimPrimary Drinking Water Regulations – Subpart B – Maximum Contaminant Levels (MCL), July 1984. It should be noted that the MCL for Nickel is in the process of being remanded and the MCL for Sulfate is a proposed standard.

TABLE 19: Summary of Radiation Dose[a], 1996

Type of Dose	Dose[b]	Standard[c]	Percent of Standard
I. Individual	**mrem**[d]	**mrem**[d]	
A. Maximum individual dose from air emissions, excluding radon[e]	0.66	10	6.0
B. Ingestion[f]			
Produce (204 kg/year or 449 pounds/year) and milk	0.04	100	0.04
Well water (2 L/day or 0.5 gallons/day)	0.25	100	0.25
Great Miami River fish (4.4 kg/year or 10 pounds/year)	0.006	100	0.006
C. Direct radiation[g]	0.0	100	0.0
D. Radon Maximum dose to public at the site fenceline 8,760 hrs/year	504	(h)	
II. 80 km (50 miles) Population Dose	**person-rem**		
Total collective dose equivalent from air emissions excluding radon for 2,740,000 people living within 80 km (50 miles)[e]	5.7	(h)	
III. Other Sources of Dose[i]	**mrem/year**		
A. Natural radioactivity			
1. Radon in homes	200		
2. Other natural background radiation: cosmic radiation plus natural terrestrial isotopes, both external and internal.	100		
B. Medical diagnosis[j]	50		
C. Consumer products	10		
D. Atmospheric weapons tests	4.6		

(a) Including dose from all radionuclides listed in Table 20.

(b) The effective dose is the weighted sum of doses delivered to the individual organs of the body. Effective doses are comparable to whole body dose equivalents when considering the effects and risks of low-level radiation doses.

(c) Standards are as included in DOE Order 5400.5., "Radiation Protection of the Public and Environment." Also incorporated are the air emission dose standards of regulation 40 CFR 61, Subpart H (NESHAP).

(d) To obtain mSv, multiply mrem by 0.01.

(e) Effective dose equivalent received as a result of 1996 estimated emissions.

(f) Fifty-year committed dose equivalents based on environmental measurements of uranium in produce, milk, water, and fish.

(g) Whole body dose calculated from highest measurement along the FEMP fenceline, using environmental thermoluminescent dosimeters corrected for background.

(h) There are no applicable standards.

(i) From NCRP-93, "Ionizing Radiation Exposure of the Population of the United States."

(j) Medical dose estimates are population averages and will not necessarily be applicable to each individual.

TABLE 20: Estimated Airborne Emissions for the FEMP, 1996(a)

Radionuclide	Total Curies	Measured Curies(b)	Estimated Curies(c)
Uranium–234	1.47×10^{-3}	5.21×10^{-6}	1.46×10^{-3}
Uranium–235	7.78×10^{-5}	2.86×10^{-7}	7.75×10^{-5}
Uranium–236	5.68×10^{-5}	2.14×10^{-7}	5.66×10^{-5}
Uranium–238	1.67×10^{-3}	5.87×10^{-6}	1.66×10^{-3}
Radium–226	1.07×10^{-6}	3.74×10^{-9}	1.06×10^{-6}
Radium–228	7.01×10^{-6}	1.50×10^{-8}	7.00×10^{-6}
Thorium–228	4.80×10^{-5}	1.96×10^{-7}	4.78×10^{-5}
Thorium–230	1.19×10^{-4}	5.95×10^{-7}	1.18×10^{-4}
Thorium–232	9.89×10^{-6}	5.45×10^{-8}	9.84×10^{-6}
Thorium–234	6.64×10^{-3}	2.33×10^{-5}	6.62×10^{-3}
Actinium-228	2.72×10^{-6}	0.00×10^{0}	2.72×10^{-6}
Bismuth-212	2.70×10^{-6}	0.00×10^{0}	2.70×10^{-6}
Lead-212	2.70×10^{-6}	0.00×10^{0}	2.70×10^{-6}
Polonium-212	1.73×10^{-6}	0.00×10^{0}	1.73×10^{-6}
Polonium-216	2.70×10^{-6}	0.00×10^{0}	2.70×10^{-6}
Radium-224	2.70×10^{-6}	0.00×10^{0}	2.70×10^{-6}
Thallium-208	9.73×10^{-7}	0.00×10^{0}	9.73×10^{-7}

(a) Emissions are used as input to the CAP88-PC program which calculates doses from these emission estimates. See page 141 for a description of the CAP88-PC computer program.

(b) Measured emissions are from Building 11 (laundry dryer exhaust), Building 15 (HEPA exhaust), and Building 71 (process vent).

(c) Includes Plant 1, 4, 5, 6, and 8, Buildings 11, 15, 20, 53, 65, 71, and 78, Waste Pits (rail yard and site improvements), and Soil Characterization and Excavation Project (SCEP).

TABLE 21: Radon in Air, 1996

Fenceline Locations[a]	Radon Concentration ± Precision [c] (pCi/L)		
	First Half of Year	Second Half of Year	Location Average
AMS 2	0.8 ± 0.0	1.4 ± 0.2	1.1 ± 0.2
AMS 4	0.8 ± 0.2	1.4 ± 0.0	1.1 ± 0.2
AMS 6	0.8 ± 0.3	1.8 ± 0.5	1.3 ± 0.6
AMS 7	0.9 ± 0.3	1.6 ± 0.2	1.3 ± 0.4
AMS 8A	(b)	1.3 ± 0.2	1.3 ± 0.2
AMS 9B	(b)	1.3 ± 0.5	1.3 ± 0.5
FEMP A	1.3 ± 0.2	1.5 ± 0.0	1.4 ± 0.2
FEMP B	1.1 ± 0.3	1.4 ± 0.2	1.3 ± 0.4
FEMP C	1.0 ± 0.2	1.2 ± 0.2	1.1 ± 0.3
FEMP D	0.7 ± 0.0	1.3 ± 0.2	1.0 ± 0.2
FEMP E	0.8 ± 0.2	1.3 ± 0.5	1.1 ± 0.5
FEMP F	0.7 ± 0.2	1.4 ± 0.2	1.1 ± 0.3
FEMP G	0.9 ± 0.3	1.5 ± 0.2	1.2 ± 0.4
FEMP H	0.8 ± 0.2	1.6 ± 0.2	1.2 ± 0.3
FEMP I	0.8 ± 0.2	1.6 ± 0.4	1.2 ± 0.4
FEMP J	0.8 ± 0.2	1.4 ± 0.2	1.1 ± 0.3
FEMP K	0.8 ± 0.1	1.6 ± 0.3	1.2 ± 0.3
FEMP L	0.8 ± 0.2	1.7 ± 0.3	1.3 ± 0.4
FEMP M	0.9 ± 0.3	1.5 ± 0.4	1.2 ± 0.5
FEMP N	0.8 ± 0.0	1.4 ± 0.3	1.1 ± 0.3
FEMP O	0.8 ± 0.2	1.7 ± 0.2	1.3 ± 0.3
FEMP P	0.9 ± 0.2	1.6 ± 0.4	1.3 ± 0.4
Interval Averages	**0.9 ± 0.4**	**1.5 ± 0.6**	**1.2 ± 0.8**

Background Locations[a]	Radon Concentration ± Precision[c] (pCi/L)		
	First Half of Year	Second Half of Year	Location Averages
AMS 11	1.0 ± 0.2	1.8 ± 0.3	1.4 ± 0.4
AMS 12	0.9 ± 0.2	1.7 ± 0.5	1.3 ± 0.5
AMS 13	1.0 ± 0.2	1.3 ± 0.2	1.2 ± 0.3
BKGD 1	0.8 ± 0.2	1.2 ± 0.2	1.0 ± 0.3
BKGD 2	0.7 ± 0.2	1.2 ± 0.2	1.0 ± 0.3
BKGD 3	0.8 ± 0.2	1.3 ± 0.4	1.1 ± 0.4
BKGD 4	0.6 ± 0.2	1.2 ± 0.3	0.9 ± 0.4
BKGD 5	0.8 ± 0.2	1.3 ± 0.0	1.1 ± 0.2
BKGD 6	0.8 ± 0.3	1.3 ± 0.2	1.1 ± 0.4
Interval Averages	**0.8 ± 0.1**	**1.4 ± 0.4**	**1.1 ± 0.4**

Nearby Offsite Locations [a]	Radon Concentration ± Precision[c] (pCi/L)		
	First Half of Year	Second Half of Year	Location Averages
AMS 10	0.9 ± 0.5	1.5 ± 0.3	1.2 ± 0.6
RES 1	1.0 ± 0.2	1.6 ± 0.2	1.3 ± 0.3
RES 2	0.9 ± 0.3	1.6 ± 0.4	1.3 ± 0.5
RES 3	0.9 ± 0.4	1.7 ± 0.5	1.3 ± 0.6
Interval Averages	**0.9 ± 0.2**	**1.6 ± 0.2**	**1.3 ± 0.3**

TABLE 21: Radon in Air, 1996

K-65 Silo Exclusion Fence Locations[a]	Radon Concentration ± Precision [c] (pCi/L)		
	First Half of Year	Second Half of Year	Location Average
K-65 A	1.4 ± 0.3	2.6 ± 0.4	2.0 ± 0.5
K-65 B	1.8 ± 0.2	3.0 ± 0.2	2.4 ± 0.3
K-65 C	2.2 ± 0.4	3.6 ± 0.9	2.9 ± 1.0
K-65 D	2.9 ± 0.5	5.7 ± 1.0	4.3 ± 1.1
K-65 E	2.8 ± 0.7	5.1 ± 0.5	4.0 ± 0.9
K-65 F	2.6 ± 0.5	6.0 ± 0.7	4.3 ± 0.9
K-65 G	1.8 ± 0.3	3.6 ± 0.5	2.7 ± 0.6
K-65 H	1.3 ± 0.2	2.6 ± 0.7	2.0 ± 0.7
K-65 I	1.1 ± 0.2	2.5 ± 0.5	1.8 ± 0.5
K-65 J	1.2 ± 0.3	2.1 ± 0.5	1.7 ± 0.6
K-65 K	1.3 ± 0.5	2.2 ± 0.2	1.8 ± 0.5
K-65 L	1.8 ± 0.2	3.0 ± 0.6	2.4 ± 0.6
K-65 M	1.8 ± 0.3	2.8 ± 0.2	2.3 ± 0.4
K-65 N	1.5 ± 0.4	3.0 ± 0.5	2.3 ± 0.6
K-65 O	1.2 ± 0.5	2.4 ± 0.3	1.8 ± 0.6
K-65 P	1.2 ± 0.2	2.4 ± 0.3	1.8 ± 0.4
Interval Averages	**1.7 ± 0.6**	**3.3 ± 0.9**	**2.5 ± 1.1**

(a) See Figures 49, 50 and 51 beginning on page 152 for locations.

(b) Location moved mid-year to fenceline location.

(c) ± 2 standard deviation

TABLE 22: DOE Quality Assessment Program for Environmental Radionuclide Analyses FEMP Laboratories Performance Results, 1996

Sample Type	Sample Number	Analysis	Units	Reported Values FEMP Laboratories	EML[a]	Ratio FEMP Value/EML Value
Water	96-03	Uranium	ug/ml	0.023	0.022	1.05
Air	96-03	Uranium	ug/filter	4.3	4.31	1.00
Water	96-09	Uranium	ug/ml	0.041	0.039	1.05
Air	96-09	Uranium	ug/filter	7.02	6.4	1.10

(a) DOE's Environmental Measurements Laboratory (EML).

TABLE 23: EPA Quality Assurance Program for Wastewater Analyses FEMP Laboratories Performance Evaluation, 1996[a]

Parameter	Units[b]	Values		EPA Acceptance Limits[d]	EPA Performance Evaluation[e]
		Site Laboratory	True[c]		
Cadmium	µg/l	138	131	113 – 148	ACCEPTABLE
Chromium	µg/l	261	250	218 – 289	ACCEPTABLE
Copper	µg/l	629	552	515 – 618	NOT ACCEPTABLE
Mercury	µg/l	4.44	4.7	3.53 – 5.91	ACCEPTABLE
Nickel	µg/l	1970	1812	1660 – 2030	ACCEPTABLE
Lead	µg/l	412	375	332 – 429	ACCEPTABLE
Zinc	µg/l	1250	1203	1100 – 1370	ACCEPTABLE
pH	S.U.	8.8	8.73	8.54 – 9.01	ACCEPTABLE
Total Suspended Solids	mg/l	263	30	20.1 – 31.4	NOT ACCEPTABLE
Oil & Grease	mg/l	19.1	19.5	11.9 – 23.9	ACCEPTABLE
Total Residual Cholrine	mg/l	0.57	0.69	0.543 – 0.834	ACCEPTABLE
Ammonia - Nitrogen	mg/l	8.93	10	8.05 – 12	ACCEPTABLE
Total Phosphorus	mg/l	2.9	2.9	2.46 – 3.43	ACCEPTABLE
Carbonaceous BOD	mg/l	13.25	11.3	5.33 – 17.3	ACCEPTABLE

(a) EPA Discharge Monitoring Report (DMR) Quality Assurance (QA) Program. The FEMP, along with all other National Pollutant Discharge Elimination Systems (NPDES) permit holders, is required to participate in these annual laboratory performance evaluation studies (Section 308[a] of the Clean Water Act).

(b) S.U. stands for standard units.

(c) Actual parameter concentrations established by EPA based on theoretical calculations or a reference value when necessary.

(d) Laboratory measured values which fall within this range are considered acceptable by EPA.

(e) EPA DMR–QA Study Number 16 conducted during 1996.

TABLE 24: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1996

Summary of Performance of the FEMP Laboratories

Parameter	Units	Number of Analyses	Range of True Values	Percent Recovery[a]			Deviations from Mean[b]			Percentage Acceptable[c]
				Min.	Max.	Avg.	Min.	Max.	Avg.	
Biochemical Oxygen Demand	mg/L	24	16.2 – 214.5	95	145	105	0.019	2.67	0.86	96
Ammonia Nitrogen as N	mg/L	24	0.29 – 17.5	73	111	96	0.001	4.12	0.76	96
Nitrate Nitrogen as N	mg/L	24	0.85 – 18.8	100	118	105	0.007	2.18	0.66	100
Orthophosphate as P	mg/L	22	0.3 – 19.0	93	110	101	0.045	7.79	1.13	95
Total Suspended Solids	mg/L	24	1.58 – 7.22	96	103	100	0.215	1.40	0.73	100
Total Dissolved Solids	mg/L	24	0.038 – 1.68	88	132	103	0.023	3.52	1.02	92
Total Solids	mg/L	24	0.093 – 1.97	93	114	101	0.022	1.77	0.73	96
Oil and grease	mg/L	24	12.9 – 88.8	87	113	97	0.026	1.62	0.55	100
Alkalinity as $CaSO_3$	mg/L	18	24.5 – 221	75	111	96	0.089	5.98	1.12	94
Calcium	mg/L	24	11.1 – 102	45	167	100	0.007	11.07	1.54	87
Chloride	mg/L	22	60.4 – 365	98	137	105	0.029	5.71	1.00	91
Conductivity	µmho/cm	22	408 – 1623	0.09	103	94	0.02	33.5	2.86	82
Magnesium	mg/L	24	1.74 – 32.4	41	207	101	0.007	21.3	1.66	92
Potassium	mg/L	24	9.08 – 183	29	341	106	0.004	31.6	2.03	92
Sodium	mg/L	24	28.2 – 194	94	108	100	0.019	1.51	0.48	100
Sulfate	mg/L	24	16.6 – 202	23	124	95	0.053	15.3	2.70	75
Total Hardness as $CaCO_3$	mg/L	14	50.2 – 356	81	102	96	0.057	6.69	1.14	93
pH	S.U.	24	3.57 – 9.63	96	104	100	0.055	1.20	0.60	100
Aluminum	µg/L	23	64.1 – 754	81	105	94	0.063	1.77	0.9	100
Arsenic	µg/L	24	20.7 – 912	81	111	101	0.0004	1.49	0.48	100
Barium	µg/L	24	110 – 1617	92	103	98	0.007	1.35	0.46	100
Beryllium	µg/L	24	22.1 – 369	96	104	100	0.004	1.12	0.41	100
Cadmium	µg/L	24	12.1 – 393	94	115	106	0.13	2.26	1.08	100
Chromium	µg/L	24	63.4 – 898	95	109	102	0.19	2.04	0.71	100
Cobalt	µg/L	24	107 – 945	99	109	104	0.019	2.17	1.05	100
Copper	µg/L	24	84.9 – 954	97	113	104	0.082	2.14	1.08	100
Iron	µg/L	24	64.2 – 949	97	110	103	0.036	2.02	0.67	100
Lead	µg/L	24	83.4 – 853	79	118	102	0.22	2.87	1.06	96
Manganese	µg/L	24	62.4 – 815	97	107	103	0.034	2.04	0.91	100
Mercury	µg/L	20	0.78 – 17.9	86	106	99	0.02	0.75	0.32	100

TABLE 24: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1996

Summary of Performance of the FEMP Laboratories

Parameter	Units	Number of Analyses	Range of True Values	Percent Recovery[a] Min.	Max.	Avg.	Deviations from Mean[b] Min.	Max.	Avg.	Percentage Acceptable[c]
Nickel	µg/L	24	71.6 – 926	97	113	103	0.057	1.84	0.97	100
Selenium	µg/L	24	12.9 – 237	71	122	97	0.248	2.26	0.88	100
Thallium	µg/L	20	34.7 – 797	85	107	94	0.024	1.32	0.53	100
Silver	µg/L	24	16.5 – 392	68	112	98	0.232	2.59	0.77	96
Vanadium	µg/L	24	66.0 – 968	91	106	102	0.065	3.76	0.88	96
Zinc	µg/L	24	67.5 – 595	94	110	100	0.017	1.19	0.58	100
Fluoride	µg/L	24	0.46 – 19.1	53	116	97	0.058	14.7	0.98	92
Hexavalent Chromium	mg/L	24	0.012 – 0.93	72	935	130	0.031	54.6	2.82	96
Uranium	µg/L	24	31 – 905	94	107	101	0.06	1.52	0.83	100
Benzene	µg/L	14	14.7 – 193	98	118	109	0.265	1.94	0.88	100
Dibromochloromethane	µg/L	4	19.5 – 131	102	139	118	0.204	4.02	1.89	75
Chlorobenzene	µg/L	14	9.50 – 178	94	116	107	0.032	2.20	0.90	100
1,2 Dichloropropane	µg/L	6	33.0 – 138	95	120	106	0.328	1.99	1.15	100
1,2 Dichlorobenzene	µg/L	6	13.8 – 127	99	112	104	0.215	1.12	0.48	100
1,3 Dichlorobenzene	µg/L	4	28.0 – 118	103	119	111	0.328	1.53	0.95	100
1,4 Dichlorobenzene	µg/L	6	18.8 – 96.7	107	117	113	1.025	2.47	1.62	100
Ethyl Benzene	µg/L	12	8.20 – 212	91	108	106	0.232	1.47	0.76	100
Toluene	µg/L	14	8.53 – 215	90	111	104	0.135	1.62	0.92	100
Bromoform	µg/L	8	9.35 – 241	52	121	99	0.096	2.53	1.13	100
Carbon Tetrachloride	µg/L	16	17.3 – 157	103	146	120	0.347	2.28	1.54	75
Chloroform	µg/L	12	12.4 – 146	91	146	115	0.577	4.66	1.75	83
1,1 Dichloroethane	µg/L	4	8.31 – 79.6	94	153	123	0.166	2.39	1.42	100
1,2 Dichloroethane	µg/L	12	22.8 – 127	93	153	123	0.322	7.36	2.47	67
Methylene Chloride	µg/L	2	17.3 – 86	104	122	113	0.118	0.60	0.36	100
1,1,2,2 Tetrachloroethane	µg/L	8	8.66 – 150	74	118	101	0.257	1.61	0.94	100
Tetrachloroethylene	µg/L	14	19.1 – 213	68	120	99	0.047	1.72	0.79	100
1,1,1 Trichloroethane	µg/L	14	8.17 – 229	97	137	119	0.2	2.50	1.50	100
1,1,2 Trichloroethane	µg/L	14	12.7 – 213	73	118	101	0.015	3.73	1.62	93
Trichloroethylene	µg/L	10	12.9 – 148	90	116	105	0.02	1.32	0.61	100
Total		**1,099**								96

TABLE 24: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1996

(a) Percent recovery is the site's measured value, divided by the true parameter concentration, multiplied by 100.

(b) The standard deviation indicates the closeness of the site's measurement result to the mean value reported by Analytical Products Group, Inc., which conducts the testing program. The standard deviation would be 0.00 if the FEMP's result and the mean value were exactly the same. The mean value is calculated from the results obtained by all laboratories participating in the control program. Any measurement results which are significantly different from the true parameter concentration or statistically different from the majority of results obtained by the other laboratories are not included in evaluating the mean value.

(c) This is the percentage of the site's measurement results for each parameter which met the EPA "Acceptable" criteria of being within 2.58 standard deviations of the mean value.

Table 25: FEMP – OEPA Sampling Comparison, 1996

Groundwater Sampling for Uranium

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] FEMP	OEPA
12	1-24-96	81	88
12	4-24-96	31	31
12	7-24-96	84	74
12	10-23-96	72	61
13	1-24-96	24	23
13	4-24-96	64	66
13	7-24-96	59	54
13	10-23-96	55	52
14	1-24-96	1.6	1.8
14	4-24-96	1.8	1.9
14	7-24-96	1.8	1.9
14	10-23-96	1.9	1.9
15	1-24-96	101	108
15	4-24-96	99	108
39	1-24-96	4.0	4.0
39	4-24-96	3.9	3.6

(a) See Figure 42 on page 127 for locations.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

Table 26: FEMP – OEPA Sampling Comparison, 1996

Surface Water Sampling for Uranium and Radium

Sampling Location[a]	Sampling Date	FEMP Results (pCi/L)			OEPA Results (pCi/L)		
		Total Uranium	Ra-226	Ra-228	Total Uranium	Ra-226	Ra-228
W3	2/96	1.2	0.14 ± 0.049	< 0.27	1.2	0.28	2.7
W3	5/96	1.2	0.32 ± 0.092	< 2.8	1.3	0.18	2.5
W3	8/96	0.8	0.16 ± 0.057	< 3.9	1.0	0.41	< 1.4
W3	11/96	0.9	0.17 ± 0.052	< 0.23	1.1	< 0.38	< 2.5
W7	2/96	3.2	0.22 ± 0.027	< 3.1	3.3	0.17	2.1
W7	5/96	1.6	0.064 ± 0.036	< 0.38	1.6	0.14	2.3
W9	2/96	1.4	(b)	(b)	1.6	(b)	(b)
W9	5/96	1.4	(b)	(b)	1.3	(b)	(b)
W9	8/96	0.9	(b)	(b)	0.9	(b)	(b)
W9	11/96	0.9	(b)	(b)	1.0	(b)	(b)
W10US	5/96	1.4	(b)	(b)	1.4	(b)	(b)
W10DS	2/96	8.8	(b)	(b)	13.5	(b)	(b)
W10DS	5/96	3.8	(b)	(b)	3.5	(b)	(b)
W10DD	4/96	1650	(b)	(b)	1490	(b)	(b)
W11	2/96	3.1	(b)	(b)	3.3	(b)	(b)
W11	5/96	1.8	(b)	(b)	1.6	(b)	(b)

(a) See Figure 35 (page 108).

(b) Sample not analyzed.

Table 27: FEMP – OEPA Sampling Comparison, 1996[a,b]

Sampling Location[c]	Sampling Date	FEMP Results		OEPA Results	
		Total Uranium (ug/g)	Ra-226 (pCi/g)	Total Uranium (ug/g)	Ra-226 (pCi/g)
Sediment Sampling for Uranium and Radium					
G2	6-28-96	1.00	0.55	2.6 ± 0.28	0.82 ± 0.12
Paddys Run	6-28-96	2.40	0.68	4.4 ± 0.46	1.2 ± 0.18

Sampling Location[c]	Sampling Date	FEMP Results			OEPA Results		
		Th-228 (pCi/g)	Th-230 (pCi/g)	Th-232 (pCi/g)	Th-228 (pCi/g)	Th-230 (pCi/g)	Th-232 (pCi/g)
Sediment Sampling for Thorium							
G2	6-28-96	0.45 ± 0.05	0.58	0.41	0.67 ± 0.043	0.97 ± 0.088	0.66 ± 0.071
Paddys Run	6-28-96	0.65	0.88	0.63	0.97 ± 0.044	1.5 ± 0.12	1.0 ± 0.098

Sampling Location[c]	Sampling Date	FEMP Results	OEPA Results
		Total Uranium (μg/g)	Total Uranium (μg/g)
Grass Sampling for Uranium			
AMS-2	7-25-96	0.069	1.5
AMS-8A	7-25-96	0.51	0.3
AMS-9B2	7-25-96	0.097	0.3
18	7-25-96	0.091	0.3
Soil Sampling for Uranium			
AMS-2	7-25-96	12	19
AMS-8A	7-25-96	27	28
AMS-9B2	7-25-96	31	26
18	7-25-96	1.5	3.6
6	8-21-96	8.9	3.9
4	8-21-96	3.1	3.4
Fish Sampling for Uranium			
RM19	9-18-96	0.05	0.04
Produce Sampling for Uranium			
4	8-21-96	0.005	0.029

(a) Results are in reported units of grams dry weight.

(b) Total uranium results are reported in μg/g to maintain consistency with OEPA reporting.

(c) See Figures 27 (page 93), 29 (page 97), 37 (page 112), and 38 (page 113) for locations.

Table 28: OU5 Media-Specific Final Remediation Levels (FRLs)(a)

Radionuclide/Analyte	FRL				
	On-Site Soil	Off-Site Soil	Groundwater	Surface Water	Sediment
Cesium-137	$1.4x10^{0}$ pCi/g	$8.2x10^{-1}$ pCi/g	N/A (d)	$1.0x10^{1}$ pCi/L	$7.0x10^{0}$ pCi/g
Neptunium-237	$3.2x10^{0}$ pCi/g	$4.9x10^{-1}$ pCi/g	$1.0x10^{0}$ pCi/L	$2.1x10^{2}$ pCi/L	$3.2x10^{1}$ pCi/g
Lead-210	$3.8x10^{1}$ pCi/g	$2.2x10^{0}$ pCi/g	N/A	$1.1x10^{1}$ pCi/L	$3.9x10^{2}$ pCi/g
Plutonium-238	$7.8x10^{1}$ pCi/g	$9.3x10^{0}$ pCi/g	N/A	$2.1x10^{2}$ pCi/L	$1.2x10^{3}$ pCi/g
Plutonium-239/240	$7.7x10^{1}$ pCi/g	$9.0x10^{0}$ pCi/g	N/A	$2.0x10^{2}$ pCi/L	$1.1x10^{3}$ pCi/g
Radium-226	$1.7x10^{0}$ pCi/g	$1.5x10^{0}$ pCi/g	$2.0x10^{1}$ pCi/L	$3.8x10^{1}$ pCi/L	$2.9x10^{0}$ pCi/g
Radium-228	$1.8x10^{0}$ pCi/g	$1.4x10^{0}$ pCi/g	$2.0x10^{1}$ pCi/L	$4.7x10^{1}$ pCi/L	$4.8x10^{0}$ pCi/g
Strontium-90	$1.4x10^{1}$ pCi/g	$6.1x10^{-1}$ pCi/g	$8.0x10^{0}$ pCi/L	$4.1x10^{1}$ pCi/L	$7.1x10^{3}$ pCi/g
Technetium-99	$3.0x10^{1}$ pCi/g	$1.0x10^{0}$ pCi/g	$9.4x10^{1}$ pCi/L	$1.5x10^{2}$ pCi/L	$2.0x10^{5}$ pCi/g
Thorium-228	$1.7x10^{0}$ pCi/g	$1.5x10^{0}$ pCi/g	$4.0x10^{0}$ pCi/L	$8.3x10^{2}$ pCi/L	$3.2x10^{0}$ pCi/g
Thorium-230	$2.8x10^{2}$ pCi/g	$8.0x10^{1}$ pCi/g	$1.5x10^{1}$ pCi/L	$3.5x10^{3}$ pCi/L	$1.8x10^{4}$ pCi/g
Thorium-232	$1.5x10^{0}$ pCi/g	$1.4x10^{0}$ pCi/g	$1.2x10^{0}$ pCi/L	$2.7x10^{2}$ pCi/L	$1.6x10^{0}$ pCi/g
Uranium, total (b)	$8.2x10^{1}$ ppm (c)	$5.0x10^{1}$ ppm	$2.0x10^{-2}$ mg/L	$5.3x10^{-1}$ mg/L	$2.1x10^{2}$ mg/kg
Acetone	$4.3x10^{4}$ mg/kg	$4.3x10^{-1}$ mg/kg	N/A	N/A	N/A
Alpha-chlordane	N/A	N/A	$2.0x10^{-3}$ mg/L	$3.1x10^{-4}$ mg/L	N/A
Antimony	$9.6x10^{1}$ mg/kg	$6.1x10^{-1}$ mg/kg	$6.0x10^{-3}$ mg/L	$1.9x10^{-1}$ mg/L	N/A
Aroclor-1254	$1.3x10^{-1}$ mg/kg	$4.0x10^{-2}$ mg/kg	$2.0x10^{-4}$ mg/L	$2.0x10^{-4}$ mg/L	$6.7x10^{-1}$ mg/kg
Aroclor-1260	$1.3x10^{-1}$ mg/kg	$4.0x10^{-2}$ mg/kg	N/A	$2.0x10^{-4}$ mg/L	$6.7x10^{-1}$ mg/kg
Arsenic	$1.2x10^{1}$ mg/kg	$9.6x10^{0}$ mg/kg	$5.0x10^{-2}$ mg/L	$4.9x10^{-2}$ mg/L	$9.4x10^{1}$ mg/kg
Barium	$6.8x10^{4}$ mg/kg	$1.2x10^{2}$ mg/kg	$2.0x10^{0}$ mg/L	$1.0x10^{2}$ mg/L	N/A
Benzene	$8.5x10^{2}$ mg/kg	$4.3x10^{-1}$ mg/kg	$5.0x10^{-3}$ mg/L	$2.8x10^{-1}$ mg/L	N/A
Benzo(a)anthracene	$2.0x10^{1}$ mg/kg	$1.6x10^{-1}$ mg/kg	N/A	$1.0x10^{-3}$ mg/L	$1.9x10^{2}$ mg/kg
Benzo(a)pyrene	$2.0x10^{0}$ mg/kg	$9.0x10^{-2}$ mg/kg	N/A	$1.0x10^{-3}$ mg/L	$1.9x10^{1}$ mg/kg
Benzo(b)fluoranthene	$2.0x10^{1}$ mg/kg	$1.6x10^{-1}$ mg/kg	N/A	N/A	$1.9x10^{2}$ mg/kg
Benzo(k)fluoranthene	$2.0x10^{2}$ mg/kg	$9.0x10^{-2}$ mg/kg	N/A	N/A	$1.9x10^{3}$ mg/kg
Beryllium	$1.5x10^{0}$ mg/kg	$6.2x10^{-1}$ mg/kg	$4.0x10^{-3}$ mg/L	$1.2x10^{-3}$ mg/L	$3.3x10^{1}$ mg/kg
Bis(2-chloroisopropyl)ether	$4.2x10^{2}$ mg/kg	$2.0x10^{-1}$ mg/kg	$5.0x10^{-3}$ mg/L	$2.8x10^{-1}$ mg/L	N/A
Bis(2-ethylhexyl)phthalate	$8.2x10^{2}$ mg/kg	$2.6x10^{1}$ mg/kg	$6.0x10^{-3}$ mg/L	$8.4x10^{-3}$ mg/L	$5.0x10^{3}$ mg/kg
Boron	$7.4x10^{3}$ mg/kg	$4.0x10^{0}$ mg/kg	$3.3x10^{-1}$ mg/L	N/A	N/A
Bromodichloromethane	$4.0x10^{0}$ mg/kg	$1.8x10^{-1}$ mg/kg	$1.0x10^{-1}$ mg/L	$2.4x10^{-1}$ mg/L	N/A
Bromoform	$3.1x10^{1}$ mg/kg	$1.6x10^{0}$ mg/kg	N/A	N/A	$1.6x10^{2}$ mg/kg
Bromomethane	$8.2x10^{3}$ mg/kg	$2.4x10^{-2}$ mg/kg	$2.1x10^{-3}$ mg/L	$1.3x10^{0}$ mg/L	N/A

Table 28: OU5 Media-Specific Final Remediation Levels (FRLs)[a]

Radionuclide/Analyte	FRL				
	On-Site Soil	Off-Site Soil	Groundwater	Surface Water	Sediment
Cadmium	$8.2x10^{1}$ mg/kg	$9.1x10^{-1}$ mg/kg	$1.4x10^{-2}$ mg/L	$9.8x10^{-3}$ mg/L	$7.1x10^{1}$ mg/kg
Carbazole	$1.2x10^{1}$ mg/kg	$3.1x10^{0}$ mg/kg	$1.1x10^{-2}$ mg/L	N/A	$6.3x10^{1}$ mg/kg
Carbon disulfide	$5.0x10^{3}$ mg/kg	$6.2x10^{0}$ mg/kg	$5.5x10^{-3}$ mg/L	N/A	N/A
Carbon tetrachloride	$2.1x10^{0}$ mg/kg	$9.1x10^{-2}$ mg/kg	N/A	N/A	N/A
Chlordane	$1.9x10^{-1}$ mg/kg	$3.8x10^{-2}$ mg/kg	N/A	N/A	N/A
Chlorobenzene	$3.4x10^{2}$ mg/kg	$1.9x10^{0}$ mg/kg	N/A	N/A	N/A
Chloroethane	N/A	N/A	$1.0x10^{-3}$ mg/L	N/A	N/A
Chloroform	$4.5x10^{1}$ mg/kg	$5.0x10^{-1}$ mg/kg	$1.0x10^{-1}$ mg/L	$7.9x10^{-2}$ mg/L	N/A
Chromium VI	$3.0x10^{2}$ mg/kg	$1.1x10^{1}$ mg/kg	$2.2x10^{-2}$ mg/L	$1.0x10^{-2}$ mg/L	$3.0x10^{3}$ mg/kg
Chrysene	$2.0x10^{3}$ mg/kg	$1.6x10^{1}$ mg/kg	N/A	N/A	$1.9x10^{4}$ mg/kg
Cobalt	$7.4x10^{2}$ mg/kg	$2.6x10^{1}$ mg/kg	$1.7x10^{-1}$ mg/L	N/A	$3.6x10^{4}$ mg/kg
Copper	$2.2x10^{5}$ mg/kg	$2.0x10^{1}$ mg/kg	$1.3x10^{0}$ mg/L	$1.2x10^{-2}$ mg/L	N/A
Cyanide	$1.2x10^{5}$ mg/kg	$8.0x10^{-1}$ mg/kg	N/A	$1.2x10^{-2}$ mg/L	N/A
Dibenzo(a,h)anthracene	$2.0x10^{0}$ mg/kg	$1.6x10^{-3}$ mg/kg	N/A	$1.0x10^{-3}$ mg/L	N/A
3,3'-Dichlorobenzidene	N/A	N/A	N/A	$7.7x10^{-3}$ mg/L	N/A
3,3'-Dichlorobenzidine	$5.5x10^{-1}$ mg/kg	$2.0x10^{-1}$ mg/kg	N/A	N/A	N/A
1,2-Dichloroethane	$1.6x10^{-1}$ mg/kg	$1.3x10^{-1}$ mg/kg	N/A	N/A	N/A
1,1-Dichloroethane	N/A	N/A	$2.8x10^{-1}$ mg/L	N/A	N/A
1,1-Dichloroethene	$4.1x10^{-1}$ mg/kg	$5.9x10^{-2}$ mg/kg	$7.0x10^{-3}$ mg/L	$1.5x10^{-2}$ mg/L	N/A
1,2-Dichloroethane	N/A	N/A	$5.0x10^{-3}$ mg/L	N/A	N/A
Dieldrin	$1.5x10^{-2}$ mg/kg	$8.8x10^{-3}$ mg/kg	N/A	$2.0x10^{-5}$ mg/L	N/A
Di-n-butylphthalate	N/A	N/A	N/A	$6.0x10^{0}$ mg/L	N/A
Di-n-octylphthalate	$1.1x10^{3}$ mg/kg	$2.0x10^{-1}$ mg/kg	N/A	$5.0x10^{-3}$ mg/L	N/A
Ethylbenzene	$5.1x10^{3}$ mg/kg	$1.0x10^{-3}$ mg/kg	N/A	N/A	N/A
Fluoride	$7.8x10^{4}$ mg/kg	$8.5x10^{2}$ mg/kg	$8.9x10^{-1}$ mg/L	$2.0x10^{0}$ mg/L	N/A
Heptachlorodibenzofuran	$8.8x10^{-4}$ mg/kg	$5.0x10^{-5}$ mg/kg	N/A	N/A	N/A
Heptachlorodibenzo-p-dioxin	$8.8x10^{-4}$ mg/kg	$5.0x10^{-5}$ mg/kg	N/A	N/A	N/A
Indeno(1,1,2-cd)pyrene	N/A	N/A	N/A	N/A	$1.9x10^{2}$ mg/kg
Indeno(1,2,3-cd)pyrene	$2.0x10^{1}$ mg/kg	$1.6x10^{-2}$ mg/kg	N/A	N/A	N/A
Lead	$4.0x10^{2}$ mg/kg	$4.0x10^{2}$ mg/kg	$2.0x10^{-3}$ mg/L	$1.0x10^{-2}$ mg/L	N/A
Manganese	$4.6x10^{3}$ mg/kg	$1.4x10^{3}$ mg/kg	$9.0x10^{-1}$ mg/L	$1.5x10^{0}$ mg/L	$4.1x10^{2}$ mg/kg
Mercury	$7.5x10^{0}$ mg/kg	$3.0x10^{-1}$ mg/kg	$2.0x10^{-3}$ mg/L	$2.0x10^{-4}$ mg/L	N/A

Table 28: OU5 Media-Specific Final Remediation Levels (FRLs)(a)

Radionuclide/Analyte	FRL				
	On-Site Soil	Off-Site Soil	Groundwater	Surface Water	Sediment
Methyl-2-pentanone	$2.5x10^{3}$ mg/kg	$9.4x10^{-1}$ mg/kg	N/A	N/A	N/A
Methylene chloride	$3.7x10^{1}$ mg/kg	$6.3x10^{-1}$ mg/kg	$5.0x10^{-3}$ mg/L	$4.3x10^{-1}$ mg/L	N/A
4-Methylphenol	$2.5x10^{2}$ mg/kg	$2.7x10^{-1}$ mg/kg	$2.9x10^{-2}$ mg/L	$2.2x10^{0}$ mg/L	N/A
4-Methyl-2-pentanone	N/A	N/A	N/A	N/A	$2.1x10^{3}$ mg/kg
Molybdenum	$2.9x10^{3}$ mg/kg	$1.3x10^{1}$ mg/kg	$1.0x10^{-1}$ mg/L	$1.5x10^{0}$ mg/L	N/A
Nickel	$1.5x10^{4}$ mg/kg	$3.4x10^{1}$ mg/kg	$1.0x10^{-1}$ mg/L	$1.7x10^{-1}$ mg/L	N/A
Nitrate	N/A	N/A	$1.1x10^{1}$ mg/L	$2.4x10^{3}$ mg/L	N/A
4-Nitroanaline	$1.5x10^{2}$ mg/kg	$8.0x10^{-1}$ mg/kg	N/A	N/A	N/A
4-Nitrophenol	N/A	N/A	$3.2x10^{-1}$ mg/L	$7.4x10^{3}$ mg/L	N/A
N-nitrosodiphenylamine	$5.1x10^{1}$ mg/kg	$1.3x10^{1}$ mg/kg	N/A	N/A	$2.6x10^{2}$ mg/kg
N-nitrosodipropylamine	$2.0x10^{-1}$ mg/kg	$2.0x10^{-1}$ mg/kg	N/A	N/A	N/A
Octachlorodibenzofuran	$8.8x10^{-3}$ mg/kg	$1.0x10^{-5}$ mg/kg	N/A	N/A	N/A
Octachlorodibenzo-p-dioxin	$8.8x10^{-3}$ mg/kg	$1.0x10^{-5}$ mg/kg	$1.0x10^{-7}$ mg/L	N/A	N/A
Pentachlorophenol	$2.3x10^{0}$ mg/kg	$9.7x10^{-1}$ mg/kg	N/A	N/A	N/A
Phenathrene	N/A	N/A	N/A	N/A	$3.0x10^{-3}$ mg/kg
Selenium	$5.4x10^{3}$ mg/kg	$2.5x10^{0}$ mg/kg	$5.0x10^{-2}$ mg/L	$5.0x10^{-3}$ mg/L	N/A
Silver	$2.9x10^{4}$ mg/kg	$1.0x10^{0}$ mg/kg	$5.0x10^{-2}$ mg/L	$5.0x10^{-3}$ mg/L	N/A
2,3,7,8-Tetrachlorodibenzo-p-dioxin	N/A	N/A	$1.0x10^{-5}$ mg/L	N/A	N/A
Tetrachloroethene	$3.6x10^{0}$ mg/kg	$1.0x10^{0}$ mg/kg	$5.0x10^{-3}$ mg/L	$4.5x10^{-2}$ mg/L	N/A
Thallium	$9.1x10^{1}$ mg/kg	$1.0x10^{0}$ mg/kg	N/A	N/A	$8.8x10^{1}$ mg/kg
Toluene	$1.0x10^{5}$ mg/kg	$2.7x10^{1}$ mg/kg	N/A	N/A	N/A
Tributyl phosphate	$2.5x10^{2}$ mg/kg	$2.9x10^{0}$ mg/kg	N/A	N/A	N/A
1,1,1-Trichloroethane	N/A	N/A	N/A	$1.0x10^{-3}$ mg/L	N/A
1,1,2-Trichloroethane	$4.3x10^{0}$ mg/kg	$1.9x10^{-1}$ mg/kg	N/A	$2.3x10^{-1}$ mg/L	N/A
Trichloroethene	$2.5x10^{1}$ mg/kg	$1.5x10^{0}$ mg/kg	N/A	N/A	N/A
Vanadium	$5.1x10^{3}$ mg/kg	$5.8x10^{1}$ mg/kg	$3.8x10^{-2}$ mg/L	$3.1x10^{0}$ mg/L	N/A
Vinyl Chloride	$1.3x10^{-1}$ mg/kg	$2.3x10^{-3}$ mg/kg	$2.0x10^{-3}$ mg/L	N/A	N/A
Xylenes, total	$9.2x10^{5}$ mg/kg	$4.0x10^{2}$ mg/kg	N/A	N/A	N/A
Zinc	$1.2x10^{5}$ mg/kg	$8.2x10^{1}$ mg/kg	$2.1x10^{-2}$ mg/L	$1.1x10^{-1}$ mg/L	N/A

(a) From "Record of Decision for Remedial Action at Operable Unit 5," Tables 9-3 through 9-6, January 1996.

(b) Total uranium is assumed to have the isotopic composition of natural uranium (50% of the activity from U-238 and 50% from U-234).

(c) The on-site soil FRL for total uranium is 82 ppm with the exception of the former production area (20 ppm FRL).

(d) N/A indicates that the FRL is not applicable for this particular radionuclide/analyte in this environmental media.

Chemical Release Information for 1996

Among the information presented in the SER for the FEMP are estimates on both radiological and nonradiological emissions to the environment. The information in this appendix includes chemical release estimates from the Superfund Amendments and Reauthorization Act of 1986 (SARA) 313 report for 1996 and a summary of emissions from the Boiler Plant during 1996. This summary includes the chemical name, type, and quantity of release, major release sources, and the basis of estimate.

To estimate releases, the FEMP used a method that followed guidelines defined by SARA 313. These estimates do not reflect actual measured emissions. Rather, the FEMP estimated releases through material balance calculation, monitoring data, or engineering calculations.

In cases where quantitative monitoring data, inventory estimates, or emission factors were not readily available, release estimates were based on best engineering judgments. Information obtained from air permits, rate of operation, quantities used, and known treatment efficiencies were used to estimate quantities released into the environment. Typically, assumptions based on best engineering judgment were required in order to perform the calculations when all variables were not known.

Calculations for Boiler Plant emissions were based on published AP–42 emission factors and coal use and analysis records for the FEMP during 1996.

The SARA 313 chemicals included in this appendix are a summary of the SARA Title III, Section 313 Report, required by SARA legislation. This legislation requires facilities to report any listed chemical manufactured or processed the previous year in excess of 25,000 pounds, or otherwise used in excess of 10,000 pounds. This report is submitted to EPA and OEPA each year on July 1 for the previous calendar year and contains chemicals on EPA's toxic substance list.

FEMP Chemical Release Information for 1996

Section One: Summary of SARA 313 Report

Chemical Name	Type of Release	Quantity Released (lb/kg)	Release Sources	Basis of Estimate
Methanol	Air: Fugitive	760 / 345	Chemical Processing Aid	Published Emission Factors
	Air: Point source	90 / 41	Chemical Processing Aid	Published Emission Factors
	Water: Great Miami River	4,400 / 2,000	Chemical Processing Aid	Best Engineering Judgment

Section Two: Boiler Plant Emissions

Chemical Name	Type of Release	Quantity Released (lb/kg)	Major Release Sources	Basis of Estimate
Particulates	Air: stack emissions	17,000 / 7,700	Fossil Fuels Combustion	Stack Testing
Sulfur Dioxide	Air: stack emissions	340,000 / 154,000	Fossil Fuels Combustion	Fuel Samples
Nitrogen Oxide	Air: stack emissions	150,000 / 68,000	Fossil Fuels Combustion	AP–42 Emission Factors
Carbon Monoxide	Air: stack emissions	57,000 / 26,000	Fossil Fuels Combustion	AP–42 Emission Factors
Non-methane Volatile Organic Compounds	Air: stack emissions	800 / 363	Fossil Fuels Combustion	AP–42 Emission Factors

FEMP Source Reduction Information for 1996

Section One: Summary of SARA 313 Report

There were no source reductions completed in 1996.

Number	Title	Scope	Status
1	Contaminated Water Under FEMP Buildings	Pump water from extraction wells underneath Plants 2/3, 6, 8 and 9; treat extracted water for removal of volatile organic chemicals and uranium before discharge	Plant 6 operational; Plant 8 operational; Plants 2/3 & 9 temporarily disabled
2	Waste Pit Area Run-off Control	Collect and treat contaminated storm water run-off from the waste pit area	Operational 7/30/92; (per 9/95 CA/FFCA/FFA-CARE Monthly Progress Report, DOE-0073-96, 10/18/95); operation ongoing
3	South Groundwater Contamination Plume	Part 1 - Install new alternate water supply and transfer to industrial user	Operational 12/7/92; operation ongoing
		Part 2 - Pump and discharge groundwater from South Plume	Operational 8/27/93; RW 5 off-line indefinitely
		Part 3 - Install and operate two Interim Advanced Waste Water Treatment (IAWWT) systems–Storm Water Retention Basin (SWRB) & Biodenitrification Effluent Treatment System (BDN-ETS) to reduce uranium contaminant loading to the Great Miami River	Operational 7/30/92
		Part 4 - Conduct groundwater monitoring and institutional controls by sampling private and existing RI/FS wells in the South Plume area and instal homeowner ion exchange treatment units.	Ongoing
		Part 5 - Conduct groundwater modeling and geochemical investigation to define the extent of the groundwater plume contaminated with uranium.	Completed 2/25/94
		OU2 - Dispute Resolution Supplemental Project: Provide for partial treatment of the South Plume discharge to further reduce uranium loading to the Great Miami River:	Operational 3/31/94;operation ongoing
		Step 1 - An additional IAWWT - South Plume Interim Treatment Project (SPIT) - to treat 200 gpm of South Plume flow;	
		Step 2 - Use off-peak capacity of Phase IAWWT for South Plume flow when no storm water requires treatment;	
		Step 3 - Eliminate low uranium concentration streams;	
		Step 4 - Extend operating life/increase capacity of the SWRB IAWWT.	
4	K-65 Silos 1 & 2	Install bentonite cap to reduce radon emissions; provide follow-on monitoring	Cap completed 11/28/91; monitoring ongoing
5	K-65 Silos Decant Sump Tank Water	Remove liquid from K-65 decant sump tank	Initial removal of liquid completed 4/16/91; periodic removal ongoing

Number	Title	Scope	Status
6	Waste Pit 6 Residues/ Exposed Materials	Eliminate potential airborne contamination by resubmerging exposed pit material	Completed 12/19/90
7	Plant 1 Pad Continuing Release	Stage 1 - Implement run-on/off control measures	Completed 1/17/92
		Stage 2 - Install new pad	Completed 12/4/92
		Stage 3 - Upgrade exisitng Plant 1 Storage Pad	Completed 9/30/94
8	Inactive Flyash Pile and Other Southfield Area Isolation Actions	Install plastic chain-link barrier and post warning signs	Completed 12/23/91
9	Removal of Waste Inventories	Disposition of low-level wast offsite	Ongoing
10	Active Flyash Pile Controls	Phase 1 - Complete interim surface stabilization	Completed 6/29/92
		Phase II - Complete active flyash pile controls	Completed 6/29/92; maintenance ongoing
11	Waste Pit 5 - Experimental Treatment Facility	Remove contents, structure, and filter material; backfill and cap with clay cover	Completed 3/20/92
12	Safe Shutdown	Remove uranium and other material from former processing equipment and ship material and equipment off-site	Ongoing
13	Plant 1 Ore Silos	Dismantle 14 ore silos and their support structures	Completed 11/18/94
14	Contaminated Soils Adjacent to Sewage Treatment Plant Incinerator	Isolate or remove and dispose of contaminated soils from the vicinity of the sewage treatment plant	Completed 11/8/94
15	Scrap Metal Piles	Phase I - Disposition LLW ferrous/non-ferrous scrap metal	Completed 11/14/94
		Phase II - Containerize scrap copper	Completed 9/29/92
		Phase IIB - Disposition scrap copper	Completed 11/21/96
16	Collect Uncontrolled Production Area Runoff (Northeast)	Collect storm water run-off from the northeast perimeter of the former production area in the Storm Water Retention Basin	Completed 8/20/93
17	Improved Storage of Soil and Debris	Improve storage of exisiting and future generated soils and debris	Ongoing
18	Control Exposed Material in Waste Pit 5	Eliminate potential airborne contamination by resubmerging exposed waste pit material	Completed 12/16/92
19	Plant 7 Dismantling	Decontaminate, dismantle and dispose of Plant 7 structure including building crane and Building 4C (Plant 4 maintenance building)	Completed 11/18/94

Number	Title	Scope	Status
20	Stabilization of UNH Inventories	Neutralize, filter and package UNH (uranyl nitrate hexahydrate inventory)	Completed
21	Expedited Silo 3 Dust Collector	Mitigate the potential release of hazardous waste material by covering and sealing dust collector hopper, removing dust collector, and capping and covering obvious release pathways	Completed 1/8/92
22	Waste Pits Area Containment Improvement	Stabilize south berm of Pit 4; regrade drainage ditches along Pits 3, 4, 5, and 6; and resurface road between Pits 3, 4, 5, and 6	Completed 7/30/93
23	Inactive Flyash Pile	Conduct field investigation to identify locations requiring material removal	Completed 4/30/92
24	Pilot Plant Sump (HWMU #22)	Remove liquid and slude from the sump	Completed 10/15/93
25	Nitric Acid Rail Tank Car and Area (HWMU #22)	Remove residual contents from tank car and decontaminate and dispose of tank car	Completed 10/11/93
26	Asbestos Removals	Mitigate the potential for contamination by and migration of asbestos fibers	Ongoing
27	Management of Contaminated Structures at the FEMP	Identify alternatives for managing contaminated structures in an Engineering Evaluation/Cost Analysis (EE/CA)	Final EE/CA approved 6/16/93; superseded by OU3 Interim Remedial Action
28	Contamination at the Fire Training Facility (HWMU #1)	Remove, decontaminate, dispose, treat or store contaminated structures, equipment, and soil from the former Fire Training Facility	Completed 6/9/95
29	Stabilization of Paddys Run Bank near Inactive Flyash Pile	Mitigate the threat of erosion induced slope failure and discharge of flyash to Paddys Run Phase I - Place 220 ft. rock berm along Paddys Run immediately adjacent to the Inactive Flyash Pile Phase II - Design and implement permanent action for same	 Completed 5/4/93 Completed 9/9/93; maintenance ongoing
30	KC-2 Warehouse/Well # 67)		Cancelled
31	Seepage Control at the South Field and Inactive Flyash Pile	Minimize future groundwater contamination by intercepting contaminated seeps that drain from the South Field and Inactive Flyash Pile and infiltrate to the Great Miami Aquifer	Completed 12/6/95

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Glossary

Activity the rate of disintegration, expressed as disintegrations per second (Becquerels) or in units of Curies (one Curie = 3.7×10^{10} Becquerels).

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).

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

Anion the negatively charged atom in an ionic compound.

Aquifer a body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

Background Radiation the radiation in the natural environment, including cosmic rays and radiation from the naturally radioactive elements, both outside and inside the bodies of humans and animals, and fallout from nuclear weapons tests.

Backlog onsite waste awaiting permitted treatment, storage, or disposal options.

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.

Billet machined ingots. During production times at the site, these billets were shipped to other DOE sites for use.

Biological Indicator organisms that reveal the presence of pollution in an ecosystem. For instance, algal blooms indicate organically or nutrient-enriched waters.

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.

Conservative Estimate used frequently in environmental monitoring and dose calculation, it is based on assumptions about an exposure situation that should result in the highest estimate of a dose.

Contamination a condition in which any substance or material is somewhere it is not supposed to be.

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 pounds).

Daughter a nucleus that results from radioactive decay; also, progeny.

Decay the disintegration process of an atomic nucleus.

Derby the main product of the former site processing of uranium metal.

Derived Concentration Guideline the concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (for example, drinking water or breathing the air) that would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and the lens of the eye.

Dose quantity of radiation absorbed in tissue.

Drum Equivalent the number of 55-gallon drums that it would take to contain a given volume of waste.

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.

Exposure Pathway a route by which materials could travel between the point of release and the point of delivery of a radiation or chemical dose to a person.

Fission the splitting of a heavy nucleus into two approximately equal parts, accompanied by the release of large amounts of energy and generally one or more neutrons.

Flux Rate a measurement of the emission rate of radon.

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

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

Glacial Till the mix of clay, silt, sand, gravel, and boulders deposited by the glaciers.

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

Hydrology the study of the properties, distribution, and circulation of water through the local environment.

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

Ingot remelted derbies and uranium scrap-metal from the former site production process. They varied in weight, size, and shape according to how they were used at this and other DOE sites.

In situ in the original location.

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.

Lithology the study, classification, and mapping of rocks and rock formations.

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 Congress in 1914 and charged with developing radiation protection standards.

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

Null Allele an inactive group of genes.

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.

Opacity how much light is blocked by particulates present in stack emissions.

Operable Unit a discrete action that comprises an incremental step toward comprehensively addressing site problems. Operable units may address geographical portions of a site, specific site problems, or initial phases of an action performed over time, or any actions that are concurrent but located in different parts of the site.

Overburden the soil, rock, and other naturally occurring material overlying the bedrock.

Overpacking the act of placing a deteriorating drum inside a new, larger drum to prevent further deterioration or the possible release of contaminants during storage.

Parent Material a radionuclide that produces a specific "daughter" product either directly or as a later result of radioactive decay or disintegration.

Person-rem a 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, pipe, or other discernable conveyance.

Positive Interference during sampling analysis, this produces a result that indicates the presence of a radionuclide when, in fact, there is very little or no presence of this radionuclide in the sample.

Potable Water water that is suitable for consumptive purposes.

Radioactive Emissions releases of radioactive materials to the environment.

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.

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.

Remedial Action — an action that is consistent with the final remedy following a formal examination of the nature and extent of the release, or threat of release, assessment of the risk, and selections of the final remedy based on an evaluation of possible alternatives (RI/FS process).

Removal Action — any necessary action to abate an immediate threat to health and the environment, including actions necessary to monitor, assess, or evaluate the threat.

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 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.

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.

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.

Scintillation Cell — produces a light pulse when struck by an alpha particle and is able to be counted.

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

Site Characterization — designed to provide the information needed to identify site hazards and to select worker protection methods.

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.

Terrace Remnants — land that stands higher than its surroundings due to erosion.

Thermoluminescent Dosimeter — used to monitor the amount of radiation to which it has been exposed.

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.

Transuranic — an element with an atomic number greater than uranium.

Wetland — areas covered or saturated with water for enough time to support water-loving vegetation. Typical wetlands include swamps, marshes, and bogs.