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Fernald Environmental Restoration Management Corporation

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Acronyms and Abbreviations

ACA	Amended Consent Agreement
AEC	Atomic Energy Commission
AHF	Anhydrous Hydrogen Fluoride
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
ESA	Endangered Species Act
ES&H	Environment, Safety, and Health
ETS	Effluent Treatment System
FACA	Federal Advisory Committee Act
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
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
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
USEPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compounds
WEMCO	Westinghouse Environmental Management Company of Ohio
WM/PP	Waste Minimization/Pollution Prevention

Conversion Tables

Multiply	By	To Obtain	Multiply	By	To Obtain
Length					
inches	2.54	centimeters (cm)	cm	0.394	inches
feet	0.3048	meters (m)	m	3.281	feet
miles	1.61	kilometers (km)	km	0.62	miles
Volume					
cubic centimeters (cm^3)	1	milliliters (mL)	mL	1	cm^3
cubic inches (in^3)	16.39	mL	mL	0.061	in^3
fluid ounces	29.6	mL	mL	0.034	fluid ounces
grams (g)	1	mL (water)	mL (water)	1	g
kilograms (kg)	1	liter (L) (water)	L (water)	1	kg
mL	1,000	L	L	0.001	mL
gallons	3.79	L	L	0.264	gallons
quarts	0.95	L	L	1.057	quarts
cubic feet (ft^3)	0.02833	cubic meters (m^3)	m^3	35.3	ft^3
Mass					
ounces	28.35	g	g	0.035	ounces
pounds	454	g	g	0.0022	pounds
pounds	0.454	kg	kg	2.2	pounds
tons	0.907	metric tons	metric tons	1.1	tons
Activity					
Curies (Ci)	10^{12}	picocuries (pCi)	pCi	10^{-12}	Ci
Becquerel (Bq)	27.02	pCi	pCi	0.037	Bq
Ci	10^6	microcurie (µCi)	µCi	10^{-6}	Ci
pCi	0.037	Bq	Bq	27	pCi
Dose					
rem	1,000	millirem (mrem)	mrem	0.001	rem
Sieverts (Sv)	100	rem	rem	0.01	Sv
For Natural Uranium in Water					
micrograms per liter (µg/L)	1	parts per billion (ppb)	ppb	1	µg/L
µg/L	0.6757	pCi/L	pCi/L	1.48	µg/L
milligrams per liter (mg/L)	1	parts per million (ppm)	ppm	1	mg/L
mg/L	675.7	pCi/L	pCi/L	0.00148	mg/L
pCi/L	1.48	ppb	ppb	0.6757	pCi/L
For Natural Uranium in Soil					
µg/g	1	ppm	ppm	1	µg/g
µg/g	0.6757	pCi/g	pCi/g	1.48	µg/g
pCi/g	1.48	ppm	ppm	0.6757	pCi/g
For Temperature					
°F	x 9/5 + 32	°C	°C	- 32 x 5/9	°F

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

The Fernald site is a Department of Energy (DOE)-owned facility that produced high-quality uranium metals for military defense for nearly 40 years. DOE suspended production at the site in 1989 and formally ended production in 1991. Although production activities have ceased, the site continues to examine the air and liquid pathways as possible routes through which pollutants from past operations and current remedial activities may leave the site.

The Site Environmental Report (SER) is prepared annually in accordance with DOE Order 5400.1, General Environmental Protection Program. This 1994 SER provides the general public as well as scientists and engineers with the results from the site's ongoing Environmental Monitoring Program. Also included in this report is information concerning the site's progress toward achieving full compliance with requirements set forth by DOE, U.S. Environmental Protection Agency (USEPA), and Ohio EPA (OEPA).

For some readers, the highlights provided in this Executive Summary may provide sufficient information. Many readers, however, may wish to read more detailed descriptions of the information than those which are presented here. All information presented in this summary is discussed more fully in the main body of this report.

Environmental Monitoring

The Fernald Environmental Monitoring Program plays a key role in the effort to investigate the effects that years of operation have had on the local environment. Environmental monitoring primarily examines the air and water pathways; other program components address *contamination* risks associated with cleanup procedures. A summary of air and liquid pathway results is presented below.

Air Pathway

Monitoring the air pathway incorporates results not only from the air monitoring stations but also from soil, grass, produce, and milk *sampling*. (Radon monitoring is discussed separately below.) Overall, the air monitoring data from 1994 were consistent with data from 1993, and with the exception of short-term *opacity* excursions, all Boiler Plant emissions were well below permit limits.

Data collected from fenceline air monitoring stations showed that average concentrations of uranium were all less than 1% of the DOE standard. Airborne emissions for 1994 were estimated to be 1.3 kg (2.9 pound). Results from monitoring the demolition from Plant 7 indicate that airborne uranium levels in the vicinity of Plant 7 remained well below the DOE standard. Airborne uranium emissions steadily dropped after processing operations were discontinued in 1989, and they have remained relatively constant since 1991.

Uranium concentrations in offsite soil *samples* ranged from 0.95 pCi/g to 2.8 pCi/g (1.4 ppm to 4.1 ppm) and are within the range of naturally occurring uranium concentrations in Ohio soil. Previous environmental monitoring has shown some *onsite* and nearby offsite soils to have elevated concentrations of uranium due to the deposition of airborne uranium released during the production period.

The 1994 results from grass sampling indicated that uranium concentrations are within the range of historical concentrations and suggest that 1994 emissions have not significantly affected uranium concentrations in grass.

Home-grown sweet corn and tomatoes are two of the major crops sold from roadside stands within 5 km (3 miles) of the site. Local residents also grow and sell beets, potatoes, apples, lettuce, pumpkins, cucumbers, and peppers. Uranium concentrations in produce in 1994 were consistent with previous years' data. Laboratory analyses did not detect any significant differences in uranium concentrations between produce grown near the site (0 to 5 km or 0 to 3 miles) and produce grown at distant locations (11 to 42 km or 7 to 26 miles).

Uranium concentrations from the local dairy's milk were comparable to those from a background dairy in Indiana. The data demonstrated that milk from the local dairy is not affected by site emissions.

Radionuclide concentrations in locally grown hay were comparable to concentrations found in hay grown distant from the site. Feed supplements used at the local and background dairy did not contain uranium in concentrations significantly higher than soil a cow might ingest while grazing, and are therefore not likely to be a large external source of uranium in the diet of local cattle.

Measurements of direct radiation indicate that levels increase with proximity to the K-65 silos. However, these levels are 90% 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.

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 1994, the average fenceline radon concentration was 0.8 pCi/L (1.2 ppb). This concentration is greater than the 1993 average concentration of 0.6 pCi/L (0.89 ppb), but it is well below the guideline of 3.0 pCi/L (4.4 ppb). For comparison, the average background concentration measured in 1994 was 1.3 pCi/L (1.9 ppb).

Liquid Pathway: Effluent and Surface Water

The effluent and surface water component of the liquid pathway is monitored to determine any impacts from the Fernald site 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.

Approximately 351 kg (772 pounds) of uranium were discharged to the Great Miami River during 1994. Of that total, 204 kg (449 pounds) were from Manhole-175 (the site's effluent pipeline), and 147 kg (323 pounds) were from South Plume groundwater pumping. Approximately 109 kg (240 pounds) of uranium reached Paddys Run through uncontrolled stormwater runoff during 1994.

The liquid effluent discharged to the Great Miami River resulted in a slightly higher measurement of uranium at the downriver sampling location than the upriver location. However, the downriver concentration was consistent with 1993 sampling results. Paddys Run continued to show effects of stormwater runoff from the site. Although the average uranium concentration at the nearest offsite sampling location was higher than in 1993, it was only 0.75% of the DOE guideline for drinking water. (That guideline is used for comparison purposes only since there is no established guideline for uranium in surface water.)

Radionuclide concentrations in the Great Miami River and Paddys Run sediments for 1994 were consistent with previous years' data and did not indicate a build-up of radioactive pollutants in the sediment.

In 1994, 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 2,512 NPDES samples taken at internal and external monitoring locations in 1994, there were only three violations of NPDES limits at Manhole-175, the final NPDES monitoring point before effluents are discharged to the river. The three violations concerned the dissolved oxygen and suspended solid concentrations of effluent released to the Great Miami River.

Liquid Pathway: Groundwater

The site 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 1994 the Fernald site routinely sampled 33 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 USEPA standard of 13.5 pCi/L (20 ppb). Of these 33 wells, 32 wells were also sampled for several metals. Four wells showed concentrations of lead at or above the Primary Drinking Water Standard as listed for the control of lead. Additionally, as is common for an area with high natural concentrations of iron and manganese, such as the area surrounding the Fernald site, several private wells showed concentrations of these two metals above the USEPA Secondary Drinking Water Standards.

Aside from the private well sampling program, the Fernald site conducts comprehensive groundwater sampling of several site-owned wells. In 1994, the site sampled 157 on- and offsite wells for uranium, and 50 wells showed detections above the proposed USEPA guideline of 13.5 pCi/L (20 ppb). All of the offsite locations were in the South Groundwater Contamination Plume area. This comprehensive program also sampled those wells for 11 metals and 31 Volatile Organic Compounds that have Primary Drinking Water Standards. Of these 42 constituents, 11 were detected above their primary standards in more than one well. Three other constituents showed single detections above the secondary standard.

Estimated Radiation Dose for 1994

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

In 1994, the hypothetical maximally-exposed individual living nearest the Fernald site, 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 0.7 *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 1994.

As discussed above, the radon concentration measured at the site fenceline in 1994 was 0.8 pCi/L (1.2 ppb). The effective dose calculated from this concentration was estimated to be 576 mrem, and it includes the annual dose received from average background levels of radon (approximately 200 mrem per year).

Introduction to the Site

Today, the Fernald site, which is owned by the Department of Energy (DOE) and operated by the Fernald Environmental Restoration Management Corporation (FERMCO), focuses extensively on environmental restoration. Because it was formerly a uranium metals processing facility, scientists closely investigate the site and surrounding areas for radioactive contamination. Remedial techniques are then developed accordingly.

This Site Environmental Report (SER) documents the results of the Environmental Monitoring Program for calendar year 1994. In accordance with DOE Order 5400.1, "General Environmental Protection Program," the information in the 1994 SER is current from January 1, 1994, through December 31, 1994.[1] In order to put the information presented in this report into perspective, Chapter One contains the following introductory sections:

- **The Fernald Site Mission: Environmental Compliance and Restoration**, a historical overview of the site's former operations and a description of its current cleanup mission and site restoration activities;
- **Environmental Program Information**, a description of site activities aimed at monitoring environmental quality;
- **Local Geography**, an introduction to the physical, ecological, and human characteristics of the area;
- **Exposure Pathways to Humans**, an examination of the physical and biological surroundings as possible routes for contaminants to reach local communities; and
- **Environmental Standards and Guidelines**, a description of the various standards with which the Fernald site must comply to protect the local environment.

The Fernald Site Mission: Environmental Compliance and Restoration

In recent years, the mission at the Fernald site has become one of environmental compliance and restoration. However, when the site was established in the early 1950s, its primary mission was to produce uranium metal.

Shortly after the end of World War II, the United States recognized a need for new facilities to produce uranium metal in support of defense activities. Existing facilities, developed for the war effort, were neither economical to operate nor capable of meeting increasing demands. The Atomic Energy Commission (AEC) required an increase in the quality and quantity of uranium metal as well as improvements in the control and safety of production operations.

After evaluating several sites, the government selected a 425-hectare (1,050-acre) area, about 27 km (17 miles) northwest of downtown Cincinnati, Ohio, as the site for a new production facility (see Figure 1). This facility was sited just north of Fernald, Ohio, a small farming community. The government broke ground on May 16, 1951, and produced the first uranium *derby* at the site's Pilot Plant on October 11, 1951. The major portion of construction was complete by 1954.

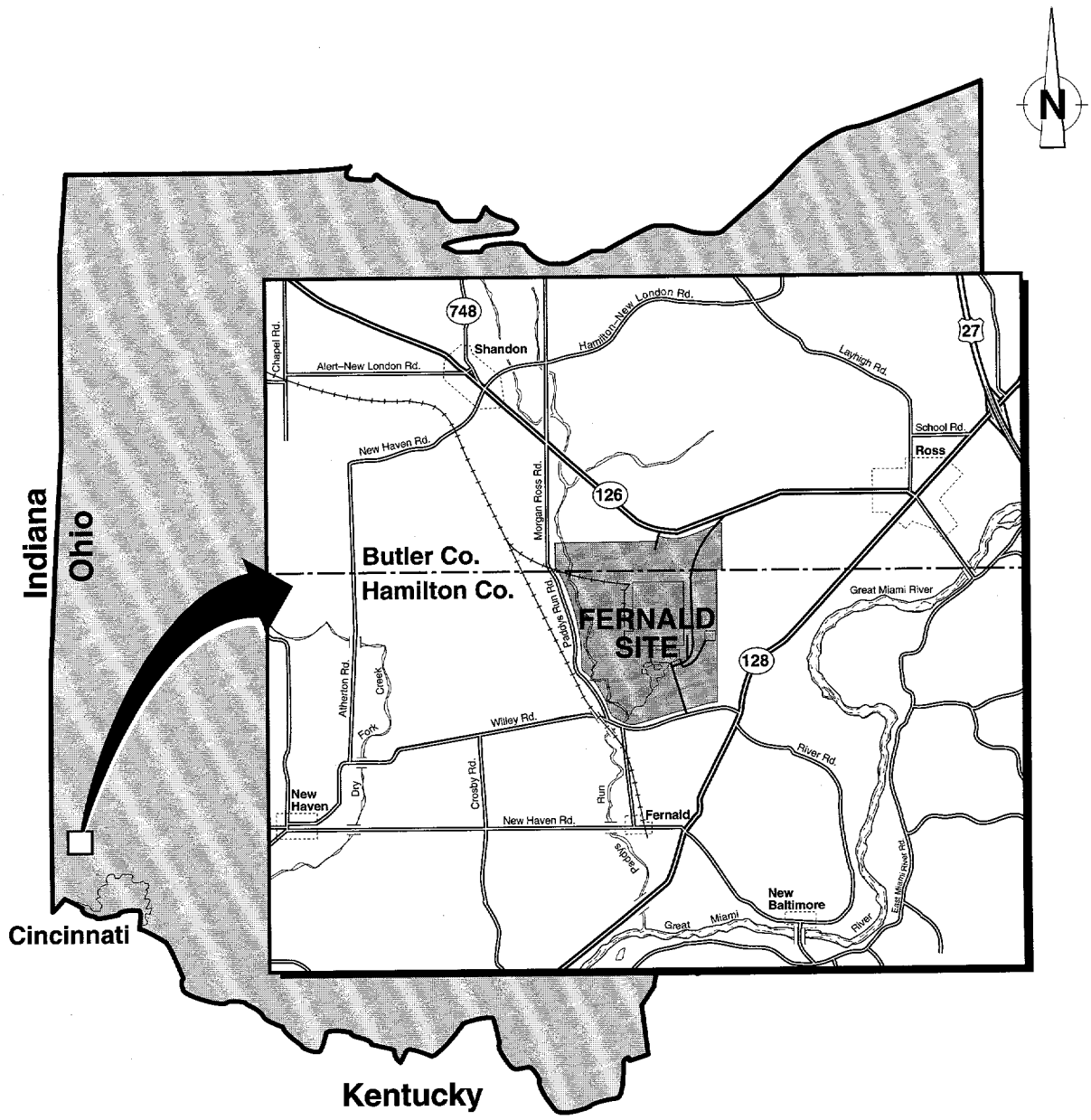
In general, the relative importance and corresponding funding of the former production and environmental activities reflect the course of U.S. Defense history from the end of World War II until today. Uranium-metal production reached a peak during the height of the Cold War in the 1950s and 1960s. During the late 1970s, funding for production and supporting organizations, including environmental monitoring, was significantly reduced. Production accelerated again in the early 1980s when the United States increased defense spending. By the late 1980s, however, an increasing demand for environmental accountability, combined with a decreasing demand for uranium metal at other DOE facilities, influenced DOE to change the site's mission from uranium production to environmental restoration.

Production was suspended in July 1989. In October 1990, DOE transferred management responsibility for the site from its Defense Programs organization to the Office of Environmental Restoration and Waste Management. In February 1991, DOE announced its intention to formally end the production mission and submitted a closure plan to Congress, which became effective in June 1991.

Ohio Field Office Formed

DOE established an Ohio Field Office at Miamisburg, Ohio, during 1994 as part of its continuing effort to improve the efficiency and responsiveness of its field structure. The Ohio Field Office oversees operations at Fernald, the Mound Plant in Miamisburg, and the West Valley Demonstration Project in West Valley, New York. The Fernald site was formerly under the Oak Ridge Field Office in Tennessee. In 1992, DOE formally reorganized Fernald as an independent field office. However, Oak Ridge continued to provide administrative and technical support until the formation of the Ohio Field Office.

Figure 1: Fernald Site and Vicinity



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

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An Overview of Former Production Operations

Although production at the Fernald site ended in 1989, a brief overview of the former production operations will provide the reader with a perspective on the ongoing Environmental Monitoring Program and other environmental investigations. The major steps in the production process are highlighted in Figure 2. A variety of materials were used in the process, including many that were received from other DOE sites. Even materials such as floor sweepings, dust collector residues, and production residues were recycled in order to recover as much uranium as possible.

Depleted and Enriched Uranium

Much of the uranium processed in more recent years at the site was depleted in the uranium–235 isotope; that is, it contained less than 0.71% uranium–235, the concentration found in naturally occurring uranium. (Isotopes are discussed in Chapter Two, "Fundamentals of Radiation and Health Hazards.") During the years of production at Fernald, the uranium processed contained various concentrations of uranium–235, ranging from depleted to 2% slightly enriched.

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 uranium metal called a "derby."

Some derbies were sent directly to other DOE sites, while the site remelted the remainder, along with uranium scrap-metal recovered from earlier production, and poured them into graphite molds to form *ingot*s. Ingots varied in weight, size, and shape according to how they were used at this and other DOE sites. Machining of these ingots occurred in plants 6 and 9, after which the *billet*s (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 Fernald site no longer produces uranium metal, 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 1994 include the following:

Radioactive

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

text continues on page 8

Figure 2: Former Site Production Process

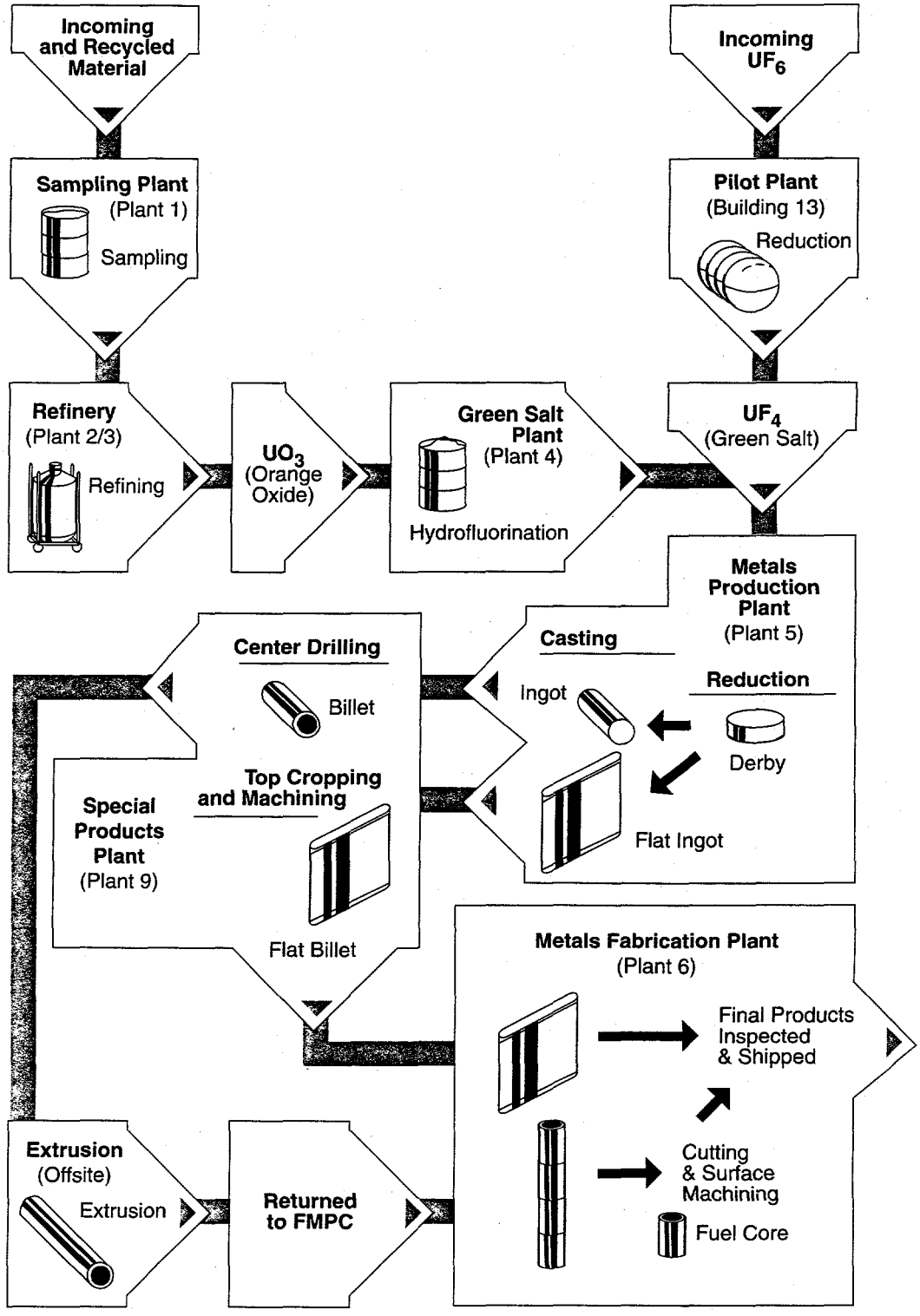
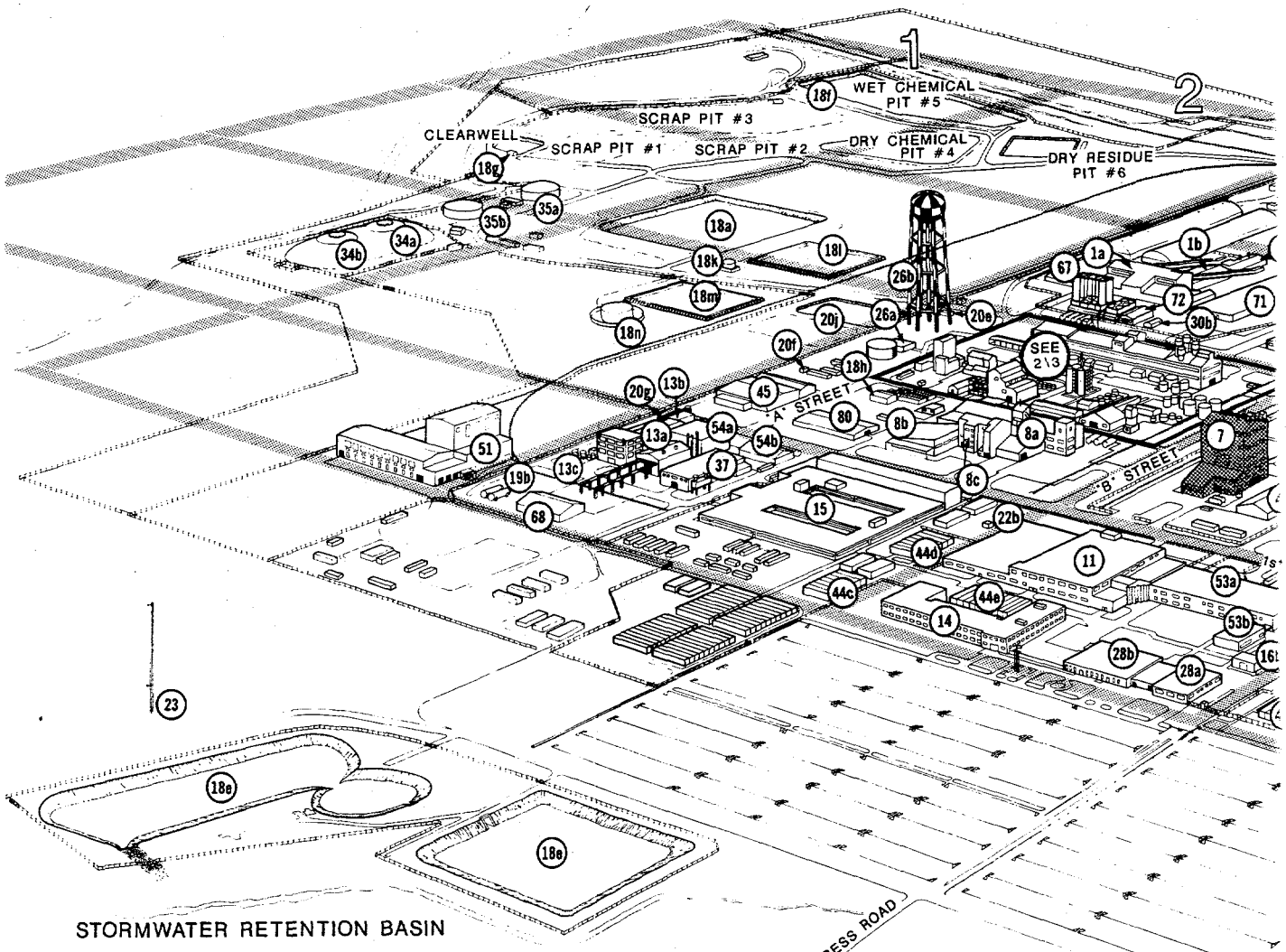
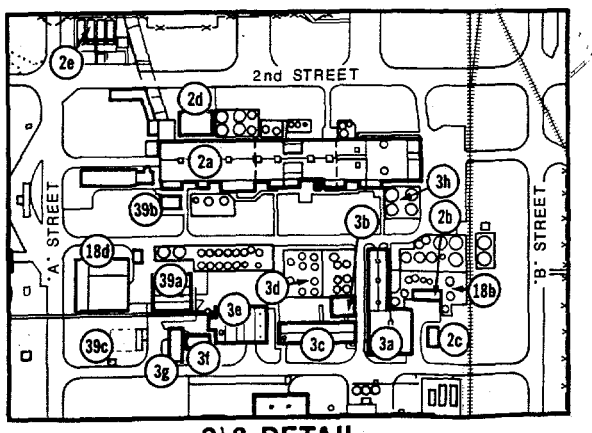


Figure 3: Fernald Site Perspective





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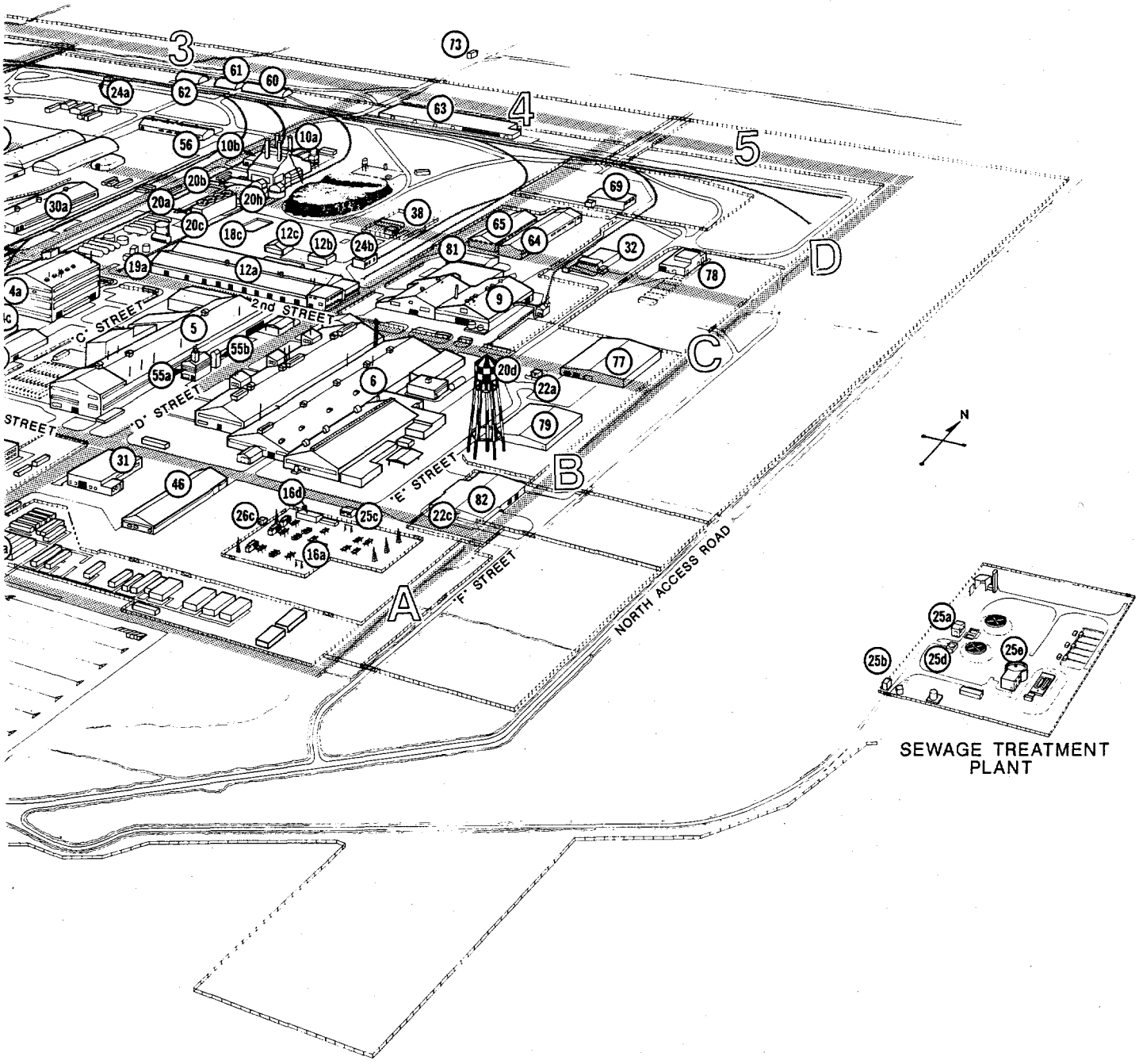


* Note : Plant 7 was imploded in September 1994 and completely demolished by the end of the year.

Building Identification

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

* Outside of Perimeter Security Fence

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

Hazardous

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

The site has repackaged some materials into new drums and removed materials no longer needed since production ended. For example, thorium previously stored in a deteriorating above-ground silo, in bins, and in drums on an outdoor pad has been repackaged in new drums and stored in a warehouse. The Fernald site continues to reduce its inventory of radioactive and hazardous materials once used for production by disposing of them at designated waste disposal facilities.

Environmental Restoration Activities

In fulfillment of its current mission, the site continues to strive for compliance with all environmental regulations while working toward site restoration. During 1994, this was evident in many activities that will contribute to the final remediation of the Fernald site. Some of the more prominent activities during 1994 are described next.

Future Land Use at the Fernald Site

An important process in remediation is the determination of what will be the future land use at Fernald. Future use will determine the cleanup levels that must be achieved during remediation. Some of the more popular suggestions for future land use at Fernald have been to provide a nature or wildlife preserve; to maintain open green space; to construct a technology center and/or museum; to maintain light industrial activity; to provide a low-level radioactive waste repository; or to use the land for agriculture, recreation, residences, or yard waste and recycling.

The Fernald Citizens Task Force was established in August 1993 to provide DOE with stakeholder recommendations regarding the remediation of the site. The stakeholders comprising the Task Force represent an array of interests and backgrounds that are critical to cleanup decisions. Seven general evaluation criteria taken into consideration for any option are long-term safety, short-term risks, onsite disposal requirements, impact on natural resources, transportation and offsite disposal requirements, community impacts and benefits, and cost.

Specific future use or uses for which the site is best suited are not yet determined. However, DOE has recommended that some portion of the site be dedicated to the long-term disposal of the contaminated materials present at Fernald. The Task Force will present their formal recommendations on waste disposition and land use in their final report in July 1995.[1a]

Plant 7 Takedown

Fernald completed demolition of the tallest and most visible former production building in December 1994. The seven-story Plant 7 was built in 1953 to house the chemical processes which produced green salt (described on page 4).

Before final demolition of the Plant 7 structure, the building was emptied of all stored material and debris; and all equipment, piping, duct work, electrical and other equipment was removed. Finally, all interior and exterior siding was removed, leaving only the structural steel framework of the building. Final demolition involved the placement and detonation of linear-shaped explosive charges on key structural supporting columns.

In the initial takedown attempt on September 10, the first two floors of the building collapsed as planned. However, splice plates that had been pre-cut on the third and fifth floors did not separate as anticipated. The building dropped approximately 6-8 meters (20-25 feet) instead of the planned 24 meters (78 feet). The final takedown on September 17 involved strategic placement and detonation of additional explosive charges at key structural supporting columns. Following the successful takedown, workers completed the project by using crane-mounted mechanical shears to cut the steel into sizes compatible with shipment offsite for recycling. (Results from the environmental monitoring activities associated with the Plant 7 takedown are presented in Chapter Four.)

Plant 7 was the first former Fernald production building to be dismantled. There are 125 structures in the former uranium production area of the site to be removed as part of the Fernald environmental restoration mission.

Fire Training Facility Demolition

The Fire Training Facility (FTF), a two-story block building located 100 yards north of the former Fernald production area boundary, was demolished on September 7, 1994. Segregation, size-reduction, and radiological surveying of the debris took three days to complete. The site is waiting for United States Environmental Protection Agency (USEPA) to name an approved facility to receive the clean debris. Consequently, the FTF debris will be stored onsite pending availability of a disposal facility, at which time the debris will be containerized for shipment and disposal offsite.

The Fernald site fire department and surrounding community fire departments operated the FTF as a training facility from 1966 to 1990. The FTF was operated much like other such facilities across the nation, except that some of the material used to start fires (primarily waste oils and solvents) were also contaminated with radionuclides. The site used the FTF about 60 days per year.

Plant 1 Ore Silos Removal

Fernald completed a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended *removal action* to dismantle 14 Plant 1 Ore Silos and their support structures in December 1994. While the ore silos had been out of service for several years, they were never thoroughly emptied and cleaned. In 1991, deteriorated valves caused residual raffinate material in the silos to leak onto an elevated concrete pad beneath them. Raffinate material is the waste residue from the processing of uranium ore after uranium is removed.

Workers dismantled the silos and support structures and cut up the concrete, steel, piping, and other material into sizes which will allow packaging for offsite disposal. Before beginning the demolition and size-reduction work on this project, workers erected enclosures around the area and constructed a size-reduction building equipped with high-efficiency particulate air filters to minimize the spread of contamination.

Minimum Additive Waste Stabilization Demonstration

During 1994, Fernald conducted a demonstration project to test the feasibility of using vitrification (transforming waste into glass) to stabilize radioactive waste at Fernald and, at the same time, reduce the volume of waste that must be disposed. The Minimum Additive Waste Stabilization (MAWS) program was an innovative approach that combines vitrification, water treatment, and soil washing processes to potentially save millions of dollars in cleanup costs through waste minimization. The purpose of the program was to demonstrate that the MAWS concept may be a safe and economical treatment alternative for the large volumes of low-level radioactive and *mixed wastes* present at Fernald. During the demonstration, workers successfully blended waste materials with contaminated soils and heated them into a stable glass form for safe and permanent disposal.

The glass produced in the MAWS system was in the form of gems, which look like flattened marbles. The glass still contains radioactive elements, but the radioactivity is trapped in a glass matrix. The potential for the spread of contamination through leaching is eliminated, and the glass is ready for safe and permanent disposal. The developments from the MAWS project supported the construction of a vitrification pilot plant now under construction at Fernald to remediate wastes from the K-65 silos.

Vitrification Pilot Plant

In July 1994, Fernald began construction of the vitrification pilot plant to convert low-level radioactive waste from the K-65 silos into a glass form that is stable, durable, and safe for permanent disposal. Radium-bearing residues from the two K-65 silos and waste from silo 3 will be heated in a furnace under controlled conditions to form a glass-like substance. 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.

Vitrification is DOE's and USEPA's preferred alternative for stabilizing the silo wastes. The purpose of the new facility is to test the feasibility of vitrifying the silo waste materials by mixing sand, calcium oxide, and other additives with the silo waste. This will enable DOE and FERMCO to better define remediation costs and engineering design for final remediation of the silos. The pilot plant is scheduled to operate using non-radioactive surrogate material beginning in late September 1995. Actual silo wastes will be fed into the furnace beginning in March 1996.

Uranium in Soils Integrated Demonstration

During 1994, Fernald continued to host DOE's Uranium in Soils Integrated Demonstration (USID), a study evaluating various technologies for removing uranium from contaminated soil. Fernald was chosen as the host site for the demonstration because its large volume of uranium-contaminated soils is representative of the technical challenges that will be faced at other DOE sites.

A soil decontamination process being developed at Fernald uses physical and chemical means to separate the uranium from the soil. After the soil passes through screens and a scrubber, it is put into a chemical solution to remove the uranium from the soil. Clean soil typically is returned to the site of excavation after the uranium is extracted through the soil-washing process.

The USID program focuses on more than just the decontamination process. One of the more costly and time-consuming aspects of remediating uranium-contaminated soil is waiting for soil samples to be analyzed in a laboratory, a process that can take days to weeks. Technologies that can deliver immediate results in a mobile field unit have already demonstrated successful detecting and mapping of surface and subsurface radionuclide concentrations at a reduced cost.

The program also is developing more efficient technologies for precise excavation and treatment and disposal techniques. The aim of developing more efficient excavation technologies is to remove only contaminated layers of soil, which would reduce the volume of soil to be treated, thereby lowering remediation costs.

Environmental Program Information

Because of the continued onsite storage of radioactive and hazardous waste, the Fernald site conducts environmental program activities to *monitor* environmental quality in the area surrounding the site. 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 that were applied during the site 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, Fernald site 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 site 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 site and enter the surrounding environment. In short, this year-round Environmental Monitoring Program has several responsibilities:

- Ensure that the site has procedures in place to detect any release of materials so that corrective actions can be taken as quickly as possible,
- Closely monitor releases to ensure that air emission and liquid effluent standards and guidelines are not exceeded,
- Evaluate the impact of site 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 site, and
- Measure progress in correcting problems from past operations and in implementing improved environmental management practices.

Meteorology Program

The Fernald site'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, and precipitation (see Table 1 on page A-2).

The meteorological instruments are inspected and re-calibrated regularly to ensure that they are functioning properly. The system is down during these 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 meteorological data from the Greater Cincinnati – Northern Kentucky International Airport, located about 27 km (17 miles) south of the site.

The meteorological data gathered at the site are primarily used to evaluate climatic conditions at the site. 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 whatever weather conditions exist. 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.

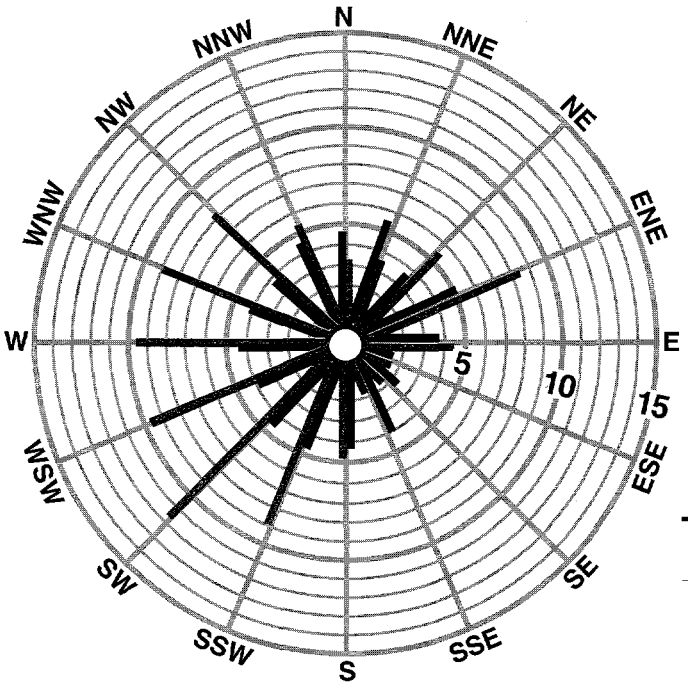
Figures 4 and 5 (on the next page) are annual wind roses, which illustrate the average wind speed and general direction measured at the 10-meter (33-foot) and 60-meter (197-foot) levels in 1994. The prevailing winds were from the southwest (11%) and from the west (9%) at the 10-meter level. The prevailing winds at the 60-meter level were from the south-southwest (13%) and from the northeast (10%) during 1994.

The prevailing west and southwest winds occur as the result of the general west to east flow of air at the midlatitudes of the earth. The winds blowing from the northeast were usually 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 set up, cooler, more dense air flows from higher elevations farther up the Great Miami River basin towards the lower elevations to the south-southwest.

In previous years, trees growing near the meteorological tower affected the measured wind speeds at the 10-meter (33 foot) level because they acted as a wind barrier. In November 1993, trees within a 107-meter (351 foot) radius were cut down. As a result, the winds as measured through 1994 appear to be much more representative of the winds which cross the site and general area. This will allow for more accurate results when the data are used in atmospheric models to determine how airborne effluents are mixed and dispersed around Fernald.

In 1994, the precipitation measured at the Fernald site was 98 cm (39 inches), which is slightly less than the average annual precipitation of 104 cm (41 inches)

Figure 4: 1994 Wind Rose Data, 10-Meter Height



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Average wind speed from this direction.

Percentage of time that the wind blew from this direction.

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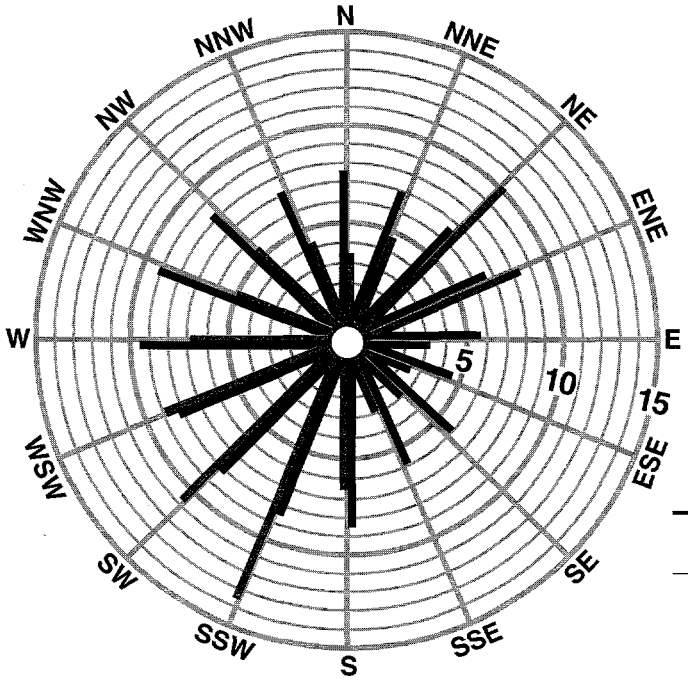
Figure 5: 1994 Wind Rose Data, 60-Meter Height



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Average wind speed from this direction.

Percentage of time that the wind blew from this direction.

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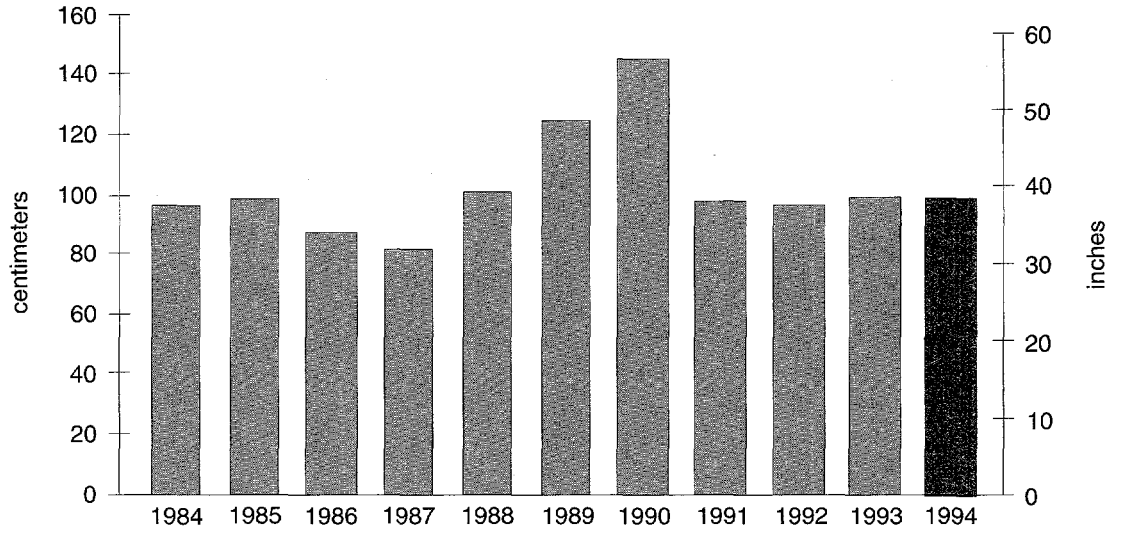
for 1964 through 1993. Figure 6 shows 1994 total precipitation for the area in relation to the annual precipitation amounts recorded since 1984. (Precipitation totals for 1984 through 1992 were taken from the measurements made at the Greater Cincinnati – Northern Kentucky International Airport because of a computer software problem at the site meteorological tower. This problem was corrected, and the 1993 and 1994 totals were taken from measurements made at the Fernald site.)

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 since the goal of waste minimization is to reduce the total amount of waste generated. However, the real challenge of the Waste Minimization Program is to reduce the amount of secondary waste generated during remediation and to recycle or reuse primary waste, as appropriate.

The Fernald site 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 at Fernald has been recognized by DOE as a benchmark program for applying waste minimization and pollution prevention principles at a remediation site. The DOE Pollution Prevention Council visited the site in 1994 to learn about the success of the program and to develop a method to transfer information and lessons learned to other DOE facilities.

Figure 6: Annual Precipitation Data, 1984 – 1994



Precipitation totals prior to 1993 are from the Greater Cincinnati – Northern Kentucky International Airport. Totals from 1993 and 1994 are from the site.

The Waste Minimization Program created waste disposition options for project activities. When evaluating waste dispositions, dependency on disposal is reduced when there are alternatives to choose from. The idea is to "drive" waste toward more cost-effective options, such as sanitary waste or reuse. Several new disposition avenues were initiated in 1994. For example, the Material Release Facility is now used to decontaminate materials for offsite release. Recycling contracts are being put into place for metal from Decontamination and Decommissioning (D&D) projects. Also, segregation techniques are being employed to ensure materials can be recycled or disposed as sanitary rather than as low-level radioactive waste.

Segregation and decontamination are essential during remediation and are part of effective project management in order to reduce the amounts of waste that must be managed. Additional waste minimization accomplishments in 1994 are listed below:

- 109 metric tons (120 tons) of scrap metal were decontaminated and released for resale or recycle through the Material Release Facility;
- 88 project and design engineers were trained in the application of waste minimization and life-cycle cost analysis during project design and implementation;
- Waste minimization personnel were integrated into project teams for each remediation activity to identify potential waste minimization;
- A contract was awarded to an outside vendor to recycle 644 metric tons (710 tons) of scrap metal from the Plant 7 D&D project;
- Three Pollution Prevention Opportunity Assessments were performed on routine waste-generating activities and identified opportunities to reduce hazardous and low-level waste generation;
- Reusable containers were used to package and transport recyclable materials from D&D activities;
- An electronic Reuse Bulletin Board was developed for an approximate monthly savings of $2,500 from the reuse of materials instead of ordering new items;
- 595 m^3 (21,000 ft^3) of Controlled Area office trash were segregated and disposed of as sanitary waste instead of low-level waste;
- 8,046 m^3 (284,000 ft^3) of office paper, cardboard, glass, and polystyrene were recycled;
- 41 kg (89.5 pounds) of freon were recovered from drinking fountains and air conditioning units for recycle;
- 5,242 m^3 (185,000 ft^3) of flyash and 22 m^3 (760 ft^3) of asbestos-containing material were segregated for disposal as sanitary waste instead of low-level waste;
- 3,140 kg (6,900 pounds) of aluminum cans and 1,295 LaserJet printer cartridges were recycled; and
- 363 kg (798 pounds) of silver-containing photographic solution were recycled.

Natural Resource Management

The management of natural resources will be an ongoing process as long as there is federal ownership of the site. Natural resources have aesthetic, ecological, educational, historical, recreational, and scientific value to the United States. The following discussions provide information on the natural resources found on Fernald site property.

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 site and in the Paddys Run 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 site, and local dairy farmers lease Fernald site 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 Fernald site 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 site. In addition to collecting extensive ecological baseline data, they also studied plants and animals to determine if any species were being stressed by former site operations. Based on statistical analyses, the study concluded that the site'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 site conducted surveys in 1993 and 1994 to update information on any threatened or endangered species that may be found onsite. The results of the surveys show 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 site. A population of state-listed threatened Sloan's crayfish (*Orconectes sloanii*) was found in the northern sections of Paddys Run. There are also several species of threatened and endangered migratory birds that pass through the site. Some of the birds that have actually been spotted onsite include the northern harrier (*Circus cyaneus*), northern waterthrush (*Seiurus noveboracensis*), and dark-eyed junco (*Junco hyemalis*).

Wetlands

Wetlands are defined as areas covered or saturated with water for enough time to support water-loving vegetation. A wetland delineation was conducted onsite in December 1992 and January 1993. A total of 15 hectares (36 acres) of freshwater wetlands were delineated on the Fernald site. 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. A wetland delineation is scheduled to be conducted every three years in order to provide current information.

Floodplains

Floodplains within the site property are confined to the north-south corridor that contains Paddys Run. Outside of the site boundaries, the 100- and 500-year floodplains of the Great Miami River extend west of the "Big Bend" region, which is east of the Fernald site. It also extends northward along Paddys Run from the confluence of the two waterways past the southern boundary of the site.

Cultural Resources

Factors such as geologic setting, surface waters, soils, vegetation, and climate determine the population and cultural growth of an area. The Fernald site 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 these characteristics, 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. This strata is known universally as the Cincinnatian Series. The shale is the relatively impermeable bedrock underlying the site.

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 Fernald site 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 site and slopes downward to 168 meters (550 feet) at Paddys Run. North and south-southwest of the site, 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 site, is about 165 meters (540 feet), while the land rises gently to about 183 meters (600 feet) west of the site. Figure 7 (on the next page) presents a cross-section of the area.

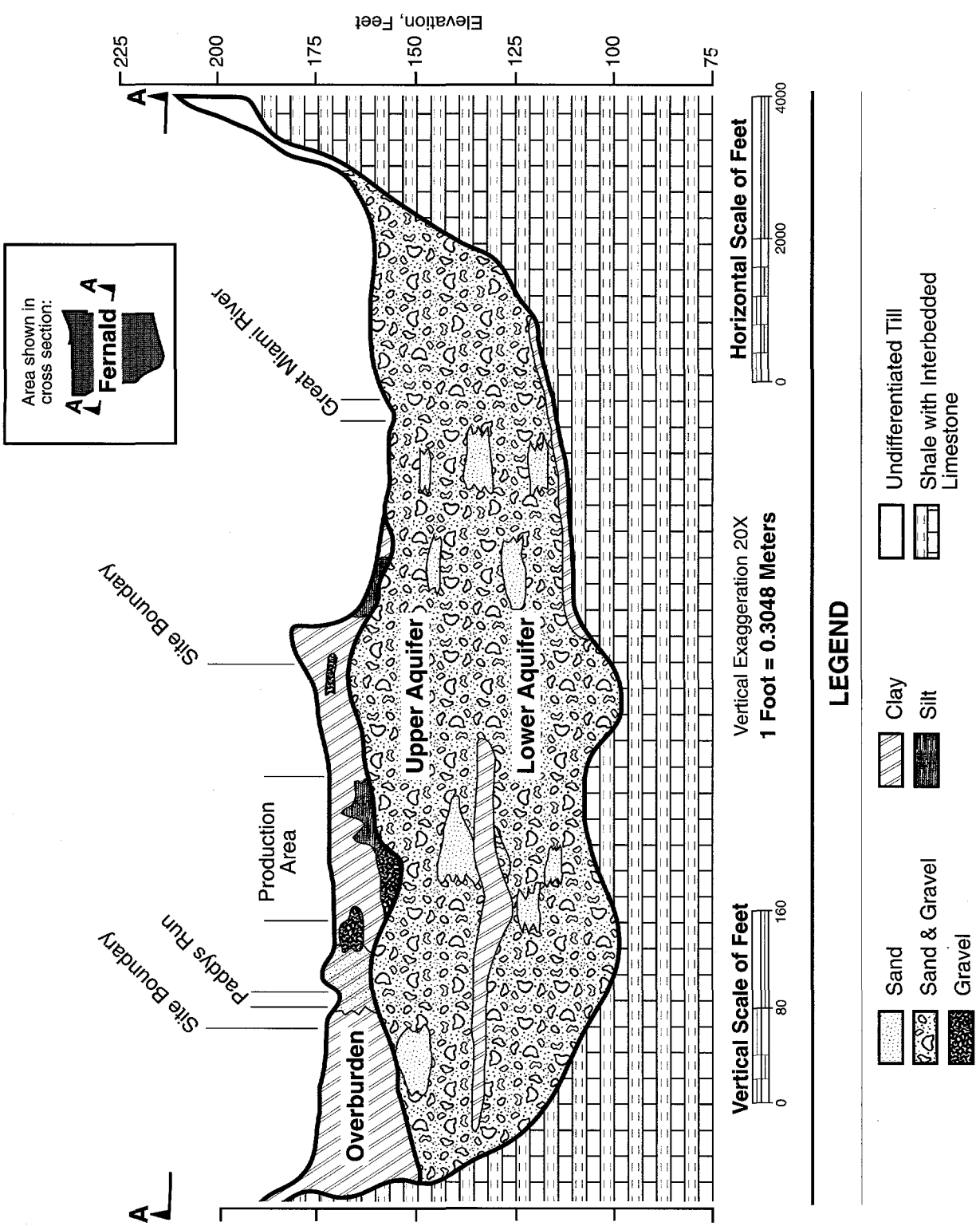
Lithology

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 site 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 site.[4]

Sand and gravel filling the New Haven Trough are 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 Fernald site, the sand and gravel is 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 ongoing Remedial Investigation and Feasibility Study (RI/FS) suggest that the clay layer extends from west of Paddys Run to the center of the production area and is present beneath the waste pit area. The clay layer does not extend east or south of the 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

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



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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. Surface hydrology, discussed in the next section, is the study of drainage systems like rivers, streams, and rainwater runoff. Groundwater hydrology, discussed here, focuses on the movement of water below the earth's surface.

Groundwater beneath the site 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 Fernald site, 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 since 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 site, and the aquifer is between 38 and 53 meters (125 and 175 feet) thick. As shown in Figure 8 (on the next page), the groundwater in the sand and gravel aquifer is moving east under the waste pit and production areas, while on the southern edge of the facility, 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.

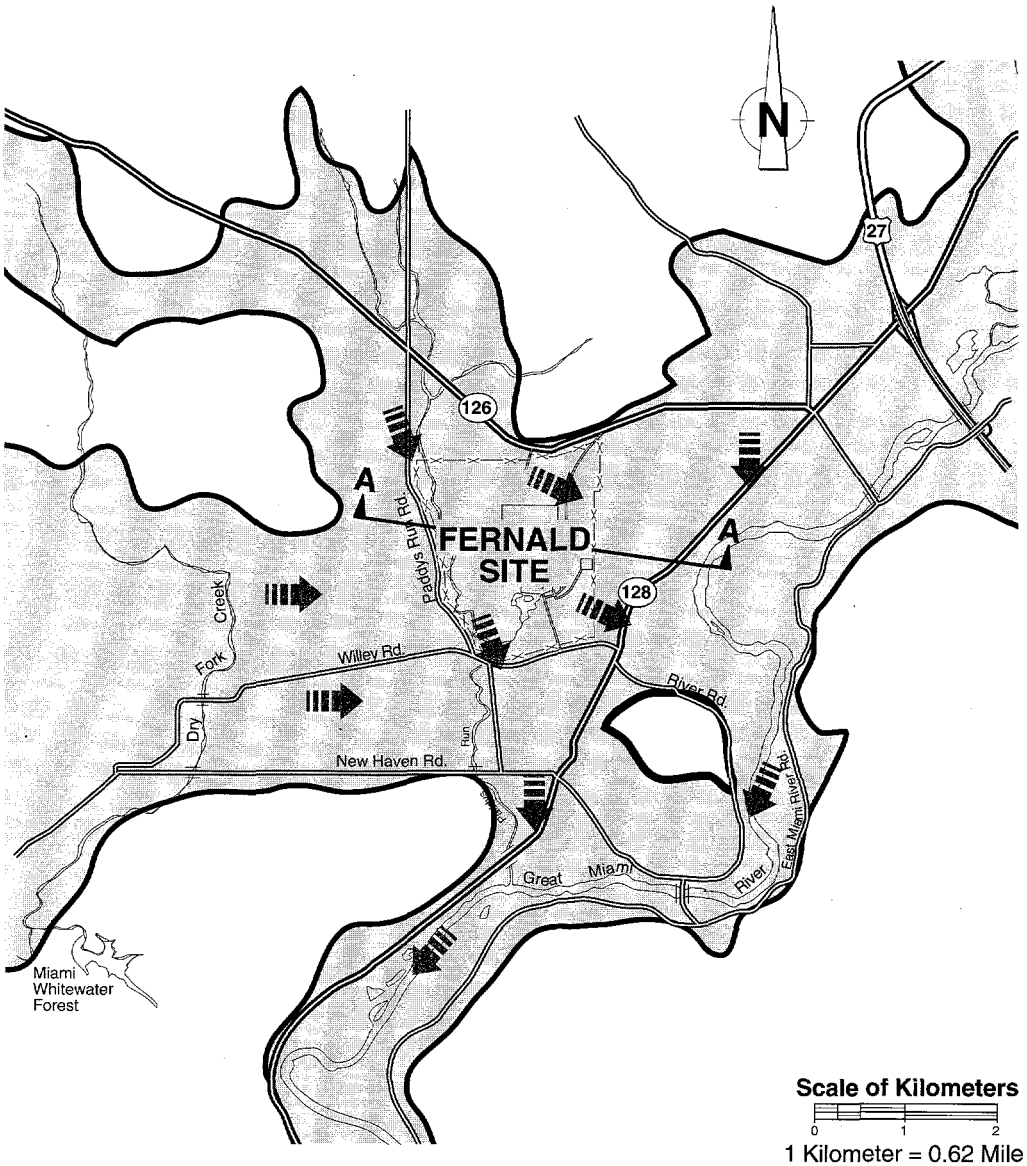
There may be groundwater even deeper in the slightly permeable rock layers below the sand and gravel aquifer; however, this water is essentially trapped in cracks and fissures and does not contribute any significant amount to the entire flow system.

Surface Hydrology

The Fernald site 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 Fernald site to the Great Miami River is primarily via Paddys Run, a small creek that begins north of the site and flows southward along the western edge of the site.

text continues on page 24

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

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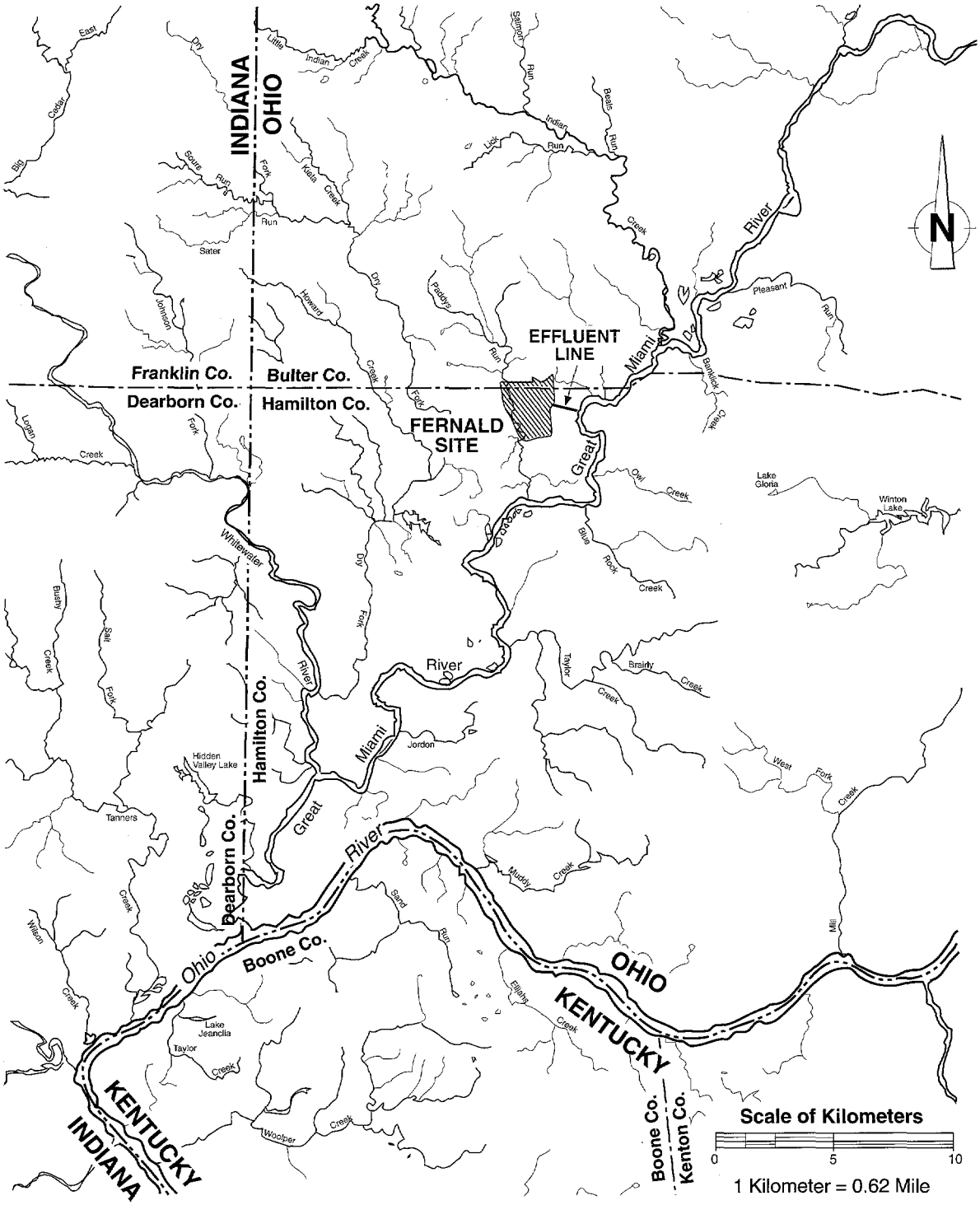
Figure 9: Great Miami River Drainage Basin



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

In addition to natural drainage through Paddys Run, site runoff is collected, treated, and discharged to the Great Miami River through an effluent pipeline (Manhole-175). The river, about 1 km (0.6 mile) east and south of the Fernald site, runs in a southerly direction and flows into the Ohio River about 39 km (24 miles) downstream of the site. Although turbulence makes the Great Miami River unsafe for swimming, some people do fish there. The segment of the river between the Fernald site and the Ohio River is not designated as a source of public drinking water.

The average flow rate for the Great Miami River in 1994 was 43 cubic meters per second (1,503 cubic feet per second), measured daily approximately 16 km (10 river miles) upstream of the effluent discharge. Flow rate also fluctuates throughout the year. In 1994, the maximum rate was 833 cms (29,400 cfs) measured in April; the minimum flow was 13 cms (467 cfs) measured in November.[8]

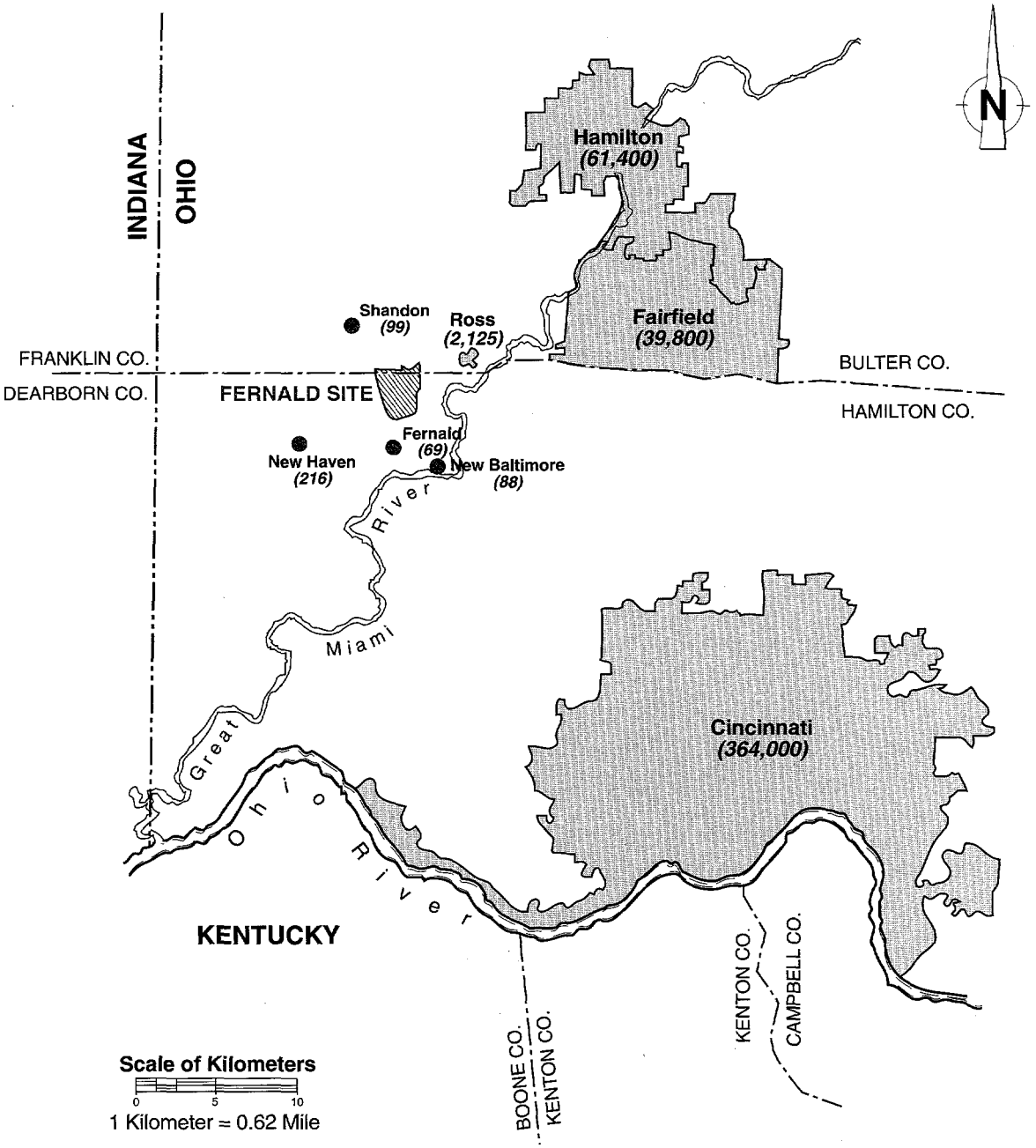
Demography and Land Use

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the site (see Figure 10). Downtown Cincinnati is approximately 27 km (17 miles) southeast of the site, 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 Fernald site, 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 dairy and 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 water company is located 2 km (1.25 miles) upstream of the site'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.

Figure 10: Major Communities in Southwestern Ohio



LEGEND

- Population in parenthesis estimated in 1989
- Population in parenthesis from 1990 U.S. Census Figures

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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 that materials may take. The actual route of the material 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 since this is of significant concern at the Fernald site. Much of this report, as well as the Environmental Monitoring Program itself, focuses on radioactive contamination. Uranium is the major radioactive pollutant at the site; 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 *transuranics* (such as neptunium–237, plutonium–239, and plutonium–240). These trace *nuclides* 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 pathways that exist, 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

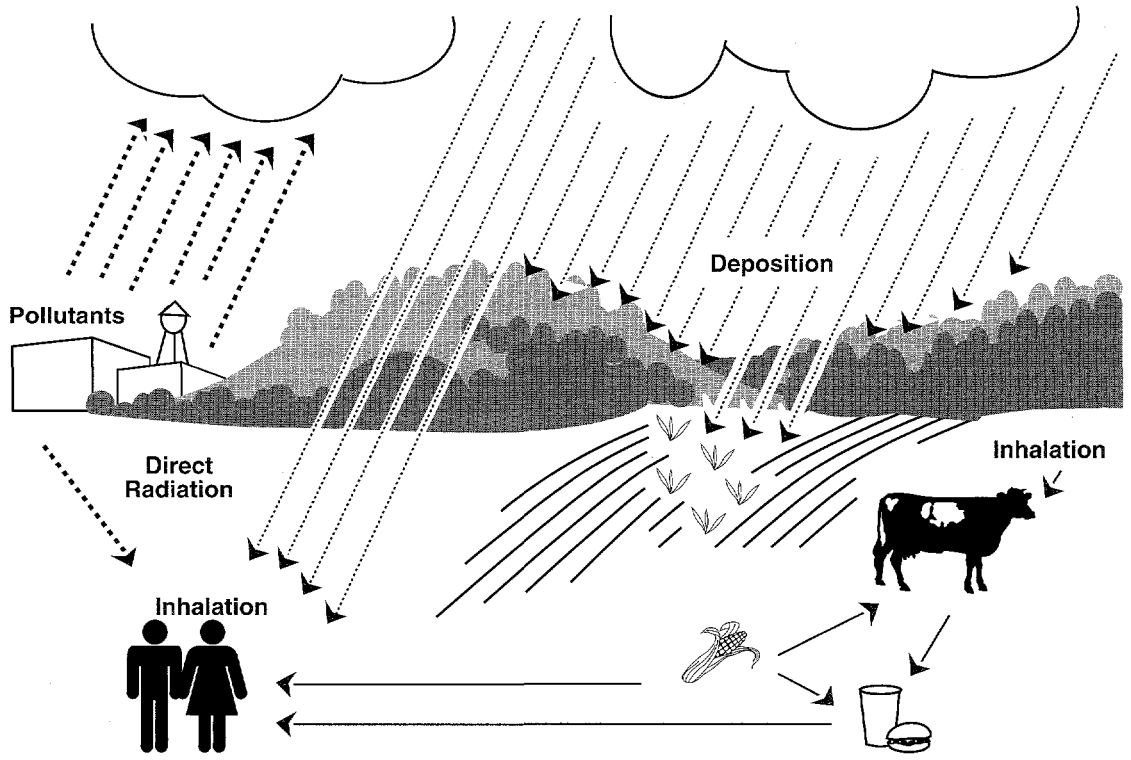
emitted directly from the site, particularly from the K-65 silos. Direct radiation is discussed further in Chapter Four.) The following sections describe how materials may follow the air and liquid pathways and briefly describe environmental monitoring procedures.

Air Pathway

The air pathway includes the airborne pollutants that may be carried from the Fernald site 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 size distributions, chemical form of pollutant, temperature and velocity of the pollutants as it leaves the stack. All of these factors and others can influence

Figure 11: General Air Pathways to Humans



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.

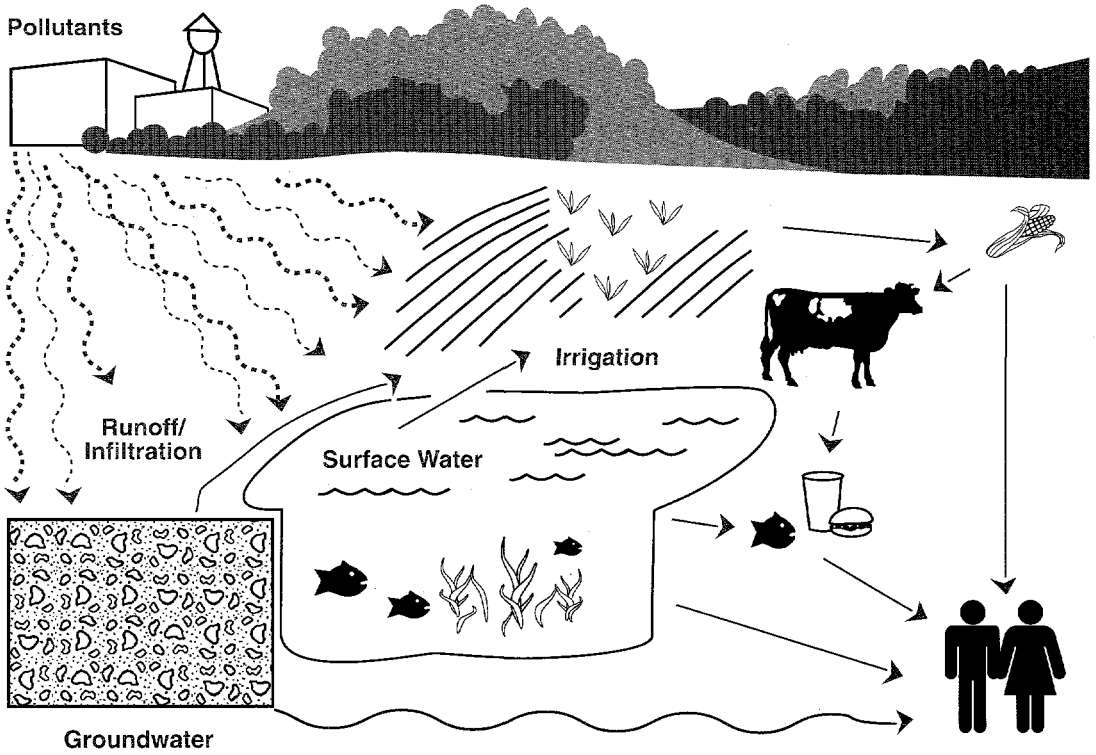
The site operated 20 air monitoring stations 24 hours a day, seven days a week, during 1994 to monitor these air emissions.

Liquid Pathway

The liquid pathway includes all releases that could carry waterborne pollutants (see Figure 12). 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 site. 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.

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

Figure 12: General Liquid Pathways to Humans



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 Fernald site 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 (USEPA), 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 that employees, people in the surrounding communities, and the environment are protected.

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 Clean Air Act states that the air pathway (air emissions and fugitive emissions from a facility) cannot contribute more than a 10 mrem effective dose in one year to a member of the public. Again, doses from radon and its decay products are covered separately.[11] For drinking water, DOE operations cannot contribute more than a 4 mrem effective dose in one year to a member of the public.[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 site personnel to review emissions and effluent data and determine if there is a need for further investigation.

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

- Annual Radionuclide Air Emissions Report to DOE and USEPA,
- National Pollutant Discharge Elimination System (NPDES) Monthly Discharge Monitoring Report to OEPA,
- Effluent Information System/Onsite Discharge Information System to DOE, and
- Monthly Consent Agreement Report to USEPA.

This SER compares the results of the site'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 Fernald site operations. For example, results are compared with background data from areas unaffected by the Fernald site activities. Fernald site scientists look for trends by comparing results from 1994 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 1994.

2

Fundamentals of Radiation and Health Hazards

Since radioactive materials and hazardous chemicals are stored at the Fernald site, it is important to understand the possible health hazards associated with these materials. Also, terms unique to radiation and its potential health effects are used extensively throughout this report. As a result, some of the important information in the report may be difficult for the non-scientist to interpret. This chapter provides a way to put that information into perspective and includes 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 who are already familiar with the concepts and terms used in the study of radiation and other health hazards may wish to proceed directly to the next chapter, the Environmental Compliance Summary.

The Atom

The world is made up of atoms. Atoms consist of two basic parts:

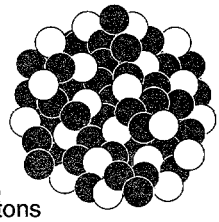
- The nucleus, and
- The electrons orbiting the nucleus.

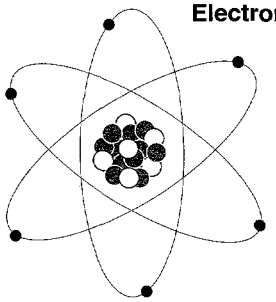
The nucleus is made up of protons, which are positively charged, and neutrons, which have no charge. Protons and neutrons are similar in size, and both are considerably larger than electrons (about 1,800 times more massive). Therefore, the weight and mass of the atom is principally concentrated in the nucleus. The electrons circling the nucleus have a negative charge. Atoms tend to move toward a neutral state in which the negative electrical charge of the orbiting electrons balances the positive charge of the nucleus. To keep the atom electrically neutral, the number of electrons in an atom must equal the number of protons (see Figure 13).

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.



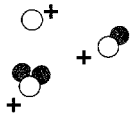


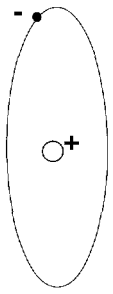
Electrons Orbiting the Nucleus

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.

Protons and electrons have many characteristics similar to magnets. Just as opposite magnetic poles are drawn toward each other, protons and electrons are attracted toward each other. This attraction keeps the electrons orbiting around the nucleus. The electrons are not pulled into the nucleus because of the electrons' energy, which keeps them constantly moving and away from the protons. The energy in the electrons and the attraction of the electrons to the protons balance each other and keep the electrons in orbit. Just as energy in the electrons keeps them orbiting, energy in the nucleus keeps the protons and neutrons together.

The number of protons in the nucleus is referred to as the atomic number, and it is the identifier of the atom. If the atomic number changes, then the number of electrons and the chemical properties of the atom change. For example, for an atom to be hydrogen, it must have one proton. If a hydrogen atom were to gain a proton, it would no longer be hydrogen; it would be helium, which has two protons. Uranium, the substance of most concern at this site, has 92 protons. Since protons are positively charged, the atom must also have 92 electrons for it to be electrically neutral.

The sum of the protons and neutrons in the nucleus is called the mass number. Unlike protons, the number of neutrons contained in a specific atom can vary since neutrons have no charge and do not need to be balanced by electrons. Therefore, the mass number can vary. 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 labelled with their mass number. A hydrogen atom without a neutron is referred to as hydrogen–1, where 1 is the mass number. The hydrogen isotope with one neutron is referred to as hydrogen–2, and the isotope with two neutrons is referred to as hydrogen–3.

Most of the uranium at the Fernald site 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. Radioactivity and radiation are described in the next section.

Radioactivity and Radiation

Radioactivity is a process in which a nucleus of an unstable atom spontaneously decays or disintegrates. Radiation is the energy that is released as particles or waves when the disintegration or decay of the nucleus occurs. This section includes a discussion of radioactive decay and the three main forms of radiation produced by radioactive decay:

- Alpha particles,
- Beta particles, and
- Gamma rays.

It should be noted, however, that not all radioactive substances emit all three types of radiation. The differences between alpha particles, beta particles, and gamma rays will be clarified in the discussions that follow.

Radioactive Decay

Atoms are radioactive because their nucleus is too large (because of the number of protons and neutrons) or has too much energy to remain stable. By emitting radiation, the nucleus releases energy and moves toward a more stable, less energetic state and eventually becomes a stable atom. Radioactive decay occurs everywhere on earth because of naturally occurring radioactive elements. When most radioactive elements decay, the resulting atom is also radioactive. This is called a radioactive decay chain. There are four natural radioactive decay chains. A common chain begins with uranium–238 and ends with lead–206 (this isotope of lead is stable, which means it does not decay). Each of the various radioactive atoms (radionuclides) created during the decay sequence has its own natural rate of decay.

Addressing Homeowner Concerns about Uses of Well Water

Several homeowners near the Fernald site have expressed concern as to why well water with low concentrations of natural uranium may be acceptable for household utility uses such as washing clothes, bathing, and watering plants, but may not be acceptable for drinking or cooking. To some, this may seem inconsistent and cause misunderstanding.

The key to understanding why the water is acceptable for external uses is an understanding of how alpha particles, of prime concern when dealing with uranium, deliver a radiation dose. Alpha particles are large, charged particles that readily interact with other materials. This interaction prevents the particles from ever penetrating very deeply. Even the most energetic alphas from uranium are stopped by the outer layers of dead skin.

However, inside the body, there are no protective dead cell layers to prevent the alpha particles from interacting with live organ cells; all emitted energy is delivered as dose to the organ. The alpha-emitting radionuclide may also be incorporated into specific kinds of cells, depending on its chemical properties. For example, the body processes several radionuclides as though they were calcium; predictably, they end up being deposited in the bones. Research has shown that uranium tends to concentrate in the bone and, to a lesser extent, in the liver, kidneys, and other tissues.

Independent of its associated radiation hazards, uranium also has a chemical toxicity. Studies on animals have indicated that uranium is toxic to the kidney at concentrations of approximately 70,000 pCi/L.[13]

Although the concentrations of concern in these studies are several thousand times greater than the concentration of uranium in local groundwater, it is desirable to limit the intake of uranium. 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 those concerned. And, even with slightly higher uranium concentrations, the water is still acceptable for external, household utility use.

It takes a different amount of time for each element to decay to the next element in the chain. The amount of time it takes for a radioactive substance to lose half of its radioactivity, or for half to become the next element in the chain, is its half-life. All decay chains found in nature begin with an isotope with an extremely long half-life. It is assumed that these atoms were formed at the same time as all the other atoms on earth and are still present because their half-lives are comparable to the age of the earth.

The uranium decay sequence is common in nature and at the Fernald site. (The uranium and thorium decay chains are presented on the next page.) Uranium–238 emits an alpha particle (two protons and two neutrons) and becomes thorium–234. Then a neutron in thorium–234 becomes a proton and an electron. The electron is emitted as a beta particle. Then thorium–234 decays to protactinium–234. The decay process proceeds in this manner until the element becomes stable as lead–206. Much of the uranium and thorium at the Fernald site has been chemically purified and separated from other elements shown in the decay series. Elements separated from uranium and thorium are some of the wastes stored onsite. The material stored in the K-65 silos is an example of such waste.

Nuclides of the Uranium Decay Chain

Isotope	Half-life	Radiation
Uranium–238	4,500,000,000 years	alpha
Thorium–234	24 days	beta, gamma
Protactinium–234m	1.2 minutes	beta, gamma
Uranium–234	250,000 years	alpha, gamma
Thorium–230	80,000 years	alpha, gamma
Radium–226	1,622 years	alpha, gamma
Radon–222	3.8 days	alpha
Polonium–218	3.05 minutes	alpha
Lead–214	26.8 minutes	beta, gamma
Astatine–218	2.0 seconds	alpha
Bismuth–214	19.7 minutes	beta, gamma
Polonium–214	0.000164 second	alpha, gamma
Thallium–210	1.3 minutes	beta, gamma
Lead–210	22 years	beta, gamma
Bismuth–210	5.0 days	beta
Polonium–210	138 days	alpha, gamma
Thallium–206	4.2 minutes	beta
Lead–206	Stable	none

Nuclides of the Thorium Decay Chain

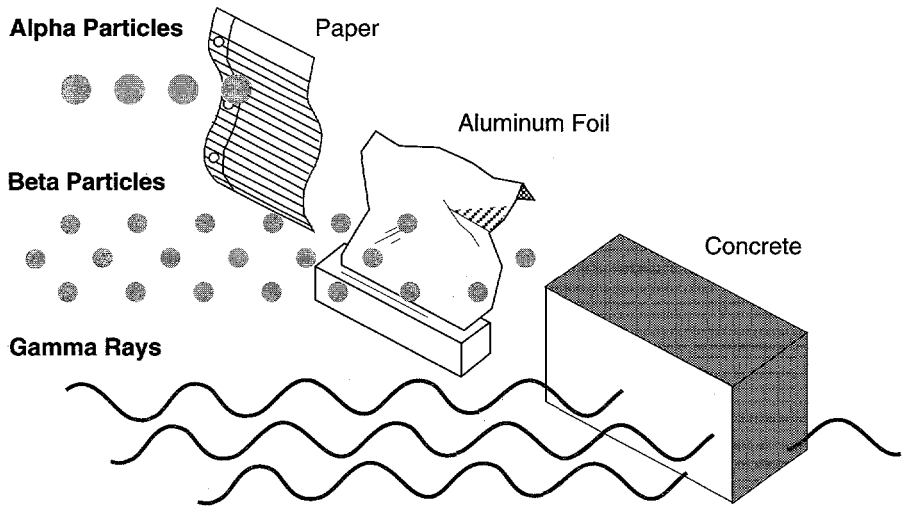
Isotope	Half-life	Radiation
Thorium–232	14,000,000,000 years	alpha
Radium–228	6.7 years	beta
Actinium–228	6.13 hours	beta, gamma
Thorium–228	1.9 years	alpha, gamma
Radium–224	3.64 days	alpha, gamma
Radon–220	55 seconds	alpha
Polonium–216	0.16 second	alpha
Lead–212	10.6 hours	beta, gamma
Bismuth–212	60.5 minutes	alpha, beta, gamma
Polonium–212	0.000000304 second	alpha
Thallium–208	3.1 minutes	beta, gamma
Lead–208	Stable	none

EXAMPLE To illustrate the idea of half-life, let's look at the 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. After another 24 days you would have 250, and so on. The half-life of some isotopes, such as uranium–238, is very long. The middle column in the uranium and thorium decay chain examples contains the half-life periods of the elements in the decay chain. All the radionuclides in the Uranium Chain can be thought of as "potential" lead–206 atoms. This will be the case many billions of years into the future when all natural radioactive isotopes will have decayed to their stable end products.

Alpha Particles

Alpha particles consist of two protons and two neutrons and have a positive charge. Because they are charged, they interact with other atoms by scattering off other charged particles, thus losing their energy. Moreover, because of their large size, alpha particles do not travel very far when emitted —1 to 8 centimeters (0.4 to 3 inches) in air. They are unable to penetrate any solid material, such as paper or skin, to any significant depth (see Figure 14). However, if alpha particles are released inside the body, they can damage the soft internal tissues because they deposit all their energy in a very small volume. Uranium decays by emitting alpha particles, so if uranium particles are inhaled or swallowed, the emitted alpha particles may damage internal tissue. Some other radionuclides present at the Fernald site that decay by emitting alpha particles include thorium–228, –230, and –232.

Figure 14: Types of Ionizing Radiation



Beta Particles

Beta particles are electrons that carry a negative electrical charge. They are much smaller than alpha particles and travel at nearly the speed of light; thus, they can travel approximately 2 to 4 meters (6 to 12 feet) in air and, as shown in Figure 14, penetrate solid materials about 1 cm (0.4 inch). Beta particles interact with other atoms in ways similar to alpha particles, but since 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.

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, and 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 not only skin, but also, depending on their energy,

can penetrate substantial distances into solid materials such as concrete or steel (see Figure 14). Gamma rays are often released during radioactive decay along with alpha and beta particles. Some of the materials stored in the K-65 silos decay by emitting gamma rays. Potassium–40 is an example of a naturally occurring radionuclide found in all human tissue 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 principally by knocking the negatively charged electrons out of orbit. This causes the atom to lose its electrical neutrality and become positively charged. An atom that is charged, either positively or negatively, is called an ion. Anything that creates an ion is said to be ionizing.

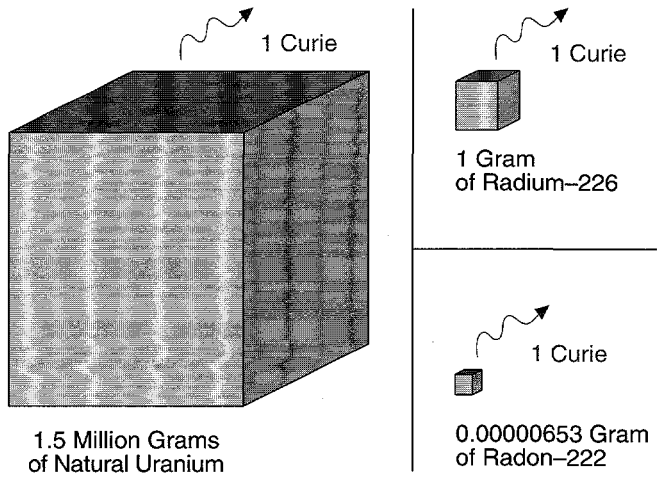
Units of Measurement

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 D).

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 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 natural uranium, which has a half-life of 4.5 billion years, to equal one Curie because natural uranium 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 gram of radon–222 is needed to equal one Curie (see Figure 15).

Figure 15: Comparison of Disintegration Rate*



* Not Drawn to Scale

Dose Equivalent

When a person comes into contact with radiation, that person has been exposed to radiation. Dose equivalent is a measure of the amount of radiation that is delivered to the body. 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 an exposed person's dose equivalent. Dose equivalent, or simply dose, is used when comparing the effects of different types of radiation. The *Roentgen equivalent man (rem)* unit is used to express dose equivalent. The more rem, the higher the potential damage. Since the amount of radiation we receive from background and the Fernald site is so small, millirem (mrem) is often used instead of rem. One mrem is equal to 1/1000 of a rem.

In this report, we use the term **dose** frequently. Unless specified differently, that term will be used in place of the term **dose equivalent**.

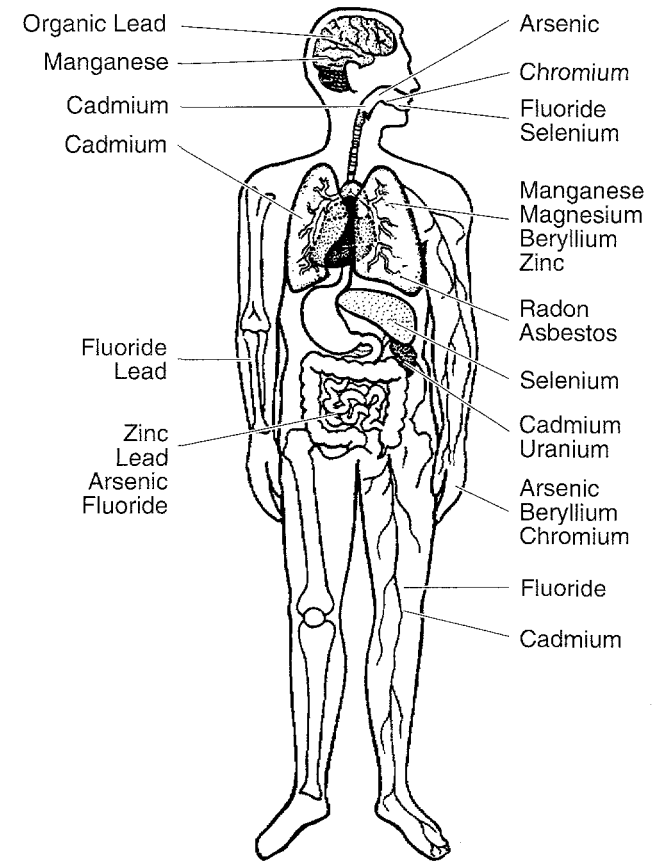
The term dose is used in four different ways in this report: organ dose, effective dose, committed effective dose, and whole body dose.

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 16 shows which organs are most affected by various substances found at the site.

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, since some organs are more sensitive to radiation than others, the organs are given different weighting factors (see 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 NCRP and ICRP recommend that an individual be exposed to no more than 100 mrem effective dose per year for all pathways (over and above the amount a person receives from background and medical radiation). This recommendation applies to the general public for long-term, continuous exposures.[14] The DOE

Figure 16: Organs Affected by Substances Found at the Fernald Site



guideline for dose to members of the public is 100 mrem per year from all pathways (excluding radon). The National Emission Standards for Hazardous Air Pollutants (NESHAP) limit for effective dose is 10 mrem per year from radionuclides (except radon) released via the air pathway.[11]

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.

The whole body dose is the amount of radiation an individual receives when the entire body is irradiated evenly by direct (gamma) radiation. Most radionuclides present at the Fernald site do not contribute toward a whole body dose because they concentrate more in some organs than others and do not emit significant amounts of gamma radiation.

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 makng up "Remainder" is 0.30.

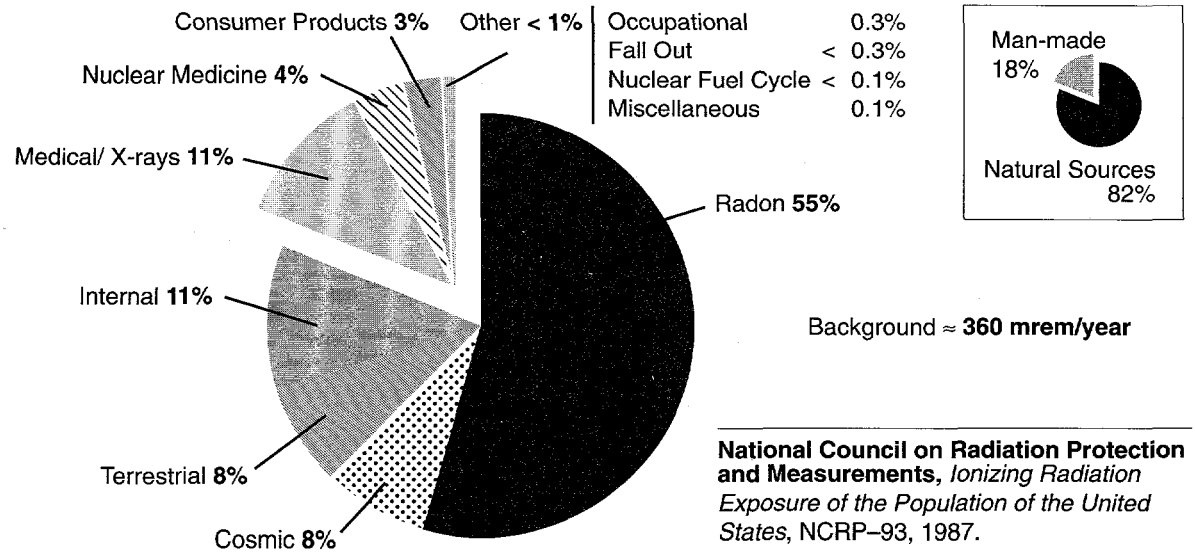
Exposure to Background Radiation

The dose terms defined in the preceding paragraphs apply to more than just the radiation we may be exposed to from facilities like the Fernald site. 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.[15] In the United States, a person's average annual exposure to background radiation is 360 mrem.[14] The DOE guidelines (as well as other radiological guidelines) apply to exposure individuals receive in addition to background radiation and medical procedures.

As the Exposure to Background Radiation Chart shows, radon is the largest contributor to background radiation (see Figure 17). 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.)

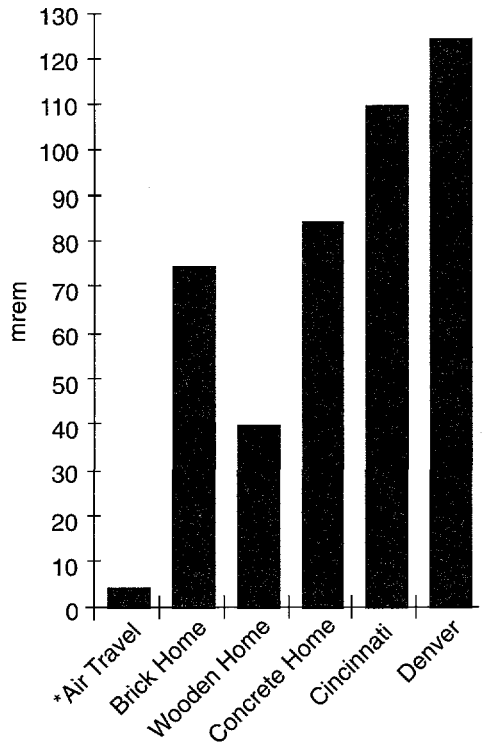
Background radiation dose will vary in different parts of the country. For example, living in the Cincinnati area will produce an annual exposure level of approximately 110 mrem, while living in Denver will produce an annual exposure level of approximately 125 mrem. This difference can be attributed to soil composition and distance above sea level. Another factor which affects annual

Figure 17: 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 18: Breakdown of Average U.S. Radiation Exposures



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

radiation dose is the type of building material used in homes. Figure 18 shows that the annual dose received from living in a brick or concrete house is about two times greater than from living in a wood frame house. Also shown in the bar chart is that a single round trip flight from Cincinnati to London (or the equivalent) produces an exposure of approximately 4 mrem.[16] In comparison, the dose received at the site's fenceline from an entire year is approximately 1.0 mrem, excluding radon.

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. The next section provides information on the effects of low-level radiation, whether it is naturally occurring or originates from a facility like the Fernald site.

Effects of Radiation

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

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

Somatic Effects

Continuous exposure to low levels of radiation can produce gradual somatic changes over extended time. For example, someone may develop cancer from

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 1993, 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.

man-made radiation, background radiation, or some other source not related to radiation. Because all illnesses caused by low-level radiation can also be caused by other factors, it is presently impossible to determine individual health effects of low-level radiation. However, there are a few groups of people under medical observation because they have been exposed to higher levels of radiation. These include the survivors of Hiroshima and Nagasaki, uranium miners in the United States and eastern Europe, a group of 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.

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

Those individuals exposed to high levels of radiation are at greater risk. We know this because at these higher radiation doses, we see that the number of radiation effects increases as the level of radiation dose increases.

A whole-body dose of 1,000 rem of radiation delivered instantaneously will 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.[17]

Significant clinical symptoms of radiation probably will not be seen in individuals who have been exposed to less than 100 rem.[18] 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.[17] Others insist there is no threshold level below which radiation exposure is safe.[19] 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.

Somatic effects have been documented only at high radiation levels. These include clouding of the lens of the eye, lowered fertility rate, and a reduced number of white cells in the blood. Problems caused by radiation seen in the development of the embryo result from large doses, not the low levels characteristic of background radiation. Therefore, the most likely somatic effect of low-level radiation is believed to be a small increased risk of cancer.[15]

Genetic Effects

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

Human cells normally contain 46 chromosomes—23 transmitted from the mother and 23 from the father. These 46 chromosomes contain about 10,000 genes which are passed on to the 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 mechanism by which such changes can occur. Spontaneous mutations and chemically induced mutations have been observed.

The mutated genes from one parent can then be passed on to offspring. They typically have no effect on the offspring as long as the genes from the other parent are not mutated in the same way. However, the genes stay in the 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 then become present in the characteristics of the offspring.[17]

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.[20, 21]

Health Hazards at the Fernald Site

Aside from radiation and its effects, there are other health hazards associated with the Fernald site. 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 which 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 which 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*** 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 CERCLA; any listed or characteristic 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.

A ***hazardous waste*** is a solid waste that must be treated, stored, transported, and disposed of in accordance with applicable requirements under Subtitle C of RCRA. 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.[22]

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. As well, CERCLA has its own reporting and response requirements when a hazardous substance released to the environment exceeds a reportable quantity.

RCRA Subtitle C, as discussed above, 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 USEPA to initiate civil actions regarding hazardous chemical substances or mixtures which 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 USEPA currently regulates PCBs, fully halogenated chlorofluoroalkanes, asbestos, and hexavalent chromium under Section 6 of TSCA.

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

Carcinogens are substances that have the potential to cause cancer. A common carcinogen located at the Fernald site 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.

When a chemical causes a substance to wear away or deteriorate, it is said to be ***corrosive***. 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 which can be easily set on fire and burn readily. Paints, gases, and fuels are common flammable materials at the site. 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 which causes an organ or any part of the body to become inflamed or sore. 1,1,1–trichloroethane, a common solvent used at the site, 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 Fernald site'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. Then, Chapter Eight discusses the Radon Monitoring Program and presents the 1994 radon monitoring and dose results.

3

Environmental Compliance Summary

The Fernald site must comply with environmental requirements established by a number of agencies governing daily operations at the site. 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 United States Environmental Protection Agency (USEPA) develops, publishes, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by Congress. USEPA Region 5 implements the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process, with the active participation of the State of Ohio EPA (OEPA).

For some programs, USEPA has authorized that the State of Ohio regulatory programs are enforced in lieu of the federal program. For these programs, Ohio promulgates state regulations which must be at least as stringent or 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, and the Safe Drinking Water Act. The site is also subject to several legal agreements with USEPA Region 5 and/or OEPA. DOE Headquarters issues directives to its field offices and conducts compliance audits. In addition, the Fernald site conducts internal audits.

The Fernald site's progress toward achieving full 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 1994 as required by DOE reporting requirements.

Compliance Status

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

Comprehensive Environmental Response, Compensation and Liability Act

The Fernald site is on the National Priorities List (NPL), a list of sites requiring environmental cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. Consistent with the requirements of CERCLA Section 120, a Consent Agreement which outlined activities and schedules to be performed in order to remedy the site conditions was signed by DOE and USEPA in April 1990. This agreement was amended in September 1991. The Consent Agreement and the Amended Consent Agreement (ACA), jointly referred to as the ACA, divided the Fernald site into *operable units* (OUs) to more effectively manage the remedial response process. The ACA defined the OUs based on their location or the potential for similar technologies to be used in site remediation. The following table shows the OU definitions.

OU	Descriptive Title	Description
OU1	Waste Pit 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 Statewide 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 sitewide basis. This encompasses the entire site.

The ACA provided schedules for the completion of the ongoing 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 site to add additional removal actions on a yearly basis. The following table presents explicit 1994 completion dates from the ACA for the various activities—RI, baseline risk assessment (BRA), FS, proposed plan (PP)—which culminate in the selection of CERCLA *remedial action* in the record of decision (ROD).

OU	ACA-explicit 1994 Deadline CERCLA Remedial Response Activities
OU1	• Draft OU1 Feasibility Study/Proposed Plan (FS/PP): submitted to USEPA March 4. • Draft OU1 Record of Decision/Responsiveness Summary (ROD/RS): submitted to USEPA November 3.
OU2	• Draft OU2 Remedial Investigation/Baseline Risk Assessment (RI/BRA) Report: submitted to USEPA February 18. • Draft OU2 FS/PP: submitted to USEPA April 29.
OU3	• *No ACA-explicit deadlines for CERCLA remedial response activities during 1994.*
OU4	• Draft OU4 ROD/RS: submitted to USEPA August 9. After DOE signature November 3, the ROD was concurred with by OEPA, and signed by USEPA December 7.
OU5	• Draft RI/BRA Report: submitted to USEPA June 24. • Draft OU5 FS/PP: submitted to USEPA November 11.
CSOU	• *No ACA-explicit deadlines for CERCLA remedial response activities during 1994.*

Figure 19A on page 51 presents an overview of how the various activities mentioned above and subsequent activities fit together to lead to CERCLA remedial action for OUs 1 – 5.

In very 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, at what levels they are present, where they are located, and to where they are migrating. Site characterization also evaluates the potential impacts of those contaminants on human health and the environment. Activities associated with this phase are the RI and the 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, 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 site cleanup.

As shown in Figure 19A, the study phases of the process at Fernald are essentially complete for the entire site and actual cleanup has started. Initial characterization of the entire Fernald site began in 1986. In 1991, a segmented RI and FS began, which completes site characterization and supports remedy selection for all five study areas (operable units) targeted for remediation; this process is substantially complete. OUs 1 through 4 already have signed or approved Records of Decision, which document remedy selection. For OU5, DOE has identified a proposed remedy which has been approved by USEPA and OEPA. OU5's ROD is expected to be approved before the end of 1995. All selected remedies have been approved by USEPA with the concurrence of OEPA.

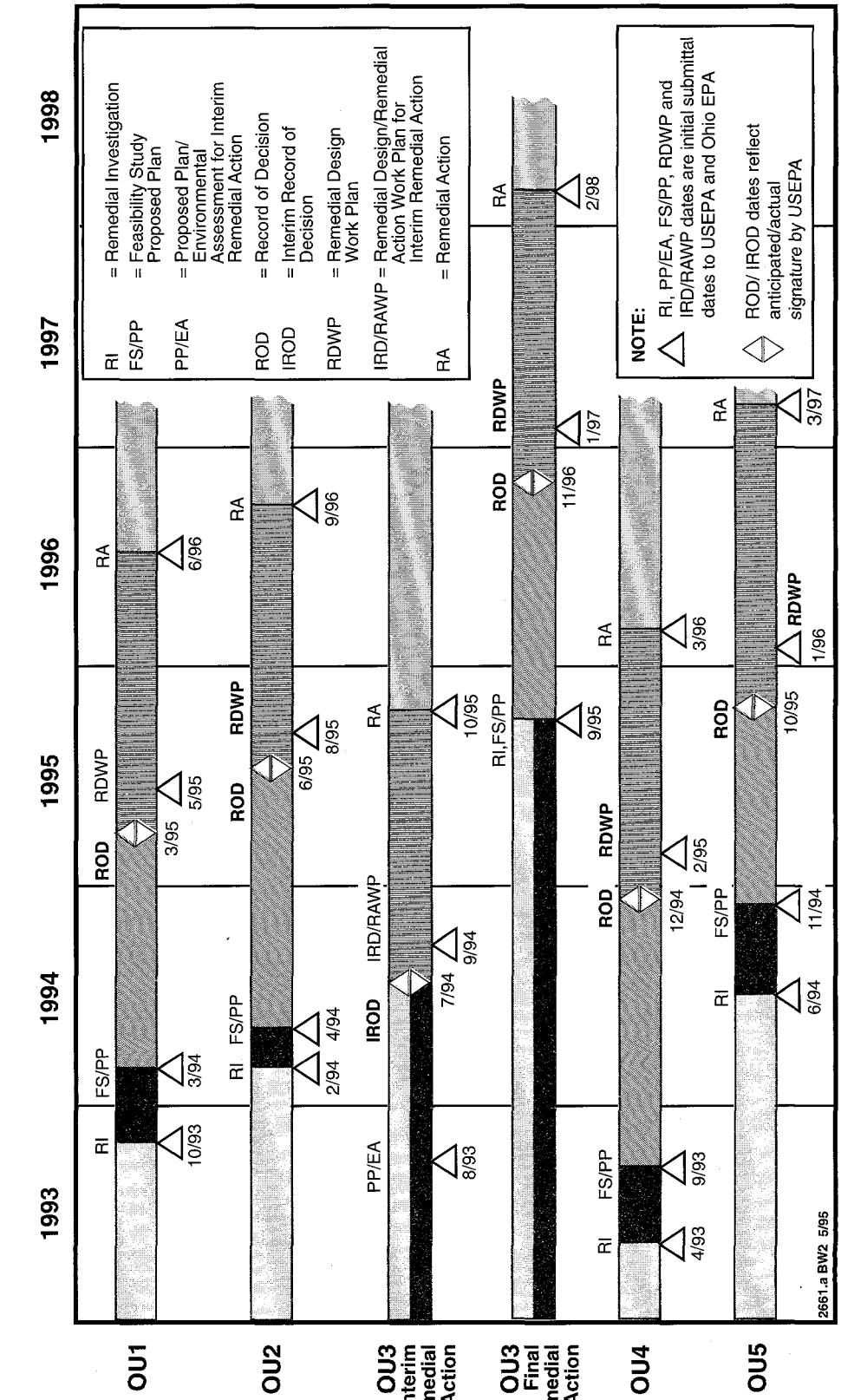
The selected cleanup options primarily use technologies and process options that have been successfully implemented at CERCLA sites throughout the country. For each innovative technology selected, extensive testing at Fernald has proven its applicability to the site. Accordingly, there do not appear to be any significant technical issues that would prevent timely implementation of the selected and proposed remedies at the site. Fernald has begun implementation of its cleanup remedies; indeed, construction has begun on a vitrification pilot plant, which will turn radioactive sludges into a glass-like form. CERCLA requires that remedial action begin within 15 months of the date the Record of Decision is signed, so actual cleanup activities will be underway for the entire site in a matter of months. In addition, 32 short-term removal actions designed to eliminate or control contamination sources prior to final cleanup either have been completed or are now in progress at Fernald.

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 report for 1994 was completed and submitted to OEPA in February 1994. That report lists the amount and location of hazardous substances stored or used in amounts greater than the minimum reporting threshold.

The SARA Title III, Section 313 Toxic Chemical Release Inventory Report was submitted to OEPA and USEPA by July 1, 1994. That report is required for any toxic chemical that is manufactured, processed, or otherwise used at a facility in

Figure 19A: Fernald Remediation



quantities greater than a minimum reporting threshold. 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 included source reduction and recycling information as required by the Pollution Prevention Act of 1990.

SARA Title III, Section 304 requires immediate notifications to local emergency planning committees (LEPC) and the state emergency response commission (SERC) in the case of any offsite release meeting the RQ. All releases occurring at Fernald 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, Resource Conservation and Recovery Act (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 1994, five releases at Fernald were reported as presented in the following table.

Fernald Release Reports in 1994

Date	Description	Reported to LEPC	SERC	NRC
04/27	A total of 99.4 kg (219 pounds) of sulfur dioxide, and 1,464.6 kg (3,226 pounds) of nitrogen dioxide and nitric oxide combined, were emitted from several large, diesel-powered portable generators being used for a major power outage. These emissions to the ambient air were an offsite release and reported as indicated.	CS	CS	CS
04/29	Emissions from the portable generators, reported earlier on April 27 (04/27), were reported as a continuous release as indicated after determining that they would exceed the RQ for some period of time. This report also included periodic testing and use of multiple stationary backup generators used as needed for emergency power.	CS	CS	CS
05/24	A diesel generator north of Building 13 released antifreeze containing 3 kg (6.7 pounds) of ethylene glycol, which exceeds the RQ. The release was reported under CERCLA, but since it was contained and did not get offsite, it was not reported under SARA.			C
07/11	An emission from the K-65 Silos was estimated as 1.92 Curies of radon–222, which exceeds the RQ. The emission to the ambient air was an offsite release and reported as indicated.	CS	CS	CS

09/30	A dump truck being used in a construction area in the southwest area of the site released antifreeze containing 12.7 kg (28 pounds) of ethylene glycol, which exceeds the RQ. The release was reported under CERCLA, but since it was contained and did not get offsite, it was not reported under SARA.	C

Key

LEPC	*Local emergency planning committee(s)*
SERC	*State emergency response commission*
NRC	*National Response Center*
C	*Reported under CERCLA Section 103*
S	*Reported under SARA Section 304*
CS	*Reported under both CERCLA Section 103 and SARA Section 304*

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 currently remains onsite. In 1994, the site shipped for disposal 70,422 kg (154,773 pounds) of mixed waste debris to Envirocare of Utah in Clive, Utah.

In addition to being subject to state and federal regulation, hazardous waste management is subject to the 1988 Consent Decree and the 1993 Stipulated Amendment (SACD) between the State of Ohio and DOE. In accordance with the SACD and RCRA, the site completed or initiated several activities relating to mixed waste storage during 1994. These activities included submittal of the RCRA Annual Report, revision of the RCRA Part B Permit Application, updated RCRA training of site personnel, and continued updating and improving the site's RCRA Inspection Program. Improvements were made to the Plant 1 East and West Storage Pads with the addition of approximately 20 cm (8 inches) of new reinforced concrete, covered by a non-reactive waterproof coating. A new tension support structure, TS-6, was also erected in 1994. This structure provides additional covered storage for the Plant 1 West Pad area.

Federal Facilities Compliance Act

The Fernald site stores mixed waste subject to the RCRA Land Disposal Restrictions (LDR). These restrictions currently prohibit the storage of certain hazardous waste streams unless an extension is approved by USEPA or the appropriate state regulatory agency (OEPA). Due to the lack of available treatment and disposal facilities for mixed wastes, DOE facilities, including the Fernald site, are continuing to store this mixed waste.

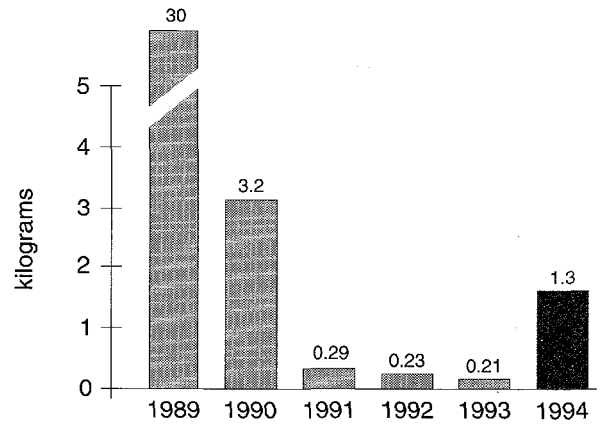
The Federal Facilities Compliance Act (FFCAct) of October 1992, an amendment to RCRA, did not waive sovereign immunity for DOE for the RCRA Land Disposal Restrictions storage prohibition until October 1995, provided that the mixed waste is managed in accordance with all other RCRA requirements. This time period may be extended if DOE submits and obtains approval of a plan for developing treatment capacity for these wastes under an enforceable order with USEPA or OEPA for treatment of mixed wastes by October 6, 1995. The site submitted a Draft Site Treatment Plan (DSTP) to OEPA in August 1994 for review and comment. The DSTP presents the preferred options and technologies for treating mixed waste currently in inventory at the site. A 60-day public comment period was open for stakeholder review and input concurrent with OEPA review. In support of the comment period, the site discussed the DSTP at a public meeting held in October 1994. Responses to these comments were included in the Proposed Site Treatment Plan (PSTP) submitted to OEPA on March 31, 1995. A 90-day public comment period for stakeholder review and input on the PSTP was opened by OEPA, which began on April 6 and is scheduled to end on July 6, 1995.

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 (NESHAPs) for radionuclides and radon. Most site air emission sources are regulated by OEPA as particulate, chemical, or toxic emission sources, and by USEPA as radionuclide sources.

The NESHAPs 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 NESHAPs monitoring points at the Fernald site are in compliance with the requirements.

Figure 19B: Total Kilograms of Uranium to Air, 1989 – 1994



Because the Fernald site is a former uranium processing plant, uranium is the radioactive particulate of most concern in monitoring airborne emissions. The Fernald site estimated that airborne uranium emissions for 1994 totaled 1.33 kg (2.93 lbs). Although this is higher than the 0.21 kg (0.46 lb) estimated in 1993 (see Figure 19B), the estimated dose to the maximally exposed offsite resident due to 1994 emissions is 0.17 mrem—only 2% of the NESHAP Subpart H limit of 10 mrem. The majority

of the increase is accounted for by the 0.67 kg (1.5 lbs) estimated uranium emissions from demolition of Plant 7.

In 1993, the State of Ohio regulation limiting sulfur dioxide (SO_2) emissions became effective. This regulation reduced the allowable SO_2 emission level from the Fernald site's coal-fired burners (sole Clean Air Act-defined major source) from 0.91 kg (2.0 pounds) $SO_2/10^6$ BTU heat input to 0.60 kg (1.3 pounds) $SO_2/10^6$ BTU heat input. The Fernald site began purchasing a low-sulfur coal in 1991 when the regulation was revised, and the site has been in compliance with the reduced limit since that time. The number of air permits will diminish as the number of sources subject to permitting are eliminated during remedial activities.

Clean Water Act

Under the Clean Water Act (CWA), the Fernald site is governed by National Pollutant Discharge Elimination System (NPDES) regulations that require the control of discharges of nonradioactive pollutants to Ohio waters.

NPDES 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 20 on the next page. The current permit expires February 9, 1995. The site submitted an application for renewal of the NPDES permit to OEPA July 12, 1994. OEPA regulations allow the site to continue operating according to the terms of the existing permit until the renewal is issued.

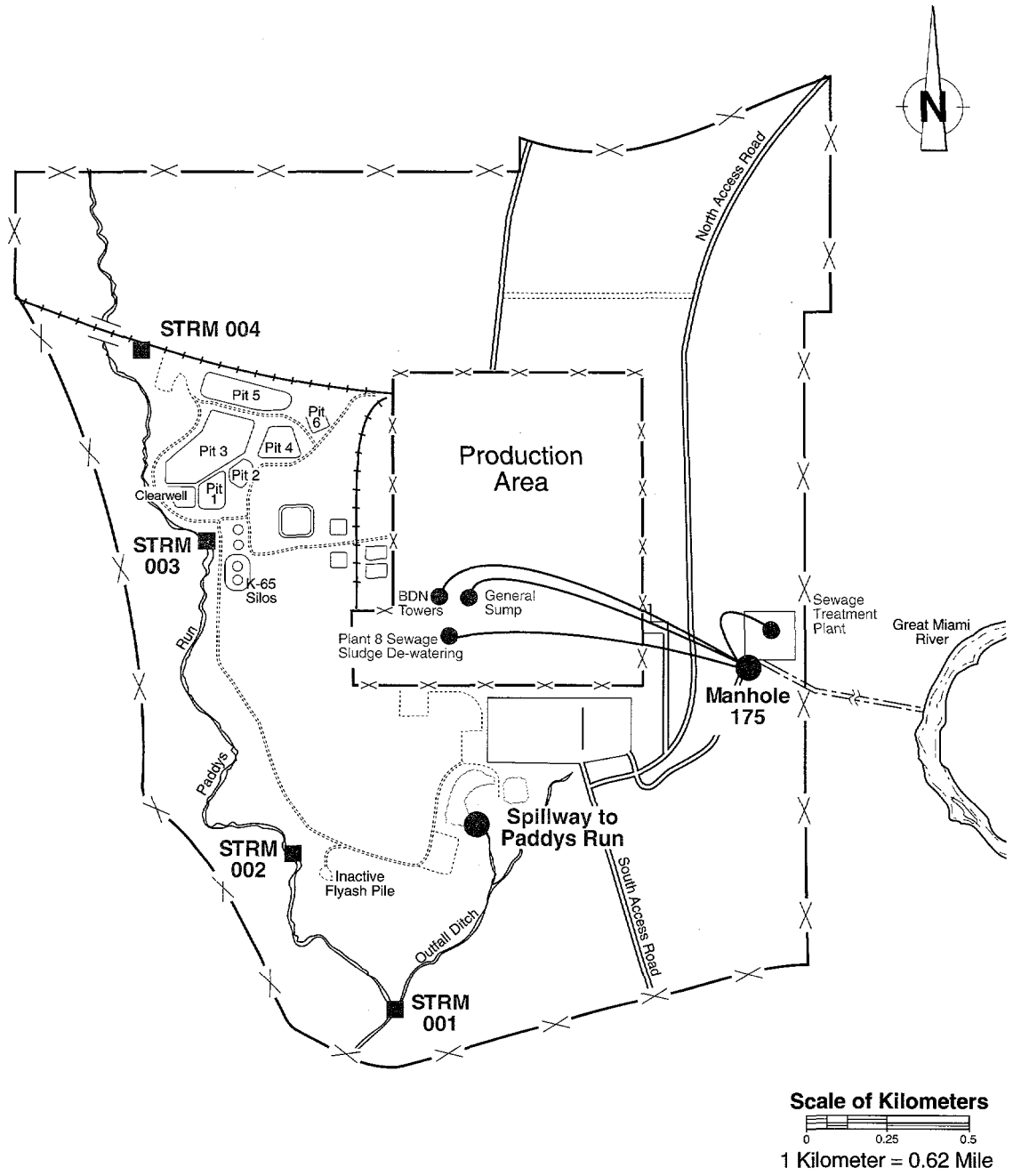
In 1994, the Fernald site was compliant with the discharge limits specified by the NPDES permit 99.9% of the time. Of the 2,512 monitoring results reported to OEPA during the year, only three were not within the discharge limits specified by the permit. All three occurred at the site's final discharge point (Manhole-175); two involved dissolved oxygen content, and the third involved suspended solids.

NPDES Stormwater Regulation

Issuance of a "Stormwater Permit Associated with Industrial Activity" is still pending OEPA review and action. The application for this permit was submitted for four stormwater discharges into Paddys Run in September 1992. These four monitoring locations are shown in Figure 20 as follows:

- STRM 001 – Collecting runoff from the east and south;
- STRM 002 – Collecting runoff from the Inactive Flyash pile;
- STRM 003 – Collecting runoff from the western property perimeter, excluding the waste management facilities; and
- STRM 004 – Collecting runoff from the northern property perimeter.

Figure 20: NPDES Effluent and Stormwater Monitoring Locations



LEGEND

- NPDES Internal Monitoring Location
- NPDES External Discharge to Ohio Waters
- NPDES Stormwater Monitoring Location
- Plant Perimeter
- Production Area Perimeter
- Effluent Line to Great Miami River

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Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) regulates generation and treatment of drinking water supplied to the public. The Fernald site drinking water system is regulated by OEPA as a non-transient, non-community public drinking water system.

During 1994, the site monitored its drinking water system and reported results for antimony, arsenic, barium, beryllium, cadmium, chromium, copper, cyanide, fluoride, lead, mercury, nickel, nitrate, nitrite, selenium, thallium, coliform bacteria, and 36 volatile organic compounds, as well as alkalinity, pH, stability, phosphate, hardness, and chlorine residuals. All results met applicable standards.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) regulates the manufacturing, use, storage, and disposal of toxic materials. Under TSCA, USEPA regulates polychlorinated biphenyls (PCBs) and PCB items at the Fernald site. The site ships non-radiologically contaminated PCBs and PCB items to TSCA-approved commercial disposal facilities for incineration on an "as-needed-basis." Radiologically contaminated PCBs and PCB items from past operations, maintenance activities, and remediation are stored onsite as disposal options are explored.

Building 81 is currently being used as the designated onsite storage area for PCBs and is in compliance with TSCA requirements. PCBs and PCB items may also be temporarily stored in Building 64 until characterization of the waste is completed. Radiologically contaminated PCB solids have no current treatment or disposal options and will remain in storage onsite until treatment or disposal capacity is available. Disposal of radiologically contaminated PCB solids 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 PSTP pursuant to the FFC Act is being considered for treatment of radiologically contaminated PCB solids.

USEPA conducted a routine TSCA compliance inspection of the Fernald site on September 21, 1994. No violations of PCB regulations were identified during the inspection.

Ohio Solid Waste Act

Enacted in 1988, the Ohio Solid Waste Act and its subsequent revisions regulate infectious waste. The Fernald site is registered with OEPA as a large generator of infectious waste, generating more than the 23 kg (50 pounds) per month limit. All infectious wastes generated in the medical department are transported to a licensed treatment facility for incineration. Fernald site 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), USEPA regulates the registration, storage, labeling, and use of pesticides (such as insecticides, herbicides, and rodenticides). Site personnel perform all insecticide and rodenticide applications onsite. Site 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 site are conducted according to Federal and state regulatory requirements. As a result of the annual FIFRA program inspection conducted on September 21, 1994, USEPA Region 5 found the site to be in full compliance with the requirements mandated by FIFRA.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires a formal evaluation of environmental, social, economic, and cultural impacts before any action, such as a construction project, is initiated by a Federal agency. DOE has published formal regulations at 10 Code of Federal Regulations (CFR) 1021 specifically addressing the integration of NEPA with other regulatory requirements.

In June 1994, DOE issued a revised policy on NEPA compliance. One of the most significant provisions of the policy would allow for DOE, with approval from stakeholders, to rely solely on the CERCLA process to meet the procedural requirements of NEPA for CERCLA actions.

In December 1994, the OU4 Feasibility Study/Proposed Plan-Environmental Impact Statement (FS/PP-EIS) and Record of Decision (ROD) received final approval from USEPA. The OU4 FS/PP-EIS and ROD integrated the requirements of both CERCLA and NEPA. The purpose of integrating the EIS with the FS/PP was to evaluate the potential environmental impacts of OU4 and to evaluate cumulative impacts resulting from remediation of the entire site. The cumulative impact analysis is updated in each OU-integrated CERCLA/NEPA evaluation.

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, USEPA ecological guidelines direct CERCLA sites to identify any threatened species present on the property or in off-property areas affected by site 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 are or may be onsite or have habitat onsite. Surveys to update the information on federal- and state-listed threatened and endangered species were initiated in 1993. Moderate habitat for the cave salamander (*Eurycea lucifuga* – state-listed endangered), was determined to be present on the Fernald property (defined as the 1,050 acres (425 hectares) within the facility boundary); however, no cave salamanders were found on the Fernald property.

Additional surveys were completed on the Fernald property in 1994. A 1988 survey found suitable habitat for the Indiana bat (*Myotis sodalis* – federally-listed endangered) in the riparian areas of Paddys Run; however the nearest population of this species was found at Banklick Creek, approximately 5 km (3.1 miles) east of the Fernald property. A comprehensive survey for this species was performed on the Fernald property in June and July 1994. Locations were sampled along Paddys Run and the Storm Sewer Outfall Ditch using mist nets. Bat detectors were used to determine bat activity in the area. Three species of bats, the big brown bat (*Eptesicus fusus*), the red bat (*Lasiurus borealis*), and the little brown bat (*Myotis lucifugus*), were netted at ten locations. The riparian habitat along Paddys Run was determined to be good for Indiana bats, based on the canopy over Paddys Run and the number of dead trees. This is especially true for the northern section of the Fernald property where the trees are older, the canopy is more complete, and water remains in the creek throughout the year.

Surveys were also conducted in 1994 for the following species:

- Running buffalo clover (*Trifolium stoloniferum* – federally-listed endangered) Transect surveys in May and June 1994 found no appropriate habitat or individuals of this species on Fernald property.
- Mountain bindweed (*Polygonum cilinode* – state-listed endangered) Surveys conducted on Fernald property in June and August 1994 determined that this species is not present.
- Slender fingergrass (*Digitaria filiformis* – state-listed endangered) Transect surveys conducted for this species on Fernald property in August 1994 determined that this species is not present.
- Spring coralroot (*Corallorhiza wisteriana* – state-listed threatened) The survey conducted for this species on Fernald property, completed in May 1994, determined that this species is not present.

Additionally, the Sloan's crayfish (*Orconectes sloanii* – state-listed threatened) is found in small streams in Ohio and Indiana. Surveys on Fernald property were completed in September 1993 and May 1994. Despite the fact that most of the section of Paddys Run located on Fernald property was dry during the 1993

survey, this species resided in pools in the north section of the property and downstream off the property. To define the range of this species in Paddys Run on the Fernald property, a follow-up survey was completed in 1994 when the stream was flowing. The population of Sloan's crayfish was limited to an area located directly south of the Fernald site's train trestle in a rocky riffle area of Paddys Run and in an area immediately south of the property boundary in Paddys Run. Subsequently, with the intermittent nature of Paddys Run, it appears that the population is not large enough to repopulate the entire stream.

Executive Order 11990, "Protection of Wetlands"

This Executive Order is a directive requiring federal agencies to institute programs to identify and protect wetlands and is implemented by the site through 10 CFR 1022. A wetlands delineation of the Fernald property was conducted in December 1992 and approved by the U.S. Army Corps of Engineers in August 1993. A total of 36 acres (15 hectares (ha)) of freshwater wetlands were delineated on the Fernald property. Delineated wetlands included 27 acres (11 ha) of palustrine forested wetlands, 7 acres (3 ha) of drainage ditches/swales, and 2 acres (1 ha) of isolated persistent emergent and scrub/shrub wetlands. In 1994, this delineation was utilized to prepare 10 CFR 1022 wetland assessments for the OU1, OU2, and OU5 remedial activities.

National Historic Preservation Act

The Fernald 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 1994, numerous activities were conducted to avoid impacts to cultural resources.

The Ohio Historic Preservation Office determined that the Fernald property was eligible for listing on the National Register of Historic Places. As a result, DOE entered into negotiations with the Ohio Historic Preservation Office and the U.S. Advisory Council on Historic Preservation. These parties worked to develop a mitigation plan that will be needed when buildings are demolished as part of remedial activities. They wrote a draft Programmatic Agreement that outlines the mitigation requirements agreed upon by the Ohio Historic Preservation Office and the U.S. Advisory Council on Historic Preservation. DOE is continuing negotiations with these regulators.

An archeological survey for the Public Water Supply Project—the installation of water pipelines along approximately 23 km (14 miles) of state and county roadways in Hamilton and Butler counties—was conducted and revealed a number of significant prehistoric artifacts, including Native American human remains. Since there was no way to avoid impacts to the human remains, plans to remove the

burials were negotiated with the Ohio Historic Preservation Office. 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. Native American organizations were contacted and asked to provide input regarding excavation, research, and reburial procedures. Field work to remove the remains began in 1994 and negotiations continue with the Ohio Historic Preservation Office and Native American organizations regarding the issue of reburial.

Cultural resource surveys were conducted for various projects on the Fernald property, including the East Field Cone Penetrometer Study, the Groundwater Well Road System, the OU1 Integrated Road and Parking Lot Installation, and the Integrated Uranium Soils Infiltration Technology Demonstration. Results of the surveys showed that no cultural resources would be impacted by field activities.

Major Accomplishments and Issues

This section presents significant compliance-related accomplishments and issues for 1994.

Comprehensive Environmental Response, Compensation and Liability Act

This section presents significant CERCLA response action accomplishments and issues for 1994. The reader is encouraged to access the numerous documents described below, the administrative record for the site, as well as the periodic OU-specific Fernald Progress Reports, and Fernald Project Cleanup Report, all of which are available at the Fernald Public Environmental Information Center (PEIC).

As discussed previously, all cleanup at Fernald 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 USEPA 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 time frame for remediation is set forth in the Records of Decision. Both USEPA and OEPA are maintaining the position that the DOE is legally obligated to complete remediation consistent with the time frames set forth in the Records of Decision. Neither USEPA nor OEPA have identified any significant technical issues that would prevent timely implementation of the selected and proposed remedies at the site. The regulators agree that the most significant constraint is related to the extent to which the cleanup efforts are funded.

CERCLA Remedial Response Actions

OU	Summary of Fernald's CERCLA Remedial Response Activities
OU1	• The Draft Final OU1 Remedial Investigation/Baseline Risk Assessment (RI/BRA) was submitted to USEPA February 4. • The Draft OU1 Feasibility Study/Proposed Plan (FS/PP) was submitted to USEPA March 4. • The Draft Final OU1 FS/PP was submitted to USEPA July 1. • The Proposed Draft OU1 Record of Decision/Responsiveness Summary (ROD/RS) was submitted to USEPA November 3.
OU2	• The Draft OU2 RI/BRA was submitted to USEPA February 18. • The Draft Final OU2 RI/BRA was submitted to USEPA June 15. • The Draft OU2 FS/PP was submitted to USEPA April 29. • The Draft Final OU2 FS/PP was submitted to USEPA August 24.
OU3	• The OU3 Treatability Study Work Plan was approved by USEPA in April. • The Proposed Draft OU3 Record of Decision for Interim Remedial Action (IROD) was submitted to USEPA April 8.
OU3	• The revised Proposed Final OU3 IROD was signed by DOE June 8, submitted to USEPA for OEPA concurrence, and signed by USEPA July 22. The OU3 IROD establishes decontamination and dismantling of the structures as the initial remedy for OU3; a final ROD will be prepared ad dressing the final disposition of the materials to be removed during the interim remedial action. • The OU3 RI/FS Work Plan Addendum – defining the process to complete the RI/FS for the final material disposition decision – was approved by USEPA in September. • The Draft OU3 Remedial Design/Remedial Action (RD/RA) Work Plan for Interim Remedial Action, along with the Draft Building 4A Implementation Plan, were submitted to USEPA September 20. • The Draft Final OU3 RD/RA Work Plan for Interim Remedial Action, and the Draft Final Building 4A Implementation Plan, were submitted to USEPA December 16.
OU4	• The Proposed Draft OU4 ROD/RS was submitted to USEPA on August 9. • The revised Proposed Final OU4 ROD/RS, was signed by DOE on November 3, submitted to USEPA for OEPA concurrence, and signed by USEPA on December 7. The selected remedial action is to remove and vitrify the contents of silos 1 - 3 and the decant sump tank sludges, then ship the vitrified waste for disposal at the DOE Nevada Test Site (NTS).
OU5	• The Draft OU5 RI/BRA was submitted to USEPA on June 24. • The Draft Final OU5 RI/BRA was submitted to USEPA on November 1. • The Draft OU5 FS/PP was submitted to USEPA on November 11.
CSOU	• Iterations of the Comprehensive Remedial Action Risk Evaluation (CRARE) were performed and submitted in sequence as an appendix to the OU4 FS/DEIS, the OU2 FS (also covering OU1), and the Draft OU5 FS; see dates for those submittals in other entries in this table.

OU1 Record of Decision Signed in March 1995

The OU1 Feasibility Study/Proposed Plan (FS/PP) underwent public comment from August 10 through September 8, 1994. After close of the public comment period, the Proposed Draft OU1 Record of Decision/Responsiveness Summary (ROD/RS) was submitted to USEPA on November 3, 1994.

After receipt of USEPA and OEPA comments on the Proposed Draft OU1 ROD, it was revised to Proposed Final. After DOE signature on January 24, 1995, OU1 ROD was submitted to USEPA for OEPA concurrence and was signed by USEPA on March 1, 1995.

The Draft OU1 Remedial Design Work Plan was submitted to USEPA on April 26, 1995.

Dewatering Excavation Evaluation Program (DEEP)

This OU1 short-term field program is aimed at determining the best technique to excavate the waste pit material to facilitate design and implementation of the ROD-selected remedial action for OU1. The field work will involve digging trenches in Waste Pits 1, 2, and 3 to test various types of excavation equipment and methods. Several different techniques are available for excavating wastes like those found in OU1. The DEEP tests will help identify the most efficient method. USEPA approved the DEEP Work Plan in August 1994.

OU2 Record of Decision Signed in June 1995

The OU2 FS/PP underwent public comment from October 26, 1994, through January 20, 1995. After close of the public comment period, the Proposed Draft OU2 ROD/RS was submitted to USEPA on February 3, 1995.

After receipt of USEPA and OEPA comments on the Proposed Draft OU2 ROD, it was revised to Proposed Final. After DOE signature, it was submitted to USEPA on April 7, 1995 for OEPA concurrence and was signed by USEPA on June 8, 1995.

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

The OU3 Proposed Plan-Environmental Assessment (PP/EA) underwent public comment from December 8, 1993 through February 8, 1994. After close of the public comment period, the Proposed Draft OU3 Record of Decision/Responsiveness Summary (IROD/RS) for Interim Remedial Action was submitted to USEPA on April 8, 1994.

After receipt of USEPA and OEPA comments on the Proposed Draft OU3 IROD, it was revised to Proposed Final. It was signed by DOE on June 8, 1994 and submitted to USEPA. After OEPA concurrence, OU3 IROD was signed by USEPA on July 22, 1994. The OU3 IROD allows for early remediation of existing structures within OU3, the former production area, several years in advance of the final ROD for OU3.

OU4 Record of Decision Signed in December 1994

The OU4 Feasibility Study/Proposed Plan-Draft Environmental Impact Statement (FS/PP-DEIS) underwent public comment from March 7 through June 19, 1994. After close of the public comment period, the Proposed Draft OU4 ROD/RS was submitted to USEPA on August 9, 1994.

After receipt of USEPA and OEPA comments on the Proposed Draft OU4 ROD, it was revised to Proposed Final. It was signed by DOE on November 3, 1994 and submitted to USEPA on November 4, 1994. After OEPA concurrence, OU4 ROD was signed by USEPA on December 7, 1994.

Vitrification Pilot Plant

A ground-breaking ceremony was held July 27, 1994, to initiate construction of the OU4 Vitrification Pilot Plant. The purpose of the facility is to conduct a larger scale (one ton per day) test of the feasibility of vitrifying the silo waste materials by conducting two phases of operation. Phase I will demonstrate vitrification of inert surrogate material; the Pilot Plant Phase I Treatability Study Work Plan was approved by USEPA in February 1994. Phase II will demonstrate and optimize vitrification of actual K-65 (silos 1 and 2) and silo 3 material. This test facility will allow DOE to better define remediation costs and engineering design for final remediation of the silos. Phase I operation of the test facility is scheduled to begin in September 1995.

OU5 Feasibility Study/Proposed Plan – Record of Decision Signature Expected in 1995

The Draft OU5 FS/PP, including data generated from treatability studies, was submitted to USEPA and OEPA for review on November 11, 1994. The Draft Final FS/PP report, reflecting changes made to incorporate EPA comments, was submitted to USEPA and OEPA on March 23, 1995.

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 USEPA and OEPA.

An overall completion status summary of Fernald removal response actions is presented below. Brief descriptions of those actions that were either completed in 1994 or are ongoing 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 Fernald is then presented. Removal actions that were conducted as a combined RCRA Closure/CERCLA Removal Action and completed in 1994 are addressed later in this chapter under RCRA Closures.

Fernald Removal Actions Completion Summary

Status	Total	ID #	Title
Previously completed	18		
Completed in 1994	4	7	Plant 1 Pad Continuing Release
		13	Plant 1 Ore Silos
		14	Contaminated Soils Adjacent to Sewage Treatment Plant Incinerator
		19	Plant 7 Dismantling
Ongoing	10	1	Contaminated Water Beneath Fernald Buildings
		3	South Groundwater Contamination Plume
		9	Removal of Waste Inventories
		12	Safe Shutdown
		15	Scrap Metal Piles
		17	Improved Storage of Soil and Debris
		20	Stabilization of UNH Inventories (HWMU Nos. 46 - 50)[1]
		26	Asbestos Removals
		28	Contamination at the Fire Training Facility (HWMU No. 1)[1]
		31	Seepage Control at the Southfield and Inactive Flyash Pile
Total	32		

Key

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

Removal Actions Completed in 1994

Removal Action No. 7 – Plant 1 Pad Continuing Release

Completed in September 1994, this removal action protects surface soils and regional groundwater from continuing releases of hazardous materials resulting from waste management activities on the eight-acre Plant 1 storage pad. The removal action was conducted in three phases.

Phase I involved the implementation of run-on and run-off control measures and the installation of underground utilities. Phase II involved the installation of a covered, 80,000 square foot concrete storage pad adjacent to the existing Plant 1 storage pad. Remaining drums of low-level radioactive waste in outdoor storage on the Plant 1 Pad have been moved into the two new covered storage structures, which are equipped with containment facilities for spill control, drainage, and stormwater run-off/run-on control. Phase III involved activities to upgrade the existing Plant 1 storage pad, including the installation of a polyurethane and epoxy coating over the pad surface to minimize contaminant migration to the environment.

The Final Report on the removal action was submitted to USEPA and OEPA in November 1994. A revision to address USEPA and OEPA review comments was submitted on February 21, 1995.

Removal Action No. 13 – Plant 1 Ore Silos

Completed in November 1994, this removal action involved the dismantling of the Plant 1 Ore Silos and their support structures. Due to deteriorated valves, materials leaked from the silos onto an elevated concrete pad in February 1991. The material, known as cold raffinate, is the waste residue from the processing of uranium ore after uranium is removed. Prior to the initiation of actual dismantling activities, the raffinate material that remained in the silos was removed, containerized and placed in safe storage pending final disposition. All 14 silos and support structures have been dismantled, cut up and packaged in containers for shipment as low-level radioactive waste to NTS.

Removal Action No. 14 – Contaminated Soils Adjacent to Sewage Treatment Plant Incinerator

Completed in November 1994, this removal action included the isolation or removal and disposition of contaminated soils with elevated levels of uranium in the vicinity of an out-of-service solid waste incinerator at the sewage treatment plant. The project was designed to mitigate the potential for contaminant migration. Activities included characterization, removal, storage and disposal of materials.

During the first phase of the removal action (characterization), site personnel discovered a larger area of contamination than previous sampling had indicated. The additional excavations were completed in accordance with the USEPA-approved Work Plan Addendum.

An area of off-property soil was excavated and verification soil samples were collected and sent to a laboratory for analyses. The excavated soil was brought on site and stockpiled in accordance with Removal Action No. 17 – Improved Storage of Soil and Debris.

The Final Report, which included validated analytical data from verification soil sampling, was submitted to USEPA and OEPA on November 18, 1994.

Removal Action No. 19 – Plant 7 Dismantling

Completed in November 1994, this removal action included characterization, decontamination, removal, containerization and disposal or reuse of materials in the building, and decontamination and dismantling of the building itself. Dismantling of the building was accomplished using controlled implosion and was completed ahead of schedule, under budget, and with no injuries.

Following the successful removal of interior contents, piping and equipment and all interior and exterior transite siding, the structural steel frame of Plant 7 was successfully imploded on September 17, 1994, on the second attempt using linear-shaped explosive charges. The final takedown completed an effort which began September 10, when explosive charges failed to take the building down completely. The first two floors of the building collapsed as planned on the first

attempt. However, splice plates that had been pre-cut on the third and fifth floors did not separate as anticipated. The building dropped approximately 9-11 m (30-35 feet) instead of the planned 18 m (60 feet).

The final takedown involved strategic placement and detonation of additional explosive charges at key structural supporting columns. The specialized steel-cutting charges were detonated sequentially to cut columns and to use the weight and configuration of the building to cause it to fall toward a pre-determined open area.

The dismantling process was completed by using track-mounted mechanical shears to cut the steel into sizes permitting shipment offsite for recycling. Steel, concrete and other materials including approximately 635 metric tons (700 tons) of structural steel have been packaged for recycling or other beneficial reuse.

Removal Actions Ongoing

- Removal Action No. 1 – Contaminated Water Beneath Fernald Buildings
- Removal Action No. 3 – South Groundwater Contamination Plume
- Removal Action No. 9 – Removal of Waste Inventories
  (See table below for summary of waste inventory removal by category during 1994.)
- Removal Action No. 12 – Safe Shutdown
- Removal Action No. 15 – Scrap Metal Piles
- Removal Action No. 17 – Improved Storage of Soil and Debris
- Removal Action No. 20 – Stabilization of UNH Inventories
- Removal Action No. 26 – Asbestos Removals
- Removal Action No. 28 – Fire Training Facility
- Removal Action No. 31 – Seepage Control at the South Field and Inactive Flyash Pile

Fernald's 1994 Removal of Waste Inventories (Removal Action No. 9)

Category	Destination	Drum Equivalents
Uranium production residues	DOE Nevada Test Site, NV	16,762.9
Process area scrap	DOE Nevada Test Site, NV	25,415
Construction and removal action waste	DOE Nevada Test Site, NV	16,949.1
Contaminated trash	DOE Nevada Test Site, NV	3,646
Thorium	DOE Nevada Test Site, NV	750.4
Armament Munitions Chemical Command waste	DOE Nevada Test Site, NV	3,878
Destination subtotal, Calendar Year 1994		64,401.4
Recyclable or reusable residues	Scientific Ecology Group, Inc., TN	8,862.2
Total to Offsite, Calendar Year 1994		76,263.6

Resource Conservation and Recovery Act

Stipulated Amendment to Consent Decree (SACD)

The Stipulated Amendment to Consent Decree (SACD) requires that the site 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 1994, the site continued to review the evaluation process, regulatory basis, and technical assumptions used to determine whether the designation of these units as HWMUs was justified. OEPA approval is being sought to change the designation for several HWMUs to SWMUs. This review of the evaluation process will continue in 1995.

Changes/Additions to Wastestreams in 1994 Facility RCRA Annual Report

A total of 47 wastestreams which appeared in the calendar year 1993 Facility RCRA Annual Report have been removed: 15 of them were archived to other wastestreams, 10 were eliminated by being shipped entirely to Envirocare, and the remaining 22 were recharacterized and determined not to be hazardous waste. Additionally, 56 of the wastestreams pending hazardous waste determination in 1993 have undergone changes. Of these, four were archived to another wastestream; seven were determined not to be hazardous waste upon complete characterization; two were determined to be hazardous waste and shipped offsite to Envirocare; and 43 were determined to be hazardous waste and remain in onsite storage.

During calendar year 1994, in addition to the 43 wastestreams previously pending hazardous waste determination, 40 new hazardous wastestreams and five new wastestreams pending hazardous waste determination were added to the report. The 1994 report reflects a net increase of 36 hazardous wastestreams, and a net decrease of 51 wastestreams pending hazardous waste determination.

The total amount of waste stored onsite has decreased through the above changes. Total weights for hazardous waste and wastestreams pending hazardous waste determination are presented below for calendar years 1993 and 1994.

Category	1993	1994	Decrease	Decrease, %
Hazardous waste	3,036,147 kg 6,672,850 lbs.	2,543,025 kg 5,589,067 lbs.	493,126 kg 1,083,793 lbs.	16
Pending hazardous waste determination	313,817 kg 689,708 lbs.	134,482 kg 295,564 lbs.	394,144 kg 394,144 lbs.	57

Thorium Management

A Thorium Management Strategy and a 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 Fernald site. 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 1994, the Fernald site shipped 750.4 *drum equivalents* of thorium material to the DOE Nevada Test Site (NTS) for disposal. Additional shipments are planned for 1995.

RCRA Closures

During 1994, activities were underway to plan and implement the closure of Fernald's Hazardous Waste Management Units (HWMUs). Many of these activities consisted of proposing, obtaining OEPA approval of, and implementing several RCRA closures in conjunction with the CERCLA response actions being undertaken under the Amended Consent Agreement with USEPA. The status of RCRA closure activities during calendar year 1994 are presented in the following table.

1994 Fernald RCRA HWMU Closure Activities

HWMU	Unit Name & Status
1	Fire Training Facility: Conducted as a combined RCRA Closure/CERCLA Removal Action (Removal Action No. 28). RAWP[1]/CPID[2] originally submitted in September 1993, resubmitted February 10, 1994. Field work began July 1994, expected to be completed in 1995.
4	Drum Storage Area Near Loading Dock (Lab): NOD[3] for the CPID received from OEPA February 1, 1994. Revised CPID submitted to OEPA March 3, 1994. A large part of the HWMU was excavated as part of a CERCLA Removal Action and the lab building extension. Closure field work expected to be completed in 1995.
5	Drum Storage Area South of W-26 (Lab): Soil sampling completed in 1994. Closure not yet scheduled.
6	Drummed Hydrofluoric Acid (HF) Storage Inside Plant 4: CPID approved on May 24, 1993. Completion of closure certification submitted to OEPA January 24, 1994.
9	Nitric Acid Rail Tank Car and Surrounding Area: Conducted as a combined RCRA Closure/CERCLA Removal Action (Removal Action No. 25). Combined RAWP/CPID submitted to OEPA in March 1993. Removal Action Final Report and completion of closure certification submitted to OEPA on October 31, 1994 and approval received from OEPA on April 25, 1995.

1994 Fernald RCRA HWMU Closure Activities

HWMU	Unit Name & Status
13	Wheelabrator Dust Collector: CPID submitted to OEPA July 18, 1994. Closure planned to begin June 1995.
22	Abandoned Sump West of Pilot Plant: Conducted as a combined RCRA Closure/CERCLA Removal Action (Removal Action No. 24). Removal of the sump completed October 12, 1993. Duriron pipe plugged and the area backfilled. USEPA approved Removal Action Final Report January 14, 1994. The soil, liquid, sump, associated piping, and pump currently stored onsite in a RCRA storage area as mixed waste. Soil remediation not yet determined.
26	Detrex Still: Revised CPID submitted to OEPA March 2, 1994. Field work initiated August 1994, completed September 29, 1994.
31/32	Bulk Storage Tanks T-5 and T-6: Field work progressed through 1994. Tanks T-5 and T-6, and the secondary containment under them, are clean in accordance with the CPID; however, because they share a common secondary containment with HWMU 54 (Tank T-2), closure certification is contingent upon Tank T-2 closure.
38	Hydrofluoric Acid (HF) Tank Car: Rev. 2 of the CPID submitted to OEPA July 1994. Bench scale testing completed May 1994. Systems design completed November 1994. Initial schedule for construction and system operation developed December 1994. Construction completion scheduled for May 1995, operation start-up scheduled for June 1995.
46-50	Uranyl Nitrate Hexahydrate (UNH) Tanks: Conducted as a combined RCRA Closure/CERCLA Removal Action (Removal Action No. 20). USEPA approved RAWP August 9, 1994. OEPA issued Director's Final Findings and Orders December 27, 1994. These Orders included a schedule for the neutralization/removal of the hazardous waste in the UNH system to be started by January 17, 1995 and completed by September 25, 1995.
52	North & South Spent Solvent Tanks: Work initiated in 1994. Field activities for steam cleaning the tanks completed June 1994. Comments received from OEPA December 5, 1994. Per OEPA, a revision of the closure plan's decontamination method and sampling and analysis plans submitted January 5, 1995. Additional comments received, expected to be revised and resubmitted in May 1995.
53	Safe Geometry Digestion Sump: Field work completed September 27, 1994. Sump is clean and capped. No formal closure plan required by OEPA, but a letter describing field activities submitted to OEPA February 13, 1995.
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). A CPID must be submitted to OEPA November 15, 1995. Specific closure procedures for this HWMU not yet established.

[1] *Removal Action Work Plan*
[2] *Closure Plan Information and Data*
[3] *Notice of Deficiency*

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

This Director's Final Findings and Orders (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 requirements at the Fernald site. Findings of the 1994 sampling and analyses from this routine groundwater monitoring program, as presented in the 1994 RCRA Annual Report, indicate that there is not a potential risk to human health or the environment from the groundwater except for certain areas (two wells) in the South Plume; these risks are 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.

Environmental Safety & Health Self-Assessment Program

Self-assessment is a quality assurance and continuous process improvement f unction that identifies strengths and weaknesses of programs, policies, and procedures in order to provide opportunities for improvement. The Environmental Safety & Health (ES&H) Self-Assessment Program has been established to encompass all programs, departments, and sections within the ES&H Division, including Medical, Occupational Safety & Health, Radiological Control, Environmental Protection, ES&H Assurance, and Safety Analysis. 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 compliance of ES&H programs with identified requirements. The program includes all appraisals, surveillances, audits, and walkthroughs conducted on ES&H activities by both internal personnel and external agencies.

Stakeholder Involvement

The DOE has pursued aggressive public involvement with stakeholders at the Fernald site. The chronology of community involvement, detailed in the site's Community Relations Plan, demonstrates how increased stakeholder awareness prompted the DOE to move from the non-participatory "decide, announce, defend" strategy to the two-way approach of shared decision making. In this approach, DOE and its stakeholders work together toward the common goal of cleaning up the site.

Stakeholder input is solicited through such mechanisms as regular briefings for the local citizens' environmental interest group, Fernald Residents for Environmental Safety and Health (FRESH), and local township trustees, person-to-person communication through the Envoy Program, workshops designed solely to identify stakeholder concerns, informational sessions, and dissemination of fact sheets and other literature.

Recognizing the importance of public involvement in the decision-making process during Fernald remediation, the DOE established the Fernald Citizens Task Force, a site-specific advisory board in August 1993. Task Force membership includes local residents, local elected officials, and representatives of FRESH, DOE, USEPA, and OEPA.

The Task Force has delivered a series of recommendations on future use of the site, cleanup objectives, waste disposal, and cleanup priorities. All of DOE's selected and proposed cleanup remedies are consistent with the existing recommendations of the Task Force. The Task Force has also recommended accelerating remediation at Fernald, citing Fernald's unique position among DOE's major remediation sites. "A relatively modest up-front investment will yield a nearly complete remediation in one-half to one-third the time projected in current reduced-budget scenarios," recommends the Task Force. The Task Force noted in its recommendation that, without funding constraints, remediation at Fernald could be conducted much more quickly and at a savings of about $3 billion. "In addition to savings billions of dollars, the symbolic significance of getting a major facility 'off the books' is incalculable ... Dollar for dollar, there must be few opportunities in the DOE complex that offer a clearer choice or more attractive dividends."

Air Pathway Monitoring

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

As discussed in Chapter One, the public may be exposed to radiation from the site 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 mid-1989, the major point source emissions from the site 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 cleanup activities are underway.

FUGITIVE DUST

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

Air pathway monitoring focuses on the airborne pollutants that may be carried from the Fernald site as a particulate or gas and how these pollutants are distributed in the environment. Stack and building vent emissions are obvious sources of pollutants, but dust from construction and remediation activities, waste handling, and wind erosion are also important 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 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: 1994 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 1994 were estimated to be 1.3 kg (2.9 pound). Results from monitoring the demolition of Plant 7 indicate that airborne uranium levels in the vicinity of Plant 7 remained well below the DOE standard during the demolition project.

Soil – Offsite soil samples ranged from 0.95 pCi/g to 2.8 pCi/g total uranium and are within the range of naturally occurring uranium concentrations in Ohio soil.[23]

Grass – The 1994 results indicate that uranium concentrations are within the range of historical concentrations and suggest that 1994 emissions have not significantly affected uranium concentrations in grass.

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 plant and produce grown at locations distant from the plant.

Milk – Uranium concentrations from the local dairy are comparable to those from a background dairy in Indiana. The data demonstrate that milk from the local dairy is not affected by site emissions.

Hay and Feed – Radionuclide concentrations in locally grown hay were comparable to concentrations found in hay grown distant from the site. Feed supplements used at the local and background dairy did not contain uranium in concentrations significantly higher than soil a cow might ingest while grazing, and are therefore not likely to be a large external source of uranium in the diet of local cattle.

Direct Radiation – Measurements of direct radiation indicate that levels increase with proximity to the K-65 silos. However, these levels are 90% 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 – With the exception of short-term opacity excursions, all emissions were well below permit limits.

Monitoring for Radioactive Pollutants

During 1994, Fernald site personnel continued to monitor radioactive materials in the air pathway by sampling air, soil, grass, produce, and milk. This monitoring enables scientists to evaluate the effects of the cleanup efforts at the site, as well as fulfill the site's obligations toward ongoing environmental surveillance and dose estimating.

Air Sampling for Radioactive Particulates

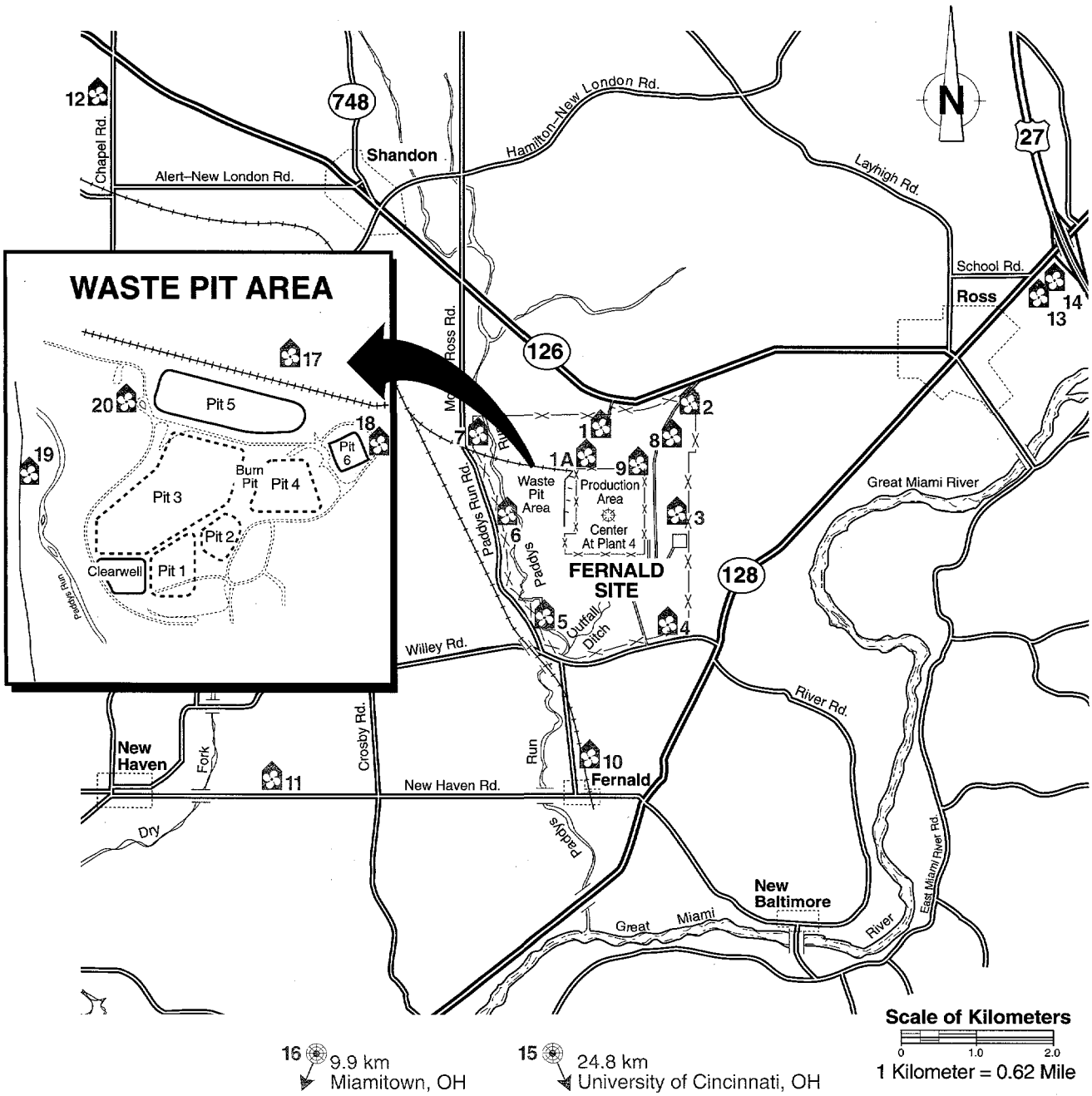
The first step in monitoring the air pathway is measuring the emission rate of the pollutants at the point of release after they have gone through treatments and filtering. This is done by means of stack sampling, and it provides preliminary information on how much pollutant is released and how it will behave in the environment. The second step in air pathway monitoring involves measuring the pollutant concentration in ambient air onsite and at the site boundary. Since only a few stacks and vents continue to emit pollutants at the site, airborne emissions from monitored stacks are substantially lower than during the years of production. However, monitoring of overall site emissions (stack and fugitive emissions) continues through the use of air monitoring stations (AMS) located onsite, near the site 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 1994, the site 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 21, for several reasons:

- AMS 1 was moved to a location closer to the former production area in mid-1993, in order to comply with DOE and EPA monitoring criteria. The new location was designated AMS 1A and is no longer on the site boundary;
- AMS 2 through AMS 7 provide data at the fenceline because this is where the public has closest access to the site, and guidelines for offsite exposure apply;
- AMS 8 and AMS 9 are in the prevailing wind direction at the site. They were added in 1986 to the northeast sector of the site 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 production area. The new location was designated AMS 9A and allows easier access to the monitor for maintenance and filter collection;

Figure 21: Air Monitoring Locations



LEGEND

- Air Monitoring Location
- Distance from Center of Production Area to Sampling Locations off Map
- Plant Perimeter
- Production Area Perimeter

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- AMS 10 through AMS 14 are located at schools and industries near the site 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 is located near the University of Cincinnati in Cincinnati, Ohio; AMS 16 is located in Miamitown, Ohio. In late 1994, road construction near AMS 15 required that the monitor be taken out of service. A replacement station is expected to be installed on the Cincinnati State Technical College campus in early 1995; and
- AMS 17 through AMS 20 were installed in 1992 to provide increased monitoring of waste pit emissions. These monitors will provide valuable information on any pit emissions which occur during waste pit remediation.

At each AMS, air is drawn through a 20 cm by 25 cm (8 inches by 10 inches) 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.

Environmental monitoring personnel collect the filters from the AMSs for analysis at weekly intervals. Beginning in 1994, weekly filters from each AMS were combined to form two-week composite samples. The change to two-week composite samples saved on the cost of analyzing the samples and freed up 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

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 1994 totaled 1.3 kg (2.9 pound), an increase from 1993 emissions of 0.21 kg (0.46 pounds). The increase in 1994 is in part attributable to the estimated emissions from the dismantling of Plant 7. Uranium discharges from monitored stacks were the only measured emissions. Emissions from all other sources listed here were 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 torn down during site remediation.

Emission Category	Amount of Uranium Emission	Sources	Comments
Monitored Stacks	<0.01kg	Six stacks	High efficiency filters used to control emissions
Unmonitored Stacks Vents	0.64 kg	Plant 8 Vents, Laboratory Hoods, Cooling Towers, and Respirator Washing Facility	Estimated based on processes and amount of material handled in each facility
Emissions from Plant 7 dismantling	0.66 kg	Uranium-contaminated dust from dismantling Plant 7	Estimated using ambient air monitoring data

occurring, short-lived radionuclides (such as radon *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, laboratory technicians heat the filters to 550 ∞C (1,022 ∞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, neptunium, 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. The intent of the DCGs is to provide reference values that enable site 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 six fenceline AMSs (AMS 2 through AMS 7) were all less than 1% of the DOE guideline. Table 3 on page A-4 lists 1994 data for uranium concentrations. Figure 22 compares uranium concentrations at the air monitoring stations for 1990 through 1994.

Figure 22: Average Uranium Concentrations in Air, 1990 – 1994

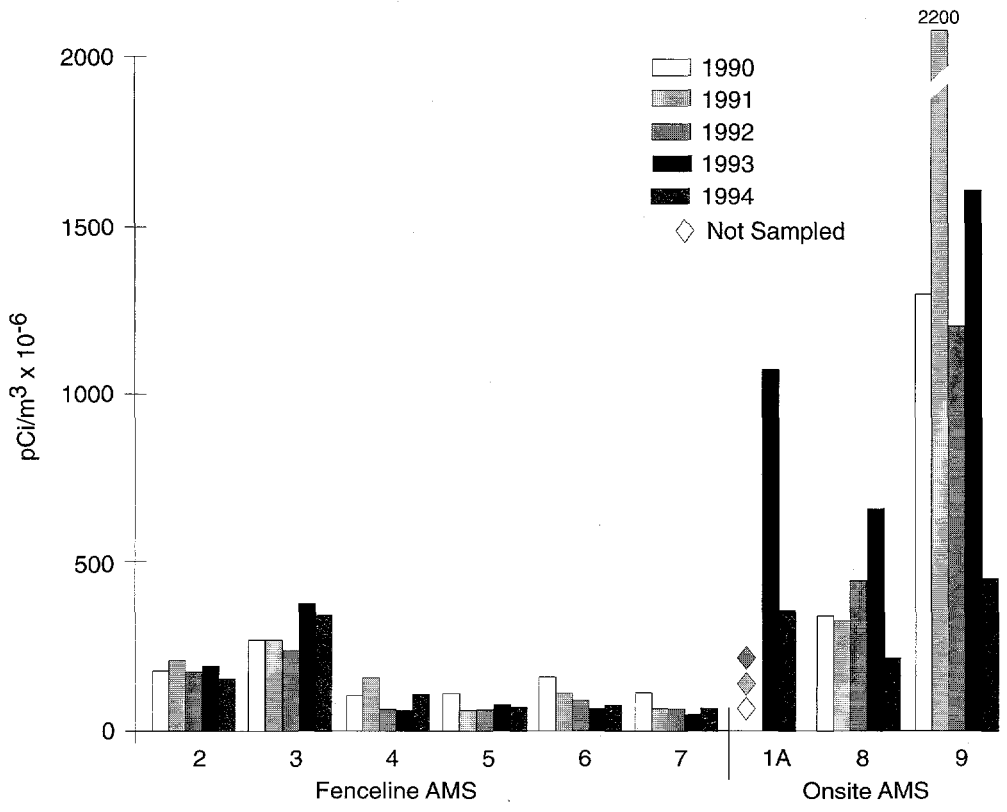
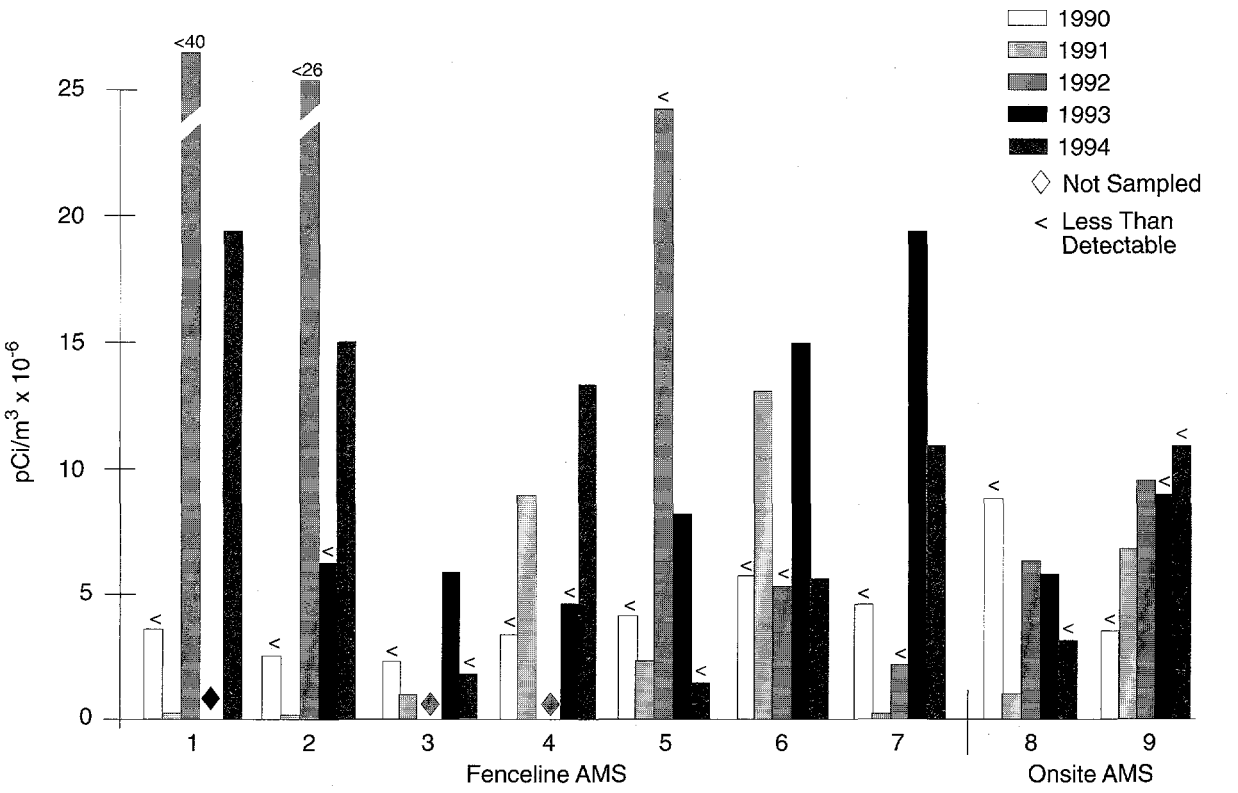


Figure 23A: Average Thorium–232 Concentrations in Air, 1990 – 1994

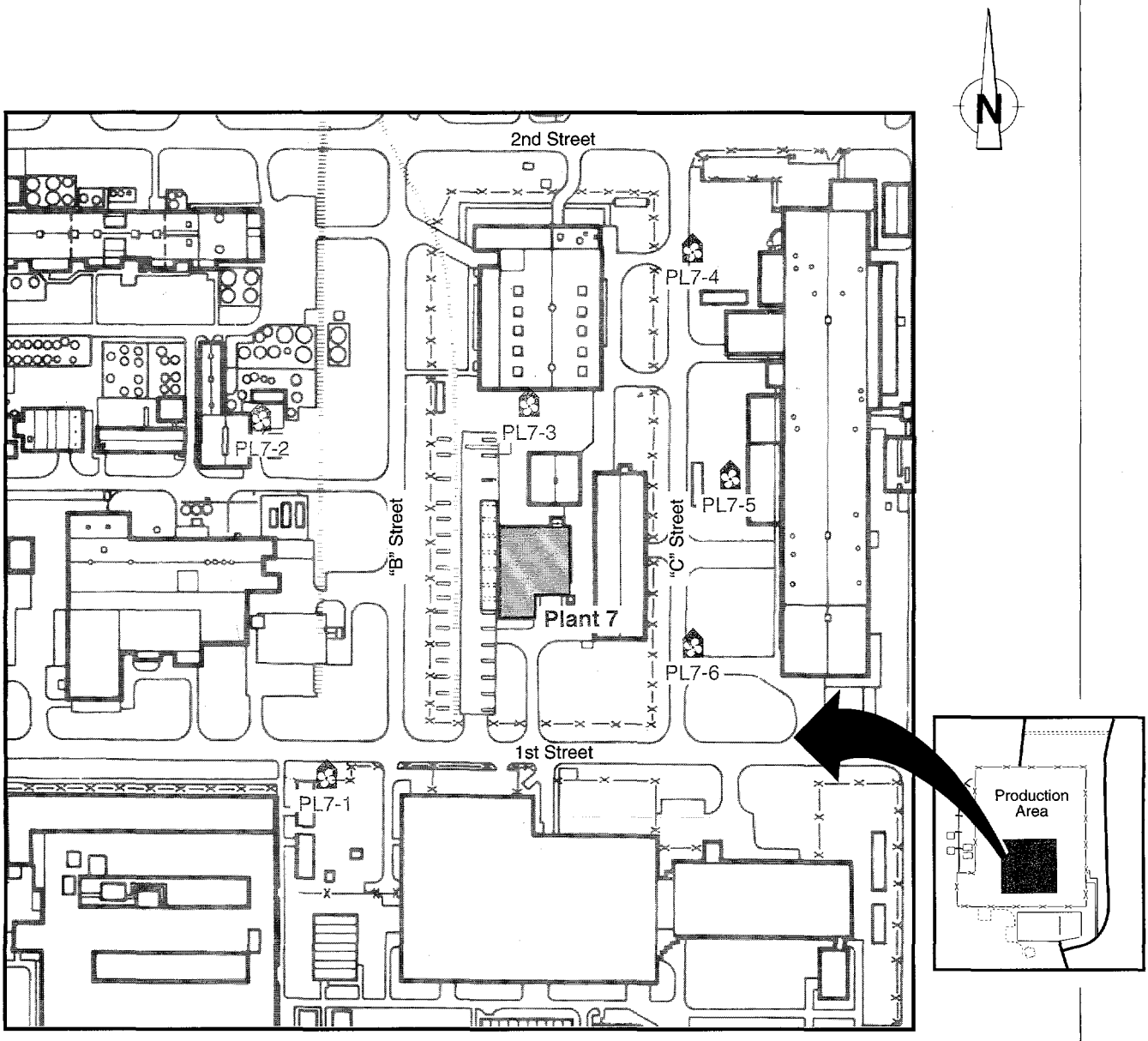


Less Than Detectable Concentrations

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 that 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}.

The data on the concentrations of trace radionuclides in 1994 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 1990 through 1994 are presented in Figure 23A. Thorium–232 and its decay products are stored in quantity at several locations onsite and are considered potential environmental contaminants.

Figure 23B: Plant 7 Monitoring Locations



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Plant 7 (PL7) Air Monitoring Location

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Monitoring Plant 7 Demolition

Prior to dismantling Plant 7, six ambient air monitors were placed around the building. The monitoring effort was designed to verify that negligible amounts of uranium, thorium, and radium in the form of airborne contamination were released to the environment while dismantling the building, particularly during the removal of the exterior siding and demolition of the steel framework. The potential for emissions was significantly reduced by washing down and sealing the interior surfaces of Plant 7 prior to dismantlement. The monitors also provided data for evaluating the effectiveness of these contamination control techniques. The monitors began operating in April 1994, prior to removal of the exterior siding. The monitors were similar to the boundary air monitors in that air was drawn through a 20 cm by 25 cm (8 inches by 10 inches) 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. A fraction of each weekly filter was used to make a composite sample. At the completion of the project, the composite samples were analyzed for isotopic uranium, thorium and radium. The locations of the Plant 7 monitors are shown in Figure 23B on the previous page.

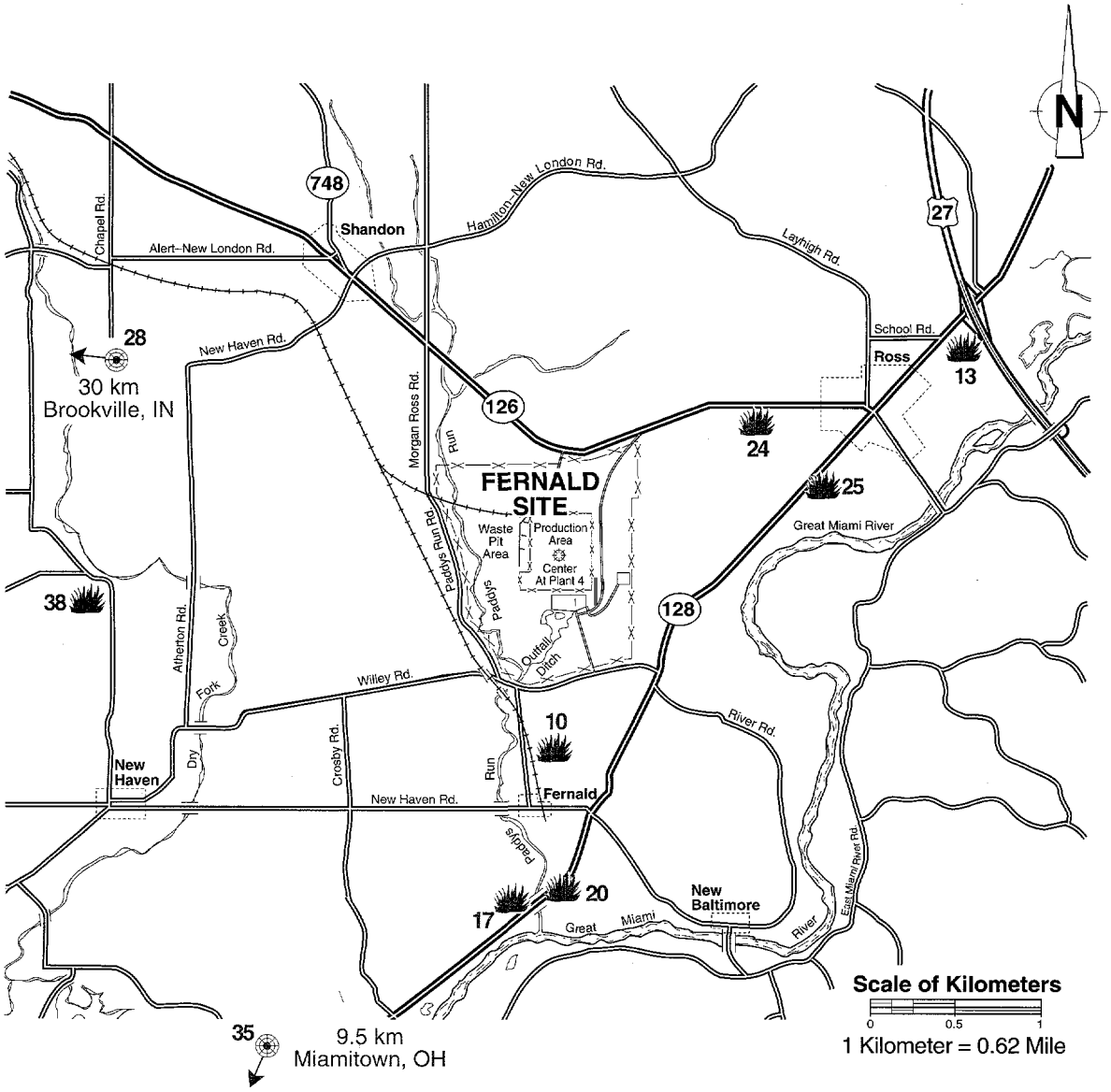
Monitoring results indicated that airborne levels were relatively constant during the removal of the exterior siding, with increased levels detected during the controlled demolition on the Plant 7 steel structure and rubble removal. Airborne uranium levels remained below the DOE guideline for uranium in air in the vicinity of Plant 7. There were no significant increases in airborne uranium levels at the site fenceline throughout the Plant 7 project. Table 5 on page A-8 is a summary of the weekly airborne uranium concentrations measured during the dismantling project.

The data from the composite samples formed during the Plant 7 project are also presented in Table 5. The results indicate that average concentrations of uranium, radium and thorium were well below DOE guidelines.

Soil Sampling for Uranium

Site technicians take annual soil samples at the air monitoring stations and offsite locations to evaluate changes in uranium concentrations that might occur through deposition, soil resuspension or other mechanisms (see Figure 24 on the next page for sampling locations). Any uranium found in the soil may be naturally occurring, added by fertilizers, or a result of site operations. The amount of uranium naturally present in rocks and soils varies greatly (see Figure 25 on page 83). For example, out of twelve samples collected throughout Ohio, the range of uranium–238 concentrations was 0.76 pCi/g to 2.2 pCi/g.[25] (The total radioactivity from uranium would be about twice this range because naturally occurring uranium in soil typically contains equal amounts of uranium–238 and uranium–234 radioactivity.) As a result, it is not possible to establish a single value for the background level of uranium and other minerals for areas such as those near the Fernald site.

Figure 24: Soil and Grass Sampling Locations



LEGEND

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

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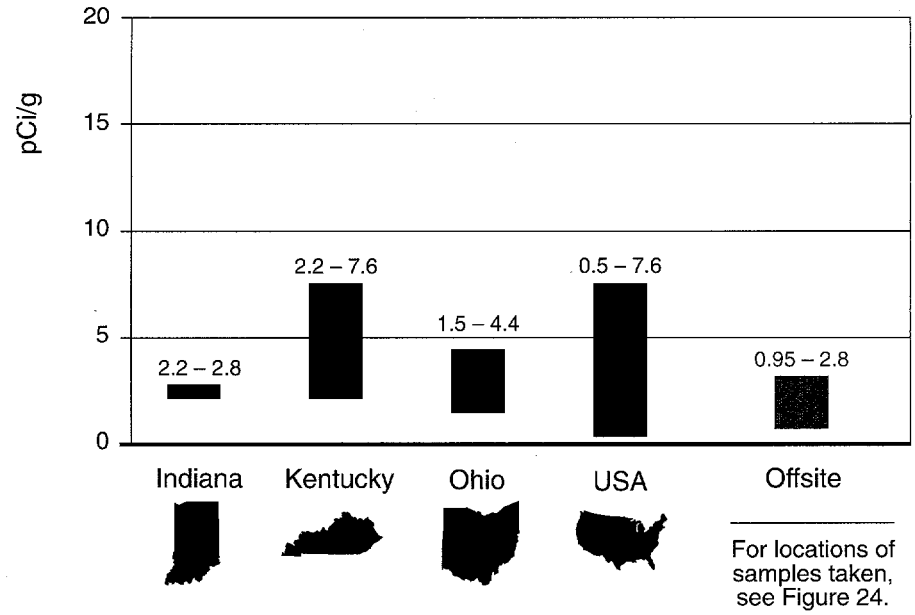
Figure 25: Range of Total Uranium Occurring in Surface Soils



To better evaluate the uranium concentration in soil, the site conducted a study to determine the amount of uranium naturally present in soil near the site. Soil samples were analyzed for a number of radionuclides; however, only uranium results are reported here. Results from this study show that the mean uranium concentration is 2.1 pCi/g with an upper limit (95% tolerance limit) of 2.8 pCi/g.[23]

As part of the soil sampling program, technicians collect 5 cm (2 inch) deep cores of soil from undisturbed plots, taking care to exclude grass from the soil samples. Due to contractual performance problems (see Chapter Nine) with one of the commercial laboratories analyzing soil samples, most of the soil sample results were considered suspect and unusable. Nine offsite soil samples were analyzed by a different laboratory, and the results are reported in Table 6 on page A-9. The uranium concentration in the offsite samples ranged from 0.95 pCi/g at sample location 38 to 2.8 pCi/g at sample location 24 and are within the range of naturally occurring uranium concentrations in Ohio soil.

Grass Sampling for Uranium

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 since 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. Fernald site personnel analyze grass for uranium to determine if airborne emissions are affecting the uranium concentration in grass.

Samples of grass were collected at the same locations as soil. Subsamples of grass are 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 each weighed about 500 grams (1 pound). An offsite laboratory air-dried and then analyzed the samples for uranium. Due to contractual performance problems (see Chapter Nine) with one of the commercial laboratories analyzing grass samples, most of the grass sample results were considered suspect and unusable. Nine offsite grass samples were analyzed by a different laboratory and the results are reported in Table 6 on page A-9.

Standards have not been established for uranium in grass; however, comparing results of 1994 offsite samples with the results of offsite samples collected in previous years provides a means to evaluate the impact of site emissions on uranium concentrations in grass.

In addition to soil sample results, Table 6 on page A-9 reports the following uranium concentrations in offsite grass samples:

- Offsite results for 1994 ranged from 0.011 to 0.084 pCi/g dry weight, and
- Offsite results from 1990 through 1993 ranged from 0.00029 to 0.68 pCi/g dry weight.

The results indicate that the 1994 uranium concentrations are within the range of historical concentrations and suggest that 1994 emissions have not affected uranium concentrations in grass.

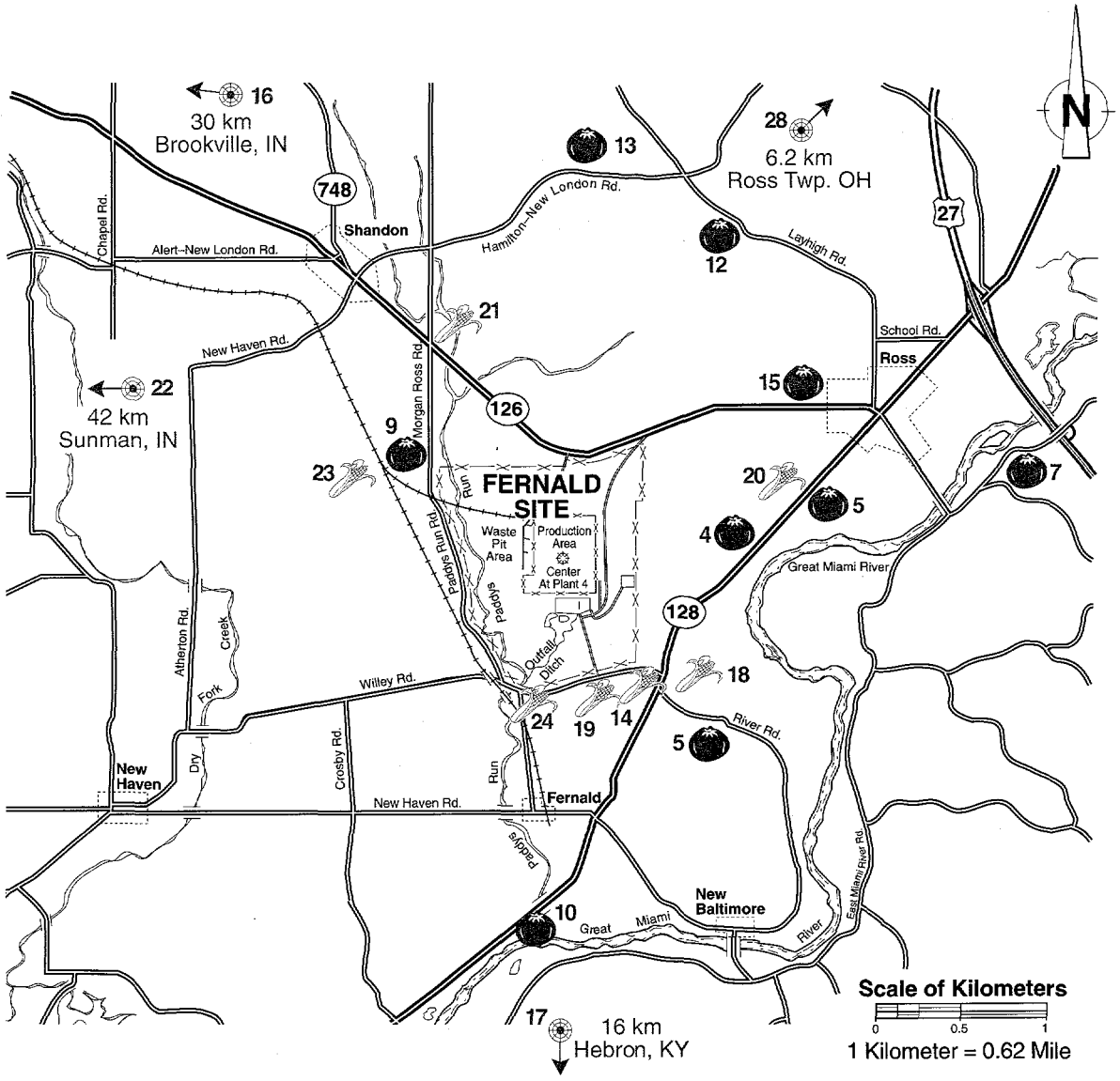
Produce Sampling for Uranium

As mentioned in Chapter One, the Fernald site is surrounded by farmland. Homegrown sweet corn and tomatoes are two of the major crops sold from roadside stands within three miles of the site. 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. Uranium detected in produce may be uranium that is naturally occurring in the soil, added by fertilizers, or deposited on the ground from airborne emissions.

Technicians sample produce each year to determine if uranium concentrations in produce grown near the site (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 site emissions (see Figure 26 on the next page 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).

Figure 26: Produce Sampling Locations



LEGEND

Sampling Locations:

- Cash Crop
- Garden Produce

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

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The results of the produce and soil sampling program are reported in Table 7 on pages A-10 and A-11. In general, uranium concentrations varied greatly for each type of produce. A comparison between the average uranium concentrations in corn and tomatoes grown near the site with concentrations in corn and tomatoes grown distant from the site determined that there was no significant difference between uranium concentrations in corn and tomatoes grown in the two areas. These comparisons suggest that there is no substantial impact from past or current Fernald site emissions on produce grown in the area.

Technicians also sample the soil in which the produce is grown. This sampling is in addition to the soil sampling described earlier and is conducted to compare uranium concentrations found in soil with the concentrations found in produce. To date, no strong correlation between uranium concentrations in soil and produce has been established. Uranium concentrations in the soil taken along with produce ranged from 1.2 to 3.9 pCi/g and were within the range of naturally occurring uranium concentrations in Ohio soils.

Milk Sampling for Radionuclides

Even though uranium is not normally concentrated in milk, the site monitors cows' milk as a component of the air pathway in response to public concerns about the dairy farm located next to the Fernald site. In 1994, technicians collected monthly samples of milk from the dairy adjacent to the site, as well as milk from a dairy in Indiana about 37 km (23 miles) west of the Fernald site. The milk samples were then frozen and shipped to an offsite laboratory for uranium analysis. In addition to monthly uranium analyses, once a year a set of milk samples is analyzed for radioactive materials present in trace concentrations (radium, thorium, etc.) in site emissions.

Table 8 on page A-12 presents the data from monthly milk sampling in 1994. The results show uranium concentrations in milk from the local dairy were comparable to the uranium concentrations measured in milk from the background (Indiana) dairy. A comparison between the average uranium concentrations in milk from both dairies indicated that the local dairy milk did not have a statistically significantly higher average concentration than milk from the background dairy.

Table 9 on page A-13 presents the results of the trace radionuclide analyses from milk. Results show that the concentrations of radionuclides in milk from the local dairy are similar to the concentrations in milk at the background dairy. The results also demonstrate that milk from the local dairy is not affected by site emissions.

Hay and Feed Sampling for Radionuclides

In 1994 technicians collected a hay and dairy cow feed supplement sample from both the local and background dairy. The purpose of the sampling was to provide additional data for use in the risk assessment studies being conducted as part of

the Operable Unit 5 (OU5) Remedial Investigation. The hay samples provide information on the concentration of radionuclides present in hay grown in the local area, while the feed supplement samples provide information on the types and concentrations which may be added from sources outside of the Fernald area. Studies have shown that feed supplements may contain relatively high concentrations of uranium and be a significant source of uranium in livestock diets.[43,44] Large external sources of uranium and other radionuclides in livestock diets complicates the measurement of the environmental risks from the Fernald site. Both hay and feed supplement samples were analyzed for Sr–90, Tc–99, Cs–137, Ra–226, Ra–228, and isotopic uranium. Technicians also analyzed the feed supplements for Th–228, Th–230, and Th–232.

Table 9 on page A-13 presents the results of the analyses of hay and feed supplement samples. Although the sampling program was limited in the number and location of samples collected, the results suggest that the radionuclide concentrations in hay from both locations are similar. Therefore locally grown hay is not likely to lead to increased risks from local beef and milk. Furthermore, the feed supplements do not contain uranium at concentrations substantially higher than soil which a cow might ingest while grazing, and are therefore not likely to be a large external source of uranium in the diet of local cattle.

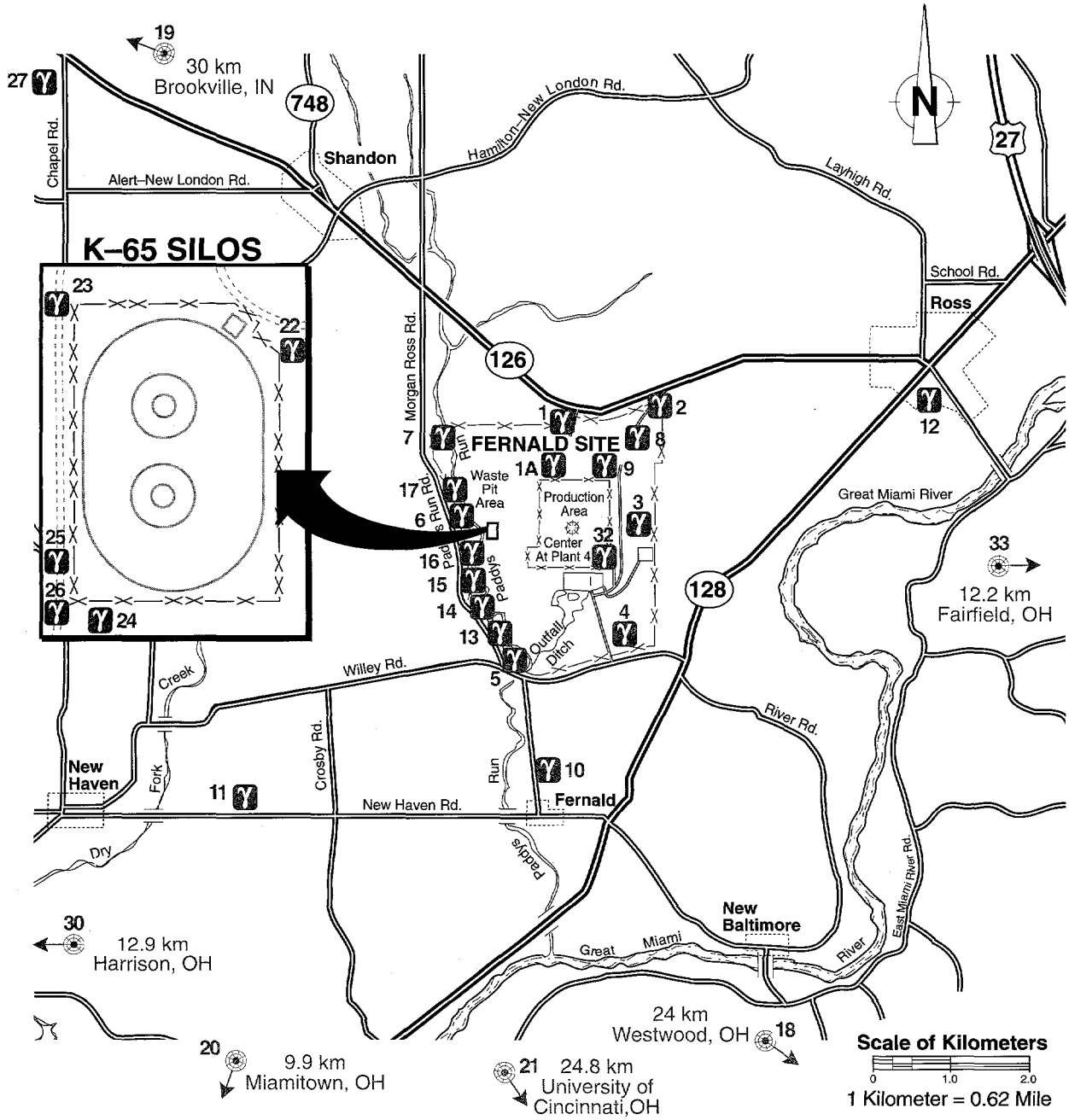
Monitoring for Direct Radiation

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, and radioactive materials at the Fernald site. The largest source of direct radiation at the site 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 Fernald site because uranium, thorium, and their decay products do not emit this radiation at levels that create a public exposure concern.

Direct radiation levels at and around the site 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, measured, and correlated to the amount of direct radiation. Figure 27, located on the next page, shows the location of the TLD monitoring points. These monitoring points were selected based on the need to monitor the K-65 silos, the site boundary, and several offsite locations, including background locations. Three TLDs are placed at each monitoring location for a three-month period, yielding more reliable quarterly measurements.

Results of direct radiation measurements for 1994 are provided in Table 10 on page A-14. Direct radiation fields vary from one location to another because of the

Figure 27: Direct Monitoring Locations



LEGEND

- Dosimeter Location
- Distance from Center of Production Area to Dosimeter Locations off Map
- Plant Perimeter
- Production Area Perimeter

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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 that levels are higher in the area near the K-65 silos. These levels are 90% 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.

Monitoring for Nonradioactive Pollutants

OEPA requires an estimate of emissions from the Boiler Plant as part of the site's effort to demonstrate compliance with the Clean Air Act. The site estimated the amount of nonradioactive pollutants including 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, is also called *opacity* and is a measure of how much light is blocked by particulates present in stack emissions.

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 1993	Butler County 1993	Combined Counties 1993	Fernald Site Boiler Plant 1993	Fernald Site Boiler Plant 1994
Particulates	2,100,000	5,800,000	7,900,000	16,000	15,000
SO_2	85,000,000	12,000,000	97,000,000	290,000	230,000
NO_X	55,000,000	14,000,000	69,000,000	152,000	160,000
CO	2,700,000	27,000,000	29,700,000	54,000	59,000

In order to estimate SO_2 emissions, scientists regularly determine the sulfur content of the coal. Using this information and the total amount of coal burned, the amount of SO_2 emissions can be calculated. For 1994, SO_2 emissions were calculated to be 230,000 kg (500,000 pounds).[27] This was well below the allowable limit of 1.1 million kg (2.3 million pounds) calculated from information in the Permit to Operate issued by OEPA.

The NO_X emissions are estimated using USEPA-developed emission factors. Nitrogen oxide emissions for 1994 were estimated to be 160,000 kg (350,000 pounds). To date, the State of Ohio has not set NO_X or CO limits for Fernald site industrial processes. Carbon monoxide emissions were estimated using USEPA-developed emission factors. Carbon monoxide emissions in 1994 were estimated to be 59,000 kg (130,000 pounds).

Electrostatic precipitators reduce particulate emissions from the Boiler Plant. These emissions were estimated to be 15,000 kg (34,000 pounds) for 1994. This estimate was based on emission factors developed from stack testing in 1988. The opacity of the emissions from the two site coal-fired boilers were continuously monitored by instruments designed for that purpose. During 1994, the boilers operated 9,405 hours, and 94,050 measurements were made and recorded at six-minute intervals. A total of 20 excursions failed to meet 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 Fernald Site, beginning with Effluent and Surface Water Monitoring in Chapter Five.

Liquid Pathway: Effluent and Surface Water Monitoring

The Fernald site investigates the effects of past and current operations on the second major pathway, the liquid pathway. Since contaminants can leave the site through the regulated liquid effluents and uncontrolled stormwater runoff, this chapter discusses sampling methodologies and results used to evaluate the site's effluents. It also discusses any impacts from the site on the Great Miami River and Paddys Run.

Results in Brief: 1994 Liquid Pathway: Effluent and Surface Water

Effluent – Approximately 351 kg (772 pounds) of uranium were discharged to the Great Miami River during 1994. Of that total, 204 kg (449 pounds) were from Manhole-175 and 147 kg (323 pounds) were from South Plume/Stormwater Retention Basin pumping. Approximately 109 kg (240 pounds) of uranium reached Paddys Run through uncontrolled stormwater runoff during 1994.

Surface Water – The liquid effluent discharged to the Great Miami River resulted in a downriver uranium concentration that was higher than the upriver concentration. However, the downriver concentrations were consistent with 1993 data. Paddys Run continued to show effects of stormwater runoff from the site. Although the average uranium concentration at the nearest offsite sampling location was higher than in 1993, it was only 0.75% of the DOE guideline for drinking water, which is used for comparison purposes only.

Sediment – Radionuclide concentrations in the Great Miami River and Paddys Run sediment for 1994 were consistent with previous years' data and did not indicate a build-up of radioactive pollutants in the sediment.

Fish – In 1994, uranium concentrations in fish were no greater in those caught in the Great Miami River downstream of the site's effluent line than in those caught upstream.

NPDES – During 1994, out of 2,512 samples collected at Manhole-175, (the final NPDES monitoring point before effluents are discharged to the river), there were only three violations of NPDES limits.

Monitoring for Radioactive Pollutants

The first section of this chapter centers on the radioactive pollutants and begins with an examination of the liquid effluent sampling and analysis program. A discussion of the river and creek surface water sampling program follows. The Fernald site conducts these programs because radionuclides in the regulated liquid effluent and in uncontrolled stormwater runoff may be a source of radiation exposure to the public.

Effluent Sampling for Radionuclides

The site's liquid effluents have been categorized into eleven basic sources. All site generated liquid effluents are monitored and, if necessary, treated before they leave the site. Figure 28 illustrates the flow of the effluents and where they are treated and monitored before they are discharged.

Sources of Effluent During 1994

The first two sources of liquid effluent are ***controlled contaminated stormwater runoffs from the waste pit area and perimeter***, which are collected and pumped to the Biodenitrification Surge Lagoon (BSL).

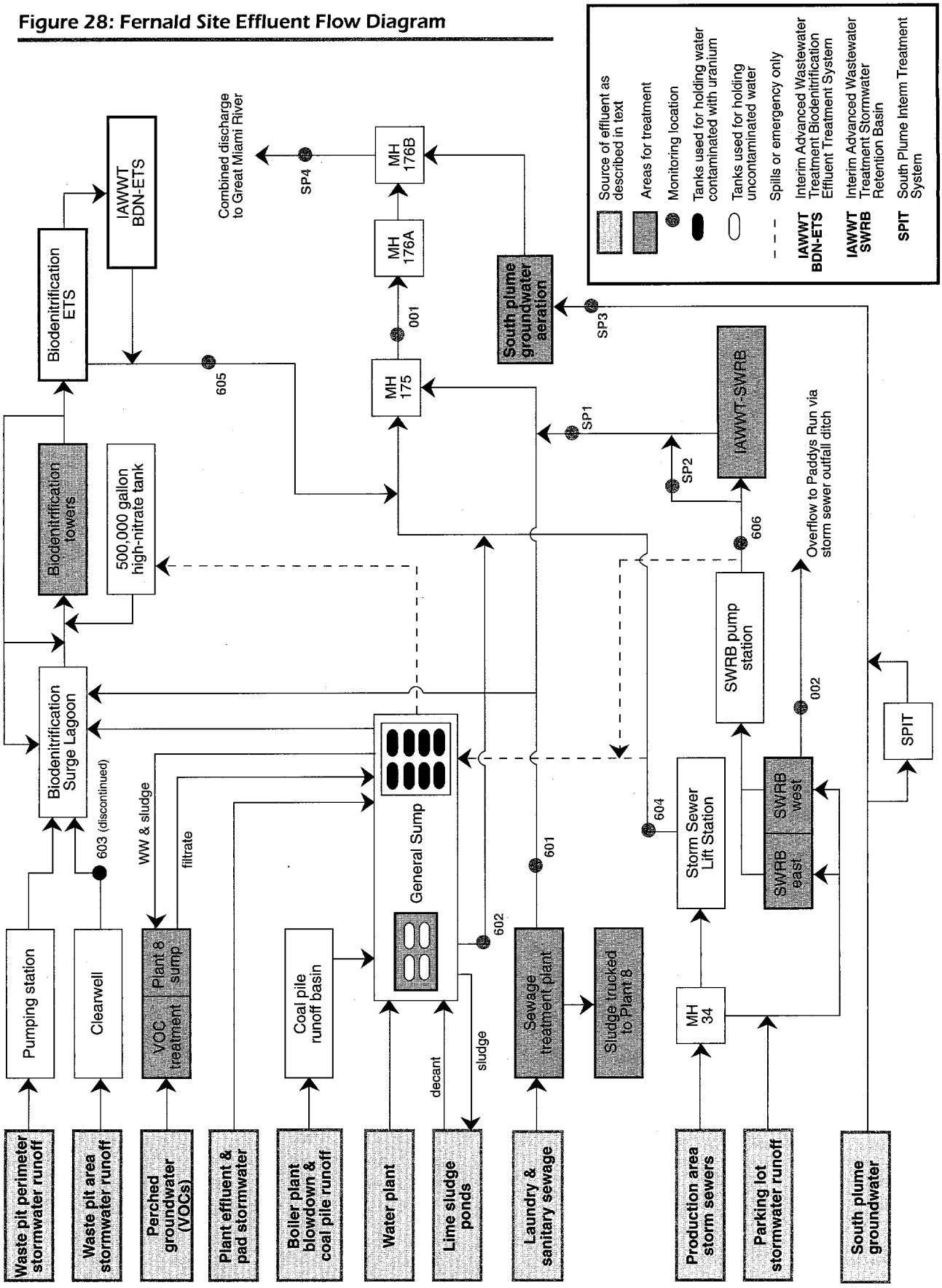
The third source of liquid effluent is ***perched groundwater,*** which is treated for volatile organic compounds (VOCs) in the Plant 8 Granular Activated Carbon System.

The fourth source of effluent is the combination of ***sanitary sewage and wastewater from the laundry***, which is processed at the Sewage Treatment Plant to remove biological contaminants. After treatment, the effluent is sent to Manhole-175 and the sewage sludge is trucked to the Plant 8 treatment system, where the sludges are dewatered. The resulting liquid is sent to the contaminated side of the General Sump, and the dewatered sludge is drummed and stored as low-level radioactive waste.

The combination of ***plant effluent and pad stormwater*** is the fifth source of effluent, and it is sent directly to the contaminated side of the General Sump. All liquids sent directly to the contaminated side of the General Sump are combined and, if needed, are sent to the Plant 8 treatment system where they are treated for uranium and heavy metals. If treatment is not required, they are sent on to the BSL for pH control.

At the BSL, runoff mixes with liquid from the contaminated side of the General Sump, and the combined liquid effluent is treated in the Biodenitrification Facility (BDN) towers to reduce nitrates. From there, the liquid flows through the BDN effluent treatment system, after which the combined treated effluent flows to an Interim Advanced Wastewater Treatment (IAWWT) System for uranium removal prior to discharge to Manhole-175.

Figure 28: Fernald Site Effluent Flow Diagram



The sixth through the eighth sources of effluent are all collected in the noncontaminated side of the General Sump. ***Boiler plant blowdown and coal pile runoff*** are collected in the coal pile runoff basin and, after clarification, are sent to the noncontaminated side of the General Sump. ***Water plant effluent*** and ***Lime Sludge Pond*** decants are sent directly to the noncontaminated side of the General Sump. After settling, the 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 ***production area storm sewers*** and ***parking lot runoff*** (see shaded areas of Figure 29) collect rain, making the nine and tenth sources of effluent. Stormwater runoff from the former production area is collected by a network of storm sewers that converge at Manhole-34. Normally all runoff is directed to the Stormwater Retention Basin (SWRB); but if needed, effluent can be pumped to Manhole-175 from the Storm Sewer Lift Station. At the SWRB the effluent mixes with runoff from the parking lot storm sewers and is allowed to settle before being pumped to the IAWWT for uranum removal. From there the effluent is sent to Manhole-176B.

SOUTH PLUME GROUNDWATER PUMPING

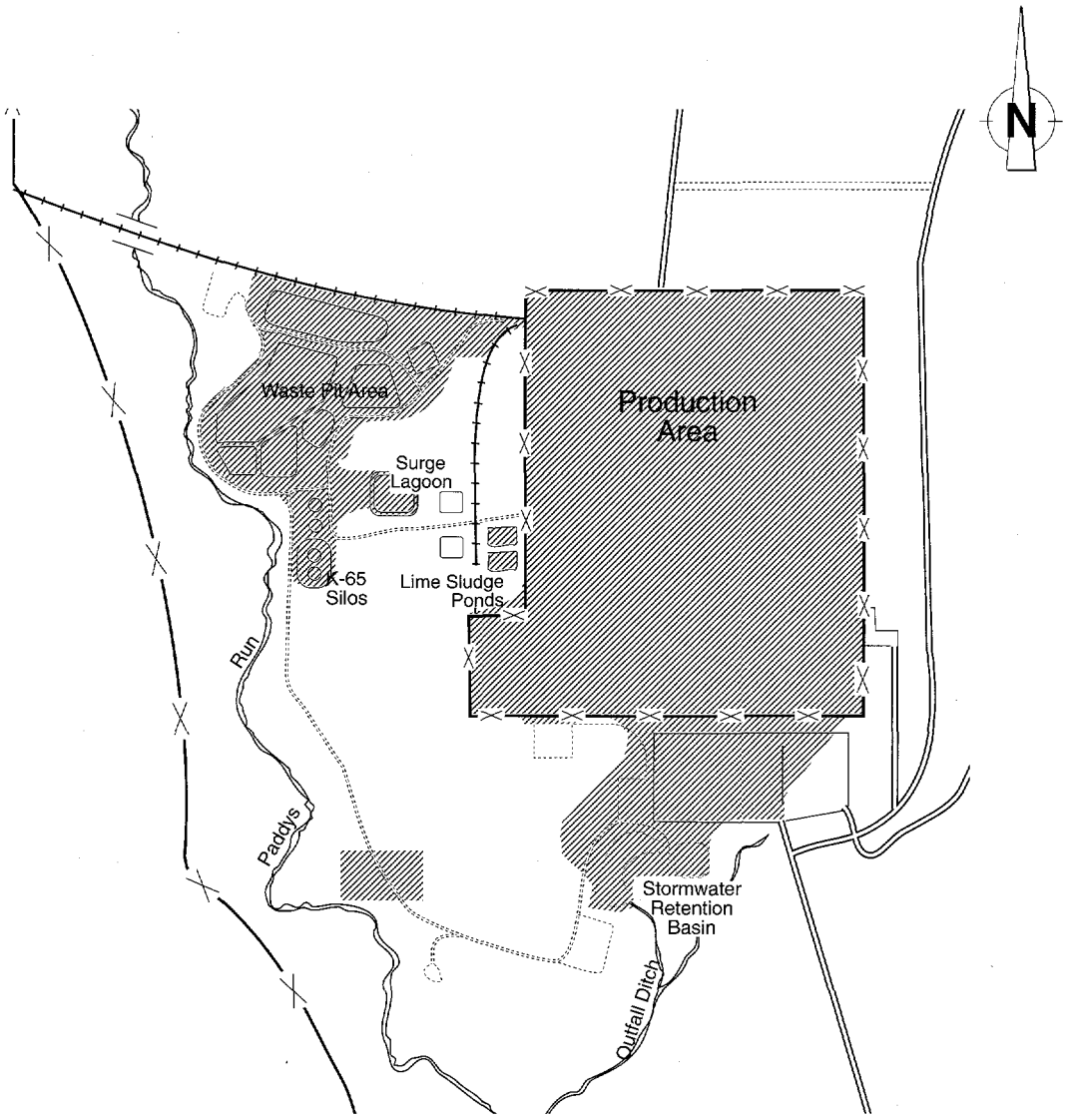
Groundwater from the South Plume is pumped back onsite before it is discharged to the Great Miami River. Once it is onsite it is considered a source of effluent. The effluents generated from the South Plume groundwater are monitored separately from the effluents generated onsite. After being monitored, all effluents are combined at Manhole-176B before being discharged to the river. Even though the effluents originating from the site and South Plume groundwater are monitored separately, the combined effluent is required to comply with all applicable permits, guidelines, and standards. This is accomplished by combining the measured concentrations.

The final source of effluent is generated from the pumping of the ***South Plume groundwater***. The South Plume groundwater is monitored before being pumped to the South Plume Aeration Building where it can be aerated if needed and then sent to Manhole-176B.

In summary, the Fernald site manages site-generated liquid effluents by monitoring and treating the effluents as necessary before they all eventually enter Manhole-176B. There, the effluents combine to form a single wastewater before flowing into the Great Miami River.

On an average day during 1994, about 2.2 billion liters (570 million gallons) of Great Miami River water flowed past the site's effluent line.[8] The site discharged an average of 9.4 million liters (2.5 million gallons) of effluent, 8.3 million liters (2.2 million gallons) from the South Plume and 1.2 million liters (0.32 million gallons) from Manhole-175, into the river each day. Therefore, on average, each liter of effluent discharged was combined with about 234 liters of river water (1 gallon of effluent combined with 62 gallons of river water). Discharge totals are averaged and may be subject to rounding discrepancies.

Figure 29: Area of Controlled Stormwater Runoff



LEGEND

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

Plant Perimeter

Production Area Perimeter

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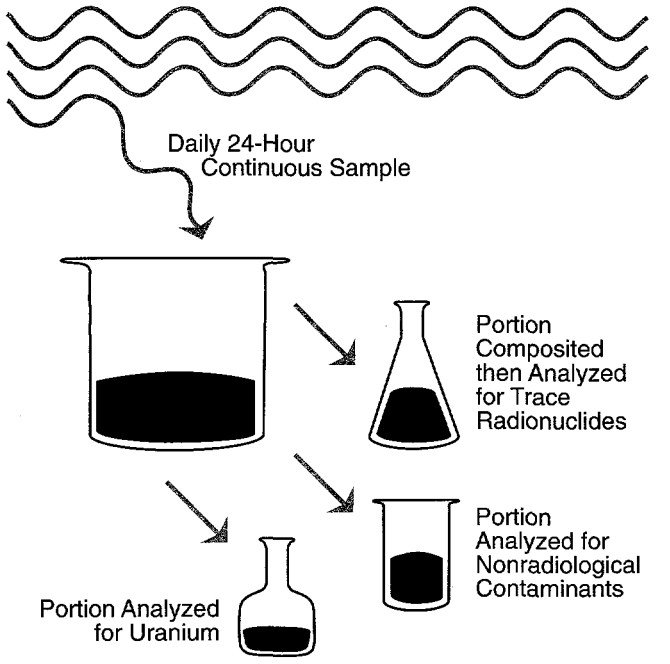
Figure 30: Continuous Sampling



Sampling Methodologies

The mixed effluent, described above, is sampled at Manhole-175 and SP3 by flow-proportional samplers (continuously operating devices that collect a sample proportional to the volume of effluent flow). After every 24 hours of operation, the collected liquid is removed from the automatic sampler to provide a daily flow-weighted sample of the effluent (see Figure 30).

Scientists analyzed a portion of each daily sample of effluent flowing through Manhole-175 and SP3 to determine the amount of total uranium discharged to the Great Miami River. In addition, monthly composites were formed for Manhole-175 and SP3 by combining the month's daily samples at each location. The monthly composites were analyzed for four uranium isotopes and nine other radionuclides listed in Table 11 on page A-15. Composites, rather than daily samples, were analyzed because many of the radionuclides are typically present in only trace amounts, and it is neither practical nor cost-effective to perform more frequent analyses for them.

The Fernald site also monitors any discharges to Paddys Run that occur from the overflow of the SWRB. During 1994 the SWRB did not overflow. Since the SWRB began operating in 1986, the amount of uranium entering the Storm Sewer Outfall Ditch (SSOD) has been substantially reduced.

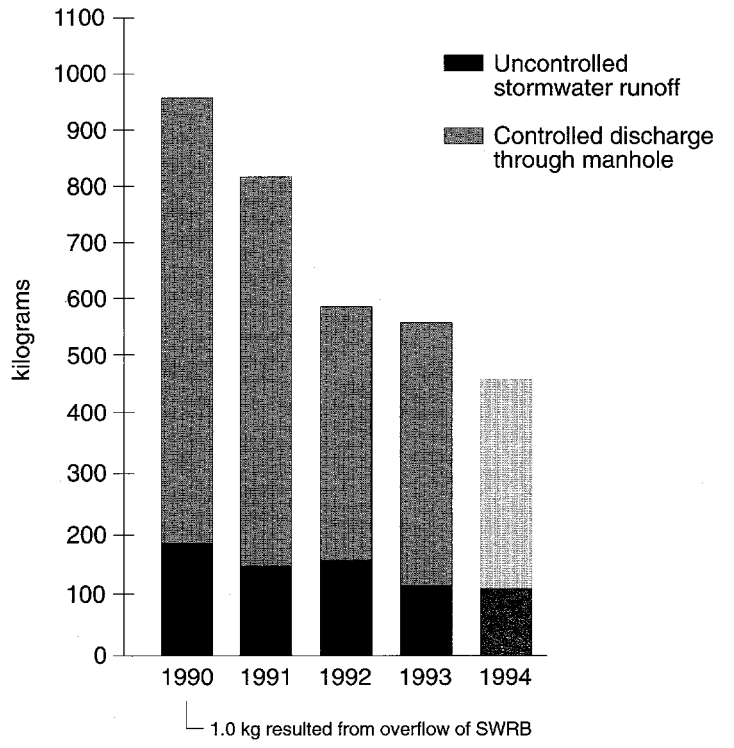
Results of Laboratory Analyses

Table 11 on page A-15 is a summary of the radionuclide analysis of the liquid effluent discharged to the Great Miami River. The table shows the total radionuclide activity (in Curies) of the effluents during 1994 and the average concentration (in pCi/L) of each radionuclide in 1994.

The average concentration of each radionuclide is compared to the Derived Concentration Guideline (DCG) or standard. DOE Orders state that a dose must be estimated based on all of the radionuclides present in the effluent. The annual average percentages of the DCG for each radionuclide, when added together (Manhole-175 and SP3 combined), must not exceed 100%. When the total is above 100%, the site is required to use the "best available technology" to reduce radionuclide concentrations in its effluent. The DCG was not exceeded in 1994.

An Advanced Wastewater Treatment Facility presently under construction will be online in early 1995 to provide "best available technology" treatment of both stormwater and process wastewater before their discharge to the Great Miami River. Similar technology has been used at the SWRB with an Interim Advanced Wastewater Treatment facility and another Interim Advanced Wastewater Treatment system that extracts uranium from wastewater discharged from the BSL.

Figure 31: Total Uranium Discharged from the Site, 1990– 1994



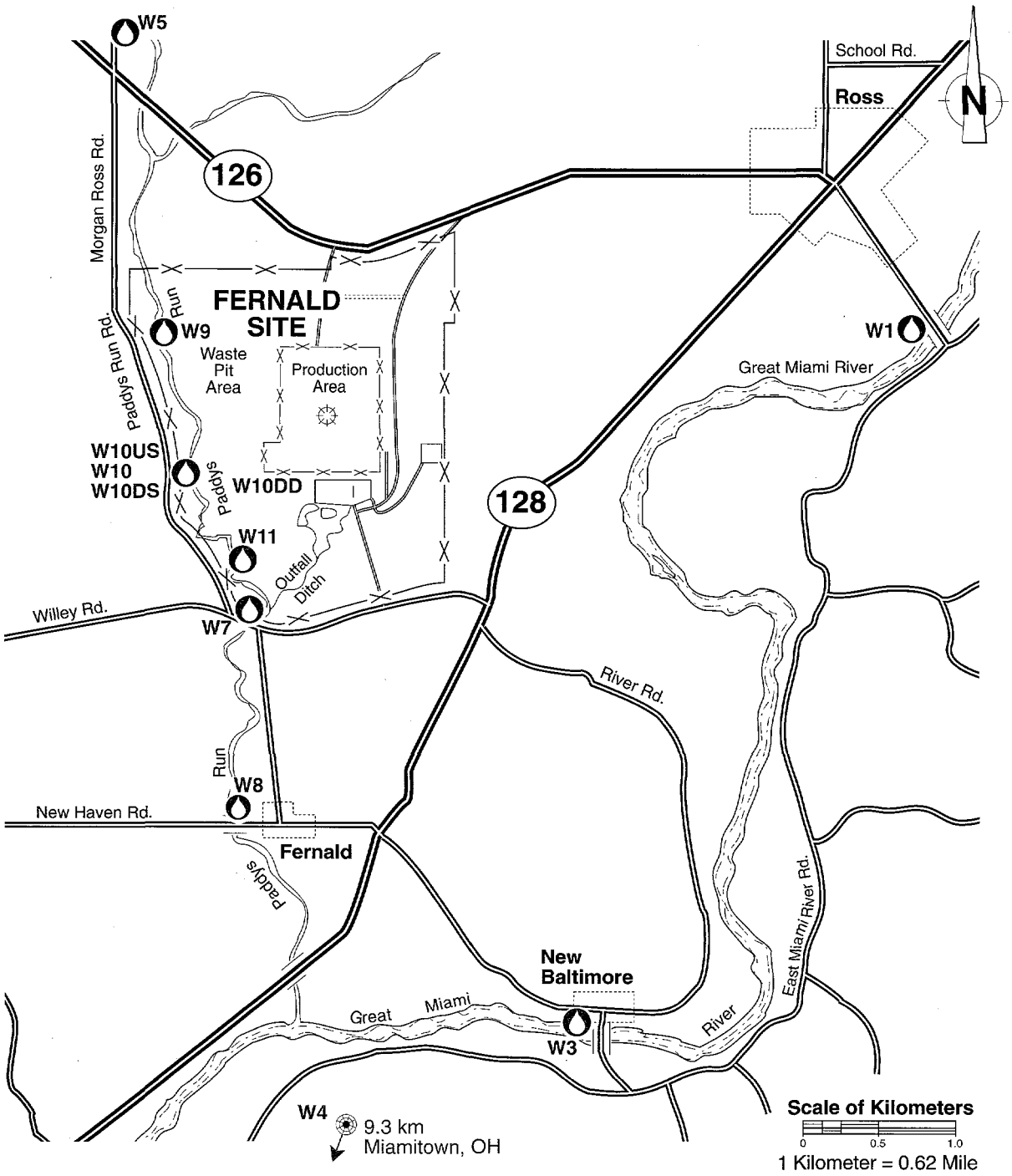
During 1994, a total of 351 kg (772 pounds) of uranium was discharged to the Great Miami River. This was a decrease of 26% in comparison to the 474 kg (1,044 pounds) of uranium discharged to the river during 1993. The uranium contained in all effluents discharged from the site also decreased from an estimated 584 kg (1,283 pounds) in 1993 to an estimated 461 kg (1,013 pounds) in 1994. This decrease may be attributed to additional treatment at the IAWWT. Comparisons of uranium discharges to the Great Miami River between 1990 and 1994 are shown in Figure 31. Additionally, all target analytes for the Manhole-175 and SP3 sampling locations were within acceptable limits.

The Fernald site reports an estimate of uranium in uncontrolled stormwater runoff into Paddys Run to USEPA. Fernald site personnel have developed a general estimate of 2.8 kg (6.3 pounds) of uranium in the runoff to Paddys Run for every inch of rain. For 1994, the estimate of uranium in stormwater runoff to Paddys Run was reported as 109 kg (240 pounds). This estimate was based on the amount of precipitation recorded by the site meteorological system (98 cm or 39 inches). Totals are subject to rounding discrepancies due to unit conversion or averaging.

Surface Water Sampling for Radionuclides

The site's surface water sampling program measures the effects of two potential sources of contamination on local waterways: the discharge of liquid effluents into the Great Miami River and the uncontrolled stormwater runoff into Paddys Run and overflow from the SWRB (which did not occur in 1994). Figure 29 on page 95 shows the area of controlled stormwater runoff.

Figure 32: Surface Water Sampling Locations



LEGEND

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

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Sampling Methodologies

During 1994, surface water was sampled at the following locations identified in Figure 32:

- Three locations along the Great Miami River (W1 – upstream from the effluent discharge, W3, and W4);
- Five onsite locations along Paddys Run (W9, W10-US, W10, W10-DS, and W11);
- One location along the drainage ditch originating near the Pilot Plant (W10-DD); and
- Three offsite locations along Paddys Run (W5 – upstream from the site, W7, and W8).

Each week, the onsite laboratory analyzed one of the daily samples from each river sampling location for total uranium. Portions of the daily samples collected along the Great Miami River were combined to form weekly and monthly composites for each location, 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.

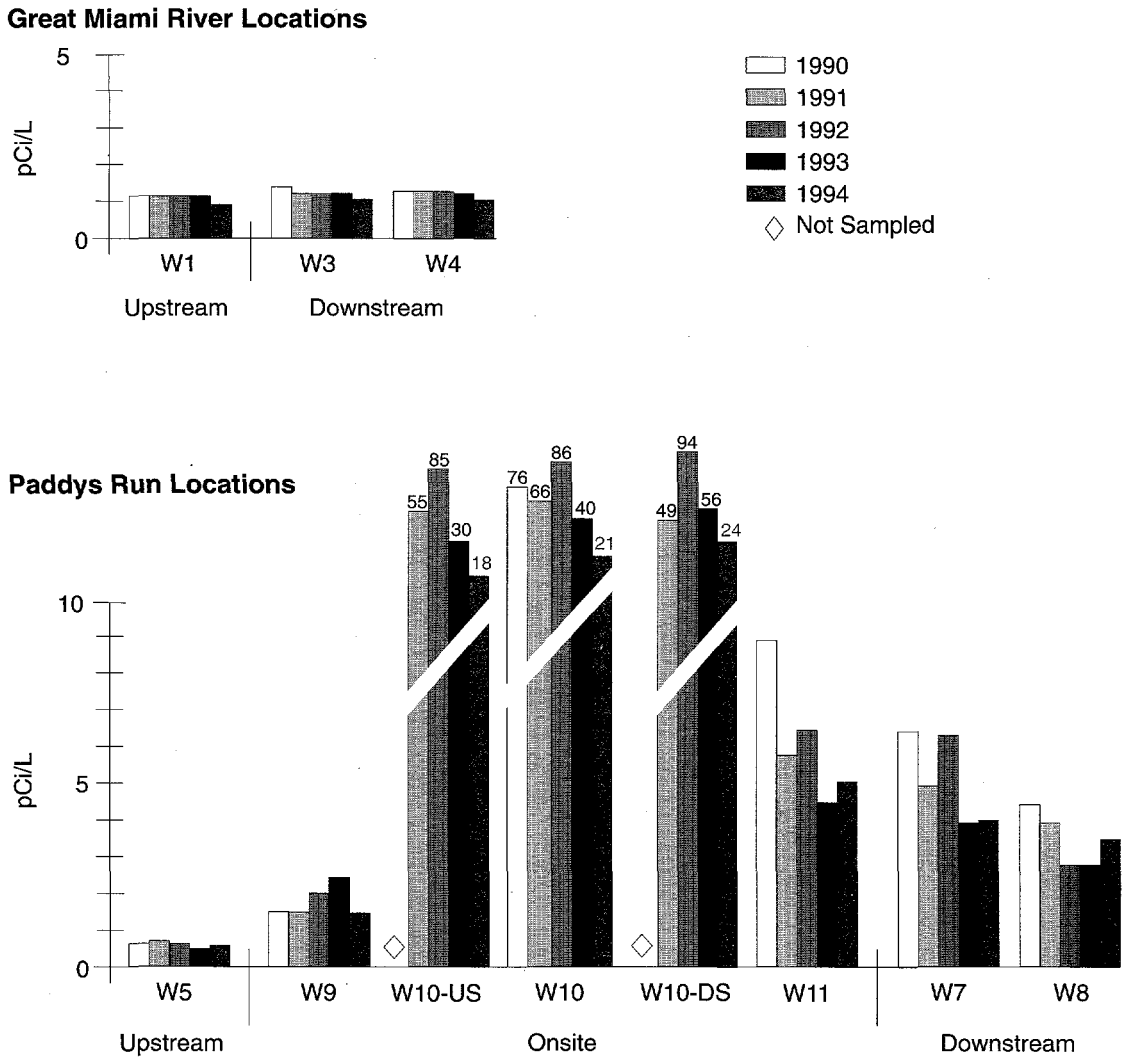
Weekly grab samples were collected at the five onsite locations along Paddys Run, one location along the drainage ditch, two locations upstream (north) of the site, and two locations downstream (south) of the site. All samples collected along Paddys Run were analyzed weekly for total uranium. Two-month composites of weekly samples from W5 were analyzed for isotopic radium, as were monthly composites at W7 (or W8 if there was not enough water at W7). Oftentimes there was not enough water present in Paddys Run to collect a sample.

Uranium concentrations at W10 have varied greatly. This may be due to the fact that uranium concentrations in surface water are not directly comparable over time due to different states of dilution as a result of varying precipitation and flow rates. Consequently, *representative sample*s cannot always be obtained because the effluent from the drainage ditch often does not have sufficient time to completely mix with the water in Paddys Run to provide a homogeneous liquid for sampling. To account for this problem, three sampling locations (W10-US – upstream of W10 and near the K-65 silos, W10-DD – along the drainage ditch, and W10-DS – just downstream of W10) were sampled.

Results of Laboratory Analyses

The radionuclide concentrations found in surface water samples collected during 1994 are summarized in Table 12 on pages A-16 and A-17. The data indicate that differences in total uranium concentrations in the Great Miami River were very small. Average uranium concentrations at W3 and W4 (1.0 pCi/L) were well below the DOE guideline for drinking water (used for comparison purposes only). Both concentrations were at 0.18% of the DCG. Figure 33 shows five-year trends of uranium concentrations in surface water from the Great Miami River and Paddys Run.

Figure 33: Average Uranium Concentrations in Surface Water, 1990 – 1994



Radium–226, radium–228, strontium–90, cesium–137, and technetium–99 results from Great Miami River samples were consistent with previous years. These data support the results in Table 11, demonstrating that the concentrations of these radionuclides in the liquid effluent discharged to the river were very low and resulted in very little, if any, increase in the concentrations already present in the river.

Environmental monitoring personnel used upstream sampling point W5 to determine concentrations of uranium and radium naturally present in Paddys Run. The data indicate that the uranium and radium concentrations found in this stream were statistically higher downstream of the site (W7 and W8) than they were upstream (W5). However, average uranium and radium concentration at all Paddys Run monitoring locations were well within DOE guidelines for drinking water standards (again used only for comparison purposes). Uranium concentrations ranged

from 0.25% of the DCG at W9 to 4.3% at W10-DS. W10-DD, which leads into Paddys Run, was 76% of the DCG.

High average values from W10-US, W10, and W10-DS were due to a few very high weekly results. The median value (the value halfway between the highest and lowest values), rather than the average, may better represent the actual conditions of the stream because the median is not as easily changed by a few extreme results. The median values of these locations were 2.43 pCi/L at W10-US, 2.84 pCi/L at W10, and 5.11 pCi/L at W10-DS. The elevated median value in the drainage ditch sample location, when compared to both W-10 and the downstream location (W10-DS), suggests that the drainage ditch contributed to the overall uranium concentrations in Paddys Run (see Table 12 on pages A-16 and A-17). The increase in both the median and average concentration from W9 to W10-US, indicates that factors other than the drainage ditch may have also influenced the uranium concentration levels in Paddys Run.

Sediment Sampling for Radionuclides

Contaminants present in surface water can settle or precipitate and thereby accumulate in sediment. Sampling and analysis of sediment provide a way to evaluate possible cumulative effects of routine discharges of treated effluents into the Great Miami River and the effects of stormwater runoff into Paddys Run.

Sampling Methodologies

In early August, technicians collected sediment samples only at those locations where sediment was most likely to accumulate. Figure 34 on the next page illustrates the following locations for sample collection:

- Eight locations at 100-meter (328-ft) intervals along the SSOD;
- Eight locations along the Great Miami River;
- Twelve locations along Paddys Run north of the SSOD;
- Twelve locations along Paddys Run south of the SSOD; and
- Four background locations along Paddys Run, north of the site.

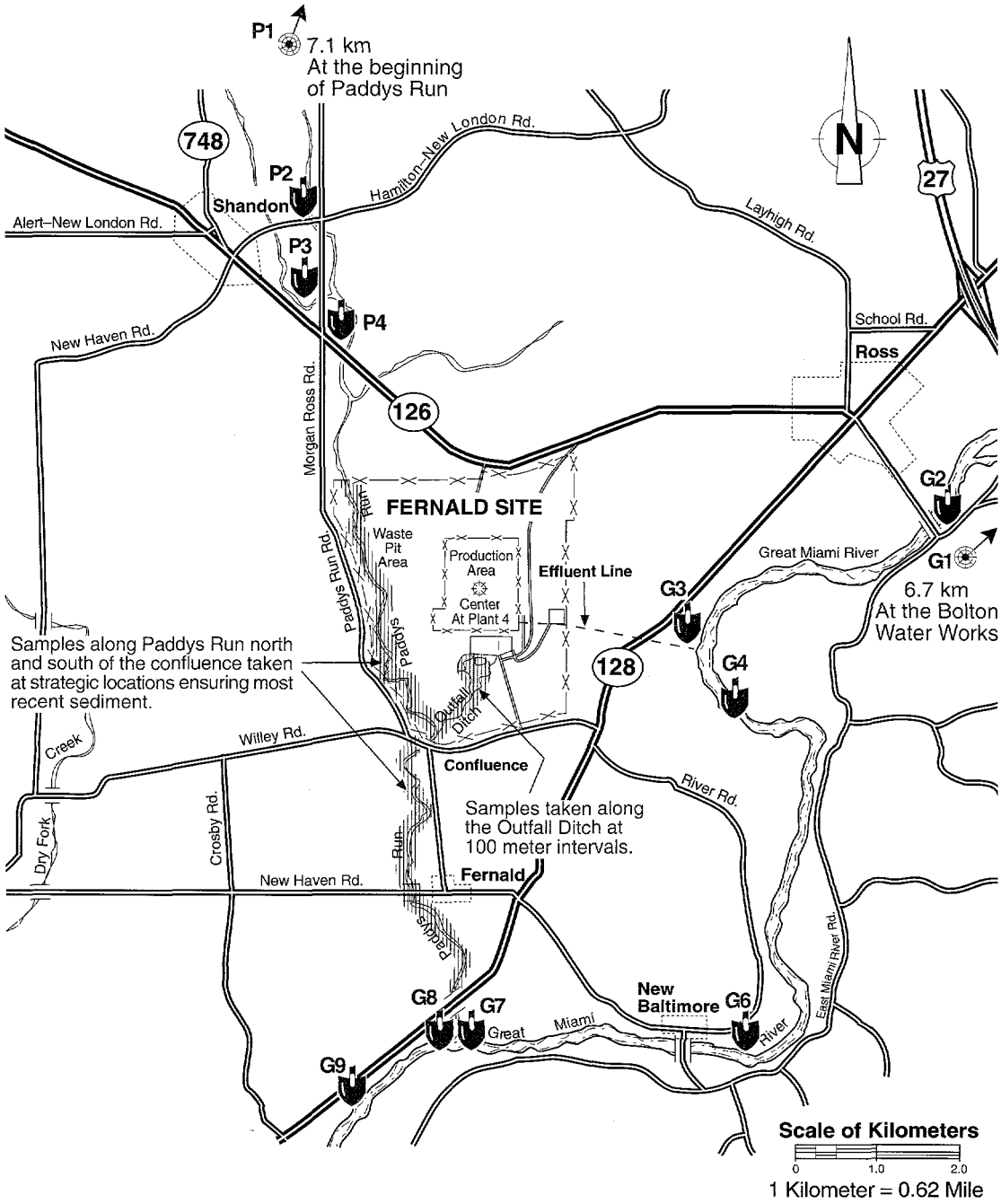
Technicians collected one sample at each location. All samples were taken from strategically chosen locations to ensure that they were representative of the most recent and greatest amount of sediment deposited.

In 1994, all sediment samples were analyzed for total uranium. Samples taken from the SSOD, Paddys Run above the SSOD, and Paddys Run background were also analyzed for radium–226 and isotopes of thorium.

Results of Laboratory Analyses

There are currently no DOE or USEPA guidelines or standards for uranium or other radionuclides in sediment. However, the data in Table 13 on page A-18 show there were no noticeable differences in the concentration of uranium and

Figure 34: Sediment Sampling Locations



LEGEND

- Single Sampling Location
- Distance from Center of Production Area to Dosimeter Locations off Map
- Plant Perimeter
- Production Area Perimeter

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other radionuclides found in sediment samples collected from the Great Miami River upstream and downstream of the site's effluent discharge line. Therefore, the site's liquid effluent discharges did not cause any discernible increase in the levels of radionuclides in Great Miami River sediment.

Radium and thorium results for 1994 were consistent with those found in recent years. Total uranium results from Paddys Run locations in 1994 were also similar to those in 1993. However, the average uranium concentration in the SSOD—4.04 pCi/g (8.85 ppm)—was still above background levels. Uranium concentrations in individual locations along this ditch have been elevated in previous years as well, probably because of runoff from onsite stormwater flowing into the SSOD over the years.

Fish Sampling for Uranium

The fish population of the Great Miami River is another component of the liquid pathway. Fernald site technicians, with the help of a research team from the University of Cincinnati, have been sampling fish in the river for over ten years. The sampling team collects fish by electrofishing. While unbiased with respect to size and species, this method is among the most efficient methods of collecting fish samples.

Sampling Methodologies

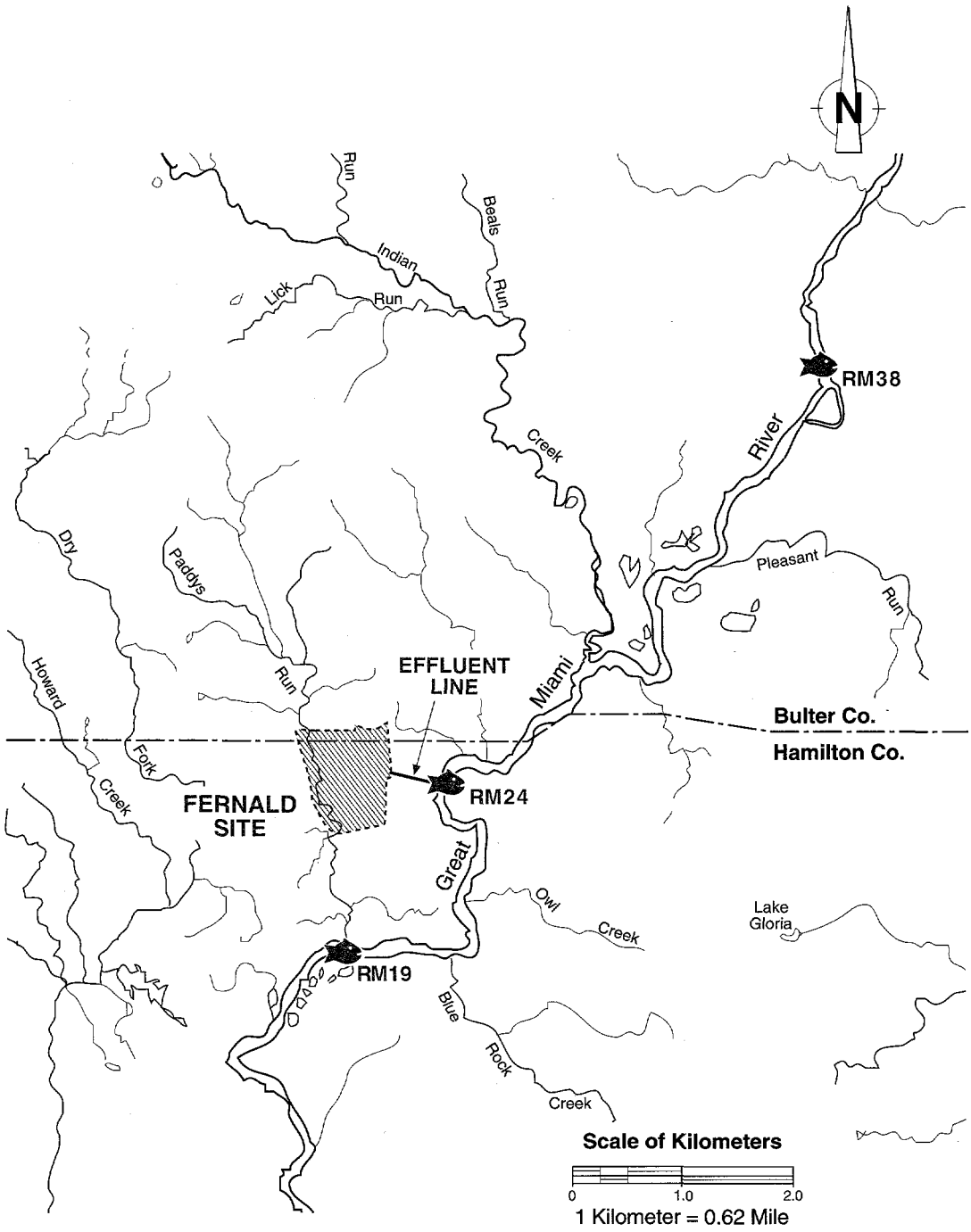
In September 1994, one month later than the 1993 collection, the team collected over 850 fish representing 27 species from three sites along the Great Miami River (see Figure 35):

- River Mile (RM) 38 – below the Route 127 bridge, north of Hamilton;
- RM 24 – at the Fernald site effluent discharge; and
- RM 19 – at the outfall point of Paddys Run.

RM 38 is used as a background location because the fish population is physically isolated from downstream activity and migration of fish by the two Hamilton dams, whereas the other locations are not. Locations RM 24 and RM 19 have the potential to be influenced by the backwater species that migrate up from the Ohio River. The variety of fish collected included gizzard shad, bluntnose minnow, carp, golden shiner, mirror carp, spotfin shiner, black buffalo, black redhorse, golden redhorse, highfin carpsucker, northern hogsucker, quillback, river carpsucker, shorthead redhorse, smallmouth buffalo, channel catfish, flathead catfish, yellow bullhead, striped bass, black crappie, bluegill, longear sunfish, smallmouth bass, white crappie, logperch, sauger, and freshwater drum.

The fish population of the Great Miami River has been stable over the course of this study. In 1994, the Fernald site was determined to have no effects on the distribution of fish. The fish species appear to be in similar health regardless of sampling location (upstream or downstream from the site).[28]

Figure 35: Fish Sampling Locations



LEGEND

Fernald Site

Sampling Location

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Results of Laboratory Analyses

Table 14 on page A-19 contains the average uranium concentrations reported in fish from all three sampling locations. Overall, the 1994 total uranium results are consistent with or lower than results from recent years at all locations. The estimated dose from eating fish caught in the Great Miami River near the Fernald site outfall is discussed in Chapter Seven.

Due to contractual performance problems at the commercial laboratory (see Chapter 9) performing radiological analyses of fish samples, data generated at the laboratory was determined to be suspect and unusable. Sixty-eight samples from three families were available for additional analyses at an alternate lab. However, samples from five families (Centrarchidae, Percidae, Percichthydae, Sciaenidae, and Ictaluradae) were not available. No data is reported for these families.

Monitoring for Nonradioactive Pollutants

The site controls the discharge of nonradioactive pollutants in liquid effluent to meet the requirements of the site's National Pollutant Discharge Elimination System (NPDES) permit. The NPDES permitting process for the site is under the jurisdiction of the State of Ohio to control the discharge of nonradioactive pollutants to Ohio waters. The permit specifies sampling locations, sampling and reporting schedules, discharge limits, and other restrictions on the site's effluents discharged to the Great Miami River and Paddys Run. Table 15 on pages A-20 through A-22 contains the NPDES monitoring data for 1994. A diagram of all monitoring locations is shown in Figure 28 (on page 93). Fernald site personnel did not collect NPDES samples from Paddys Run because the SWRB did not overflow during 1994. Out of 2,512 NPDES samples taken in 1994, only three were not in compliance (99.9% compliance).

By controlling the concentration of radionuclides in the effluent and by reducing the amount of stormwater runoff to Paddys Run, the site can lessen its impact on the various components of the liquid pathway. In particular, surface water runoff can enter the aquifer and influence groundwater quality. The next chapter looks at the groundwater component of the liquid pathway.

Liquid Pathway: Groundwater Monitoring

This chapter continues the discussion of the liquid pathway, as surface water runoff can leach through the soil and may contaminate the groundwater. The site 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. 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 site to better define the steps it should take to control present contamination and to prevent additional contamination from occurring.

Results in Brief: 1994 Liquid Pathway: Groundwater

Private Well Sampling for Uranium – Thirty-three private wells were sampled for uranium in 1994. Laboratory analyses of the samples indicated that three wells had average uranium concentrations above the proposed standard of 13.5 pCi/L (20 ppb). Each of these wells are located in an area of known uranium contamination called the South Groundwater Contamination Plume (South Plume).

Private Well Sampling for Nonradioactive Pollutants – Our scientists sampled 32 private wells in the area to screen for nonradioactive pollutants. One well showed a detection of arsenic that slightly exceeded the Primary Drinking Water Standard of 0.05 mg/L for arsenic in drinking water. Several wells indicated iron and manganese concentrations above the Secondary Drinking Water Standards. However, these results are consistent with previous years' results and are common for water in an area, such as the Fernald site, with naturally occurring iron and manganese.

Comprehensive Sampling For Uranium – Of the 157 on- and offsite DOE-owned wells that were sampled for uranium, 50 wells showed detections above the proposed USEPA guideline of 13.5 pCi/L (20 ppb). All offsite locations with detections were in the South Plume area.

Comprehensive Sampling For Nonradioactive Pollutants – The Comprehensive Groundwater Monitoring Program also sampled for 11 metals and 31 volatile organic compounds (VOCs). Nine metals and two VOCs were detected one or more times at concentrations above their Primary Drinking Water Standards. These wells were also sampled for Secondary Drinking Water Standards. Consistent with previous years, iron and manganese were detected above their drinking water standards in several wells. Also, aluminum was detected at two wells above its drinking water standard.

History of Groundwater Monitoring at the Site

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

In late 1981, the State of Ohio sampled three wells south of the site and found elevated levels of beta activity. It was found that 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 site. 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 Fernald site officially established the ***Radiological Environmental Monitoring (Private Well) Program*** with the monthly sampling of 19 privately owned wells.

Around this same time, the site focused more attention on onsite groundwater contamination. The disposal of barium chloride in Waste Pit 4 from 1980 to 1983 led to the establishment of the ***RCRA Detection and Groundwater Quality Assessment Programs***, separate from the existing environmental monitoring activities. Federal and state environmental regulations required the Fernald site to determine whether or not hazardous waste had entered the groundwater, and, if so, to identify the rate and extent of migration and the concentration of any hazardous waste in the groundwater. When the RCRA Detection Program confirmed that the groundwater had been impacted, the RCRA Groundwater Quality Assessment Program began in May 1988 and has since provided valuable information on the quality of groundwater beneath the waste pit area. (Analytical results of this sampling and assessment can be found in the *RCRA Annual Report for 1993*.[30])

Also in May 1988, additional groundwater sampling was initiated as part of the ***Remedial Investigation and Feasibility Study (RI/FS)***. This CERCLA-driven study investigates the nature and extent of potential environmental impacts from past and current operations at the site, with particular regard to the Great Miami Aquifer.

By late 1989, more than 200 wells were being sampled under the various programs. To eliminate duplication of effort, all long-term groundwater monitoring responsibilities were shifted to the Environmental Monitoring group. In 1990, this

group developed the ***Comprehensive Groundwater Monitoring Program*** to coordinate the sampling schedules of the original Environmental Monitoring Groundwater Program and the RCRA Assessment Program. In December 1992, the administration of the Comprehensive Groundwater Monitoring Program was transitioned to OU5. This change was implemented to consolidate all groundwater monitoring and data interpretation under one group.

Coal Pile Runoff Basin Monitoring

In accordance with Ohio Permit to Install (PTI) No. 05-4172, issued and effective on September 13, 1990, the site installed two monitoring wells (Wells 1675 and 1676) to detect any leaching that might occur from the Coal Pile Runoff Basin. These wells are sampled on a quarterly basis.

Today, as this Comprehensive Groundwater Monitoring Program monitors DOE-owned wells in accordance with the applicable regulations, the private well sampling program continues under Radiological Environmental Monitoring as a service to local residents and as an additional source of offsite groundwater information. Results are presented in this chapter as either private well results or as comprehensive sampling results.

Monitoring for Radioactive Pollutants

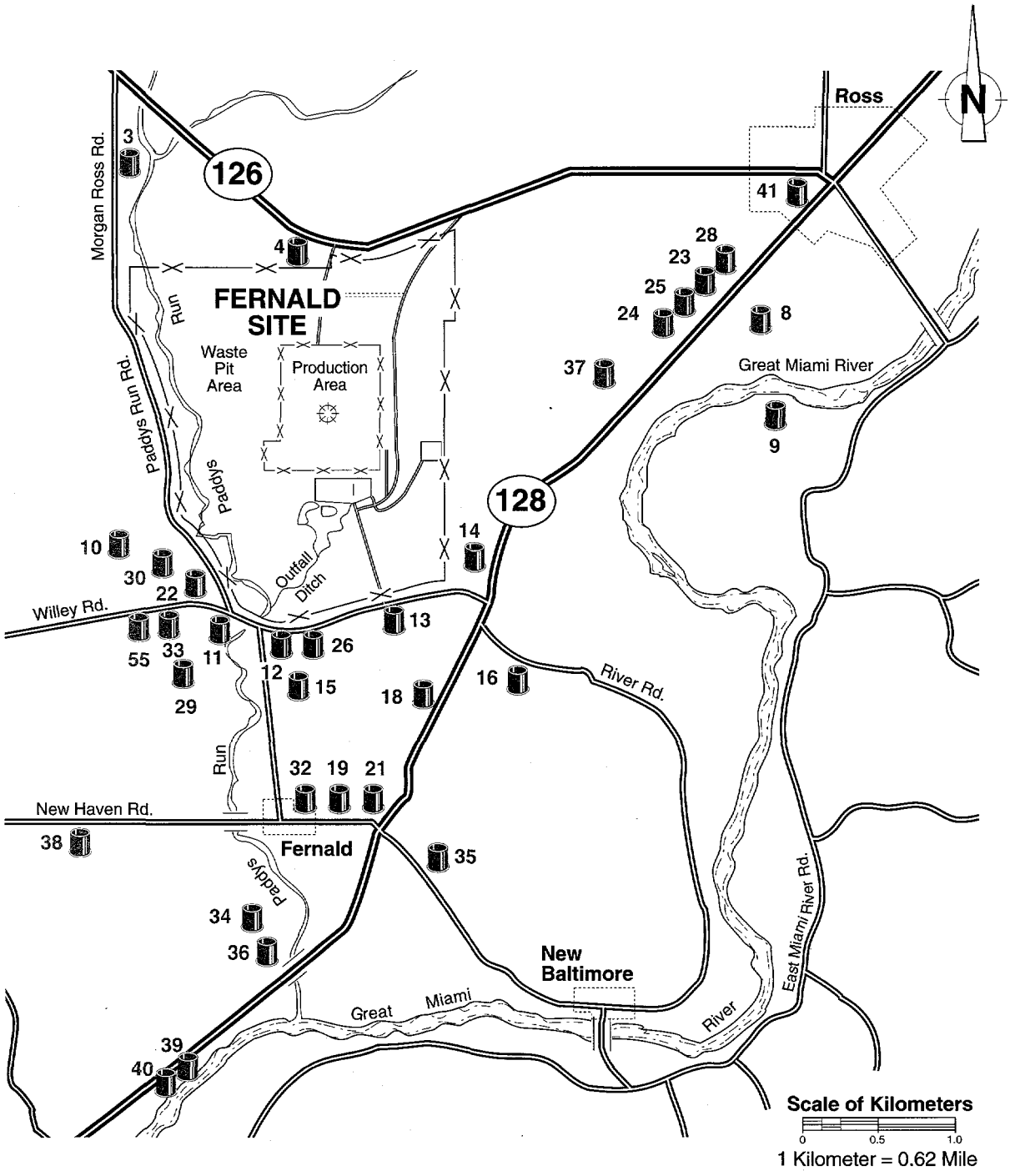
As part of the total liquid pathway, the movement of radioactive pollutants into and through the groundwater is of significant concern. This section discusses the results of private well sampling and of the Fernald site's comprehensive sampling program.

Private Well Sampling for Uranium

The Radiological Environmental Monitoring Program encompasses all sampling of privately owned wells. The program itself is divided into non-routine sampling and routine sampling.

At a property owner's request, any drinking water well near the site will be sampled for uranium to gain additional information about local groundwater quality, and the one-time sample results are reported to the well owner. If one of these "special request" samples shows a questionable or significant total uranium concentration, or if the well is believed to be representative of an area based on its location, the property owner has the option to participate in the routine sampling program. This program has grown from 19 wells in 1984 to 33 wells in 1994. Well locations are shown in Figure 36 on the next page. (As many as 37 wells were sampled under this program in 1991.) The data from the routine sampling program are presented in Table 16A on page A-23. Figure 37 on page 111 shows average uranium concentrations found in private wells from 1990 to 1994.

Figure 36: Private Well Monitoring Locations



LEGEND

Sampling Location

Plant Perimeter

Production Area Perimeter

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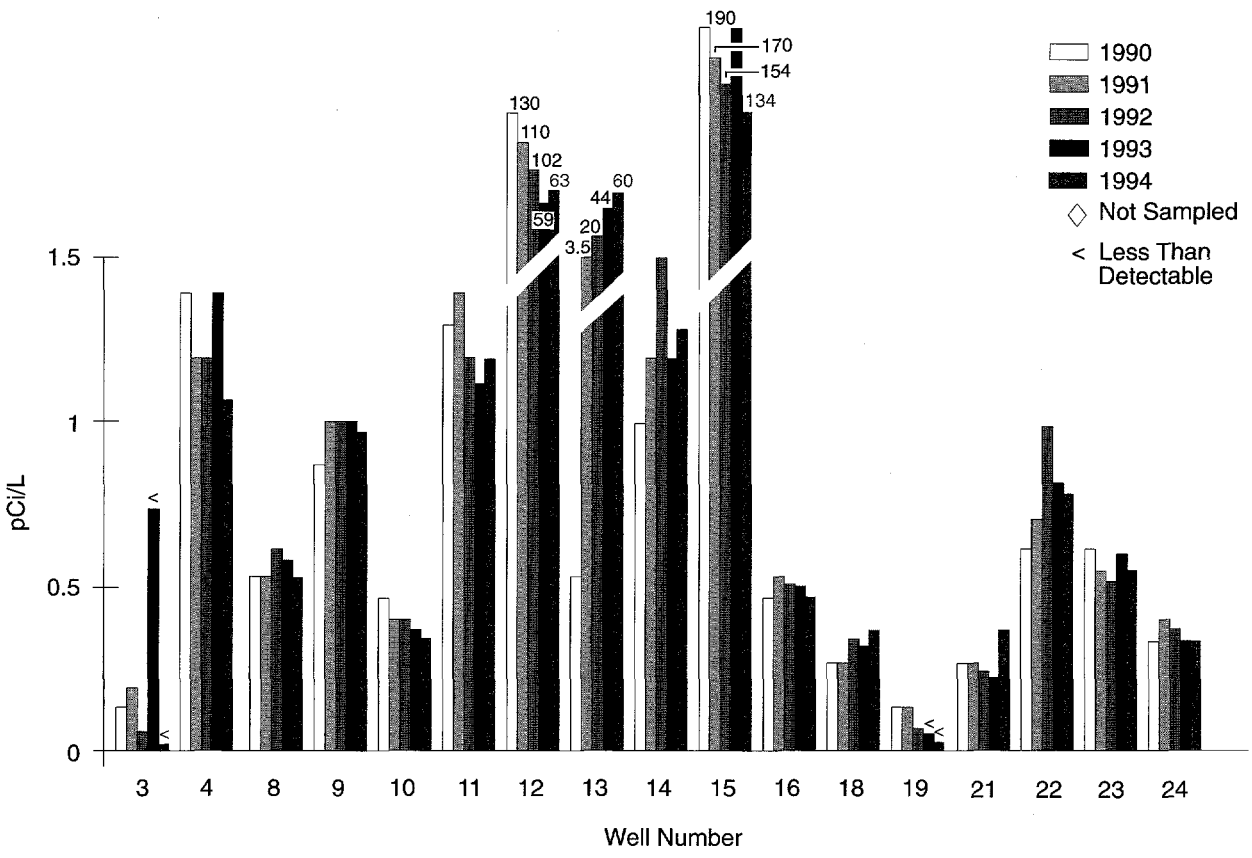
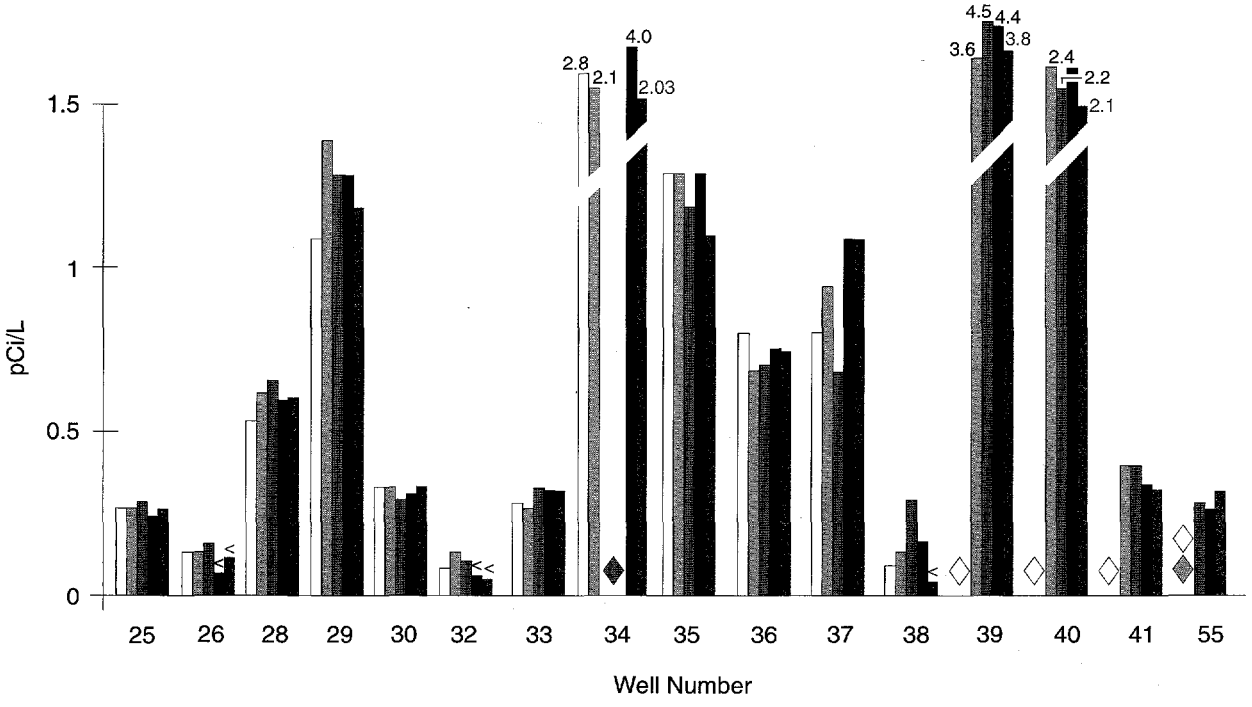
Figure 37: Average Uranium Concentrations in Private Wells, 1990 – 1994





Proposed USEPA 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.

USEPA 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 USEPA standard for a particular substance, guidelines are set by other agencies such as DOE and the Nuclear Regulatory Commission; 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 or 30 parts per billion (ppb). Past site reports have used this reference for comparison. However, in 1991, USEPA proposed a standard for uranium in drinking water of 13.5 pCi/L or 20 ppb. As of December 1994, this standard had not yet been approved. This 1994 report will continue to use this proposed USEPA standard for comparison with well monitoring results, as it is the more stringent of the two.

During 1994, the 33 offsite wells belonging to individuals and industries in the vicinity of the site were sampled monthly or quarterly and analyzed for total uranium. Only wells 12, 13, and 15 exceeded this proposed standard in 1994. The national background level for total uranium in groundwater ranges from 0.07 to 6.8 pCi/L (0.1 to 10 ppb) and local background level ranges from 0.07 to 2.0 pCi/L (0.1 to 3.0 ppb), which scientists have determined using a 95% confidence interval.[31, 32, 41]

The uranium concentration at Well 13 has been slowly increasing since 1989. In June 1992, an ion exchange system was installed at this location. This system is designed to remove the uranium from the well water by filtering the water. Results from the water filtered through the ion exchange system indicate that the uranium is removed and the uranium concentration in the treated water is within the background range for this area. Well 13, located just south of the site in an area of known groundwater contamination, continues to be a point of monitoring. The uranium-contaminated water in this area, known as the South Plume, is being pumped from the aquifer as part of the South Groundwater Contamination Plume Removal Action. The plume itself is discussed later in this chapter.

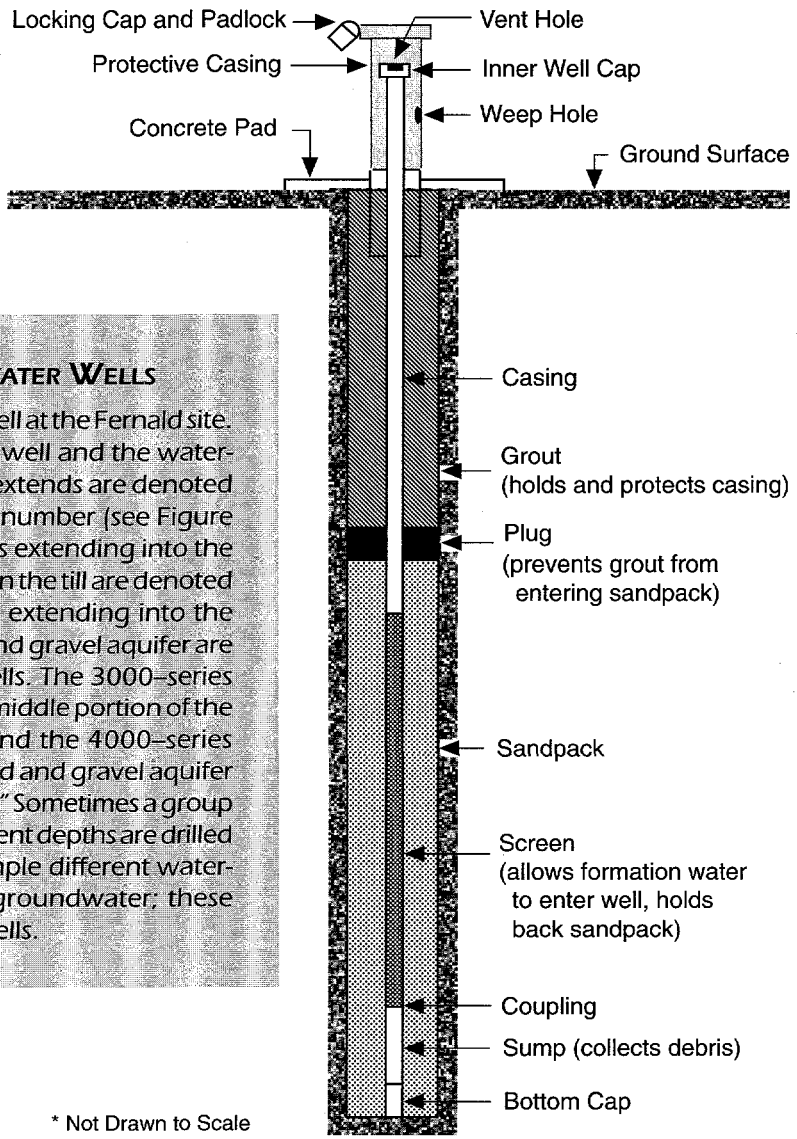
Comprehensive Sampling for Uranium

The Comprehensive Groundwater Monitoring Program encompasses all sampling of DOE-owned monitoring wells. Groundwater monitoring personnel do not monitor all wells each quarter, nor do they monitor all wells for the same constituents. As discussed earlier, site personnel sample as necessary to provide each of the groundwater monitoring subprograms with a complete database for reporting purposes. However, when taken together, as done here, the comprehensive sampling results present a rather detailed and complete description of groundwater under and around the site. The 1995 Final Remedial Investigation Report for Operable Unit 5 presents a more detailed discussion of uranium distribution in and around the site[42].

The movement of uranium in the groundwater has been a key factor in determining the sources of contamination in the area. In 1994, the Groundwater Monitoring Program received results from 28,177 analyses for uranium from samples at 157 on- and offsite locations. Of these uranium analyses for 1994, the highest concentration was 1,000 ppb, well above the proposed USEPA standard of 20 ppb. This sample was drawn from Well 11075 in the glacial overburden directly beneath the Production Area. Uranium concentrations in other samples at onsite and offsite locations were also above the USEPA drinking water guideline. (All offsite locations were in the South Plume area, currently being addressed by a RI/FS removal action – see Chapter Three.) These 50 above-guideline sample concentrations and their relative locations are listed in Table 17 (on page A-26).

Figure 38: Well Diagram*

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

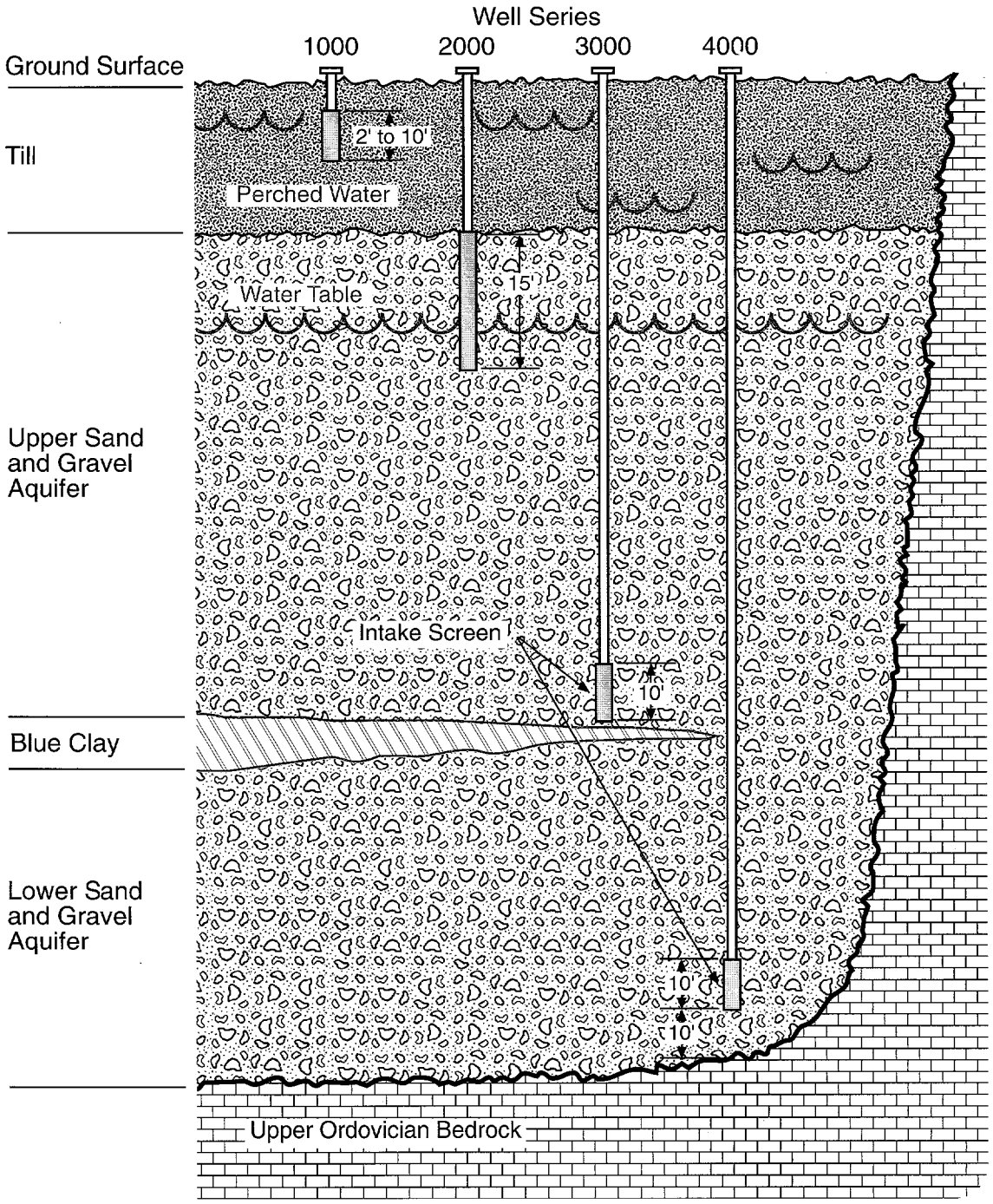


Fernald Site Groundwater Wells

Figure 38 depicts a typical well at the Fernald site. The depth of a Fernald site well and the water-bearing zone into which it extends are denoted by the first digit of the well number (see Figure 39, on the next page). Wells extending into the perched groundwater within the till are denoted as 1000–series wells. Wells extending into the upper portion of the sand and gravel aquifer are denoted as 2000–series wells. The 3000–series wells are placed within the middle portion of the sand and gravel aquifer, and the 4000–series wells are installed in the sand and gravel aquifer beneath a layer of "blue clay." Sometimes a group of two or more wells of different depths are drilled at the same location to sample different water-bearing zones within the groundwater; these groups are called cluster wells.

* Not Drawn to Scale

Figure 39: Monitoring Well Depths and Screen Locations



Metric Conversion
1 Foot = 0.3048 Meters

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Comprehensive Groundwater Monitoring for Other Radionuclides

The Comprehensive Groundwater Monitoring Program is used to sample for radium, strontium, technetium, and thorium. Gross alpha activity, gross beta activity, cesium, plutonium, ruthenium, and neptunium in the groundwater are also monitored as indicators of radionuclide contamination. Of these radionuclides, gross alpha, radium–226 and radium–228 have USEPA-proposed drinking water standards. Groundwater monitoring personnel do not monitor all wells each quarter, nor do they monitor all wells for the same constituents. As discussed earlier, site personnel sample as necessary to provide each of the groundwater monitoring subprograms with a complete database for reporting purposes. However, when taken together, as done here, the comprehensive sampling results present a rather detailed and complete description of groundwater under and around the site.

In the 1993 SER, data was not available by the due date for the document. Since then the 1993 and 1994 gross alpha, radium–226 and radium–228 data have become available (see Tables 16B and 16C on pages A-24 and A-25, respectively). Gross alpha results for 1993 had 28 detections above the proposed USEPA Standard of 15 pCi/L (22 ppb) at 16 locations. The highest detection was 1400 pCi/L (2072 ppb) in well 2945 which is located southeast of the Storm Water Retention Basin. This compares to 1994 results for gross alpha of 15 detections at 11 locations (see Table 16C on page A-25). The highest concentration in 1994 was 250 pCi/L (370 ppb) in well 11075 which is east of the heavy equipment building.

Radium–226 and radium–228 results for 1993 had one detection each above the proposed USEPA Standard of 20 pCi/L (30 ppb) for each isotope. Both radium–226 and -228 were detected at well 1892 at 36 pCi/L (53 ppb) and 24 pCi/L (36 ppb) respectively. This well is located in the K-65 Silo Area. The data for well 1892 compares to 1994 results at the same location for radium–226 and –228 of 72 pCi/L (107 ppb) and 23 pCi/L (34 ppb), respectively. The radium–226 detection was in well 11077 in the Waste Pit Area, while the radium–228 was in well 4424 in the East Field Area.

Public Water Supply Program

DOE has supplied bottled water to homeowners whose private wells have been impacted by the South Plume. This action is, 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 has committed to providing its fair share of the cost for installation of the water mains in the South Plume area. This funding is in conjunction with the Hamilton County Department of Public Works, the agency responsible for coordinating all water supply within Hamilton County.

The portion of this proposed action that is of concern to DOE involves the installation of approximately 23 km (14 miles) of pipeline within Hamilton and Butler counties. This installation will occur 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. Installation will also occur along Willey, New Haven, and Paddys Run roads.

Construction for the Public Water Supply Program has progressed since it was proposed in 1992. The overall schedule is contingent on the construction schedule of Hamilton County, but work should be completed by the end of calendar year 1995.

South Groundwater Contamination Plume

The evaluation of groundwater monitoring results over the past several years has led to the identification of the South Groundwater Contamination Plume, an area immediately south of the site with known elevated levels of uranium concentrations (see Figure 40). Contamination from the site flows with the groundwater, generally to the east and south, toward the Great Miami River. Therefore, wells to the north or west of the site should not show increased concentrations of site contaminants, whereas wells to the south and east may show increased concentrations.

Since August 27, 1993, a five-well recovery system has been in operation to capture the width of the South Groundwater Contamination Plume and to prevent the further southern migration of uranium identified to the north of the recovery well field. During the course of 1994 several system shutdowns have occurred due to mechanical failures. Despite these temporary disruptions the recovery well field has operated effectively. As of December 31, 1994, the recovery well field has pumped over 1010 million gallons of uranium-contaminated groundwater resulting in the removal of over 55 kg (120 pounds) of uranium from the aquifer.

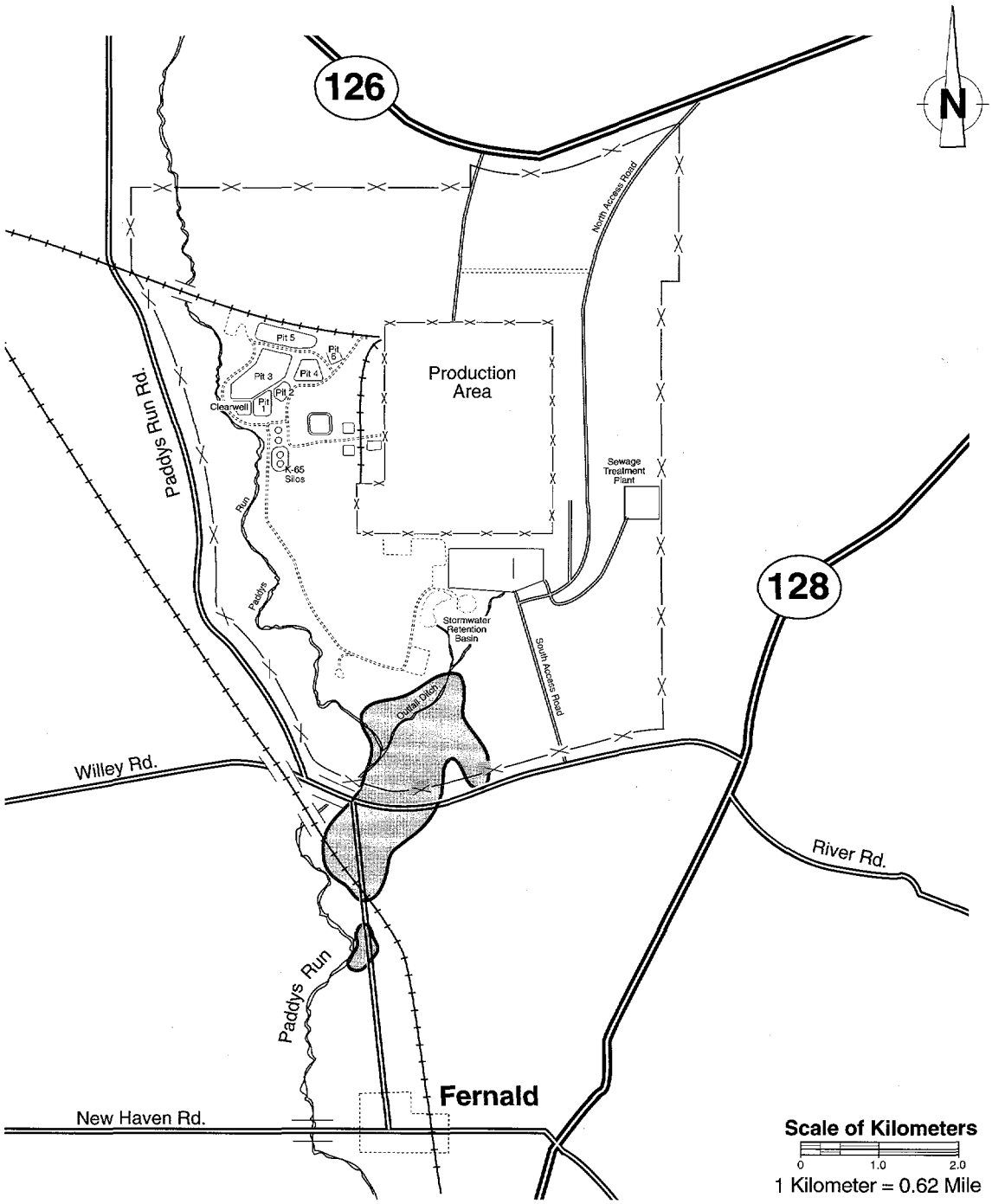
Monitoring for Nonradioactive Pollutants

Protection of the Great Miami Aquifer also includes monitoring for a number of nonradioactive pollutants and general water quality indicators. Site technicians generally sample for those constituents listed in the National Primary and Secondary Drinking Water Standards. Primary standards apply to those substances that pose definite health threats if present beyond the regulated concentrations; secondary standards control contaminants that primarily affect the aesthetic qualities of drinking water and are not federally enforceable.[33] In addition to these USEPA-listed constituents, the RCRA wells within the Comprehensive Groundwater Monitoring Program are sampled for many RCRA-listed constituents.

Private Well Sampling for Metals

In 1994, all but one of the 33 wells in the private well sampling program were sampled for the 16 metals listed in Table 18 on pages A-27 through A-29. One well had a detection of arsenic slightly higher than the primary standard of 0.05 mg/L. Additionally, several wells had concentrations of iron and manganese higher than the respective secondary drinking water guidelines. However, high concentrations of those natural elements are typical for groundwater in this area.[5, 12, 33] Of the 16 metals, no DOE or USEPA standards have been established for calcium, magnesium, nickel, potassium, or sodium, but they continue to be monitored for comparison purposes.

Figure 40: South Groundwater Contamination Plume



LEGEND

Area of Total Uranium Exceeding 13.5 pCi/L (20 ppb)

Plant Perimeter

Production Area Perimeter

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Comprehensive Sampling for Hazardous Substances

Various groundwater sampling programs monitor for nonradioactive constituents in the groundwater to identify areas that might have harmful chemical concentrations as a result of past and present site activities. Site wells are sampled and analyzed for metals, volatile organic compounds (VOCs), and water quality indicators listed in the National Primary and Secondary Drinking Water Standards depending on project specific and/or regulatory requirements. This section focuses on the incidences in which these constituents occur above the applicable standards. Those wells with detections above the primary standards and the proposed USEPA guideline for uranium are mapped in figures 41A through 44.

Detections above Primary Standards

The site analyzes for metals and VOCs which have applicable Primary Drinking Water Standards. Of those metals and VOCs, the constituents that had detections above their respective Primary Drinking Water Standard Maximum Contaminant Levels (MCL) are listed below and in Table 19 on pages A-30 and A-31.

Metals

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Lead
- Nickel
- Thallium

Volatile Organic Compounds

- Pentachlorophenol
- Toluene

Barium, beryllium and pentachlorophenol had only one detection each above their respective standards. The remaining eight constituents had more than one detection above their standards in 1994. These detections and the areas in which they were found are discussed below.

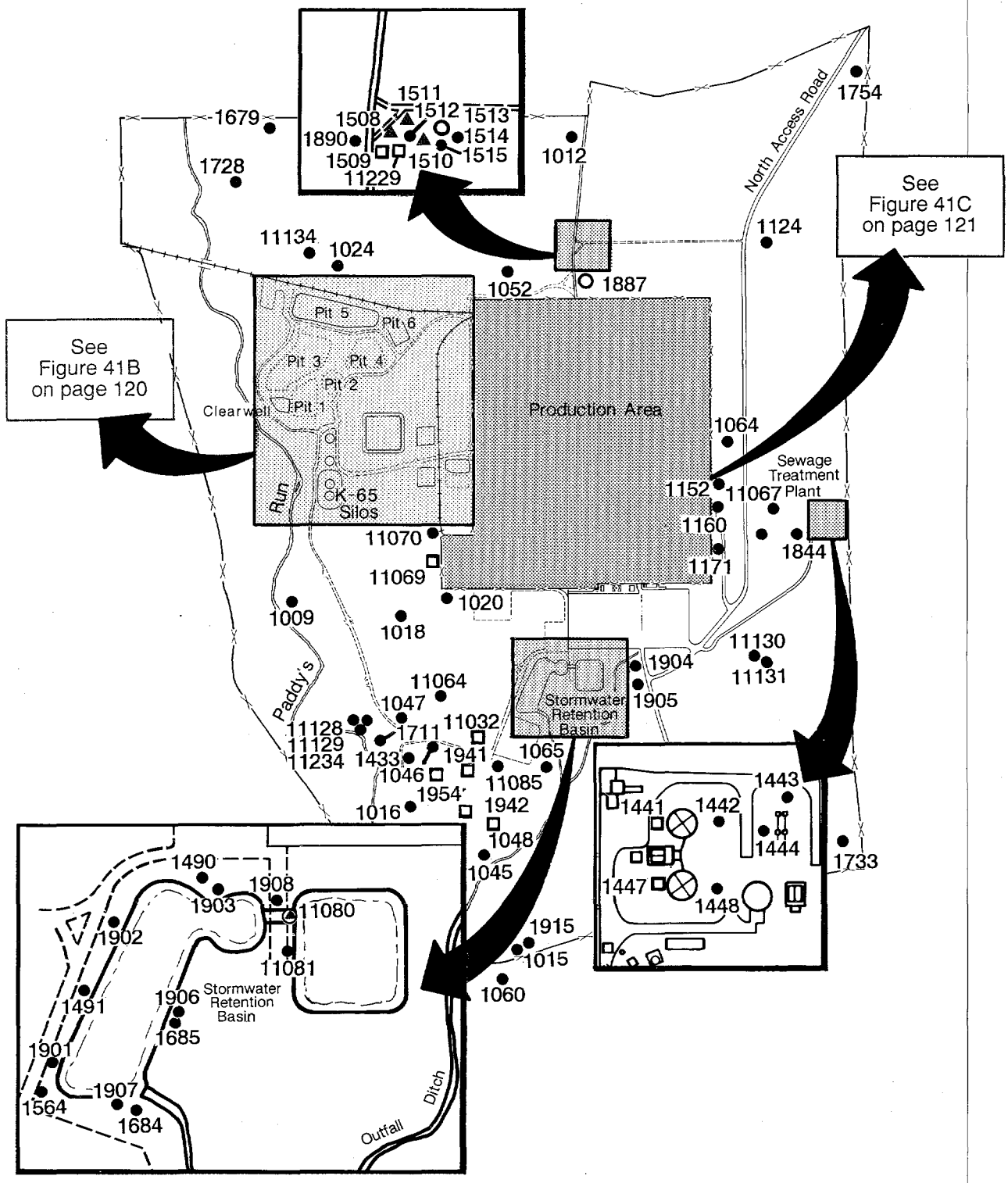
Antimony was detected above the 0.006 mg/L (ppm) MCL in nine wells during 1994. Three detections were in the east field, two in the waste pit area, two in the silo area, one in the South Plume area offsite and one detection was southeast of the production area. These detections ranged from 0.0266 to 0.0392 mg/L (ppm).

Arsenic was detected above the 0.05 mg/L (ppm) MCL in four wells. These four wells are located in the South Plume area offsite. There was a total of seven detections at these wells ranging from 0.0548 to 0.0855 mg/L (ppm).

Cadmium had five detections at four wells above the MCL of 0.005 mg/L (ppm). Four detections were in the east field and one in the fire training facility area. These detections ranged from 0.0054 to 0.0545 mg/L (ppm).

text continues on page 125

Figure 41A: 1000–Series Wells



LEGEND

● 1000	Series Wells	□ 0000	Proposed USEPA Standard Total U Detection 1993
O 0000	Primary NDWS Detection	▲ 0000	Proposed USEPA Standard Total U Detection 1994

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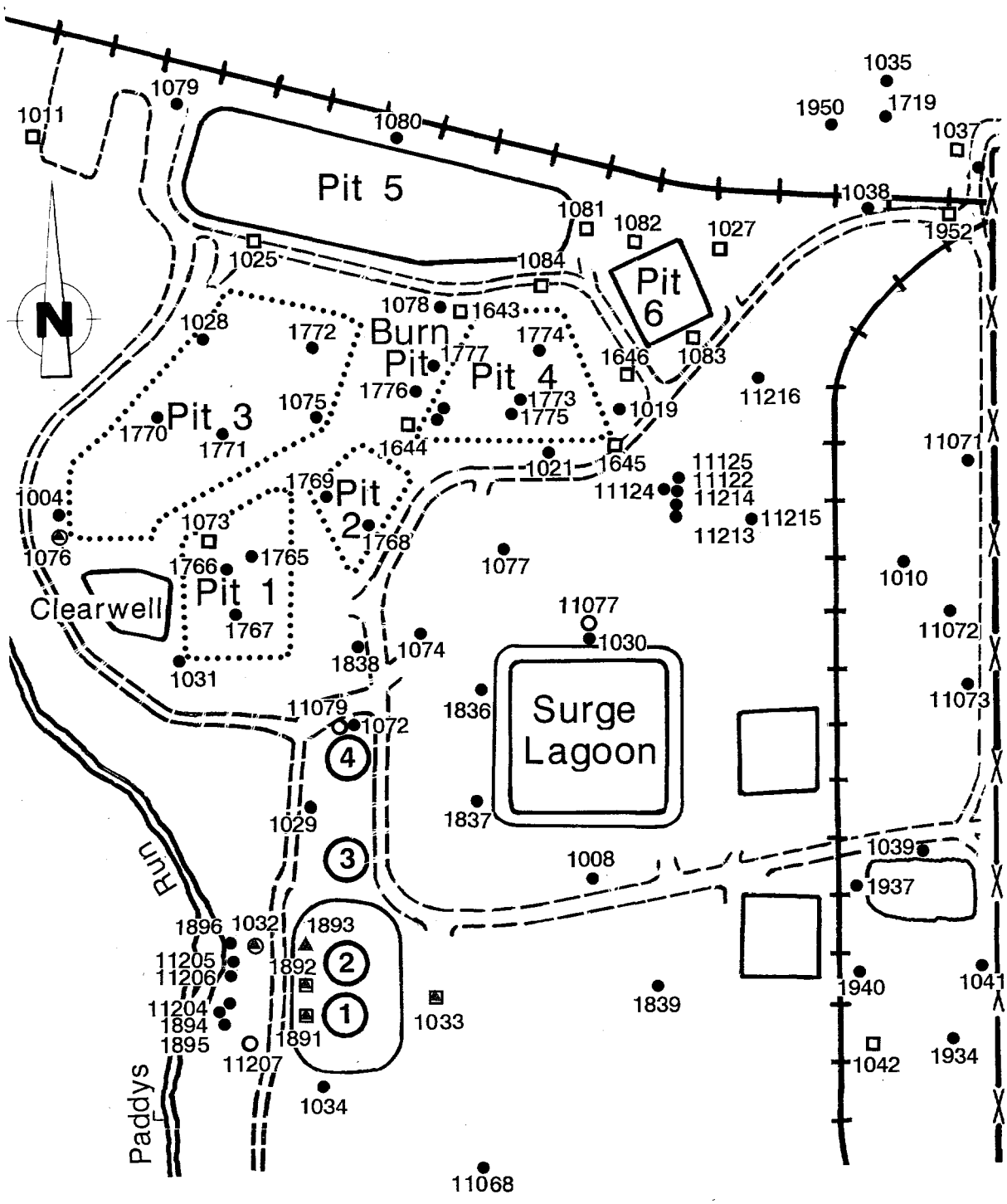
Figure 41B: 1000–Series Wells



LEGEND

- ● 1000 Series Wells
- ○ 0000 Primary NDWS Detection
- ••••• Covered Pits
- ═══ Roadway
- □ 0000 Proposed USEPA Standard Total U Detection 1993
- ▲ 0000 Proposed USEPA Standard Total U Detection 1994

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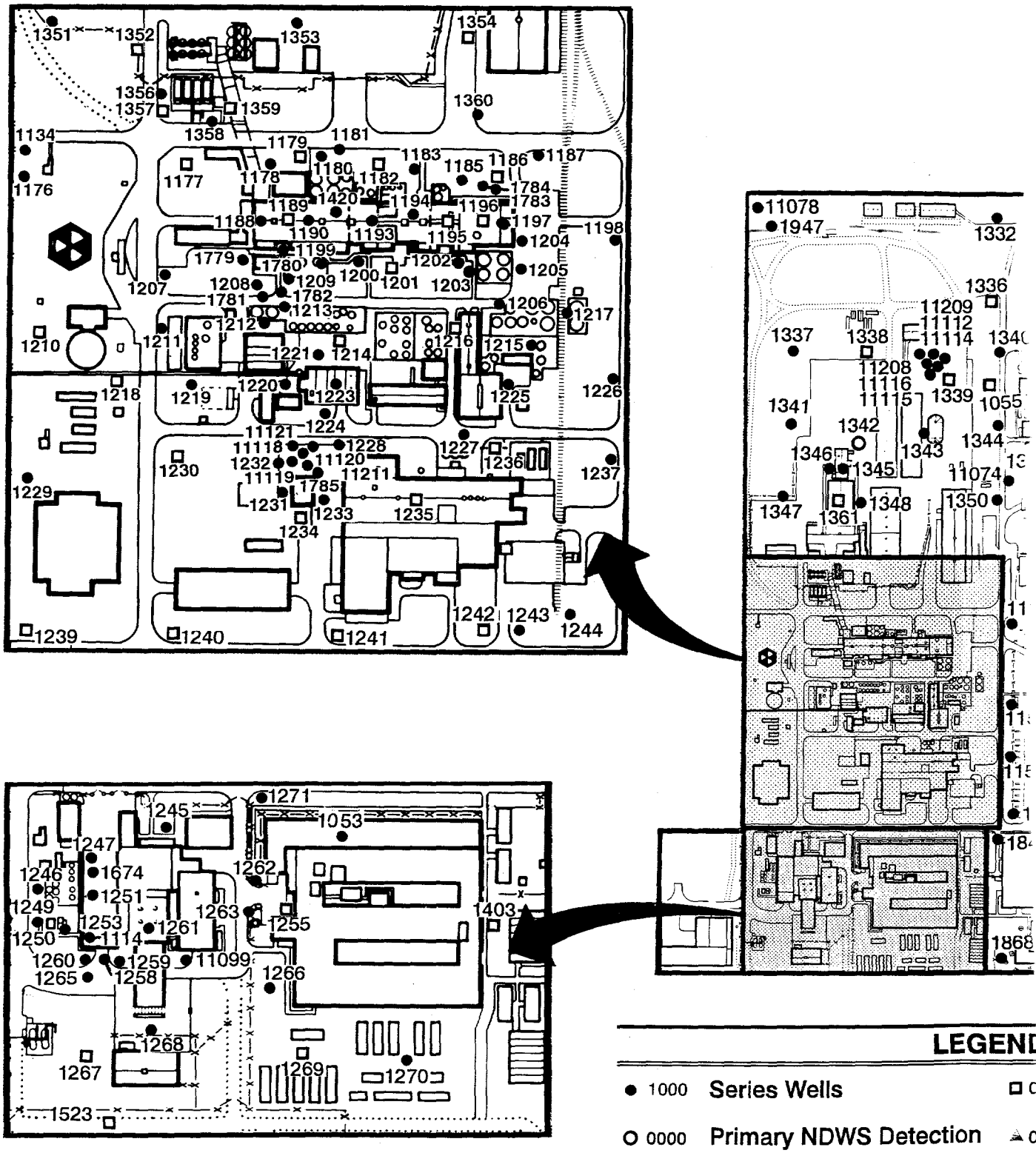
Figure 41C: 1000-Series Wells



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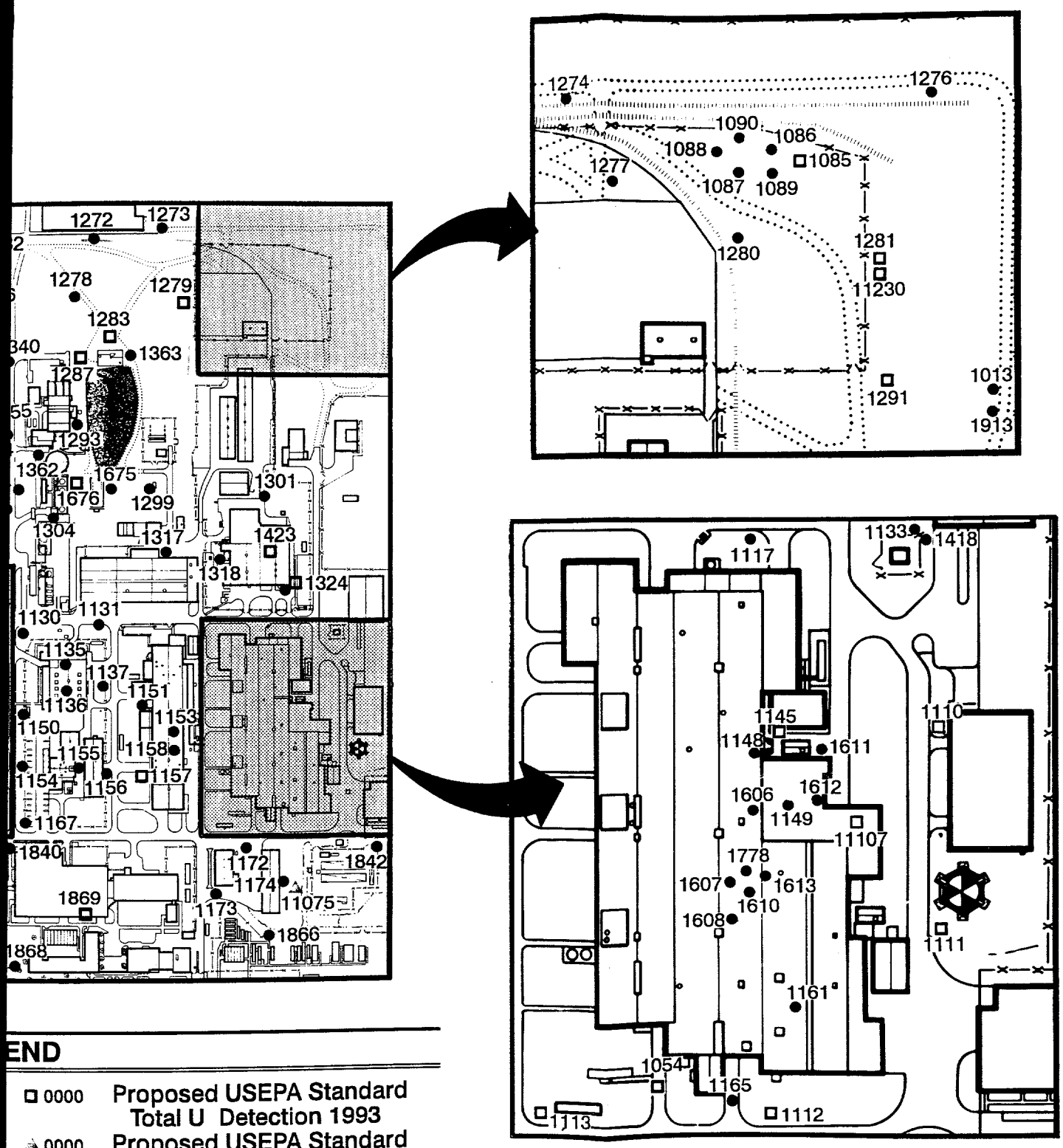
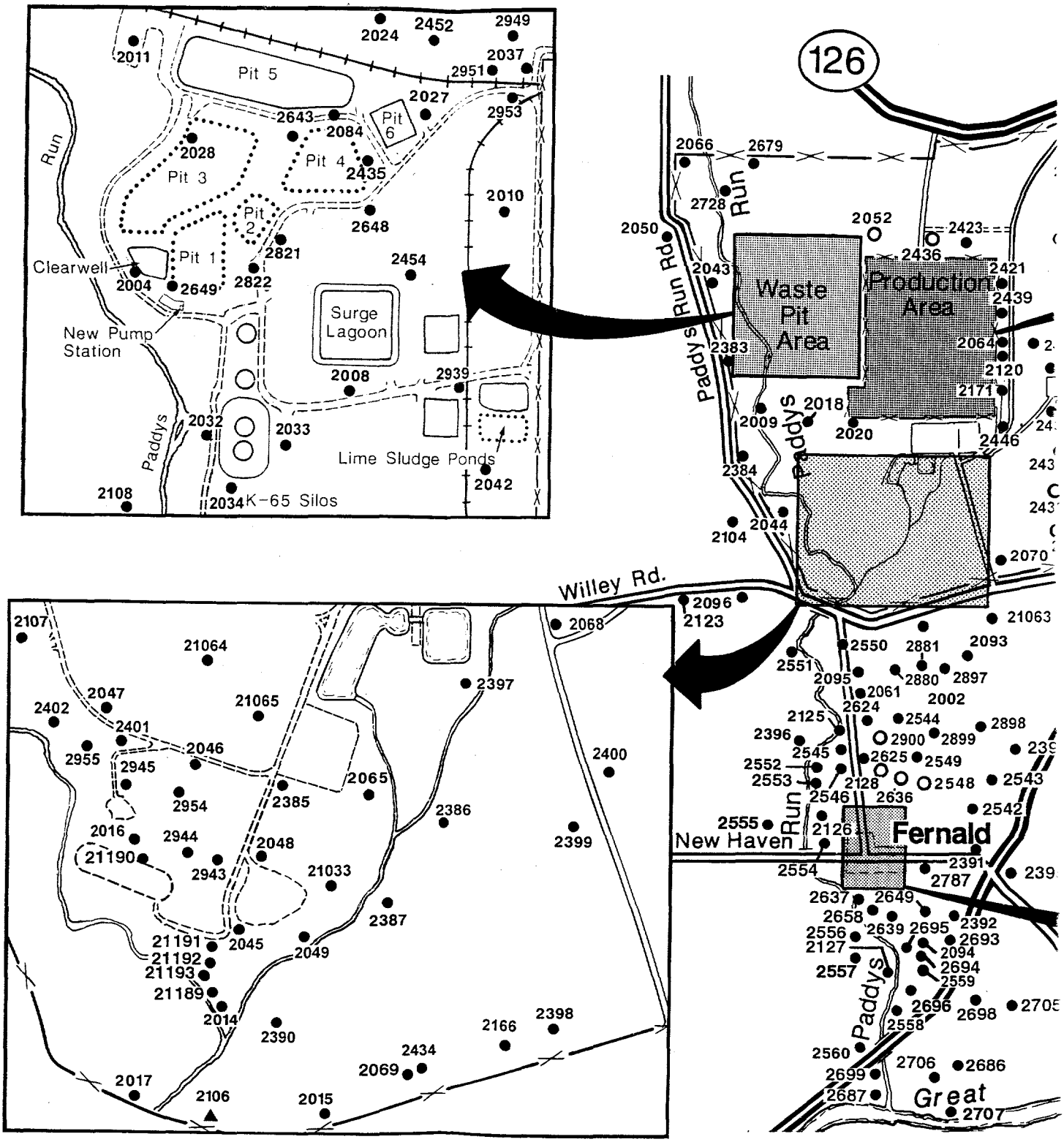


END

- □ 0000 Proposed USEPA Standard Total U Detection 1993
- ◭ 0000 Proposed USEPA Standard Total U Detection 1994

Figure 42: 2000-Series Wells



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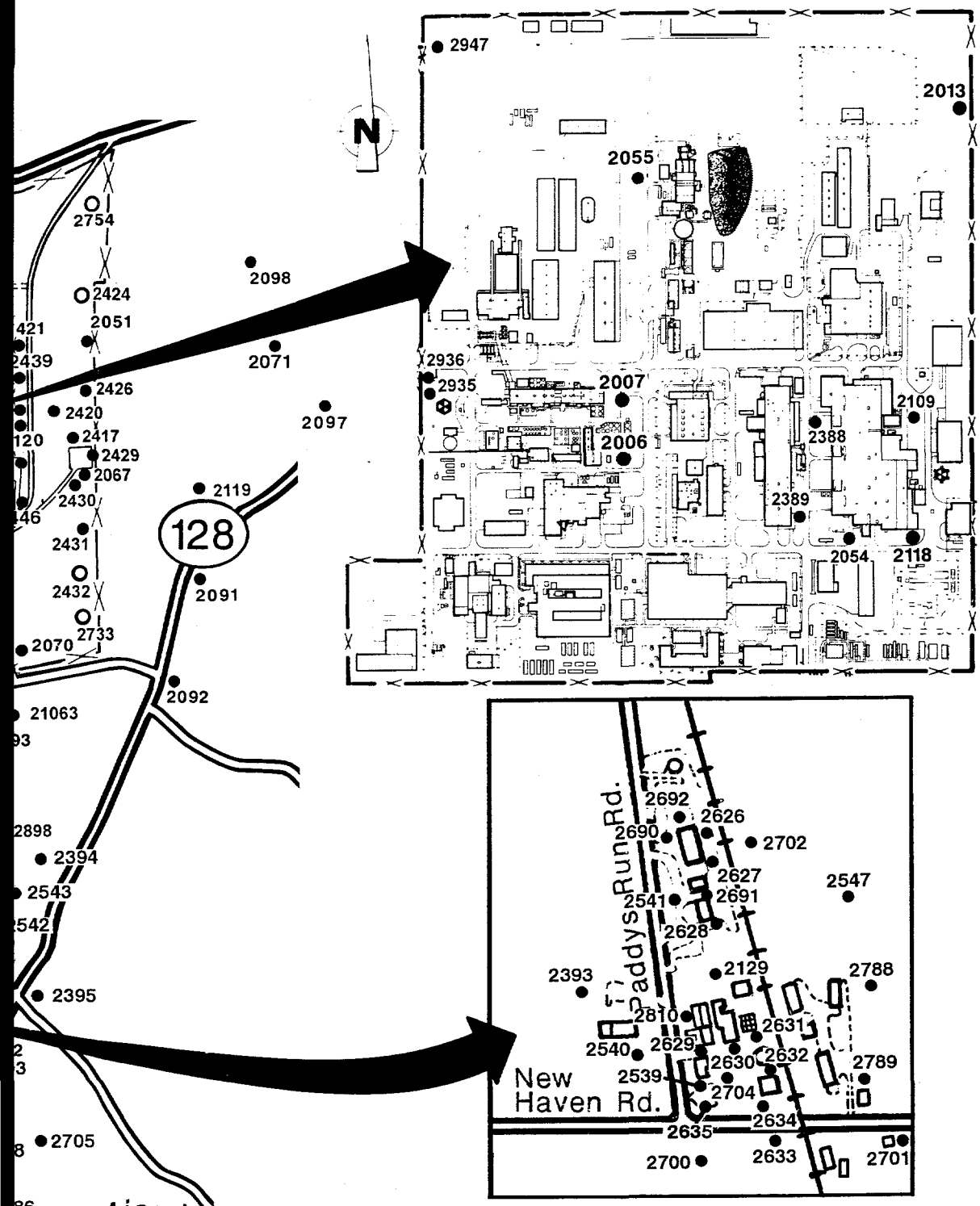


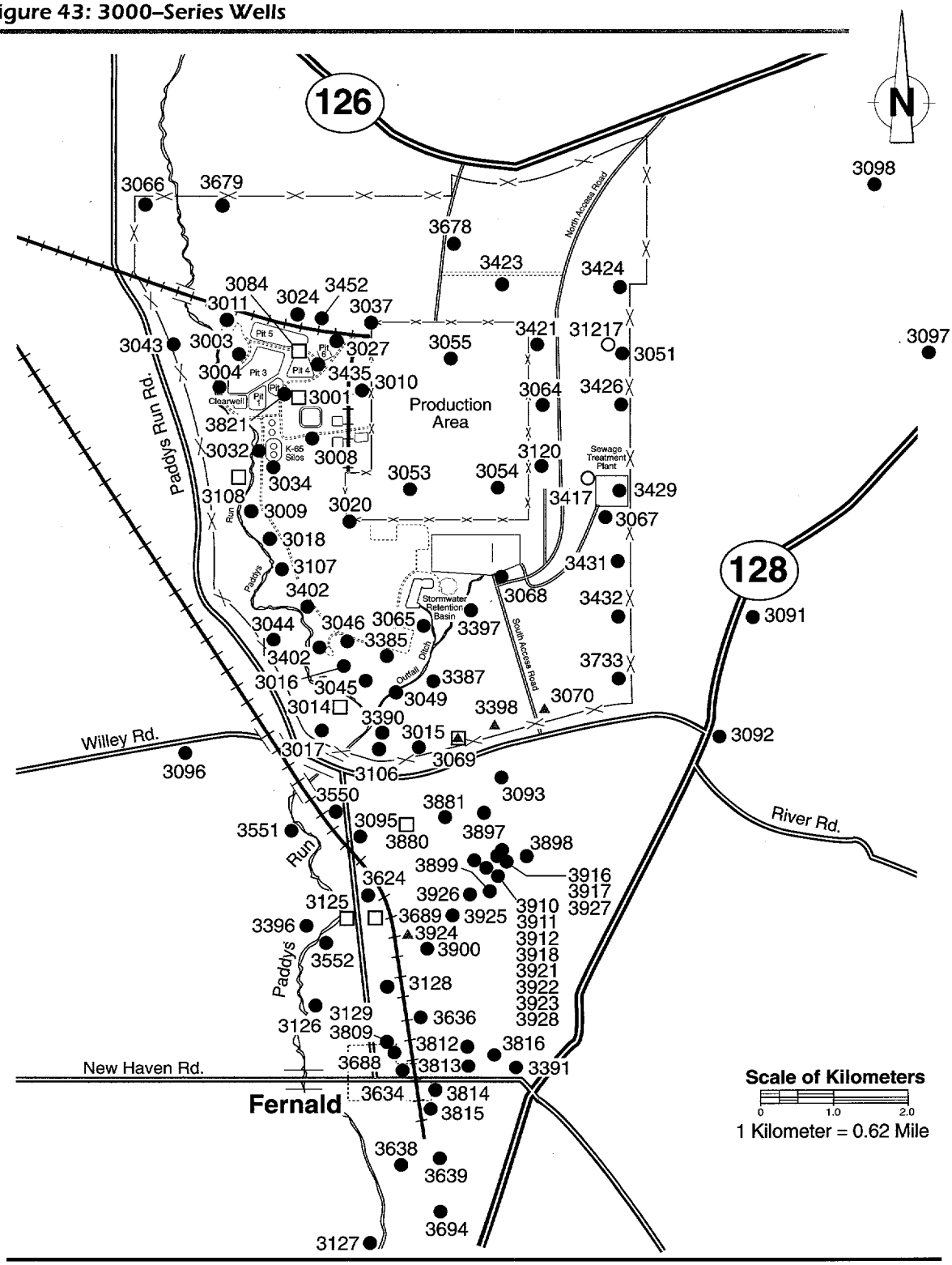
LEGEND

● 2000 Series Wells

O 0000 Primary NDWS Detection

▲ 0000 Proposed USEPA Standard Total U Detection

Figure 43: 3000–Series Wells

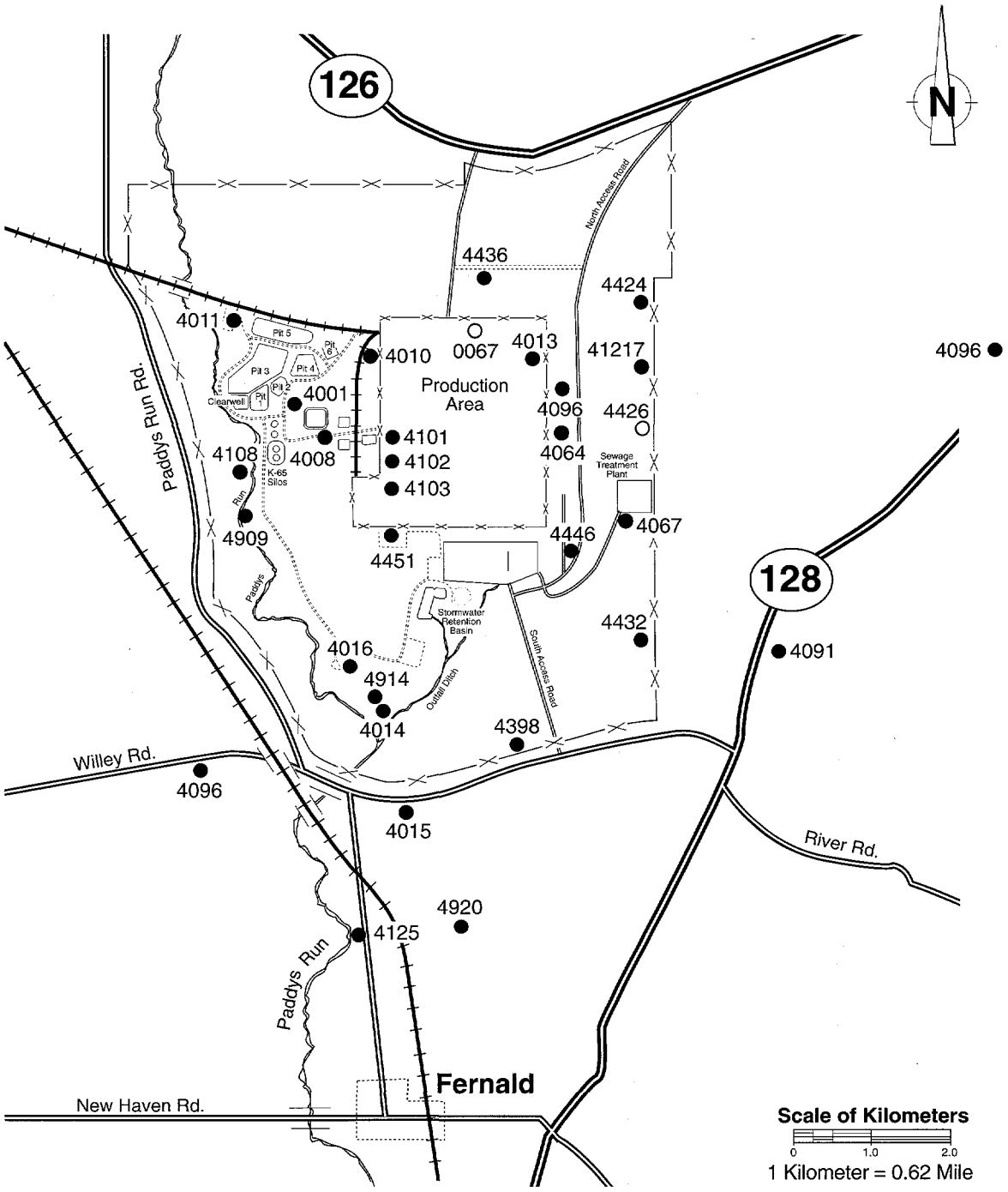


LEGEND

- ● 3000 Series Well
- ○ 0000 Primary NDWS Detection
- ▲ 0000 Proposed USEPA Standard Total U Detection 1994
- □ 0000 Proposed USEPA Standard Total U Detection 1993

3309

Figure 44: 4000–Series Wells



LEGEND

- ● 4000 Series Well
- ○ 0000 Primary NDWS Detection
- ▲ 0000 Proposed USEPA Standard Total U Detection 1994
- □ 0000 Proposed USEPA Standard Total U Detection 1993

3309

Chromium was detected at five well locations above the MCL of 0.1 mg/L (ppm). These detections fell in the range of 0.101 to 3.510 mg/L (ppm). There were four detections in the east field and three in the South Plume area offsite. The KC-2 Warehouse, storm water retention basin, and silo area each had one detection.

Eleven wells showed detections of lead above the U.S. EPA action level of 0.015 mg/L (ppm). The detections ranged from 0.0152 to 0.0911 mg/L (ppm). Three detections were located in the South Plume area offsite, east field, and fire training facility. There was also one detection southeast of the fire training facility along with one detection at the storm water retention basin, KC-2 Warehouse, waste pit, and silo area.

Nickel has a MCL of 0.1 mg/L (ppm). It was detected at six wells, and the detections ranged from 0.117 to 16.8 mg/L (ppm). Five of the detections were from two east field wells. The storm water retention basin, South Plume, fire training facility and waste pit area each had one well with a detection.

Thallium has a MCL of 0.002 mg/L (ppm). It was detected at two wells, and the detections were 0.005 and 0.0054 mg/L (ppm). One well is located in the fire training facility and the other is north of the production area.

Toluene had two detections above the 1.0 mg/L (ppm) MCL at one well located in the Plant 1 pad area. The two detections were 1.2 and 7.4 mg/L (ppm).

Detections above Secondary Standards

Some constituents were detected above their secondary standards in 1994. However, it should be noted that many of these constituents are naturally occurring, and their presence does not pose a threat to human health or to the environment except at considerably higher concentrations.

Iron and manganese are two particularly noteworthy examples of such naturally occurring elements. Both are commonly found at high levels in southwest Ohio. Iron was detected above its secondary standard at 65 wells, and manganese was detected above its standard at 66 wells. The total number of wells with detections of iron and manganese drastically decreased from the 1993 detections. This is due to the completion of the sampling conducted in support of the Remedial Investigation (RI) activities. The 1994 sampling was less frequent since the majority of RI sampling has been completed. Current sampling activities are being performed under project-specific programs directed by CERCLA and RCRA requirements.

Aluminum exceeded the secondary MCL range of 0.05 to 0.2 mg/L at several well locations. The detections ranged from 0.0583 to 77.7 mg/L. Fourteen detections were in the east field, 12 in the South Plume area offsite, 11 in the fire training facility, and seven in the silo area. There were three detections east of the production and waste pit areas respectively. Locations northeast of the production area, near the storm water retention basin, at the KC-2 Warehouse, in the production area, and in the south field each had one detection.

RCRA Groundwater Monitoring at the Fernald Site

The disposal of barium chloride in Waste Pit 4 from 1980 to 1983 necessitated groundwater monitoring under RCRA at the Fernald site. In response, a Detection Monitoring Program was initiated at Waste Pit 4 in August 1985. The program included monitoring of 41 wells upgradient and downgradient of Waste Pit 4 for general water quality, drinking water suitability, and indicator parameters.

Based on the statistical comparisons that were completed as part of the Detection Monitoring Program, the site notified USEPA and OEPA in November 1987 that Waste Pit 4 may be affecting groundwater quality in the vicinity of the pit. At that time, the RCRA Detection Monitoring Program was changed to the RCRA Assessment Monitoring Program, and the RCRA Groundwater Quality Assessment Program Plan (GQAPP) was submitted to USEPA and OEPA. Beginning in March 1988, wells were sampled quarterly for one year. In March 1989, the GQAPP was revised on the basis of a detailed evaluation of the available water quality and flow information. Forty-three wells were identified for quarterly monitoring of 35 site-specific analytical parameters. The site submitted another revision of the GQAPP in April 1991 to include findings from previous RCRA sampling, address regulatory comments, and provide more detailed sampling procedures. This revision also expanded the program by adding 11 more wells.

The RCRA Assessment Monitoring Program at the Fernald site was altered 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 EPAs in December 1991, replacing the GQAPP. The Groundwater Monitoring Plan was designed to monitor groundwater downgradient of the nine land-based units. The site defined three monitoring well networks to provide adequate monitoring of the Waste Pit Area, the Production Area, and the site's 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 both impractical and impossible 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 CERCLA and RCRA activities at the site.

In an effort to integrate CERCLA and RCRA monitoring activities under a single program, DOE proposed an Alternate Monitoring Program. This program is comprised of two components:

- Groundwater characterization activities under CERCLA as defined by the OU5 RI/FS Work Plan and Addenda, and

- Quarterly groundwater monitoring of the downgradient property boundary under the Routine Monitoring Program as defined in the "Project Specific Plan for the Routine Groundwater Monitoring Program Along the Downgradient Boundary of the FEMP."

The Project Specific Plan was submitted in July 1993 and defined the objectives of the Routine Monitoring Program. This program is comprised of 33 monitoring wells at the property boundary, including the monitoring wells installed for the downgradient facility boundary monitoring network defined in the RCRA Groundwater Monitoring Plan. In September 1993, after negotiations with DOE, OEPA issued the Director's Findings and Orders, which provided guidance on the Alternate Monitoring Program, identified elements to be included in the 1993 RCRA Annual Groundwater Report, and identified elements to be revised in the Project Specific Plan for the Routine Monitoring Program. A revision of the Plan was submitted to OEPA in October 1993.

During 1994, OU5 presented a comprehensive characterization of groundwater in its RI Report, as well as a comprehensive baseline risk assessment and a determination of the nature, rate, and extent of contamination sufficient to select a remedial alternative. Six contaminant plumes were identified in the Great Miami Aquifer, each with a distinct line or point source:

- Waste storage area A plume – a result of leaks from the OU1 waste pits. The principal contaminants detected with sufficient frequency to be discerned as plumes are: total uranium, technetium-99, calcium, iron, magnesium, potassium, sodium, ammonia, chloride, nitrate, and sulfate.
- Waste storage area B plume – a result of surface water infiltration along Paddys Run. The only contaminant detected with sufficient frequency to be discerned as a plume was total uranium.
- Plant 6 plume – a result of leaks through the glacial overburden beneath Plant 6 and the sewage lift station. The principal contaminants detected with sufficient frequency to be discerned as plumes are: total uranium, cadmium, calcium, cobalt, and sulfate.
- South Plume A – a result of leachate and surface water that infiltrates in the vicinity of the OU2 flyash piles and the South Field. The principal contaminants detected with sufficient frequency to be discerned as plumes are: total uranium, calcium, chromium, and magnesium.
- South Plume B – a result of surface water infiltration along the storm sewer outfall ditch and Paddys Run. The principal contaminants detected with sufficient frequency to be discerned as plumes are total uranium, calcium, and magnesium.
- South Plume C – a result of surface water infiltration along the southern stretch of Paddys Run. The only contaminant detected with sufficient frequency to be discerned as a plume was total uranium.

In addition to the above, other radionuclides, inorganics, and organics occur as isolated above background detections in each plume. Two of the six plumes—South Plume B and C—are commingled with contaminant plumes that originate at an independent industrial facility located south of the site. The findings from the OU5 RI Report are consistent with those indicated in the 1994 RCRA Annual Report, and the data collected through the Routine Monitoring Program support the proposed remedial action areas for the Great Miami Aquifer.

Review of the Routine Monitoring Program analytical results indicate that although some of the results from the wells were elevated, none appear to be above regulatory thresholds or a potential risk to human health or the environment except for those wells (2106 and 3069) that monitor the South Plume. The elevated uranium levels found in the South Plume wells are being addressed through the South Plume Removal Action which was initiated in August 1993. This removal action is currently being monitored under the Design, Monitoring, and Evaluation Program Plan. In general, other elevated concentrations of general chemistry and metal parameters from routine monitoring wells appear to be stable (no increasing or decreasing trend) while total uranium results remain at low concentrations.

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

Estimated Radiation Doses for 1994

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 environmental regulations, Fernald site 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 Fernald site; 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 1994, and
- An interpretation of the significance of these estimated doses.

Results in Brief: 1994 Estimated Doses*

Air Pathway

Airborne Emissions – The estimated maximum committed effective dose to a member of the public from 1994 airborne emissions was calculated as 0.17 mrem.

Foodstuffs – The committed effective dose from eating foodstuffs produced within three miles of the site was estimated to be 0.2 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 1994.

Liquid Pathway

Well Water – The estimated committed effective dose from drinking well water from the area around the Fernald site was 0.3 mrem.

Fish – The estimated committed effective dose from eating fish from the river near the Fernald site effluent line was 0.4 mrem.

* These doses for 1994 are also presented in Table 20 on page A-32. 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 Fernald site 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 site is well within the DOE dose limit to members of the public of 100 mrem per year from all exposure pathways, Fernald site 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 Fernald site, 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 Fernald site. Models also estimate pollutant concentrations and doses which 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 site 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. Since the mathematical formulas that represent the environmental and biological processes are simplifications and generalizations, applying them to the specific conditions at the site 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 Fernald-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 Fernald 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 following chapter of this report.

Estimated Doses from Airborne Emissions

At the Fernald site, scientists obtain dose estimates from onsite airborne emissions measurements using a set of computer programs called CAP88-PC. The site uses CAP88-PC to determine compliance with the NESHAP requirements of the Clean Air Act. Within the programs, the AIRDOS program calculates 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.

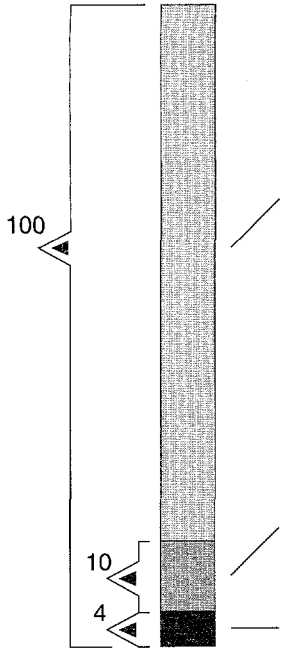
The CAP88-PC program calculates airborne radionuclide concentrations based on onsite airborne emissions measurements. The results from the fenceline ambient air monitoring stations are compared to the CAP88-PC concentrations, but are not used in inhalation dose calculations.

The CAP88-PC computer programs calculate both individual and collective doses. Collective dose is the sum of individual doses to people in the Fernald 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 site 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 Fernald 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 2 and 21, 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 site made very *conservative estimates* for these and all other emission sources which 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 site operations during 1994.

Results of the CAP88-PC programs estimated the maximum effective dose from 1994 airborne emissions to be 0.17 mrem to a person located east-southeast of the former production area. This dose estimate assumed that the person remained outside his or her home 100% of the time in 1994. The dose was well below the NESHAP standard of 10 mrem from the air pathway and was only 0.17% of the DOE guideline of 100 mrem per year from all pathways (see Figure 45).

Figure 45: Department of Energy Dose Limits



Regulations which limit specific pathway doses provide a reference point for measuring the Fernald site compliance. DOE Order 5400.5 charges that no individual in the general public shall be exposed to 100 mrem per year, from combined sources, as a result of site operations during any year.

This order further indicates that no individual in the general public shall receive 10 mrem per year from the air pathway (excluding radon). This standard is adopted from the National Emission Standards for Hazardous Air Pollutants of the Clean Air Act.

Finally, the order mandates that no person in the general public shall receive greater than 4 mrem per year from drinking water. This standard conforms to National Primary Drinking Water Standards of the Safe Drinking Water Act.

The collective effective dose from 1994 airborne emissions (not including radon) to the population within 80 km (50 miles) of the site was also calculated by CAP88-PC. This dose was estimated to be 2.14 person-rem for a population of 2,740,000. 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 Fernald Site

Since the CAP88-PC program only calculated doses from 1994 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, vegetables, and milk.

Uranium deposited in soil during the years the Fernald site 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, vegetables, and milk comes from gardens and farms in the Fernald area. This modeled diet assumes an annual consumption of 18 kg (40 pounds) of leafy vegetables (cabbage, lettuce, etc.), 45 kg (100 pounds) of grains (corn, soy beans, wheat, etc.), 68 kg (150 pounds) of fruit, 28 kg (62 pounds) of below-ground vegetables (potatoes, carrots, etc.), 45 kg (100 pounds) of other vegetables, and 112 liters (30 gallons) of milk.[36] To represent the foods in the diet, scientists analyzed cabbage, corn, soybeans, apples, potatoes, tomatoes, green beans, and milk sampled 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 uranium. This assumption is reasonable because a large amount of uranium produced at the Fernald site 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.[37]

The committed effective dose received over the course of 50 years was calculated to be 0.2 mrem, only 0.2% 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

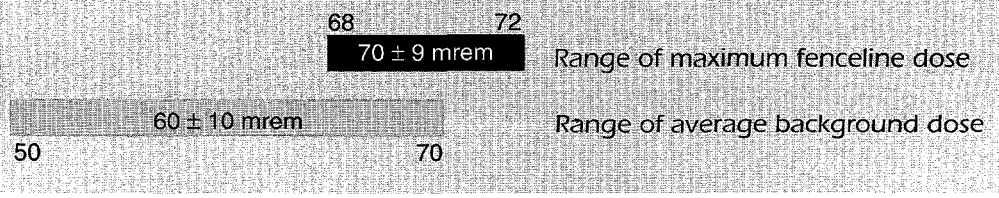
Unlike the air and liquid pathways where a radionuclide in the form of a particulate or gas delivers its dose after inhalation or ingestion, direct radiation dose is the result of radiation (gamma and X-rays) emitted from radionuclides stored onsite. The largest sources of direct radiation are the wastes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

Direct radiation dose was estimated using the highest dose from the twelve fenceline monitoring locations (see Table 10 on page A-14) and subtracting the average dose measured at five background TLD locations (locations 18, 19, 20, 21, and 33 as shown in Figure 27 on page 88). 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.

From the data in Table 10, the highest 1994 fenceline dose occurred at location 2 and is 70 ± 1.5 mrem per year (2 sigma). The average background dose from locations 18, 19, 20, 21, and 33 is 60 ± 10 mrem per year. At first glance, it appears that

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 largely 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.



the direct radiation dose would be 10 mrem per year above background at the site 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 68.5 mrem (70-1.5) and 71.5 mrem (70+1.5) per year, while the average background dose is between 50 mrem (60-10) and 70 mrem (60+10) per year. Since the range of background and the range of fenceline doses overlap, 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 1994. TLD results from fenceline locations do not show any increasing or decreasing trends over the past five years.

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 Fernald Site

As discussed in Chapter Six, the site 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 site[31,32].

In order to estimate dose from drinking well water in the area around the site, the average uranium concentration in wells located north and west of the site was subtracted from the maximum concentration found in wells located south and east of the site. Data from wells 1, 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 site was found in Well 34. For the purpose of dose calculation, the uranium in Well 34 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 34 would be 0.3 mrem.

Estimated Dose from Drinking Great Miami River Water

Although the Great Miami River downstream of the site is not designated as a public water supply by OEPA, the site 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-15) 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 Fernald releases received over the course of 50 years would be 0.01 mrem.[36]

Estimated Dose from Eating Fish from the Great Miami River

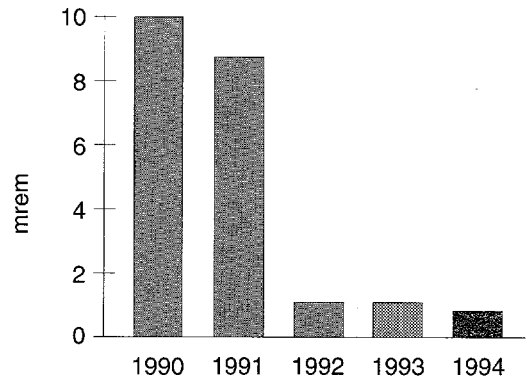
The estimated dose from eating fish from the river was calculated using the maximum uranium concentration in edible fish collected at RM 19 and RM 24 (see Figure 35 on page 104). The average background uranium concentration in edible fish collected at RM 38 was subtracted from the maximum concentration 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 pounds) of fish from the Great Miami River, the committed effective dose would be 0.04 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. Since it is not possible to single out a specific individual in the Fernald 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 1994 airborne emissions (excluding radon), consuming foodstuffs produced in the Fernald area, drinking water from a well in the Fernald area, eating fish from the Great Miami River, and receiving the direct radiation dose above background at the site 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.

Figure 46: Dose to Maximally-Exposed Individual, 1990 – 1994



The 1994 dose to the maximally-exposed individual is estimated to be 0.7 mrem, well below the guideline of 100 mrem per year for all pathways. Figure 46 shows the doses to the maximally-exposed individual from 1990 to 1994.

DOSE TO MAXIMALLY-EXPOSED INDIVIDUAL

Pathway	Dose Attributable to the site	Applicable Guideline
Air		
Estimated 1993 emissions	0.17 mrem	10 mrem/air
Foodstuffs grown in Fernald area	0.2 mrem	100 mrem/all pathways
Direct radiation	0.0 mrem	100 mrem/all pathways
Liquid		
Well water in the Fernald area	0.3 mrem	4 mrem/drinking water
Fish from Great Miami River	0.04 mrem	100 mrem/all pathways
Maximally-exposed individual	**~0.7 mrem**	**100 mrem/all pathways**

Significance of Estimated Radiation Doses for 1994

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 site 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 of the public receive no more than 100 mrem per year as a result of site operations, and DOE has incorporated this limit into Order 5400.5 as well. The sum of all estimated doses from site operations for 1994 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 Fernald site.

The Radon Monitoring Program

Radon is a radioactive gas that occurs naturally throughout the environment. Everyone is exposed to radon at varying concentrations, and exposure to radon and its daughter products is part of the annual background radiation dose that people receive. As discussed in Chapter Two, this background exposure contributes approximately 55% to a person's average annual dose.

In addition to the radon found naturally in the environment, Fernald stores some materials onsite that emit radon as it radioactively decays. The primary source of radon is from the material stored in the K-65 silos. Also, the six Waste Pits and Building 65 (the Thorium Warehouse) are potential or relatively small radon sources onsite. Because these sources are present, the Radon Monitoring Program has monitored radon levels onsite since the early 1980s to assess the impact of these radon sources on the public and the environment. This program operates in compliance with the requirements of DOE Order 5400.5, "Radiation Protection of the Public and the Environment." Radon monitoring results and attributable dose are reported separately from the air pathway in order to clarify the presentation of information and regulations that are unique to radon.

Results in Brief: 1994 Radon Monitoring

Fenceline Concentrations – The average fenceline concentration measured in 1994 was approximately 0.8 pCi/L, well below the DOE guideline of 3.0 pCi/L. The 1993 average concentration was approximately 0.6 pCi/L.

Background Concentrations – The average background concentration measured in 1994 was approximately 1.3 pCi/L. The 1993 average background concentration was approximately 1.0 pCi/L.

Dose Received from Radon – The calculated dose at the fenceline in 1994 was estimated to be 576 mrem incorporating the methodology used by the National Council on Radiation Protection (NCRP). This dose in 1993 was 454 mrem at the fenceline.

The net dose contribution from Fernald sources was not measurable. Measured background concentrations were greater than the Fernald fenceline concentrations.

Introduction to Environmental Radon

Radon is a naturally occurring, chemically inert, radioactive gas. This element consists of three *isotopes*: radon–219 (actinon), radon–220 (thoron), and radon–222 (radon). The decay chains for the parents of the radon isotopes are shown in Figure 47. Due to the short half-lives of radon–219 (4 seconds) and radon–220 (55 seconds), these isotopes of radon are relatively insignificant contributors to the radiation dose attributed to radon. Generally, the term radon refers to the radon–222 isotope. (Throughout the rest of this report, the term radon will refer to radon–222.)

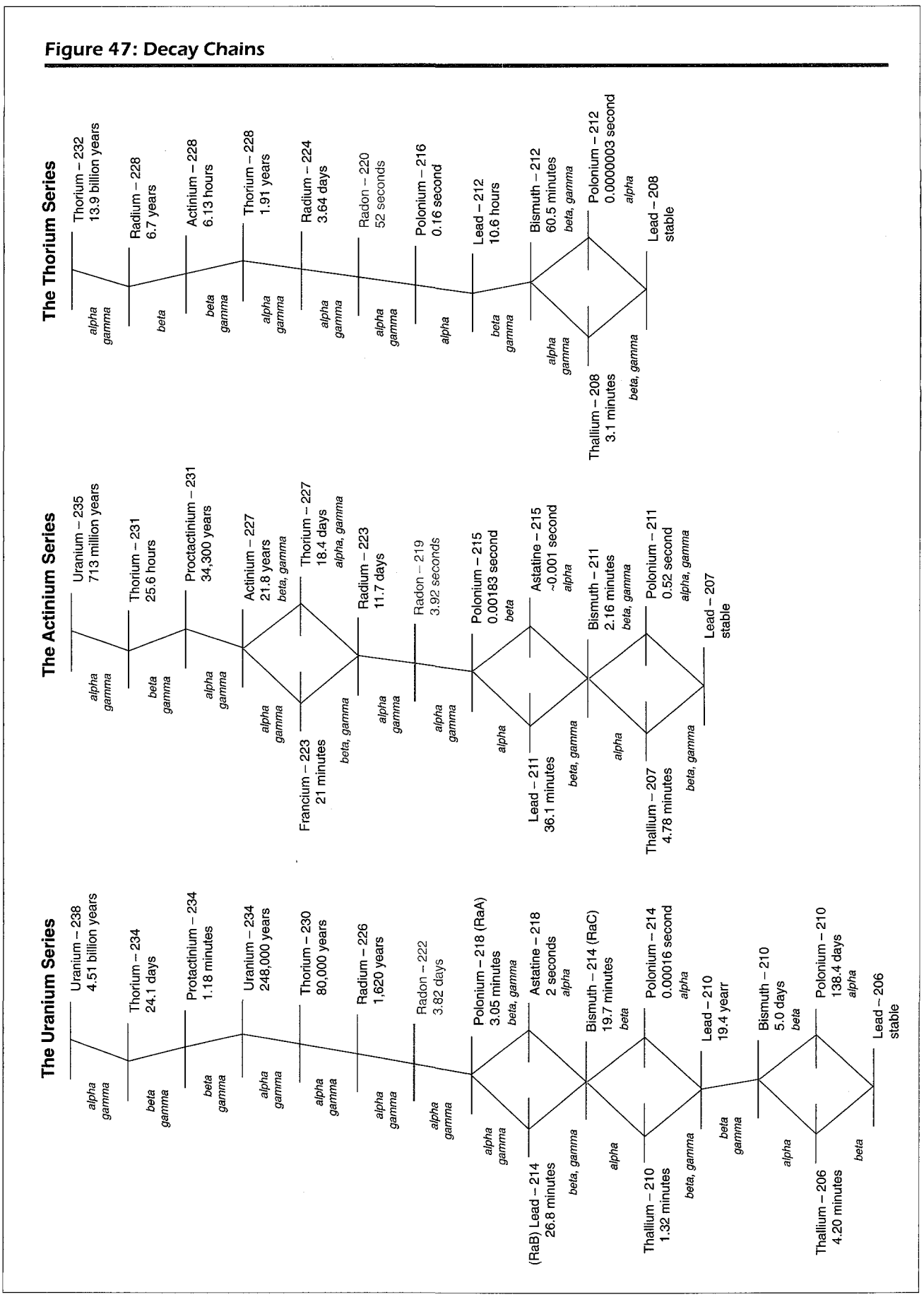
Radon–222 is a daughter product of the uranium–238 decay chain. The radionuclides of the uranium–238 decay chain are naturally occurring and are distributed throughout the earth's crust. Radon–222 is formed by the radioactive decay of radium–226. Radon–222 has a long enough half-life, 3.82 days, to allow for radon–222 to emanate from the earth's crust and be distributed into the atmosphere. Once radon is present in the atmosphere and is inhaled by individuals, it becomes a significant contributor of radiation exposure to the public.

Radon–222 decays into a series of short-lived radionuclides that are collectively referred to as radon "daughter products." As radon and its daughter products decay, alpha particles are emitted. The daughter products are adsorbed on dust particles present in the atmosphere. When the atmospheric dust with the attached daughter products is inhaled, some of it is deposited in the lung, which may cause an internal exposure. The daughter products that are deposited in the lung will emit alpha particles when they decay. The alpha particles may then cause damage to the cells lining the airways. Actual damage to the cells lining the airway is primarily caused by the alpha particles emitted by the radon daughters; to a lesser extent, the alpha particles emitted by radon itself may also damage the cells lining the airway.

The physical characteristics of the soil and local weather conditions affect radon's ability to migrate into air and water. Upon decay, radon may escape into the air spaces around soil particles and diffuse into the atmosphere. Local rainfall and snowcover may inhibit radon's ability to escape from the soil.

The outdoor concentration of radon in the atmosphere shows daily, seasonal, and annual fluctuations. These changes are caused, in part, by atmospheric conditions. They are also caused by changes in the rate that radon is released from the ground because of precipitation and freezing temperatures. Because radon tends to accumulate under stagnant weather conditions, concentrations increase during periods of calm winds and temperature inversions. (During temperature inversions, warm air traps cooler air near the earth's surface and prevents mixing and turbulence of the air near the surface. When these inversions occur, radon is also trapped near the earth's surface.)

Figure 47: Decay Chains



Radon Monitoring at the Fernald Site

All releases applicable to site activities are monitored at Fernald and radiation exposures to members of the public are assessed. DOE Order 5400.5 provides guidelines for radon concentrations and emissions in the atmosphere above facility surfaces or openings. This order defines radiological protection requirements and guidelines for cleanup of residual radioactive material, the management of resulting wastes and residues, and the radiological release of property. These requirements and guidelines are applicable at the time the property is released and state that radon levels must not exceed the following limits when added to background levels:

- 100 pCi/L at any given point,
- An annual average concentration of 30 pCi/L over the "facility site,"
- An 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 Environmental Radon Monitoring Program at the Fernald site uses two types of radon detectors to measure radon concentrations in the environment: long-term (cumulative) alpha track-etch integrating devices and continuous alpha scintillation devices.

Long-term (cumulative) Radon Monitoring

An ***alpha track-etch detector*** is a cup that contains a special plastic chip inside. Some of the alpha particles from the decay of radon (or its daughter products) will interact with the plastic chip by leaving a latent track in the material. The tracks are made detectable by chemical or electrochemical etching. The number of etches or tracks in the material is proportional to the number of alpha particles that have reached the plastic. This number can then be related to the average concentration of radon in the cup. Filters are placed over the cup to allow only radon to enter the cup so it can be measured. These detectors are exchanged every three months to provide long-term radon measurements.

Alpha track-etch detectors can be used when monitoring requirements pertain to annual limits because they accumulate data over time and provide an overall average concentration. Alpha track-etch cups are placed on- and offsite to gather both background information and site-specific information regarding the dispersion of radon from the K-65 silos. Currently, there are approximately 55 locations. Each location contains either two, three, or four radon cups. Accuracy for the cups collected over several years based on the site's and the vendor's data indicate that deviation from a true value can vary up to ± 25%.

At the site boundary, the Environmental Radon Monitoring Program obtains data from 20 locations using alpha track-etch detectors. As well, data are collected from three area residences and six background locations (see Figure 48 on the next page). Alpha track-etch detectors were also used to measure radon concentrations adjacent to the silos and in the predominant wind direction from the silos (see Figure 49A on page 145).

When alpha track-etch detectors record data at Fernald or at the facility fenceline, there are potentially three components to the measurement: the natural background radon concentration from the area, the track etches that are present in the plastic before it is exposed to radon (detector background), and the possible contribution of radon from the site. The detector background must be accounted for to determine a true reading.

The detector background can be easily segregated and subtracted from the recorded measurement to provide a net detector concentration value. The radon concentration contribution from the silos can be determined by subtracting the area's background radon concentration from the total radon concentration recorded. Unfortunately at one location, one cannot measure both the background radon and potential radon contribution from Fernald sources because there is no distinguishable feature of the radon from each source. Chemically and radiologically, it is one and the same.

To determine the radon contribution from Fernald sources, the average background value (from all offsite background locations) is subtracted from the gross radon measurement. Background radon concentrations vary with the geographical area. These differences can be as much as 0.2 pCi/L, which is 50% of the typical range of environmental radon concentrations (0.3 to 0.4 pCi/L). Additionally, the uncertainty of a radon detector measurement increases as radon concentrations decrease. At the low environmental concentrations it is difficult to identify contributions from external sources compared to natural background concentrations. Significant contributions, however, would be detectable. For example, if a reading of $10.0 \pm .1$ pCi/L was recorded, the uncertainty represented would be 1%. If a reading of $1.0 \pm .1$ pCi/L was recorded the uncertainty represented would be 10%.

At Fernald, alpha track-etch detectors are used to collect and measure radon for a period of exposure for approximately 90 days (one quarter). The sensitivity for such a detector is approximately 100 pCi/L-days of exposure. This means that the detectors can accurately measure an average daily radon concentration of approximately 1.0 pCi/L over a 90-day exposure period. Although the analytical reporting is capable of reporting radon concentration values less than 1.0 pCi/L, the uncertainty in the measurement increases with lower concentrations. The unit of exposure (pCi/L-days) divided by the length of exposure equals the average radon concentration. As the amount of radon concentration measured decreases, the uncertainty associated with the concentration measurement being accurate increases.

text continues on page 146

Figure 48: Selected Offsite and Fenceline Radon Monitoring Locations

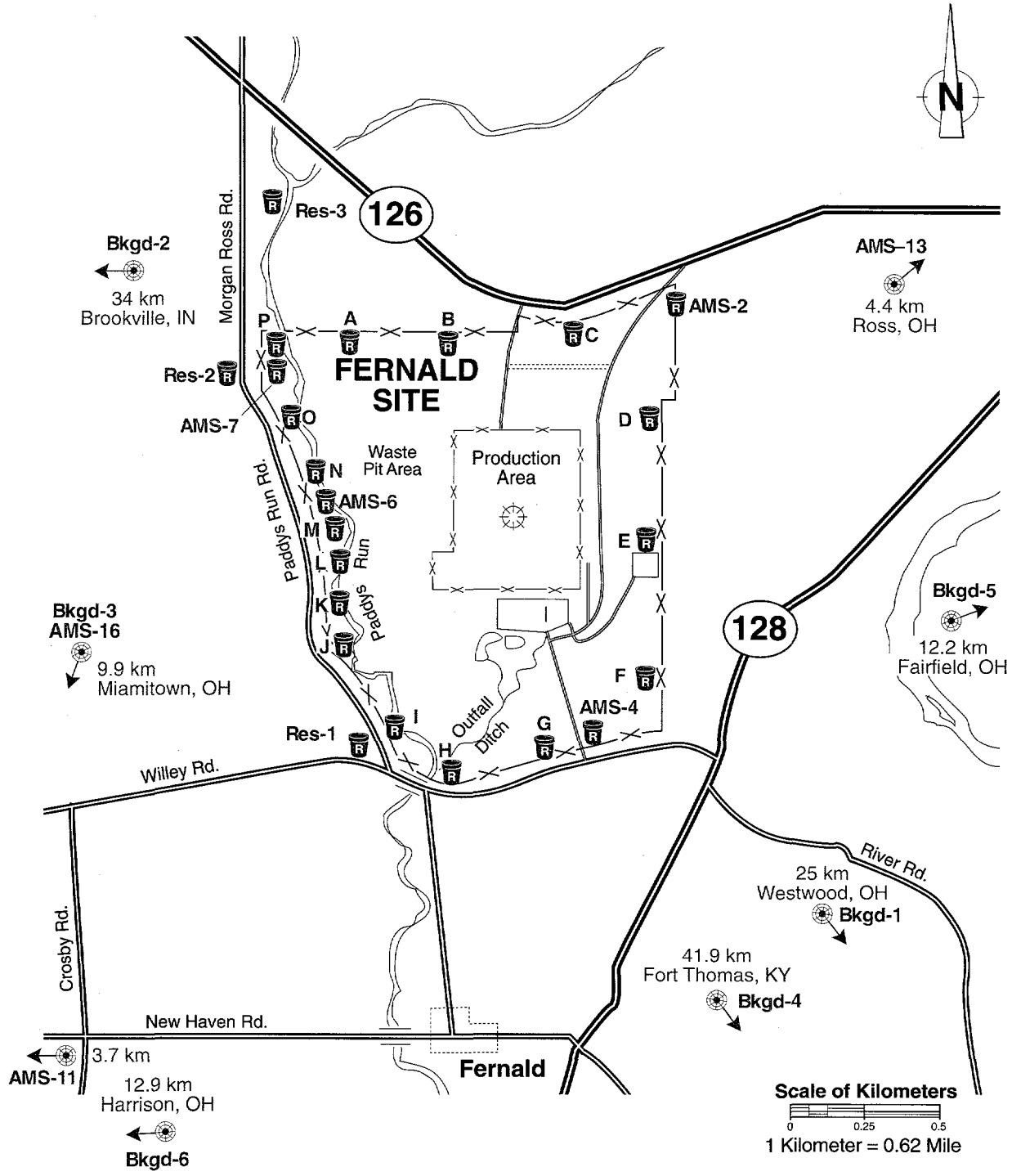
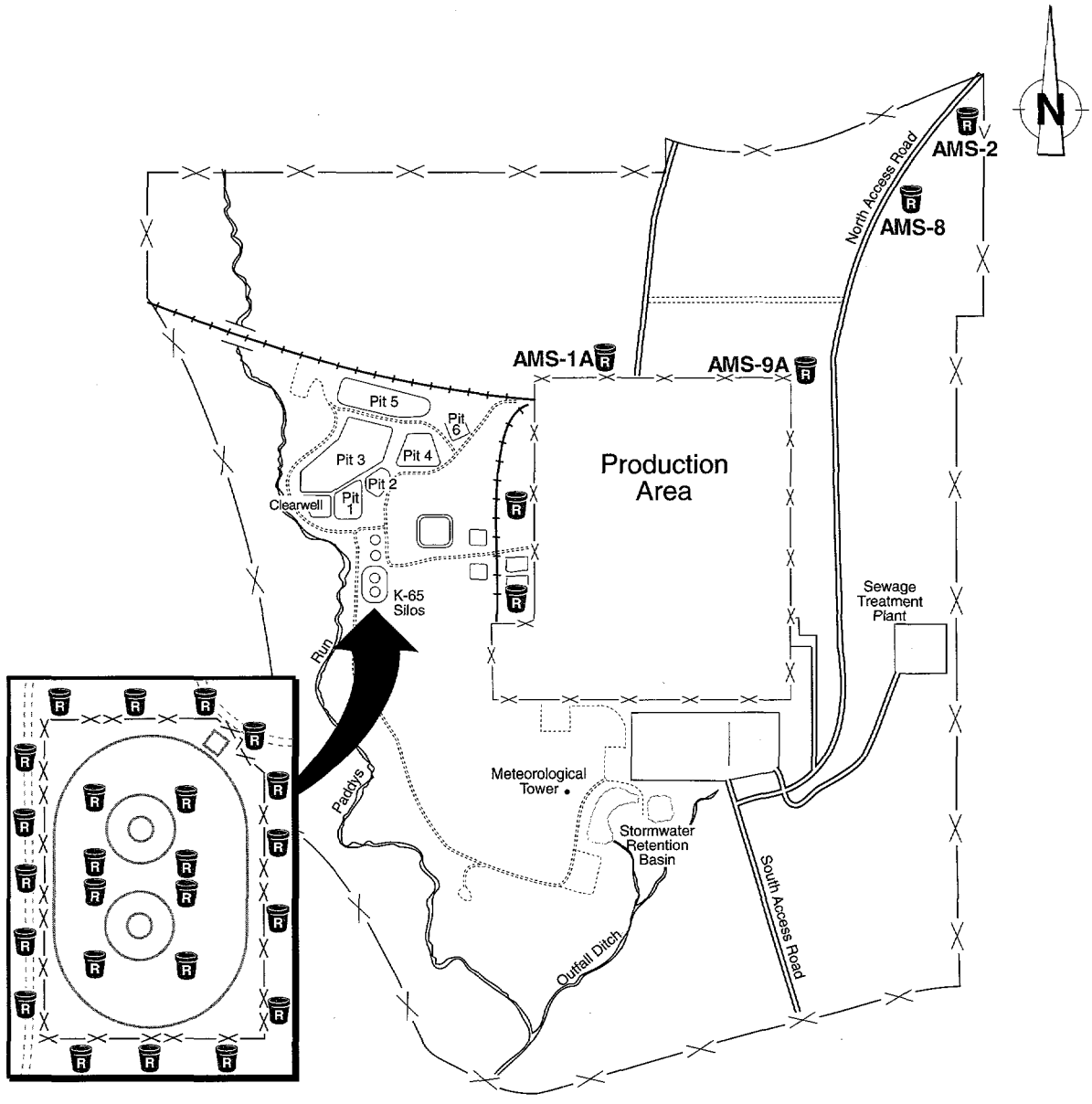


Figure 49A: Onsite Passive Environmental Radon Monitoring Locations Near the Silos



LEGEND

- Onsite Locations
- K-65 Silos Area Perimeter
- Plant Perimeter
- Production Area Perimeter

3309

Figure 49B: Measurement Uncertainty

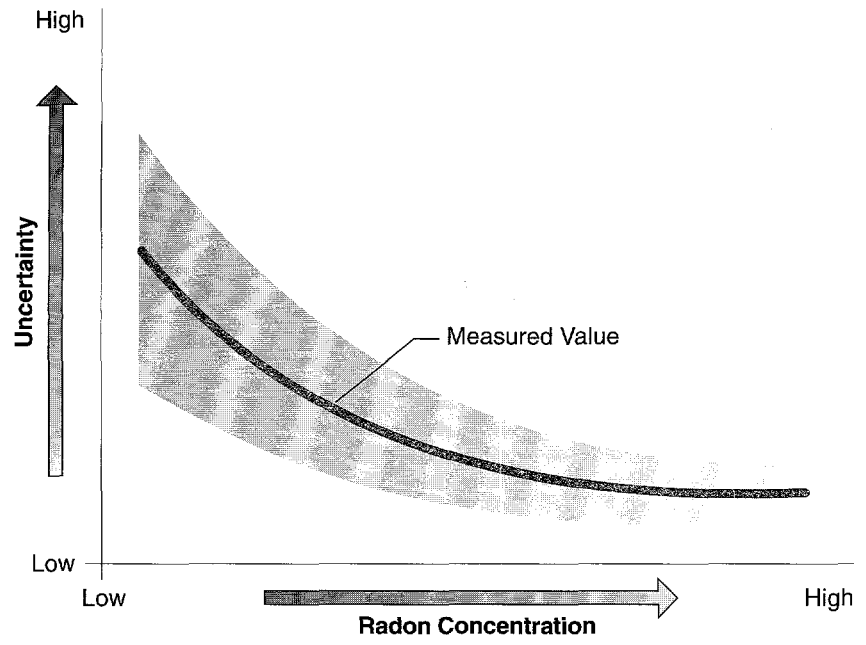


Figure 49B graphically presents this situation. At lower concentrations of radon, the range of values observed is likely to vary from the true measurement by a substantial amount. As the concentration increases it is likely that observed values will be closer to the true value. This is primarily due to the fact that whenever observed measurements are nearer to the detection capabilities of the detection instrument, the uncertainty is at an increased amount. This situation is true for the measurement of radon as well as any other parameter that is measured.

Since radon is a gas, it exists virtually everywhere that air is. As a result, the vendor stored "background" detectors are exposed to some radon over time. In the case of the detectors that Fernald returns to the vendor for analysis, there is at least an extra three months of "background" building up in the "background" detectors. To obtain the actual concentration of radon measured, the vendor subtracts the "background" measurement from the actual measurement. The "background" used is the "background" from the detector chips that are stored by the vendor. In prior years the data that was reported was obtained by subtracting the detector "background" from the measurement.

Because Fernald uses approximately 250 radon detectors each quarter for environmental monitoring and quality assurance purposes, detectors are purchased in large quantities and stored at an offsite field office. Over the past year and a half, a review of prior data has indicated that the radon detectors that Fernald used as blanks or controls had more alpha tracks on them than the vendor "background" detectors. During 1994, the calculation of radon concentrations was performed using the Fernald blank or control data. As a result the reported radon concentrations are more representative of the true concentrations. Data prior to 1993 was not corrected for the effects of the site-specific background; as a result, the calculated exposure was overestimated. Prior reported data was more conservative

(higher) because a smaller value was subtracted from original measured concentration. Again this was an improvement or refinement in the data that was collected and analyzed during 1994. Future exposure data will be calculated using the detector background from the blanks or controls in Fernald's storage area.

Continuous Radon Monitoring

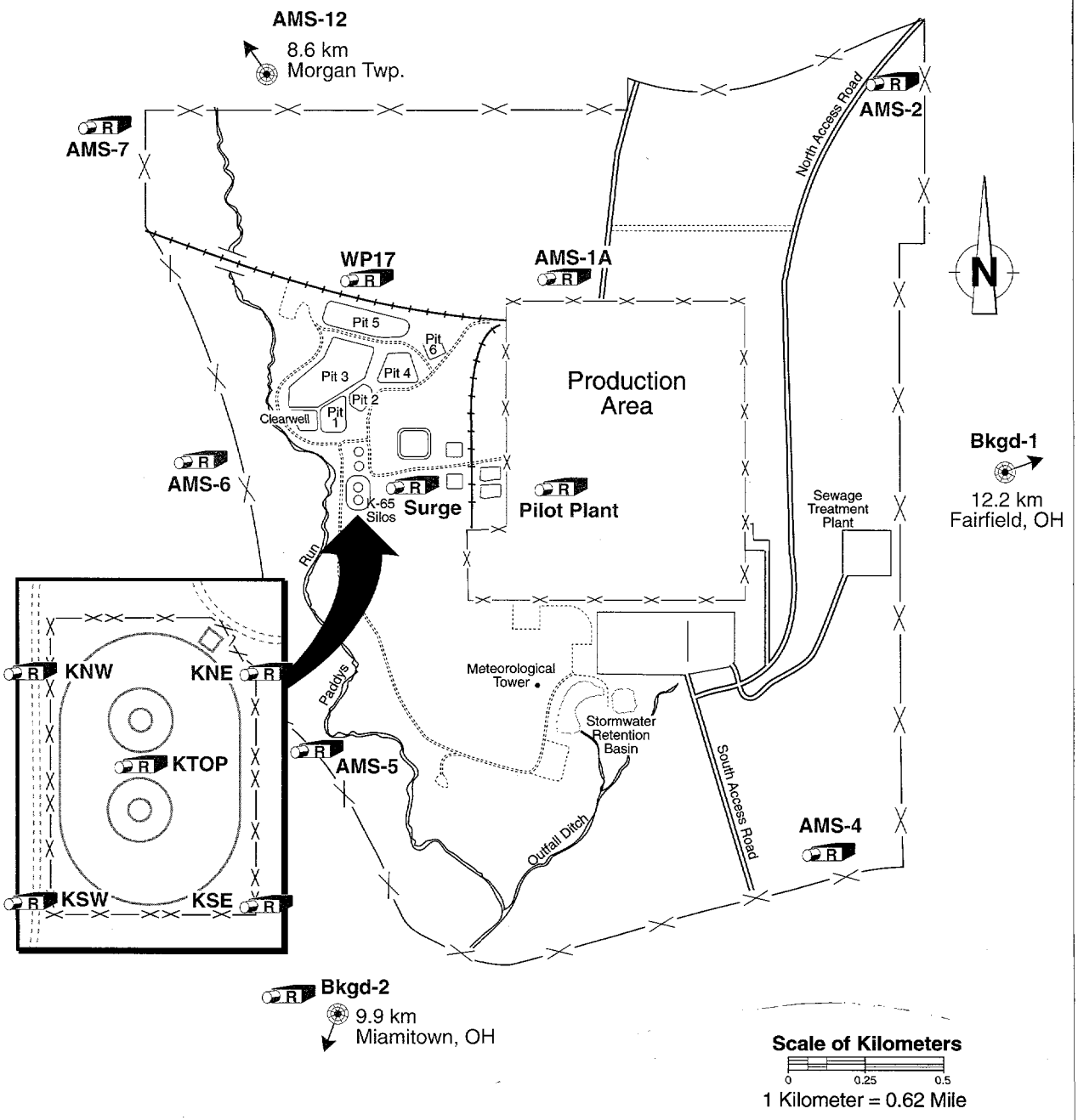
As previously stated, radon is a gas that radioactively decays and releases some of its energy in the form of alpha particles. ***Alpha-scintillation detectors*** use special cylindrical cells that continuously monitor radon concentrations by detecting the alpha particles emitted as the radon gas decays. These continuous monitors record radon concentrations on an hourly basis. An *alpha-scintillation cell* uses a coating of a special material inside the cell that interacts with the alpha particles and gives off light as a result of the interaction. The alpha particles are produced from both the radon gas and from the decay of its daughters. The light pulses produced inside the cell are amplified and counted. The number of light pulses counted is proportional to the radon concentration inside the cell. When monitoring the outside air, the air diffuses into the scintillation cell through a foam barrier. The foam barrier blocks out or filters alpha particles from other sources in the air. The radon gas present in the air diffuses through the foam barrier and decays into its daughter products inside the cell, emitting alpha particles, which are then counted. This technique is called passive sampling as there are no moving parts, such as a pump, to draw air into the scintillation cell.

Continuous radon monitors have the advantage of providing information on changes in radon concentration throughout the day. Continuous radon monitors however, are limited to locations where electricity is currently available. During extreme cold weather conditions the reliability of the instrument is also affected. Continuous monitoring was conducted at select fenceline locations during 1994, namely, air monitoring stations 2, 4, 5, 6, and 7. Continuous monitoring was also conducted at various locations onsite. These locations include the perimeter of the silo berm, silo headspace, the top of the silos, and two locations in the prevailing wind direction. The locations of these monitors are shown in Figure 50 on the next page.

Continuous monitors reveal important information regarding the dynamics of radon concentrations on- and offsite. These monitors allow for timely review of radon concentrations, which may indicate if radon concentrations are changing significantly from week to week.

Three components of the measurement recorded by the radon monitor include: (1) natural background radon concentration from the area, (2) the electronic signal contribution to the reading (electronic "noise"), and (3) potential contributions of radon from the site. One of the most difficult components to measure is the electronic "noise" of the instrument. Even in a radon-free environment, the continuous monitor will indicate that radon is measured.

Figure 50: Selected Continuous Radon Monitoring Locations



LEGEND

- Onsite Locations
- Distance from Center of Production Area to Monitoring Locations off Map
- Plant Perimeter
- Production Area Perimeter

3309

This electronic noise phenomena is common to all types of electronic instrumentation, from digital thermometers to digital multi-meters used by electronics technicians to note tuners used by musicians to tune their instruments. For proper use of the instrumentation, the determination of a reference point is needed. In the case of continuous radon monitors, the "electronic noise" element is determined by taking measurements in a radon-free environment. To obtain a more correct measurement, this data would be subtracted from the gross reading.

At this time, radon data collected by Fernald is not corrected for the electronic noise, and all recorded observations include the electronic noise contribution of the instrument. Therefore, all data is conservative in that the true value is less than the recorded value. Studies are ongoing to determine the variability in the electronic noise portion of the recorded concentration and its stability over time. Once studies are complete, an electronic noise background value will be used for each instrument if appropriate, and that value will be subtracted from the gross recorded value.

To determine the "background" environmental radon concentration, a similar process is employed. The difficulty here though is determining accurately what the "background" radon concentration is since it so easily changes with location. The problem here is the same as the situation previously presented in the in the alpha track-etch section. Once these two parameters are determined the third component remains which is the contribution from Fernald.

February Radon Release

In February 1994, elevated ambient radon concentrations in excess of 100 pCi/L were identified for short periods of time in the vicinity of the K-65 silos. Investigation into the causes of these elevated concentrations revealed that radon adsorption testing was being conducted during this time. Although this testing was designed to be a closed loop system which would not increase radon emissions, operation of the system may have inadvertently caused the pressure in silo 2 to increase. Continuous radon monitors located on the site fenceline did not indicate elevated radon concentrations during the times of the release. There was no evidence of any impact to nearby residences or the environment. After the release, the radon adsorption testing process was redesigned to prevent pressurization of the silo headspace. Additionally, this release was reported to local, state, and federal agencies (please see page 52).

The radon monitors used at the site have a minimum detection level (MDL) of 1.0 pCi/L for a one-hour counting interval. Although the instrument is capable of reporting radon concentrations less than 1.0 pCi/L, the uncertainty of the measurement increases to an unacceptable level with concentrations less than 1.0 pCi/L.

Routine Monitoring

The K-65 silos are undergoing remedial actions to transfer and treat the radium-bearing materials stored within. Prior to the completion of the remedial action, DOE entered into an agreement with the USEPA where information regarding the radon monitoring of the K-65 silos will be reported to the USEPA on a monthly basis. This report is referred to as the FFA report. This activity will continue until the remedial action has been completed per the terms and conditions of the agreement, unless amended. The resulting material will then be stored onsite until it can be shipped offsite. Radon data at the silos is also collected using radon monitoring cups. Additionally, environmental radon monitoring takes place at both onsite and offsite locations for environmental measurement and comparison purposes.

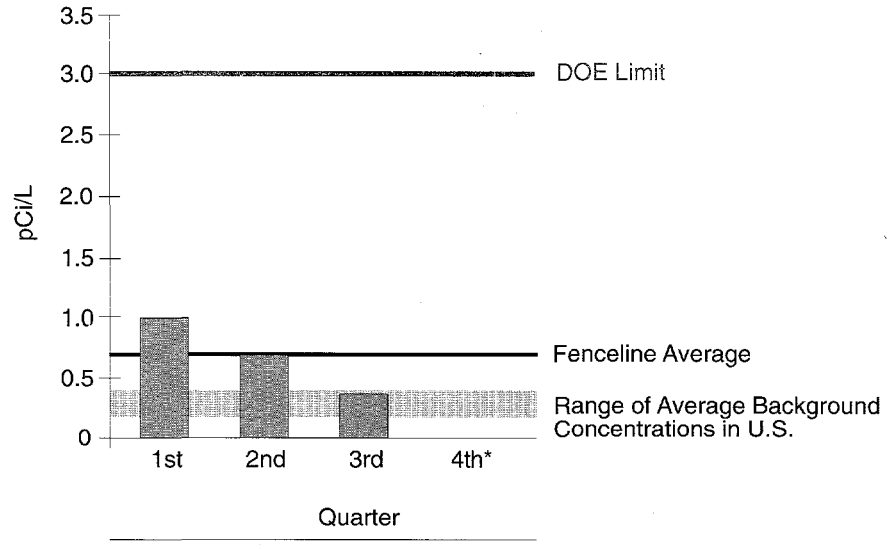
Special Project Monitoring

In 1994, OU1 performed drilling activities in support of the Dewatering, Excavation Evaluation Program (DEEP) on Waste Pits 1, 2, and 3. These drilling activities required monitoring for radon emissions from the drilling sites. Monitoring results from these sites did not indicate elevated radon concentrations due to these drilling activities. Radon monitoring/surveillance on Waste Pits 1, 2, and 3 will continue in 1995 as OU1 continues its investigations to determine the most appropriate way to remove the waste pit materials.

1994 Environmental Radon Monitoring Results

Alpha track-etch results for 1994 are provided in Table 22 on pages A-34 and A-35. Due to inaccuracies in quality assurance detectors, the fourth quarter results are not included. (See shaded box on the next page.) Comparison of quarterly radon concentrations at the six background locations to the 20 fenceline locations do not indicate any measurable contribution at the fenceline from Fernald sources. The quarterly results are also shown in Figure 51. Average fenceline radon concentration was 0.7 pCi/L (1.0 ppb) and was considerably less than the DOE limit of 3.0 pCi/L (4.4 ppb). The range of values for any location on the fenceline varied from less than 0.4 pCi/L (0.6 ppb) to a maximum of 1.5 pCi/L (2.2 ppb), excluding fourth quarter results. The maximum measurement was still considerably less than the DOE limit.

Figure 51: Quarterly Fenceline Radon Concentrations, 1994



* 4th quarter data deemed suspect and not usable.

The average background radon concentration as measured by the alpha track-etch monitors was 1.7 pCi/L (2.5 ppb). The concentration for any of the background locations varied from less than 0.4 pCi/L (0.6 ppb) to a maximum of 2.0 pCi/L (3.0 ppb), excluding fourth quarter data.

Because of the difficulties in accurately measuring radon concentrations at low environmental concentrations, background concentrations are subtracted from the indicator or control locations to provide a net concentration. Since natural radon background concentrations vary with location, the net radon concentration provides a better means for analysis of the data to determine any radon impact. Unless a difference between background and the fenceline radon concentration is significantly large, the positive or negative difference is simply related to the variability of the differences in background radon concentrations.

Fourth Quarter QA/QC Issues:

After a rigorous review of data obtained from radon alpha track-etch detectors for the fourth quarter 1994, the data were deemed suspect and unusable. This determination was made after a review of quality assurance data that indicated the results were not reliable. Quality assurance samples can serve as a check on the ability of the contract laboratory to perform measurements accurately at a specific detection level or to detect if blanks were contaminated during shipment or storage. In the case of the radon samples for fourth quarter 1994, environmental and background samples which typically record low concentrations of radon and blanks (nonexposed cups), read unusually high results. Cups that were intentionally exposed to a higher level concentration of radon ("spiked cups" used as a check for a laboratory to measure a known amount), failed to read higher concentrations of radon after analysis.

Investigative efforts have not provided an explanation as to the nature of the cause but have provided information that an unusual condition resulted which adversely affected the data. Sources of potential error for radon exposure include the storage area for cups prior to analysis, shipment of samples, and errors in the laboratory analysis. To date, the exact source of error has not been determined. Due to the problems associated with quality assurance of the data, fourth quarter radon data was not used. The vendor has reanalyzed the data and the results were essentially the same. Additional information from the vendor is being sought and further testing of blank samples is being conducted.

Estimated Radiation Dose from Radon

The radiation dose from radon in 1994 was estimated using a method that is used by the National Council on Radiation Protection (NCRP).[38] In 1994, the dose from radon was estimated to be 576 millirem (mrem). This dose was calculated from the average annual fenceline radon concentration recorded using the alpha track-etch cups for the first three quarters of 1994. The chart below presents the 1994 dose estimates including any background radon present at the fenceline.

1994 Radon Dose Estimates at the Fenceline

	1994	1993	Comments
Radon Concentration	0.8 pCi/L	0.6 pCi/L	Average fenceline concentration
Estimated Dose	576 mrem	454 mrem	Individual engaged in light activity 24 hours a day
Estimated Dose	511 mrem	403 mrem	Individual engaged in light activity 16 hours a day, 8 hours resting

The 1994 dose estimate assumed that the ambient concentration ratio of radon to radon daughters offsite (radon-222:RaA:RaB:RaC) was at a ratio of 1:0.9:0.7:0.7 — approximately a 0.7 equilibrium ratio. (Figure 47 on page 141 identifies radon-222 daughters RaA, RaB, and RaC.) This ratio for ambient outside air is in accordance with a national, widespread sampling that is referenced in the NCRP report. Actual values for radon daughters have not been measured at offsite or fenceline monitoring locations. A rigorous monitoring program would need to be developed to account for seasonal and spatial variations. This type of monitoring would then produce an average value equilibrium ratio. It is likely that this value would be similar to the average values referenced in the NCRP report.

The dose estimate also assumed that the dose was calculated for a maximally-exposed individual who continuously breathed air at the fenceline while engaged in light physical activity 24 hours a day for an entire year. The dose estimates presented in this report are for the "reference man," which assumes an average body size and breathing rate.

An exposure conversion factor, using the previously stated assumptions, was used to calculate the radiation exposure to the lung from radon and its daughters based on radon concentrations in the air. The exposure was converted to a lung dose by using the quality factor for internal alpha particles.[39] The lung dose was converted to an estimated dose equivalent (whole body dose) by using the weighting factor for the lung.[40] (See Chapter Two for a discussion on weighting factors.)

Dose estimates for radon use variables with a range of possible values. The second dose estimate is presented to illustrate the effects of changing any one factor in the calculation of an estimated dose from radon. This estimate used a more realistic assumption that the hypothetical person continuously breathed air at the fenceline for 24 hours a day but spent eight hours resting and 16 hours engaged in light activity each day for the entire year. Changing this one assumption resulted in a reduction of about 10% of the radon dose estimate. Therefore, the radon dose conversion factor can be as high as approximately 120% of the values reported if all parameters except the radon–222 concentration are unspecified.

Control of Radon at the Fernald Site

DOE strives to operate its facilities and conduct its activities so that radiation exposures to members of the public are As Low As Reasonably Achievable (ALARA). At the K-65 silos, the major source of radon on site, a bentonite (clay) sealant layer was placed over the residues contained in them to reduce the amount of radon emitted to the environment. This November 1991 removal action resulted in lowering the radon concentrations observed in the silo headspace from 25 to 30 million pCi/L to approximately 5 million pCi/L.

Radon-flux measurements were performed in 1991 on all waste pits known to contain radium. Pit 4 was measured in 1993. Measurements on pits 1, 2, 3, and 4 were all below the 20 pCi/m^2 per second limit. Pits 5, 6 and the Clearwell are covered with water, and radon-flux measurements are not required as long as the waste materials are submerged.

Quality Assurance of the Radon Monitoring Program

Radon monitoring at the site is conducted using state-of-the-art equipment. Many challenges are evident in the monitoring for environmental levels of radon. Instrumentation is required to be rugged, weather-resistant, portable, reliable, and able to measure extremely low concentrations of radon. Each of the two monitoring methods utilized by the radon monitoring program include some, but not all of these requirements. Improvements in the program are anticipated to continue in 1995.

In recent years, numerous quality assurance practices have been implemented to improve the quality of data obtained from the alpha track-etch detectors. Duplicate detectors are placed at each monitoring location. Blind or "spiked" samples are sent to the laboratory, as well as blank samples. At the low radon concentrations typically measured in the environment, the results have an accuracy of approximately $\pm$ 25%. Complexities in the analytical methods, including the

extremely low radon concentrations being measured, result in alpha track-etch detector results being primarily qualitative in nature.

Efforts in 1994 to improve the quality of data obtained from the continuous radon monitors centered primarily on attempting to increase the reliability of the monitors during extreme weather conditions. Due to monitor inconsistencies during extremely cold temperatures, heaters have been added to select continuous monitors. This modification has improved the amount of data retained from the continuous radon monitors. Upgrades over time will likely result in all units being upgraded. The continuous monitors are also calibrated once a year to National Institute of Standards and Technology (NIST) traceable sources, and the counting efficiencies are checked once a month.

Verification sampling was performed on the radon concentrations present in the K-65 silo headspace. Alternate measurement technologies were compared against the field measurement technique. The results of this verification sampling show that the results between the different technologies were comparable within ± 25%. This information supports the relative accuracy of the technique employed to currently record the concentrations of the silo headspace radon concentration.

The next chapter discusses the procedures and practices at the Fernald site that are used to ensure that environmental monitoring data are accurate representations of the conditions at the site.

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 Fernald site has developed comprehensive procedures that define how environmental sampling and analysis are to be conducted. These procedures generate consistency between programs and ensure that environmental sampling and analysis use USEPA, 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: 1994 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. One water sample was unacceptable as reported.

USEPA's Discharge Monitoring Report – All of the Fernald site analyses of USEPA wastewater samples were within acceptable limits.

Proficiency Environmental Testing (PET) – Of the 397 PET samples analyzed, 92% were within acceptable limits.

Sitewide CERCLA Quality Assurance Project Plan

Environmental sampling and analysis activities mandated or supported by USEPA must contain a centrally managed QA program. Since the Fernald site 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 investigation, 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 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. In 1994, the Fernald site implemented the SCQ.

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 that 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 site'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 compliance 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 helps ensure the traceability and accountability of field activities sampling.

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.

Fernald 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 analysis 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 USEPA 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 Fernald site uses a variety of procedures to ensure that 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 Fernald site are stipulated by federal laws and regulations. From time to time, modifications to these methods are needed to adjust for matrix effects or other interferences. In addition, other methods, primarily those used in radiological analyses, have not been established as standard USEPA methods. 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, USEPA 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.

Fernald 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

During October 1994, it was brought to the attention of Fernald management that the commercial laboratory which was performing radiological analyses of samples for the Radiological Environmental Monitoring (REM) program may not have been complying with all of the requirements specified in the contract. An extensive investigation, including several surveillances and an audit of the laboratory, was conducted to thoroughly evaluate the situation. While the laboratory had provided satisfactory radiological analytical services in the past, it was found that the personnel, administrative controls, and data reduction/management systems were no longer adequate for producing data in conformance with the site's newer, more extensive sample analysis requirements.

As a result, the laboratory's contract was terminated. In addition, all 1994 REM analytical results received from the laboratory were judged to be suspect and unusable for evaluating environmental conditions at the site. Subcontracts were then placed with other laboratories for the radiological analyses required to support the REM program. These laboratories were selected from the list of laboratories that have been evaluated and approved by the site for providing analytical laboratory services for site environmental monitoring and remediation activities.

REM samples that were sent to the original laboratory but still had the chain-of-custody seals intact were retrieved. These samples, along with duplicate backup samples that had not been sent for analysis, were then submitted for analysis at the alternate laboratories to ensure that reliable data was obtained for use in preparing this Site Environmental Report.

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 Fernald Site 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 Fernald site 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 1994 are listed in Table 23 on page A-36. The results for the 1994 soil sample was within acceptable limits since the ratio of the result was 1.36. The 1994 air filter sample's ratios were 1.04 and 1.09, which are also acceptable. The ratios of results for the water samples were 1.10 and 1,100. It was determined that the water analysis ratio of 1,100 was the result of an error in units reported. Using the correct units (µg/mL instead of µg/L), the ratio becomes 1.10, which is acceptable. The Fernald site 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.

USEPA's Discharge Monitoring Report

USEPA 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 Fernald site laboratories' performance began in 1985. This

program evaluates the ability of laboratories to measure nonradioactive contaminants in wastewater. As directed by USEPA, a corresponding QA sample must be analyzed for each parameter listed in the NPDES permit. The NPDES permit parameters that are measured by the Fernald site laboratories are discussed in Chapter Five under "Monitoring for Nonradioactive Pollutants." USEPA evaluates the results for the QA samples as acceptable or unacceptable.

Results obtained by the Fernald site laboratories for the 1994 DMR QA samples are summarized in Table 24 on page A-37. All of the results submitted during 1994 for DMR QA were determined to be acceptable by USEPA.

Commercial Proficiency Environmental Testing

The Fernald site 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 Fernald site 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 Fernald site 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 site laboratories in the PET QA program during 1994 is provided in Table 25 on pages A-38 and A-40. For the 59 parameters reported, 92% of the results met acceptable criteria. The PET program does not specify criteria for overall evaluation of a laboratory; however, 92% shows a good performance, consistent with 96% in 1993.

Split Sampling Program

Another enhancement to the Fernald site QA program is the split water, sediment, and milk 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 submitted to two independent laboratories for analysis.

Prior to 1994, the Fernald site split samples with the Ohio Department of Health (ODH). In 1994, DOE entered into an Agreement in Principle (AIP) with the Ohio Environmental Protection Agency (OEPA). Part of this AIP calls for OEPA to split samples with the site. The split sampling program remains unchanged except that the site now splits samples with OEPA instead of ODH. The site split samples with ODH through June 1994 and began splitting samples with OEPA in July 1994.

The site did not receive results for ODH samples collected during 1993 in time to be included in the 1993 SER, so they are presented in this report (see Table 26 on pages A-41 through A-43). The results for the 1994 ODH and OEPA split samples are presented in Tables 27 and 28 (pages A-44 through A-47, respectively).

These tables show a good agreement between Fernald and ODH/OEPA samples. Over the last two years, 93% of the ODH and OEPA water sample results have agreed with Fernald's results within 50%. All milk results from ODH and OEPA have been less than 1.0 pCi/L, consistent with Fernald's results. And, with the exception of sediment samples collected in May 1993, 100% of the ODH/OEPA sediment sample uranium and radium results have agreed with Fernald's results within 50%. (ODH results for sediment samples collected in May 1993 were significantly higher than Fernald's results.) The sediment sample thorium results generated by Fernald and OEPA in 1994 do not show a good agreement; Fernald's results are consistently higher. The reason for this discrepancy is not entirely understood.

Contract Laboratory Quality Assurance

Because of the great number of analyses required to support all its various environmental sampling and analyses programs, the site 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.

The Fernald site employed QA measures to evaluate the contract laboratory's analysis of uranium in milk samples. Spiked sample recoveries measure the accuracy of the analyses. Table 8 on page A-12 shows the percent recovery for the milk QA spike samples sent to the contract laboratory used for 1994 milk samples. Spiked sample results were available for October, November, and December; the spiked sample results for January-September were deemed unusable (see shaded box on page 160, this chapter). The spiked recoveries ranged from 92% to 98% with an average of 94%. All these recoveries were within the acceptable range of 50% to 150%.

Fernald Site Environmental Monitoring Data for 1994

Numerous sampling and analysis data are required to evaluate compliance with environmental regulations and to obtain accurate indications of the Fernald site's operations during 1994. 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 which 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 which 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, 1994

	Units	January	February	March	April	May	June	July	August	September	October	November	December
10 – Meter Wind Speed													
Maximum hourly average	kph[a]	21	27	32	29	21	19	17	16	21	18	28	23
Minimum hourly average	kph[a]	1.0	0.6	0.7	1.0	0.4	0.6	0.5	0.2	0.4	0.3	0.3	0.5
60 – Meter Wind Speed													
Maximum hourly average	kph[a]	38	46	54	50	34	33	24	28	32	32	47	41
Minimum hourly average	kph[a]	1.5	1.2	1.0	0.2	0.2	0.4	0.7	0.3	0.2	1.1	1.6	1.3
Ambient Air Temperature[b]													
Average	°C	- 4.8	- 0.1	5.3	13	15	23	23	21	17	13	9.2	3.6
Maximum	°C	11	21	24	29	31	35	33	31	31	29	22	15
Minimum	°C	- 34	- 15	- 8.9	- 3.2	- 1.2	6.4	13	8.2	4.5	- 3.0	- 5.5	- 7.3
Dew Point[b]													
Average	°C	- 9.1	- 5.0	- 0.7	5.6	9.1	17	20	18	11	7.3	4.2	1.3
Maximum	°C	4.4	10	8.9	16	18	23	23	22	16	16	14	13
Minimum	°C	- 30	- 16	- 12	- 2.2	2.2	2.2	11	11	6.7	- 0.6	- 6.7	- 6.1
Precipitation													
Monthly Total	cm[c]	7.3	4.7	4.2	16	5.8	9.8	17	11	2.6	2.8	9.7	7.6
Daily Maximum	cm[c]	1.7	2.6	1.4	4.8	2.6	4.9	6.9	7.3	1.2	0.86	2.4	2.34

(a) To obtain wind speeds in miles per hour, divide 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 Fernald Site, 1994[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, 1994

Sampling[a] Location	Number of Samples	Concentration ($pCi/m^3 \times 10^{-6}$) [b] Maximum	Average	Percent of Standard[c] Maximum	Average
Fenceline					
AMS 2	26	400	120	0.40	0.12
AMS 3	26	1,100	320	1.1	0.32
AMS 4	26	270	90	0.27	0.090
AMS 5	26	190	67	0.19	0.067
AMS 6	26	190	71	0.19	0.071
AMS 7	26	170	60	0.17	0.060
Onsite					
AMS 1A	25	1,200	370	1.2	0.37
AMS 8	26	600	190	0.60	0.19
AMS 9	26	1,200	400	1.2	0.40
Waste Pit Area					
AMS 17	27	240	87	0.24	0.087
AMS 18	27	1,800	430	1.8	0.43
AMS 19	27	320	79	0.32	0.079
AMS 20	27	200	67	0.23	0.067
Offsite					
AMS 10[e]	10	100	17[d]	0.1	0.017
AMS 11[e]	9	65	15(d)	0.065	0.015
AMS 12[e]	10	110	<50(d)	0.11	0.050
AMS 13[e]	10	95	25(d)	0.095	0.025
AMS 14[e]	10	89	25(d)	0.089	0.025
AMS 15[e]	5	66	50(d)	0.066	0.050
AMS 16[e]	10	41	1[d]	0.041	0.0010

(a) See Figure 21 on page 76 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). Negative results indicate that the amount of uranium in the sample was less than the amount of uranium measured in a blank filter.

(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) Median concentration reported.

(e) Partial year results, 8/15/94 through 12/28/94. Due to contractual performance problems with one of the commercial laboratories analyzing air filters, most of air sample results were considered suspect and unusable.

TABLE 4: Radionuclides in Air, 1994

Sampling Location[b]	Concentration[a] ($pCi/m^3 \times 10^{-6}$) Strontium–90[e]	Technetium–99	Cesium–137	Radium–226[e]	Radium–228[e]
AMS 1A	< 11	1900 ± 170	< 12	< 14	44 ± 54
AMS 2	< 28	1300 ± 120	< 6.7	< 5	< 8.3
AMS 3	< 4.8	730 ± 91	< 6.6	< 19	220 ± 91
AMS 4	21 ± 9.4	1700 ± 170	< 6.8	< 4.7	< 9.4
AMS 5	< 7.9	2300 ± 200	< 6.3	< 23	< 63
AMS 6	< 3.1	3200 ± 280	< 6.5	< 4.5	< 15
AMS 7	< 5.0	3900 ± 320	< 5.9	< 6.3	< 12
AMS 8	< 7.1	630 ± 75	< 6.2	< 4.1	< 9.6
AMS 9	< 7	1600 ± 140	< 6.2	< 13	< 40
AMS 10[f]	31 ± 17	760 ± 500	<24	<47	110 ± 59
AMS 11[f]	<23	1200 ± 540	<23	<49	<110
AMS 12[f]	26 ± 17	900 ± 500	<25	<44	<93
AMS 13[f]	39 ± 18	<490	<19	<43	<82
AMS 14[f]	<22	1300 ± 460	<21	<48	<85
AMS 15[f]	<38	8500 ± 2800	<41	<86	<190
AMS 16[f]	31 ± 15	670 ± 480	<20	51 ± 32	<89
DCG[c]	9,000,000	2,000,000,000	400,000,000	1,000,000	3,000,000

TABLE 4: Radionuclides in Air, 1994

Sampling Location[b]	Concentration[a] ($pCi/m^3 \times 10^{-6}$) Thorium–228[e]	Thorium–230[e]	Thorium–232[e]	Neptunium–237	Plutonium–238
AMS 1A	37 ± 10	51 ± 13	19 ± 7.8	< 0.53	< 0.31
AMS 2	28 ± 7.8	36 ± 8.7	15 ± 6.0	< 0.28	< 0.05
AMS 3	< 7	< 2.5	< 2.0	NA	< 0.70
AMS 4	34 ± 17	24 ± 12	13 ± 9.8	NA	< 0.17
AMS 5	16 ± 10	11 ± 7.1	< 1.6	NA	< 0.08
AMS 6	13 ± 5.2	17 ± 5.4	5.6 ± 4.7	NA	0.33 ± 0.22
AMS 7	25 ± 12.6	16 ± 8.7	11 ± 8.5	< 0.15	< 2.5
AMS 8	< 8.3	17 ± 14	< 3.5	< 0.46	NA
AMS 9	< 24	< 11	< 11	NA	NA
AMS 10[f]	<130	<52	49 ± 30	<2.8	<0.91
AMS 11[f]	<74	43 ± 22	37 ± 20	<4.5	<1.5
AMS 12[f]	<66	36 ± 21	34 ± 18	<5.3	<1.5
AMS 13[f]	<63	52 ± 26	<27	<3.2	<0.94
AMS 14[f]	<52	64 ± 26	29 ± 19	<3.4	<0.96
AMS 15[f]	120 ± 52	62 ± 31	37 ± 23	<7.6	<1.5
AMS 16[f]	88 ± 47	39 ± 27	40 ± 26	<3	<0.93
DCG[c]	40,000	40,000	7,000	20,000	30,000

TABLE 4: Radionuclides in Air, 1994

Sampling Location[b]	Concentration[a] ($pCi/m^3 \times 10^{-6}$) Plutonium–239/240	Uranium–234	Uranium–235/236[d]	Uranium–238
AMS 1A	< 0.20	110 ± 23	19 ± 6.8	150 ± 25
AMS 2	0.79 ± 0.17	30 ± 14	< 4.6	28 ± 13
AMS 3	3.5 ± 1.4	110 ± 20	< 4.8	120 ± 21
AMS 4	< 0.15	20 ± 14	< 4.7	26 ± 14
AMS 5	< 23	< 7.5	< 4.2	< 6.3
AMS 6	< 0.21	< 16	< 9.8	< 13
AMS 7	< 1.8	< 9.2	< 5.0	< 7.1
AMS 8	NA	67 ± 20	< 7.1	46 ± 18
AMS 9	NA	130 ± 26	< 7.8	140 ± 27
AMS 10[f]	<1.9	<17	<4.3	<18
AMS 11[f]	<3.0	<17	<4.3	<18
AMS 12[f]	<2.1	<17	<4.3	<18
AMS 13[f]	<1.9	25 ± 12	<4.3	19 ± 13
AMS 14[f]	<2.1	<17	<4.3	<18
AMS 15[f]	<4.1	<17	<4.3	<18
AMS 16[f]	<1.6	<17	<4.3	<18
DCG[c]	20,000	90,000	100,000	100,000

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

(b) See Figure 21 on page 76 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).

(d) Concentration of uranium-235 plus uranium-236. AMS samples analyzed for isotropic uranium by alpha spectrometry which measures combined uranium-235 and uranium-236 activities.

(e) Data should be considered an estimate. Laboratory experienced difficulties (low tracer yields, matrix interferences, etc.) in the separation and measurement of this radionuclide.

(f) Reflects monitoring rsults for the period 8/16/94 through 12/28/94. Due to contractual performance problems with one of the commercial laboratories, results from earlier in 1994 were considered suspect and unusable.

NA Data Not Available.

Table 5: Plant 7 Monitoring Results, 1994

Uranium in Air

Sampling Location [a]	Number of Samples	Concentration ($pCi/m^3 \times 10^{-6}$)			Percent of Standard[b]		
		Minimum	Maximum	Median	Minimum	Maximum	Median
PL7-1	31	210	12000	1200	0.21	12	1.2
PL7-2	37	470	13000	1900	0.47	13	1.9
PL7-3	37	760	45000	5800	0.76	45	5.8
PL7-4	33	1100	24000	3300	1.1	24	3.3
PL7-5	32	740	12000	1500	0.74	12	1.5
PL7-6	36	390	21000	3100	0.39	21	3.1

Radionuclides in Air

Sampling Location[a]	Concentration[c] ($pCi/m^3 \times 10^{-6}$)							
	^{226}Ra	^{228}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
PL7-1	<0.85	<7.8	<4.6	<4.3	<2.4	380 ± 52	38 ± 7.5	570 ± 73
PL7-2	<0.66	<6.4	<4.8	190 ± 120	<2.5	860 ± 120	100 ± 19	1000 ± 170
PL7-3	52 ± 28	<7.3	<13	380 ± 73	21 ± 11	1700 ± 210	120 ± 18	2200 ± 270
PL7-4	34 ± 28	<8.0	<4.6	130 ± 120	<2.1	850 ± 130	110 ± 23	1300 ± 200
PL7-5	44 ± 30	30 ± 27	18 ± 16	310 ± 65	21 ± 10	650 ± 150	76 ± 25	1100 ± 230
PL7-6	<0.67	<8.7	<4.6	<3.5	<1.9	1100 ± 190	110 ± 26	1800 ± 290
DCG[d]	**1000000**	**3000000**	**40000**	**40000**	**7000**	**90000**	**100000**	**100000**

(a) See Figure 23B on page 80 for sampling locations.

(b) Standard is 100,000 x 10^{-6} pCi/m^3, as listed in DOE Order 5400.5, "Radiation Protection of the Public and the Environmental," February 1990.

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

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

TABLE 6: Uranium in Grass and Soil, 1994

Sampling Location[a]	Distance from Center of the Site (km)	Grass Uranium Concentration (pCi/g dry)[b]	Soil Uranium Concentration (pCi/g)[b]
Offsite			
24	2.4	0.080 ± 0.007	2.8 ± 0.31
10	2.6	0.044 ± 0.003	2.2 ± 0.22
25	2.7	0.071 ± 0.005	2.6 ± 0.27
17	3.7	0.037 ± 0.005	1.6 ± 0.16
20	3.7	0.071 ± 0.007	0.92 ± 0.093
13	4.2	0.011 ± 0.001	1.8 ± 0.18
38	4.8	0.015 ± 0.002	1.6 ± 0.16
35	9.8	0.040 ± 0.005	1.7 ± 0.18
28	40	0.055 ± 0.006	1.0 ± 0.11

(a) Locations (see Figure 24 on page 82) are listed in order of increasing distance from the center of the Fernald site production area (Plant 4).

(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 7: Uranium in Produce and Soil, 1994

Sampling Location[a]	Distance from Center of the Site (km)	Concentration (pCi/g dry) [b]
Soil		
19	1.4	3.9 ± 0.42
14	1.6	3.0 ± 0.32
9	1.6	2.5 ± 0.27
23	1.6	1.8 ± 0.20
23	1.6	2.2 ± 0.24
24	1.6	1.9 ± 0.21
4	1.9	2.8 ± 0.30
18	1.9	1.6 ± 0.18
18	1.9	1.3 ± 0.14
18	1.9	1.2 ± 0.12
18	1.9	2.2 ± 0.24
6	2.0	2.0 ± 0.22
20	2.1	2.6 ± 0.29
20	2.1	2.0 ± 0.23
15	2.4	2.7 ± 0.29
21	2.4	1.7 ± 0.20
21	2.4	1.5 ± 0.16
30	2.6	2.4 ± 0.23
5	2.9	2.0 ± 0.22
12	3.6	3.0 ± 0.32
13	3.8	2.6 ± 0.28
10	4.0	1.6 ± 0.17
7	4.9	2.4 ± 0.26
28	6.2	2.3 ± 0.24
17	16	2.0 ± 0.21
16	30	2.3 ± 0.24
16	30	2.3 ± 0.24
22	42	1.8 ± 0.19
22	42	2.1 ± 0.22

Sampling Location[a]	Concentration (pCi/g dry)[b]
Tomatoes	
9	0.0032 ± 0.00028
4	0.0038 ± 0.00023
15	0.0017 ± 0.00030
5	0.0099 ± 0.00084
12	0.011 ± 0.0037
13	0.0084 ± 0.0018
10	0.0053 ± 0.00045
7	0.051 ± 0.0040
28	0.0018 ± 0.00031
17	0.011 ± 0.0011
16	0.0019 ± 0.00024
Green (G) & Red (R) Peppers	
4 (R)	0.0034 ± 0.0069
4 (G)	0.0045 ± 0.00029
15 (G)	0.0017 ± 0.00014
5 (G)	0.016 ± 0.0012
10 (G)	0.0019 ± 0.00024
7 (G)	0.011 ± 0.00091
17 (G)	0.019 ± 0.0025

Sampling Location[a]	Concentration (pCi/g dry)[b]
Corn	
19	0.0036 ± 0.00047
23	0.00059 ± 0.000041
4	0.0035 ± 0.00062
18	0.00094 ± 0.00023
6	0.0011 ± 0.00009
20	0.0013 ± 0.00012
21	0.0011 ± 0.00007
15	0.0011 ± 0.000091
5	0.0076 ± 0.00056
7	0.0020 ± 0.00011
17	0.0019 ± 0.00014
22	0.0043 ± 0.0072

TABLE 7: Uranium in Produce and Soil, 1994

Sampling Location[a]	Concentration (pCi/g dry)[b]
Potatoes (P) & Onions (O)	
15 (P)	0.0063 ± 0.00050
12 (P)	0.0014 ± 0.00009
13 (P)	0.012 ± 0.0010
7 (O)	0.0028 ± 0.00031
17 (O)	0.017 ± 0.00013
17 (P)	0.0098 ± 0.00073
Apples	
13	0.0010 ± 0.00016
7	0.0075 ± 0.00071
17	0.0078 ± 0.00061
Soybeans	
14	0.0014 ± 0.00015
23	0.0020 ± 0.00014
24	0.0013 ± 0.00012
18	0.00081 ± 0.000079
18	0.0022 ± 0.00023
18	0.000058 ± 0.015
20	0.0046 ± 0.00033
21	0.0010 ± 0.000067
22	0.016 ± 0.0013

Sampling Location[a]	Concentration (pCi/g dry)[b]
Cucumber (C), Eggplant (E), Green Beans (G), & Squash (S)	
4 (C)	0.0047 ± 0.00027
4 (E)	0.012 ± 0.00076
6 (G)	0.015 ± 0.0036
15 (G)	0.0022 ± 0.00021
5 (E)	0.016 ± 0.0013
7 (E)	0.012 ± 0.0016
17 (E)	0.0061 ± 0.00091
17 (G)	0.0095 ± 0.00072
Cabbage	
4	0.0021 ± 0.0002
5	0.011 ± 0.00082
17	0.020 ± 0.0016

(a) Locations (see Figure 26 on page 85) are listed in order of increasing distance from the center of the Fernald site production area (Plant 4).

(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: Uranium in Milk, 1994

Concentration of Uranium

Month	Local Dairy (pCi/L)[a]	Background Dairy[b] (pCi/L)[a]	QC Spike Recovery (pCi/L)[a] Background Dairy	
			Expected	Measured
January	<0.26	<0.3	NA[d]	NA[d]
February	<0.18	0.48 ± 0.12	NA	NA
March	0.86 ± 0.14	0.24 ± 0.10	NA	NA
April	<0.22	<0.15	NA	NA
May	<0.17	<0.16	NA	NA
June	<0.18	<0.15	NA	NA
July	(c)	(c)	NA	NA
August	<0.17	<0.16	NA	NA
September	0.26 ± 0.10	0.28 ± 0.10	NA	NA
October	<0.13	<0.23	5.0	4.5 ± 0.4
November	0.027 ± 0.066	0.059 ± 0.066	4.7	4.4 ± 0.3
December	0.16 ± 0.08	0.14 ± 0.08	5.0	4.5 ± 0.34

(a) To obtain Bq/L, multiply pCi/L by 0.037. Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(b) Dairy is about 37 km (23 miles) WSW of the Fernald site.

(c) Sample invalidated due to error in laboratory processing.

(d) Results not available. See page 164 for discussion.

TABLE 9: Dairy Analyses, 1994

Radionuclides in Milk

Radionuclide	Local Dairy (pCi/L)[a]	Background Dairy[b] (pCi/L)[a]
Cesium–137	<10	2.6 ± 3.7
Radium–226	0.95 ± 0.39	3.3 ± 0.62
Radium–228	0.27 ± 1.0	<1.0
Strontium–90	0.94 ± 1.1	1.4 ± 0.84
Technetium–99	<273	<33
Thorium–228	<0.84	<0.72
Thorium–230	0.15 ± 0.33	<0.34
Thorium–232	<0.27	<0.22
Uranium–234	<0.13	<0.094
Uranium–235/236	<0.10	<0.075
Uranium–238	<0.78	0.018 ± 0.045

Radionuclides in Feed Supplement

Radionuclide	Local Dairy Feed Supplement (pCi/g)	Background Dairy Feed Supplement (pCi/g)
Strontium–90	0.033 ± 0.23	0.014 ± 0.22
Technetium–99	0.20 ± 1.5	0.44 ± 1.1
Cesium–137	0.011 ± 0.054	<0.067
Radium–226	<0.17	<0.15
Radium–228	0.060 ± 0.18	0.027 ± 0.16
Thorium–228	0.016 ± 0.53	0.018 ± 0.54
Thorium–230	0.042 ± 0.063	0.34 ± 0.087
Thorium–232	<0.029	<0.036
Uranium–234	0.24 ± 0.60	0.4 ± 0.074
Uranium–235	<0.037	<0.033
Uranium–238	0.22 ± 0.055	0.39 ± 0.071

Radionuclides in Hay

Radionuclide	Local Hay (pCi/g)	Background Hay (pCi/g)
Strontium–90	0.18 ± 0.20	0.21 ± 0.19
Technetium–99	0.29 ± 1.5	0.32 ± 1.7
Cesium–137	0.042 ± 0.16	0.095 ± 0.17
Radium–226	<0.47	<0.46
Radium–228	0.069 ± 0.64	0.44 ± 0.55
Total Uranium	0.013 ± 0.00078	0.0027 ± 0.00016

(a) To obtain Bq/L, multiply pCi/L by 0.037. Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(b) Dairy is about 37 km (23 miles) WSW of the Fernald site.

TABLE 10: Environmental TLD Direct Radiation Measurements, 1994

Location Description[a]	Location Number	1994 Dose Rate (mrem/yr)[b, c]	1993 Dose Rate (mrem/yr)[b, c]
Fenceline			
AMS 1[d]	1	—	64 ± 2.4
AMS 2	2	70 ± 1.5	72 ± 1.5
AMS 3	3	61 ± 1.5	65 ± 2.1
AMS 4	4	64 ± 1.2	67 ± 1.3
AMS 5	5	65 ± 5.9	66 ± 1.1
AMS 6	6	67 ± 2.5	68 ± 0.9
AMS 7	7	62 ± 1.5	64 ± 1.3
Site fenceline near K-65 silos	13	66 ± 1.5	69 ± 1.3
Site fenceline near K-65 silos	14	63 ± 1.2	65 ± 1.2
Site fenceline near K-65 silos	15	67 ± 1.9	73 ± 9.1
Site fenceline near K-65 silos	16	66 ± 1.4	68 ± 1.2
Site fenceline near K-65 silos	17	62 ± 2.5	67 ± 0.9
Onsite			
AMS 1A[e]	1A	110 ± 2.3	120 ± 2.0
AMS 8	8	63 ± 1.6	67 ± 2.0
AMS 9	9	89 ± 4.2	91 ± 2.7
K-65 perimeter fence	22	320 ± 17	250 ± 13
K-65 perimeter fence	23	300 ± 14	260 ± 10
K-65 perimeter fence	24	190 ± 6.1	160 ± 2.9
K-65 perimeter fence	25	260 ± 9.6	200 ± 6.4
K-65 perimeter fence	26	170 ± 6.8	140 ± 4.3
OSH Building, Room 218[f]	32	49 ± 1.2	50 ± 1.0
Offsite			
AMS 10	10	50 ± 0.9	52 ± 1.1
AMS 11	11	63 ± 1.4	62 ± 1.0
AMS 13	12	56 ± 1.9	57 ± 0.7
Westwood, OH	18	65 ± 1.3	69 ± 1.0
Brookville, IN	19	58 ± 1.1	61 ± 0.6
AMS 15, Miamitown	20	59 ± 2.4	54 ± 3.0
AMS 16, University of Cincinnati	21	57 ± 1.2	56 ± 0.9
AMS 12	27	57 ± 1.0	61 ± 0.8
Beta Building, St. Rt. 128[f]	30	57 ± 0.9	53 ± 1.2
Background in Fairfield[g]	33	66 ± 1.1	—

(a) See Figure 27 on page 88 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) 1993 dose for AMS 1 is based on two quarterly measurements.

(e) 1993 dose for AMS 1A is based on one quarterly measurement.

(f) TLDs 30 and 32 are located inside buildings and are used as control locations.

(g) Background location added to program in 1994.

TABLE 11: Radionuclides Discharged to the Great Miami River, 1994

Manhole-175

Radionuclide[a]	Total Curies 1994	1994 Average Concentration (pCi/L)[b]	Standard[c] pCi/L	Percent of Standard[d]
Actinium–228[e]	< 0.00083	<1.9	60,000	0.0032
Radium–224[f]	0.00011	0.25	400	0.06
Radium–226	0.000052	0.12	100	0.12
Radium–228	< 0.00083	<1.9	100	1.9
Thorium–228	0.00011	0.250	400	0.06
Thorium–230	< 0.000086	<0.20	300	< 0.07
Thorium–231[g]	0.0025	5.6	100,000	0.0056
Thorium–232	< 0.000014	<0.032	50	< 0.06
Thorium–234[h]	0.068	156.3	10,000	1.6
Uranium–234	0.047	107.3	500	21.46
Uranium–235	0.0025	5.6	600	0.93
Uranium–236	0.0017	4.0	500	0.80
Uranium–238	0.068	156.3	600	26.05

South Plume (SP3)

Radionuclide[a]	Total Curies 1994	1994 Average Concentration (pCi/L)[b]	Standard[c] pCi/L	Percent of Standard[d]
Actinium–228[e]	<0.0062	<2.08	60,000	0.0035
Radium–224[f]	<0.00012	<0.04	400	0.0095
Radium–226	0.00072	0.24	100	0.2429
Radium–228	<0.0062	<2.08	100	2.0838
Thorium–228	<0.00012	<0.04	400	0.0095
Thorium-230	<0.00036	<0.12	300	0.0396
Thorium–231[g]	0.000090	0.03	100,000	0.0000
Thorium–232	<0.000090	<0.03	50	0.0663
Thorium–234[h]	0.049	16.39	10,000	0.1639
Uranium–234	0.040	13.45	500	2.6897
Uranium–235	0.0022	0.76	600	0.1267
Uranium–236	0.0015	0.44	500	0.0871
Uranium–238	0.049	16.39	600	2.7321

(a) Radionuclide concentrations in the plant effluent discharged to the Great Miami River through the effluent pipeline are determined from monthly or quarterly composites of daily, 24-hour continuous samples at Discharge 001 (Manhole-175) and SP3.

(b) Averages are flow-weighted. To obtain Bq/L, multiply pCi/L by 0.037.

(c) As stated in DOE Order 5400.5, "Radiation Protection of the Public and Environment."

(d) Percent of standard relates to the average concentration. Where less than (<) is reported, the maximal possible value is assumed.

(e) Calculated based on radioactive decay equilibrium with radium–228.

(f) Calculated based on radioactive decay equilibrium with thorium–228.

(g) Calculated based on radioactive decay equilibrium with uranium-235.

(h) Calculated based on radioactive decay equilibrium with uranium–238.

TABLE 12: Radionuclides in Surface Water, 1994

Parameter	Sampling Location[a]	Number of Samples	Concentration (pCi/L)[b] Minimum	Maximum	Average	Standards (pCi/L)[c]	Percent of Standard Minimum	Maximum	Average
Great Miami River									
Total Uranium									
Upstream of Effluent Line	W1	40	0.68	1.4	0.91	550	0.11	0.25	0.16
Downstream of Effluent Line	W3	41	0.74	1.6	1.0	550	0.12	0.29	0.18
Downstream of Effluent Line	W4	40	0.74	1.5	1.0	550	0.13	0.27	0.18
Radium–226[d]									
Upstream of Effluent Line	W1	12	0.07	0.18	0.14	100	0.07	0.18	0.14
Downstream of Effluent Line	W3	12	0.08	0.17	0.14	100	0.08	0.17	0.14
Downstream of Effluent Line	W4	12	0.12	0.20	0.14	100	0.12	0.20	0.14
Radium–228[d]									
Upstream of Effluent Line	W1	12	< 2.2	5.8	< 3.2	100	< 2.2	5.8	< 3.2
Downstream of Effluent Line	W3	12	< 2.3	8.2	< 3.9	100	< 2.3	8.2	< 3.9
Downstream of Effluent Line	W4	12	< 2.3	9.4	< 4.1	100	< 2.3	9.4	< 4.1
Strontium–90[d]									
Upstream of Effluent Line	W1	2	< 0.5	< 0.5	< 0.5	1,000	< 0.05	< 0.05	< 0.05
Downstream of Effluent Line	W3	2	< 0.5	< 0.5	< 0.5	1,000	< 0.05	< 0.05	< 0.05
Downstream of Effluent Line	W4	2	< 0.5	< 0.5	< 0.5	1,000	< 0.05	< 0.05	< 0.05
Cesium–137[d]									
Upstream of Effluent Line	W1	2	< 3.2	< 3.2	< 3.2	3,000	< 0.11	< 0.11	< 0.11
Downstream of Effluent Line	W3	2	< 3.2	< 3.2	< 3.2	3,000	< 0.11	< 0.11	< 0.11
Downstream of Effluent Line	W4	2	< 3.2	< 3.2	< 3.2	3,000	< 0.11	< 0.11	< 0.11
Technetium–99[d]									
Upstream of Effluent Line	W1	2	< 4.0	< 4.0	< 4.0	100,000	< 0.004	< 0.004	< 0.004
Downstream of Effluent Line	W3	2	< 4.0	< 4.0	< 4.0	100,000	< 0.004	< 0.004	< 0.004
Downstream of Effluent Line	W4	2	< 4.0	< 4.0	< 4.0	100,000	< 0.004	< 0.004	< 0.004

TABLE 12: Radionuclides in Surface Water, 1994

Parameter	Sampling Location[a]	Number of Samples	Concentration (pCi/L)[b] Minimum	Maximum	Average	Standards (pCi/L)[c]	Percent of Standard Minimum	Maximum	Average
Paddys Run									
Total Uranium									
Upstream of the Site	W5	37	0.41	2.0	0.77	550	0.07	0.36	0.14
Onsite	W9	28	0.41	3.0	1.4	550	0.07	0.55	0.25
Onsite	W-10 US	19	1.4	170	18	550	0.25	31	3.3
Onsite	W10	19	1.5	180	21	550	0.27	33	3.8
Onsite	W-10 DD	27	120	950	420	550	22	170	76
Onsite	W-10 DS	18	1.7	140	24	550	0.31	25	4.3
Onsite	W11	17	2.1	10	5.1	550	0.38	1.8	0.92
Downstream of the Site	W7	16	2.0	9.5	4.1	550	0.36	1.7	0.75
Downstream of the Site	W8	21	1.6	8.0	3.4	550	0.29	0.62	1.6
Radium–226[d]									
Upstream of the Site	W5	6	0.03	0.01	0.06	100	0.03	0.10	0.06
Downstream of the Site	W7	6	0.04	0.11	0.06	100	0.04	0.11	0.06
Downstream of the Site	W8	1	0.14	0.14	0.14	100	0.14	0.14	0.14
Radium–228[d]									
Upstream of the Site	W5	6	< 2.3	< 3.4	< 2.8	100	< 2.3	< 3.4	< 2.8
Downstream of the Site	W7	6	< 2.2	5.7	< 3.2	100	< 2.2	5.7	< 3.2
Downstream of the Site	W8	1	< 3.4	< 3.4	< 3.4	100	< 3.4	< 3.4	< 3.4

(a) See Figure 32 on page 98 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 Fernald site 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 daily samples from W1 and W3,
- One-month composites of weekly samples from W4 and either W7 or W8,
- Two-month composites of weekly samples from W5, and
- Semiannual 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, 1994[a]

Radionuclide	Number of Samples[e]	Concentration (pCi/g dry)[b,c] Minimum	Maximum	Average for All Samples
Great Miami River North of the Effluent Line[d]				
Total Uranium	3	1.1 ± 0.11	2.0 ± 0.21	1.5
Great Miami River South of the Effluent Line, and North of Paddys Run[d]				
Total Uranium	2	0.90 ± 0.09	1.01 ± 0.11	0.96
Great Miami River South of Paddys Run[d]				
Total Uranium	4	1.6 ± 0.16	1.6 ± 0.16	1.6
Paddys Run Background (North of S.R. 126)				
Radium–226	5	0.65 ± 0.12	0.98 ± 0.13	0.86
Thorium–228	5	0.62 ± 0.26	1.2 ± 0.51	0.84
Thorium–230	5	0.73 ± 0.30	1.4 ± 0.56	1.0
Thorium–232	5	0.50 ± 0.21	0.97 ± 0.41	0.72
Total Uranium	5	1.1 ± 0.12	2.0 ± 0.21	1.6
Paddys Run North of the Storm Sewer Outfall Ditch				
Radium–226	13	0.46 ± 0.08	1.3 ± 0.14	0.88
Thorium–228	13	0.31 ± 0.12	1.5 ± 0.54	0.81
Thorium–230	13	0.61 ± 0..36	3.4 ± 1.2	1.3
Thorium–232	13	0.29 ± 0.11	1.4 ± 0.49	0.69
Total Uranium	13	1.2 ± 0.13	8.0 ± 0.82	2.3
Storm Sewer Outfall Ditch				
Radium–226	9	0.59 ± 0.09	0.94 ± 0.12	0.77
Thorium–228	9	0.42 ± 0.18	0.84 ± 0.31	0.64
Thorium–230	9	0.75 ± 0.31	1.9 ± 0.77	1.1
Thorium–232	9	0.39 ± 0.17	0.79 ± 0.32	0.54
Total Uranium	9	2.2 ± 0.10	8.1 ± 0.36	4.0
Paddys Run South of Storm Sewer Outfall Ditch				
Total Uranium	13	1.1 ± 0.04	4.2 ± 0.16	1.7

(a) See Figure 34 on page 102 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 sample locations.

(e) Includes QA samples.

TABLE 14: Uranium Concentrations in Fish from the Great Miami River, 1994

Sampling Location[a]	Family[b]	Number of Samples	Concentration pCi/g[c]		
			Minimum	Maximum	Geometric Mean
RM 38	1	7	0.0026	0.0133	0.0053
Upstream of	2	9	0.0017	0.027	0.0037
the Hamilton Dam	3	2	0.0036	0.004	0.0038
	Location Summary	**18**	**0.0017**	**0.027**	**0.0042**
RM 24	1	6	0.0008	0.0324	0.0053
At the Effluent Line	2	8	0.0007	0.011	0.0029
	3	7	0.0010	0.0104	0.0575
	Location Summary	**21**	**0.0007**	**0.032**	**0.0036**
RM 19	1	4	0.0027	0.0418	0.0044
At confluence of	2	6	0.0014	0.0115	0.0050
Paddys Run and	3	17	0.0012	0.0389	0.0089
the Great Miami River	**Location Summary**	**27**	**0.0012**	**0.0389**	**0.0114**

(a) See Figure 35 on page 104 for sampling locations.

(b) Family:
1 = Cyprinidae (carp and shiner)
2 = Catostomidae (carpsucker, redhorse, quillback, and buffalo)
3 = *Clupeidae (gizzard shad)*

(c) All concentrations are reported in dry weight. Multiply by 0.037 to obtain Bq/g (dry weight).

TABLE 15: NPDES Data, 1994

Sampling Location and Parameter	Units[a]	Monitoring Requirements	Daily Monitoring Results Minimum	Maximum	Average[b]	Permit Limits[c] Daily Maximum	Monthly Average	Percent Compliance[d]
Discharge 001 (MH175 to Great Miami)								
Flow Rate	MGD	Continuous	0.003	1.820	0.317	N/A	N/A	N/A
pH	S.U.	Continuous	3.2	9.8	NA	Range = 6.5 to 9.0		100.0
Dissolved Oxygen	mg/L	Weekly/Grab	4.1	14.2	8.5	Minimum = 5.0		95.74
Suspended Solids	mg/L	Wk/24hr Comp	< 2	76	7	45	30	98.33
Oil & Grease	mg/L	Weekly/Grab	< 5	7.7	5.1	15	15	100.0
Copper	µg/L	Wk/24hr Comp	< 14.0	19.2	14.6	94	23	100.0
BOD-C	mg/L	Wk/24hr Comp	0.26	6.91	2.08	30	20	100.0
Suspended Solids	kg/day	Wk/24hr Comp	< 0.6359	79.5418	7.5748	149	99	100.0
Oil & Grease	kg/day	Weekly/Grab	< 1.5897	26.5139	5.2155	50	50	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0054	0.0923	0.0163	0.31	0.077	100.0
BOD-C	kg/day	Wk/24hr Comp	0.2382	14.3438	2.5891	99	66	100.0
							Percent Compliance	**99.76**
Discharge 002 (Spillway to Paddys Run)								
Flow Rate	MGD	Estimate	The Stormwater Retention Basin did not overflow during 1994.			N/A	N/A	N/A
pH	S.U.	Event/Grab				Range = 6.5 to 9.0		100.0
Suspended Solids	mg/L	Event/Comp				100	N/A	100.0
Chromium (total)	µg/L	Event/Comp				3,986	N/A	100.0
Chromium (+6)	µg/L	Event/Comp				19	N/A	100.0
Oil & Grease	mg/L	Event/Grab				15	N/A	100.0
Copper	µg/L	Event/Comp				45	N/A	100.0
Nickel	µg/L	Event/Comp				3,137	N/A	100.0
Silver	µg/L	Event/Comp				11.6	N/A	100.0
							Percent Compliance	**100.0**

TABLE 15: NPDES Data, 1994

Sampling Location and Parameter	Units[a]	Monitoring Requirements	Daily Monitoring Results			Permit Limits[c]		Percent Compliance[d]
			Minimum	Maximum	Average[b]	Daily Maximum	Monthly Average	
Discharge 601 (Sewage Treatment Plant)								
Flow Rate	MGD	Continuous	0.001	0.306	0.124	N/A	N/A	N/A
Suspended Solids	mg/L	Wk/24hr Comp	< 2	15	3	40	20	100.0
Fecal Coliform[e]	#Col/100 ml	Wk/24hr Comp	0	1,700	13	2,000	1,000	100.0
BOD-5	mg/L	Wk/24hr Comp	0.72	19.20	4.70	40	20	100.0
Suspended Solids	kg/day	Wk/24hr Comp	< 0.2120	8.8001	1.2926	19	9.5	100.0
BOD-5	kg/day	Wk/24hr Comp	0.3516	11.2642	2.5188	19	9.5	100.0
							Percent Compliance	**100.0**
Discharge 602 (General Sump)								
Flow Rate	MGD	Continuous	0.010	0.130	0.053	N/A	N/A	N/A
Chromium (total)	µg/L	Wk/24hr Comp	< 6.0	11.5	< 6.4	54	41	100.0
Copper	µg/L	Wk/24hr Comp	< 14.0	16.1	< 14.0	111	66	100.0
Nickel	µg/L	Wk/24hr Comp	< 17.0	110.0	< 22.9	165	91	100.0
Chromium (total)	kg/day	Wk/24hr Comp	< 0.0006	0.0025	< 0.0011	0.013	0.010	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0015	0.0058	< 0.0024	0.027	0.016	100.0
Nickel	kg/day	Wk/24hr Comp	< 0.0018	0.0167	< 0.0039	0.040	0.022	100.0
							Percent Compliance	**100.0**

TABLE 15: NPDES Data, 1994

Sampling Location and Parameter	Units[a]	Monitoring Requirements	Daily Monitoring Results			Permit Limits[c]		Percent Compliance[d]
			Minimum	Maximum	Average[b]	Daily Maximum	Monthly Average	
Discharge 605 (Bioreactor)								
Flow Rate	MGD	Continuous	0.025	0.205	0.104	N/A	N/A	N/A
Suspended Solids	mg/L	Wk/24hr Comp	< 2	40	9	45	30	100.0
Nitrate-Nitrogen	mg/L	Wk/24hr Comp	< 0.1	26.0	2.7	145	72.7	100.0
Chromium (total)	µg/L	Wk/24hr Comp	< 6.0	14.6	6.5	27	12	100.0
Copper	µg/L	Wk/24hr Comp	< 14.0	23.2	14.9	90	45	100.0
Nickel	µg/L	Wk/24hr Comp	< 17.0	27.7	17.3	42	29	100.0
BOD-5	mg/L	Wk/24hr Comp	0.72	26.52	4.20	45	30	100.0
Suspended Solids	kg/day	Wk/24hr Comp	< 0.3028	20.5904	3.4307	38	26	100.0
Nitrate-Nitrogen	kg/day	Wk/24hr Comp	< 0.0473	7.8728	1.0827	124	62	100.0
Chromium (total)	kg/day	Wk/24hr Comp	< 0.0009	0.0072	0.0026	0.022	0.0101	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0021	0.0123	0.0060	0.077	0.0387	100.0
Nickel	kg/day	Wk/24hr Comp	< 0.0026	0.0137	0.0069	0.036	0.025	100.0
BOD-5	kg/day	Wk/24hr Comp	0.1908	13.6514	1.6812	38	26	100.0
							Percent Compliance	**100.0**

(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) Average value has been calculated as a geometric mean.

N/A Not Applicable

TABLE 16A: Uranium in Private Wells, 1994

Well Number[a]	Number of Samples	Concentration (pCi/L)[b]			Percent of Standard[c]		
		Minimum	Maximum	Average	Minimum	Maximum	Average
3	12	< 0.068	0.14	< 0.068	< 0.50	1.0	< 0.50
4	12	0.74	1.6	1.1	5.5	11	8.5
8	12	0.47	0.68	0.54	3.5	5.0	4.0
9	12	0.81	1.1	0.95	6	8.5	7.0
10	12	0.27	0.68	0.34	2.0	5.0	2.5
11	12	1.0	1.7	1.2	7.5	13	9.0
12[d]	12	26	110	63	200	850	470
13[d]	25	45	68	60	330	500	450
14	23	1.1	1.5	1.3	8.0	11	9.5
15[d]	12	110	150	130	850	1,100	990
16	12	0.34	0.68	0.47	2.5	5.0	3.5
18	12	0.27	0.41	0.34	2.0	3.0	2.5
19	12	< 0.068	0.068	< 0.068	< 0.50	0.50	<0.50
21	12	0.14	1.4	0.34	1.0	10	2.5
22	12	0.54	1.5	0.74	4.0	11	5.5
23	12	0.27	0.68	0.54	2.0	5.0	4.0
24	12	0.27	0.54	0.34	2.0	4.0	2.5
25	4	0.20	0.27	0.27	1.5	2.0	2.0
26	12	< 0.068	0.27	< 0.09	< 0.50	2.0	< 0.67
28	4	0.61	0.68	0.61	4.5	5.0	4.5
29	12	1.1	1.4	1.2	8.0	11	9.0
30	4	0.34	0.34	0.34	2.5	2.5	2.5
32	12	< 0.068	<0.068	< 0.068	<0.50	0.50	< 0.50
33	12	0.20	0.41	0.34	1.5	3.0	2.5
34	11	0.88	5.7	2.2	6.5	43	16
35	12	0.34	1.3	1.1	2.5	9.5	8.5
36	12	0.54	0.88	0.74	4.0	6.5	5.5
37	1	—	—	1.1	—	—	8.0
38[e]	3	< 0.068	< 0.068	< 0.068	< 0.50	< 0.50	< 0.50
39[d]	12	2.8	5.5	3.8	21	41	28
40[d]	12	1.7	3.1	2.1	12	23	16
41	12	0.20	0.50	0.34	1.5	4.0	2.5
55	4	0.27	0.34	0.34	2.0	2.5	2.5

(a) See Figure 36 on page 110 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 USEPA standard of 13.5 pCi/L (20 ppb).

(d) These wells are used for monitoring purposes only.

(e) Sample collected from a cistern.

TABLE 16B: Gross Alpha, Radium–226, and Radium–228 Data Greater than or Equal to Proposed Drinking Water Standards, 1993

Well	Location	Sample Date	Concentration (pCi/L)
	Gross Alpha[a]		
1042	W of Production Area	April 22	27
1934	Waste Pit Area	May 13	24
1937	W Side of Lime Sludge Pond	June 1	43
1941	Southwest of SWRB	April 30	314
1941	Southwest of SWRB	May 28	609
1941	Southwest of SWRB	December 28	1073
1942	Southwest of SWRB	May 1	220
1942	Southwest of SWRB	May 28	1080
1942	Southwest of SWRB	December 28	21
1952	NW of Production Area	May 15	26
1954	Southwest of SWRB	June 22	38
2045	South Plume, Onsite	December 15	206
2046	Southwest of SWRB	May 11	319
2046	Southwest of SWRB	December 20	110
2049	South Plume, Onsite	May 10	60
2049	South Plume, Onsite	December 17	30
2049	South Plume, Onsite	December 17	22
2106	South Plume, Onsite	July 26	31
2106	South Plume, Onsite	September 16	25
2385	South of SWRB	April 28	50
2385	South of SWRB	December 16	79
2945	Southwest of SWRB	April 28	1410
2945	Southwest of SWRB	December 28	664
2954	Southwest of SWRB	June 21	781
2954	Southwest of SWRB	December 27	905
11085	N of Active Flyash Pile	June 16	198
21033	South Plume, Onsite	June 17	23
21033	South Plume, Onsite	December 18	25
	Radium–226[b]		
1892	K-65 Silo Area	April 23	36
	Radium–228[b]		
1892	K-65 Silo Area	April 23	24

(a) Proposed USEPA standard for gross alpha is 15 pCi/L.

(b) Proposed USEPA standard for radium–226 and radium–228 is 20 pCi/L.

TABLE 16C: Gross Alpha, Radium–226, and Radium–228 Data Greater than or Equal to Proposed Drinking Water Standards, 1994

Well	Location	Sample Date	Concentration (pCi/L)
	Gross Alpha[a]		
1032	K-65 Silo Area	May 10	43
1719	Waste Pit Area	January 3	217
1891	K-65 Silo Area	May 12	39
1893	West of Silos	May 12	19
2106	South Plume, Onsite	January 25	35
2754	East Field Area	January 25	22
3069	South Plume, Onsite	January 26	17
3069	South Plume, Onsite	July 6	15
3069	South Plume, Onsite	September 7	18
3398	South Field Area	January 25	28
11075	E of Heavy Equip. Build.	May 14	249
11076	NW of Clearwell	May 19	190
11076	NW of Clearwell	May 21	156
11080	Storm Water Ret. Basin	May 12	96
11080	Storm Water Ret. Basin	May 12	183
	Radium–226[b]		
11077	Waste Pit Area	May 22	72
	Radium–228[b]		
4424	East Field Area	April 17	23

(a) Proposed USEPA standard for gross alpha is 15 pCi/L.

(b) Proposed USEPA standard for radium–226 and radium–228 is 20 pCi/L.

TABLE 17: Comprehensive Groundwater Samples with Uranium Concentrations above USEPA Proposed Standard, 1994(a)

Well(b)	Location	Sample Date	Concentration (pCi/L)(c)	Concentration (ppb)
	Total Uranium			
1032	K-65 Silo Area	May 10	122	180
1033	K-65 Silo Area	May 13	22	32
1891	K-65 Silo Area	May 12	29	43
1892	K-65 Silo Area	May 13	378	560
1893	East Field	May 12	62	98
2106	South Plume, Onsite	Sept. 6	36	54
2106	South Plume, Onsite	Sept. 6	32	48
3069	South Plume, Onsite	July 5	24	35
3069	South Plume, Onsite	Sept. 7	43	64
3069	South Plume, Onsite	January 26	24	35
3070	East Field	January 25	54	80
3398	Southern Bndry of Site	January 25	22	33
11075	Production Area	May 14	676	1000
11076	Waste Pit Area	May 21	554	820
11080	Stormwater Retn Basin	May 12	405	600
11080	Stormwater Retn Basin	May 12	358	530

(a) Proposed USEPA standard of 13.5 pCi/L (20 ppb).

(b) See figures 41A through 44 on pages 119 through 124 for well locations.

(c) To obtain Bq/L, multiply pCi/L by 0.037.

TABLE 18: Metals in Private Wells, 1994

Metals Listed in Primary Drinking Water Regulations

Well Number[a]	Concentration (mg/L)						
	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Selenium
3	< 0.050	0.434	< 0.050	< 0.01	< 0.025	< 0.003	< 0.005
4	<0.1	< 0.20	< 0.005	< 0.01	< 0.0266	0.0036	< 0.005
8	< 0.1	< 0.20	< 0.005	< 0.01	< 0.025	< 0.003	< 0.005
9	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.050
10	< 0.050	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0035	< 0.0050
11	< 0.050	< 0.20	< 0.0050	< 0.010	0.062	0.0053	< 0.0050
12	< 0.050	< 0.20	< 0.0050	< 0.010	< 0.025	0.0116	< 0.0050
14	< 0.050	< 0.20	< 0.0050	< 0.005	< 0.025	< 0.003	< 0.0050
15	< 0.1	< 0.20	< 0.0050	< 0.010	0.055	0.0042	< 0.0050
16	< 0.1	< 0.20	< 0.0050	< 0.010	0.037	0.0047	< 0.005
18	< 0.05	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
19	0.063	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.003	< 0.0050
21	< 0.05	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
22	< 0.05	< 0.20	< 0.0050	< 0.010	0.0258	< 0.003	< 0.0050
23	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
24	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.0048	< 0.005
25	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.050
26	< 0.050	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.003	< 0.0050
28	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.005	< 0.0050
29	< 0.05	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.003	< 0.0050
30	< 0.05	< 0.20	< 0.0050	< 0.010	0.0527	0.0067	< 0.0050
32	< 0.05	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.003	< 0.0050
33	< 0.05	< 0.20	< 0.0050	< 0.010	0.1852	0.0053	< 0.0050
34	< 0.010	< 0.20	< 0.0050	< 0.010	0.1669	0.0038	< 0.050
35	< 0.05	< 0.20	< 0.0050	< 0.010	< 0.025	0.0055	< 0.0050
36	< 0.010	< 0.20	< 0.0050	< 0.010	0.172	< 0.003	< 0.050
37	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
39	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.0032	< 0.0050
40	< 0.1	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
41	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.050
55	< 0.05	< 0.20	< 0.0050	< 0.010	< 0.025	0.0032	< 0.0050
Primary Standard[c]	**0.05**	**2.0**	**0.005**	**0.1**	**1.0[d]**	**0.015[d]**	**0.05**

TABLE 18: Metals in Private Wells, 1994

Metals Listed in Secondary Drinking Water Regulations

Well Number[a]	Concentration (mg/L) Iron	Manganese	Silver	Zinc
3	3.417	0.0176	< 0.01	< 0.020
4	< 0.1	< 0.015	< 0.010	0.0586
8	< 0.1	0.1085	< 0.010	0.0408
9	< 0.10	0.2233	< 0.010	0.0227
10	3.303	0.2779	< 0.010	< 0.020
11	< 0.10	< 0.015	< 0.010	0.2122
12	2.525	0.1906	< 0.010	0.6248
14	0.7427	0.342	< 0.010	0.022
15	< 0.1	< 0.015	< 0.010	0.0226
16	2.392	0.3736	< 0.010	0.0345
18	2.558	0.2237	< 0.010	< 0.020
19	1.057	0.2405	< 0.010	< 0.02
21	0.457	0.2356	< 0.010	0.0223
22	2.605	0.2736	< 0.010	< 0.020
23	< 0.1	< 0.015	< 0.010	< 0.020
24	< 0.10	< 0.015	< 0.010	0.0232
25	< 0.10	< 0.015	< 0.010	< 0.020
26	3.577	0.2975	< 0.010	0.0219
28	< 0.1	< 0.015	< 0.01	0.0335
29	< 0.1	0.0854	< 0.010	0.020
30	< 0.10	< 0.015	< 0.010	< 0.020
32	0.7697	0.2908	< 0.01	< 0.020
33	< 0.10	< 0.015	< 0.010	< 0.020
34	0.9115	0.0168	< 0.010	0.0521
35	< 0.10	< 0.015	< 0.010	0.0498
36	< 0.10	< 0.015	< 0.010	0.0618
37	0.1587	< 0.015	< 0.010	< 0.020
39	0.1674	< 0.015	< 0.010	< 0.020
40	< 0.1	< 0.015	< 0.010	0.109
41	< 0.10	< 0.015	< 0.010	0.113
55	< 0.1	< 0.015	< 0.010	< 0.020
Secondary Standard[c]	**0.3**	**0.05**	**0.01**	**5.0**

TABLE 18: Metals in Private Wells, 1994

Metals Not Listed in Drinking Water Regulations

Well Number(a)	Concentration (mg/L) Calcium	Magnesium	Nickel	Potassium	Sodium
3	75.5	22.45	< 0.040	< 5.0	28.72
4	100.4	56.69	< 0.040	< 5.0	44.38
8	78.41	27.39	< 0.040	< 5.0	18.430
9	76.89	26.89	< 0.040	< 5.0	32.9
10	112.9	28.4	< 0.040	< 5.0	11.53
11	80.56	22.5	< 0.040	< 5.0	9.734
12	76.3	18.970	< 0.040	< 5.0	10.94
14	126.9	34.39	< 0.040	8.431	18.75
15	66.57	20.27	< 0.040	< 5.0	12.280
16	131.8	34.63	< 0.040	< 5.0	80.25
18	101.2	24.88	< 0.040	< 5.0	10.11
19	64.04	41.650	< 0.040	61.21	33.08
21	100.4	24.45	< 0.040	< 5.0	8.878
22	97.12	25.650	< 0.040	< 5.0	8.177
23	5.053	< 5.0	< 0.040	< 5.0	167.62
24	114.3	32.4	< 0.040	< 5.0	7.488
25	118.6	32.280	< 0.040	< 5.0	8.706
26	93.3	22.38	< 0.040	< 5.0	9.704
28	< 5.0	< 5.0	< 0.040	< 5.0	114.5
29	82.84	20.73	< 0.040	< 5.0	13.23
30	87.54	23.29	< 0.040	< 5.0	12.58
32	95.05	22.67	< 0.040	7.611	5.316
33	98.84	26.73	< 0.040	< 5.0	9.216
34	< 5.0	< 5.0	< 0.040	< 5.0	195.800
35	121.9	32.93	< 0.040	< 5.0	27.720
36	129	26.440	< 0.040	< 5.0	16.360
37	50.07	24.62	< 0.040	< 5.0	9.525
39	159.6	27.69	< 0.040	< 5.0	42.750
40	128.6	26.86	< 0.040	< 5.0	22.92
41	101.3	32.890	< 0.040	< 5.0	30.94
55	< 5.0	< 5.0	< 0.040	< 5.0	211.80

(a) See Figure 36 on page 110 for well locations. One sample was collected from each well. All samples were taken during the month of July.

(b) Samples collected from a cistern.

(c) USEPA drinking water regulations taken from 40 CFR Part 141, National Interim Primary Drinking Water Regulations - Subpart B – Maximum Contaminant Levels, July 1992, and from CFR Part 143, National Secondary Drinking Water Regulations – Section 143.3 – Secondary Maximum Contaminant Levels.

(d) USEPA drinking water regulations taken from 40 CFR Part 141, National Interim Primary Drinking Water Regulations - Subpart I – Control of Lead and Copper, July 1992.

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1994

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Antimony	3417 East Field	April 4	0.0392	0.006
Antimony	41217 East Field	April 5	0.0357	0.006
Antimony	11207 Silo Area	May 17	0.0318	0.006
Antimony	4426 East Field	July 5	0.0318	0.006
Antimony	11077 Waste Pit Area	May 19	0.0316	0.006
Antimony	1032 K-65 Silo Area	May 10	0.0315	0.006
Antimony	11076 Waste Pit Area	May 19	0.0303	0.006
Antimony	2432 Southeast of Production Area	July 11	0.0278	0.006
Antimony	2636 South Plume	February 4	0.0266	0.006
Arsenic	2548 South Plume	October 3	0.0855	0.050
Arsenic	2636 South Plume	February 4	0.0762	0.050
Arsenic	2636 South Plume	July 18	0.0717	0.050
Arsenic	2636 South Plume	February 4	0.0716	0.050
Arsenic	2128 South Plume	October 3	0.0586	0.050
Arsenic	2636 South Plume	May 3	0.0558	0.050
Arsenic	2900 South Plume	February 2	0.0548	0.050
Barium	2548 South Plume	February 1	31.1	2.0
Cadmium	2754 East Field	January 25	0.0545	0.005
Cadmium	887 Fire Training Facility	August 31	0.0095	0.005
Cadmium	2754 East Field	April 5	0.0094	0.005
Cadmium	2424 East Field	April 17	0.0077	0.005
Cadmium	2733 East Field	January 24	0.0054	0.005
Chromium	2754 East Field	January 25	3.510	0.1
Chromium	11080 Stormwater Retention Basin	May 12	0.980	0.1
Chromium	2754 East Field	April 5	0.456	0.1
Chromium	2636 South Plume	February 4	0.295	0.1
Chromium	2636 South Plume	February 4	0.275	0.1
Chromium	2636 South Plume	May 3	0.187	0.1
Chromium	0078 KC-2 Warehouse	August 17	0.122	0.1
Chromium	2754 East Field	September 7	0.119	0.1
Chromium	2754 East Field	July 6	0.102	0.1
Chromium	1032 Silo Area	May 10	0.101	0.1

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1994

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Lead	2548 South Plume	February 1	0.0911	0.015
Lead	11080 Stormwater Retention Basin	May 12	0.0801	0.015
Lead	0067 KC-2 Warehouse	August 17	0.0539	0.015
Lead	2548 South Plume	February 1	0.0286	0.015
Lead	2436 Fire Training Facility	August 30	0.0267	0.015
Lead	11079 Waste Pit Area	May 14	0.0262	0.015
Lead	2733 East Field	April 18	0.0243	0.015
Lead	31217 East Field	April 5	0.02	0.015
Lead	11207 Silo Area	May 17	0.0172	0.015
Lead	2548 South Plume	May 3	0.0168	0.015
Lead	2754 East Field	April 5	0.0152	0.015
Nickel	2754 East Field	January 25	16.8	0.1
Nickel	2754 East Field	July 6	1.06	0.1
Nickel	11080 SWRB	May 12	0.719	0.1
Nickel	2754 East Field	September 7	0.427	0.1
Nickel	2754 East Field	April 5	0.349	0.1
Nickel	2548 South Plume	February 1	0.142	0.1
Nickel	11079 Waste Pit Area	May 14	0.128	0.1
Nickel	41217 East Field	April 5	0.117	0.1
Pentachlorophenol	11076 Waste Pit Area	May 21	0.02	0.001
Thallium	2052 North of Production Area	August 30	0.0054	0.002
Thallium	1887 Fire Training Facility	August 31	0.005	0.002
Toluene	1342 Plant One Pad	June 16	7.4	1.0
Toluene	1342 Plant One Pad	June 16	1.2	1.0

(a) See figures 41A through 44 on pages 119 through 124 for well locations.

(b) USEPA drinking water regulations taken from 40 CFR Part 141, National Uranium Primary Drinking Water Regulations – Subpart B – Maximum Contaminant Levels, July 1984.

TABLE 20: Summary of Radiation Dose[a], 1994

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]	0.17	10	1.7
B. Ingestion[f]			
Produce (204 kg/year or 449 pounds/year) and milk	0.2	100	0.2
Well water (2 L/day or 0.5 gallons/day)	0.3	100	0.3
Great Miami River fish (4.4 kg/year or 10 pounds/year)	0.04	100	0.04
C. Direct radiation[g]	0.0	100	0.0
D. Radon Maximum dose to public at the site fenceline 8,760 hrs/year	574[k]	(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]	0.3	(h)	
III. Other Sources of Dose[i]			
A. Natural radioactivity	**mrem/year**		
1. Radon in homes	200		
2. Other natural background radiation: cosmic radiation plus natural terrestrial isotopes, both external and internal.	100		
3. Well water in Fernald site area	0.4		
B. Medical diagnosis[j]	50		
C. Consumer products	10		
D. Atmospheric weapons tests	4.6		

(a) Including dose from all radionuclides listed in Table 21.

(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 1994 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 Fernald site 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.

(k) Based on three quarters; fourth quarter data is suspect.

TABLE 21: Estimated Airborne Emissions for the Fernald Site, 1994

Radionuclide	Total Curies	Measured Curies[a]	Estimated Curies	
			Plt 7 Dismantling[b]	Remaining Sources[c]
Uranium–234	0.000385	0.0000003294	0.000204	0.0001806706
Uranium–235	0.00002045	0.0000000102	0.0000108	0.0000096398
Uranium–236	0.00001479	0.0000000101	0.00000791	0.0000068699
Uranium–238	0.000446	0.0000003917	0.000228	0.0002176083
Radium–226	0.000000288	(d)	0.000000145	0.000000143
Radium–228	0.00000116	(d)	0.000000588	0.000000572
Thorium–228	0.00001221	0.0000000549	0.00000612	0.0000060351
Thorium–230	0.00002764	0.0000001481	0.000018	0.0000094919
Thorium–232	0.000001941	0.0000000297	0.000000962	0.0000009493
Thorium–234	0.001081	(d)	0.0009	0.000181

(a) Measured emissions are from Plant 1, Plant 9, Building 11, and Building 15 monitored stacks.

(b) Fugitive emissions from the Plant 7 dismantling.

(c) Includes three unmonitored stacks, two building vents, laboratory hoods, and the cooling tower.

(d) Data not available due to insufficient sample size.

TABLE 22: Radon in Air, 1994

Fenceline Locations[a]	Radon Concentration (pCi/L)[b]				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average (Qtrs 1-3)
AMS 2	1.0	0.7[c]	0.4[c]	(e)	0.7
AMS 4	1.3	0.7[c]	0.4[c]	(e)	0.8
AMS 6	1.4	0.7[c]	0.4[c]	(e)	0.8
AMS 7	1.3	0.7[c]	0.5	(e)	0.8
FEMP A	0.8	0.7[c]	0.4[c]	(e)	0.6
FEMP B	0.8	0.7[c]	0.4[c]	(e)	0.6
FEMP C	1.0	0.7[c]	0.4[c]	(e)	0.7
FEMP D	1.2	1.5	0.4[c]	(e)	1.0
FEMP E	0.6	1.1	0.4[c]	(e)	0.7
FEMP F	1.1	0.7[c]	0.5	(e)	0.8
FEMP G	0.9	0.9	0.5	(e)	0.8
FEMP H	0.8	1.0	0.4[c]	(e)	0.7
FEMP I	0.8	1.5	0.4[c]	(e)	0.9
FEMP J	1.1	0.7[c]	0.7	(e)	0.8
FEMP K	1.3	0.7[c]	0.4	(e)	0.8
FEMP L	0.7	0.7[c]	0.4	(e)	0.6
FEMP M	0.7	0.7[c]	0.4[c]	(e)	0.6
FEMP N	1.5	0.7[c]	0.4[c]	(e)	0.9
FEMP O	1.3	0.7[c]	0.4[c]	(e)	0.8
FEMP P	1.2	0.7[c]	0.6	(e)	0.8
Quarterly Averages	1.0	0.8	0.4	(e)	0.8

TABLE 22: Radon in Air, 1994

Background Locations[a]	Radon Concentration (pCi/L)[b]				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average (Qtrs 1-3)
Bkgd 1	1.4	1.0	1.5	(e)	1.3
Bkgd 2	0.6	0.7[c]	1.3	(e)	0.9
Bkgd 3	1.3	0.7[c]	0.4[c]	(e)	0.8
Bkgd 4	1.3	0.9	(e)	(e)	1.1
Bkgd 5	(d)	(d)	(e)	(e)	NA
Bkgd 6	(d)	(d)	(e)	(e)	NA
Quarterly Averages	1.2	0.8	1.1	(e)	1.0

Other Locations[a]	Radon Concentration (pCi/L)[b]				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average (Qtrs 1-3)
AMS 1A	1.3	0.7[c]	0.5	(e)	0.8
AMS 8	0.3	0.7[c]	0.4[c]	(e)	0.5
AMS 9	0.7	NA	0.4[c]	(e)	0.5
AMS 10	0.4	0.7[c]	0.4[c]	(e)	0.5
AMS 11	0.3	0.7[c]	0.4[c]	(e)	0.5
AMS 12	0.3	0.7[c]	0.4[c]	(e)	0.5
AMS 13	0.6	0.7[c]	0.4[c]	(e)	0.6
RES 1	0.4	0.7[c]	0.4[c]	(e)	0.5
RES 2	0.3	0.7[c]	1.4	(e)	0.8
RES 3	0.4	0.7[c]	0.6	(e)	0.6
Quarterly Averages	0.5	0.7	0.5	(e)	0.6

(a) See Figure 48 on page 144 for locations.

(b) All values corrected for instrument background.

(c) Values less than Minimum Detectable Level (MDL). The MDL concentration divided by the square root of two is used as the minimum detectable value. The MDL value varies by quarter and detector blanks.

(d) Sampling location not in service during this quarter.

(e) Data deemed suspect and unusable.

NA Data not available.

TABLE 23: DOE Quality Assessment Program for Environmental Radionuclide Analyses Fernald Site Laboratories Performance Results, 1994

Sample Type	Sample Number	Units	Uranium Values		Ratio
			Site Laboratories	EML[a]	Site Value/EML Value
Soil	94-03	µg/g	1.36	1.00	1.36
Air Filter	94-03	µg/Filter	16.4	15.8	1.04
Air Filter	94-09	µg/Filter	10.3	9.45	1.09
Water	94-03	µg/ml	1.22	1.11	1.10
Water	94-09	µg/ml	97.8	0.089	1,100

(a) DOE's Environmental Measurements Laboratory (EML).

TABLE 24: USEPA Quality Assurance Program for Wastewater Analyses Fernald Site Laboratories Performance Evaluation, 1994[a]

Parameter	Units[b]	Values		USEPA Acceptance Limits[d]	USEPA Performance Evaluation[e]
		Site Laboratories	True[c]		
Chromium	µg/L	970	960	760 – 1100	ACCEPTABLE
Copper	µg/L	340	320	280 – 358	ACCEPTABLE
Nickel	µg/L	2900	2800	2500 – 3100	ACCEPTABLE
pH	S.U.	8.5	8.4	8.1 – 8.7	ACCEPTABLE
Total Suspended Solids	mg/L	24	26	20 – 28	ACCEPTABLE
Oil & Grease	mg/L	19	18	12 – 23	ACCEPTABLE
Ammonia – Nitrogen	mg/L	2.3	2.3	1.7 – 2.9	ACCEPTABLE
Nitrate – Nitrogen	mg/L	2.9	2.8	2.2 – 3.3	ACCEPTABLE
Carbonaceous BOD	mg/L	16	15	8.1 – 22	ACCEPTABLE
5 Day BOD	mg/L	13	13	4.7 – 22	ACCEPTABLE

(a) USEPA Discharge Monitoring Report (DMR) Quality Assurance (QA) Program. The Fernald site, 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 USEPA based on theoretical calculations or a reference value when necessary.

(d) Laboratory measured values which fall within this range are considered acceptable by USEPA.

(e) USEPA DMR–QA Study Number 013 conducted during 1994.

TABLE 25: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1994

Summary of Performance of the Fernald Site's 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]
Biochemical Oxygen Demand	mg/L	8	15.5 – 289	93	113	100	0.010	0.71	0.29	100
Chemical Oxygen Demand	mg/L	8	23.5 – 469	63	108	96	0.23	1.9	0.87	100
Total Organic Carbon	mg/L	4	9.70 – 105	84	117	101	0.91	2.1	1.6	75
Ammonia Nitrogen as N	mg/L	10	0.22 – 17.1	92	126	99	0.022	0.73	0.39	100
Nitrate Nitrogen as N	mg/L	10	0.30 – 21.7	25	1210	280	0.030	44	13	60
Orthophosphate as P	mg/L	8	0.58 – 11.2	100	109	104	0.011	1.3	0.64	100
Total Phosphorus as P	mg/L	7	0.19 – 11.3	26	406	117	0.94	27	6.7	29
Total Suspended Solids	mg/L	8	35.4 – 495	95	193	110	0.49	15	2.7	88
Total Dissolved Solids	mg/L	8	152 – 1800	89	105	98	0.14	2.2	0.75	88
Total Solids	mg/L	3	278 – 2170	100	101	100	0.036	0.49	0.26	100
Oil and grease	mg/L	10	5.00 – 97.2	77	104	94	0.017	2.2	0.69	90
Alkalinity as $CaSO_3$	mg/L	8	16.5 – 184	83	121	105	0.094	1.5	0.76	100
Calcium	mg/L	8	5.98 – 52.5	77	104	95	0.056	3.3	1.1	88
Chloride	mg/L	8	24.1 – 471	96	126	106	0.074	2.8	1.1	88
Conductivity	µmho/cm	8	201 – 2390	95	100	99	0.19	0.51	0.32	100
Magnesium	mg/L	10	1.06 – 46.8	84	104	97	0.041	2.7	0.79	90
Potassium	mg/L	10	3.26 – 262	3	2637	344	0.067	200	23	80
Sodium	mg/L	10	23.6 – 212	84	105	96	0.017	4.6	1.2	80
Sulfate	mg/L	8	12.7 – 214	84	109	96	0.30	2.7	0.96	88
Total Hardness as $CaCO_3$	mg/L	8	21.5 – 191	43	99	90	0.038	7.7	1.4	88
pH	S.U.	8	4.05 – 9.40	98	101	99	0.012	0.76	0.33	100
Aluminum	µg/L	7	41.6 – 670	79	105	93	0.040	1.6	0.80	100
Arsenic	µg/L	6	8.9 – 494	88	102	94	0.035	1.1	0.66	100
Barium	µg/L	8	97.8 – 2370	95	107	99	0.045	1.4	0.55	100
Beryllium	µg/L	8	18.3 – 470	96	100	98	0.016	0.37	0.16	100
Cadmium	µg/L	8	25.6 – 252	102	110	107	0.50	1.6	1.0	100
Chromium	µg/L	8	66.9 – 856	101	106	103	0.25	1.1	0.58	100
Cobalt	µg/L	8	42.5 – 718	102	108	106	0.32	2.4	1.2	88
Copper	µg/L	8	22.7 – 800	95	111	104	0.51	1.8	1.2	100

TABLE 25: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1994

Summary of Performance of the Fernald Site's 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]
Iron	µg/L	8	96.4 – 618	95	109	103	0.30	1.1	0.75	100
Lead	µg/L	4	94.1 – 521	74	101	90	0.080	5.1	1.7	75
Manganese	µg/L	8	52.6 – 738	102	108	104	0.34	1.6	0.83	100
Mercury	µg/L	6	0.88 – 12.7	56	101	85	0.33	2.4	1.2	83
Nickel	µg/L	8	28.2 – 623	99	129	109	0.25	3.7	1.2	88
Selenium	µg/L	4	9.94 – 143	80	89	85	0.82	1.7	1.2	100
Silver	µg/L	8	14.9 – 205	97	110	104	0.035	1.6	0.66	100
Vanadium	µg/L	8	61.0 – 2000	95	105	101	0.032	1.3	0.68	100
Zinc	µg/L	4	24.9 – 410	93	132	107	0.17	5.1	1.6	75
Fluoride	mg/L	8	0.060 – 15.1	98	117	104	0.028	0.87	0.40	100
Total Organic Halide	µg/L	8	10.7 – 731	82	102	93	0.13	1.6	0.55	100
Hexavalent Chromium	mg/L	7	0.016 – 514	60	100000	42000	0.099	27000	7000	57
Uranium	µg/L	10	30.9 – 961	97	103	100	0.007	0.85	0.47	100
Benzene	µg/L	6	11.8 – 153	80	106	93	0.34	1.5	0.66	100
Chlorobenzene	µg/L	4	27.2 – 173	95	111	102	0.076	1.4	0.69	100
1,2 Dichlorobenzene	µg/L	6	21.7 – 125	91	100	97	0.035	0.58	0.22	100
1,4 Dichlorobenzene	µg/L	4	8.5 – 56.6	96	103	100	0.12	0.62	0.43	100
Ethyl Benzene	µg/L	6	7.35 – 168	86	114	98	0.19	1.5	0.71	100
Toluene	µg/L	6	8.84 – 117	89	109	102	0.016	1.4	0.82	100
Bromodichloromethane	µg/L	2	32.1 – 95.9	101	101	101	0.047	0.27	0.16	100
Bromoform	µg/L	3	28.0 – 177	94	103	98	0.27	0.31	0.30	100
Carbon Tetrachloride	µg/L	6	14.5 – 139	90	109	103	0.006	1.5	0.67	100
Chloroform	µg/L	4	6.14 – 174	84	107	97	0.22	1.3	0.67	100
1,2 Dichloreoethane	µg/L	6	12.9 – 279	105	135	118	0.15	3.6	1.6	50
Methylene Chloride	µg/L	6	21.7 – 183	88	113	97	0.17	0.82	0.48	100
1,1,2,2 Tetrachloroethane	µg/L	2	28.3 – 193	87	95	92	0.30	0.78	0.54	100
Tetrachloroethylene	µg/L	2	32.6 – 63.3	89	92	91	0.021	0.40	0.21	100
1,1,1 Trichloroethane	µg/L	2	15.3 – 125	111	113	112	1.2	1.5	1.4	100
1,1,2 Trichloroethane	µg/L	4	23.7 – 223	94	116	105	0.38	1.3	0.76	100
Trichloroethylene	µg/L	6	7.59 – 218	89	98	96	0.11	0.67	0.40	100
Total		**397**								92

TABLE 25: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1994

(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 site'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 USEPA "Acceptable" criteria of being within 2.58 standard deviations of the mean value.

TABLE 26: Fernald Site – ODH Uranium Sampling Comparison, 1993

Groundwater Sampling Locations

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] Fernald Site	ODH
Well 4	1/28/93	1.6	2.4
Well 4	2/24/93	1.4	< 1.0
Well 4	3/24/93	1.4	1.8
Well 4	4/28/93	1.5	1.2
Well 4	5/26 /93	1.4	1.9
Well 4	6/23/93	1.1	< 1.0
Well 4	7/28/93	0.81	1.6
Well 4	8/25/93	0.88	3.3
Well 4	9/29/93	1.2	< 1.0
Well 4	10/27/93	1.4	2.2
Well 4	11/24/93	1.4	1.7
Well 4	12/29/93	1.6	2.5
Well 14	1/28/93	1.3	1.2
Well 14	2/24/93	1.3	< 1.0
Well 14	3/24/93	1.3	1.3
Well 14	4/28/93	1.2	< 1.0
Well 14	5/26/93	1.3	2.2
Well 14	6/23/93	1.1	1.4
Well 14	7/28/93	1.3	1.9
Well 14	8/25/93	1.3	1.6
Well 14	9/29/93	1.3	1.9
Well 14	10/27/93	1.3	< 1.0
Well 14	11/24/93	1.2	1.5
Well 14	12/29/93	1.3	1.6
Well 15	1/28/93	180	200
Well 15	2/24/93	200	210
Well 15	3/24/93	200	130
Well 15	4/28/93	200	170
Well 15	5/26/93	200	220
Well 15	6/23/93	200	210
Well 15	7/28/93	200	220
Well 15	8/25/93	200	180
Well 15	9/29/93	210	200
Well 15	10/27/93	190	170
Well 15	11/24/93	160	160
Well 15	12/29/93	150	150
Well 19	1/28/93	0.07	< 1.0
Well 19	2/24/93	0.07	< 1.0
Well 19	3/24/93	0.07	< 1.0
Well 19	4/28/93	0.07	< 1.0
Well 19	5/26/93	0.07	< 1.0
Well 19	6/23/93	0.07	< 1.0
Well 19	7/28/93	0.07	< 1.0
Well 19	8/25/93	0.07	< 1.0
Well 19	9/29/93	0.07	< 1.0
Well 19	10/27/93	0.07	< 1.0
Well 19	11/24/93	0.07	< 1.0
Well 19	12/29/93	0.07	< 1.0
Well 21	1/28/93	0.27	<1.0
Well 41	2/24/93	0.34	< 1.0
Well 36	3/24/93	0.68	< 1.0
Well 40	4/28/93	2.8	2.4
Well 1	5/26/93	0.14	< 1.0
Well 18	6/23/93	0.27	< 1.0
Well 36	7/28/93	0.74	1.1
Well 33	8/25/93	0.34	< 1.0
Well 21	9/29/93	0.20	< 1.0
Well 32	10/27/93	0.07	< 1.0
Well 10	12/29/93	0.41	< 1.0

TABLE 26: Fernald Site – ODH Uranium Sampling Comparison, 1993

Surface Water Sampling

Sampling Location	Sampling Date	Concentration (pCi/L) Fernald Site	ODH
SW1	1/28/93	1.2	1.2
SW1	2/24/93	1.2	1.3
SW1	3/24/93	1.0	< 1.0
SW1	4/28/93	1.1	< 1.0
SW1	5/26/93	1.4	1.4
SW1	6/23/93	1.0	1.9
SW1	7/28/93	1.2	1.0
SW1	8/25/93	1.0	1.3
SW1	9/29/93	1.0	< 1.0
SW1	10/27/93	1.2	< 1.0
SW1	11/24/93	1.2	< 1.0
SW1	12/29/93	1.3	1.4
SW3	1/28/93	1.4	1.5
SW3	2/24/93	1.4	1.0
SW3	3/24/93	1.0	< 1.0
SW3	4/28/93	1.2	< 1.0
SW3	5/26/93	1.5	1.7
SW3	6/23/93	1.0	1.4
SW3	7/28/93	1.2	< 1.0
SW3	8/25/93	1.4	1.5
SW3	9/29/93	1.1	1.4
SW3	10/27/93	1.8	2.2
SW3	11/24/93	1.2	1.5
SW3	12/29/93	1.4	1.6
SW4	1/28/93	1.3	1.3
SW4	2/24/93	1.4	1.4
SW4	3/24/93	1.1	1.2
SW4	4/28/93	1.2	< 1.0
SW4	5/26/93	1.4	1.7
SW4	6/23/93	1.2	< 1.0
SW4	7/28/93	1.4	1.0
SW4	8/25/93	1.4	1.5
SW4	9/29/93	1.2	1.6
SW4	10/27/93	1.6	9.3
SW4	11/24/93	1.1	1.4
SW4	12/29/93	1.4	2.1
SW7	1/28/93	4.2	4.7
SW7	2/24/93	3.3	2.6
SW7	3/24/93	2.5	1.8
SW7	4/28/93	3.2	2.3
SW7	5/26/93	NA	NA
SW7	6/23/93	NA	NA
SW7	7/28/93	NA	NA
SW7	8/25/93	NA	NA
SW7	9/29/93	NA	NA
SW7	10/27/93	NA	NA
SW7	11/24/93	NA	NA
SW7	12/29/93	NA	NA
SW8	1/28/93	3.9	5.0
SW8	2/24/93	3.4	2.1
SW8	3/24/93	2.0	< 1.0
SW8	4/28/93	2.8	2.7
SW8	5/26/93	2.9	2.7
SW8	6/23/93	2.2	2.4
SW8	7/28/93	NA	NA
SW8	8/25/93	1.2	1.2
SW8	9/29/93	NA	NA
SW8	10/27/93	NA	NA
SW8	11/24/93	NA	NA
SW8	12/29/93	NA	NA

TABLE 26: Fernald Site – ODH Uranium Sampling Comparison, 1993

Surface Water Sampling (Continued)

Sampling Location	Sampling Date	Concentration (pCi/L) Fernald Site	ODH
SW9	1/28/93	1.6	1.9
SW9	2/24/93	1.9	1.2
SW9	3/24/93	1.0	1.3
SW9	4/28/93	1.4	< 1.0
SW9	5/26/93	1.2	1.4
SW9	6/23/93	0.81	1.8
SW9	7/28/93	NA	NA
SW9	8/25/93	0.47	< 1.0
SW9	9/29/93	NA	NA
SW9	10/27/93	1.6	1.8
SW9	11/24/93	4.1	3.6
SW9	12/29/93	NA	NA

Sediment Sampling

Sampling Location	Sampling Date	Concentration (pCi/L) Fernald Site	ODH
SE 2	5/26/93	0.52	2.0
SE 3	5/26/93	0.47	31
SE 7-3	5/26/93	0.41	2.3
SE 7-4	5/26/93	0.49	2.0
SE 10	5/26/93	0.80	7.0
SE 24	5/26/93	0.43	2.0
SE 2	11/27/93	0.86	< 1.0
SE 3	11/27/93	1.1	1.3
SE 7	11/27/93	0.93	1.5
SE 10	11/27/93	1.1	< 1.0
SE 24	11/27/93	1.3	1.3

Milk Sampling

Sampling Date	Concentration (pCi/L) Fernald Site	ODH
3/24	0.047	< 2.0
6/23	0.15	< 2.0
9/29	0.02	< 2.0
12/29	0.095	< 2.0

(a) See figures 32 on page 98 and figure 36 on page 110 for locations.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) These wells are used for monitoring purposes only.

NA Denotes sample not collected due to low water levels or frozen conditions.

Table 27: Fernald Site – ODH Uranium Sampling Comparison, 1994

Surface Water Sampling

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] Fernald Site	ODH
SW1	1/26/94	0.67	< 1.0
SW1	2/23/94	1.0	1.5
SW1	3/23/94	1.4	1.4
SW1	4/27/94	1.0	< 1.0
SW1	6/1/94	NA	NA
SW1	6/22/94	NA	NA
SW3	1/26/94	0.74	< 1.0
SW3	2/23/94	0.81	< 1.0
SW3	3/23/94	1.2	1.3
SW3	4/27/94	1.1	< 1.0
SW3	6/1/94	NA	NA
SW3	6/22/94	NA	NA
SW4	1/26/94	0.74	1.1
SW4	2/23/94	0.88	1.4
SW4	3/23/94	1.3	0.8
SW4	4/27/94	1.2	1.6
SW4	6/1/94	NA	NA
SW4	6/22/94	NA	NA
SW7	1/26/94	2.0	2.4
SW7	2/23/94	2.5	2.5
SW7	3/23/94	3.4	2.9
SW7	4/27/94	NA	NA
SW7	6/1/94	NA	NA
SW7	6/22/94	NA	NA
SW8	1/26/94	1.6	2.2
SW8	2/23/94	2.3	2.3
SW8	3/23/94	3.2	3.3
SW8	4/27/94	2.6	3.0
SW8	6/1/94	NA	NA
SW8	6/22/94	NA	NA
SW9	1/26/94	0.41	1.2
SW9	2/23/94	0.81	1.1
SW9	3/23/94	1.4	1.5
SW9	4/27/94	1.7	1.9

Well Water Sampling

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] Fernald Site	ODH
SW9	6/1/94	NA	NA
SW9	6/22/94	NA	NA
GW 4	1/26/94	1.2	1.2
GW 4	2/23/94	1.4	2.3
GW 4	3/23/94	1.6	2.0
GW 4	4/27/94	1.2	2.2
GW 4	6/1/94	1.2	1.7
GW 4	6/22/94	1.0	1.9
GW 14	1/26/94	1.3	1.3
GW 14	2/23/94	1.2	1.9
GW 14	3/23/94	1.1	1.4
GW 14	4/27/94	1.3	1.9
GW 14	6/1/94	1.3	1.6
GW 14	6/22/94	1.4	2.8
GW 15[c]	1/26/94	150	150
GW 15[c]	2/23/94	150	160
GW 15[c]	3/23/94	140	150
GW 15[c]	4/27/94	140	130
GW 15[c]	6/1/94	140	170
GW 15[c]	6/22/94	140	72
GW 19	1/26/94	< 1.0	< 1.0
GW 19	2/23/94	< 1.0	< 1.0
GW 19	3/23/94	< 1.0	< 1.0
GW 19	4/27/94	< 1.0	< 1.0
GW 19	6/1/94	0.07	< 1.0
GW 19	6/22/94	0.07	< 1.0
GW 11	1/26/94	1.7	1.0
GW 12	2/23/94	59	53
GW 22	3/23/94	0.54	< 1.0
GW 25	4/27/94	0.27	< 1.0
GW 29	6/1/94	1.3	2.2
GW 35	6/22/94	1.2	1.4

Table 27: Fernald Site – ODH Uranium Sampling Comparison, 1994

Milk Sampling

Sampling Date	Concentration (pCi/L)[b] Fernald Site	ODH
3/23/94	0.86	< 1.0
6/22/94	< 0.18	< 1.0

(a) See figures 32 on page 98 and figure 36 on page 110 for locations.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) Well #15 is used for monitoring purposes only.

NA Denotes sample not collected due to low water levels or frozen conditions.

Table 28: Fernald Site – OEPA Sampling Comparison, 1994

Surface Water Sampling for Uranium and Radium

Sampling Location[d]	Sampling Date	Fernald Site Results (pCi/L) Uranium	^{226}Ra	^{228}Ra	OEPA Results (pCi/L) Uranium	^{226}Ra	^{228}Ra
SW 1	7/27/94	NA	NA	NA	NA	NA	NA
SW 1	8/24/94	NA	NA	NA	NA	NA	NA
SW 1	9/28/94	0.74	0.18	< 3.4	1.0	< 1.0	2.0
SW 1	10/26/94	0.74	0.10	< 2.6	1.2	< 1.0	5.1
SW 1	11/23/94	0.74	0.13	3.0	< 1.0	< 1.0	< 1.0
SW 1	12/28/94	0.81	0.12	< 2.9	< 1.0	< 1.0	1.1
SW 3	7/27/94	NA	NA	NA	NA	NA	NA
SW 3	8/24/94	NA	NA	NA	NA	NA	NA
SW 3	9/28/94	0.88	0.15	4.1	1.0	< 1.0	< 1.0
SW 3	10/26/94	0.74	0.14	< 2.7	1.2	< 1.0	< 1.0
SW 3	11/23/94	1.0	0.12	< 2.9	< 1.0	< 1.0	< 1.0
SW 3	12/28/94	1.4	0.16	< 2.9	1.2	< 1.0	< 1.0
SW 4	7/27/94	NA	NA	NA	NA	NA	NA
SW 4	8/24/94	NA	NA	NA	NA	NA	NA
SW 4	9/28/94	0.88	0.14	< 3.4	1.0	< 1.0	2.5
SW 4	10/26/94	0.88	0.12	< 2.7	1.3	< 1.0	< 1.0
SW 4	11/23/94	1.0	0.16	< 2.9	< 1.0	< 1.0	< 1.0
SW 4	12/28/94	1.5	0.13	< 2.9	1.7	< 1.0	< 1.0

Sediment Sampling for Uranium and Radium

Sampling Location[e]	Sampling Date	Fernald Results (pCi/g) Uranium	^{226}Ra	OEPA Results (pCi/g) Uranium	^{226}Ra
G2	11/23/94	1.0	0.52	0.90	0.31
G3	11/23/94	1.0	0.49	0.96	0.34
G8	11/23/94	1.0	0.60	0.78	0.38
P5	11/23/94	0.99	0.59	0.74	< 0.25
P6	11/23/94	1.2	0.57	0.84	0.53

Milk Sampling for Uranium

Sampling Date	Concentration (pCi/L)[b] Fernald	OEPA
9/28/94	< 1.0	< 1.0
12/28/94	< 1.0	< 1.0

Table 28: Fernald Site – OEPA Sampling Comparison, 1994

Groundwater Sampling for Uranium

Sampling Location[a]	Sampling Date	Concentration (pCi/L) Fernald Site	OEPA
GW 4	9/28/94	1.3	0.93
GW 4	10/26/94	1.0	0.83
GW 4	11/23/94	0.74	0.81
GW 4	12/28/94	1.1	1.1
GW 14	9/28/94	1.4	1.3
GW 14	10/26/94	1.7	1.2
GW 14	11/23/94	1.4	1.4
GW 14	12/28/94	1.4	1.4
GW 15[c]	9/28/94	130	120
GW 15[c]	10/26/94	120	97
GW 15[c]	11/23/94	120	120
GW 15[c]	12/28/94	110	110
GW 19	9/28/94	< 1.0	< 1.0
GW 19	10/26/94	< 1.0	< 1.0
GW 19	11/23/94	< 1.0	< 1.0
GW 19	12/28/94	0.07	< 1.0
GW 24	9/28/94	0.54	0.39
GW 28	10/26/94	0.68	0.26
GW 41	11/23/94	0.27	0.29
GW 40	12/28/94	2.1	1.9

Sediment Sampling for Thorium

Sampling Location[e]	Sampling Date	Fernald Results (pCi/g) ^{228}Th	^{230}Th	^{232}Th	OEPA Results (pCi/g) ^{228}Th	^{230}Th	^{232}Th
G2	11/23/94	0.44	0.56	0.48	< 0.10	0.10	< 0.10
G3	11/23/94	0.16	0.59	0.20	0.11	0.72	< 0.10
G8	11/23/94	0.29	0.68	0.26	< 0.10	0.15	0.10
P5	11/23/94	0.28	0.72	0.22	< 0.10	0.20	< 0.10
P6	11/23/94	0.31	0.66	0.27	< 0.10	< 0.10	< 0.10

(a) See Figure 32 on page 98 for locations.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) Well 15 is used for monitoring purposes only.

(d) See Figure 36 on page 110 for locations.

(e) See Figure 34 on page 102 for locations.

NA Denotes sample not collected due to low water levels or frozen conditions.

Chemical Release Information for 1994

Among the information presented in the SER for the Fernald site 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 1994 and a summary of emissions from the Boiler Plant during 1994. This summary includes the chemical name, type and quantity of release, major release sources, and the basis of estimate.

To estimate releases, the Fernald site used a method that followed guidelines defined by SARA 313. These estimates do not reflect actual measured emissions. Rather, the Fernald site 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 Fernald site during 1994.

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 USEPA and OEPA each year on July 1 for the previous calendar year and contains chemicals on USEPA's toxic substance list.

Fernald Site Chemical Release Information for 1994

Section One: Summary of SARA 313 Report

Chemical Name	Type of Release	Quantity Released (lb/kg)	Release Sources	Basis of Estimate
Methanol	Air: Fugitive	339/154	Chemical Processing Aid	Published Emission Factors
	Air: Point source	141/64	Chemical Processing Aid	Published Emission Factors
	Water: Great Miami River	648/295	Chemical Processing Aid	Best Engineering Judgment
Sulfuric Acid	Water: Great Miami River	0/0	Ancillary or other use	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	33,000/15,000	Fossil Fuels Combustion	Stack Testing
Sulfur Dioxide	Air: stack emissions	506,000/230,000	Fossil Fuels Combustion	AP–42 Emission Factors
Nitrogen Oxide	Air: stack emissions	352,000/160,000	Fossil Fuels Combustion	AP–42 Emission Factors
Carbon Monoxide	Air: stack emissions	129,800/59,000	Fossil Fuels Combustion	AP–42 Emission Factors
Non-methane Volatile Organic Compounds	Air: stack emissions	1,700/774	Fossil Fuels Combustion	AP–42 Emission Factors

Fernald Site Source Reduction Information for 1994

Section One: Summary of SARA 313 Report

There were no source reductions completed in 1994.

References

1 *General Environmental Protection Program, U.S. Department of Energy Order 5400.1,* November 9, 1988.

1a Fernald Citizens Task Force, *Interim Report: Preliminary Recommendations on Future Use and Cleanup levels for the Fernald Site*, November 1994.

2 Facemire, C.F., S.I. Guttman, D. R. Osborne, and R.H. Sperger, *Biological and Ecological Site Characterization of the Feed Materials Production Center,* Miami University, Oxford, Ohio, 1990.

3 Feed Materials Production Center, Fernald, Ohio, *Remedial Investigation Report for Operable Unit 4 Task 6 Report, Final Draft*, U.S. Department of Energy, Oak Ridge Operations Office, October 1990.

4 GeoTrans, Inc., *Preliminary Characterization of the Groundwater Flow System Near the Feed Materials Production Center, Great Miami River Valley-Fill Aquifer, Fernald, Ohio,* September 1985.

5 Speiker, A. M., *Groundwater Hydrology and the Geology of the Lower Great Miami River Valley, Ohio, USGS Professional Paper 605-A,* 1968.

6 Dames and Moore, *Groundwater Study Task C Report,* June 1985.

7 FMPC Environmental Monitoring Section, *1990 Groundwater Monitoring Annual Report for the Fernald Site, Draft,* November 1991.

8 Rozelle, James L., *Facsimile to T. R. Neyer,* April 20, 1994.

9 *Radiation Protection for the Public and the Environment, U.S. Department of Energy Order 5400.5*, February 8, 1990.

10 International Commission on Radiological Protection, *Annals of the ICRP, Recommendations of the International Commission on Radiological Protection, ICRP Publication Nos. 26/30, Parts 1, 2, 3*, Pergamon Press, Oxford, NY, 1977, 1979, 1980, and 1981.

11 *National Emission Standards for Hazardous Air Pollutants – Subpart H – National Emission Standards for Emissions of Radionuclides other than Radon from DOE Facilities, Code of Federal Regulations, Title 40, Parts 61.93 and 61.94, Vol. 50, No. 25,* February 1985.

12 *National Interim Primary Drinking Water Regulations – Subpart B – Maximum Contaminant Levels, Code of Federal Regulations, Title 40, Part 141*, July 1, 1984.

13 Maynard and Hodge, 1949, as referenced in *FR, Volume 56, No. 138*, p. 33077, July 18, 1991.

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

15 Upton, Arthur C., *The Biological Effects of Low-Level Ionizing Radiation, Scientific American*, pp. 41-49, February 1982.

16 The American Nuclear Society and the International Atomic Energy Agency, *Radiation – A Fact of Life*, 1979.

17 Eisenbud, Merril, *Environmental Radioactivity, 2nd ed.*, New York, Academic Press, 1973.

18 Murray, Raymond L., *Understanding Radioactive Waste, 2nd ed.*, Columbus, Ohio, Battelle Press, 1983.

19 Kingman, Sharon, *A Lot of Fuss About a Few Millisieverts, New Scientist*, May 15, 1986.

20 Marx, Jean L., *Lower Radiation Effect Found, Science*, September 9, 1988.

21 National Research Council, *Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V*, National Academy Press, 1990.

22 U.S. Department of Energy, Office of Environmental Guidance, *"Hazardous" Terminology*, January 1991.

23 U.S. Department of Energy, *CERCLA/RCRA Background Soil Study, Fernald Environmental Management Project, Final*, March 1993.

24 U.S. Environmental Protection Agency, *Method for Estimating Fugitive Particulate Emissions from Hazardous Waste Sites, EPA/600/2-87/066, PB87-232203*, Cincinnati, Ohio, August 1987.

25 Myrich, T. E., B. A. Berven, and F. F. Haywood, *Determination of Concentrations of Selected Radionuclides in Surface Soil in the U.S., Health Physics, 453*, 1983.

26 *Radiological Effluent Monitoring and Environmental Surveillance, Code of Federal Regulations, Title 10, Part 834, Draft,* January 10, 1991.

27 Ohio Environmental Protection Agency, *Measurements and Procedures, Laws and Regulations, Regulation No. 3745-1804*, November 1984.

28 Miller, Michael C., *Electrofishing Survey of the Great Miami River, August 20 – 23, Draft,* University of Cincinnati Department of Biological Sciences, November 1992.

29 Bardo, R. W., *Great Miami River Fish Data for 1993, M:ESH:ESHA:ESA:94-0046*, May 4, 1994.

30 Fernald Environmental Restoration Management Corporation, *1993 RCRA Annual Report, Volume 1*, April 1994.

31 Hem, John, D., *Study and Interpretation of the Chemical Characteristics of Natural Water, Geological Survey Water Supply Paper 1473*, 1982.

32 Varchol, B. D., *Statistical Evaluation of Homeowner Wells, WMCO:R:(EM): 90–0296,* June 7, 1990.

33 *Secondary Maximum Contaminant Levels, Code of Federal Regulations, Title 40, Part 143*, July 1, 1988.

34 Controls for Environmental Pollution, Inc., *Drinking Water Handbook,* Santa Fe, New Mexico, 1988.

35 *National Secondary Drinking Water Regulations, Code of Federal Regulations, Title 40, Part 143*, July 1991.

36 Miller, Charles W., ed., *Models and Parameters for Environmental Radiological Assessments, Report DOE/TIC – 11468*, Oak Ridge National Laboratory, 1984.

37 U.S. Department of Energy, *Internal Dose Conversion Factors for Calculation of Dose to the Public, DOE/EH-0071,* July 1988.

38 National Council on Radiation Protection and Measurements, *Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States, NCRP-78*, 1984.

39 International Commission on Radiological Protection, *Limits for Intakes of Radionuclides by Workers, ICRP-30*, July 1978.

40 International Commission on Radiological Protection, *Recommendations of the ICRP, ICRP-26*, January 1977.

41 U.S. Department of Energy, 1994, *Characterization of Background Water Quality For Streams and Groundwater,* Draft Final, Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

42 U.S. Department of Energy, 1995, *Remedial Investigation Report for Operable Unit 5,* Final, Fernald Environmental Management Project, DOE, Fernald Area Office, Cincinnati, OH.

43 Reid, D. F., W. M. Sackett, and R. F. Spalding, *Uranium and Radium In Livestock Feed Supplements,* Health Physics, Vol. 32, pp. 535-540, 1977.

44 Linsalata, P., R. Morse, H. Ford, M. Eisenbud, E. Penna Franca, M. B. de Castro, N. Lobao, I. Sachett, M. Carlos, *Transport Pathways of Th, U, Ra, and La from Soil to Cattle Tissues,* J. of Environmental Radioactivity, Vol. 10, pp. 115-140, 1989.

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.

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 any substance or material that 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.

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.